Coastlines, Submerged Landscapes, and Human Evolution:

The Red Sea Basin and the Farasan Islands

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To be published in: Journal of Coastal and Island Archaeology 2 (2), 2007

ABSTRACT

We examine some long-standing assumptions about the early use of coastlines and marine resources and their contribution to the pattern of early human dispersal, and focus on the southern Red Sea basin and the proposed southern corridor of movement between Africa and Arabia across the Bab al-Mandab straits. We reconstruct relative sea levels in light of isostatic and tectonic effects, and evaluate their paleogeographical impact on the distribution of resources and human movement. We conclude that the crossing of the Bab al-Mandab posed little significant or long-lasting physical or climatic barrier to human transit during the Pleistocene and that the emerged continental shelf during periods of low sea level enhanced the possibilities for human settlement and dispersal around the coastlines of the Arabian Peninsula. We emphasise the paleogeographical and paleoenvironmental significance of Pleistocene sea-level change and its relationship with changes in paleoclimate, and identify the exploration of the submerged continental shelf as a high priority for future research. We conclude with a brief description of our strategy for underwater work in the Farasan Islands and our preliminary results.

Keywords: Paleoclimate, Sea-level change, Shell mounds, Tectonics, Underwater archaeology

INTRODUCTION

The idea that coastal environments and marine resources were an important factor in early human development has had a long and fitful history. Over a hundred years ago, Lewis Henry Morgan prophetically remarked on the universal distribution of such resources, their independence from climatic variation, and their value in facilitating human expansion beyond the boundaries of a primordial terrestrial habitat (Morgan 1871: 21). Carl Sauer (1962) eloquently elaborated the theme and saw the attractions of seacoasts as significant both in human origins and subsequent dispersal. Sir Alister Hardy, inspired by Sauer, lent notoriety to the idea by arguing for a biological phase of specialised aquatic adaptation as a necessary condition of emergent tool-use, meat-eating and bipedalism by hominins (Hardy 1962, see also Morgan 1982). Palaeoanthropologists have rejected such a notion on the grounds that the palaeontological, archaeological, and genetic evidence argues for a straightforward line of descent from plant-eating arboreal apes to meat-eating, ground-dwelling humans. Archaeologists, in their turn, have tended to discount coastlines and marine resources in overviews of world prehistory (cf. Gamble 1993, Klein 1999).

In recent years, there has been a revival of interest in the deeper antiquity of coastal adaptations, resulting from a variety of mostly indirect considerations. General assessments of the ecology and relative attractiveness of coastal and aquatic resources and increased finds of mollusc shells and other aquatic food remains in Palaeolithic deposits (Erlandson 2001), simulation of dispersal patterns (Mithen 2002), modelling of genetic histories (Macaulay et al. 2005, Templeton 2002), and recognition of the overwhelming bias against survival of coastal evidence because of sea-level change and coastal erosion, have persuaded many that exploitation of coastal environments and marine resources could have been an attractive option from the earliest period, and that coastlines and seaways may have acted as gateways rather than barriers to human movement (Bailey 2004a, 2004b; Bailey and Milner 2002; Erlandson 2001; Erlandson and Fitzpatrick 2006; Flemming et al. 2003; Mannino and Thomas 2002; Stringer 2000; Turner and O'Regan 2007; Walter et al. 2000).

Evaluation of the coastal factor is of particular importance in the larger pattern of human dispersal because the interface between the major continents is primarily a marine and coastal one. Between Africa and Eurasia there is only one certain land corridor that has persisted throughout the past 3 million years across the whole 5000 km arc from Morocco to Somalia, and that is the Sinai Peninsula. By convention this has been treated as the only pathway out of Africa, and the notion of a single narrow exit from Africa, intrinsically vulnerable to blockage by physical, climatic or ecological factors, also provides an attractive geographical rationale for bottlenecks in patterns of biological and cultural evolution (Derricourt 2005). A sea channel at least 10 km wide persisted during the period under review at the Gibraltar Straits in the west. Whether the Bab al-Mandab Straits at the southern end of the Red Sea, currently 29 km wide, remained open throughout the Quaternary is less certain, but variations in salinity as recorded in the isotopic record of deep-sea marine cores suggest that the Red Sea remained narrowly open to exchange of seawater with the Indian Ocean throughout at least the last 450,000 years and perhaps further back in time (Siddall et al. 2003). Hence, any broadening of the zone of contact between Africa and Eurasia would have required sea crossings by swimming, rafting or use of boats (Flemming et al. 2003). Between Asia and North America, a land passage across the Bering Strait and southwards beyond the North American ice sheet was available only intermittently (Mandryk et al. 2001), while movement from Southeast Asia into Australia and

New Guinea would always have involved sea crossings of some sort (Allen 1989; Allen and Holdaway 1995; Lourandos 1997; Roberts et al. 1994).

In all these examples a case has been made, or can be made, for the significance of coastlines, marine resources, and water crossings in the pattern of dispersal (Bowdler 1977, 1990; Erlandson 2002; Stringer 2000). The possibility that maritime seal-hunters might have followed the edge of the pack ice across the North Atlantic from the Iberian Peninsula to the eastern seaboard of the Americas during the Last Glacial Maximum has also been proposed (Stanford and Bradley 2002), but the plausibility of such a dispersal across more than a thousand kilometers and the archaeological evidence cited in its support have been vigorously contested (Straus et al. 2005). Some technological capacity to make sea crossings was certainly present in some parts of the world after 50,000 years ago, given the evidence for the colonisation of Australia, but how much further back in time such skills can be traced remains highly uncertain. The presence of early artefacts dated at ca. 800,000 years on the island of Flores in the Indonesian archipelago (Bednarik 2003; Morwood et al. 1999) and of claimed Lower and Middle Palaeolithic material on Mediterranean islands (Cherry 1990; Vita-Finzi 1973) provides hints of earlier sea crossings, but the distances involved are mostly small (~10–20 km), the precise paleogeographical configuration of palaeoshorelines rarely attempted in light of local isostatic and tectonic effects (but see Lambeck 1996a for the Aegean), and the dates of the Mediterranean artefacts unconfirmed.

Between Africa and Eurasia, particular interest has focussed on the ‘southern dispersal route’ (Lahr and Foley 1994), across the southern end of the Red Sea and the Arabian Peninsula to the Indian Subcontinent, with the attractions of coastal and marine resources on this route hypothesised as a particularly potent factor in the rapid dispersal of anatomically modern humans

(Field and Lahr 2005; Field et al. 2007; Stringer 2000; Walter et al. 2000). The technological similarities of Middle Stone Age industries in East Africa with those of southern Arabia, and the contrasts with material of broadly similar age in the Levant (Beyin 2006, Rose 2004) are suggestive, but not decisive. Similarities in stone-tool industries and mammalian faunas on either side of sea channels such as Bab al-Mandab and Gibraltar do not provide decisive evidence for or against sea crossings or the existence of temporary land bridges, since the populations in question could have ended up on opposite shores by taking a longer and more circuitous route by land. The greater time that might be involved in movement via the longer route is insignificant on the time scales of observation that are generally applicable in the Pleistocene.

