An Integrated 3S and Historical Materials Analysis of the Keriya Paleoriver, NW China

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Abstract. Combining analysis of 3S (RS, GIS and GPS) and historical materials (historical records, ancient map and academic and literary writings) allows mapping of the Keriya Paleoriver of Southern Xinjiang, NW China. Keriya Paleoriver, one of the ancient Four Green Corridors which passes through the Taklimakan Desert from south to north in the Tarim Basin, recorded changes of the climate-environment in the ancient Silk Road of the region. According to the archaeological data, historical materials and paleoclimates information, its eco-environment and climate have had great changes since the 1.09 Ma B.P., especially during the last 2,000 years, which has led to many famous ancient cities to be abandoned and the route of the ancient Silk Road to be moved southward. Using RS (optical and radar imagery), GIS (mapping and spatial analysis) and GPS (study area investigation), we mapped a major paleodrainage system of Keriya River, which have linked the Kunlun Mountains  to the Tienshan Mountains through the Taklimakan Desert, possibly as far back as the early Pleistocene. This study illustrates the capability of the 3S and historical materials, in mapping the Keriya Paleoriver drainage networks and archaeological study on the ancient Silk Road.

1. Introduction
The ancient Keriya River, one of the Four Green Corridors from the Kunlun Mountains to the Tienshan Mountains, has important significance in the agriculture, culture, ecosystem, transportation, politics, and economy. While this region is now arid to hyper arid, remains of paleoriver system have been detected using remote sensing imagery, leading some authors to propose paleodrainage pathways between south route of the Silk Road and the middle route of the Silk Road [1-3]. Until now, however, detection of paleochannels has been hampered by the sand dunes in the desert.

Previous studies [4-5] undertaken in Taklimakan Desert region revealed that optical images (Landsat MSS) were of great success for the fuzzy recognition of paleochannels in areas characterized by desert, which are barely seem using other remote sensing products and the historical materials, mainly those required a great deal of man power and specific knowledge and skills. However, the analysis of 3S and historical materials from a sanded area of southern Tarim Basin indicated a new system of paleochannels not previously detected using only remote sensing images.
The present work has the main goal of testing 3S and historical materials in order to characterize these paleochannels and potentially use them to better reconstruct the latest geological history of Tarim Basin. In addition, contrasting the results from radar data might help to decipher why these features could not be recognized with basis on the optical data, while in other locations of Tarim Basin these data were successful for mapping of paleochannels in immediately adjacent areas.

2. Study area and datasets

The Keriya River is now more than 800 km long (see figure 1). It flows north through the piedmont of the Kunlun Mountains, and forms a large aggraded valley plain and oasis in Yutian. The Daliyaboqy Oasis, the lower reach of the Keriya River, is located in the middle of the Taklimakan Desert. The paleochannels of the ancient Keriya River, more than 600 km, was buried by the sand dunes. The dunes of the extensive sands preclude detailed reconstruction of paleoriver by using the optical images, but a 600 km-long link to the Tarim River through the Taklimakan Desert paleochannels are truth according to the radar data, as well as the historical records. In this study, two kinds of RS images, including Landsat ETM+ and SIR-C (L band), were chosen for the archaeological study of Keriya River, and some basic pre-processing was carried out on the images.

![Figure 1. Overview of the study area and Landsat TM color composition (bands 7, 4, 2) images (white lines are paleochannels)](image)

3. Analysis of study area using 3S and historical materials

3.1. Image interpretation and analysis of study area using RS and GIS

Landsat images provided the basis for paleochannels mapping in the Tarim Basin, where the morphological aspects of the buried features can be exceptionally observed due to its physiographic nature dominated by water and vegetation. The majority of the paleochannels in the study area was more promptly recognized using optical images. Hence, these features could be easily observed on
Landsat images, particularly using a R(7)G(4)B(2) (see figure 2). It is interesting to note that three series of the paleochannels, eastern, northern and western, were delineated from the Landsat composition images. Hedin had investigated the Taklimakan Desert in 1897[6]; he found that there were two main channels in northern Daliyaboyi. In some years the Keriya River flowed through the eastern channel, and in other years this river took the western channel. At that time the river course was quite long and water flowed to 100 km north of the Daliyaboyi.

Through the observation of the result derived from the Landsat composition images, this study proposes that stream capture of Niya Paleoriver by the eastern branch of the Keriya paleoriver (see figure 2), and the western paleochannel flowed into the Khotan paleoriver then northward into the Tarim River (see figure 1). The geomorphology indicates that the Keriya River did not flow straight from south to north, but eastward and then flowed into the Tarim River (see figure 1). The eastern channel, more than 600 km, is the latest paleochannel of the Keriya River. 14C radiocarbon dating shows that the eastern branch of the Keriya paleoriver flowed through the northern Taklimakan Desert into the Tarim River at 400 B.P. [7].

