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Research Progresses in Morphological Features of the Area with "Big Ear" Image in Lop Nor Region and Its Environmental Significance

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Abstract: In 1972, a Landsat MSS image clearly showed a "Big ear" shape in Lop Nor region, Xinjiang, China, which is one of the extreme drought regions in the world, and is a typical area to research environmental change of arid zones. For a long time, many researchers and common people expressed concern about the meaning and origin of the "Big ear" shape. In this paper we summarize research developments in these areas. The researched results show that the morphological pattern like the "Helix lines" of human being is the yearly and seasonal salt sedimentary structure lines in the process of forming salt crusts. The dark and light change of color tone depends on the burial depth of brine layers, the sand content in the salt crust, and the change in surface texture (roughness). There are different estimates of the age of formation of the "Big ear" from the 1930s to 1965. In the future, in order to clearly reveal the process of "Big ear" formation, it is necessary to conduct further accurate measures of the lake basin landform, and regional water balance analysis, and to systematically define the function of human activities in the process of Lop Nor drying.

Key Words: Big ear, Dating, Environmental change, Lop Nor

1. Introduction

Lop Nor region is located in the eastern Tarim Basin, within Bayinguoleng Mongolian Autonomous Prefecture of Xinjiang, China, which is surrounded by Beishan Mountain in the east, by Tarim River in the west, by Jueluotagh Mountain of the front range of Tianshan Mountains in the north, and by the north slopes of the Altyn Mountains in the south. It is a famous area in the arid zone of China, the communication center of the ancient Silk Road, a passageway linking up the eastern cultures with the western cultures, and enjoys a high reputation in Chinese ancient history (Lop Nor Comprehensive Investigation Team of Xinjiang Branch of Chinese Academy of Science, 1987). However, due to the changes of the natural condition and social economy, this region has become a piece of inaccessible desert and a mysterious area full of natural and cultural curiosities.

In the past hundred years, scholars including Chen Zongqi and Wang Wenbi during 1927-1935, as well as Nikolai Mikhaylovich Przhevalsky during 1879-1880, Sevn Hedin during 1890-1901, Marc Aurel Stein during 1990-1913, and Huntington Ellsworth in 1905, travelled to this area to investigate (Xia *et al*., 2007).

The study of Loulan Civilization is an important activity. However, the progress in studies of the Lop Nor remained slow until the 1990s due to its difficult environment and remote location, despite growing interest in the area (Dong *et al*., 2012).

The formation and evolution of Lop Nor "Big ear" shown on the satellite image is an important question and the focus of significant research efforts. In this paper, we have summarized the recent progresses in this research area in order to attract more scholars to pay attention to this, and to provide new data for the research on high resolution environmental change in extreme arid zones.

2. Origin of the "Big ear"

In 1972, the satellite image of Landsat MSS of United States clearly showed the "Big ear" shape in Lop Nor region (**Fig. 1**) (Xia *et al*., 2007). In 1980, when the author, Xia Xuncheng, as a member of the Desert Investigation Delegation of Chinese Academy of Sciences, visited Prof. Farouk El-Baz, a remote sensing specialist in Washington, D. C. USA, they discussed the "Helix", "Ear hole" and "Earlobe" of the "Big ear" shape on the Lop Nor image that was hanging in El-Baz's home. Since then, the "Big ear" has become an extensive concern for society.

3. Morphological Characteristics

At present, the area with the "Big ear" shape is a dried-up saline playa. Its area is 5350 km^2 just within the region

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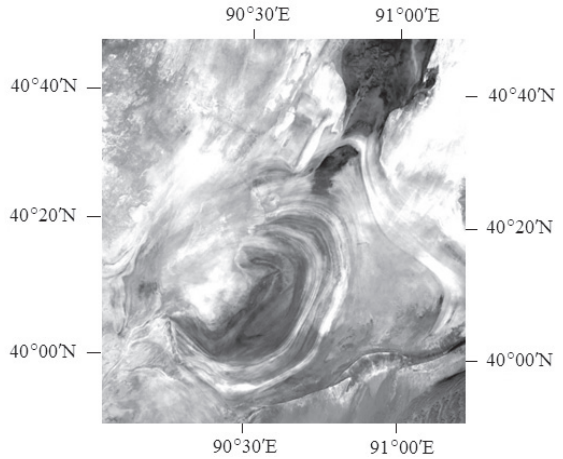

Fig. 1. The completely dry Lop Nor lake basin has formed the "Big ear" or "Helix lines" shape on the satellite image.

surrounded by the isoline of 780m a. s. l. The ground surface of the "Big ear" area is covered by various kinds of modern salt crusts formed in the final Lop Nor drying-up process.

