Geomorphology 101 (2008) 458–470

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Geomorphological and palaeoenvironmental investigations in the southeastern Arabian Gulf region and the implication for the archaeology of the region

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ARTICLE INFO

Article history:
Received 1 September 2005
Accepted 1 April 2007
Available online 12 March 2008

Keywords:
Arabian Gulf
Holocene
Neolithic
Geomorphology
Bronze age
Rub' al-Khali

ABSTRACT

During the Late Quaternary, the climate of Arabia has fluctuated between periods of higher rainfall and fluvial activity, dominated by the influence of the Indian Ocean Monsoon (IOM) and drier/arid conditions under the influence of the westerlies. This has left a rich legacy of landforms from which temporal and spatial patterns of environmental change are reconstructed. The coastal desert region of the southeastern Arabian Gulf has been a focal point for human settlement since ~8000 cal yr BP. The region is strategically located on an important trade route between two ‘cradles of civilization’, namely, Mesopotamia and the Indus. Changes in the evolution and modification of this landscape under varying climatic conditions have influenced humans living in and exploiting this landscape for food and water, raw materials and trade routes.

In this study, geomorphological and palaeoenvironmental investigations are integrated to provide a framework of environmental change for the Late Glacial and early–mid Holocene periods against which the archaeology of the area can be set. The Late Glacial and earliest Holocene was characterised by intense aridity and accumulation of mega linear dunes driven by the Shamal winds. In the Arabian Gulf region, this continued into the earliest part of the Holocene, whilst southern Arabia was under the influence of the IOM. The monsoon rains migrated into the Gulf region between 8500–6000 cal BP. During this time, semi-nomadic herders occupied this region and grazing their animals in a landscape covered with C3 savanna grassland. The Neolithic peoples also practised hunting and fishing and the collection of shellfish was an important activity. Pottery shows links with Mesopotamia at this time.

From 6000 cal BP the IOM retreated south and rainfall was derived from winterly westerly sources. Under drier conditions a switch occurred to a sparser cover of C4 grasses. From 4500 cal BP the climate became much drier with the development of stronger westerly summer Shamal winds and the reactivation of dunes across the region. An intense arid period occurred at 4100 BP which corresponds with major drought conditions in Mesopotamia and the Indus region, which led to major changes in society. This event occurs at a major transition in the Arabian Gulf Bronze Age archaeological record with a decline in population and trade. The last 4000 yr has largely been characterised by arid conditions similar to those found in the region today.

1. Introduction

The Indian Ocean summer monsoon (IOM) represents one of the most dynamic interactions between atmosphere, oceans, and continents on Earth affecting climate on a seasonal basis from eastern Africa, through southern Arabia and into central Asia. Arabia is pivotal for understanding late Quaternary climate behaviour and ecosystem responses in the low-latitude regions. Changes in the position of the inter-tropical convergence zone (ITCZ) is central to understanding the rapid, high-amplitude shifts in climate driven by variations in the relationship between the forcing of Indian Ocean Monsoon (IOM) rainfall and the westerlies.

During the Holocene, Southeast Arabia has undergone a number of important changes in vegetation, fauna, and human occupation and utilisation of the landscape largely driven by changes in the regional climate. It has long been recognised that the early to mid-Holocene period (11000 to 5000 cal BP) was characterised by wetter conditions across the Arabian landmass because of the incursion of the Indian Ocean Monsoon (IOM) (Lézine et al., 1998; Parker et al., 2004, 2006a,b; Neff et al. 2001; Fleitmann et al., 2003). This has mainly been driven by changes in solar radiation across the Northern Hemisphere (deMenocal et al., 2000). In turn, millennial-scale changes in solar forcing

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0169-555X/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.geomorph.2007.04.028

have altered the land–ocean interactions and atmospheric responses to these variations. Such changes have been enhanced by variations in vegetation cover, ice cover over the Himalayas, and the albedo changes related to such changes. In addition, recent work has highlighted the importance of abrupt decadal and centennial changes superimposed on top of the longer millennial-scale changes and the potential impact on human populations across the Old World low-latitude sub-tropics (Weiss, 2000; Staubwasser et al., 2003).

The range of landforms in southeast Arabia is diverse, reflecting extremes of climate during the Quaternary. Until recently the evolution of the physical landscape of southeast Arabia was poorly understood. Recent geological, geomorphological and palaeoenvironmental work, however, has addressed large gaps in this knowledge (Cox et al., 1999; Nasir and Musallam, 1998; White et al., 2001). Terrestrial evidence is available from dunes (Glennie and Singhvi, 2002; Goudie et al., 2000a), peridesert loess (Goudie et al., 2000b), lacustrine sediments (Parker et al., 2004, 2006a,b), wadi terraces (Dalongeville et al., 1991) and alluvial fans (al-Farraj, 1995), sabkha (Evans, 1979), raised shorelines (Bernier et al., 1995) and archaeological sites (Vogt, 1994). Most Quaternary land records, however, are discontinuous and many contain stratigraphic gaps. Singularly these provide important localised information, often for brief time intervals. When combined, they provide a powerful network of sites from which the long-term climate and evolution of the landscape can be reconstructed.

In recent years an increasing body of literature supports the notion of climate induced societal change within the archaeological record at various periods within the Holocene (Dalfes et al., 1997; Weiss, 2000; Weiss and Bradley, 2001). Within the low-latitudes it has been suggested that reduced precipitation was a major driving factor in societal collapse in Mesopotamia (Weiss et al., 1993) and the Indus Valley (Staubwasser et al., 2003). Southeast Arabia is located midway between these two 'cradles of civilisation' and is, thus, strategically placed in examining the relationships between climate and archaeology in this marginal landscape.

