

Growth pattern research on the modern deposition of Ganjiang delta in Poyang lake basin by spatio-temporal remote sensing images

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Abstract. It is of great importance for petroleum exploration to study the sedimentary features and the growth pattern of shoal water deltas in lake basins. Taking spatio-temporal remote sensing images as the principal data source, combined with field sedimentation survey, a quantitative research on the modern deposition of Ganjiang delta in the Poyang Lake Basin is described in this paper. Using 76 multi-temporal and multi-type remote sensing images acquired from 1973 to 2015, combined with field sedimentation survey, remote sensing interpretation analysis was conducted on the sedimentary facies of the Ganjiang delta. It is found that the current Poyang Lake mainly consists of three types of sand body deposits including deltaic deposit, overflow channel deposit, and aeolian deposit, and the distribution of sand bodies was affected by the above three types of depositions jointly. The mid-branch channels of the Ganjiang delta increased on an exponential growth rhythm. The main growth pattern of the Ganjiang delta is dendritic and reticular, and the distributary channel mostly arborizes at lake inlet and was reworked to be reticulatus at late stage.

Key words: Remote sensing, Modern deposition, Growth pattern, Ganjiang delta, Poyang Lake.

1. Introduction

Over recent years, the petroleum exploration in continental basins of China has revealed that typical fluvial dominated shoal water deltas is developed in large depression lake basins. The researches on modern deposition of shoal water deltas can build petroleum exploration depositional



pattern with more comparable bases. With respect to its advantages (such as wide imaging scope and fine details), remote sensing is taken as an important base for modern deltaic deposit survey. According to its multi-temporal and multi-stage characteristics like historical filing and repeated monitoring, remote sensing is also utilized to quantitatively and dynamically analyze the sedimentary features and growth patterns of modern deltas.

2. Data source

Ganjiang delta spreads in a fan shape horizontally. Its apex is located in the vicinity of Bayi Bridge, Nanchang City, Jiangxi Province, whereas its front presents an irregular arc, with two end points at Wucheng Town and Sanjiangkou Town. The lobe at front of the mid-branch is a delta lobe growing the fastest and preserved the most intact in recent years, therefore, it is selected as the key study area in this paper.

A total of 76 cloud-free images were collected from 1973 to 2015: including 17 MSS images, 2 SPOT images, 1 ALOS image, 1 QuickBird image, 2 GF1 images, 2 HJ images, 5 ZY images, 44 TM/ETM images and 2 ASTER images.

Table 1. Different types of Satellite images in Ganjiang Delta

Satellite Sensor	Temporal List
MSS (17Images)	19731224; 19751030; 19760427; 19761006; 19770703; 19770826; 19771106; 19790403; 19790702; 19790912; 19791105; 19810507; 19810928; 19830128; 19831011; 19831128; 19841106;
TM/ETM (44Images)	19890213; 19890715; 19930312; 19950326; 19950902; 19950918; 19951105; 19951207; 19960209; 19960904; 19961022; 19991210; 20000923; 20010606; 20010910; 20020929; 20030220; 20030308; 20041012; 20050929; 20060612; 20061103; 20070106; 20070802; 20080516; 20081210; 20090409; 20090511; 20090604; 20091026; 20091103; 20091221; 20100223; 20100615; 20100802; 20100818; 20100919; 20101005; 20101021; 20101106; 20131122; 20140109; 20150213; 20151011;
Others (15Images)	20010129ASTER; 20010214 ASTER ; 20071122ALOS; 20080327SPOT; 20111204QB; 20111224HJ; 20120324ZY3; 20120506HJ; 20130102ZY02C; 20130305SPOT6; 20131104ZY3; 20140220GF1; 20141014ZY3; 20141019ZY3; 20141208GF1;

how to extract useful information from these large data sets has become a difficult problem. data sieving, thematic information extracting and spatio-temporal rules mining are key research contents.

3. Methodology

Based on the sedimentary features of shoal water lake basin and Ganjiang delta of the Poyang

Lake, combined with the characteristics of remote sensing data, an analysis process of remote sensing survey technique for shoal water delta of modern lake basins is proposed in this paper. The whole process consists of four steps, including sieving and processing of remote sensing data, remote sensing interpretation of lake basin delta, remote sensing quantitative statistical analysis of delta growth element and analysis, and summing-up of delta growth pattern, as shown in Fig.1. In the first step, on the basis of sieving and preprocessing of image data, combined with field verification on sedimentation, remote sensing interpretation of lake basin delta is conducted. In the second step, based on the interpretation vectors of multi-temporal delta images, quantitative statistical analysis on delta growth elements, and quantitative superposition analysis on object oriented sedimentary facies are conducted. In the third step, based on quantitative statistical analysis, the growth and depositional patterns of delta are described.

