Science in China Series E: Technological Sciences

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On geo-basis of river regulation —A case study for the middle reaches of the Yangtze River

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From the point of view that people have to obey the river's geo-attributes in the river regulation, the definition and the meaning of the geo-attributes of a river are discussed. The geo-basis of the river regulation of the middle reaches of the Yangtze River is expounded in five aspects, including the structural geomorphology environment of flood storage and discharge, the distribution characteristics of subsidence and the sedimentation areas of Dongting Basin, the history evolution of Jianghan Basin, the function of Jianghan Basin and Dongting Basin as the flood water detention areas of Jingjiang River reach in ancient time, and the geological characteristic of Jingjiang River reach. Based on the geo-attributes of the middle reaches of the Yangtze River, some ideas about the middle reach regulation of the Yangtze River are put forward: to process the interchange between the lakes and diked marsh areas in Dongting Basin, to canal the new river route as the flood diversion channel of Jingjiang River reach with the paleo river, to recover the function of Jianghan Basin as flood detention area of the middle reaches. And we should take into consideration the geo-environment of the whole Yangtze River in the river regulation of middle reaches.

river, geo-attributes, river regulation, the Yangtze River, flood

1 Introduction

When reviewing flood control systems of the rivers in China, we have found that there are some thresholds in almost every system of rivers. For example, the threshold of the middle reaches of the Yangtze River is to restrict the water level at Chenglingji gauging station within 34.3 m; the flux at Huayuankou gauging station should not be more than 22600 m^3/s for the safety of the lower reaches of the Yellow River; as the threshold of floods in Taihu Lake basin, the water level at Linqiao gauging station in Wangyu River should be controlled within 4.2 m, Pingwang station in

Received June 13, 2006, accepted December 10, 2006
doi: 10.1007/s11431-008-0068-y
Supported by the National Natural Science Foundation of China (Grant No. 50579039)

Taipu River within 3.3 m and Taihu Lake within 4.8 m. Moreover, the threshold of Huaihe River floods control is to keep the water level at Zhengyangguan gauging station within 26.4 m, and that of Songhuajiang River at Ha'erbin gauging station where the flood discharge should be controlled within 15700 m^3/s, etc. These thresholds act as the key points in the flood control system, as well as the focus in flood control and the establishment of its plan. Although these thresholds are decided based on the historical evolution of the flood control systems, the flood control standard as well as the balancing interests of every related department and region, they could still imply: Are these thresholds indispensable and objective? Are they actually 'sticking points' due to the disagreement of flood control systems of the rivers with their geo-attributes?

In the practice of the river regulation in China, many important science problems have been brought forward. For example, (1) what will the future of the lower reaches of the Yellow River – "above-ground river" be? Are the prospects of "the related below-ground river" and the "blocking, discharging, depositing, diverting, dredging" strategies on the lower reaches of the Yellow River regulation in accordance with the evolution of river channels? Or is to artificially change its route really inevitable at some suitable time and place on the lower reaches of the Yellow River in the future? (2) What is the final solution to the flood control in the middle reaches of the Yangtze River? Is the current flood prevention strategy based on "the river-lake relationship" controlled by water level at Chenglingji gauging station in accordance with the real condition and rules of the flood formation in the middle reaches of the Yangtze River? How will the "the river-lake relationship" evolve? (3) What is the reason of the channel shrinkage and estuary sediment, which are the big problems of Haihe River? What are the effects of human and geo-factors on this process? The Yellow River diverted during Eastern Han Dynasty and its canalization afterwards make all the rivers in Hebei Plain finally flow together to form a fan-shaped river system of Haihe catchment with Haihe's main reaches as the stem[1]. Does the modern flood control framework of "the separate conduct to sea, zonal flood defense" based on comb-shaped water system agree with the natural evolution of Haihe water system? Will the modern framework contrarily aggravate channel shrinkage and estuary sediment with too many artificial channels separating water and therefore being unable to support the river? (4) The ancient Huaihe River flowed directly to sea in a single channel[2]. From 1128 to1855 the Yellow River captured Huaihe River, plenty of sediment changed the middle reaches of Huaihe River to "the above-ground river", the old channel to sea was blocked up, the branches dried out or changed direction, the original lakes died out, and the disused Yellow River, whose river-bed was several meters above land surface, divided Huaihe river basin into Huaihe and Yi-Shu-Si water systems, which completely destroyed Huaihe water system. Therefore, it is the Yellow-Huai river relationship that determines the evolution of Huaihe River. How can we understand the geo-background of Yellow-Huai river relationship and its evolution, so as to find out the measures and the theories of the modern river regulation of Huaihe? (5) What is the relationship between Taihu Lake Plain floods and geo-attributes, which is changing from a fresh water lake into a seclusion lake (the current renewing rate of Taihu Lake water is only 1.1 times per year)[3]? Drainage channels in Taihu Lake plain have been stagnated and shrinking. What are the number and scale of the drainage channel that the water production rate of modern Taihu, 13.67×10^9 m^3, can support? (6) In Liaohe River basin, the reservoir storage and the runoff rate is nearly 1.0, which makes the river fully under human control, but floods are still frequent and reservoirs still need construction. Is there a certain 'extent' of the river regulation? What is its control factor? How can we understand and determine it? etc.

