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WORKSHOP ON REMOTE SENSING TECHNIQUES WITH APPLICATIONS TO AGRICULTURE, WATER AND WEATHER RESOURCES

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LECTURE ABSTRACT

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WIND SYSTEM AND SAND DUNES IN THE TAKLAMAKAN DESERT (PEOPLE'S REPUBLIC OF CHINA)

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ABSTRACT

A 337,600 sq km sandsea, the Taklamakan, which has a positive sediment budget dominantly composed of transverse dunes, offers on its borders the possibility of development of the biggest and most original oases in the world. The general wind system, the encroaching sand on human settlements and control solutions can be proposed from an analysis of the Landsat satellite images.

INTRODUCTION

The sandy dry areas in China are arid, semi-arid, sub-humid steppic. They occupy a total area of 637,000 sq km, (Chao Sung-Chao 1981). They are located in the temperate zone between 35 to 50°N, (Petrov 1966).
The west most one is the Sin-Kiang region, between 37° to 42° N. and 76° to 89° E. Sin-Kiang is formed in its southern part by the Tarim basin which is 400,000 sq km (1,300 km from east to west and 500 km from north to south) occupied by the huge sandsea of Taklamakan (337,600 sq km), mainly formed of shifting sands.

The use of Landsat imagery reveals a sandsea with a positive sand budget apparent from the transverse dunes which are dominant. Because of the presence of water and of sandy soils fed by alluvial deposits brought in abundance by the numerous rivers flowing from the snow capped fringe of high mountains and reshaped by wind activities, a necklace of millenar oases appeared at the foot of the mountain. All these oases are in a vulnerable location and highly prone to water and wind erosion. The analysis of the structure of Taklamakan sandsea and the encroaching sand directions on human settlements is done with Landsat satellite imagery as shown in the other deserts, (Mainguet and Callot 1978 and Mainguet and Jacqueminet 1984)..

I. A NATURAL AREA SITUATED AT THE CONTACT BETWEEN AEOLIAN AND FLUVIAL DOMAINS

Visible on Landsat images are high mountains which surround the basin on three sides: in the north the Tian Shan, in the west the Pamir mountain range, in the south the Kunlun Shan mountains. At the foot of the ranges, alluvial cones are formed from river deposits. The rivers are the Kaxgar and Yarkant in the west, flowing north-eastwards; in the north, the Aksu flows towards the Taklamakan sandsea; in the south, the Hotan flows northwards through the southern half of Taklamakan sandsea. These four rivers are dependent on the 2,000 km long Tarim river which runs towards the Lop Nor depression.

The peripheral area of the basin has a dense drainage system which is rich in fluvial and aeolian deposits which are interdeposited on the southern boundary

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of Taklimakan sandsea. The limit between the fluvial and the aeolian zones is difficult to trace because alluvial deposits enter far into the Taklamakan sandsea.

In this peripheral area, all the dunes are too small to be visible on Landsat imagery. However they are well mapped on "Study on the Geomorphology of Wind Drift Sands in the Taklamakan Desert". They are well developed in the alluvial plains: (Figure 1)

a. BARCHANIC EDIFICES: The small mobile barchans and the transverse chains represent a real danger for the oases and much protection work has been done to protect human settlements against encroaching dunes. The most remarkable works of protection are in the Turpan oasis. The analysis of these barchanic edifices as wind indicators reveal:

- west of the basin and more precisely west of the oasis of Skacha the dominant winds are from the north west but the north east direction is also represented.
- north of the basin from east of the Korla oasis until Bachu oasis the dominant winds blow from ENE to NE to WSW and SW.
- east of the Korla oasis and south of Lake Bosten, two efficient and opposite wind directions appear ENE to WSW and WNW to ESE.
- in the eastern part of the basin near Lop Nor depression the NE to SW winds are dominant.
- south of the basin, west of Hotan, the dominant winds are WNW and ESE. Between the oasis of Hotan and Yuttan, two efficient wind directions can be observed W to E and NW to SE.
- in the area between the oasis of Yuttan, Yingfong and Qiéma, the winds blow from WNW to ESE and from WSW to ENE, a third direction becomes efficient ENE to WSW. This last direction becomes dominant east of Qiéma.

b. STAR DUNES are indicators of a multidirectional wind regime: these dunes are formed east of Lake Bosten and result from ENE to WSW and WNW to ESE winds. East and west of the Holger alluvial fan two areas of dunes result from SW to NE and NE to SW winds.