Given all the above uncertainties, the significance of identifying the particular pathways of human dispersal may be questioned. On one level or scale, it might be argued that the fact and timing of human dispersals from one region or continent to the next may be the significant achievement of interest rather than detailed knowledge of the particular pathways by which they were accomplished. Our view is that a focus on dispersal routes is important for two reasons. First, the ease of passage, and whether it was constrained to a single narrow corridor or possible at many points across a broader geographical range, clearly has implications for the availability, extent and duration of cultural contact and gene flow between the regions in question, and is therefore highly relevant to a broader understanding of large scale cultural and biological variability. Many of the interpretations currently being offered to explain such variability are based on untested assumptions about climatic and paleogeographic change, and human cognitive and technical abilities, or on quite specific inferences from palaeontological and genetic data that require corroboration against independent sources of evidence (cf. Forster and Matsumura 2005; Macaulay et al. 2005; Thangaraj et al. 2005). Secondly and perhaps more importantly, a focus on pathways of dispersal highlights our ignorance about the habitat preferences and palaeodiets of the populations in question, the availability of terrestrial and marine resources in different regions and at different times, and the attractiveness of particular landscapes under paleoclimatic and paleogeographical conditions that were clearly very different from those of today. Derricourt (2005) recently made a persuasive case for the land route via the Sinai Peninsula as the key to dispersal beyond Africa, on the grounds that this provides the most parsimonious explanation of the available data. However, there are good reasons for supposing that the available data are not only incomplete but seriously biased.

Throughout these debates, arguments have relied on largely untested assumptions about human paleoeconomies and the nature and persistence of physical and environmental barriers to dispersal, rather than on direct evidence. The problem of differential survival and visibility of evidence poses particular difficulties. All shorelines are subject to peculiarly active geological processes of erosion and sedimentation leading to high risks of removal or burial of evidence and the transformation of shoreline conditions relative to the present day. This situation is aggravated by the fact that for most of human existence sea levels have persisted at levels much lower than the present, by at least 40 m and for shorter periods by over 100 m. Such a large drop in sea level has obvious and well-recognized advantages for prehistoric populations in narrowing sea channels and creating land bridges for human dispersal on foot. But the same processes of sea-level change have ensured that most of the relevant coastlines, much of their immediate hinterlands, and any associated archaeology that might contradict land-based views of human development and dispersal, are now submerged, eroded away, or buried under marine sediments. Changes of sea level have also almost certainly been accompanied by considerable changes in marine and coastal ecology compared to present day conditions. If we consider that many coastal environments are likely to have provided relatively attractive conditions for human settlement, with improved water supplies (see Faure et al. 2002) and greater richness and diversity of resources on the landward side as well as the addition of marine resources at the shore edge, especially in relation to the relatively arid conditions that generally prevailed during glacial periods, then we may be missing a very large part of the Pleistocene record, and perhaps the most significant part. Reconstructions of dispersal routes and barriers that take no account of the very different conditions of local topography, hydrology and environment that obtained in coastal regions on the exposed continental shelf during periods of lowered sea level must be considered at best misleading and at worst quite wrong.

Here we focus on the southern end of the Red Sea Basin as a dynamic coastal landscape and a potential migration corridor involving a crossing of the Bab al-Mandab Straits. We pay particular attention to the evidence of sea level change during glacial cycles, the impact on shoreline reconstructions of isostatic and tectonic processes, and the effects of these changes on the possibilities of human settlement and dispersal. We evaluate critically the current archaeological evidence for or against an early use of coastal and marine resources, and we present new information on a project designed to explore submerged coastlines in the region and our strategy for locating relevant material underwater.

THE RED SEA BASIN: GEOLOGICAL AND ENVIRONMENTAL CONTEXT

The Red Sea separates Arabia from Africa (Figure 1). It is nearly 2000 km long with a maximum width of about 280 km, and extends from 12.5° N to 30° N (Braithwaite 1987; Head 1987). In the north it branches into the Gulf of Suez and the Gulf of Aqaba. Its sole natural link to the world ocean at its southern entrance, the Bab al-Mandab, currently has a maximum depth, at the

Hanish sill, of 137 m. In winter, warmer and fresher water flows into the Red Sea near the surface, while cooler and saltier water flows into the Gulf of Aden at depth. In summer the surface flow is reversed, and

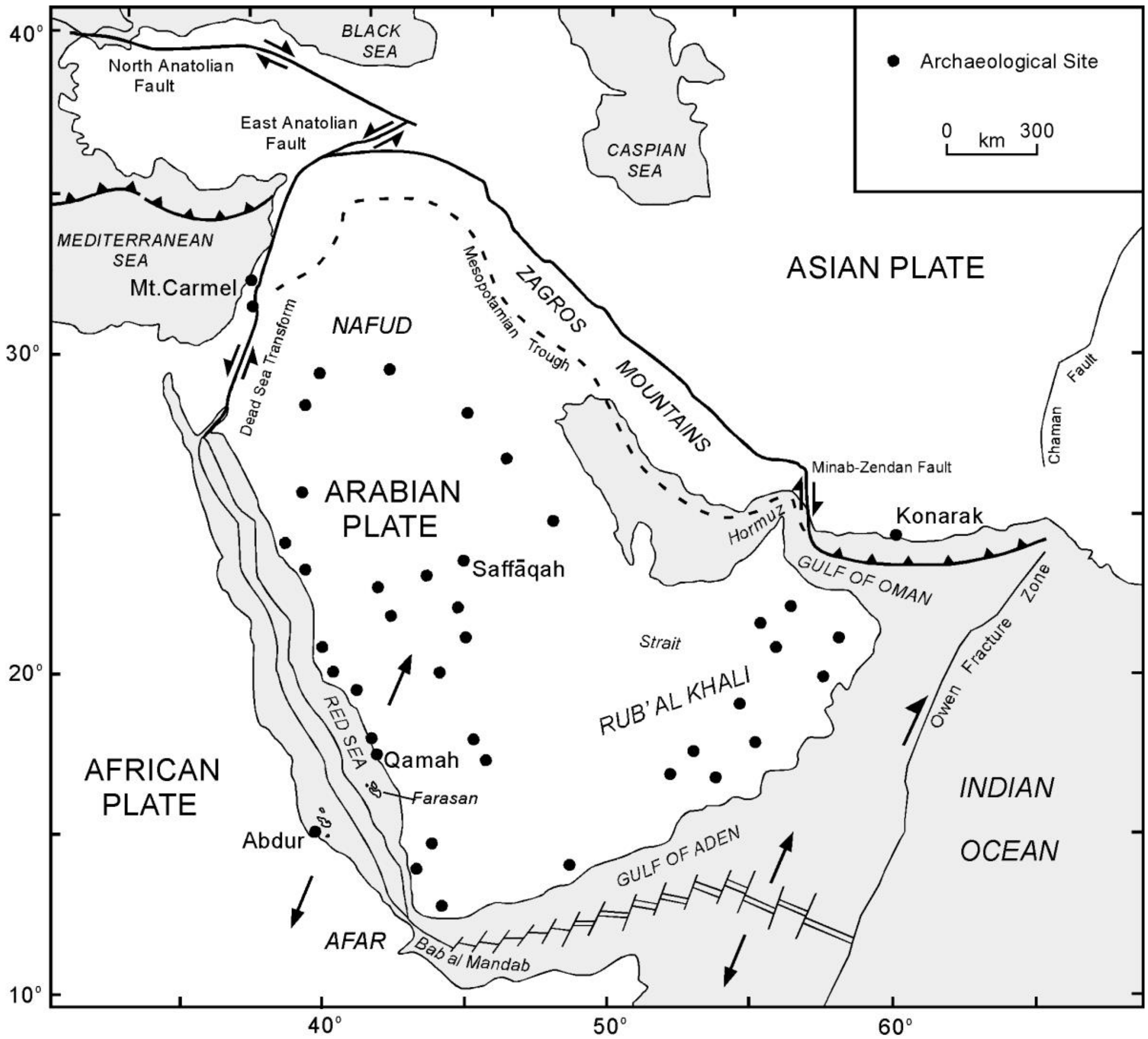

Figure 1. *General map of the Arabian Peninsula and adjacent regions showing major tectonic features and Palaeolithic sites. See text for sources of site information (compiled and drawn by G. Bailey and C. Vita-Finzi.*

intermediate water from the Gulf of Aden flows into the Red Sea between the two outflowing layers (Siddall et al. 2002). The eastern shore is bordered for much of its length by a steep and locally high escarpment. In the south there is a coastal plain, the Tihamah, with an average width of about 60 km backed by the Asir Highlands, which include the highest mountains of the Arabian escarpment. On the western, African side there are plains and tablelands to the north and the mountains of Sudan, Ethiopia, and Eritrea to the south, with the Afar Depression in the southwest corner. Both sides of the growing rift are composed of crystalline basement and sedimentary rocks locally capped by basalt flows. These are bordered by coastal sediments, evaporites, and coral reefs.

