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LANDSAT image enhancement study of possible submerged sand-dunes in the Arabian Gulf

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Abstract. Digital image enhancement of selected LANDSAT Multispectral Scanner (MSS) image data for the coastal area of eastern Saudi Arabia reveals large sandbanks in relatively clear water, 8–10 m deep. LANDSAT MSS imagery of wave length range 0·5–0·6 μm was masked digitally to remove onshore spectral data and the contrast range of sea areas enhanced to display tonal variations which correspond in form to major barchanoid-shaped shoals on the sea floor. The shape, scale and orientation of the sandbanks suggest that they may be submerged aeolian dunes. If these sandbanks are submerged dunes, they predate the last eustatic sea level rise (8000–10 000 years BP) and must have been stabilized by cementation prior to submergence in order to survive palaeo-wind and current erosive action.

1. Introduction

The study area, indicated by the box in figure 1, is located approximately 9 km off the eastern coast of Saudi Arabia, between Bahrain island and the Qatar peninsula. A LANDSAT MSS image representing the wavelength range 0·5–0·6 μm was used to show the submarine form of shoals and sandbanks in coastal waters 8–10 m deep. The

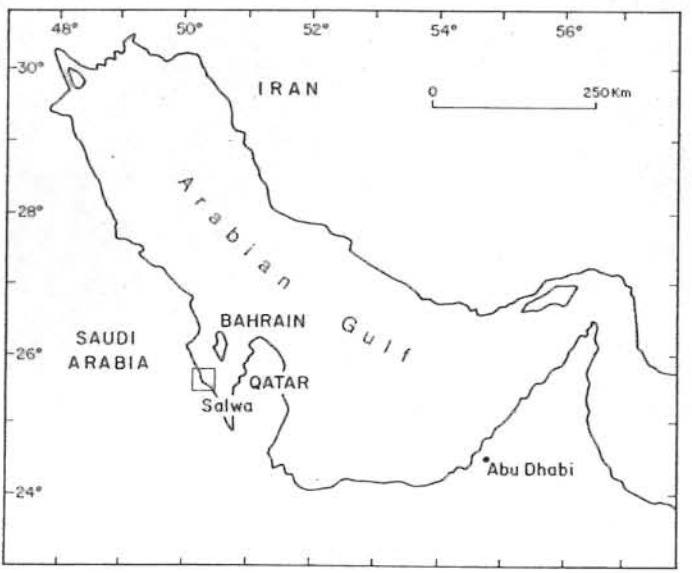

Figure 1. Location of study area.

submarine features are visible in such images because of the partial penetration and transmission of blue-green light by clear water (Polcyn *et al.* 1970).

This letter describes the enhancement procedures used to optimize the display of these submarine features and includes a preliminary hypothesis on the origin of the submerged sandbanks, a topic which will be reported more fully at a later date (Al-Hinai 1987).

2. Enhancement techniques

A LANDSAT MSS band 1 (LANDSAT 4/5 nomenclature) digital image (0·5–0·6 μm wavelength range), acquired on 26 January 1973 (path 176, row 42), was digitally pre-processed for noise removal (sixth-line dropouts, and sixth-line banding).

In order to display tonal features to the best advantage, land and sea areas were each separately masked in turn, and contrast enhanced independently. This was achieved by application of an interactive contrast stretch to MSS band 1 which saturated land areas as white leaving a full range of tone (digital numbers, or DN) for areas of sea (figure 2).