The 51 km range from the Lake Center Island (40º10.753'N, 90º26.691'E) to Lop Nor Town (40º28.148'N, 90º52.002'E) can be divided into about 5 salt crust zones. From 0 km to 12.5 km is the micro-mound salt crust, the thickness of which is 15-25 cm, the diameter of the single block is 45-80 cm, and the upward height is 5-15 cm. From 12.5 km to 18.5 km is the crack-like salt crust, the thickness of which is 25-45 cm, the diameter of the single block is 30-50 cm, the upward height is 10-25 cm. From 18.5 km to 27.5 km is also a type of the crack-like salt crust, the thickness of which is 25-60 cm, the diameter of the single block is 40-70 cm, the upward height is 20-120 cm. From 27.5 km to 39.0 km is similar to that from 12.5 km to 18.5 km. From 39.0 km to 51 km is the flat salt crust, the thickness of which is 20-30 cm, the diameter of the single block is 30-70 cm, the upward height is less than 5 cm (Zhao *et al*., 2006). The different salt crust types have evolved from the flat salt crust to the crack-like salt crust, to the micro-mound salt crust, and eventually to the flat salt crust again along the order from the younger to the older (Zhao *et al*., 2005).

The semi-circle-shaped "Helix lines" as seen on the satellite image are yearly or seasonal salt sedimentary marks left by Lop Nor sequential drying. The color difference is caused by the change of the depth of brine layer, sandy content in salt crust, and the roughness of the ground surface (Zhao *et al*., 2006).

On the basis of the field measurements, the material composition analysis, and the satellite image interpretation, Zhao *et al*. (2006) revealed that within the "Big ear" area of the East Lake of Lop Nor, the surface materials are mainly comprised of rock salt, especially chloride (**Table 1**), and the detrital minerals are mainly comprised of quartz. The

Table 1. The chemical composition of different salt crust types.

Salt crust type	Content of different chemical composition (%)							
	I	II	III	IV	V	VI	VII	VIII
Flat salt crust	1.76	0.02	0.01	3.91	3.94	1.15	0.6	63.74
Crack-like salt crust	1.31	0.03	0.01	3.55	1.02	1.7	0.9	78.24
Micro-mound salt crust	0.44	0.01	0.01	2.95	2.69	0.74	0.26	77.82

Note: I - $CaCO_3$, II - Na_2CO_3, III - $Ca(HCO_3)_2$, IV - $CaSO_4$, V - Na_2SO_4, VI - $MgSO_4$, VII - KCl, VIII - NaCl.

formation of "Big ear" shape is controlled by the original mid-lake island and the lakeshore landform. Cai *et al*. (2011) pointed out that the total salt content of the surface soil and the micro-topographical characteristics are the direct causes of the formation of the "Helix lines". Gao (2012) also thought that the total salt content of the sediments is the basic reason for the Lop Nor "Big ear".

By using of the mosaic map of aerial photographs with high resolution, combined with the topographic map, elevation point, digital elevation model, as well as CORONA image on December 12, 1961, researchers analyzed the Lop Nor water area distribution in 1958 (Xia *et al*., 2007). The results show that the major water source of Lop Nor was from the northern Kongque River which flowed into the lake. In the southern Kalaheshun Lake there are no obvious water flow vestiges. The west lake area is significantly larger than the water area in 1958 (Xia *et al*., 2007).

