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MAPPING AND ANALYSIS OF SAND DUNE FIELDS AND RELATED EOLIAN EROSIONAL FEATURES IN RELATIVELY INACCESSIBLE REGIONS

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16. Abstract

ERTS coverage of the Namib, Tarim, Turkestan and Baluchistan deserts as well as portions of the Sahara, Libyan and Gobi deserts was used to map major eolian landforms and landform patterns. These data add to our understanding of the relatively inaccessible and little-known areas and permit interpretation of environmental parameters. Very little new information was obtained for the better-known areas of North Africa and the Middle East. Because the anisotropies on ERTS photos are free of stochastically varying localized effects, use of these photos for studies of dune and draa morphology can add substantially to our understanding of regional eolian processes.

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PREFACE

ERTS coverage of the Namib, Tarim, Turkestan and Baluchistan deserts as well as portions of the Sahara, Libyan and Gobi deserts was used to map major eolian landforms and landform patterns. These data add to our understanding of the relatively inaccessible and little-known areas and permit interpretation of environmental parameters. Very little new information was obtained for the better-known areas of North Africa and the Middle East. Because the anisotropies on ERTS photos are free of stochastically varying localized effects, use of these photos for studies of dune and draa morphology can add substantially to our understanding of regional eolian processes.

INTRODUCTION

The work reported on here was initially proposed to NASA (#555) by Professor H.T.U. Smith of the Department of Geology, University of Massachusetts. Professor Smith had devoted a career spanning nearly 40 years to the study of eolian geomorphology. His field studies had carried him to many remote parts of the globe and he was an authority on the use of aerial photography f the study of desert geomorphology. The primary objectives of thi study, as expressed by Professor Smith are as follows:

> The objectives of the project are broad rather than narrow. It aims not at the testing of any single hypothesis or solution of any single limited problem, but rather at the acquisition and analysis of otherwise unobtainable data relating to a range of problems, the ultimate solution of which must rest on the coordination of many types of data.
>
> The primary immediate objective is to obtain basic data on the geography and geomorphology of major dune forms and patterns in relatively inaccessible and little-known areas, and to relate these to environmental parameters, in so far as the latter can be interpreted from the photos or ascertained from published literature. A related secondary objective will be to evaluate the relative effectiveness of the various spectral bands, singly or in combination, for discrimination of significant eolian phenomena.
>
> The geographic areas (see Appendix) for the proposed study are as follows, in order of decreasing priority:
>
> [A] Namib Desert of South West Africa.
> [B] Tarim Basin Desert of central Asia.
> [C] Gobi Desert of Mongolia.
> [D] Libyan Desert of Egypt and Libya.
> [E] Turkestan Desert.
> [F] Central and western Sahara.
> [G] Baluchistan Desert.

I learned of the proposed work through casual conversations with Professor Smith. In February 1973, Professor Smith was seriously injured and died several weeks later. In April 1973, a request for transferal of the grant was made and I was notified of the transfer in September 1973. The ERTS imagery was received from Professor Smith's effects in September and

October. The results reported here are based on work since that time.

Methods Used

For the most part, the methods are those developed for conventional photogeologic interpretation. ERTS black and white prints (MSS 5 proved to be satisfactory) were mosaicked and subjected to analysis. Enlargement of transparencies with a Variscan Mark II viewer was found to be of limited value in increasing resolution. The limitations of time available for the project precluded experimentation with optical enhancement.

FIRST PHASE

The project was subdivided into three phases. Phase 1 was devoted to developing and validating interpretive techniques. Areas D and F, the Libyan Desert of Egypt and Libya and the central and western Sahara, were used for this purpose because the regional geomorphology of these areas is fairly well known and maps are readily available. This is, in part, a consequence of work done during and in connection with World War II and work related to petroleum exploration. Overlays showing interpreted regional geomorphology were prepared and then compared to published maps made from low altitude aerial photography. Disparities between the two were evaluated by referring to published field studies and other maps. At the conclusion of this phase it was evident that ERTS imagery does not provide high resolution data but that it does furnish concise regional patterns of large geomorphic features and it displays these data without the smaller, stochastically varying features which complicate the interpretation of other data.