Obviously, only when these questions are correctly answered, can the structure and the general strategy be framed properly. In addition, when researching into these scientific problems, we have found out that one of the essences of the problems is how to thoroughly understand and obey geo-attributes of rivers, and make the structure and strategy of the river regulation in agreement with it. Accordingly, 'the geo-basis of the river regulation' is brought forward as an important scientific topic.

2 Definition

The geo-basis of the river regulation means the regulation of river should obey the geo-attributes of rivers, including geo-elements as geology, geomorphy, hydrology, climate and physical geography of river basins.

The geology of river basins mainly refer to the original landscape formed during the Neo-tectonic Movement (tectonic movements after Neogene), and it determines the basic properties such as flow direction slopes of rivers, as well as the local uplift or the subsidence movements of rivers in China. For example, Himalaya tectonic movement formed the topography of being high at the west and low at the east, in the form of three-stair slope towards east, making large rivers, such as the Yangtze River and the Yellow River, flow to the east; the Neo-Cathaysian tectonic system formed huge structure zones with several alternate uplift and subsidence zones in East Asia from east to west: ① the first subsidence zone of Bohai Sea-Yellow Sea-East China Sea; ② the first uplift zone of Liao-Lu-Min-Zhe geodome system; ③ the second subsidence zone of Songliao Plain, North China Plain, Jianghan and Dongting Plain connected with each other; ④ the second uplift zone of Taihang-Wuling geodome system (Figure 1)[4]. Such huge structure zones of alternate uplift and subsidence determine the macro erosion and sediment characters of rivers in eastern China.

The geomorphy of rivers is formed by the long-term interaction of the river valley, river flow and sediment based on the geologic structure. Moreover, the geomorphy of rivers can counteract the river flow and sediment. Therefore, the geomorphy is not only the history record of the river's evolution, but also the dominative factor of its current shape and developing trend. Modern researches on geomorphy of rivers cover both the shaping function of the external motive force on the river and the tectonic geomorphy since Quaternary[5]. Actually, storms and floods in a large area from Songliao Plain, North China Plain, Jianghan Plain to Dongting Plain are just caused by the tectonic geomorphy of the second subsidence in East Asia, which makes floods there easy to converge but difficult to discharge.

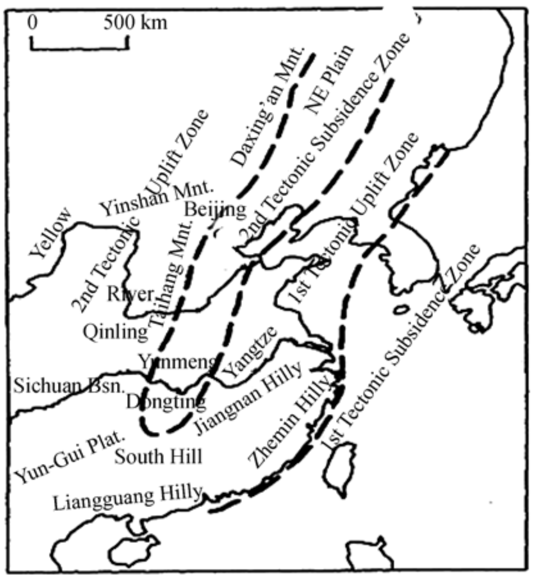

Figure 1 Sketch showing structure geomorphology of Southeastern Asia (ref. [4]).

The hydrology and climate are most active factors on rivers. In China, East Asian monsoon determines river's water regime in eastern part, as well as the development of rivers. From the perspective of hydrology and climate, rivers are the result of climate, and climate determines hydrology of rivers, namely the flux of material flow (river flow, sediment and solute) and energy flow of rivers, as well as its hydrodynamic property including flood and drought, erosion and sediment.

The physical geography of river basins, including the water and sediment source and the ecologic characters etc., provides specific environment basis of river evolution. Destruction of river's physical geography will do harm to the river's health and result in the shrinkage or even the death of rivers.

Just as 'the gene' of a river, these geo-factors altogether constitutes the river's geo-attributes, which remain stable with time, or only behave regular annual change, but have inherent, permanent and dominant effect on the river's evolution.

The river regulation is the interaction between human and rivers, and is the dialogue between human and river. However, human always holds leading place in the regulation of rivers, and they have the increasing impact on rivers in various manners and scales. But the geo-attributes of rivers do not change with the human's wish, and the management on rivers against the geo-attributes will certainly get revenge from the rivers. Thus, the geo-attributes of rivers should be the basis of the river regulation.