Climatic conditions throughout the region are arid. Rainfall in coastal and lowland regions rarely exceeds 180 mm per year, with semi-desert vegetation that supports a sparse fauna of rodents and antelopes (Head 1987; Sanlaville 1992). Inland and at higher elevation rainfall is much higher. In the Asir Mountains, annual rainfall ranges between about 300 and 1000 mm, and this is the wettest region in the whole of the Arabian Peninsula. To the east, the Indian Ocean Monsoon brings summer rains and relatively fertile conditions to coastal areas facing the Gulf of Aden. The northern part of the Red Sea is influenced by the North Atlantic oscillation, which leads to periods of greater or lesser aridity every 6 years or so (Felis et al. 2000).

Coastal regions throughout the Arabian Peninsula provide access to productive marine environments. In the Red Sea, coral reefs, sea grasses, and intermittent mangroves support a rich marine biota of reef and pelagic fish, sea mammals such as dugongs and cetaceans, and marine molluscs, especially on the more extensive areas of shallow continental shelf in the southern part of the basin. The shallow plankton-rich waters around the archipelagos of Dahlak and Farasan support the most abundant fisheries in the Red Sea today.

The Red Sea was originally a northern extension of the African Rift, associated with modest opening and overall extension, though the onset of this process is poorly determined. A major phase of activity came later when Arabia started to split from Africa, and the Gulf of Aden began to open, allowing the sea to enter the continent. Opening of the Gulf of Aden seems to have started in the east and extended to the west to the present day Afar, and it has been argued that the Red Sea has also been associated with a propagation of activity from the Afar to the north (Bonatti 1985; Omar and Steckler 1995). None of this tectonic activity is well dated and different dates have been attributed to different parts of the boundary of the Arabian Plate. However, opening of the Gulf of Aden had begun by 13 Myr (e.g. Hubert-Ferrari et al. 2003; Manighetti et al. 1997), with approximately contemporaneous activity in the Caucusus (e.g. Hubert-Ferrari et al. 2002) and the Dead Sea Rift (Garfunkel and Ben Avrahem 1996; Garfunkel et al. 1981). Girdler and Styles (1974) suggested two major phases of sea-floor spreading within the Red Sea proper, the first 41–34 Myr ago, corresponding to activity of the proto-Red Sea Rift when it was still a land basin, and the second during the last 4–5 Myr, involving opening of an already established Red Sea marine basin.

Rifting is the result of thinning and separation of the Earth's crust and is accompanied by volcanism and faulting, subsidence of the rift floor, and progressive uplift of the rift flanks. In East Africa the result is complex landforms comprising near-vertical fault scarps, lake basins, numerous volcanic cones, and extensive lava flows of considerable significance in understanding patterns of human evolution (King and Bailey 2006). In the Red Sea, as a consequence of the separation of Arabia, the process of rifting has proceeded much further to form an incipient ocean. Continental extension is associated with the creation of a deep axial trough in the center of the basin (the Rift or Graben) and uplift of the rift margins to form the mountain escarpments. The highest mountains are in the south in Yemen and Ethiopia, with elevations exceeding 3000 m, while the deepest part of the axial trough is 2850 m.

During the Miocene, from about 25 Myr to 5 Myr, the Red Sea basin shows little direct evidence of continued rifting, but high rates of evaporation in a semi-enclosed basin resulted in the formation of thick deposits of salt or evaporites (Girdler and Whitmarsh 1974). These have resulted in different and dramatic tectonic processes on a more localized scale. Because evaporites are less dense than overlying deposits, they tend to push upwards to create salt domes or diapirs. The salt can also be dissolved by water action, resulting in localised salt withdrawal and formation of deep depressions. The region of the Farasan Islands and Jizan on the adjacent mainland is located above an uplifting salt dome, while the offshore topography of the Farasan Islands has a number of deep depressions resulting from salt solution (Bosence et al. 1998; Plaziat et al. 1998; Warren 1999).

Both types of tectonic movement have a significant bearing on the assessment of paleogeographical conditions relevant to human settlement during the Pleistocene, rifting because it has probably altered the width and geometry of the mouth of the Red Sea at its southern end, and salt tectonics because it has caused localized warping and distortion of shorelines, which complicates the task of palaeoshoreline reconstruction at a local scale.

THE ARCHAEOLOGICAL CONTEXT

In spite of early discoveries of Palaeolithic implements in the south of the Arabian Peninsula towards the middle of the last century (Caton-Thompson 1953), the region has suffered from comparative neglect in terms of its archaeological potential. Difficulties of access, limited surveys, lack of dated sites, and an assumption that the Arabian Peninsula was an arid and inaccessible cul-de-sac cut off by the Red Sea, have resulted in a greater emphasis on the Levant and the Fertile Crescent with their longer history of investigation and apparently richer and better-watered environments. In fact there are many Palaeolithic sites in Arabia. The Comprehensive Archaeological Survey Program of Saudi Arabia, conducted in the late 1970s, discovered a large number of sites of broadly Palaeolithic date, together with discoveries by American expeditions led by Norman Whalen, and recently summarised by Petraglia (2003) and Petraglia and Al-Sharekh (2003), to which can be added material discovered in the Yemen (Al-Ma'mary 2002; Amirkhanov 1991) and more recently discovered finds in Saudi Arabia (Al-Sharekh 2006) and the Yemen and Oman (Rose 2004).

One general handicap in assessing the Arabian evidence is the rarity of chronometric dates. Currently, only one site has any radiometric dates, and that is Saffāquah, near Dawadmi (Figure 1). Here Uranium series dates of calcite concretions on the underside of the artefacts have given two different sets of determinations, at c. 100,000 and 200,000 years (Whalen et al. 1984). These are, of course, minimum dates, since the calcite formation postdates by an unknown interval the deposition of the artifacts themselves. Otherwise, attempts have been made to date sites by means of typological comparisons with African and European assemblages. At least three categories have been identified: Oldowan, Acheulean, and Middle Palaeolithic. Oldowan material is identified primarily on the basis of simple flaked stones, Acheulean by the presence of bifacially flaked handaxes, and Middle Palaeolithic by the presence of flakes produced from prepared cores. However, it is far from certain that the so-called Oldowan material necessarily indicates an early age. Acheulean and Middle Palaeolithic are more reliable categories that can reasonably be assumed to represent a broad chronological sequence, but the earliest date and time span of the Acheulean, and the earliest date of the Middle Palaeolithic are unknown, though the latter is believed to date back at least to MIS Stage 5e on the basis of associations with raised marine terraces along the Red Sea of presumed Last Interglacial date. Evaluation is further complicated by the fact that almost all the known artifacts are surface finds on deflation surfaces with no depth of deposit and no stratigraphic integrity. Consequently there is no guarantee that collections of material found in the same location are coherent assemblages rather than palimpsests representing aggregations of artifacts coincidentally deposited in the same place on different occasions over thousands or tens of thousands of years.

