STUDY ON THE COMPUTER DYNAMIC SIMULATION OF THE YELLOW RIVER DELTA ENVIRONMENTAL EVOLUTION

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Abstract The Lower Yellow River is the famous "suspended river" for its silt sediment, and the Yellow River Delta(YRD) is one of the most active delta in the world because the river tail changes its course very frequently. In our research, we applied the Geographic Information System (GIS) and remote sensing to geo-analysis and simulated the environmental evolution of the Lower Yellow River and the Delta. The aim of our research is to try to reveal the delta evolutional rule, to simulate the environmental evolution procedure and to forecast the future development of the Yellow River Delta.

1. Looking back the developed history of the Lower Yellow River and its Delta.
2. Establishing the Digital Elevation Model(DEM), and analysing and researching the silt depositional situation of the Yellow River Delta.
3. By designing the special computer simulation and display software, establishing the computer dynamic simulational demonstration system, and reproducing the historical evolution of the river courses and coast lines from B.C. 2278, From 1855 and from 1934 to present in the Yellow River Delta area.
4. Analysing the vegetation evolution from 1855, implementing the quantitative research, and forecasting the future development.

I. RESEARCH AREA

The Lower Yellow River is a famous river for its massive silt. Due to the silt sediment, the river bed is rising quickly every year. More and more, the river course has been being in the instant situation. From B.C 2278, the Lower Yellow River has always been being in the vicious circle of "silting up -- rising -- extending -- changing route".

The Yellow River Delta(YRD) studied in the paper is the Yellow River New Delta which began in 1855 and bursted in Tongwaxiang. The range is E 118 15' -- 119 13', N 37 30 -- 38 10'. The area is about 6606 km^2. YRD is located in North-temperate, semi-moist and monsoon climate zone. There are a smooth terrain and a very different kind of climate. The continentlity of the delta is 0.65.

The Yellow River is the main river in the area. Every year, the Yellow River carries 10 to 12 hundred million ton silt to the area. 2/3 of the silt deposits the delta area. So the delta is expanded rapidly.

II. ANALYSIS OF THE DEPOSITIONAL STATE OF THE DELTA

1. The Structure of the Yellow River Delta

(1). The Delta Deposition

Based on the delta deposition, YRD is formed by the overlay of the different sub-delta deposits which were produced by the swings of the river tail in the different periods. These sub-delta deposits are as follows :

a. Yanwo-Xiaoshenmiao sub-delta (1855 -- 1904)
b. Yanwo-Taipingzhen sub-delta (1904 -- 1929)
c. Ninghai-Xishuanghe sub-delta (1929 -- 1934)
d. Tianshuigou sub-delta (1934 -- 1938, 1947 --
e. Shenxiangou sub-delta (1953 -- 1963) 1953)
f. Diaokouhe sub-delta (1963 -- 1976)
g. Qingshuigou sub-delta (1976 -- present)

(2). The Different Depositional periods of the Delta

From the point of view of the depositional sequence, we can find that the present YRD is composed of two period delta deposits(one is 1855 to 1934, the other is 1934 to present) in a proper order based on YRD.

The continuous deposition makes the delta develop rapidly from south-west to north-east and form the highest fan-shaped terrain (H1). The river tail swing (on the apex of Ninghai) continues forming two new fan-shaped areas beside the old fan-shaped area (H1). They composed the main frame of the new delta (F2). After 1934, the Yellow River started to build the newest fan-shaped delta area (F3). Its apex is in Yuwa. At present, human activity is acting on the newest delta intensely. So, we can see some anomalous phenomena, for example the elevation changes suddenly near the river and its courses.

2. Digital Elevation Model (DEM)

(1). Terrain

YRD is formed by the overlay of the many sub-deltas which were built by the swings of the river tails in different term. The terrain characteristics of the delta is :

a. The distribution of higher areas is along with the Yellow River and the old river courses. They extend in the radiation state.

b. The lower areas distribute on between natural high areas or the brink of the deelta.

c. The delta terrain is very smooth and inclines slowly from the delta apex (near Ninghai) to the shore area. If we look at the delta from the air. Because of the action of the river tail swings, the complicated micro-terrain has been formed.