3 Geo-basis of the middle reaches of the Yangtze River's regulation

In the Yangtze River's regulation for nearly half a century, the remarkable achievement has been made in the flood control and the channel regulation of the middle reaches, but the situation of flood control is still serious there, one of the most important reasons is probably the inadequate understanding of its geo-attributes. Actually, the severity of the water problems in the middle reaches of the Yangtze River is not only owing to big floods from the upper reaches, but determined by the special geo-attributes of the middle reaches. From the perspective of river regulation, the geo-attributes of the middle reaches of the Yangtze River mainly include the flow condition of floods, the sediment of Dongting Basin, the evolution of Jianghan Basin, the distributaries of river, the change of Jingjiang River channel, the climate and hydrological condition of the middle reaches, etc.

3.1 Flow of floods in the middle reaches

The storage and discharge of floods in middle reaches means the initiation, confluence and effluence condition, which is formed comprehensively by the tectonic geomorphy of middle reaches and the East Asia Monsoon. On tectonic geomorphy, as shown in Figure 1, the low-lying middle reaches of the Yangtze River is located in the south of the second tectonic subsidence of East Asia Neo-Cathaysian, to the east of which is the first uplift zone consisting of Dabie Mountain and Southeast Hills, and to the west is the Neo-Cathaysian second uplift zone formed by Daba Mountain, Wuling Mountain, Xuefeng Mountain. Such geomorphy makes the east slope of the second uplift formed by Daba Mountain, Wuling Mountain and Xuefeng Mountain the windward of east summer monsoon, and the largest storm region in China.

On the other hand, the first uplift blocks flood from discharging to the east, and thus floods in the middle reaches are easy to converge but difficult to discharge in the valley of the first and second uplifts on the east and west sides. Therefore, the comprehensive effect of the specific tectonic geomorphy environment and East Asia monsoon is an important factor to form serious flood condition in the middle reaches of the Yangtze River.

3.2 Modern sediment character of Dongting Basin

Dongting Basin was formed in later period of Yanshanian Tectonics, and is an intensive down-faulted basin in arc uplift of Xuefeng Mountain[6], which is an important regulator of the Yangtze floods and is significant to the middle reaches of the Yangtze River regulation. Based on the research on the formation and evolution of Dongting Lake, the sediment character of Dongting Basin has three aspects:

(1) Generally, Dongting Basin is still in the process of tectonic subsidence with the current average subsidence rate around 5—10 mm/a[6]. Obviously, this is due to the vertical distortion of Dongting Basin controlled by geologic environment, located in the second subsidence zone of East Asia Neo-Cathaysian.

(2) Sediment in Dongting Basin is uneven, with subsidence and relative uplift alternately distributing. Because Dongting Basin is a down-faulted basin formed by crustal movement, undergoing an inter-shearing and different vertical movement between faults of northeast-southwest and northwest-southeast, the sub-concave and convex are formed in this down-faulted basin[7]. Such concave and convex form basic structure of physiography in the lake basin, and control the water system and the subsidence distribution in the lake area.

(3) In Dongting Lake Basin, the spatial distribution of subsidence and sediment are uneven. Besides the hills, there are mainly flood passages, lakes, and diked marsh areas in Dongting Lake Basin[8]. Sediments in the basin mainly come from the 'three mouths (flood diversion passages)' (Songzi Mouth, Taiping Mouth and Ouchi Mouth) which connect the Yangtze Rive and Dongting basin and 'four branches' (Xiangjiang River, Zijiang River, Yuanshui River and Lishui River), among which sediment from 'three mouths' takes up 86% and from 'four branches' 24%. These sediments mainly fill flood channels and lakes, while seldom in diked marsh areas due to the protection of dikes. In general subsidence trend of the basin, sediment rate is higher than subsidence rate, resulting in annual net sediment thickness of about 60 mm/a[9]. Therefore, elevation in diked marsh areas decreases for the subsidence, while elevation in flood channels and lakes increases for sediment, which finally makes the elevation of flood channels and lakes higher than that of diked marsh areas. For example, the average elevation of western Dongting Lake bottom near Hanshou County is 4.4 m higher than adjacent diked marsh areas; the average elevation of southern Dongting Lake bottom is 3.6 m higher than nearby Nanxian County diked marsh areas, forming a scene of 'above-ground lake' and 'above-ground river'[9]. Such uneven subsidence and sediment act as an important cause of floods in Dongting Lake Basin.

3.3 Geomorphy evolution of rivers and lakes in Jianghan Basin

Both Jianghan Basin and Dongting Basin are located in the southern part of the second subsidence zone in Neo-Cathaysian structure of East Asia, and were formed by the down-warped movement in early Cretaceous period. Jianghan Basin has been subsiding ever since late Mesozoic, and several lakes have formed contemporarily. Yunmengze was a large lake formed in early Mid-Holocene due to tectonic subsidence and sea level rising in Postglacial Period and the stay of the Yangtze River water in the basin.