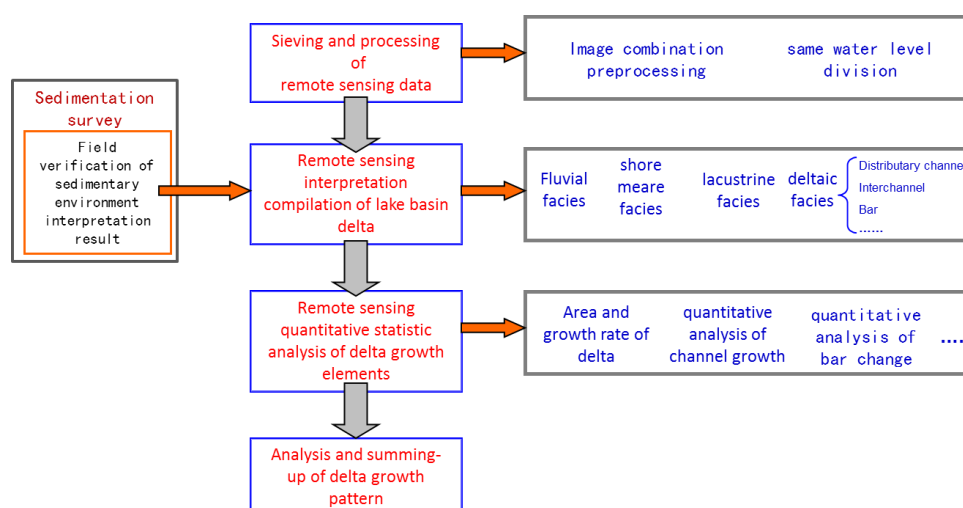


Fig.1 Analysis process of remote sensing survey technique for modern deposition of shoal water deltas in lake basins

3.1 Optimization and Preprocessing of Remote Sensing Data

(1) Image combination preprocessing

For the sake of studying the dynamic growth pattern of delta, it needs to try to collect different types of remote sensing images with the maximum time span. In this study, we collect and sort out 60 moderate resolution and 6 high resolution remote sensing images of Ganjiang delta in Poyang Lake basin got in 1973-2013. The moderate resolution landsat images are adopted for macro study, and the high resolution satellite images are used for local growth study. The data type of remote sensing image is primarily optical image, and the wave band scope covers visible light and near-infrared band.

Because there are differences of spectral signatures and spatial coordinates among remote sensing data of different satellite sensors, and they have larger influence to the quantitative analysis and superposition analysis on the images, a preprocessing method combining image fusion, geometric fine correction and image enhancement is adopted to reduce these discrepancies. The image fusion is accomplished using the IHS transformation fusion method, and the geometric fine correction is finished using the polynomial method. The combination preprocessing of images strengthens the resolution of remote sensing images, ensures the accurate spatial coordinate corresponding relationship among multi-temporal images, and makes the results of subsequent image interpretation and growth change quantitative analysis more reliable.

(2) Image water level gradation and optimization The water-level fluctuation of Poyang Lake is very large all the year round; the imaging time of different remote sensing images is different, the corresponding water level is different, and the exposure status of delta front is also different; as a result, dynamic quantitative correlation and analysis cannot be conducted directly, and it needs to conduct gradation and optimization on the water level of images. When the hydrologic data related to images are available, the real water level data should be used as the water level gradation criteria of all images. However, if the hydrologic data related to them are not available, it should, based on the water-level fluctuation status of Ganjiang delta of Poyang Lake all the year round, select relatively stable reference object to conduct water level gradation of images. The reference objects selected may include: ① the maximum lakeshore (embankment); ② delta front lobe; and ③ dragon's pool (exposure of dragon's head and tail). Based on the exposure status of reference objects on different images, the relative water levels of the images can be indirectly judged, and then, the water levels of the images are divided into different grades.

The same water level grade remote sensing images with constant duration within the scope of the maximum time span, including 5 moderate resolution (December 24, 1973; November 28, 1983; December 7, 1995; November 3, 2006 and November 22, 2013) and 3 high resolution (November 22, 2007; December 4, 2011 and March 5, 2013) images, are selected as the basic image data for follow-up analysis.

