REMOTE SENSING OBSERVATIONS OF SAND MOVEMENT IN THE BAHARIYA DEPRESSION, WESTERN EGYPT

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ABSTRACT

Aerial photographs taken in the 1940's have been used in combination with recent Landsat MSS and TM data to study dune movement in the Western Desert of Egypt. The El-Ghorabi dunes track northwest to southeast along the eastern edge of the Bahariya Depression. These dunes are of complex longitudinal form with well-defined, lag-covered interdune corridors. Studies using both aerial coverage and multitemporal MSS and TM image data reveal little or no net southward extension or movement of the seifs, although field measurements and remote sensing data indicate small-scale lateral migration of dune crests and interdune corridors through time. The primary process of sand transport for these dunes seems to be in response to seasonal shifts in dominant wind direction, as reflected in the development and rapid response of sand shadows leeward of the main dune masses.

1. INTRODUCTION

Although multispectral satellite images have been available only for the past 14 years, the time scale for observations of environmental changes can be extended by using aerial photography taken several decades ago. For studies of sand transport in arid regions, this extended time interval is extremely valuable in that large dunes move much slower than can be detected

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with the 14-year record of Landsat MSS data. Field studies in southern Egypt indicate that the large barchan dunes of that region move at an average rate of 7-10 m/yr, which equates to only a one- to two-pixel change over the entire record of Landsat data. Smaller barchans in isolated depressions may move much faster. Embabi (1982) found that barchans in the Kharga depression may move as fast as 100 meters/year; however, these rapidly-moving dunes are approximately 20 m across, well below the resolution of the Landsat MSS sensors. In the Bahariya depression in western Egypt, we are extending our dune migration studies based on MSS and Thematic Mapper image data by using aerial photographs taken 40 years ago. Used together, these complementary data sets indicate natural environmental changes due to dune migration, as well as the impact of human habitation in an active area of sand transport. In addition, the spectral information contained in Thematic Mapper data is being used to map compositional variations in dune and desert floor sediments.

This study concentrates on a group of longitudinal dunes at the northern part of the Ghard Abu Muharik, a complex longitudinal dune system that stretches 400 km from the Bahariya depression in the north to its downwind end at the Kharga depression. The El-Ghorabi longitudinal dunes at the eastern edge of the Bahariya depression are separate from the main seif dunes. The interdune corridors which separate individual duneforms are covered by desert lag deposits. As a first step towards understanding the dynamics of the northern end of this dune system, we are investigating both seasonal and long-term variations of sand distribution.

2. GEOMETRIC CORRECTION

Available maps are at a scale of 1:250,000, and were based primarily on mapping carried out for strategic purposes during World War II. For this reason, we are using a Satellite Navigation instrument (Satnav) to precisely locate control points for geometric rectification of Landsat MSS and TM images, and SPOT multispectral images. Tests of Satnav locations obtained on different days during the same field trips, and from 1985 and 1986 field work in southern Egypt, indicate an accuracy of about 50 meters.

The location of these control points on MSS images in an area of active sand movement can be a problem in the open desert areas to the south, but in the Bahariya area, sufficient bedrock knobs and irregularities in the scarp bounding the depression exist so that accurate location of field sites on images is possible. Based on estimates of the accumulated error in the Satnav system, measurements and in the location of field measured sites on digital image data, we believe that the geometric control on the Landsat TM data is accurate to within 3-4 pixels, or 90-120 m.

Landsat MSS images (Table 1) were more difficult to correct because of the imprecision of control point locations on the lower spatial resolution images. We estimate the error involved in those corrections at 4-5 pixels (300-400 m), although the coregistration between the 1972 and 1984 MSS scenes was better than registration between the MSS and TM scenes. For ease in comparing the disparate scales, the MSS scenes were resampled to 30 m/pixel.

3. TEMPORAL COMPARISONS

Examination of co-registered MSS and TM images of the southern extension of the Ghorabi dunes reveals little net advance of the dune field. However, changes have occurred in the morphologies of individual dunes within the system. The seif dunes that make up the Ghorabi system are resolvable in the 1944 air photos and appear to be anchored by topographic highs northeast of the Bahariya escarpment (Figure 2). Over the interval of study, individual dunes have separated and rejoined in response to local conditions, as evidenced by both field measurements and remote sensing data (Figure 3).

