



# Landform evolution in the arid northern United Arab Emirates: Impacts of tectonics, sea level changes and climate



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## ABSTRACT

The interaction of wind and water may well be the key influence on the modern geomorphology of the arid regions of the world, and has had a strong influence on long-term landscape evolution in these areas. This is the case for the landforms of the northern United Arab Emirates, where aeolian landforms in the west lie on alluvial deposits, and are adjacent to fluvial landforms in the east. Even within the aeolian forms there is evidence of modern and past water activity. Modern river flow is rare and largely confined to the mountains. However, rivers and alluvial activity were more important during certain periods in the past. This study describes the landforms of the Northern Emirates (NE) and relates their form and evolution to alternating periods of arid and humid climates. The study was initially carried out to provide a background for the soil survey of the NE. Details of landform character and materials were explored during the survey, which involved detailed site and soil descriptions at 10,020 auger and Geoprobe sites (2 m depth), 200 backhoe pits (2 m depth), and 150 drill observations (10 m depth). The main landforms identified in the study area are the Hajar Mountains, alluvial plains (fans, plains and wadis), dunes (ridges, sand veneer, rising dunes) and coastal forms. The influence of uplift and tilting of the Hajar Mountains during the Miocene and more recently is considered. Sea level changes in the Arabian Gulf are also important. The impacts of past climate change on the evolution of landforms is discussed and related to alternating periods of arid and wet climates. The north-westerly Shamal wind is primarily responsible for the formation and continued evolution of the dune fields seen in the NE today.

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## 1. Introduction

The interaction of wind and water is a key factor explaining the geomorphology of the arid regions of the world, and has had a strong influence on long-term landscape evolution in these areas (Bullard and Livingstone, 2002; Nash, 2000). In many areas, dryland aeolian and fluvial systems do not operate independently (Bullard and Livingstone, 2002). Fluvial processes are not confined to humid phases, nor are aeolian processes confined to dry phases; rather, shifting boundaries between the two regimes cause the importance of humid and arid phases to vary over time. Moreover, rain and floods deliver fine sediment to alluvial areas that can then be reworked by aeolian processes (Bullard and Livingstone, 2002). Similarly, wind delivers sand and dust to slopes and alluvial areas where they can then be moved by water as surface wash or in channels.

Aeolian and fluvial processes affect all major components of the Earth system and provide important biogeochemical linkages between

the atmosphere, hydrosphere, biosphere, and pedosphere (Belnap et al., 2011; Munson et al., 2011; Schlesinger et al., 1990; Syvitski, 2003). Understanding aeolian–fluvial interactions at a range of time-scales is important not only for reconstructing past climates, but also for understanding aspects of contemporary landscapes such as channel styles and dune morphology. The implications of such interactions are not necessarily spatially confined and can attain global significance (Bullard and McTainsh, 2003).

It is becoming increasingly clear that the Arabian Deserts were not always as arid as they are today (Petraglia et al., 2011, 2012), and scientists are only just beginning to determine the timing of these changes and their extent and consequences (Drake et al., 2011; Lézine et al., 2011). The remains of ancient lake deposits found in the Arabian deserts show that in the past the region experienced much more humid conditions than present (McClure, 1976). On the other hand, extensive dune fields and sand seas were presumably deposited during times of greater aridity with conditions similar to those that prevail today (Preusser, 2009). As Glennie and Singhvi (2002) pointed out, landforms in the SE Arabian Desert include a range from alluvial fans to dunes and coastal features, all with their accompanying sediments. This suggests a wide range of environments of formation, with an equally wide range in climate.

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This study focuses on the landforms of the Northern Emirates (Sharjah, Ajman, Umm Al Quwain, Ras Al Khaimah and Fujairah) (NE) and relates their form and evolution to alternating periods of arid and wet climates. It is in part a review, but with new data obtained during a soil survey of the area.

## 2. Area and methods

### 2.1. Regional setting

The UAE is a federation of seven emirates in the southeast part of the Arabian Peninsula and adjacent to the Arabian Gulf (Fig. 1). It borders Oman and Saudi Arabia. The total area of the country is about 82,880 km<sup>2</sup>. The NE lie between latitude 24° 44' N and 26° 04' N, and longitude 55° 20' E and 56° 22' E. They consist of the northern five of the seven emirates that make up the UAE. The NE cover 6475 km<sup>2</sup>,

about 8.2% of the country's surface area. Hellyer and Aspinall (2005) provided a comprehensive background to the natural history of the UAE.