**Figure 2.** Landsat ETM+ R (7) G (4) B (2) compositions, see inside box in figure1 for location, with paleochannels highlighted by brighter colors. (I-western branch, II-northern branch, III-eastern branch, IV- paleochannels of the Niya River)

Because of the subsurface imaging ability of radar in desert regions, the Spaceborne Imaging Radar (SIR-C) L-band data were used for this study. The high-resolution (25m) SIR-C L-band images reveal that fluvial features in the Taklimakan Desert are closely linked to voluminous accumulations of sand.
This includes the high sand dune concentrations in the middle of the Tarim Basin, where three major paleochannels extends southward from the Tarim River to the Daliyaboyi Oasis (see figure 2).

The present study extracts the possible paleochannels according to the SIR-C image interpretation experience in the desert region. The SIR-C 25m image provided, in general, a good view of several other paleochannels in the study area (see figure 3(a)). However, the paleochannel contours were not entirely satisfactory to generate a precise map, and the tracing of many smaller size paleochannels was ambiguous. Likewise, the SIR-C-25m image failed to reveal all the paleochannels present in the study area, but where detected, the paleochannels could be delineate with great precision (see figure 3(c)). Despite the fact that some paleochannels could not be recognized in these Radar products, it is interesting to note that channel continuity was best achieved in those areas where these features could be seen (see figure 3(b, c)).

![Figure 3. SIR-C 25m of the study area. (a) A general view of the study area (see inside box in figure 2 for location). (b) A detail from the inside box in (a) for location. (c) A detail from the inside box in (b) for location. Arrows locate the paleochannels.](image)

3.2. Field investigation (GPS)

Based on the preliminary analysis of the study area, the expedition route was determined. With the use of GPS and these recorded geographical coordinates extracted from the corrected Landsat ETM+ and SIR-C images on the study area, field investigation was conducted in September of 2012 in the Taklimakan Desert by camel. More importantly, paleochannels (dried and buried) were found in desert, and some of the shrubs were still alive in the channel as shown in figure 4(a). Broken pottery pieces and fluvial features also were found on the sand dunes (see figure 4(b, c)).

By analyzing surface morphology, it can be found that it is easy for optical and radar signal to form special effects owing to the structure between the ground surface and paleochannels (dried and buried). The resulting from RS images provided an excellent view of the paleochannels, which are highlighted in contrasting light colours with respect to the areas surrounding them.
3.3. Historical materials
With 5,000 years of continuous history, China is one of the world's oldest civilizations. The ancient Chinese composed and preserved a large number of historical materials on the Western Regions from Han to Qing Dynasty. These materials are widely used in the research of paleogeography, paleogeology, paleoclimatology, paleoecology and archaeology nowadays. Historical materials, which were abstracted as maps and digitized in the used ESRI ARC-INFO software v.10, has been employed for generating the digital ancient maps in this study (see figure 5).

Figure 5. Sketch of the watercourses of the river in the Tarim Basin, recorded in the Records of Rivers (The red circle indicates the position of the Keriya River, which has been flowed into the Tarim River)
The Keriya River called as Jiandeli River or Dadeli River in the New Book of Tang, and Pimochuan in Great Tang Records on the Western Regions, and Keridiya River in the Records of Rivers in the Western Regions. On the western side of the Daliyaboyi there are ruins of oases with dead populus stems now present [7]. Paleochannels indicate that the Keriya River flowed through this area, and even at the end of the nineteenth century there were a large number of dead Populus stems [6]. On the terrace of the paleochannel there are a few ruins of human settlements that extend in an area 6 km north-south and 4 km east-west [7]. The most famous is the ancient town of Kelaton. As is evident from the historical materials [8-11], the Keriya was a massive river system with the densest populus euphratica forest in some regions, particularly in its middle reaches.

4. Conclusions
Images derived from Landsat ETM+ and SIR-C reveal three major paleochannels in northern Daliyaboyi oasis where the ancient Keriya River had flowed into the Hotan River and the Tarim River in different directions respectively. The paleochannels of the Keriya River has been mapped here by integrating Landsat ETM+ images with SIR-C scenes and Historical Materials. With a length of at least 1,500 km, the Keriya paleoriver is one of the largest paleodrainage systems yet identified and mapped in the Taklimakan of NW China. In addition to delineating the former drainage patterns of the Keriya basin, this study might aid future exploration for groundwater and oil resources, and help to inform the Silk Road, archaeological, and paleoclimates research efforts in the study area.

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