3.2 Remote Sensing Identification Chart for Sedimentary Microfacies

The Ganjiang delta of Poyang Lake is a typical open flow shoal water lake basin delta. Based on the sedimentary system of lacustrine delta, combined with the morphological characteristics spread of Ganjiang delta images, after having conducted preliminary analysis, it is believed that sedimentary microfacies like channel, interchannel, natural levee and crevasse splay are mainly developed in Ganjiang delta. All sorts of sedimentary microfacies have obviously different reflections on the remote sensing images. Fine correction and enhancement processing are conducted for different types and different-temporal remote sensing images, and systematic observation and description are implemented on the remote sensing image characteristics of all sorts of microfacies; furthermore, sedimentation survey of Ganjiang delta is carried out at the same water level episode of images, and the remote sensing image data of the corresponding periods are acquired. Based on the correspondence of image characteristics and surface features, the remote sensing identification chart of sedimentary microfacies (channel, interchannel, channel bar, distributary bar, crevasse splay, natural levee and abandoned channel) of Ganjiang delta is built (Fig.2), and the image characteristics of various sedimentary microfacies are summed up as the following:

- (1) Channel: water is dusty blue, low curvature ribbon channel predominates;
- (2) Interchannel: low-lying shoal water swamp between channels, yellow green, overlain by water locally;
- (3) Distributary bar: in the vicinity of lake inlet of channel, mostly yellow-gray, having fusoid and crescent bottomlands;
- (4) Channel bar: shoal exposed in dry season in the centre of channel, resulted from waster accumulation, elongated;
- (5) Crevasse splay: fan shape spread waster accumulation body in interchannel, resulted from pour of flood after it has made a breach in natural levee;
- (6) Natural levee: tint ribbons distributed at both sides of channel, and extended parallel to it;
- (7) Abandoned channel: in interchannel, dark ribbon with channel shape.

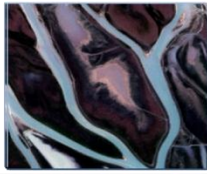
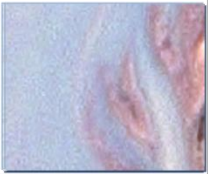

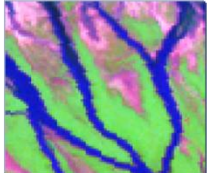
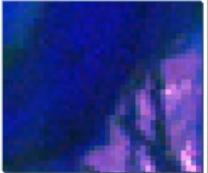
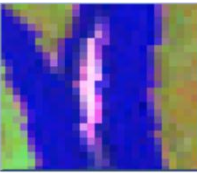



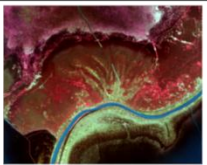
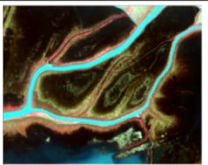
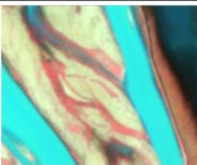
Data type	Interchannel / channel	Distributary bar	Channel bar
Remote sensing satellite SPOT6			
Remote sensing satellite TM/ETM			
Field photo			
	Crevasse splay	Natural levee	Abandoned channel
Remote sensing satellite ZY-3			

Fig.2 Remote sensing identification chart for sedimentary microfacies of Ganjiang delta of Poyang Lake

3.3 Sedimentary facies remote sensing interpretation

Based on multi-temporal remote sensing analysis, the sedimentary facies of the whole Poyang Lake basin are interpreted by medium resolution images(Fig.3).

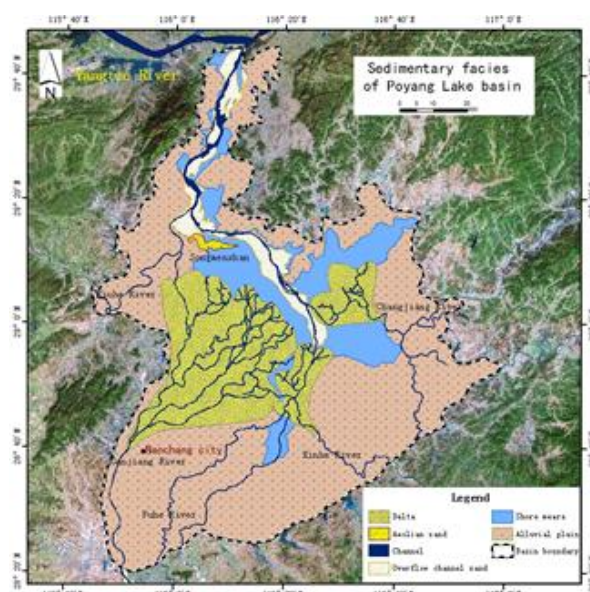


Fig.3 Remote sensing interpretation map of sedimentary facies in the Poyang Lake Basin

