

AEOLIAN MOBILITY AND STABILITY OF THE CENTRAL ASIAN ERGS, A STUDY BY REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS

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ABSTRACT:

Ergs are large, relatively flat, areas of deserts covered by wind-swept sand with a varying degree of vegetation cover. Central Asian ergs span from Turkmenistan to the Syr-Darya River in Kazakhstan, crossed by the Amu-Darya River; to the north lies Kyzyl-Kum and to its south the Kara-Kum. Ergs are sensitive to climate change and observable dune forms contain information on past wind directions and power. Additional environmental factors such as rainfall, grazing and human activity also affect dune development. This research focuses on identifying and mapping the ergs of Central Asia, and analyzing climate factors that have set the dunes in motion and later stabilized them. The vast area and the ground inaccessibility make traditional mapping methods virtually impossible. A variety of spaceborne imagery with varying spectral and spatial resolutions is used. These images provided the base for mapping the sand distribution, dune forms, and vegetation cover. Spectroscopy and lab analysis (X-ray diffraction, electron microscope) were used for mineral identification.

Wilson (1973) defined these ergs as active ones based on precipitation. Our results show that these ergs are mostly stabilized, and the estimated sand mantled area of the Kara-Kum desert is 260,000 square kilometers and 200,000 square kilometers of the Kyzyl-Kum.

The age of the sand samples is being determined by optically stimulated luminescence, providing insights into past climate. GIS analysis along side field work provides validation and verification.

1. INTRODUCTION

1.1 Ergs are large, relatively flat, areas of deserts covered by wind-swept sand with a varying degree of vegetation cover. Central Asian ergs have accumulated in the Turan basin, northwest to the Hindu Kush range, and span from south Turkmenistan to the Syr-Darya River in Kazakhstan. The ergs are crossed by the Amu-Darya River; to the north lies the Kyzyl-Kum (red sands) and to its south lies the Kara-Kum (black sands). The area of these ergs was estimated by over 600,000 square km, similar in size to the Rub' al Khali. Wilson (1973) defined these ergs as active ones based on precipitation. Ergs are sensitive to climate changes and the current dune forms may imply past directions and wind power. Furthermore, additional environmental factors including rainfall, grazing and human impact affect dune development and may also contribute to our understanding of these ergs and their stabilization cause. To date a small number of works was carried out in this area.

1.2 Objective

The purpose of this research is to identify and map the sand seas and analyze the climate factors that have set the dunes in motion and later stabilized them.

2. METHODS AND RESULTS

2.1 Sand mapping using RS and GIS

Because the area is vast and mostly inaccessible remote sensing using varying spectral, spatial and temporal information was used. These data assist in mapping the past and present sand distribution and enable to determine dune forms and vegetation cover. The sand distribution map (Figure 2) was compiled according to the steps in Figure 1:

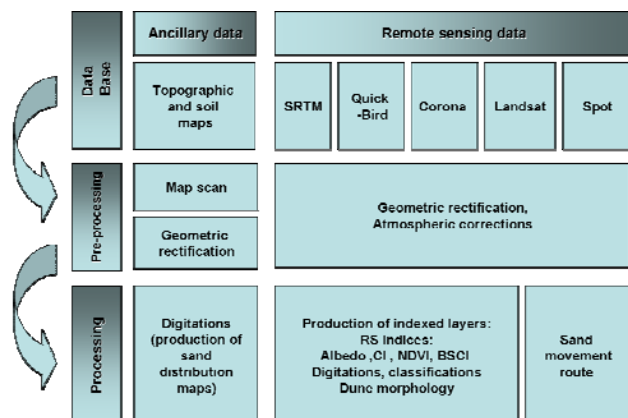


Figure 1. Central Asian ergs area map preparation outline.

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2.2 Sand mobility and stability – precipitation analysis

Dunes may be classified either as active (mobile sands) or fixed, based primarily on vegetation cover and wind power (Thomas, 1997). Stabilization will occur provided that there is low wind power, no human interference (Pye & Tsoar, 1990; Tsoar, 2005) and rainfall above 50-60 mm/year as in the Negev desert (Tsoar, 2008).