Although net southward advancement of the dune system is seen to be minimal, the data indicate that seasonal reversals of dominant wind direction are significant in the sand transport process. Images taken in September-November show marked sand shadows on the southwest (downwind) side of the Ghorabi dunes (Figure 4), while sand shadows appear on the northeast side of the dunes in late spring (Figure 5). Accurate multitemporal mapping of these sand shadows requires the spatial resolution of TM data; at MSS resolution, the rapid response of these areas of thin sand veneer to changes in wind regime would be masked in both spectral and spatial domains. Analyses of TM data reveal sufficient spectral differences as well as spatial indicators to ensure appropriate mapping of dunes and associated sand shadows (Figure 6).

4. CONCLUSIONS

Landsat images and aerial photography taken in September-November show that the dominant north to northeast winds of that season create well-defined sand shadows on the downwind (southwest) side of the Ghorabi dunes. Reversal of the dominant direction of sand transport occurs in late spring, when sand shadows are apparent on the northeast side of the dune system. Net southward movement or elongation of the dunes cannot be confirmed; instead, seasonal reversals in wind direction and associated sand transport are the dominant modifying factors of the dune field. Some small growth east of the main dune mass may represent another seif forming at the present time. Thus, the evidence in this case tends to support the conclusions of Tsoar and others (1985) for the importance of bimodal winds in the growth of longitudinal duneforms, while models based on unidirectional winds (such as Folk's 1971 roller vortex model) do not seem to apply.

Use of MSS data alone for similar studies would likely result in a significant overestimation of the extent of sand cover, due to the coarser spectral and spatial resolution of the MSS data. Thus, the rapid response of the sand shadows to changes in wind regime would likely be missed, resulting in different interpretations as to dominant surface processes.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Embabi, N.S., 1982, Barchans of the Kharga Depression. In: F. El-Baz and T.A. Maxwell, Editors, Desert Landforms of Southwest Egypt: A Basis for Comparison with Mars, NASA CR-3611, pp. 141-155.

Folk, R.L., 1971, Genesis of longitudinal and oghurd dunes elucidated by rolling upon grease. GSA Bulletin 82:3461-8.

Tsoar, H., K.R. Rasmussen, M. Sorensen and B.B. Willetts, 1985, Laboratory studies of flow over dunes, Proc. Intl. Workshop on the Physics of Blown Sand, Aarhus, May 28-31, 1985, pp. 327-349.

Table 1. Data Sources

SOURCE	ACQUISITION DATE	RESOLUTION	USED WAVELENGTH
Air Photographs	5/18/44	____	Panchromatic
Landsat 1 MSS	9/19/72	80 m	Band 4 (0.8-1.1 microns)
Landsat 5 MSS	5/29/84	80 m	Band 4 (0.8-1.1 microns)
Landsat 5 TM	11/5/84	30 m	Band 5 (1.55-1.75 microns)

Figure 1. The Bahariya depression is located 300 km southwest of Cairo, and encloses several small inhabited oases. The surrounding bedrock consists of Pliocene gravels and Eocene limestone. This TM Band 5 scene is shown at 1/3 resolution (every third line and element) after geometric correction using Satnav control points. The area discussed in this paper is occupied by the El Ghorabi dunes at the northeastern edge of the depression (A).

