Characteristics of the gravel size and potassium in the *Ejin Alluvial Fan* from remote sensing images and stratigraphic section.

Lu Zhang[1], Huadong Guo, Qinjun Wang
The key Laboratory of Digital Earth, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences
E-mail: luzhang@ceode.ac.cn

Abstract. The Ejin Alluvial Fan (EAF), located in the north-west of China, is an important recorder of both paleoclimatic and tectonic information of the north margin of the Qinghai-Tibet Plateau. Remote sensing technics, including optical and microwave sensors, have been the key spatial observation tools to extract the surface information related to the paleoenvironment. In this paper, the gravel size and chemical element potassium *K* distributions of the EAF were obtained from RadarSat-2 Synthetic Aperture Radar (SAR) data and LandSat TM optical data, respectively. In addition, the stratigraphic section of the EAF was established and the corresponding geological information in the vertical direction with different periods was obtained. Combining the geological survey information and surface distribution information, it can be concluded as follows. 1) The EAF covers an area of above 30,000 km^2 and may be the largest arid and semi-arid alluvial fan in the world based on the remote sensing survey. 2) Some surface parameters which are related to the paleoenvironmental change can be obtained from remote sensing data, such as the gravel size and potassium *K* parameters. 3) The forming process of the EAF and the corresponding environments will be understood deeply, combining the paleoenvironmental related parameters derived from remote sensing data and the geologic survey data.

1. Introduction

The Ejin Alluvial Fan (EAF), located in the north margin of the Qinghai-Tiibet Plateau, north-west of China, covers an area of above 30,000 km^2 and may be the largest arid and semi-arid alluvial fan in the world according to the remote sensing survey. The environmental evolution of this area was affected by each tectonic phase caused by reciprocal compression between Eurasian plate, Indian plate and Pacific plate, so paleoenvironmental researches in the EAF can also provide evidence for studying environmental impact of the upwelling of the Qinghai-Tibet Plateau and formation of East Asian monsoon [1]. As a result, the EAF is an ideal area for studying the Quaternary geological and environmental change in western China.

Many scholars have conducted many researches focusing on the EAF. The geological related researches include the studies on the Quaternary lake changes located in the edge of the alluvial fan, such as Gaxunnur Lake, Sugunur Lake, Juyanze Lake and Gurinan Lake [2-5], and the studies on the morphologic evolution characteristic of the alluvial fan and relationship between the tectonic and

[1] Corresponding author: Lu Zhang, luzhang@ceode.ac.cn.

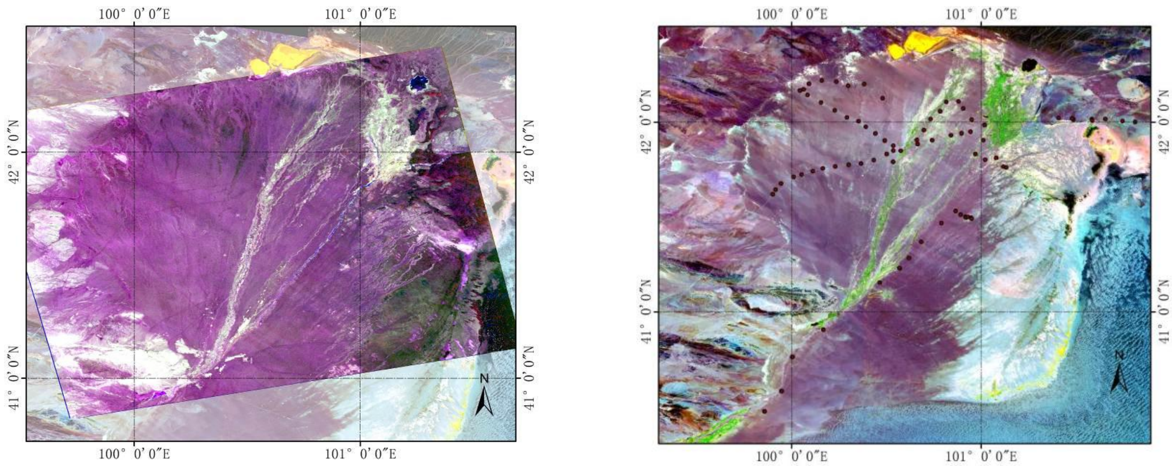
climatic events [6,7]. Recently, more and more scientists have noticed the important role of remote sensing in the study of alluvial fans [8-10]. Take the EAF as the study area, the relevant researches also be conducted. For example, utilizing SIR-A, SIR-B, SIR-C, Radarsat and Landsat images, a number of old river valleys and lake basins buried by wind-blown sand were recognized in this area [1,11]. Based on long series remote sensing images, the ecological environment of the Ejin Oasis was dynamic monitored and analysed [12,13].