Based on remote sensing identification chart, the sedimentary facies of mid-branch of Ganjiang delta are interpreted by high resolution image, including channel, inter channel, distributary bar and channel bar(Fig.4).

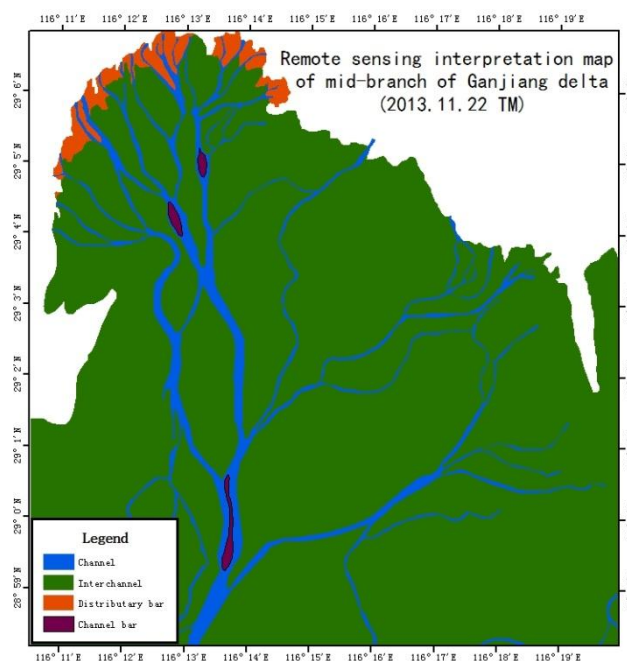


Fig.4 Remote sensing interpretation map of mid-branch of Ganjiang delta

4. Results

Based on interpretation analysis of remote sensing images and verification of field sedimentation survey, there are three types of sand body deposits in the center of the Poyang Lake Basin: deltaic deposit, overflow channel deposit and aeolian deposit.

The overflow channel of the Poyang Lake starts from Sanjiangkou in the southern lake region, runs across the north of Songmenshan beach bar, continually flows northward and mingles into the Yangtse River from lake outlet (Fig.3). Under the coaction of inflow-outflow current and tractional current, following the once swinging of the overflow channel, overflow channel sand body parallel to the channel is formed. The overflow channel is 2-3 km wide, while the sand bodies at both sides of it can be as wide as 4.5 km maximally, with an area about 400 km².

Linear deflation geomorphology is developed at lake outlet section of the Poyang Lake; furthermore, the linear deflation trend is consistent with the dominant wind power of the Poyang Lake, i.e., they both come from the NNE direction. The sands at lake neck were raised by the NNE wind, and extensively deposited in the Poyang Lake region; among which, the coarser sands were firstly deposited, and resulted in the formation of Songmenshan beach bar in the southern lake neck. The Songmenshan beach bar is a typical aeolian deposit, where medium sands predominate; the beach bar sand body is about 14 km long, its maximum width is 2.6 km, and its maximum thickness exceeds 70 m, and the area of aeolian sand is 68.5 km² (Fig.3).

The analytic results of sedimentary facies interpretation show that: from 1973 to 2013, the mid-branch front sand body had grown the most rapidly in the Ganjiang delta, and its area had

increased from 6 km² to 25 km² ; among which, the right wing of mid-branch of Ganjiang delta was the sub-branch that had grown most rapidly during 2007-2013, advanced for more than 600 m towards lake, and became the key growth point of the Ganjiang delta at next stage.

Based on integrated analysis on channel growth of the Ganjiang delta, the growth rhythm of channel front of mid-branch of the Ganjiang delta is summed up as exponential type (Fig.5), and the growth pattern of the Ganjiang delta is furthered summed up as dendritic and reticular.