(2). DEM

The great amount of silt sediment and the frequent swings of the Yellow River tail make the delta terrain beget an evident change in a short periods. The silt sediment within different periods formed different terrain situation. On the other hand, the different terrain situation also reflects the different depositional environment. In the paper, we have researched the silt sediment deposition by analysing the micro-terrain of the YRD therefore.

During our initial research, we set up some DEM of YRD and its subaqueous delta according to the different periods. The elevation difference of DEM of the Yellow River Delta in 1980 is 0.25 meter, in 1954, 1972 and 1984 is 2.5 meter. The elevation difference of DEM of the subaqueous delta is 2.5 meter, which the time is in 1980.

3. Analysis of the Depositional Situation

(1). The Silt Sediment of YRD

By analysing the present terrain of YRD, we found :

a. There exists about 1/3 delta area in which the elevation is lower than two meters. this is the area of the smoothest terrain.

b. The area where the elevation is higher than nine meters is also smooth, although it is not as smooth as that of the area where the elevation is under two meters.

c. The area where the elevation is between six and nine meters is more complicated in the terrain.

d. the area where the elevation is between two and six meters is the most complicated in the terrain.

Our explanations of the above phenomena are as follows :

a. The area where its elevation is under two meters is in the range of the marine power action. The depositional silt within the area is transported and deposited again. The result is to make the terrain become smooth gradually.

b. The area where its elevation is above nine meters was formed before 1855. the long time action (including natural and factitious action) has changed the terrain into the smooth terrain.

c. The area where its elevation is between six and nine meters was formed between the year of 1855 and 1934. Because the formed time is less than that of the term b, the terrain is more complicated than that of the term b.

d. The area where its elevation is between two and six meters is the most unstable area in which the Yellow River tail is affecting the area and the silt sediment is very evident. So the terrain in the area is the most complicated.

(2). Estimation of the Silt Sediment amount from 1855 to 1934

It was estimated, between 1855 and 1934, that the area above zero meter elevation increased 2018 km^2 in YRD. The annual average increment is 25.5 km^2. In this period, the volume of the delta deposit increased 85.25 hundred million m^3. The annual average increment is 1.07 hundred million m^3

(3). The Calculation of the Silt Sediment Amount since 1954

The Yellow River tail flows into the Bohai sea first by Shenxian River(before 1964), then by Diaokou River(before 1976) and now by Qingshui River since 1953.

Chart 1. The change of the silt depositional amount

items \ years / data		1855-1934	1954-1971	1972-1984
Changed area	Increased area km^2	2018	467.6	265.1
	Annual increment km^2/year	25.5	27.5	20.4
Changed volume	Increased volume 10^8 m^3	85.25	10.25	10.53
	Annual increment 10^8 m^3	1.07	0.60	0.81
Silt amount	Silt amount 10^8 ton		119.11	109.26
	annual silt amount 10^8 ton		11.71	8.40
Increased area by each 10^8 ton (km^2/10^8ton)			2.35	2.43
Increased volume by each ton (m^3/ton)			0.051	0.096

Comparing with the DEM data among 1954, 1972 and 1984 in chart, we can get some conclusions:

a. From 1954 to 1971, the area above zero meter elevation increased 467.6 km . The annual increment is 27.5 km^2. From 1972 to 1984, the area in creased 265.1 km . The annual increment is 20.4 km^2. The latter is less than the former. The amount between 1855 to 1934 is less than the former but more than the latter. This change may mean the change of the river silt.

b. From 1954 to 1971, the total silt amount in Lijin hydrologic station is 119.11 hundred million ton. The annual amount is 11.71 hundred million ton; From 1972 to 1984, the total silt amount is 109.26 hundred million ton, the annual amount is 8.40 hundred million ton. The latter is less than the former.