In Mid-Holocene (5000—12000 a BP), Jianghan Basin was overland flow area of Jingjiang section in the Yangtze River, and Yunmengze was an outflow lake in this overland flow area linking the Yangtze River. During Pre-Qin Dynasty, Yunmengze was located in the middle area of Jianghan Basin, to the west of which was Jingjiang Delta with Shashi City as a vertex, and to the east was floodplain spreading to Wuhan City. Water area of Yunmengze then grew to its largest extent, and was a main flood regulator of the Yangtze floods. In Han, Jin, and the Northern and Southern dynasties, because of the eastward movement of Jingjiang Delta and southward movement of Jianghan Delta, the body of Yunmengze was forced to move east, and water area was less than half in Pre-Qin Dynasty and water got shallow; meanwhile the height of Jianghan Basin was increasing with sediment, thus showing a swamp scene and remarkably weakened regulation ability to the occurring floods. In Tang, Ming and Qing dynasties, the growth of Jingjiang Delta shrank Xiashui and Yongshui rivers which originated from the delta, and water flow from Jingjiang River by Xiashui and Yongshui rivers to Yunmengze decreased, aggregating shrinkage of Yunmengze to dotted groups of lakes, which were rudiments of current lake groups in Jianghan area. Also, Jianghan Basin has grown to plain scene with frequent floods[10].

Based on the above analysis, from the perspective of river regulation, the geomorphy attributes of Jianghan Basin mainly are: ① During the past 10000 years, due to its geological condition of the second tectonic subsidence zone in East Asia Neo-Cathaysian, Jianghan Basin has been tectonically subsiding, providing tectonic geomorphy condition for the evolution of lakes and the regulation of the Yangtze floods in the basin. ② Evolution of Jianghan Basin is closely connected with the formation and the development of the ancient Jingjiang River Delta, and thereby, the formation, evolution and development of Yunmengze. During such process, Jianghan Basin has always been a main regulator of the Yangtze floods, which was gradually weakened owing to human agriculture activities ever after some historical period especially Mid-Ming Dynasty[11]. Up to now, as illustrated in Figure 2, the average land surface elevation of Jianghan Basin has been lower than that of Dongting Lake Basin.

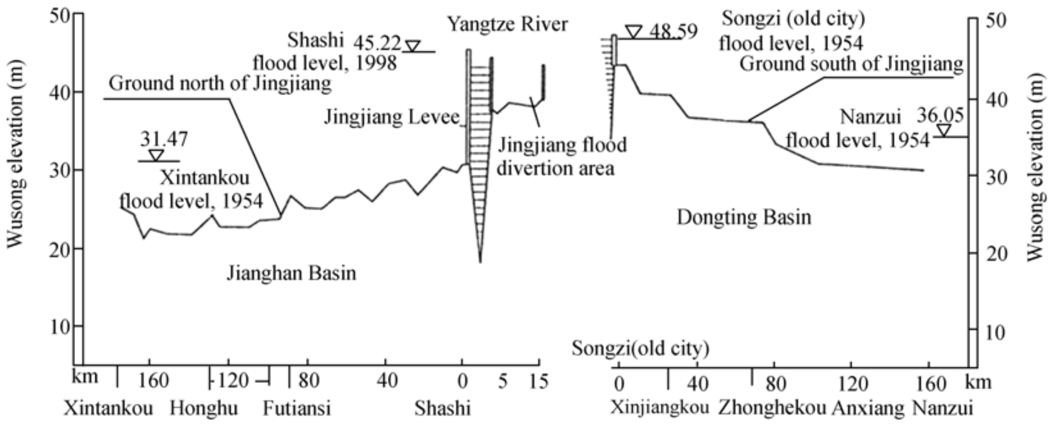

Figure 2 Section of Dongting and Jianhan basins showing topography and flood water level (according to the Design Institute of Changjiang Water Resources Commission).

3.4 Distributary attributes of the middle reaches channel

Distributaries of the middle reaches channel refer to floods in Jingjiang River channel flowing separately to Dongting Basin and Jianghan Basin, which reflects geomorphy condition of hydrologic connection between Jingjiang River, Dongting Lake and Jianghan Basin.