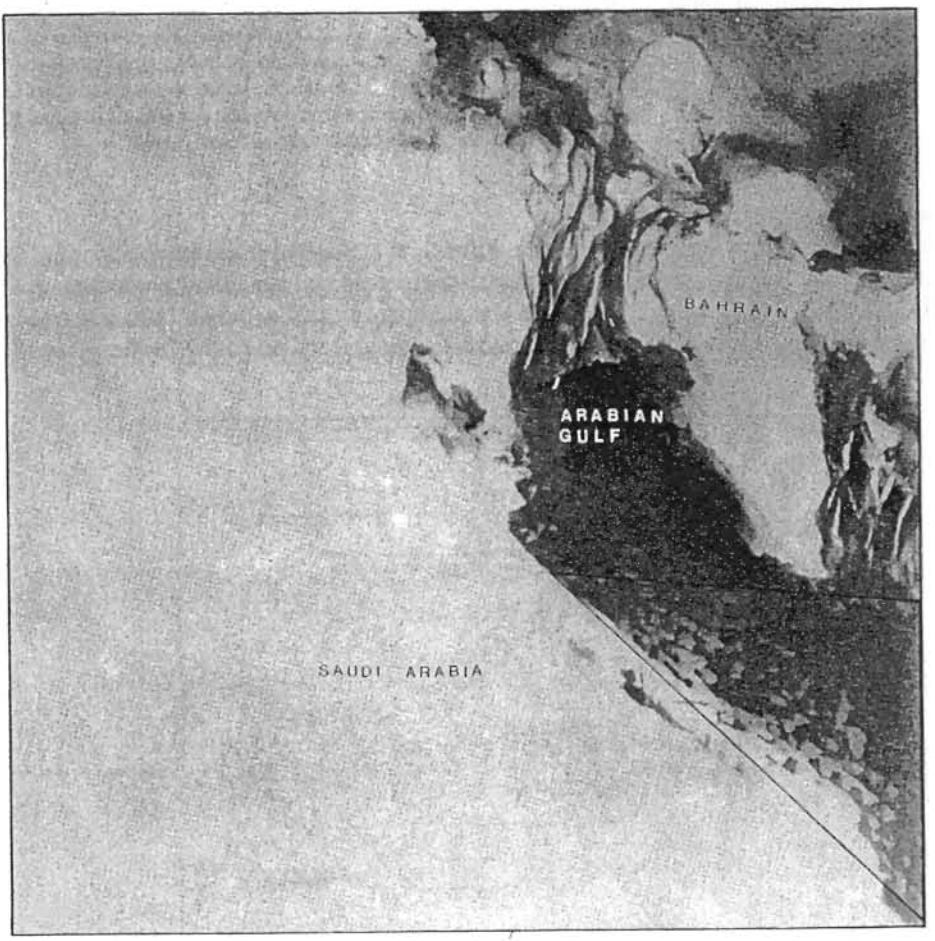

Figure 2. Band 1 MSS imagery (176/42: 26 January 1973) interactively stretched to show offshore features. The submerged sandbanks discussed in this Letter occur in the area outlined.

Data for MSS band 2 (0·6–0·7 μm) and MSS band 4 (0·8–1·1 μm) were then contrast enhanced separately, using a piecewise linear function which clips the histogram tails at the 0·25 and 99·75 percentiles and sets the mean at 128 DN. Using the offshore image (MSS 1) as a digital mask, the stretch parameters were exclusively drawn from the land, thus optimizing the onshore contrast in the band 2 and band 4 images. Each stretched image was then merged with the offshore image to produce a colour composite image representing the land and sea areas. This colour composite image is reproduced in monochrome as figure 3.

3. Image interpretation

The enhanced image (figure 3) clearly shows the form of shoals and submarine sandbanks in the coastal sea between Saudi Arabia, Bahrain island and Qatar.

The general shape and approximate barchanoid outlines of the submarine sandbanks, together with their orientation, indicate that these banks could be submerged aeolian dunes related to a palaeo-wind system blowing north-north-westward. This is a similar orientation to that in certain nearby onshore dunes.

The form and scale of the submarine sandbanks is similar to those of large aeolian