Nevertheless, the overall distribution of the material provides some general indications (Figure 1). The most noticeable feature is that Palaeolithic finds are widely distributed across the Arabian Peninsula. Material is found in coastal locations, in the broad sense of that term, as well as inland and in desert regions which today lack sufficient water for human survival, and especially around dried up lake basins. That feature of the archaeological distribution, together with geological indications of water flow in the form of stream deposits, tufas, and lake deposits in the arid interior (Sanlaville 1992), also shows that climatic conditions in the Peninsula were generally wetter than today at certain periods during the Pleistocene. We discuss the chronology and duration of these wetter periods below, but it is clear in broad terms that human populations took advantage of such conditions from an early period and established settlement far into the interior of the Peninsula.

Two other factors have attracted greater attention to this region. The first is the suggestion that the southern end of the Red Sea may have posed much less of a barrier to dispersal between Africa and Arabia than once thought, and may even have been cut off from the Indian Ocean by a land connection at some periods. The second is the greater interest in the potential of marine resources and especially marine molluscs at the shore edge to provide an added attraction and a means of subsistence that may have facilitated viable human settlement and dispersal, especially in otherwise arid regions. As in other parts of the world there are many indications of maritime adaptations dating from about mid-Holocene times onwards, with shell mounds and coastal settlements clearly indicating well-organized and intensive fishing and shellgathering activities, especially on the eastern side of the Peninsula (Beech 2004; Biagi and Nisbet 2006). However, as elsewhere, the appearance of this material at about 7000 to 6000 years ago coincides with the establishment of modern sea level, and the absence of earlier material of similar type may simply reflect submergence or loss of evidence accumulated during periods of lowered sea level. Thus particular interest attaches to the evidence of coastal sites associated with the high sea levels of the Last Interglacial, and to the prospects of discovering underwater shorelines and associated archaeology formed at the lowered sea levels that persisted during the period between about 125,000 years and 7000 years ago.

SEA-LEVEL CHANGE

For localities far from former ice sheets, a first approximation of the impact of sea level change on coastal paleogeography is to take global models of eustatic sea-level variation and apply them to selected bathymetric contours (e.g. Van Andel 1989a, 1989b). This can give useful general results, depending on the level of accuracy required, but is limited by a number of uncertainties and potential errors. Navigational charts provide bathymetry that is quite accurate down to depths of about 30 m, sufficient to allow ships to navigate safely, but below that depth soundings give only the most general indication and a false sense of smooth topography that may disguise local complexity. Sediment cover, the growth of coral reefs, erosion associated with transgressive phases, and other factors can also affect the accuracy of paleoshoreline and coastal landscape reconstructions. Also, different proxies for measuring sea level change give somewhat different results, together with a substantial margin of error on the dating of particular sea-level stands, so that even if one can establish with confidence where the shoreline was when sea-level was, say, 40 m below present, the dating of that event may be

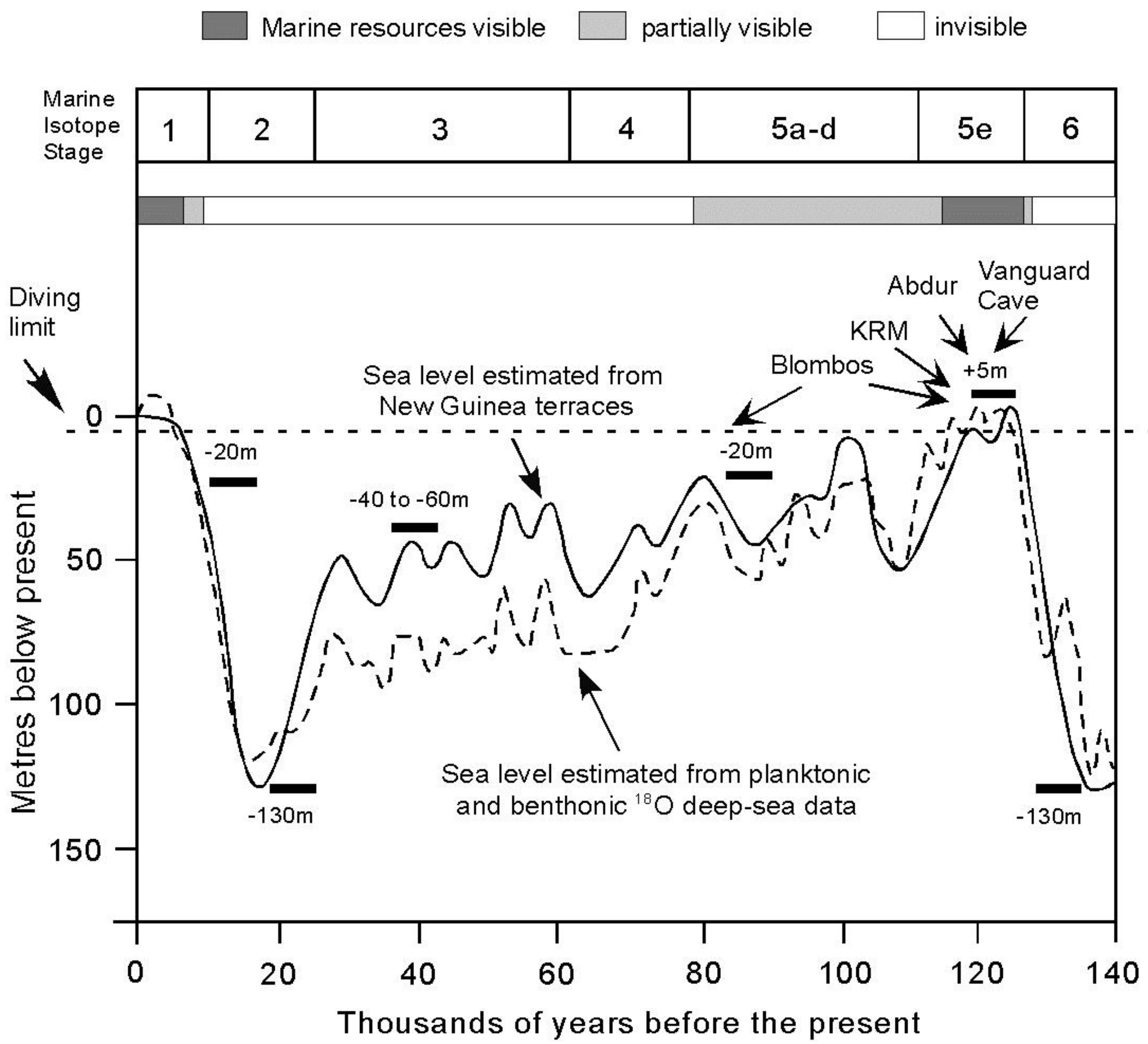

Figure 2. *Global sea level change over the past 140,000 years according to the isotope record of deep-sea cores, showing the correction indicated by measurements of elevated marine terraces. Horizontal bars indicate approximate date and depth of submerged shorelines, which may be re-worked at successive sea-level stands after initial formation. Visibility of marine resources shows the periods when archaeological sites on or close to the modern coastline were close enough to the palaeoshoreline to accumulate remains of marine food resources (data from Chappell and Shackleton 1986; Lambeck and Chappell 2001; Shackleton 1987; Van Andel 1989a, drawn by G. Bailey).*