Precipitation data for over 50 stations retrieved from “Central Asia Temperature and Precipitation Database”, for the years 1879-2003 were processed using ordinary krigging to assess the average annual rainfall spatial distribution (Figure 2). These were used to understand whether the ergs are located above the rainfall threshold for vegetation (50 – 80 mm yr⁻¹ on annual average).

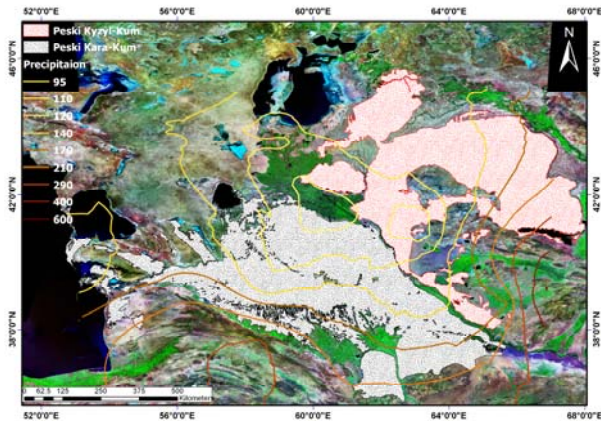


Figure 2. Central Asian ergs distribution and precipitation map on Landsat mosaic (bands 7, 4, 2). The black dotted area is the Kara-Kum, the red dotted area is the Kyzyl kum.

It is apparent from figure 2 that the precipitation in these two sand seas is above the threshold, ranging between 95 mm/year in around the Amu-darya delta and to 400 mm/year in the Kopet-dag range. Analysis of the past 100 years shows that the precipitation is sufficient to support vegetation.

2.3 Drift Potential calculations

In determination of sand dunes mobility, wind power was found to be the most important physical factor in areas with rainfall above the vegetation threshold (Tsoar and Werner, 1998; Tsoar, 2005). Fryberger (1979) developed a method for calculating the wind power as DP - sand drift potential, from hourly average wind data:

$$DP = \frac{U^2(U - U_t)}{100} t \quad (1)$$

where U = wind velocity (in knots), measured at a height of 10 m.
 U_t = is the threshold wind velocity (=12 knots).
 t = is the time the wind blew above the threshold velocity (in percent).
 division by 100 is for reducing the result to a smaller number.

DP, calculated and mapped from meteorological data retrieved from scattered stations in the research area, are shown Figure 3.

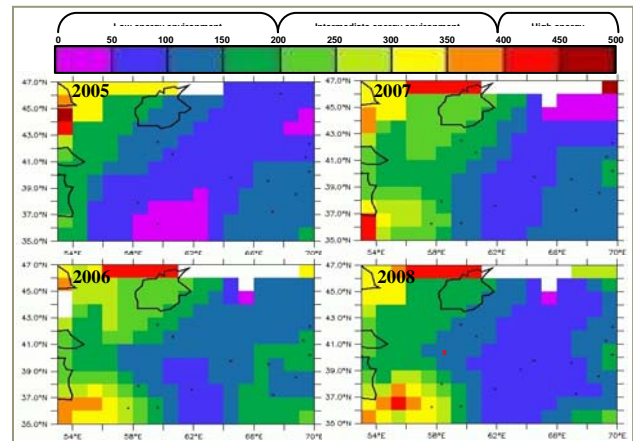


Figure 3. Drift Potential maps based on real weather stations. a=2005, b=2006, c=2007 and d=2008. In 2008 an additional station was added; Darvaza marked as x, DP=87.

The sand drift potential in the research area is low and can support vegetation cover (figure 3).