Integrating geomorphological and palaeoecological records establishes the environmental background against which patterns of human activity, provided through the archaeological record of this region, can be set. Radiocarbon chronologies generated for archaeological localities reflect patterns of human settlement and activity in the region. Changes in the physical landscape have had profound effects on the way in which humans have adapted and utilised this landscape, especially in terms of trade (land and sea), mineral resources, vegetation (for fuel, construction, food, grazing amongst others) and water resources during the Holocene.

The desert landscape of Southeast Arabia is dominated by mega linear sand dunes of Late Glacial Maximum (LGM), Younger Dryas (YD) and earliest Holocene ages with reactivation during the late Holocene (Goudie et al., 2000a). Interdunal dry lake basins provide proxy records of climatic change and vegetation development between 8500 and 4000 ka cal BP associated with rainfall derived by the northwards migration of Indian Ocean monsoon rainfall (McClure, 1976; Gebel et al., 1989; Parker et al., 2004, 2006a). These wet conditions led to the development of savanna grassland and scattered tree cover during Neolithic and Bronze Age times (Parker et al., 2004). Evidence for Neolithic occupation and activity is largely restricted to the coastal margins of the desert where a large number of shell middens have been identified (Vogt, 1994; Uerpmann, 2002; Potts, 1990). To date only a handful of inland sites have been identified, with many buried under the current sand sea.

Southeast Arabia has been a focal point for human settlement since at least 8000 cal BP with access to agricultural and marine resources as well as trade routes, a combination that is unique on the western coast of the Oman Peninsula. This paper integrates the geomorphological and palaeoenvironmental records from dated dune, wadi and lacustrine sediment sequences in southeast Arabia with the records of Neolithic and Bronze Age human activity in the Arabian Gulf region.

2. Area descriptions, methods and material studied

Southeast Arabia (Fig. 1) lies at the interface between the hot desert climate of the Rub' al-Khali desert and the Oman Mountains (Ru'us al Jibal) (max. elevation 2042 m asl) (Parker et al., 2004). The region is characterised as arid to hyper arid and is currently located outside the range of the Indian Ocean Monsoon (IOM) summer rainfall. Rainfall enhanced by the orographic effects of the Oman Mountains occurs in the winter months and is associated with middle–high latitude westerly depressions that originate as cyclonic depressions in the eastern Mediterranean, penetrating into the Arabian Gulf hemmed in to the north by the Zagros Mountain range in Iran. Rainfall is characteristically low (~120 mm), but higher than most other places in the UAE, and a strong precipitation gradient exists across the region between the Ru'us al Jibal (~140 mm) and Dubai (~80 mm). The wind regime is complex with 52% of sand-moving winds blowing from the west and north west, driven by the Shamal, and 28% of sand-moving winds blowing from the south east (Goudie et al., 2000a; White et al., 2001).

Large, low angle alluvial fans coalesce at the mountain front where wadi systems debouch from the Oman Mountains and form large expanses of gravel plain (al-Farraj, 1995). The coastline in characterised by spits, bars, beaches and coastal sabkhas (Goudie et al., 2000c).

The region was mapped from air photographs (1:50 000) and Landsat 7 satellite imagery onto published topographic maps (1:50 000 and 1:25 000). Geomorphological zones were identified and between 1998 and 2005 checked in the field for detail and accuracy. In addition Landsat 7 satellite imagery was used to map the iron and carbonate geochemical components of the Rub' al-Khali dune field (White et al., 2001), whilst cartographic analysis of maps published over a 200 year period and aerial photographs from 1950 were used to reconstruct changes in the coastal region (Goudie et al., 2000c). Field sampling, through exposed dune sections during quarrying for sand, provided details of aeolian activity and sampling opportunities for Optical Stimulated Luminescence (OSL) dating (Goudie et al., 2000a). Analysis of lacustrine sediments provided details for vegetation change and dating for wet periods (Parker et al., 2004). Evidence for the deposition of alluvial fans and wadi activity was made from field observations and from other existing studies (e.g. al-Farraj, 1995; Dalongeville, 1999).

The archaeological survey builds upon the earlier work of Boucharlat et al. (1991), Uerpmann (1992) and Vogt (1994) from the coastal region between Sharjah and Ras al-Khaimah. Radiocarbon dates from wadi, lacustrine and Neolithic sites were calibrated using Calib v.5.0.1 (Stuiver and Reimer 1993). For shell samples the local marine calibration curve for the Arabian Gulf (Southon et al., 2002) was implemented using the Delta_R offsets as defined in Stuiver and Braziunas (1993).

Radiocarbon dates are expressed in cal BP and OSL ages as BP. It should be noted, however, that no age difference occurs between the two.

3. Results and analyses

Geomorphological, palaeoenvironmental and archaeological evidence from across the southeast Arabian Peninsula is presented below based on the key landform regions present in the study area.

3.1. Oman Mountains (Ru'us al Jibal)

The Oman Mountains of the Oman Peninsula and southeast Arabia comprise high relief, rising to a maximum altitude of 2042 m asl at Jebel Harim. Limestones and dolomitic limestone rocks dominate the northern part of these mountains, whilst argillaceous limestones, shales and cherts play an important, but subsidiary role. The Musandam limestones