SECOND PHASE

Phase 2 consisted of processing the ERTS data for the remaining areas using the methods described above. Cloud cover and incomplete coverage presented minor problems. Dune and draa systems were delimited and classified. Interpretation of prevailing wind directions and direction of sand transport were made when possible. These synoptic maps present a concise statement of the eolian geomorphology. Undoubtedly Professor Smith's first hand knowledge of the field areas would have greatly increased the value of this work.

At the conclusion of Phase 2, a number of smaller areas suitable for detailed studies of eolian processes or morphology were identified. Although many of these will require equipment or computer software presently unavailable, these study areas will be "fodder" for future work in our geomorphology program. Phase 3 of the study consisted of detailed studies of two regions, the Grand Erg Oriental and the Namib Desert.

THIRD PHASE

Grand Erg Oriental

The Grand Erg Oriental of western Algeria is a vast region of extremely complex eolian features vaying in scale from bedforms to draas. Because the draas are well developed and because our ERTS coverage of the area was complete and of exceptionally good quality, it was selected for detailed study. The objective was to classify and map eolian landform types and to use these maps to interpret genetic and/or environmental parameters. The latter is based on the assumption that draas are equilibrium forms which are adjusted to long term environmental conditions. Just as ripple marks and other small scale bedforms are adjusted to the influences of a storm or series of storms and dune morphology is a response to intermediate periods (seasons to decades), so draas reflect yet longer-term conditions by their location and morphology.

ERTS coverage of the region depicts the spatial and geometric relationships of these large features at a scale suitable for identifying vectoral properties. Linear and curvalinear trends of landforms and transitional changes in style, which at larger scales would appear much more chaotic, can be easily identified. In this regard, ERTS imagery serves as a filter removing "noise" (i.e. stochastic variation) from the data.

Figure 1 shows a portion of the northern Grand Erg Oriental and the central and southern parts of this desert. Barchanoid dunes and draas in the northwest coalesce to form an aklé pattern which is best developed in the region shown at the top of Figure 1. The linear trends of dunes and draa crests form a three element reticulate network. Two of these elements are interpreted as reflecting seasonal prevailing wind directions and the third as their vector mean. There is no basis for interpreting whether these elements have a parallel or transverse relationship to the wind pattern which created them.

The central part of the erg is dominated by large peaked dunes and draas collectively referred to as rhourds in this report. On the photographs and on published maps made from low altitude aerial photography, the rhourds appear to be haphazardly distributed. Marking the prominent summits, or oghourds, with a dot (Figure 1) discloses a pattern of linear and curvalinear elements shown in Figure 2. The trends of these elements are subparallel to those found to the north. The rhourds are largest, best developed and most uniformly distributed in the south-central part of the erg. In this region they reach over a kilometer in diameter and have approximately 500 meters of relief.

The southern Grand Erg Oriental (Figure 3) contains long (up to 75+ km.) draa ridges which have, more or less, uniformly spaced oghourds. Although the draas appear to be concatenated rhourds, they are most likely draa-size aklé. Spacing, or wavelength of the draa ridges decreases in a westerly