subject to a margin of error of several thousand years. Movements of the Earth's crust resulting from loading and unloading of ice, water, or sediments (glacio-hydro-isostatic effects) and tectonic movements introduce additional variables that may differ considerably from region to region. The standard measure of eustatic sea-level change is the deep-sea record of changes in oxygen isotope composition (Figure 2), which forms the basis for the marine isotope stratigraphy widely used as a framework for Quaternary studies. Since variations in $\delta^{18}O$ reflect variations in the isotopic composition of the sea water with differential removal of the lighter ^{16}O isotope to feed the growth of the continental ice sheets, this curve is in effect a measure of changes in global ice volume and hence a measure of sea level change (Shackleton 1987). However, dated elevations of marine beaches on rapidly uplifting coastlines such as the Huon Peninsula of northern New Guinea demonstrate that the isotope record during a large part of the last glacial period is amplified by a drop in sea temperature, which exaggerates the amount of sea-level fall if uncorrected (Figure 2). A third sea level curve has been derived from deep-sea cores from within the Red Sea (Figure 3), in which the oxygen isotope record is converted into sea-level variation via a more complex model of salinity changes. In this model, the salinity of the Red Sea increases as sea level drops because of reduced exchange of seawater with the Indian Ocean through the narrow and shallow Bab al-Mandab, combined with high rates of evaporation (Siddall et al. 2003). The effect of temperature change is factored into the model and the result is a high-resolution record on a 100-year time scale back to about 450,000 years ago, compared to the coarser 1000-year time scale but longer time span of the oceanic deep-sea records.

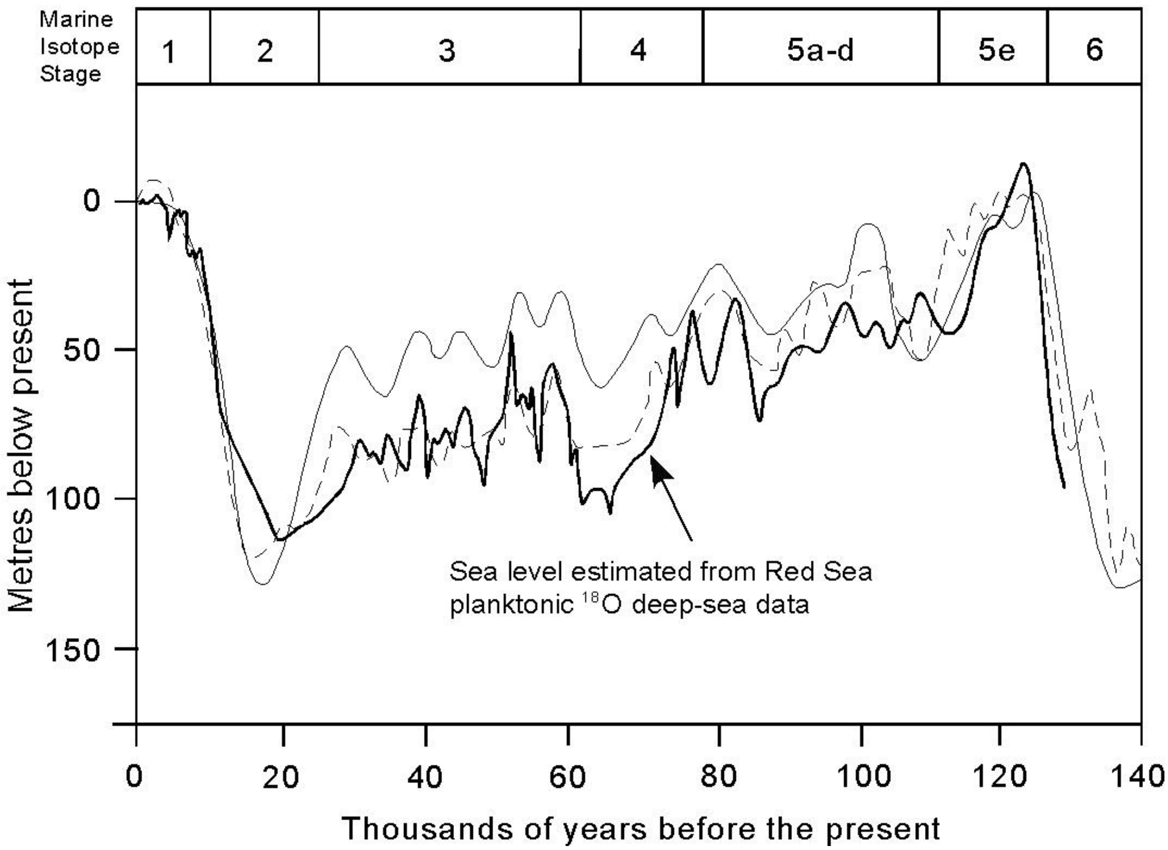

Figure 3. *Global sea-level change over the past 140,000 years according to the Red Sea isotope record (gray and dashed gray lines show the sea level curves of Figure 2); data from Siddall et al. 2003, drawn by G. Bailey.*

These different measures show broad agreement over the glacial-interglacial cycle of the past 140,000 years, even if they differ in detail. One point that is clearly evident is that periods of high sea level have been relatively short-lived, and that for most of the intervening millennia sea levels have oscillated within a range of 40–60 m below present, with occasional sea level stands as low as –130 m and others at about –20 m. Moreover, sea level change appears to have followed a very similar amplitude and periodicity over the past 800,000 years. Before that, the amplitude of variation in the isotope signal is lower, but it suggests that sea levels significantly lower than the present have been the norm throughout the earlier Pleistocene, even if the extreme lowstands associated with more recent glacial maxima were not reached. These facts reinforce the point made earlier that the archaeological record of Pleistocene coastal settlement is likely to be severely under-represented.

Some idea of the amount of land exposed by sea level lowering in the Red Sea can be gained from the –100 m bathymetric contour (Figure 4). The shallowest part of the continental shelf is clearly in the southern part of the basin, where the coastline on either side extended seawards by 60 to 100 km, incorporating the present day Dahlak Archipelago and Farasan Islands into the adjacent mainland. To the north the offshore topography steepens and in the far north-eastern corner in the Gulf of Aqaba, the offshore gradient is so steep that there is almost no additional increment of land at lowered sea level. The cross-sections emphasize this variation, with the deep axial trough reaching to a depth of 2000 m and more in the central basin, and becoming dramatically shallower and narrower towards the Hanish sill and the Bab al-Mandab. With the Hanish sill at a depth of 137 m, close to the maximum eustatic sea level regression, the accuracy of palaeoshoreline reconstructions becomes critical, and in this respect two further effects need to be examined.