c. From 1855 to 1934, the annual increment in volume is 1.07 hundred million m^3; From 1954 to 1971, the annual amount increment is 0.60 hundred million m^3; And from 1972 to 1984, the annual increment is o.81 hundred million m^3. The change in volume is first decreasing o.47 hundred million m^3 and then increasing 0.21 hundred million m^3.

d. The more the silt amount was deposited, the more the increment in area is, but the less the increment in volume is. The cause which begot these phenomena may be relative to the water amount and the total silt amount each year.

(4). Analysis of the Depositional Situation of the Subaqueous Delta

The Yellow River Subaqueous Delta is the natural extension of YRD under sea level. It is the important part of YRD. The area between -25 to 0 meter is about 6907 km^2.

Chart 2. Silt depositional distribution of the Subaqueous Delta

elevation m	area km^2	volume 10^8 m^3	terrain status	volume each km 10^6 m^3/km^2
-26.0 to -25.0	74.25	0.04	0.89	0.59
-25.0 to -22.5	842.75	2.05	1.83	2.43
-22.5 to -20.0	856.50	4.00	-0.47	4.68
-20.0 to -17.5	962.75	6.90	-5.85	7.17
-17.5 to -15.0	905.00	8.79	-5.32	9.72
-15.0 to -12.5	777.75	9.44	-1.07	12.14
-12.5 to -10.0	887.50	13.09	0.04	14.75
-10.0 to -7.5	543.50	9.30	-5.43	17.10
-7.5 to -5.0	373.75	7.35	-5.97	19.65
-5.0 to -2.5	350.00	7.75	-1.2	22.13
-2.5 to -0.8	407.75	10.01	2.08	24.56

Based on the subaqueous delta DEM data, we have got some results (see chart 2). Let's analyse the data in chart 2. we can obtain following results :

a. The silt sediment of the subaqeous delta is deposited within -20 meter isobath.

b. Most of the silt sediment is concentrated in the range from -10 to 0 meter.

c. The silt sediment decreased very quickly between -15 to -10 meter.

d. The isobath which the elevation is -10 meter may be an important curve. The silt depositional characteristics may exist some evident difference within -10 meter area for different times of the subaqueous delta.

III. THE RIVER COURSE AND COASTLINE EVOLUTION

1. Evolution of the Lower Yellow River Courses

Dyke burstings of the Lower Yellow River took place over 1500 times, and large burstings also took place more than 25 times since B.C. 2278. After 1855, the Yellow River

abstracted the Daquing River, dyke burstings have taken place over 50 times, and large burstings and course changing was 12 times.

2. Coastline Evolution in YRD Area

Coast zone is one of the most active geographic units on the earth surface. Some scientific researchers have studied the migration of the Bohai Gulf from Pleistocene epoch by researching the drilling data and analysing MSS, TM satellite image.

3. Dynamic Display System of the River Course and Coastline

Evolution in the Lower Yellow River and Its Delta

From ancient time, the migration of the Yellow River took place incessantly, especially in the lower reaches and river mouth area. By studying the migration of river courses and coastlines, we can understand the historical change and change pattern. Lately, we have done some studies which is how to describe dynamic changes of river courses and coastlines with computer and graphic software system. So we have developed "the Dynamic Display System of the River Course and Coast line evolution in YRD (DDSYRD). The results indicate that the dynamic display software is a useful tool not only for reproducing the dynamic evolution on the computer screen about some natural phenomena, but also for studying the evolutional model and forecasting the further development.

The Dynamic Display System includes three parts :

a. System specification

b. Dynamic display subsystem of river course and coastline evolution in the Lower Yellow River area (LYRA). (from B.C. 2278 to 1976)

c. Dynamic display subsystem of river course and coastline evolution in the New YRD(NYRD). (from 1855 to 1987)

Fig 1 and Fig 2 demonstrates the data processing and the procedure of system execution.