Figure 1

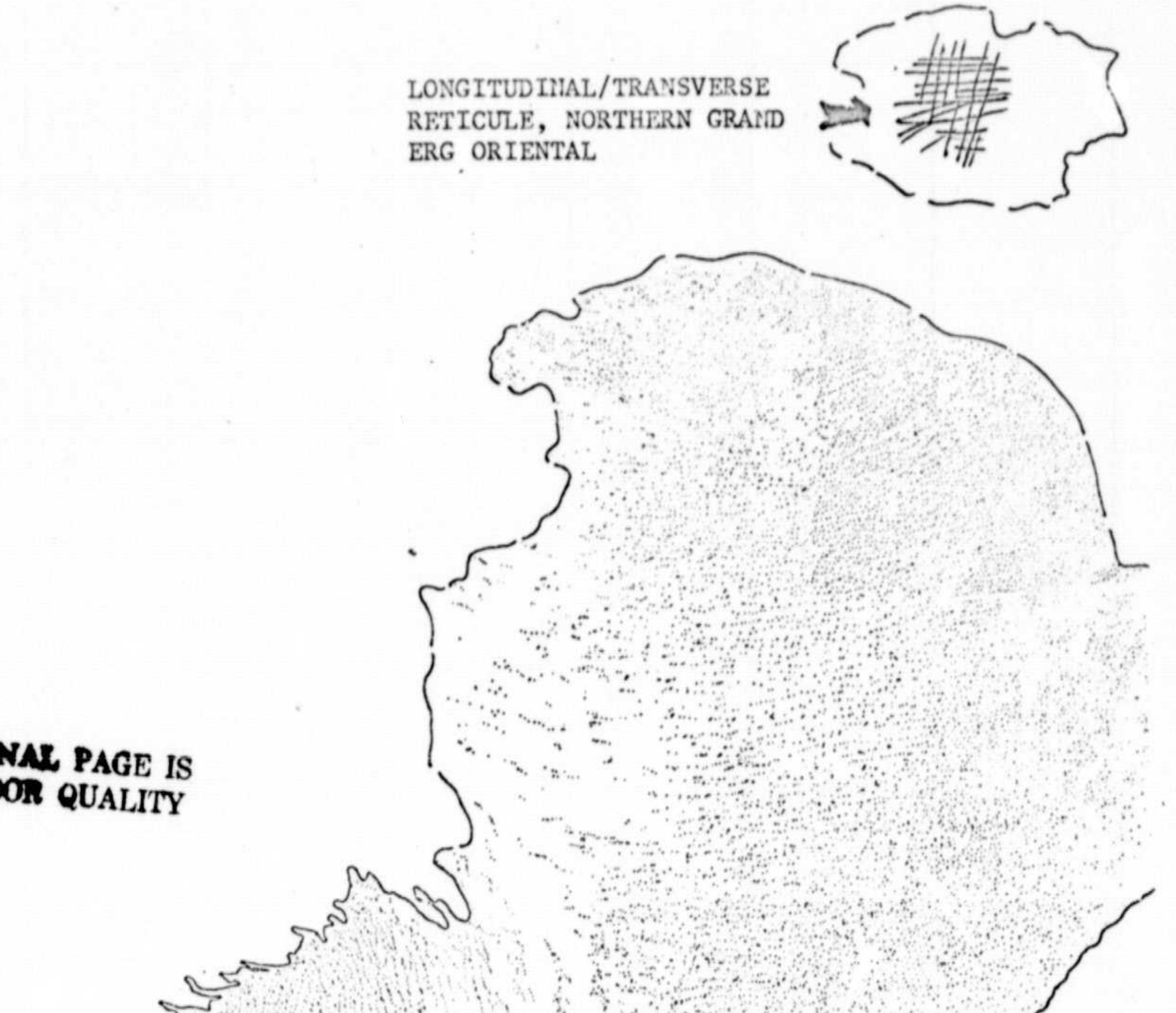
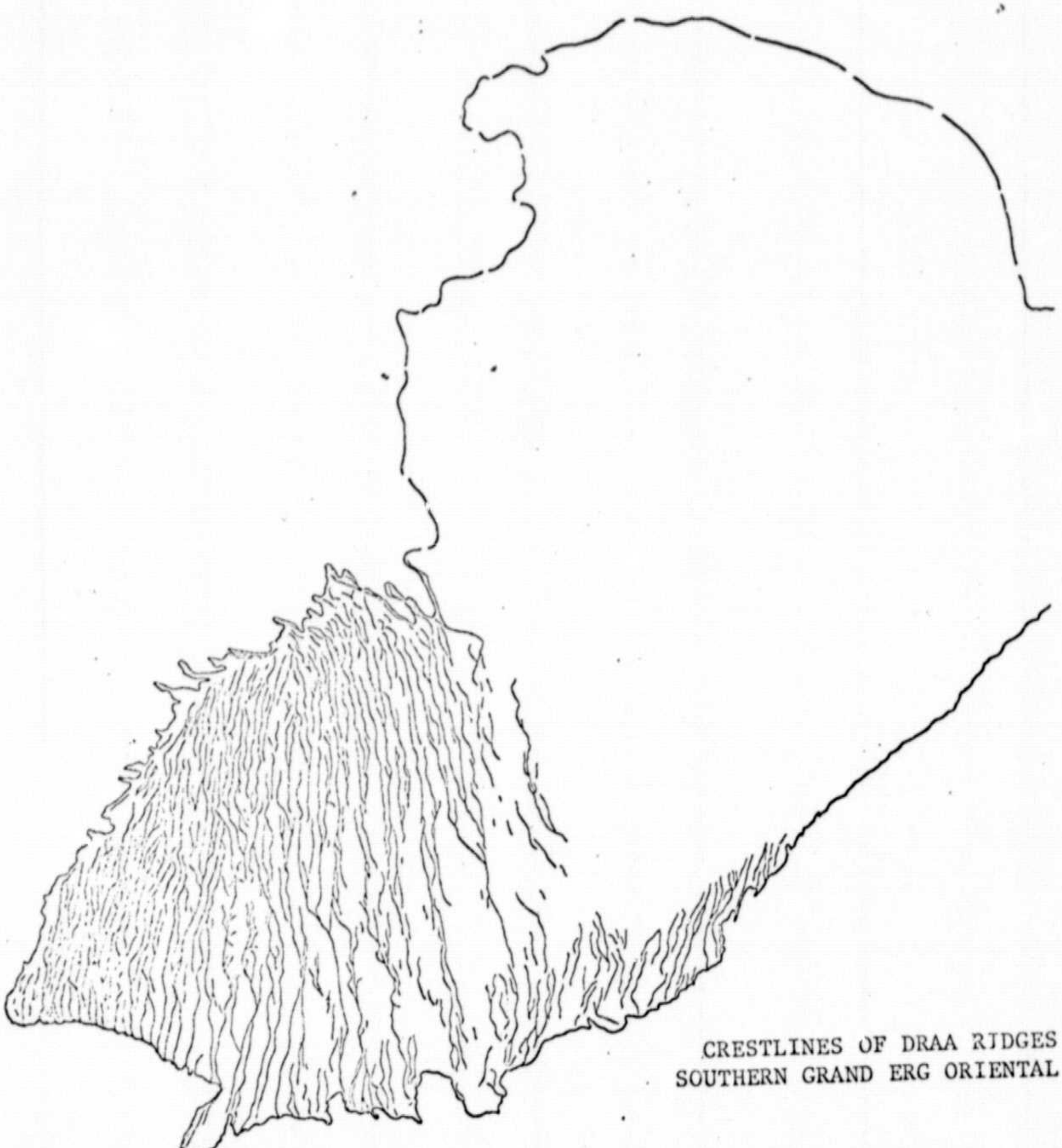