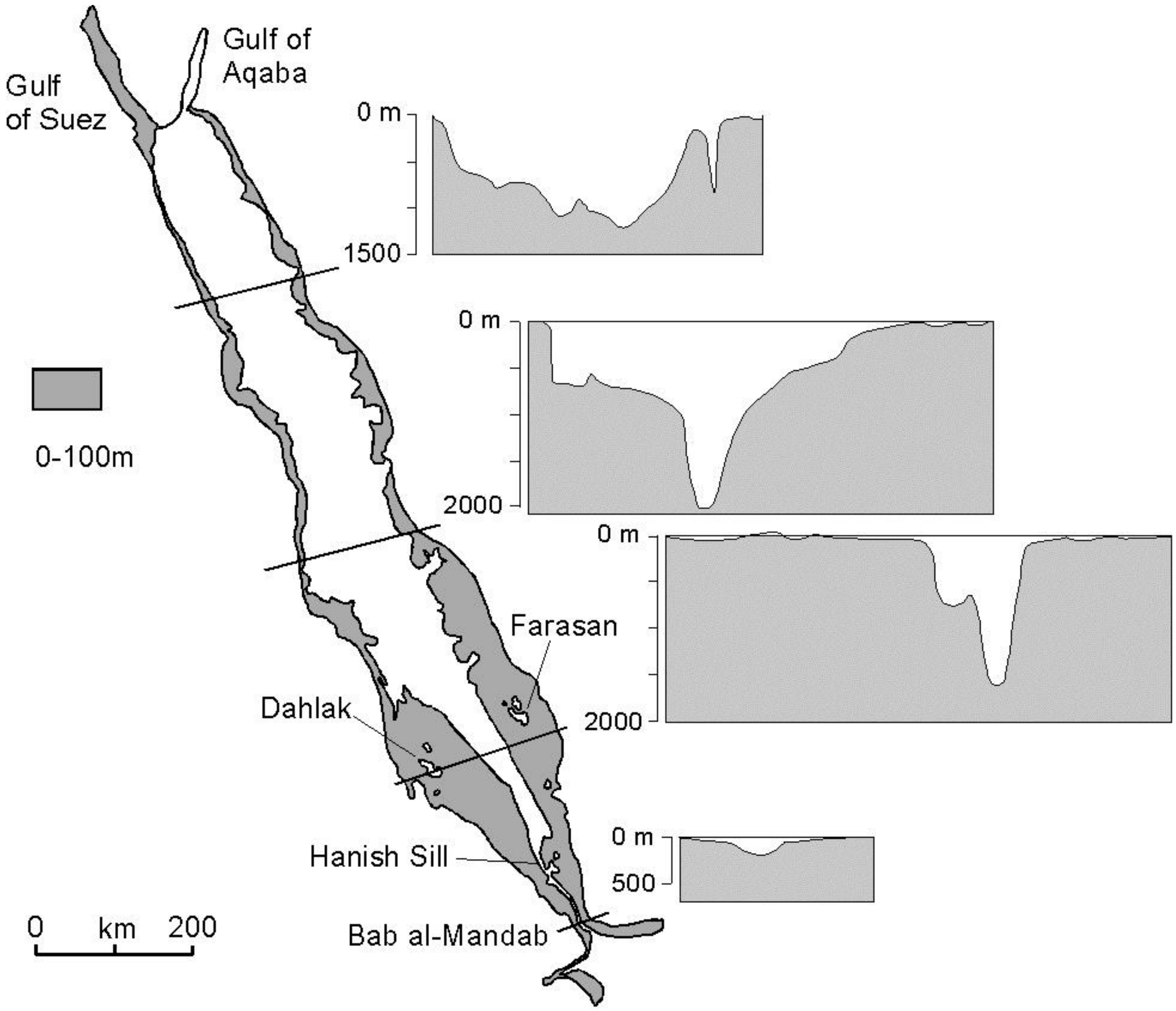

Figure 4. *The Red Sea showing area of land exposed at the –100 m bathymetric contour (after Head [1987, figure 1.2], drawn by G. Bailey).*

Isostatic effects

Loading and unloading of ice and seawater results in isostatic adjustment of the Earth's crust. Far from the continental ice sheets, the principal changes are due to seawater loading on the sea floor, and these hydro-isostatic effects may account for up to 30% of the eustatic signal during lowstands. This is the dominant isostatic factor in the Red Sea. As an example, the loading of seawater resulting from a sea level rise of 100 m on a linear coastline would cause subsidence of the sea floor by as much as 30 m, although there would be a time lag in the response of the mantle and lithosphere. The land at the coast would be dragged down to a lesser extent, while inland there would be no change or perhaps a slight uplift as material in the underlying mantle was redistributed to compensate for the loading offshore. With lowering of sea level of course, the reverse effects would take place, namely a slow rebound of the sea floor and the coast margin and slight subsidence of the hinterland. The crust also responds to glacio-isostatic effects, that is loading and unloading of ice, and while this is the dominant signal in areas of glaciation, it may also have some effect at greater distance from the ice margin. Ice models based on the configuration of the ice sheets, and earth models based on the thickness of the lithosphere and the viscosity of the upper mantle, together with information on the local geometry of the continental shelf, can be used to estimate the position of shorelines under varying isostatic conditions (e.g. Lambeck 1995, 1996b, 2004). Details of the parameters and models used in the calculation of shoreline positions in the Red Sea are described elsewhere, together with calibration of the results against the available evidence of dated shoreline features and elevated terraces (Bailey et al. In prep). Here we present some maps illustrating the results and consider some of their paleogeographical implications.

Our first set of maps illustrates successive shoreline positions in the vicinity of the Hanish sill and the Bab al-Mandab during the last glacial cycle and their approximate dates (Figure 5). The narrowest sea crossing today is 29 km, divided into two channels by Perim Island, the western channel 26 km wide, and the eastern 3 km. At the Last Glacial Maximum 20,000 years ago, the channel would have been so shallow and narrow that it is not possible to be certain within the available margins of error whether the seabed was above or below sea level (Figure 5d). In any case the land elevation at this crossing could have been at most only a few metres and would not have formed an effective barrier isolating the waters of the Red Sea from the Indian