The gravel size and potassium *K* are two important parameters for studying the environmental changes of alluvial fans. However, based on conventional geological survey, only vertical information can be obtained from few geological sampling points. The distribution information of the surface is missing. In this paper, the gravel size and element *K* invention methods were proposed from RadarSat-2 Synthetic Aperture Radar (SAR) data and LandSat TM optical data, respectively. Then the distributions of gravel size and element *K* of the EAF are obtained and analysed incorporated the geological survey data. On the one hand, this research will further explore the application potential of remote sensing technology on geological study. On the other hand, it will make us better understand the evolution and paleoenvironmental events of the EAF.

2. The study area and data

2.1. The Remote sensing data of EAF

The EAF (40.5°~42.6°N, 99.5°~102.0°) is located in the arid area of northwestern China, on the south by the northern Qilian Mountain, on the west by the Mazong Moutain, on the north by the Altai Moutain and on the east by the Badain Jaran Desert. It has a vast area of about 30,000km^2. The terrain is relatively flat within the fan and the elevation height is from 890 to 1130 m. The Heihe River that rises in Qilian Mountain flows through the EAF and then into the Juyanhai Lake.



(a) (b)

Figure 1. The pseudo-color composite images of RADARSAT-2 data (a) and LandSat TM (b)

The remote sensing images used in the EAF include both optical multi-spectral images and the SAR images. Two C-band dual-polarization RadarSat-2 wide mode data acquired in August 16 and September 9 of 2009 were collected. The incidence angle ranges from 19 to 31 degrees. The optical images are acquired from LandSat TM in 2000. The resolutions of both the SAR and optical images are 30 m. Table 1 shows detailed the parameters of the collected remote sensing data.

Table 1. The parameters of remote sensing data collected in EAF.

Data	Time	Band	Polarization	Resolution *(m)*	Incidence angle *(degree)*
RadarSat-2	2008-8-16	C band	HH HV	30	19-31
RadarSat-2	2008-9-9	C band	VV VH	30	19-31
LandSat-TM	2000	7 band		30	

Figure 1a and 1b are the red-green-blue (RGB) pseudo-color composite mosaic images of RADARSAT-2 data and LandSat TM, respectively. The red, green and blue colors in Figure 2a represent the backscattering coefficient combinations of HH, HV, and VV channels of RadarSat-2 data, in Figure 2b represent the 7, 4 and 1 bands of LandSat TM data.

2.2. Field Survey data

Two field investigations of the EAF which were carried out from 27th June to 4th July, 2011 and from 8th May to 16th May, 2012. More than 100 samples were collected in this area and some information was obtained from them, such as gavel size measured from field pictures, some chemical elements obtained by X-ray fluorescence spectrometric method, and the mineral components and dating information measured by using optically simulated luminescence (OSL) method. The locations of the samples are shown in Figure 1(b).