Before 550000 a BP, there was no 'ancient Jingjiang River channel' where the Yangtze River flowed into Jianghan Basin. At that time when the Yangtze River flowed out of the valley, it first entered Dongting Basin from southeast side and then flowed northeast to Jianghan Basin. 40000 years ago, 'ancient Jingjiang River channel' formed and the Yangtze River started to flow directly eastwards to Jianghan Basin by Chen'erkou between Yidu and Zhicheng City. 'Ancient Jingjiang River' at that period was in overland flow state, and gradually formed the fan-shaped gravel delta with vertex near current Qixingtai. About 18000 a BP, the Last Glacial Maximum period, sea level of the East China Sea was about 120 m lower than the modern level. Consequently due to the entrenchment of riverbed in the middle reaches of the Yangtze River, ancient Jingjiang River channel changed from overland flow mode into fan-shaped distributary water system, and then formed three deep river channels. These ancient river channels have great impact on the evolution of Jingjiang River distributary channel. Global climate turned warm during 12000－5000 a BP, the rising sea level of the China East Sea and correspondingly the ascending base level of the Yangtze River caused the lengthways slope of riverbed decreased, and intensive headward sediment at Jingjiang Delta, the development of which made Jingjiang channel the overland-flow flood passage again. Around 5000 a BP, the climate of China changed from warm Atlantic period to cold, and Jingjiang water system returned from distributary flood channels to overland flow mode. Contemporarily, distributary water system of Jingjiang River left bank was formed with Xiashui, Yongshui and Yangshui rivers, and then evolution of Jingjiang channel was accelerated. In Pre-Qin period, Jingjiang Delta with Shashi City as a vertex had grown to a terrestrial delta, and distributary channels as Xiashui, Yongshui which originated from the delta fully developed, diverting some Jingjiang floods into Yunmengze (Figure 3)[10]. In Han, Jin and Southern dynasties, with the development of Jingjiang Delta and shrinkage of Yunmengze, the distributary channels of Xiashui, Yongshui and Heshui gradually degraded to seasonal flood channels which dried up in winter. Contemporarily, Lunshui River was formed in Youkou section near Gong'an County on the right bank of Jingjiang River diverting water to Dongting Basin. In Tang and Song dynasties, with further development of Jingjiang Delta, flood channels of Xiashui and Yongshui vanished, and were replaced by the natural seasonal mouths of flood diversion passages, as an old saying of 'nine mouths and thirteen openings' describing the situation at that time. Meanwhile, due to the distributaries of Hudu River on the right bank and Shengjiang River diverted from Jingjiang Basin to Dongting Basin, fantastic 'eight-hundred-li-Dongting' scene came into being. In Yuan, Ming and Qing dynasties, on the left bank natural diversion channels gradually vanished and Jingjiang levees were constructed; on the right side, the river bank was breached in catastrophic floods of 1860 and 1870, forming Ouchi River and Songzi River, and finally Jingjiang River changed from totally flowing to Jianhhan Basin into totally to Dongting Basin (Figure 4)[10].

From the above distributary attributes of the middle reaches of the Yangtze River, it can be summarized that: ① since geological age usually there have been several channels draining floods in the middle reaches of the Yangtze River; ② the evolution of Jingjiang River channel diverting flow from left bank to right side reveals that Dongting Basin and Jianghan Basin are the places both diverting and regulating floods; ③ the evolution of Jingjiang River channel is closely related to the change of Jianghan Basin and Dongting Basin, all of which are integrated with each other.

3.5 Geology and geomorphology attributes of Jingjiang River channel

(1) Geology and geomorphy attributes along the river channel

Jingjiang River channel lies across the second subsidence zone of the East Asia Neo-Cathay-

1) One li equals 0.5 km.

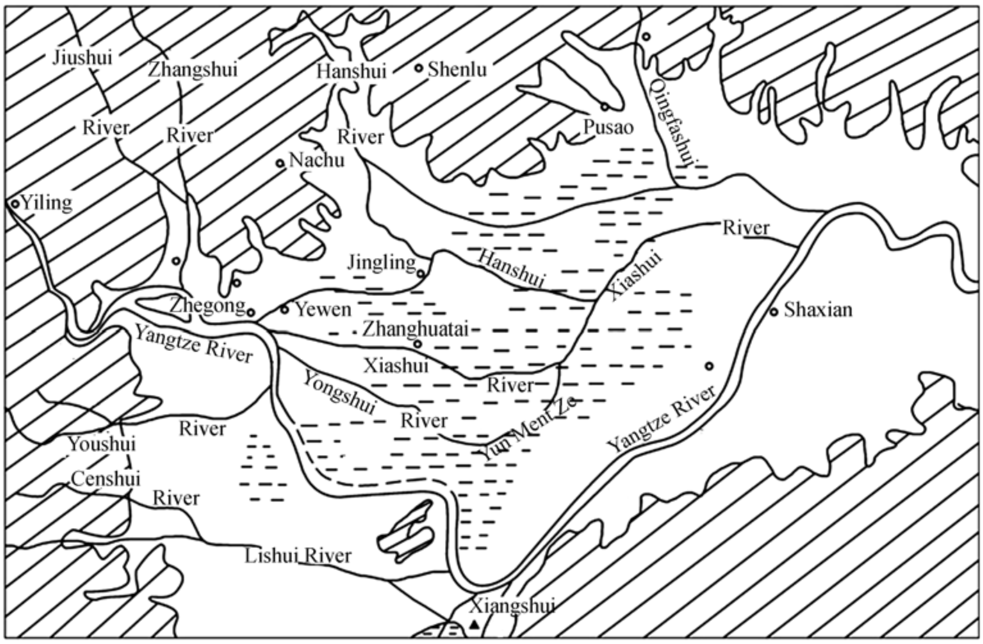

Figure 3 Distributaries of Jingjiang River flowing into Yunmengze during 221—206 BC.