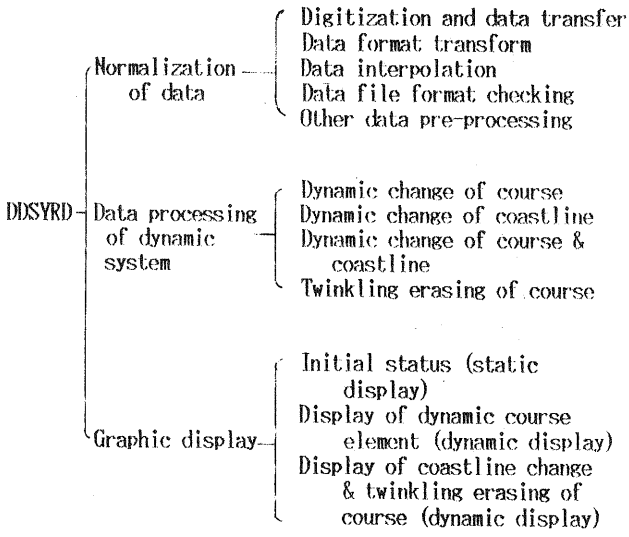


Fig 1. Data processing of DDSYRD

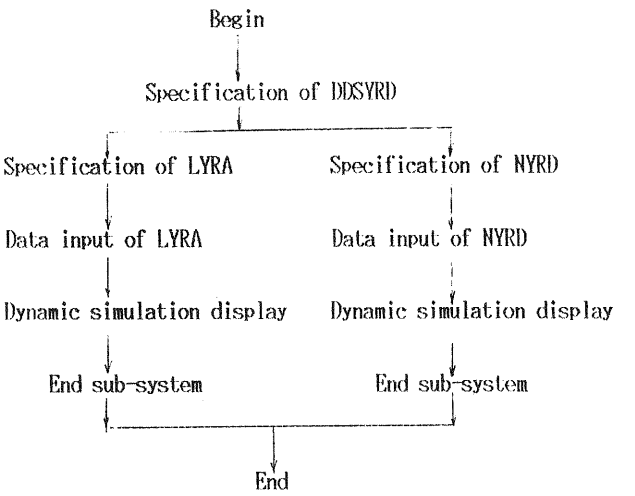


Fig 2. Execution diagram of DDSYRD

IV The Change of the Vegetation Distribution in YRD during Recent 30 Years

On the basis of the maps of vegetation distribution in YRD, which we made with 3 terms data of 1955, 1972 and 1985, we analysed the changes of the vegetation distribution during 1955 -- 1985 in the area.

The vegetation in YRD is classified to 10 types, according to the sequences which appearance from the seashore to the inland, they are : 1).mud flat; 2).salt lick; 3).reed mixing with some salt-enduring grass; 4).reed mixing with some salt-enduring shrub; 5).salt-enduring grass-shrub; 6).salt-enduring grass-arboret; 7). halo-steppe; 8).forest; 9).rice field; 10).cultivated land (including the lands of corn, cotton, wheat and some artificial land).

comparing the 3 maps, we found some evident changes in YRD area:

(1) The forests and salt-enduring grass-arboset tend to be on the decreasing:

a. In 1955 there were some large-area forests located in the north part of the Yellow River, especially gathered in the area was higher than 5 meters. The salt-enduring grass-arborsets located along the two sides of Yellow River course which wasted lately, were parallel to coastline.

b. In 1972, the large-area forests located in inland area had disappeared, only few remained near the places where Yellow River changed its course in 1964. The range of salt-enduring grass-arbosets located near coastline become to be narrow.

c. In 1985, the forests had remained only in some scattered lands, along the course of the Yellow River wasted in 1964 and in 1976 of northeast of the YRD there were forests in belt area.

The salt-enduring grass-arbosets had disappeared on the whole, they were taken place by reeds, salt steppe or artificial lands.