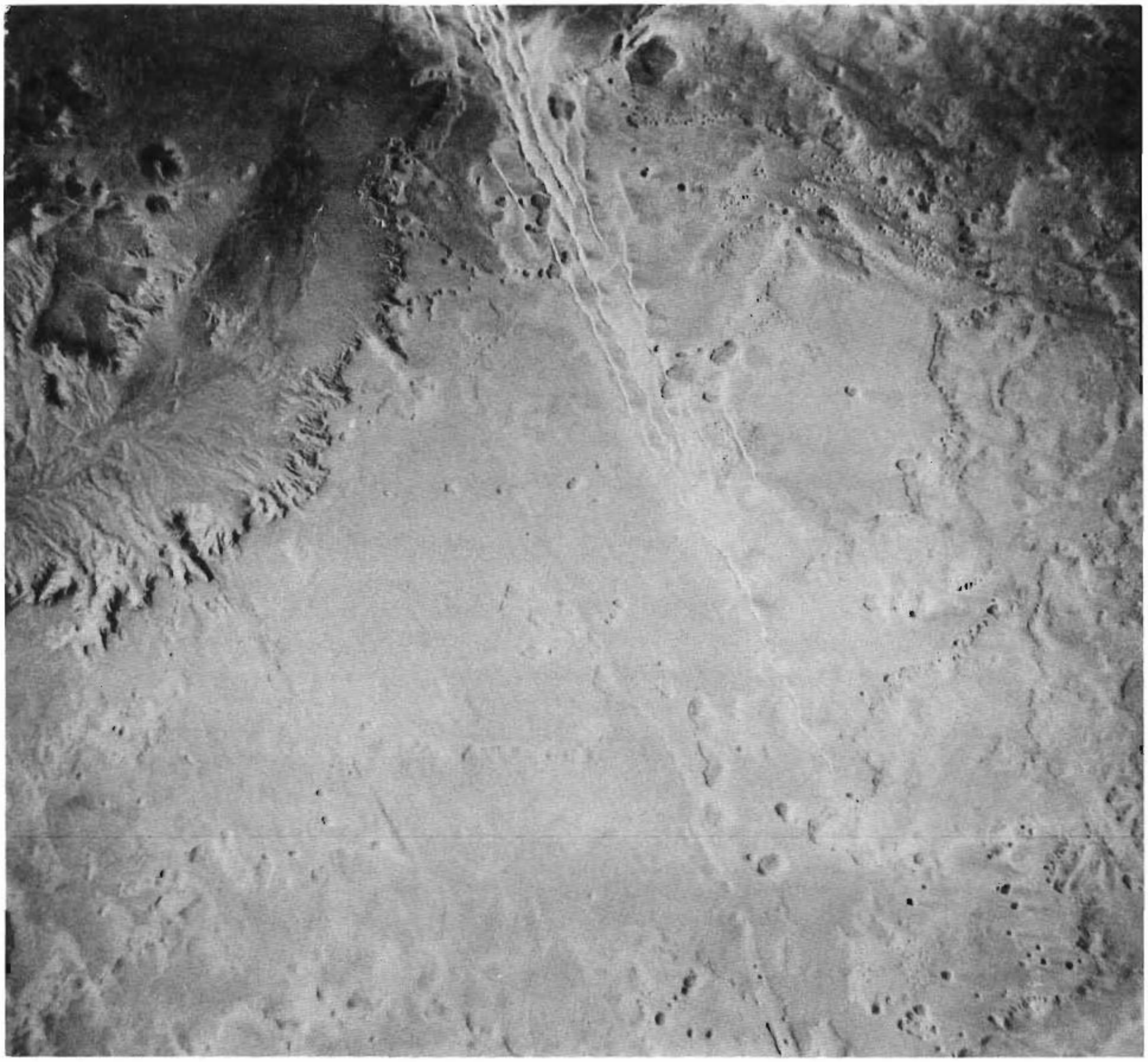

Figure 2. Air photo taken May 18, 1944. Individual seif dunes are visible, and are stabilized by knobby terrain NE of the escarpment. Dark wind streaks in the lee of knobs (lower right of photo) indicate dominant westerly winds during the spring.

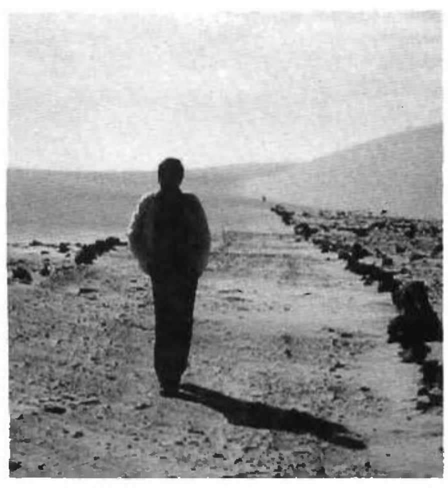

Figure 3 originally in color.