LONGITUDINAL/TRANSVERSE
RETICULE, NORTHERN GRAND
ERG ORIENTAL
OGHUORDS (DRAA PEAKS) IN THE CENTRAL
AND SOUTHERN GRAND ERG ORIENTAL
0
1000 km.

Figure 2

ALIGNMENT OF RHOURDS
CENTRAL GRAND ERG ORIENTAL

Figure 3



CRESTLINES OF DRAA RIDGES
SOUTHERN GRAND ERG ORIENTAL

direction and appears to do so in a systematic manner. If a means of accurately estimating mean relief of each ridge can be found, spectral and Fourier analyses will be used to synthesize the geometry. The general trend of the crestlines shown in Figure 3 is not parallel to any of the three elements found in the northern or central part of the erg. This trend is, however, approximately normal to one of these elements. This relationship is supported by the fact that aklé patterns tend to occur as transverse features where there is an abundant supply of sand.

Based on the photoanalysis three landform types have been identified and mapped. Elements within these landforms are thought to be related to two seasonal prevailing wind directions and the third element to their vector mean. Based on subtle aspects of morphology and faint sediment plumes it appears that sand transport follows an arcuate path from North to South across the erg. Although this is not in accord with the Sahara sandflow lines constructed by Wilson, 1971, it is consistent with climatological data from one station adjacent to the Grand Erg Oriental (Landsberg, 1972). Wilson's interpretation requires the flow of sand upwind. The climatological data also show seasonal prevailing winds oriented close to the two major elements found in the landforms. A mean vector of the wind directions weighted for duration yields an orientation which is within 5° of the third element found in the landform analysis.