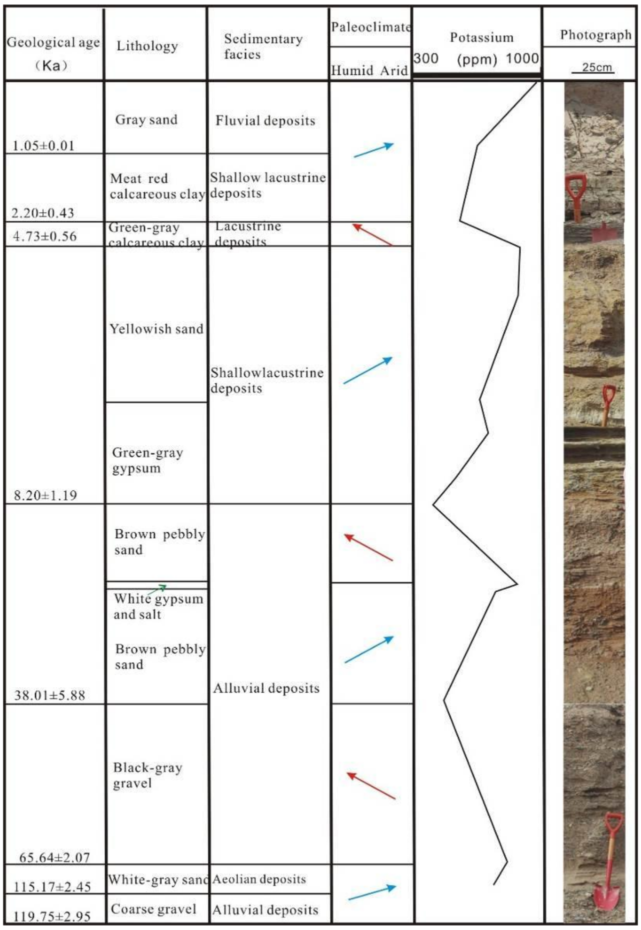


Figure 2. The stratigraphic section of the EAF.

3. Stratigraphic section

The stratigraphic section of the EAF shown in figure 2 was constructed according to geological age's ascending order which was composed of six columns, including geological age, lithology, sedimentary facies, paleoclimate, potassium content and photograph. The geological time was determined by the OSL dating method and the lithology is determined by field lithological descriptions, photographs and samples collected on site. Sedimentary facies and Paleoclimate change were analyzed based on the components. Potassium content was determined by INNOV-X XRF analyzer.

The stratigraphic section shows the information during the Late Pleistocene and the Holocene (120ka-today). The paleoclimate changed alternately between arid and humid. Contrasting the column 4 to column 5 in figure 2, the change of the potassium content is consistent with the paleoclimate trend deduced by the sedimentary facies. Therefore, the potassium content in arid areas can reflect the paleoclimate trend relatively. The higher the potassium content is, the more arid the paleoclimate becomes relatively [14].

4. The potassium content distribuiton of the EAF

Paleoclimate conditions deducing through the element content has been introduced by many scientists [15-17]. From the stratigraphic section, the chamical element potassium is related to the paleoclimate. This conclusion gives us a clue to predict paleoclimate conditions from the potassium distribution of alluvial fans' surface by remote sensing, which can express the paleoclimate in the time when the surface deposit was formed.

Based on the results of field investigation, the relationship between potassium content and the pixel spectrum was built by 40 samples' potassium content and the corresponding spectrum in the same location. The fitted formulation was shown in equation (1).

$$y=-20.7996*b1+16.5683*b2-14.7124*b3+7.3303*b4-1.2515*b5+5.5162*b7+1980.9087 \quad (1)$$

In which, y is the potassium content and b1 to b7 is the band value in the corresponding location of the image. The simulated result between observed and fitted values is shown in figure 3. In which, the horizontal axis is the observed value and the vertical axis is the fitted value. The determination coefficient is 0.529. In other words, the correlation coefficient between them is 0.727 which indicates that the remote sensing image can be used to predict the potassium content.

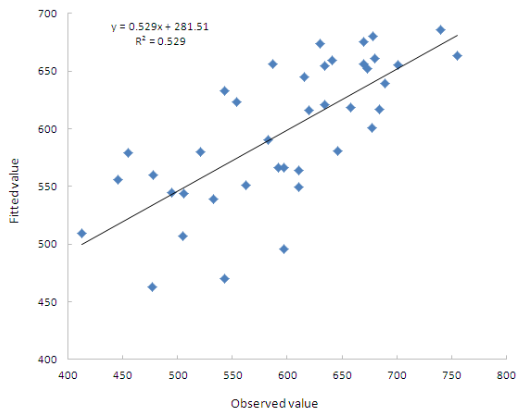


Figure 3. Simulated result between observed and fitted values.

Plane distribution of potassium calculated by equation (1) was shown in figure 4. From which, we can see that the potassium content is high in the fan foot and becomes less to the frontier. Areas with low potassium content are distributed around Saihantaolai in the north-western, Gurinai and swan lake in the eastern side. Areas with high potassium are mainly distributed in the fan foot from Dingxin town to Karakhoto and from the Fengwei Mountain to the Hei River. This is because the southern elevation is higher than that in the northern side. Water flows from southern to the northern along the Hei River to form lakes and oasis in the northern side. On the highland, not only water cannot be retained but also were the deposits influenced seriously by modern climate such as wind, temperature to form strong weathering sites. Therefore, local climate on the highland is more arid than that in the low-lying land in the study area. This phenomenon indicates that the potassium content in arid and semi-arid areas can reveal the climatic conditions at the depositional time which is consistent with the conclusion drawn from cross sections.