Based on the comprehensive field investigation, combined with the information provided from the remote-sensing images, and the elevation measurement data with high-accuracy by DGPS on the spot, Li *et al*. (2008) showed that the relative depth of Lop Nor "Big ear" in the lake basin is about 5.2 m, the average gradient in the southwest is 0.19‰, in the northeast is 0.09‰, and the deepest point is located at the "Ear hole". The "Helix lines" elevations have lowered gradually from the outer edge of the lake basin to the lake center area, and the elevation value of the same "Helix line" is equivalent. The density change of the "Helix lines" has an obvious congruent relationship with the elevations. In other words, the sparser the "Helix lines" are, the slower the gradient is, which provides a certain scientific basis to determine that the "Helix lines" are the salt sedimentary marks formed in the lake water drying process.

Using radar remote sensing techniques which can see through the wind-sandy sedimentary layers and the extreme arid salt crust layers, Shao *et al*. (2011) found the shorelines of the ancient East Lake buried under the lacustrine sediments of the West Lake of Lop Nor. This work confirmed there is a shoreline of the ancient East Lake extending westward continuously, and explains that the West Lake overlays on the East Lake. This scientific discovery shows that the ancient

shoreline of Lop Nor is in a ring shape, not only an ear shape, and locates the ancient shorelines of Lop Nor in the north and west.

4. Chronology

As early as 1987, Zhu (1987) mentioned that the various rings of salt dikes in Lop Nor region are due to Lop Nor gradually drying. By using the salt formation theory of modern salt lakes, combined with formative factors of the semi-ringed shape on synthesized TM images, Xie *et al*. (2003, 2004a, 2004b) discussed the dating method of the "Helix lines" by means of remote sensing spectral characteristics and special climate mark layers. On the basis of topographic map data, landform measurement data, and evaporation rate, Zhao *et al*. (2006) calculated that the Lop Nor became completely dry between 1964 and 1965.

Combined with the water records left by Chen Zongqi in 1931 and in 1934 (Chen, 1936), Zhong *et al*. (2005) and Li *et al*. (2005) calculated that the "Big ear" may have become completely dry in the late 1930s or early 1940s. Through interpretation of remote sensing data, Duan *et al*. (2013) stated that during 1958 and 1959 the "Big ear" area was covered by water, and thereafter, the "Big ear" formed.

5. Environmental Implication and Significance

Besides the traditional geological methods, the study of Lop Nor region by remote sensing techniques began in 1980s, but due to the lack of theoretical basis, many of those works remain in the stage of optical remote sensing image processing and visual interpretation (Xia *et al*., 2007). During the period of 2006-2010, Shao *et al*. (2008) for the first time detected the ancient lake basin area of Lop Nor region by means of radar remote sensing techniques, studied the detection mechanism of new imaging radar detecting underground targets and concealed characteristic extraction.

Aiming at the typical targets in arid zones, in some respects such as ground target dielectric property, microwave and electromagnetic scattering and mechanism of transmission, and particle polarization theory, Shao *et al*. (2012) demonstrated the ability for SAR to detect underground targets, and for the first time quantitatively illustrated the electrical property of the sediments containing water and salt and its response characteristics on radar images.

Shao *et al*. (2012) preliminarily inferred that the distribution range of the ancient East Lake of Lop Nor may exceed 10000 km^2, much larger than the original measured area of 5350 km^2. The radar image shows 6 alternately dark and bright stripes, which recorded 6 events of lacustrine facies sedimentary environmental changes in the process of Lop Nor withering and drying, which represent at least 6 events of climatic change between the dry and the wet.

6. Recommendations

Current research of climatic changes in the Lop Nor region relies primarily on the traditional geological method. The use of the new technique is still inadequate. Accurate extraction of climate and environment proxy information about the climatic change sequence, the environmental evolution process, the spatial pattern and change of the river system distribution, and the high resolution dating are still in need of further strengthening. The degree and contribution rate of natural factors and human factors influencing the Lop Nor drying-up process cannot yet scientifically be assessed. Thus, future systematic and continuous observation and study are necessary to adequately measure climatic and environmental change.

In order to further clarify the drying process of the "Big Ear", it is necessary to continue accurate measurement of the lake basin landform, to continue analysis of water balance based on the three-dimensional modeling and the limited hydrologic data, and to discover more details about the influencing factors with regard to the Lop Nor drying process (Duan *et al*., 2013).

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