Namib Desert

The Namib Desert, located on the western coast of South Africa, is of great interest to geomorphologists because of its extreme aridity and very strong winds. This region, also known as the Diamond Desert, has very limited surface access and is restricted owing to the occurrence of diamonds. Professor Smith had done field work in the area and had made numerous observations from small aircraft. I selected the Namib for detailed work because of the extremely good ERTS coverage and the complexity of the eolian landforms. Objectives were the same as those described for the Grand Erg Oriental but emphasis was placed on producing a map of the landforms (Figure 4).

The Namib trends north-south and consists primarily of regs and a substantial area of eolian sand accumulation. The low flat regs occur both north and south of the dunal area and are separated from it by the Kuiseb and Koichab rivers respectively. No other watercourses appear to have the vitality necessary to cross the dunal area. Five mapping units are used on Figure 4 and dune crests and playas are marked with symbols.

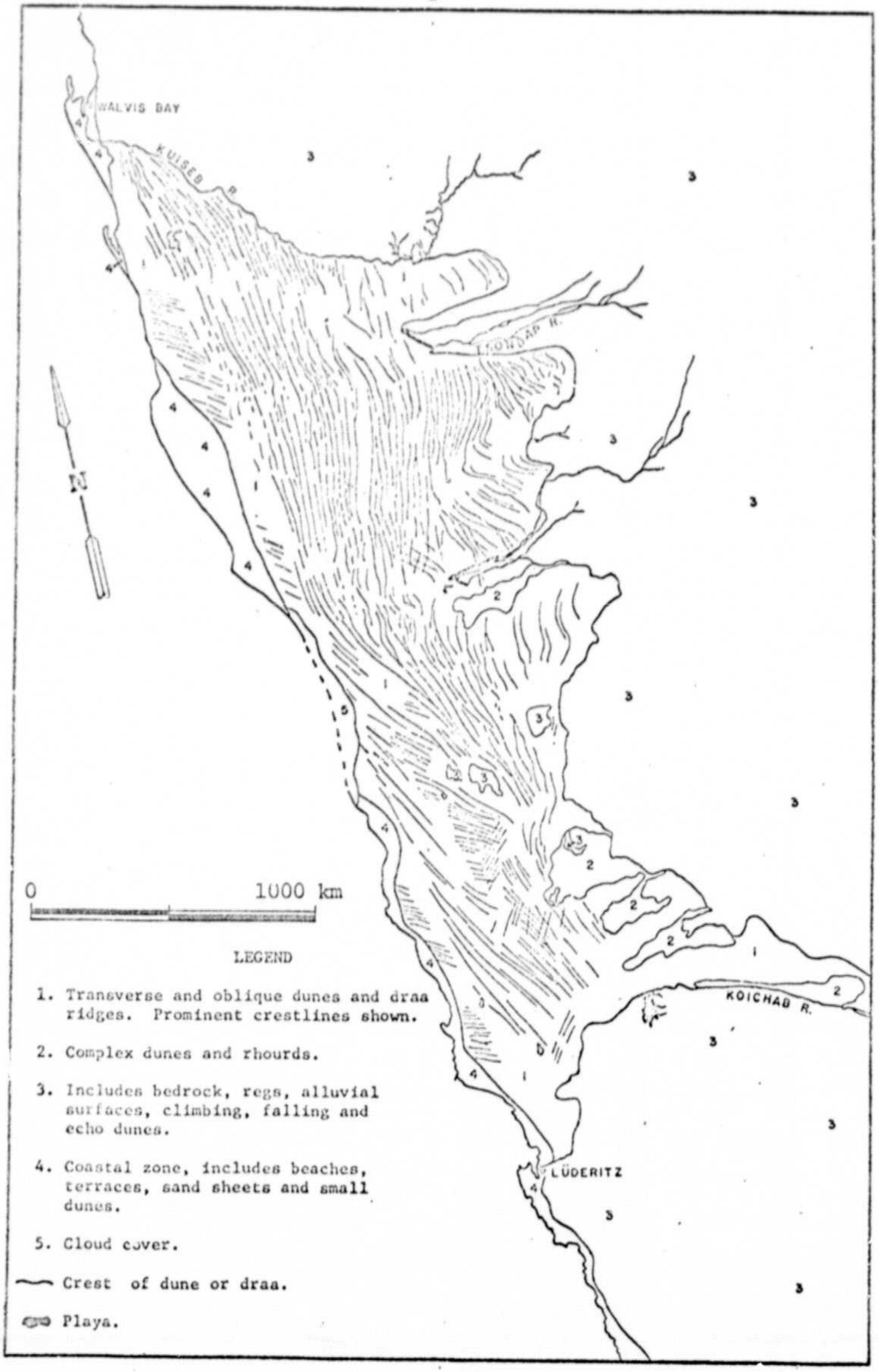
Unit 5 denotes a small area obscured by cloud cover. Unit 4 marks a relatively narrow coastal zone which consists of beach deposits, low terraces which in places support darker colored lag gravels, and eolian sand accumulations with landforms too small to discern on the photos.