Figure 3. Separation and rejoining of individual duneforms has occurred in the past 25 years. The road was built in the early 1960's as an access route to the iron deposits atop Gebel Ghorabi. The pass between the dunes is now 2 km to the south.

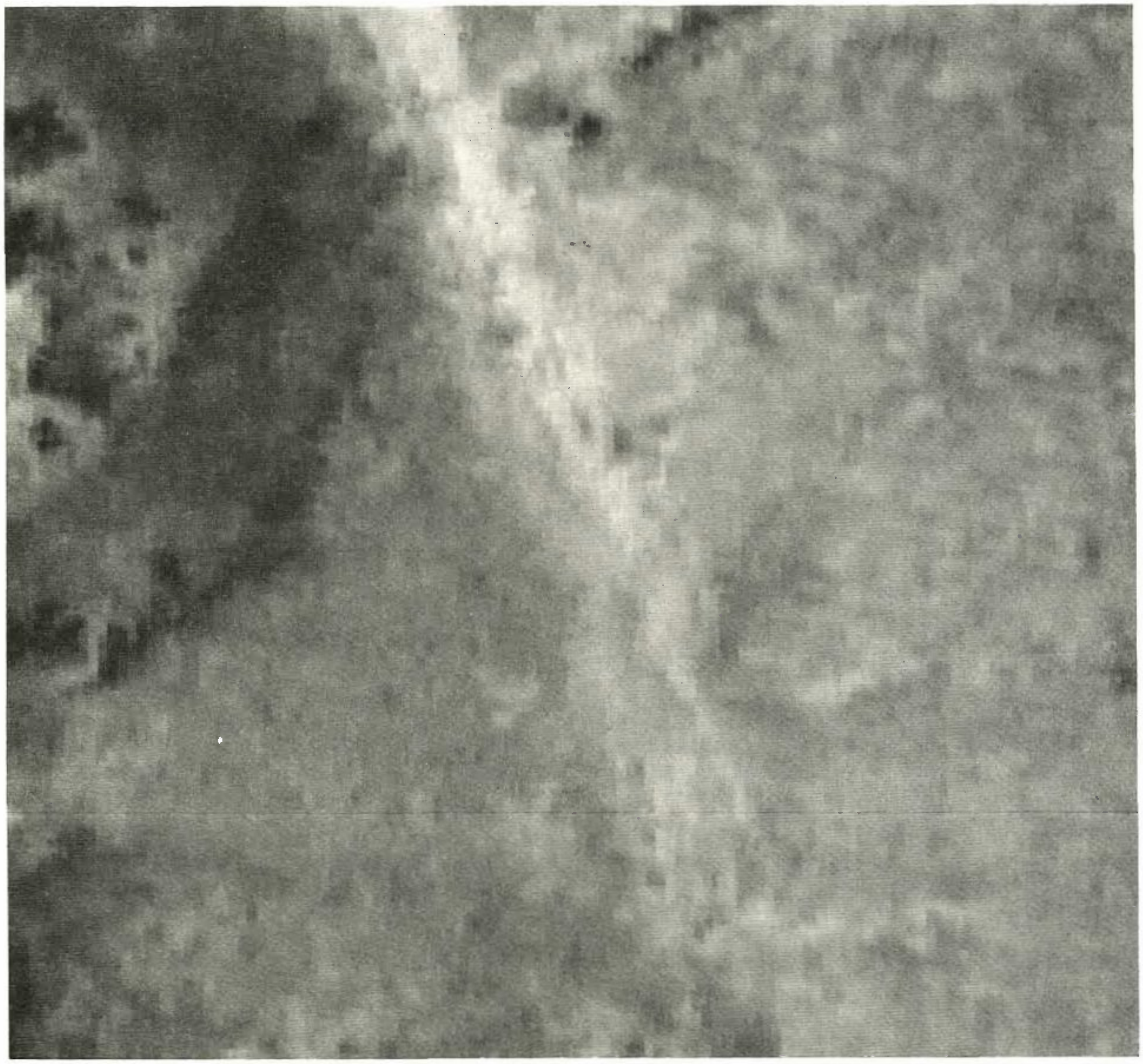

Figure 4. 1972 MSS Band 4 image of the southern tip of the Ghorabi dune field. Image was taken in September, 1972, and was geometrically corrected and resampled to 30-meter pixel size for comparison with TM data. Wind direction is from northeast; note sand cover on southwest side of longitudinal dunes.

