Study of Paleolakes in Tibetan Plateau based on SIR-C/X-SAR and Other Data Sets: Implication to Paleo-climatic Changes*

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Abstract — The Qinghai-Tibet Plateau of Western China exists mostly elevated and densely distributed lakes in the world. Having undergone the uplifting of Qinghai-Tibet plateau, the paleolakes had 8-10 schemes of retreat, indicating that the climate at that time had 8-10 comparatively arid periods on the plateau. Many ancient shorelines are well preserved on the lake basins in this area. The highest shoreline is 60m above the present lake level of Tianshuihai Lake. During the highest lake level epoch, the biggest ancient Tianshuihai Lake combined with ancient Aksayqin Lake and formed a united big lake, which is 7 to 8 times in area as large as the present two lakes. While at the foot of the Kunlun Mountains, the famous lake Lop Nur also presents several ancient shorelines. These shorelines' features can be clearly depicted from SIR-C/X-SAR and Radarsat images. This paper presents the radar backscatter's characteristics at different wavelength and polarizations, and analyzes SAR imaging mechanisms. The results have shown that like-polarization images are better than cross-polarization images for characterizing the shoreline features. Based on SAR image and literature, the paleo-environment of Qinghai-Tibet area is analyzed.

INTRODUCTION

Imaging radar has a great potential for detecting hydrological environment. It has been widely used in surveying and mapping for wetland, ice and snow, drainage pattern, coastline and lakeshore. Even some buried paleo-drainage features were revealed by long wavelength L-band SIR-A, and some paleo-lakes were recognized from SIR-C/X-SAR data [1].

Lake has close links with its interactions of atmosphere, bioshpere, soil-sphere and hydrosphere. Its appearance and disapperance, enlargement and shrinkage as well as its impact on the evolving of ecological environment are results of joint works of tectonics and meteorology on global, regional and local scales. Therefore, studying the evolution of paleolakes has important significance on the research of paleo-climatic changes. In our study, we have used SIR-C/X-SAR and Radarsat data to study paleo-climatic changes in Qinghai-Tibeten plateau and Lop Nur area of Tarim basin respectively based on the variation of paleolake shorelines. This paper will present the characteristics of lake shorelines produced by different imaging parameters, and discuss the response of lake shorelines to radar signals.

SAR DETECTION OF TIBETAN PALEOLAKES

Qinghai-Tibetan plateau has more than 2000 lakes (including saline lakes) distributed scatteredly, with total area exceeding 27000 km^2, in which there are more than 50 lakes with area great than 100 km^2. These lakes are nowadays the largest and highest inland lake group in the world. The largest two, Namuchu and Selin lakes, have areas of 1920 km^2 and 1865 km^2 respectively. The origins of the lakes in Qinghai-Tibetan plateau may be due to the following three aspects [2]: (a) The depressions were caused by glaciation, and water filled in the depressions; (b) The differential movement of the crust resulted in the uplifting of lower river beds, or the

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accumulated materials blocked river valleys; (c) The lakes are structural controlled.

Our study mainly focused on the Aksayqin Lake near the boundary of Xinjiang and Tibet, which was imaged by SIR-C/X-SAR. The lake is situated in a depression belt of southern Kunlun mountains. At present, its elevation is about 4840m above sea level. There are 129 glaciers from Kunlun glacier group providing water resources to the catchment of Aksayqin Lake. Three major rivers named Litian, Keqikebing and Qiongbing flow into the Aksayqin River, which is directly connected to the Lake.

From the mosaic of MSS imagery [3], some earlier studies (e.g. [4]) as well as our field investigation suggest that there was a very large ancient Tianshuihai Lake which combined with ancient Aksayqin Lake and formed an united big lake (Figure 1)[5]. The paleolake at that time was about 1400 km^2. While, the lake area measured from X-SAR image is 168 km^2. This suggests that the ancient united lake is at least 8 time as big as the present one, indicating that an intensive lake retreating was occurred in the past due to climatic change.

It is common that there were 8 to 10 rhythms of lake retreat in Qinghai-Tibetan plateau, indicating that the climate at that time had 8-10 comparatively arid periods on the plateau [6]. It was observed that there were 8 rhythms of lake retreat from the southeast band of the Lake. In the vicinity of Tianshuihai, paleo-lacustrine plain is well developed, with 30 to 40 ancient shorelines. The highest shoreline was 4860 m above sea level, which was 60 m higher than the water surface of Tianshuihai lake. On SIR-C/X-SAR image taken in April 1994, many discontinuous small lakes are clearly seen. Because of the decrease of rainfall and increase of evaporation, a lot of salt crust can be identified from SAR image; and because of the difference in soil moisture in various areas, there are some differences shown on different polarization and wavelength images. Comparison of SIR-C image and Landsat TM image suggests that SIR-C image has accentuated subtle variation of lake shorelines, thus, provides a better tool for studying paleo-lake evolution.

Figure 2 shows a color composite image of L-HH (R), C-HH (G) and X-VV (B) for Aksayqin lake area. The shorelines on the north and northwest bank of Aksayqin lake as well as Aksayqin River are clearly seen. A comparison of shoreline features of Aksayqin lake on different frequency and polarization of SIR-C/X-SAR data as well as on ERS-1 SAR data was made. The results suggest that like-polarization images show better shoreline variation than cross-polarization, particularly L band HH polarization (L-HH) image shows best. For Tianshuihai area, L-HH image is also the best one for identifying shorelines, compared to which on the images of L-HV, C-HH and C-HV (Figure 3).