Unit 3 includes non-eolian terranes peripheral to the principal dunal area and associated featureless eolian landforms.

The major dunal area consists of units 1 and 2. The complex system of dune and draa ridges included in Unit 1 exhibit three prominent crestline trends. A narrow zone of relatively closely spaced dune ridges trending roughly southeast occurs inland from the coastal zone. The normality of these features to the coastline suggests that they are related longitudinally or slightly oblique to the summer prevailing winds which blow inland from the Atlantic. In the south central portion of the desert these elements coexist with another closely spaced system of ridges that trend northeast.

The most prominent eolian landforms are the enormous sinuous draa ridges that trend approximately north-south. They are interpreted as being

Figure 4


WALVIS BAY
KUISEB R.
KOICHAB R.
LÜDERITZ
N
0
1000 km
LEGEND
1. Transverse and oblique dunes and draa ridges. Prominent crestlines shown.
2. Complex dunes and rhourds.
3. Includes bedrock, regs, alluvial surfaces, climbing, falling and echo dunes.
4. Coastal zone, includes beaches, terraces, sand sheets and small dunes.
5. Cloud cover.
Crest of dune or draa.
Playa.

related to the strong south wind which prevails during the winter months. The curvature of the draa ridges appears to mimic the irregular front of the mountainous region to the west. The temptation to relate these features to aerodynamic perturbations caused by the geometry of the mountain fronts is great. Yet, without more detailed climatological data and low altitude photography this must be regarded as speculation. The relatively small areas of complex dunes and draas mapped as Unit 2 are clearly related to topographic irregularities. These smaller scale features occur near or adjacent to wadis, inselbergen and other topographic irregularities. Attendant perturbations of the wind account for these features. Eolian processes transport sediment northerly and easterly and fluvial processes carry this material westward to the coast or dune fields. Longshore currents and littoral drift distribute the debris northward and southward along the coast.

Work on the Namib demonstrated that ERTS imagery is useful for mapping regional geomorphology with fairly good detail. Moreover, this activity permits the identification of problems that can be solved by field observations or other types of data. Work with ERTS photos provides an excellent means of erecting multiple working hypotheses of regional importance. Although my literature search for geomorphic maps of the Namib is not complete, thus far, Figure 4 of this report appears to be the most comprehensive and detailed map available. Publication of both the Grand Erg Oriental and Namib Desert studies is anticipated.

SUMMARY AND CONCLUSIONS

A. ERTS black and white 9.3 inch paper prints of eolian terranes can be mosaicked and used to produce accurate, regional maps of large landforms. Band MSS5 was found to be suitable for this purpose and produced images which can be interpreted using standard aerial photo techniques.

B. Large anisotropies on ERTS photos represent regional features which are free from the stochastically varying local effects that complicate analysis of more conventional data.

C. Study of the large dune and dráa systems is thought to relate to long term environmental parameters and is useful in devising working hypotheses of regional importance.