c. DOME DUNES AND REBDOUS: Rebdous are sandy edifices which accumulate around a vegetal obstacle. For example Tamarix trees which grow simultaneously with sand accumulation are found south of the Akou oasis in the north eastern part of the Yarkant alluvial plains and in the northern part of the Hotan alluvial plains in an area where fluvial and aeolian influence interact. Domes and rebdous do not indicate wind direction but rather mobile available sand. Between the Qiéma oasis and the Minfeng oasis, fluvial sand originating from Altun mounts is reshaped into domes.

d. CORASION STRIKES AND YARDANGS: At the eastern boundary of Taklamakan and Lop Nor depression, corasion strikes and yardangs indicate a monodirectional wind regime from NNE 30°.

II. SURFACE STRUCTURE OF THE SAND IN TAKLAMAKAN SAND SEA.

a. BARCHANIC EDIFICES AND SHORT TRANSVERSE CHAINS: Barchanic edifices and short transverse chains are not visible on the Landsat mosaic. They are all located in areas of thin sand veneer and negative sand budget. They are relay dunes which appear in negative balance transport area and feed the positive balance sectors. At the western border of Taklamakan a circular cyclonic sand movement is deciphered from these edifices.

South of Yuli, on the left and right banks of Tarim river, barchans

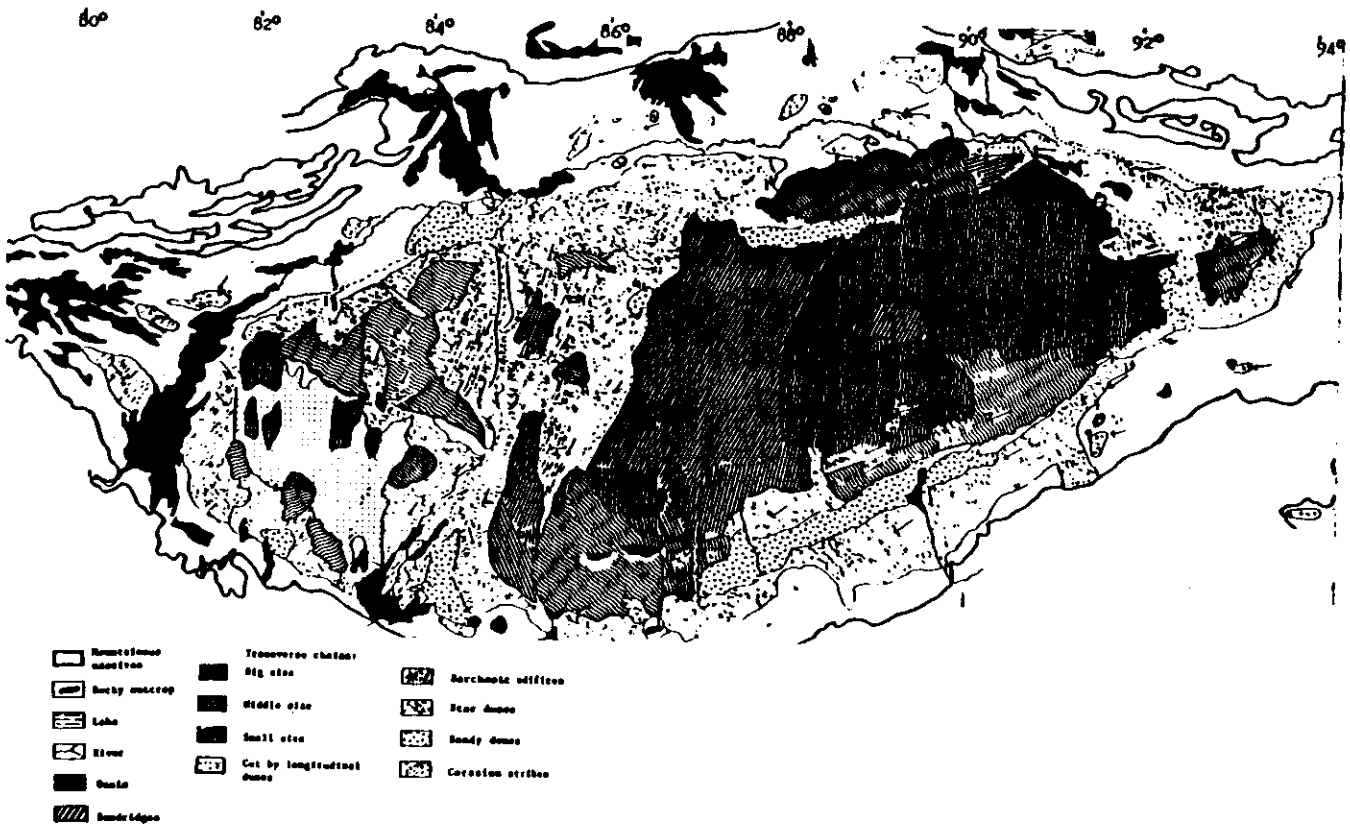

Fig. 1: The Dunes in Taklamakan Desert obtained after Analysis of a Landsat Mosiac

indicate an east to west wind and sand movement. East of Taklamakan on the right bank of the Tarim river, the aeolian direction is ENE to WSW 75°. Further east towards the Lop Nor direction on the right bank of Korgi, some barchans are migrating, in an ENE to WSW 75° direction, north of the sandsea and NE to SW a little further south.

b. TRANSVERSE CHAINS: These complex dunes are predominant in the Taklamakan sandsea. They exist in all scales:
i) Small edifices are almost invisible on Landsat satellite images at 1:1,000,000 scale - but they indicate sand accumulation in the framework of a positive sediment budget.
ii) Middle-size edifices are generally at the border of large transverse chains areas.
iii) Large transverse chains are building areas of very thick sand sheets where the sediment balance is highly positive. Two types of transverse chains can be distinguished: 1) one with coalescent chains, 2) the second with chains separated by corridors. 70% of the sandsea is occuped by transverse chains which in the eastern part of the sandsea represent a positive sediment budget.

The first type corresponds to areas upwind of rocky obstacles such as :
- 30 km upwind of the Qokkatag outcrop the sandy deposits appear, oriented NW to SE and cover an area of 100 km long. The chains have a maximum length of 15 km and a spacing of 1 km. Some longitudinal strikes cut them more or less perpendicularly.
- the outcrop of Mazartag also generates a thick sandy accumulation 25 km upwind from the obstacle over an area 80 km long with the same orientation as upwind of Qokkatag, but with chains of a maximum of 7 km only and with an interdunal distance of 2 km.
- between the Xnai and Niya valleys, the chains are north to south with a maximum length of 60 km, a width of 2 km and interdunal corridors of 1 km.
- further west between Niya and Kerya valleys the transverse chains have a length of 40 km and a width of 1 km with corridors of 2 km.

70% of the sandsea is made up of transverse chains oriented N to S to NNE to SSW. E to NE winds explain this transversal orientation. The maximum length of these tranverse chains is 60 km, the maximum width is 2 km and the interdunal corridors being 1 km. In general, the size of the edifices decreases from north to south.

LONGITUDINAL SANDRIDGES

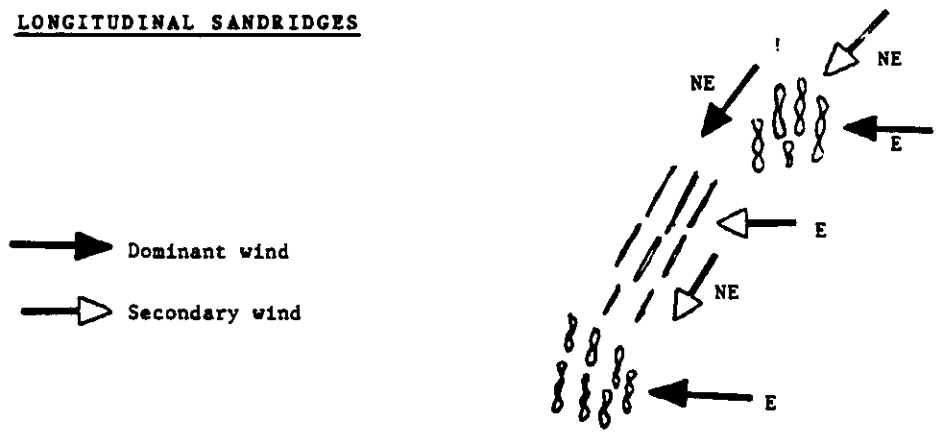

Fig. 2: Centre of Taklamakan passing from transverse to longitudinal dunes.