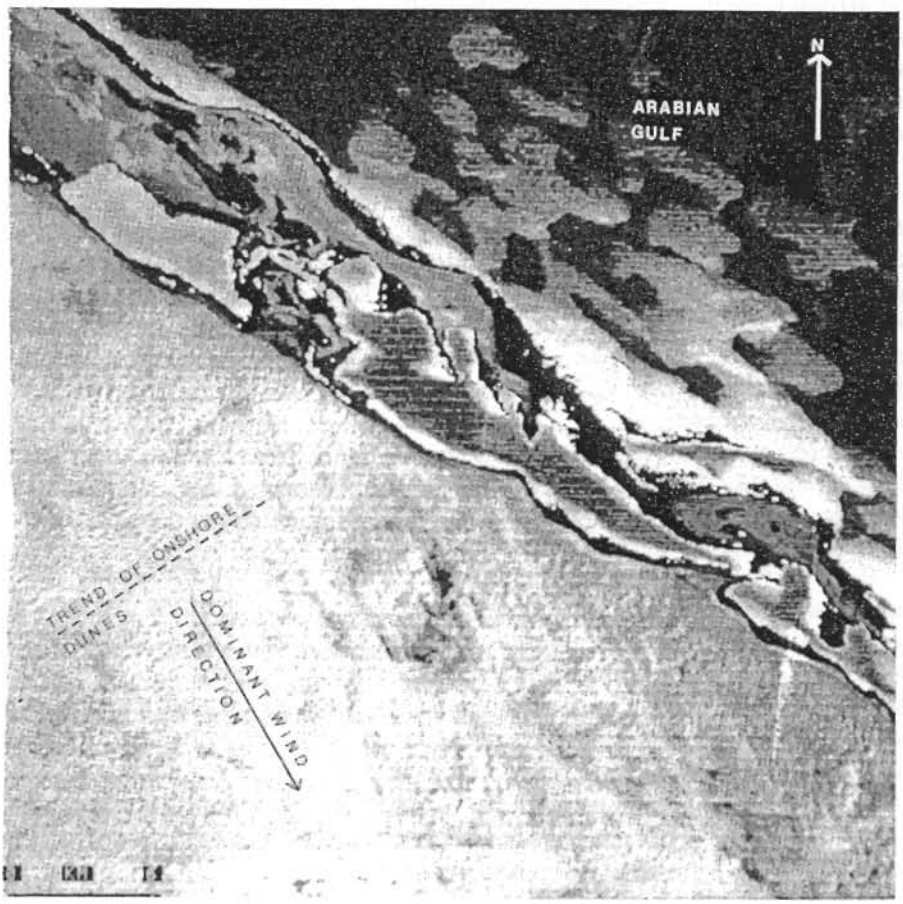

Figure 3. Combined image (false colour composite MSS bands 4 2 1 reproduced in black and white) showing both offshore and onshore areas.

dune complexes in the north-eastern part of the Rub Al Khali area (Empty Quarter) of Saudi Arabia (figure 4). In the Empty Quarter, individual compound crescentic dunes or 'mega-barchans' as defined by Norris (1966) are generally larger than individual crescentic dunes. The mega-barchans are complicated in shape by the presence of smaller crescentic dunes on their gently-sloping windward flanks. Mega-barchans in the Empty Quarter are about 3 km across. This is a comparable scale with that of the submarine sandbanks (figure 4(*c*). The outline form of both onshore dunes and submarine features are functions of the tonal contrast between sand and substrate which, in the Empty Quarter, is a mud plain (*sabkha*).

4. Discussion

The approximate barchanoid form of the submarine sandbanks suggests the intriguing possibility that they are the drowned dunes proposed by Doornkamp *et al.* (1980), forming part of the fossil dune systems which include those of Qatar and Abu Dhabi (Shinn 1973). Doornkamp *et al.* (1980) produced many lines of argument to support the presence of drowned dunes in the Gulf of Salwa between Bahrain and the Saudi Arabian coast. Kassler (1973) suggested that the sands for Abu Dhabi dunes may have arrived there by migrating across the Gulf of Salwa and the Qatar peninsula prior to 7000–8000 years BP. Dunes studies by Seltrust Engineering Ltd (1980) showing movement rates of about 8 m per year in Qatar indicate that all Quatar's major dunes, which are in the south-eastern part of the peninsula, could have migrated the 60 km from the west coast in the 8000–10 000 years since sand supply was cut off by sea level rise.

The suggestion that the sandbanks identified and defined by this image enhancement study may be drowned dunes is tentative. Clearly some modification by submarine currents must have occurred and further work is obviously necessary to investigate the alternative possibility that the banks have been wholly created (as mega-ripples?) by marine currents rather than aeolian processes. Submerged fossil dunes must have been cemented, like some of those on Bahrain island (Doornkamp *et al* 1980) and in Abu Dhabi (Evans *et al.* 1973, Purser and Evans 1973), to survive the erosive processes of submergence.