D. Because of the low resolution, ERTS photography is not a substitute for field observation or low altitude photography of eolian features. It does, however, provide a new means of obtaining a synoptic view of large features with spatial integrity preserved. The ERTS coverage used for this work will provide data for years of qualitative and quantitative analysis.

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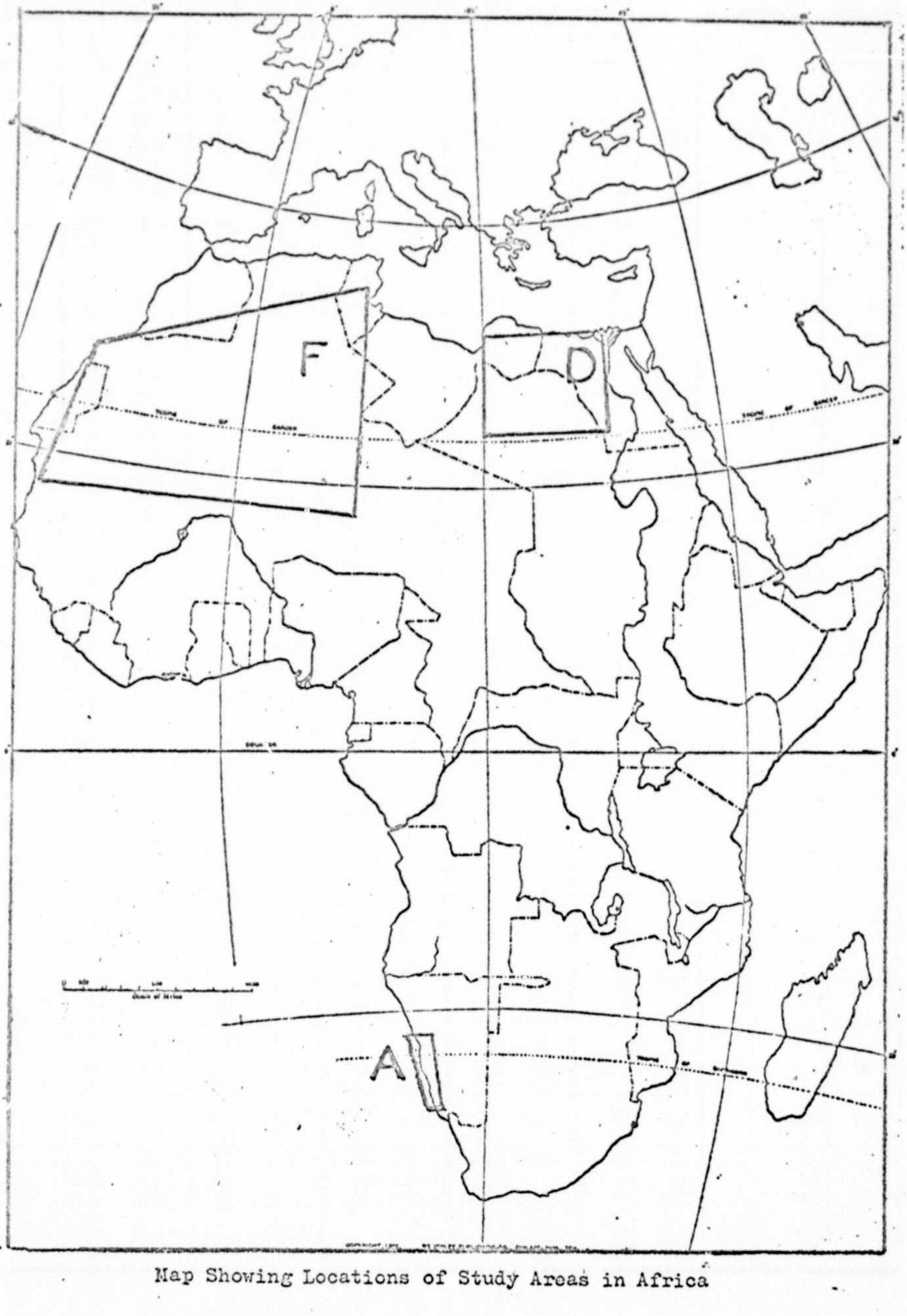
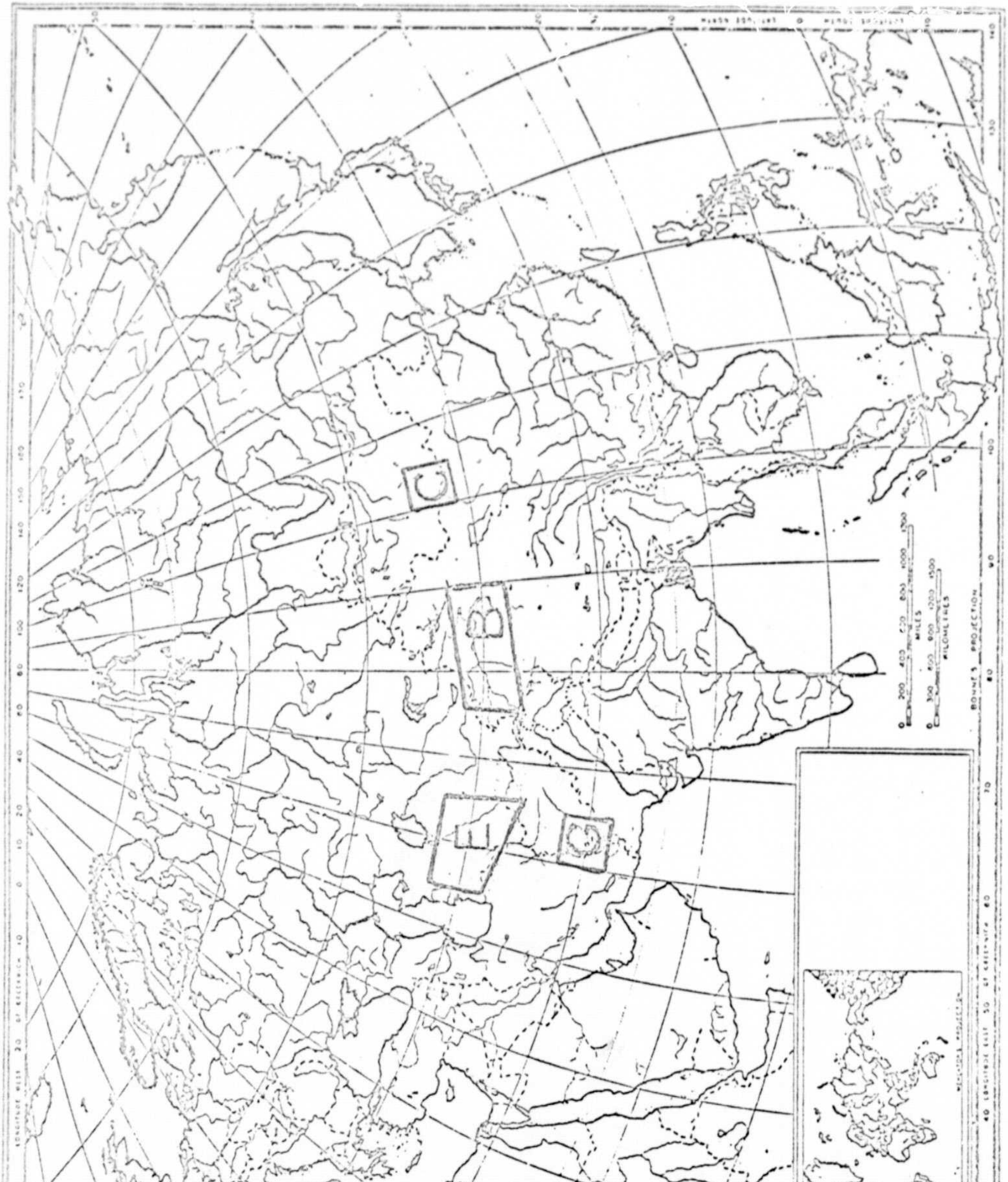
APPENDIX I

LOCATION OF STUDY AREAS



Map Showing Locations of Study Areas in Africa



Map Showing Locations of Study Areas in Asia