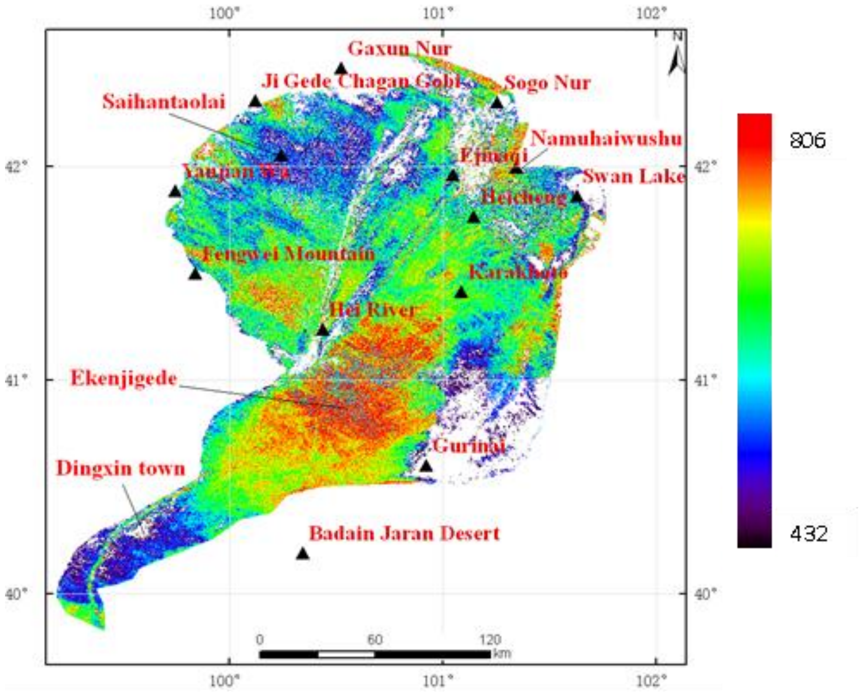
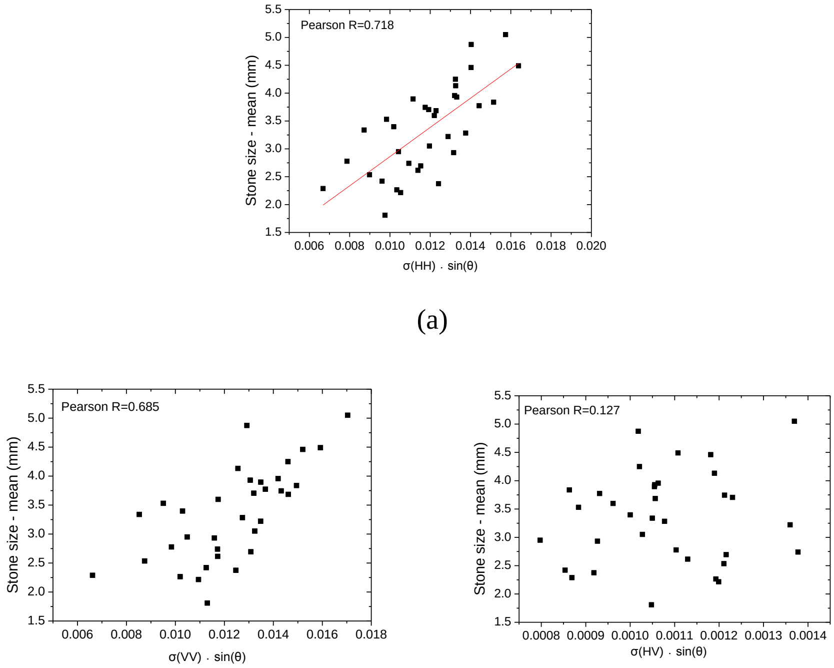


Figure4. Plane distribution of inversed potassium *K*

5. The gravel size distribution of EAF

Alluvial fans in arid areas are mainly composed of lots of gravel and sand. The gravel size, one of the important geomorphic parameters, is relevant to many factors, such as the amount of material and water sources of the alluvial activity, the location related to the fan heart and the exposure time of alluvial fan surface.