(2) The salt lick tends to be on the increasing:

Contrasting to the decreasing of the forests, the salt lick tends to be on the increasing in YRD. There are two types of salt lick in the area. One type is large-area

and located in the northeastern and southeastern of the YRD. Another type is in scattered lands. the former is due to its location closed to seashore and is influenced by the sea. The latter is scattered from seashore to inland. Composing the maps of 1955 and 1985, we found the latter type in 1985 is clearly more than in 1955 in the inland in cultivated area.

(3) The range of artificial land is expended and the inner boundary of the natural vegetation is moved forward the seashore:

Due to the continuously expanding in YRD since 1855, more and more farmers come to YRD to open up the virgin soil, and the cultivated land area is continuously expanded. So the inner boundary of the natural vegetation is gradually move to the northeast of the YRD. Comparing with 1955, the newly expanded artificial lands mainly located over the fan-shaped area ranged from the course before 1976 to the course before 1954, the elevation is higher than 3 meters in the area.

(4) The distribution range of the reeds tends to be on the increasing:

a. In 1955, the reeds were mainly located in the part close to seashore of the course wasted in 1953, and in the northeast of the YRD.

b. In 1972, the range of the reeds was expanded to the course wasted in 1964 and the lower reaches of the new course at that time.

c. In 1985, the range of the reeds was further expanded to the area close to seashore of the current course. In the meantime the salt-enduring grass-arboset and salt-enduring grass-shrub were gradually decreased and on the whole disappeared in the same area.

(5) The distribution in the two side of northwest and southeastern of the YRD is stable on the whole:

Contrasting finely with the changes of the vegetations in the northeast of the YRD at the same time,the vegetations located in the northwest and in the southeast of the YRD are stable in the main, although the range was more or less changed.According to the pattern of the distribution of the vegetation over the two areas, the appearing sequences of the vegetation types, in both areas are mud flat --> salt-enduring vegetations --> cultivated lands from the seashore to the inland, are not changed. Especially, it is not influenced by the change its course of the Yellow River for 60 years in the northwest of the YRD, and for 30 years in the southeast of the YRD. So the inner boundary of the natural vegetation in both areas are stable near the range which elevation is about from 3 to 4 meters, where is the upper limit influenced by the storm surge.

So we can found the summary knowledges of the follow:

(1) The basic characteristics of the distribution of the vegetation are belting and zoning

The belting means that the appearing sequence of the vegetations is mud flat --> halo-vegetation --> salt-enduring vegetation --> cultivated land, though the ranges and the types are more or less changed.

The zoning means that there are differences between the northeast with northwest and southeast in the YRD, the former one is mainly covered by reeds due to the lower elevation and close to the current and wasted courses of the Yellow River, and in the northwest and in the southeast of the YRD, in the both areas the natural vegetation are halo-plant and halo-enduring plant.

(2) the dominant(leading) factors which change the ranges of the vegetation in YRD are the swings of the Yellow River tail and the human actives.

Due to the swings of the Yellow River tail were limited in the northeast of the YRD during the recent 30 years, the vegetation range was evidently changed in the area, the dominant species of the biocommunity is the reed. In contrasting with the change in the area, the natural vegetation in the northwest and in the southeast of the YRD, which coastlines are stable for a long time, their ranges are not to be changed.

The human actives caused the range of the cultivated land to expand and result in the decreasing of the forest during past 30 years.

(3) The succession of the natural community in the YRD

The leading factors limiting the range of the vegetation in YRD are soil moisture and soil salinity, and the climate in YRD is not clearly changed in past 30 years. So the succession of the natural community is mud flat --> halo-plant --> salt-enduring plat --> salt-unenduring plant in the YRD. In the lower and flat area, likely in the northeast of the YRD, the dominant species is the reeds, and in the other areas, the dominant species are halo-plant and-enduring plant.