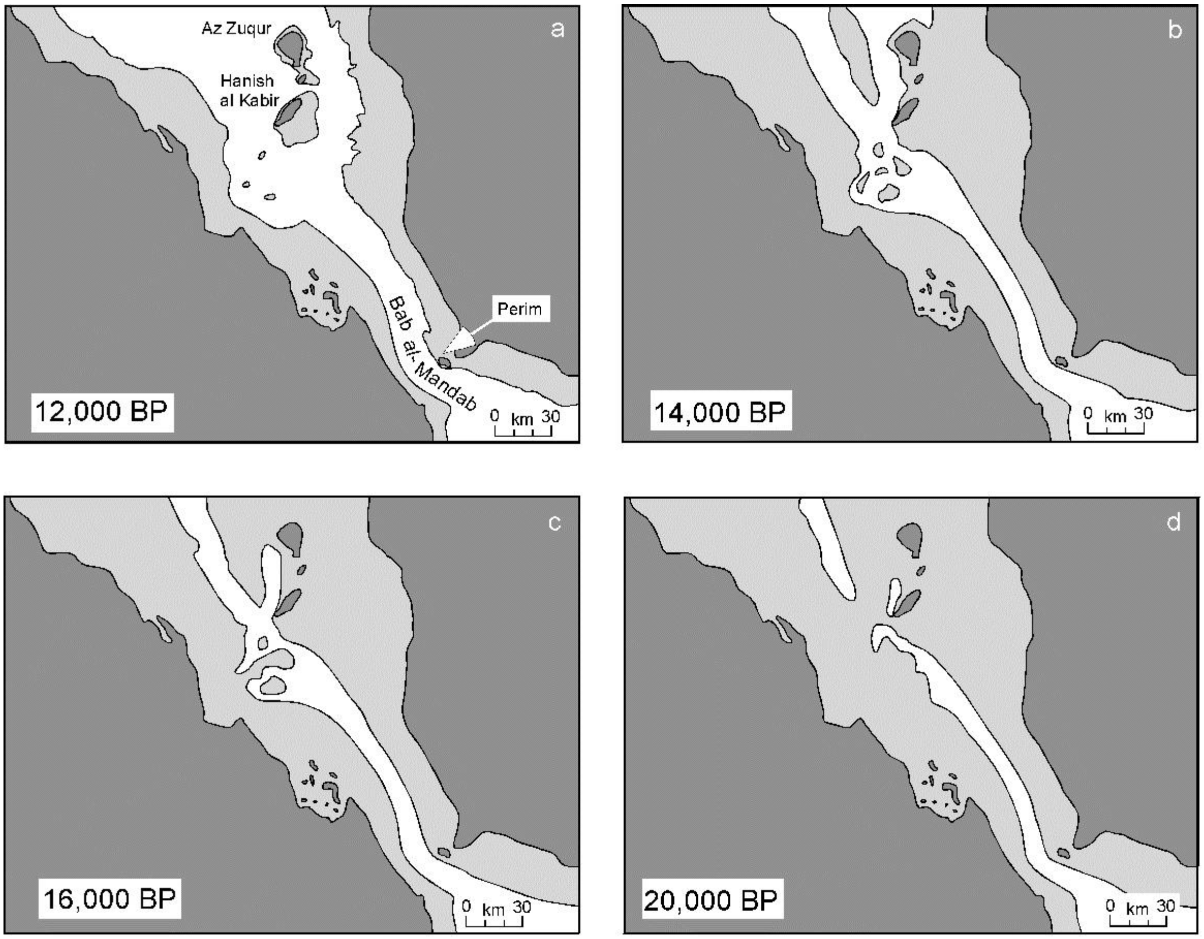

Figure 5. *Shoreline positions in the region of the Bab al-Mandab Straits and the Hanish Sill at different dates in the most recent sea-level cycle (data compiled by K. Lambeck, drawn by G. Bailey).*

Ocean. The deep-sea core record from the Red Sea reinforces this conclusion, demonstrating that water circulation with the Indian Ocean was never completely cut off at the maximum regression of sea level, or not for long enough to register in the isotope record. Fernandes et al. (2006) refer to a water depth of 15±6 m over the Hanish sill and a width of channel of 4 km at the glacial maximum. But it is unclear how accurately the depth and width of the channel can be inferred from the isotope data, or whether it was a single channel or a series of braided channels, and Siddall et al (2003) include an error term of ±12 m in their estimates of sea level variation. The isotopic and isostatic records, which are derived from independent sources of information, are in very close general agreement, which gives confidence in the overall reconstruction. Neither method appears sufficiently sensitive to capture a situation of alternating wet and dry conditions fluctuating over short time scales across the southern end of the Red Sea, however, or to reject decisively the existence of an intermittently dry pathway between the African and Arabian shores at lowest sea-level stands. Whether wet or dry, the crossing at the glacial maximum posed no significant barrier to the dispersal of humans or many other mammals. Even at sea levels up to about –50 m, the channel would have remained long and narrow, with intervening islands to act as stepping-stones, and water crossings no more than a few kilometres wide for the period between about 90,000 and 12,000 years ago (Figure 5a). The opposite shore would have offered a visible target extending for tens of kilometres. The probability of successful landfall in such circumstances is very high, regardless of whether the crossing occurred intentionally or accidentally, or by swimming, rafting, or in boats, because there is little danger of failure when being carried parallel to the shore by water currents (cf. Birdsell 1977).

Estimates of water currents at lowered sea level can provide some control on this assessment. Using a two-layer model to compute the flow in and out of the Red Sea, and assuming a water depth of 32 m above the Hanish sill, the annual average velocity of water flow in the upper layer is 0.4396 m/, equivalent to 1.58 km/hr (Biton, pers. comm., July 2007). Given a channel width of 4 km at that depth, and assuming that prehistoric peoples could swim at 1 km per hour, the crossing time is 4 hours, during which the swimmer would be swept sideways a distance of 6 km. At a water depth of 17 m above the Hanish sill, the water flow is 0.7098 m/s, and the extent of sideways movement nearly 10 km assuming the same channel width and swimming speeding. Neither situation would pose any danger of being swept far away from land, given that the channel was more than 100 km long (see Figure 5). If the water above the Hanish Sill was even shallower, current velocities might increase accordingly, though their effects on lateral displacement would have been offset to some degree by further narrowing of crossing distances. But even in this case the dangers would be slight given the length of the channel. Moreover, there were probably seasonal fluctuations in current flow, with slacker conditions at certain times of year.

If lower sea levels enhanced the attractions of the southern corridor, we should also look at sea-level effects on alternative pathways, across the northern end of the Red Sea, and to the east in Gulf region between Arabia and Iran. In both cases there are shallow conditions that would have been exposed as dry land quite early on in the glacial cycle, and the maps illustrated show successive shorelines corrected for hydro-isostatic effects at selected stages of the cycle. The Gulf of Suez would have remained an exposed basin until about 14–15,000 years ago when sea levels rose above about –50 m (Figure 6), broadening the potential pathway via the Sinai. On the eastern side of the Peninsula, the Tigris-Euphrates river system would have extended out into a now submerged low-lying region with a narrow sea inlet throughout a large part of the glacial period, offering a potentially attractive pathway for dispersal on a northwest-southeast axis (Figure 7). The continental shelf around the Gulf of Oman, though relatively narrow in places, would also have offered a significant addition of low-lying coastal land that could have facilitated movement from the Arabian Peninsula to the Indian subcontinent, whether originating from the north via the Tigris-Euphrates catchment or from the south via southern Arabia. In other words, the paleogeographical effects of a lowered sea level would have been advantageous to ‘northern’ as well as ‘southern’ routes of dispersal.

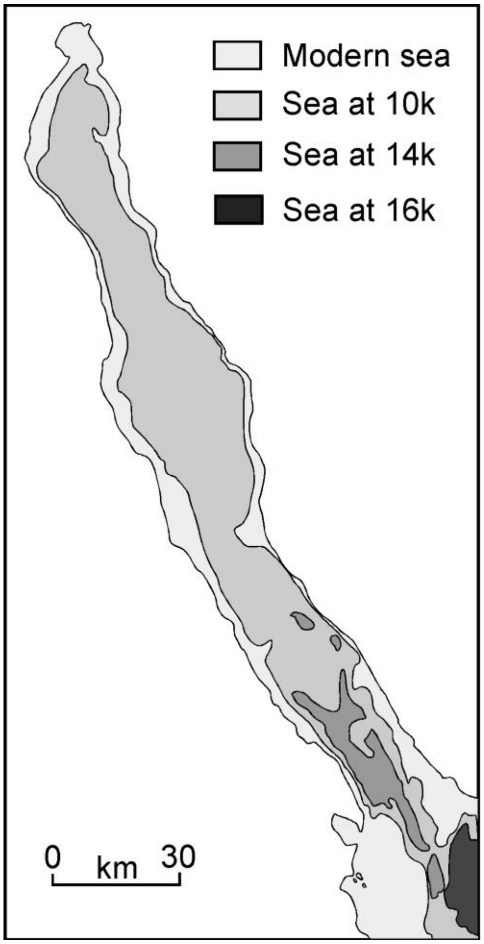

Figure 6. *Shoreline positions in the Gulf of Suez at different dates in the most recent sea-level cycle (data compiled by K. Lambeck, drawn by G. Bailey).*