SAR remote sensing technic, due to the capability of recording the multi-polarization, multi-band and high-resolution microwave backscattering returns and the sensitivity to the geomorphic features, plays an important pole for extracting the geomorphic features of the alluvial fan surface [8-10]. In this paper, by using RadarSat-2 SAR data acquired in the EAF, the relationship between the backscattering coefficients with HH, VV, and HV polarizations and the gravel size that was measured in the field survey were studied. Because of the wide incidence angle range (19-31 degrees) of RadsarSat-2 Wide mode, the effects of incidence angle need to be considered. In this paper, the backscattering coefficient was multiplied by a sine function of the incidence angle. The scatter diagrams are shown in Figure 5, in which the horizontal axis is $\sigma()\bullet\sin(\theta)$ and the vertical axis is observed gravel size. The Pearson correlation coefficients between the mean of gravel size and the backscattering coefficient of HH, VV, and HV polarizations are 0.718，0.685，0.127 respectively. It is indicated that like polarization is better suitable for extracting the gravel size information.



(a)

(b) (c)

Figure 5 . The scatter diagrams of the gravel size versus the backscattering coefficient. (a: HH; b: VV; c: HV)

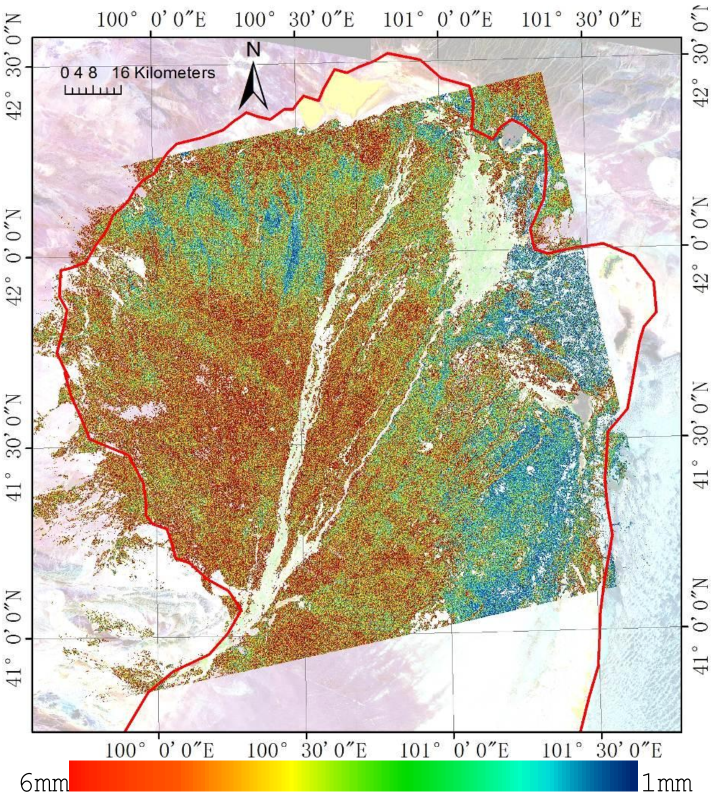


Figure 6. The gravel size distribution of EAF

$$D(\text{gravel})=0.24035+262.07332*\sigma(HH)\cdot\sin(\theta) \quad (2)$$

Based on the HH channel, the experience model was proposed by linear fitting and shown in Equation (2), where D is the average gravel size, σ is the backscattering coefficient, θ is the incidence angle. The red line in Figure5(a) is the fitted line. The gravel size distribution can be computed from RadarSat-2 data by using Equation (2) and is shown in Figure 6. From it, the distribution feature of gravel size is similar to the potassium distribution in the west region. The gravel size is high in the fan foot and becomes less to the frontier. However, in the east area, the gravel size is small for the serious desertification.

6. Conclusions

The EAF, located in the north-west of China, is an important recorder of both paleoclimatic and tectonic information of the north margin of the Qinghai-Tibet Plateau. It covers an area of above 30,000 km^2 and may be the largest arid and semi-arid alluvial fan in the world based on the remote sensing survey.

The gravel size and potassium *K* are two important parameters to study the environmental changes of alluvial fans. From the stratigraphic section, the vertical information related to different time in the fixed simple point can be obtained. But the surface distribution information is difficult to be obtained from the conventional geological technology. In this paper, utilizing remote sensing data, the gravel size and element K invention methods can be developed from RadarSat-2 SAR data and LandSat TM optical data, respectively. Then the distributions of gravel size and element *K* of the EAF are obtained and analyzed.