V CONCLUSION

Based on the discussion above, we can reach following conclusions:

a. The great silt sediment results in the river course and coastline migration. On the other hand, the river course and coastline migration results in the delta forming, evolution and development. So for exploiting YRD, understanding above situation is the key.

b. DEM can reflect the different situation of the different silt depositional order to some extent. Because the different sub-deltas have different depositional characteristics. the syntheses of the characteristics constructs the terrain boundary among these different sub-deltas.

c. The ranging of the vegetation in YRD have changed very evidently in the past 30 years. The main factors caused the change are the swings of the Yellow River tail and the artificial activaties.

d. The swings of the Yellow River tail also is the main reason of other environmental factors' development.

REFERENCES

1. Chen Shupen, Some Information of Quaternary Environment hances from Satellite Image in North China Plain, Quaternary sciences, No. 1, 1990
2. Chen Feng, The analysis and application of the Micro-terrain DEM for the Yellow River Delta, Regional Study and Exploitation Special Issue, 1990
3. Chen Feng, The Computer Dynamic Simulation Display of the River Course and Coastline Evolution in the New Delta of the Yellow River, LREIS Annual Report, 1989-1989
4. Pang Jiazhen and Si Shuheng, Evolution of the Yellow River Mouth, 1979
5. Tang Xinqiao, Analysis of the Environment Evolution in the Yellow River Delta, Report of the Researches of Water and Ice Warning Information system in the Yellow River Delta, 1990
6. Ye Qingchao and Yang Yifen, The forming of the Yellow River Alluvial Apron, 1981