The landscape ranges from small areas of level coastal plains and sabkha to an undulating desert sand plain, extensive areas of linear and transverse dunes, an alluvial plain up to 15 km wide, and mountainous rock outcrop along the Hajar Mountains, which reach a height of 3017 m at Jebel Akhdar in Oman. In the western part of the NE, linear dunes rise up to 100 m above the surrounding landscape, interspersed with small areas of almost level deflation plains and flats (Abdelfattah, 2013).

#### 2.1.1. Climate

As part of the Arabian Desert, the UAE is one of the hottest countries in the world. Because the Arabian Gulf is surrounded by land, the climate is continental with high seasonal fluctuations (Purser and

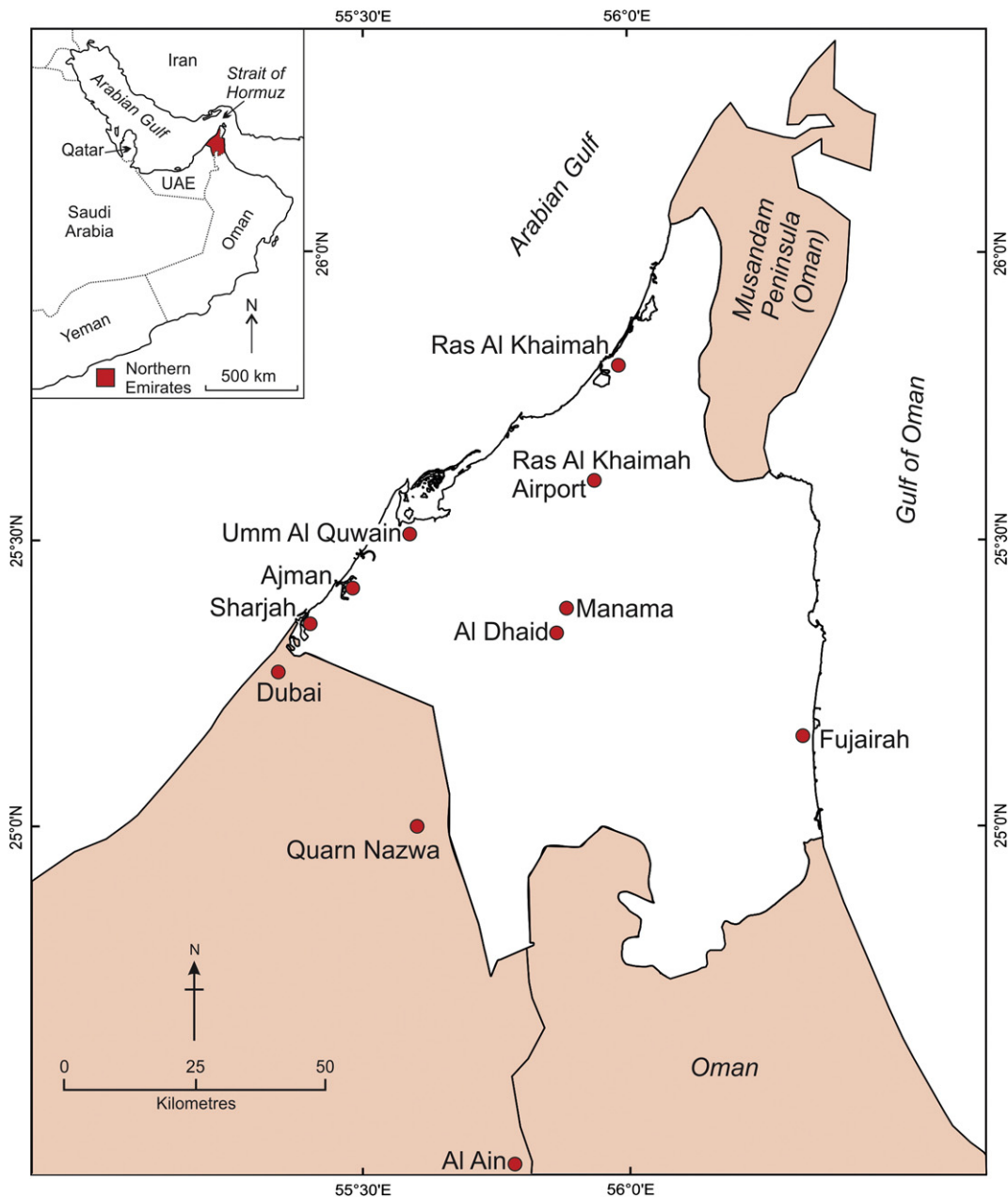


Fig. 1. The Northern Emirates, with places mentioned in the text (other place names can be found in Figs. 3 and 5). Inset – location of the Northern Emirates on the Arabian Peninsula.

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