According to the study, it can be concluded as following: 1) The chemical element *K* can be derived from the multi-frequency optical data. SAR data are more sensitive to the gravel size which is one of the important geomorphic features of alluvial fans and like-polarization is better suitable for extracting the gravel size information. 2) The *K* and gravel size are related to the paleoenvironmental change. 3) The forming process of the Ejin Alluvial Fan and the corresponding environments will be understood deeply, combining the paleoenvironmental sensitive factors derived from remote sensing images and the geologic survey data.

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Reference

[1] Guo H D, Liu H, Wang X Y, Shao Y and Sun Y 2000 Subsurface old drainage detection and paleoenvironment analysis using spaceborne radar images in Alxa Plateau *Science in China* **43** 4 pp 439-449

[2] Chi Z Q, Wang Y, Yao P Y and Min L R 2006 Sedimentary Features of XK1 Core and Paleaoenvironment in Ga Xun Nur of Inner Mongolia Since Late Quaternary *Journal of lake science* **18** 2 pp 106-113

[3] Zhang Z K，Wu R J and Wang S M 1998 Environmental changes recorded by lake sediments from East Juyanhai Lake in Inner Mongolia during the last 2600 years *Journal of Lake Science* **10** 2 pp 156-161

[4] Qu W C, Wu R J and Wang S M 2000 Sedimentary pigment and its environmental signification of East Juyanhai in Inner Mongolia since the past 2600 years *Acta Sedimentologica Sinica* **18** 1 pp 13-17

[5] Chen F H, Wu W and Zhu Y A 2004 Mid-Holocene drought interval as evidenced by lake desiccation in the Alashan Plateau Inner Mongolia China *Chinese Science Bulletin* **48** 14 pp 1401-1410

[6] Chi Z Q, Wang Y, Yao P Y, Min L R and Liu X 2006 Tectonic and Climatic Events Recorded by Morphologic Units in EjinQi Inner Mongolia *Geological Review* **52** 3 pp 370-379
[7] Lü Y W, Gu Z Y and Aldahan A 2010 Be in Quartz Gravel from the Gobi Desert and Evolutionary History of Alluvial Sedimentation in the Ejina Basin Inner Mongolia China *Chinese Sci Bull* **55** doi: 10.1007/s11434-010-4103-6
[8] Farr T G and Chadwick O A 1996 Geomorphic processes and remote sensing signatures of alluvial fans in the Kun Lun Mountains China *Journal of Geophysical Research* **101** 23091−23100
[9] Crouvi O, Ben-Dor E and Beyth M 2006 Quantitative mapping of arid alluvial fan surfaces using field spectrometer and hyperspectral remote sensing *Remote Sensing of Environment* **104** 103-117
[10] Frankel K L and Dolan J F 2007 Characterizing arid region alluvial fan surface roughness with airborne laser swath mapping digital topographic data *Journal of Geophysical Research* **112** F02025
[11] Wang X Y, Guo H D and Chang Y M 2004 On paleodrainage evolution in mid-late Epipleistocene based on radar remote sensing in northeastern Ejin Banner Inner Mongolia *J. Geogr. Sci.* **14** 235—241
[12] Wang X Y, Guo H D, Wang C L and Liu H 2001 Dynamic Monitoring of Ecological Environment of Ejina Banner Oasis by Remote Sensing *Bulletin of Soil and Water Conservation* **21** 1 pp 60-62
[13] Zhang X Y, Gong J D, Zhao X and Zhou M X 2005 The Change of Land cover /land use in ejina oasis over 20 years *Advances in Earth Science* **20** 12 pp 1300-1305
[14] Cao B Y 2010 Geomorphology and Quaternary Geology *China University of Geosciences Press*
[15] Chen W N, Gao S Y and Sun Z 1994 On the Holocene geochemical landscape characteristics and its paleoclimate meaning, Mu US sand Sea *Journal of desert research* **14** 1 pp 22-30
[16] Li J W, Yan D R , Vasconcelos P M, Duzgoren-Aydin N S, Hu M G and Chen M H 2004 Geochronology of Supergene K-bearing Manganese Oxides and its Paleoclimatic Implications *Earth Science Frontiers (China University of Geosciences, Beijing)* **11** 2 pp 589-598
[17] Jin H L, Xiao H L, Zhang H and Sun Z 2005 Evolution and Climate Changes of the Juyan Lake Revealed from Grain Size and Geochemistry Element Since 1500 a BP *Journal of Glaciology and Geocryology* **27** 2 pp 233-240