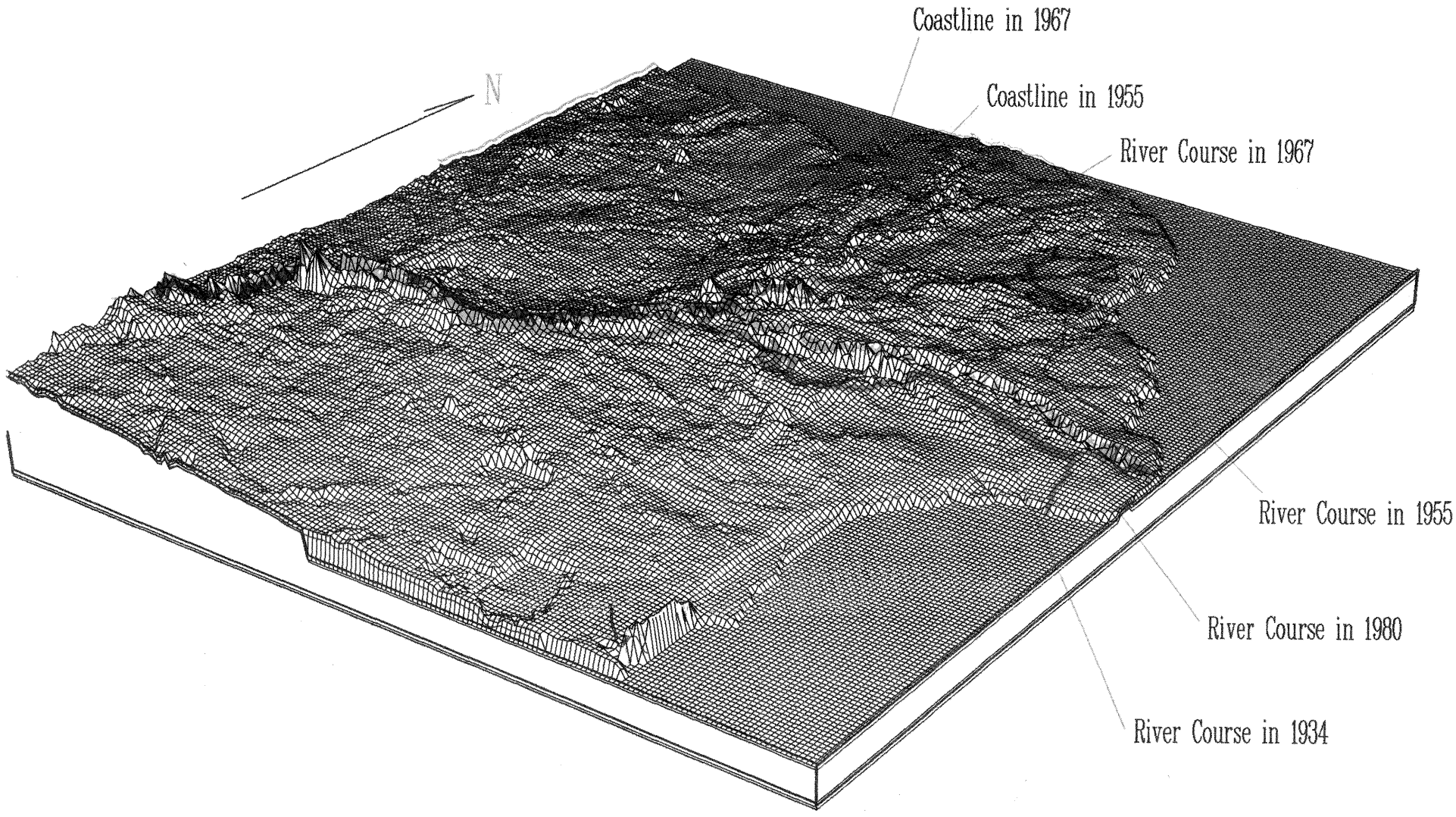


Fig. 3. Micro-Terrain DEM in YRD(Elevation difference 0.25 meter)

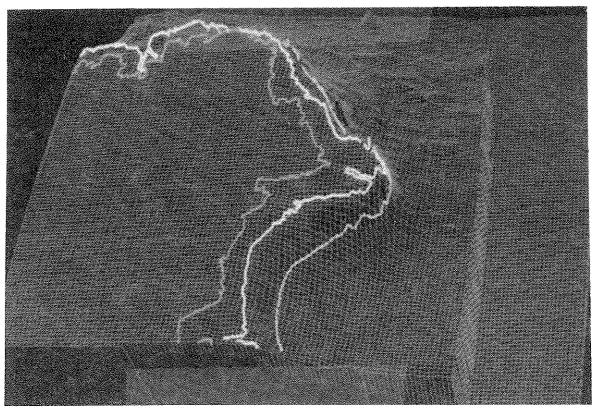
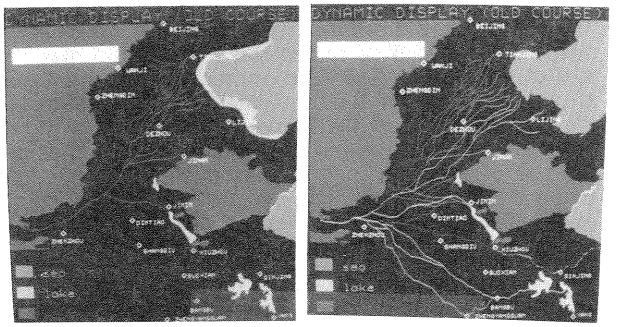
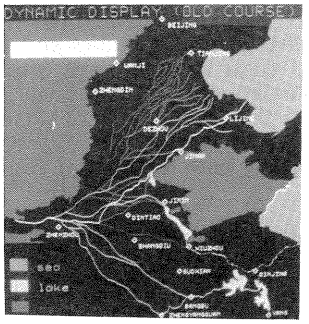


Fig. 4. DEM of Subaqueous Delta in YRD



a b

(1) Sub-system of LYRA (from B.C. 2278 to present)