The central part of the Taklamakan sandsea is occupied by longitudinal sandridges. This central area begins with the transformation of transverse chains into longitudinal sandridges, when the dominant wind from NW becomes more efficient than the eastern wind. The interdunal corridors become wider, the edifices straighter and the orientation NE to SW, depending on the direction of the dominant wind. The maximum length of the sandridges is only 30 km, the width 1 km and the width of the corridors 2 km.

More south, in the wind direction, the longitudinal sandridges are relayed by transverse chains when eastern winds become again dominant.

Some other small sectors of the sandridges exist: - west of Qokkatag outcrop sandridges result from a skirting and tightening of the wind streams around an obstacle and their tightening with a higher efficiency and negative sediment balance; - south west leeward of the same mountain range of Qokkatag in the area of Bir Kum, longitudinal strikes cut the transverse chains indicating the beginning of export of particules in an area of tightened stream lines at the confluence of two branches of a wind current leeward of the obstacle.

Between Hotan and Kenya there is a stretch of sandridge 20 km long and 800 m wide. From north to south, the sandridge orientation changes from NE to SW, to N to S and to NNW to SSE confirming the circular wind movement.

III. SOURCE OF SAND AND WIND SYSTEM IN TAKLAMAKAN (Figure 3)

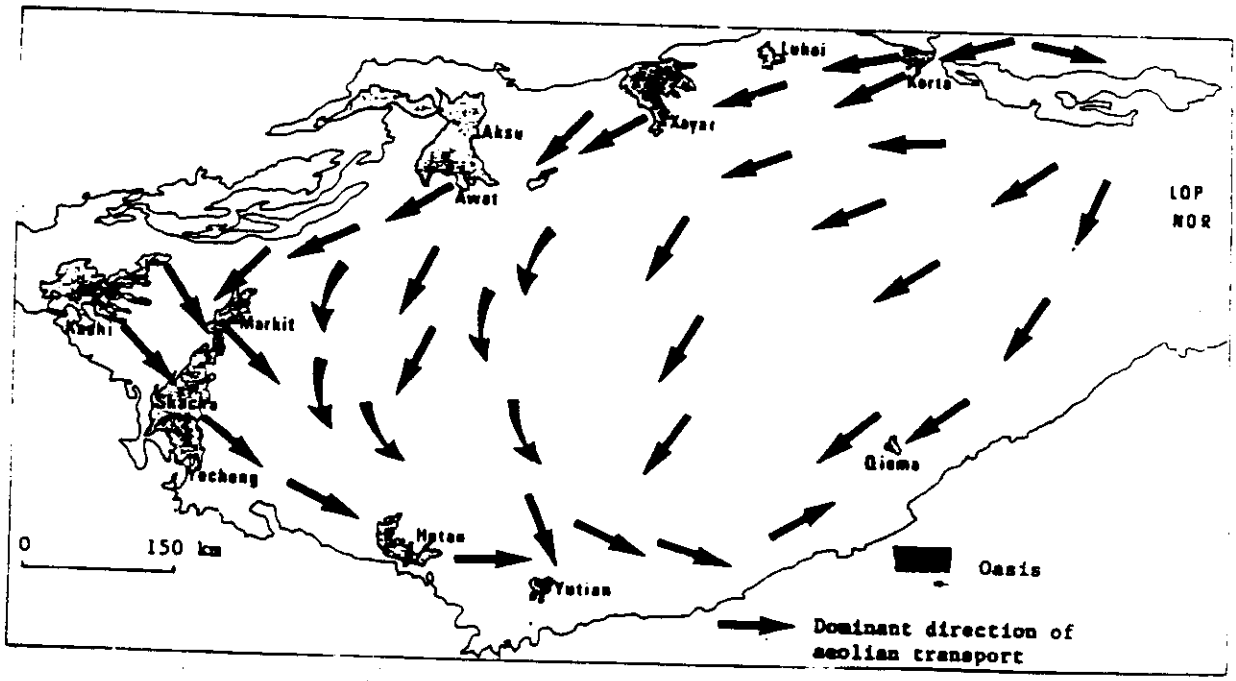

Fig 3: COUNTERCLOCKWISE WIND SYSTEM IN THE TAKLAMAKAN DESERT OF CHINA

The Taklamakan sandsea has a positive sediment balance with 75% of the dunes higher than 100 m. The volume of sand is considerable. Geologists have found thicknesses of 400 - 500 m. of Pleistocene sand. Alone, the alluvial source of sand cannot explain these big volumes. The actual or inherited glacial origin of the material from the surrounding tops of high mountains reshaped on the slopes by fluvial actions must be principally be taken into account.