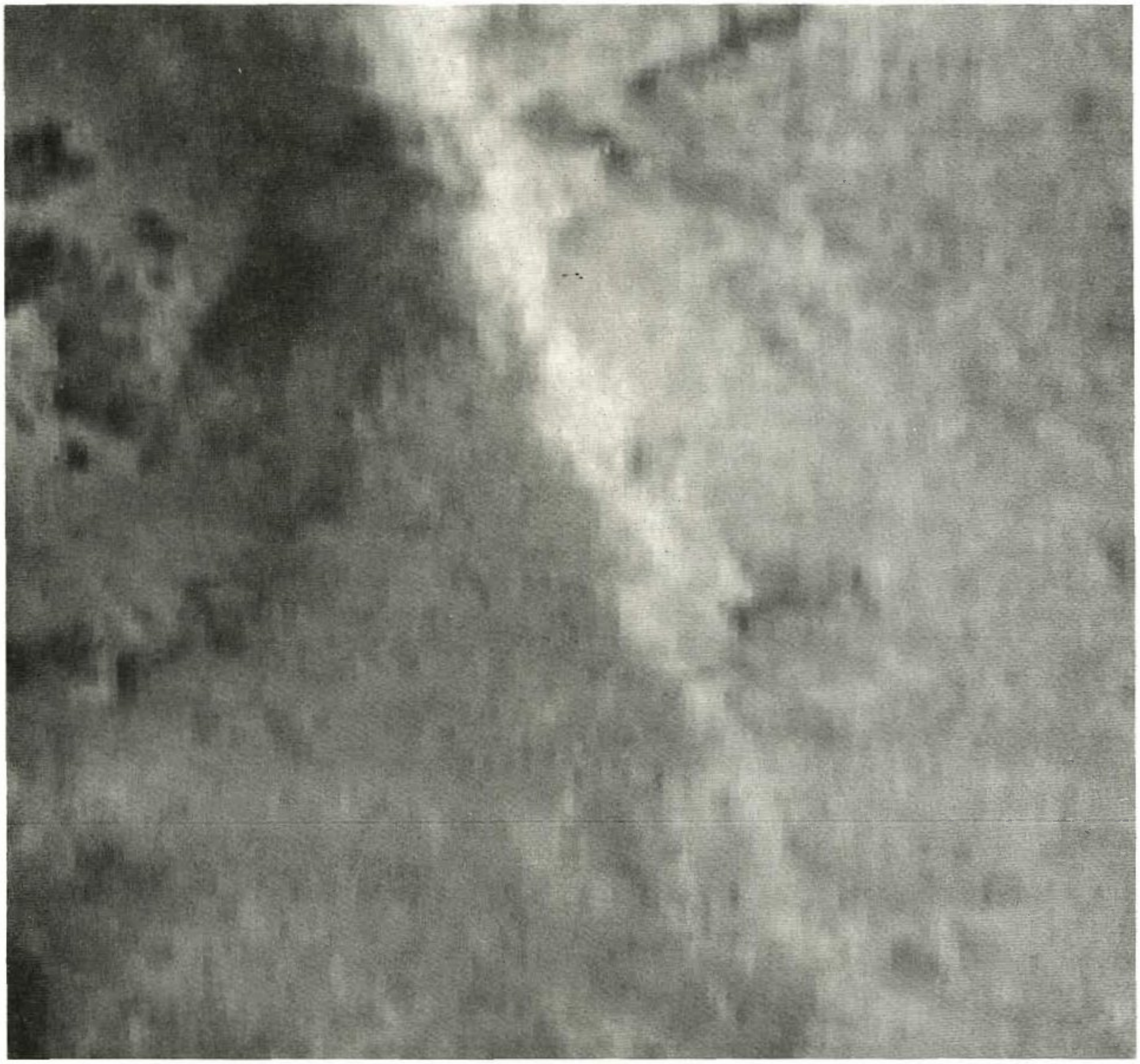

Figure 5. 1984 MSS Band 4 image taken in May. Note disappearance of sand shadow caused by seasonal change in wind regime.