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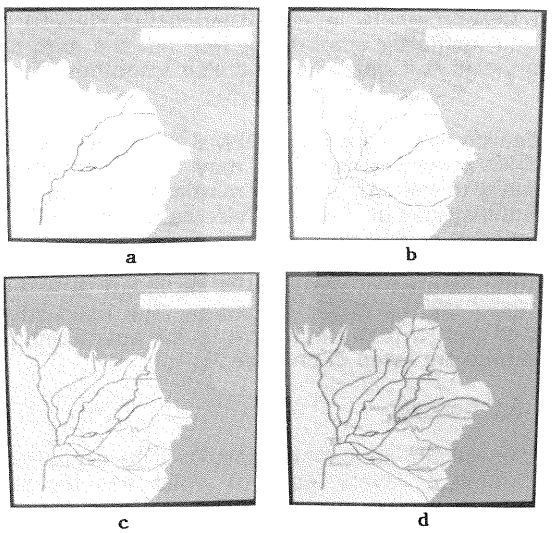
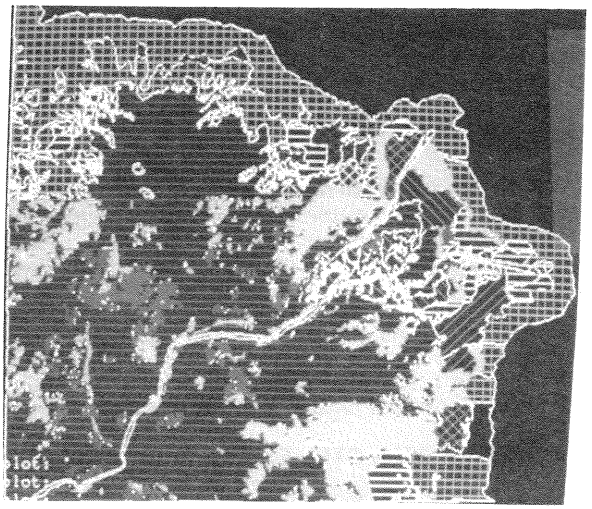


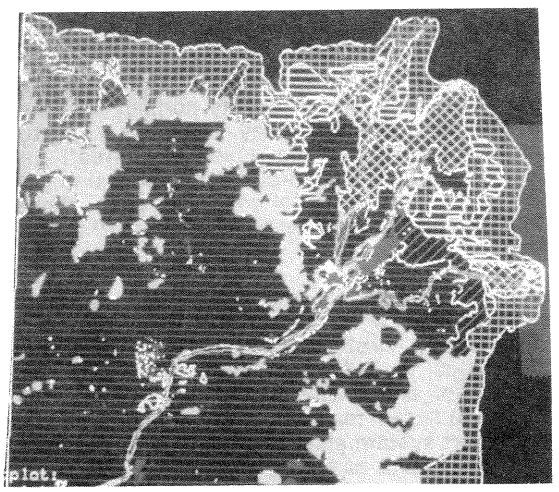
a b c d

(2) Sub-system of NYRD(from 1855 to present)

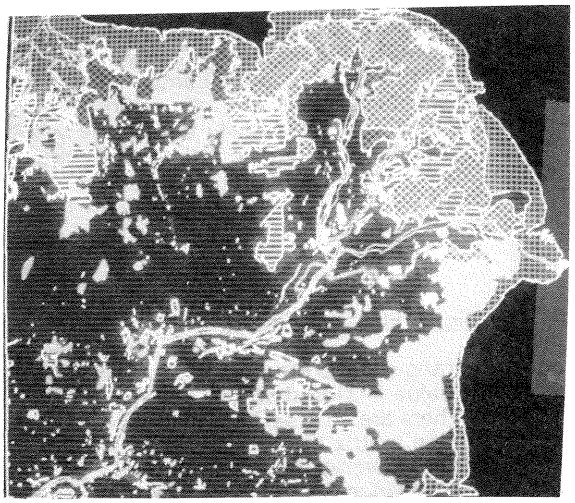
Fig. 5. Dynamic display system of river course and coastline evolution in LYRA and NYRD



a (1954)



b (1972)



c (1985)

Fig. 6. Vegetation change of YRD (from 1954 to 1985)