2.4 In situ field measurements

In support of the remote sensing analysis, ground truth measurements in Uzbekistan and Turkmenistan were carried out by the research associates. Field observations are indispensable in order to examine the relationships between the remotely sensed data and the surface conditions at corresponding points on the ground (Campbell, 1996).

During September 18-25, 2008, and October 12-20, 2009 two field trips were undertaken to Uzbekistan. During the field work sand and biogenic samples were brought for further analysis in laboratory conditions and OSL dating. Geographical coordinates, providing locational information, were gathered using a GPS (global positioning system) measurements in order to validate and assess the accuracy of the classifications and remote sensing analysis.

2.5 OSL

Optically stimulated luminescence (OSL) is an optical dating method measuring the last exposure to sunlight which enables the determination of the age when stabilization started (Lancaster, 1997; Stokes, 1999; Jacobs et al., 2003). This measurement provides new insights into the landscape evolution and geomorphologic processes in the research area and assists in the determination whether and when climate change, that caused stabilization has occurred in the specified deserts of Central Asia. The OSL analysis was done at the Luminescence dating lab of the Geological Survey of Israel in Jerusalem.

For three samples from Uzbekistan the results are as follows (figure 4):

OSL sample 1 (41°23'30"N, 61°23'15"E): 6.0 +/- 0.5 ka,
 OSL sample 2 (42°16'49"N, 60°28'10"E): 4.8 +/- 0.4 ka,
 OSL sample 3 (41°18'53"N, 60°23'26"E): 7.3 +/- 0.8 ka.
 All date back to Mid-Holocene. In the Russian literature this phase is known as the Liavliakan, (Lioubimtseva et al, 2005, Boomer et al). At this phase, between the early and the mid-

Holocene the climate changed from cold and dry to much warmer and wetter).

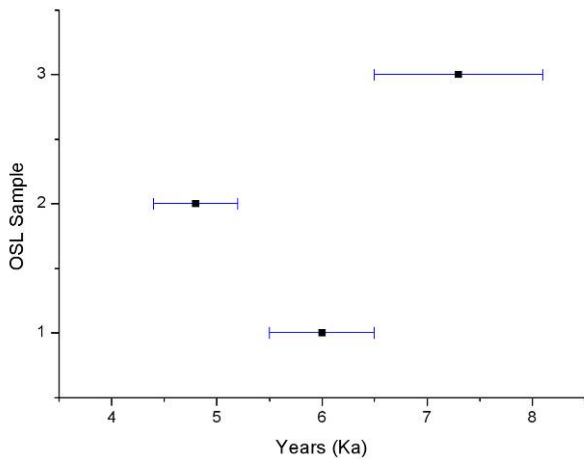


Figure 4. OSL results. Horizontal lines show the values of the errors.

3. CONCLUSIONS

From this research several conclusions can be drawn based on the results:

1. The ergs in the study area are mostly stabilized, and the estimated sand covered area for the Kara-Kum desert is ~260000 Km² and ~195500 Km² for the Kyzyl-Kum desert.
2. Although the climate of the ergs is defined as arid, precipitation is above the minimal threshold for vegetation under the current low wind power (DP).
3. The age of sand samples was determined by optically stimulated luminescence, and supports insights regarding past climate and stabilization age.
4. The central Asian Ergs, stabilized because of a climatic change that occurred during Mid-Holocene.

4. FUTERE WORK

In order to better understand the climate change that has stabilized these dunes more OSL dating will be done on sand already sampled in the field. Furthermore, spectral measurements of the sand samples will be undertaken using the FieldSpec FR spectrometer (ASD). The device measures wavelengths from 350 to 2500 nm, with a spectral resolution set at 3nm for the region 350-1000 nm and 10 nm for the region 1000-2500 nm (ASD, 2007). This range of wavelengths corresponds to the portions of the visible light, near infrared and short wave infrared, which will enable the use of the indices that will be applied to the RS data such as Redness index. This data will than be correlated with results retrieved from the Landsat imagery, to better understand and spectrally characterize the sand in the research area.

5. REFERENCES

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