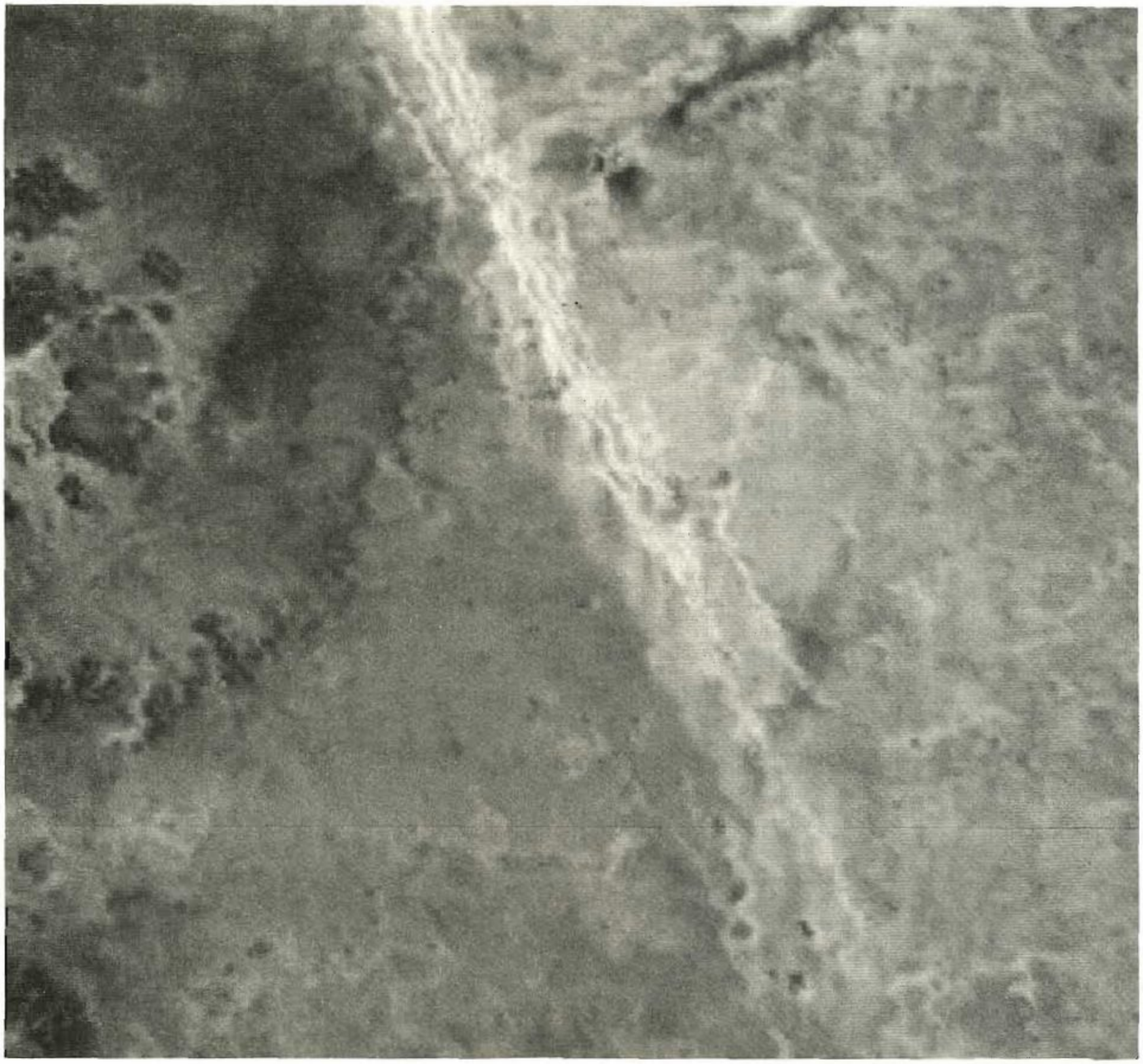

Figure 6. 1984 TM Band 5 image taken in November. The sand shadow on the western flank of the dunes has reappeared and is more distinct due to increased TM resolution. Individual seif dunes can now be compared to those shown in 1944 air photos (shown in Fig. 2).