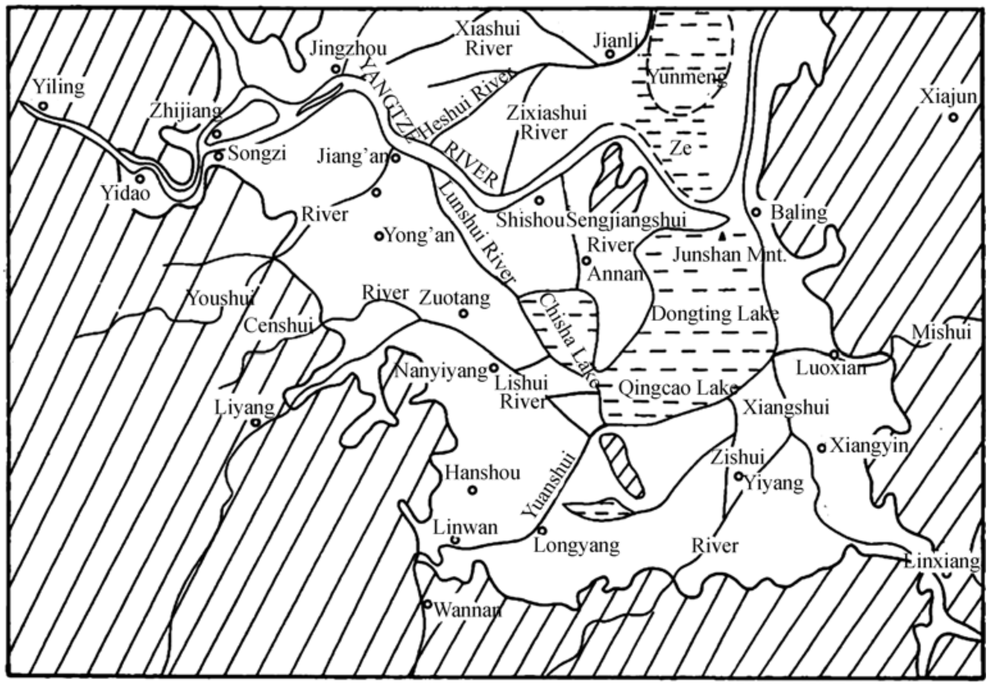

Figure 4 Distributaries of Jingjiang River flowing into Dongting Lake during 420—589 AD.

sian, on the west side of which is Three Gorges tilted uplift zone, on the east is fluvial plain formed by Yunmengze, and on the south and north sides are Tongbai-Dabie Mountain east-west tectonic zone and the South Mountain east-west zone. Such geology and geomorphy environment generally determine the evolution of Jingjiang River channel.

Jingjiang River Channel lies on the third step of Chinese topography, flowing from hills to subsiding fluvial plain. Jingjiang Valley was formed by geology, topography and water-sand dynamic effect along it. The geology and geomorphy conditions are changing along the river, therefore the dominant factor and mechanism of the evolution vary with river sections, resulting in large difference in geo-attributes and characters between each river sections, which is quite clear in its three river sections:

① Yi-Zhi section, the river section between Nanjinguan and Songzikou, lies in valley of hills. Regions the river flows by are in Neo-tectonic movement in depressed and broken configuration of uplifting in west and subsiding in east with the subsiding center gradually moving eastward, therefore the valley was dominated by geological units as 'Yi-Zhi Tilted Structure', 'Yichang Monocline', 'Zhicheng Depressed and Broken Formation' and 'Jiangling Depression' along the river, forming this section with both characters of valley in mountainous area and transition zone from valley in mountains to plain areas.

② Up-Jingjiang section, the river section from Songzikou to Jiaoziyuan, is located in Jianghan Depression zone of Quaternary inherited differential subsidence movement, and is fluvial river on Zhijiang and Shashi fan-shaped plains. For the riverbed entrenched into Late Pleistocene gravel layers which had undergone compaction and slight cementation and are of higher scour resistance than Holocene sediment in upper layers. Therefore the collapse and the retreat of banks process slowly, with slightly horizontal swing of riverbed, and shoals mainly stretch longitudinally, showing a straight branched channel character.

③ Lower-Jingjiang section, the river section between Jiaoziyuan and Chenglingji, is formed in tail of the delta in ancient Yunmengze Lake. Riverbed of Lower-Jingjiang section entrenched into Holocene fluvial and lacustrine sediment layer, and the materials of riverbed and bank consist of homogeneous fine sand and even fine sediments, thus having poor scour resistance ability, tending to form free meander under certain flow and sediment conditions. Therefore Lower-Jingjiang river channel is tortuous and is a typical meandering river.

(2) Southward movement of channel

Geological researches on the middle reaches of the Yangtze River[12,13] conclude that since late period of early Pleistocene, Tongbai-Dabie Mountain Neo-tectonism caused north-to-south heterogeneous incline and uplift in this region, with uplift in Tongbai-Dabie Mountain area and subsidence to their south (Figure 5). Tongbai-Dabieshan incline and uplift movement has notable impact on the environment of Jianghan Plain and the evolution of the middle reaches channel of the Yangtze River.