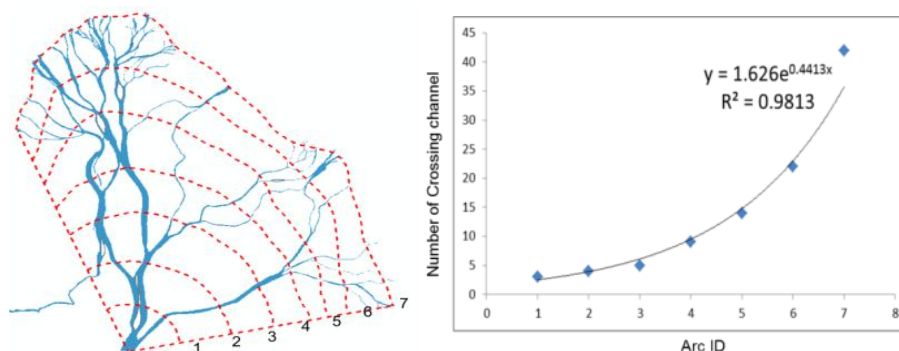


Fig.5 The mid-branch channels of the Ganjiang delta increased on an exponential growth rhythm

In spatial dimension, the distributary channels at west of the SN trend main channel of Ganjiang River flow into the lake in NW trend, and exhibit a dendritic distribution on the whole and reticular distribution locally; whereas those at east of it flow into the lake in NE and NEE trends, and exhibit a distribution pattern to the contrary. In temporal dimension, the distributary channels mostly arborize at lake inlet and were reworked to be reticulatus at late stage (Fig.6). The Ganjiang delta presents a dendritic growth in spatial and temporal dimensions, accompanied by the enclosure and mergence of distributary channels, which make the channel sands present a dendritic and reticular distribution, and it represents the distribution and growth pattern of two kinds of typical sand bodies of the Ganjiang delta.

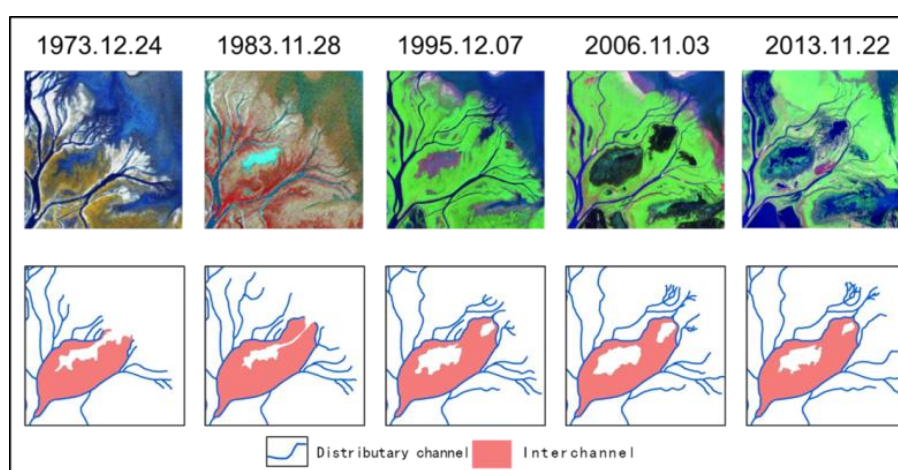


Fig.6 Growth pattern of transformation from dendritic deposit to reticular deposit

5. Conclusions

Based on quantitative research on modern deposition of the Gangjiang delta in the Poyang Lake

Basin by remote sensing technique, some conclusions are obtained as the following:

- (1) Remote sensing is an important advanced technical means for modern deposition survey.

By means of unique advantages like global imaging and detail highlighted, historical filing and repeated monitoring, global scope and unrestricted, the remote sensing technique can be used to study the depositional pattern of shoal water deltas in lake basins, and it is an important advanced technical means for modern deposition survey.

- (2) Multiple types of sand body deposits are developed in continental lake basin.

Based on remote sensing image analysis, combined with field survey verification, it is believed that three types of sand body deposits are mainly developed in the Poyang Lake Basin: deltaic deposit, overflow channel deposit and aeolian deposit; and the distribution of sand bodies in the lake basin is affected by the above three types of depositions jointly.

- (3) Multi-temporal remote sensing dynamic quantitative analysis reveals the growth pattern of delta.

Based on multi-temporal remote sensing dynamic quantitative analysis, the growth rhythm of channel front of mid-branch of the Ganjiang delta is exponential type, the growth pattern of the Ganjiang delta is dendritic and reticular, and the distributary channel mostly arborizes at lake inlet and was reworked to be reticulatus at late stage.

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