It can be seen from Figure 3 that shoreline features are easily discriminated from alluvium in like-polarization images than in cross-polarization images, e.g. L-HH vs. L-HV images. As like-polarization images mainly reflect the result of simple scattering, and cross-polarization images reflect multiple scattering, the poor exhibition of HV images in showing the variation of shorelines indicates that less depolarization was occurred, due to small surface roughness of dry sand beds. While, for like-polarization images the radar bright and dark features are enhanced due to its illumination to undulated shorelines. L-HH image shows bettern than C-HH and X-VV images probably suggests that L-band SAR signal met buried coaser gravel and returned stronger radar backscatter.

SAR DETECTION OF LOP NUR SHORELINES

Lop Nur was a saline lake with an area of 1900 km^2 in Tarim basin. Because of dry climate, insufficient water supply, and man-made hydrological buildings in 1950s, the lake gradually shrank and died eventually in 1970s. The Radarsat image (S4) with incidence angle 34° ~ 40° has shown this ear-like lacustrine plain (Figure 4). Because the surface of salt crust, 30 cm to 100 cm thick, is not smooth, most of lake shorelines are in radar bright relative to C band SAR. From the shoreline rhythms, the climatic change in this area can be inferred.

PALEO-CLIMATIC CHANGE STUDY

Although SAR image can not directly provide age information of the evolving paleo-lakes, the shoreline patterns can depict the outlook of their evolution. According to ^{14}C data of lacustrine geology, the evolving history of the

lakes in western Kunlun mountain can be divided into three phases [7]. (1) 46,000 years ago, the uplifting of the plateau was unable to block warm currents from Indian ocean entering the area, thus climate was wet. There was a huge lake containing Tianshuihai, Akesayqin and other lakes. However, because of dry climate the huge lake shrank a lot and its area was getting smaller and smaller in a period after 46000 year. (2) Around year 35,000 from now, the warm climate caused thawing of glaciers, which had raised water level and conntected several lakes as one. (3) After entering Holocene, the climate of west Kunlun Mountain area was getting drier and drier. The united lake was gradually separated and shrunk. This indicates that the united huge lake was formed at least 20,000 years ago, then the lake had undergone a large extent shrinking.

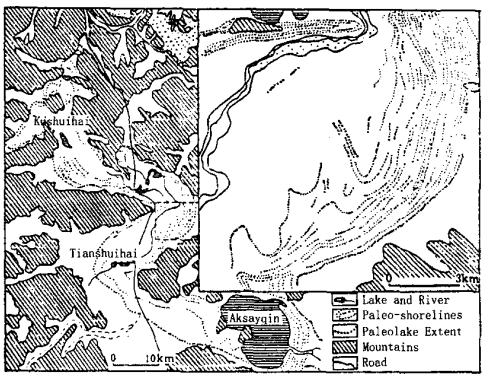

Fig.1 Paleolake extent of Tianshuihai-Aksayqin Lake

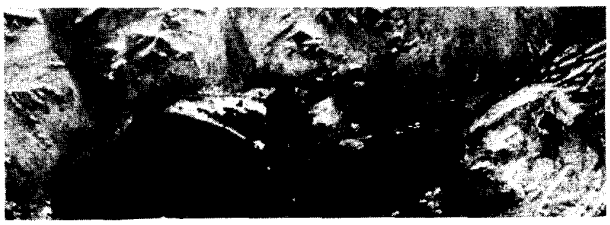

Fig. 2 SIR-C/X-SAR color composite image (L-HH: R, C-HH: G, X-VV: B) showing Aksayqin lake shoreline and river

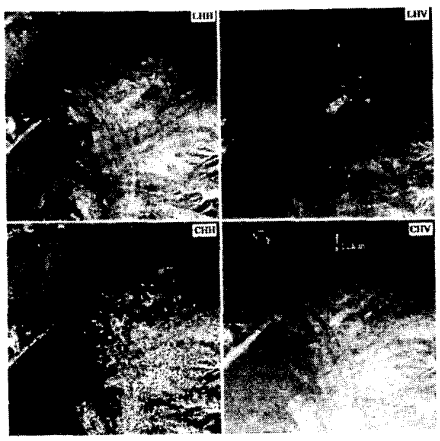

Fig. 3 Comparison of SIR-C images for Tianshuihai shorelines

Fig. 4 Radarsat image showing Lop Nur shoreline features

REFERENCE

[1] Pachur, H. J., Rottinger, F., 1997, Evidence for a large extended paleolake in the eastern Sahara as revealed by spaceborne radar images, *Environment of Remote Sensing,* 61:437-440.

[2] Chen Z. M. The genesis of lakes in Tibetan plateau, *Ocean and Limnology*, 12(2): 178-187.

[3] Wang, C. L. 1997, Use of SIR-C/X-SAR for Western Kunlun Geoscience Analysis, Postdoctoral Report, IRSA/CAS.

[4] Li, B. Y., 1995, Discussion on the evolution of lakes in Northern Qiangtang, Tibet, *Research on the Formation, Environmental Change, and Ecology System in Qinghai-Tibet Plateau,* pp. 261-266.

[5] Li, B. Y., Zhang, Q. S., and Wang, F. B., 1991, Evolution of the Lakes in the Karakorum-West Kunlun Mountains, Quaternary Sciences, 1:64-71.

[6] Chen, Z. M., 1986, Retreat and its climatic significance of Qinghai-Tibetan Plateau, *Ocean and Limnology,* 17(3): 207-216.

[7] Li, S. J., Zheng, B. X., Jiao, K. Q., 1993, Preliminary discussion on lake evolution in west Kunlun Mt., *Ocean and Limnology,* 24(1): 37-44.