It is an interesting coincidence that the submarine banks should; have a form and orientation remarkably similar to those of documented onshore dunes and; have an orientation consistent with those dunes which may have migrated across the same piece of terrain, which is now the bottom of the Gulf of Salwa.

5. Conclusions

Image processing techniques of the type used in this study to display the form and distribution of sandbanks in shallow waters of the Arabian Gulf are useful aids to conventional geomorphic and hydrographic survey techniques in areas of clear water. The procedure of separate enhancement for areas of water, after masking land areas, gives the best possible imagery for interpretation.

In the area investigated, there is an interesting possibility that sandbanks revealed by enhanced LANDSAT MSS imagery may be fossil aeolian dunes. The submarine sandbanks need field investigation before this hypothesis can be confirmed or refuted.

Acknowledgments

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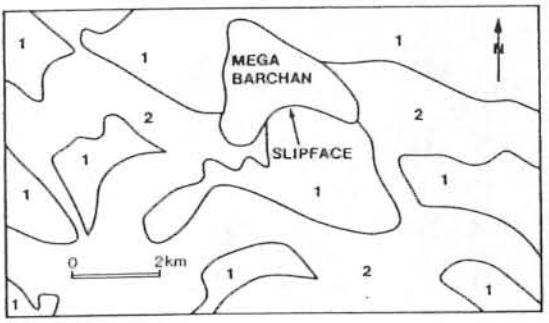
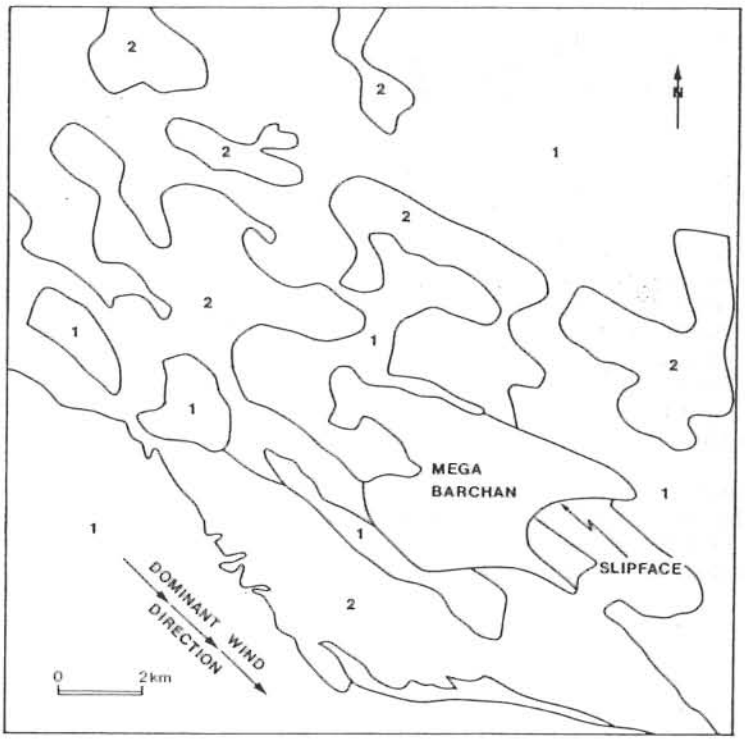
(a)



(*b*)

(*c*)



(*d*)

Figure 4. (*a*) Compound crescentic ridges in the eastern part of the Empty Quarter (Rub Al Khali) sand sea. Approximately 23 N, 54 E. A giant crescentic dune is outlined for scale comparison with the submarine banks in the Arabian Gulf. The width of this mega-dune is about 3 km and it is about 3·2 km long. Photograph by U.S. Department of Defence (reproduced from McKee 1979). (*b*) Interpretation map based on aerial photograph shown in (*a*). Annotations (1) and (2) represent inter-dune *sabkha* areas and crescentic ridges respectively. Notice the similarity in shape and scale of these aeolian features and (*c*). (*c*) An enlargement of part of figure 3 showing submerged sandbanks. A possible giant crescentic dune (mega-barchan) is outlined for comparison with the mega-barchan shown in (*a*). The width of this dune is about 3·2 km. (*d*) Interpretation map derived from (*c*). Annotations (1) and (2) are interpreted as possible inter-dune areas and crescentic ridges respectively.

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