Paleoclimatological studies agree that the dry climate of north west China appeared in late Cretaceous or early Tertiary periods with a sub-tropical high pressure belt and north-easterly trade winds blowing over a huge peneplaned area. From north west China to the Yangtze plain, the arid to semi-arid belt was covered with a steppic and woody grassland. When later in late Tertiary the Chinese Himalayan tectonic movement gave the present topography to China, with uplifting of the Tibetan plateau, the continentality of the climate increased the present day monsoon system installed with accentuation of the aridity in western China and strengthening of the high pressure centre also pushed northward to about 55°N, (Lin Chun-Yu et al 1978 and Geng Kuankong 1985)

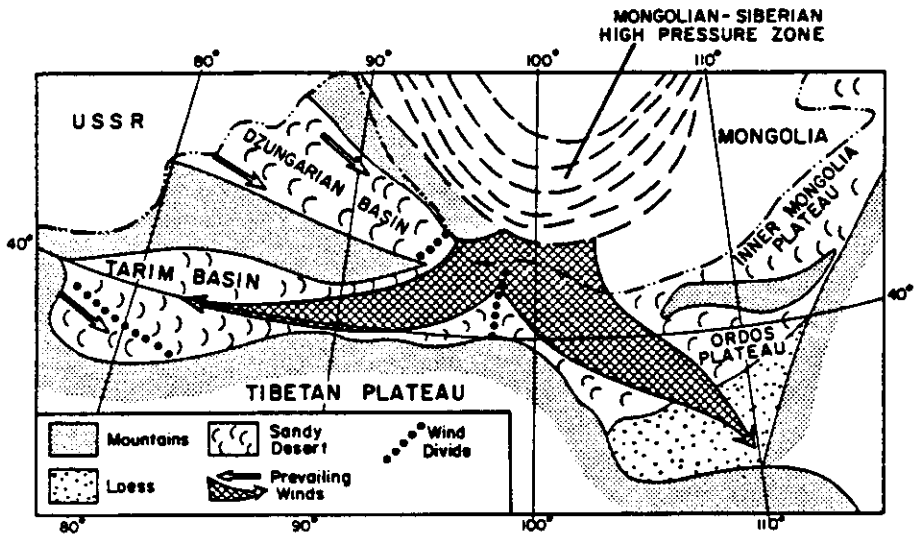

Fig. 4: Winter dominant winds in Northern China

The Mongolian Siberian high pressure centre (Fig. 4) gives a very classic pattern of circular dry and cold winds blowing in a clockwise direction towards the Tarim Basin, (Zhao Songquiao 1981 and Geng Kuangkong 1985). But because of blockage by the Tibetan plateau there appears a new complexity at the longitude of 97°E where the wind meeting the northern edge of the Tibetan Plateau diverges into two branches, one blowing from the NE to the SW, the other from NW to SE. The former affects the Tarim basin, especially in winter. In summer, the scheme is different. The south eastern monsoon which brings high rainfalls to south east China does not reach easily - because of the long distance from the sea and the barrier effects of topography - the Tarim basin.

In the Taklamakan desert the originality of the wind movement is partly its counterclockwise direction at the western and southern borders and clockwise direction north and east of sand sea. The dominant winds are from NE to SW and east to west, but because of the topography they deviate according to the directions north to south and NW to SE.

CONCLUSION

The combination of a high mountainous fringe capped with glaciers and a well developed fluvial system converging to the Tarim basin produces abundant amounts of sand which feed the Taklamakan sandsea - the most positive balance sandsea in the world. The wind movement which would normally blow in a clockwise direction is complicated by the mountainous fringe which produce deflexion and deviations from the original wind direction as shown on Figure 3.

Thanks to the availability of water at the foot of these mountains, oases and a very sophisticated system of irrigation were developed. However, the oases stand in precarious sites for the wind and sand movement. The satellite imagery shows clearly the arrival and deposit of sand. Instead of the sand passing, it is trapped because of roughness introduced by human settlements and especially the cultivated vegetation. However, from the ancient Chinese experience, they are knowledgeable in the control and balance of deposit with the vegetation recovery.

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