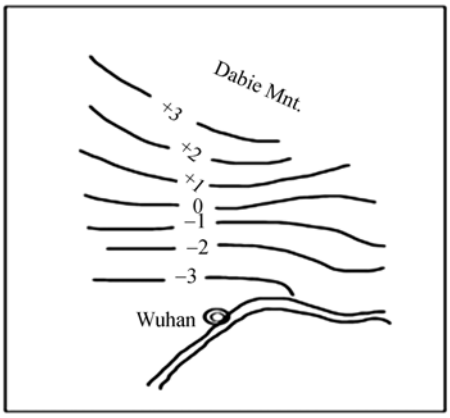

Figure 5 Sketch map of crust deformation of Wuhan-Dabieshan area (unit: mm/a).

Firstly, Tongbai-Dabieshan incline and uplift movement dominates the framework and the evolution of the middle reaches of the Yangtze River water system, and the U-shape of which flowing in Jianghan Plain is mainly the result of incline lift movement of Tongbai-Dabie Mountain.

Secondly, Tongbai-Dabieshan incline and lift movement forces the main channel of the Yangtze

River to move southward, which to a great extent causes diverting branches of ancient Yangshui, Xiashui and Yongshui rivers vanishing, and forms a single channel of the current river. Southward movement of main channel blocks joints on the north bank of Jingjiang River, while develops those on south bank, and finally conduces diverted flow pattern on the south bank. This southward movement also originates from the old channel and bayou lake along north bank of modern Yangtze River[12] (Figure 6).

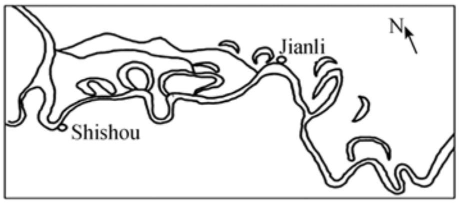

Figure 6 Sketch map of bayou lakes and paleo-rivers along the Lower-Jingjiang section.

Thirdly, it is the Tongbai-Dabieshan incline and lift structure and corresponding water flow and sediment condition in channels that cause the asymmetry pattern of the geomorphy in Jingjiang River valley. For example, the geomorphy of Jingjiang River's left bank is low and open, and its valley is long and gentle, while its right bank is near the hilly region, and the valley is short and sloping, resulting in southward movement of Jingjiang thalweg, the distribution of sand islands in channel, and the development of meander in Jingjiang lower reaches.

The research shows[13] that Tongbai-Dabieshan tectonic incline and uplift movement now is still processing in a rate of 2—3 mm/a, and the southward movement of river channel has been accelerating since 3000 a BP, resulting in the modern channel of the middle reaches of the Yangtze River moving from north to Shashi in middle Holocene to south end of Jianghan Basin. Therefore, it is incline and uplift movement of the Three Gorges area and Tongbai-Dabie Mountain, as well as the consequent southward movement of river channel, that are the dominant factors of the evolution of the middle reaches of the Yangtze River, as well as the geological and tectonic condition for hydrodynamic process in Jingjiang section, and also the geological and geomorphic basis of Jingjiang section regulation.

4 Conclusions

(1) The geo-basis of the river regulation means the obedience of the river's geo-attributes in river regulation, including the geo-attributes of the basin such as geology, geomorphy, hydrology, climate and physical geology, etc. Just like 'gene' of a river, these geo-factors together constitute the river's geo-attributes, which remain stable with time, or only behave regular annual changes, but have inherent, permanent and dominant effect on the evolution of rivers. The regulation of river is actually a talk between human and rivers, which could only be equal and harmonious with the respect of the river's geo-attributes. Some recent river regulation has cost us a lot for the underestimation or neglect of its geo-attributes, but now it is high time to thoroughly understand and pay attention to the river's geo-attributes.

(2) The middle reaches of the Yangtze River is located in the transition zone from the second stair to the third one, and is one of the most famous storm areas in China with its west side at the windward slope of southeast monsoon. Meanwhile, since the middle reaches of the Yangtze River crosses the south part of the second tectonic subsidence zone in Eastern Asian structure, the floods in the middle reaches are easy to converge but difficult to discharge from the valley of the first and second uplifts on east and west sides. Such geomorphy, climate and tectonic geomorphic environment compose macro geo-environment of floods in the middle reaches.

(3) Since at least 40 ka BP, after the Yangtze River flowed past the Three Gorges area and entered Jianghan-Dongting Basin, it flowed slowly for a long period, forming many channels, with the paleo-Jingjiang River as one of the largest branches. As the evolution of paleo-Jingjiang River channel and development of Jingjiang Delta, the branches like Xiashui, Yongshui, and Yangshui rivers were formed in Jianghan Basin, and branches on the right bank like Lunshui, Shengjiangshui, Songzihe, Ouchihe rivers were formed one after another after the branches on north bank shrank. Such process shows that a single channel is impossible to drain vast floods from the middle reaches, while discharging flood in several channels is in accordance with the geo-attributes. Therefore, to canal flood diversion channel based on paleo-Jingjiang channel on north bank is a sound choice. For example, Li et al.[12,13] Yin proposed a tentative project to canal flood diversion channel from Jiangliang to Qiangjiang, then into Hanshui River, and from Jiayu to Ezhou, then into the Yangtze River taking advantage of the paleo-river on the left bank of Jingjiang River; Zhou et al.[14] proposed a plan to expand Shuangsha Channel to flood diversion channel of Jingjiang River, both reveal geo-attributes of middle reaches as diffluent in several channels.

(4) Located in second subsidence zone of Neo-Cathysian geo-environment, Jianghan Basin and Dongting Basin have always been the regulators of the middle reaches of the Yangtze River. Since recent time, as uplift of Dongting Basin due to the sediment rate being much higher than subsidence rate, meanwhile Jianghan Basin in subsidence process, average land surface elevation of Dongting Basin is higher than that of Jianghan Basin. Thus to return some regulation function of Jianghan Basin is indeed a measure in obedience with geo-attributes. For example, Lin[15] proposed a plan to settle sediment in north bank of Jingjiang River in 1964, which respected geo-attributes of Jianghan Basin as regulator of floods in the middle reaches of the Yangtze River.

(5) Under the condition of continuous subsidence of Dongting Lake, since the rate of sediment within flood channel and lake is much larger than subsidence rate, land surface of flood channels and lakes increases year by year, while land surface of diked marsh kept decreasing for the sediment deficit from land subsidence. With land surface in flood channels and lakes higher than that in diked marsh, current ‘above-ground lakes’ and ‘above-ground rivers’ were gradually formed, turning into a main reason of flood disasters in Dongting Basin. Therefore, to implement ‘interchange between lakes and diked marsh’ by taking proper steps would be a measure to ‘Restore Lake from Farmland’[7].

(6) The evolution of Jingjiang River channel and Jianghan-Dongting Lake is closely related to each other, and both act as the condition and the result of each other. The change of Jingjiang River channel is controlled by the geology and geomorphy along the river, and the different geology and geomorphy conditions form different geo-attributes in each section, and consequently river attributes. The incline and uplift movement of Dabie-Tongbai mountains forced Jingjiang River to move southward, having much impact on the evolution of Jingjiang River channel. Therefore, the evolution of Jingjiang River is formed by the comprehensive function of many factors, and the regulation of Jingjiang River should take geo-environment of the middle reaches into consideration, other than a single river section or even water level or flow rate at some specific site.

As a part of the Yangtze River, the evolution of the middle reaches is processing on the whole Yangtze River environment. Therefore, in the river regulation of the middle reaches of the Yangtze River, the geo-attributes of the middle reaches should be combined with that of the whole river basin.

1 Feng Y. Series of River Flood Control in China —— Volume of Haihe River (in Chinese). Beijing: China Water Power and Electrical Power Press, 1993. 40－46
2 Zhao Z P. Series of River Flood Control in China —— Volume of Huaihe River (in Chinese). Beijing: China Water Power and Electrical Power Press, 1993. 11－18
3 She Z X. Water and Soil Resources and Regimes of Yangtze River Delta (in Chinese). Beijing: China Hi-Tech Publication, 1997. 74－76
4 Chen G D. On geologic structure issues in flood disaster release of Dongting Lake. Geotectonics and Metallogeny (in Chinese), 1999, 23(1): 1－2
5 Yang H R, Yang D Y. Basic issues on recent tectonic landform and climate landform. J Nanjing Univ (Natl Sci) (in Chinese), 1982, (2): 503－507
6 Chen X G. On tectonic subsidence of Dongting Lake area. West-China Expl Eng (in Chinese), 2004, (9): 108－111
7 Dong H J. Probing into regulation of Dongting Lake from the point of view of geology. Hunan Geol (in Chinese), 1997, 16(3): 141－146
8 Changjiang Water Resource Commission. Images of Dongting Lake Region, Maps of Flood Control in the Yangtze River (in Chinese). Beijing: Science Press, 2001. 102－103
9 Gong Z G. On geological disasters and its relief measure in Dongting Lake region. Chin Geol (in Chinese), 1999, (5): 37－38
10 Yang H R, Tang C R. Research on Evolution of Jingjiang River in Middle Reaches of the Yangtze River (in Chinese). Beijing: China Water Power and Electrical Power Press, 1999, 23, 88－90, 96－99, 102－113
11 Zhou K Y. Chinese History of Science and Technology —— Volume of Water Conservancy (in Chinese). Beijing: Science Press, 2002. 155－160
12 Li C A, Du Y. Environment Evolution and Flood Control Strategy in the Middle Reaches of the Yangtze River (in Chinese). Wuhan: China University of Geosciencese Press, 2001. 15－19
13 Li C A, Yin H F, Chen D X. Issues on flood control in middle reaches area of the Yangtze River and countermeasures. Earth Sci (in Chinese), 1999, 24(4): 329－334
14 Zhou J J, Lin B N, Zhang R. A diversion canal for mitigating the floods in the middle reaches of the Yangtze River and lower reaches of Han River. J Hydraul Eng (in Chinese), 2000, (11): 84－88
15 Lin Y S. Suggestions on sediment settlement in north bank of Jingjiang River. Yangtze River (in Chinese), 1964, (3): 1－7