On the time scale of the last glacial cycle, the dominant temporal and spatial variation in relative sea level within the Red Sea is likely to have been the combined eustatic-isostatic effect. Extrapolation further back in time becomes more debatable because global glacial history becomes increasingly uncertain and tectonic contributions, tending to be secular or cumulative, may become more significant. Thus the situation we have described so far applies with some confidence to the last glacial cycle, which covers the span of time that encompasses the postulated date of dispersal out of Africa of anatomically modern humans, and with decreasing confidence to earlier glacial cycles. What of earlier periods and the possibilities for movement of the earliest populations to leave Africa (*Homo ergaster* or *Homo erectus*), according to current opinion at about 1.8 million years ago (but see Dennell and Roebroeks 2005)? If we consider only the global isotope records available from the early Pleistocene, conditions like those at the last glacial maximum would have been absent and a situation closer to that shown in Figure 5b or perhaps Figure 5c would have been the best available by way of easing transit. Even under these conditions, island hopping, sea crossings over relatively short distances, and a long and relatively narrow channel, would seem to offer possibilities of dispersal across the straits for archaic humans with quite modest capacities for floating, swimming, or improvised rafting. However, an additional variable that becomes significant in this earlier period is the effect of tectonic movement associated with rifting. This raises the possibility that the straits may have been narrower than today at 1.8 Myr, and perhaps shallower, because of ongoing seafloor spreading since then that has widened the gap between Africa and Arabia.

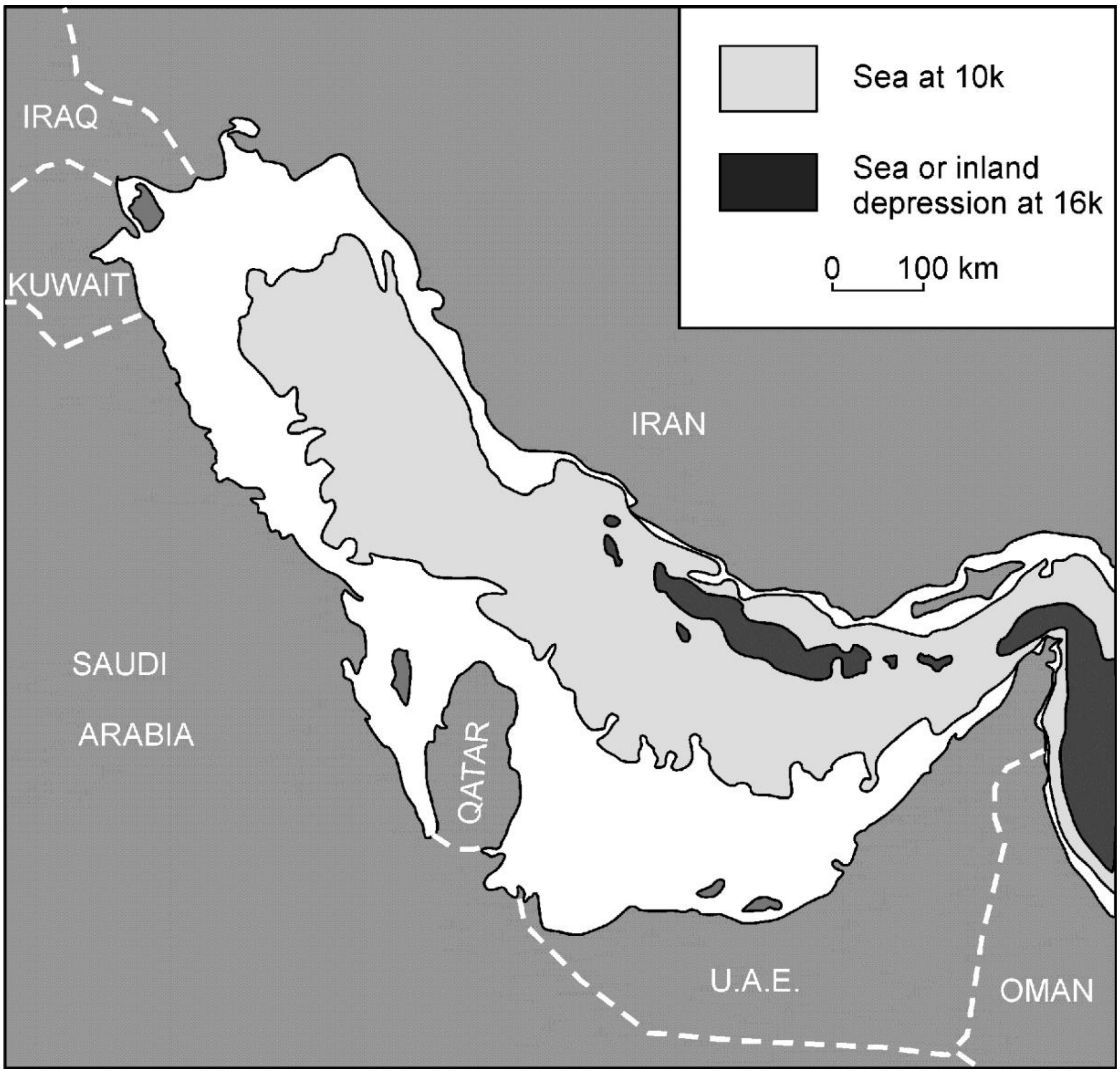

Figure 7. *Shoreline positions in the Persian Gulf at different dates in the most recent sea-level cycle (data compiled by K. Lambeck, drawn by G. Bailey).*

Tectonic effects

Spreading rates for the opening of the Red Sea have been derived from the seafloor palaeomagnetic record. Girdler and Styles (1974) proposed an average rate of separation between the African and Arabian margins of 13 mm yr^{-1} during the earlier phase of rifting over 30 Myr ago, with a slower rate of about 9 mm yr^{-1} following resumption of rifting after 5 Myr. If we take the lower figure, and assume that it can be applied to the southern opening of the Red Sea at a uniform rate over the past 2 million years, that implies a separation of 18 km, clearly enough to substantially alter the possibilities of transit, even with a lower amplitude of sea level variation during glacial periods. There are, however, considerable uncertainties about these rates and the appropriateness of applying them to the Bab al-Mandab Straits.

Some recent measurements have produced rates for the last 3.2 Myr that range from ~16 mm yr^{-1} near 18° N to 10 mm yr^{-1} at 25° 30' N (Chu and Gordon 1998). Separation between Sinai and Africa during the Late Pleistocene has been 0.8–1.2 mm yr^{-1} (Bosworth and Taviani 1996). GPS data for the Red Sea are still of limited value as they are based on only one continuous GPS station and three survey-mode GPS stations on the Arabian Peninsula (McClusky et al. 2003), but they yield a Nubia-Arabia Euler vector in statistical agreement with that derived from magnetic anomalies, with an associated angular displacement at the central Red Sea of ~0.4° Myr^{-1}, amounting to extension at about 7 mm yr^{-1} on a roughly NE azimuth.

These rate variations may be explained by the great disparity in the length of the periods in question, but might suggest a real slowing in the rate of extension. Spreading history can also be assessed by reference to the isotopic composition of foraminifers from cores taken from the Red Sea floor (Vita-Finzi and Spiro 2006), on the assumption that spreading is primarily coseismic and thus associated with pulses of hydrothermal activity. This approach has yielded evidence of a major tectonic event prior to 40,000 years ago but none subsequently, and suggests that tectonic widening of the Red Sea has been more modest for the last 40,000 years and possibly longer. This is consistent with the evidence from many locations of elevated marine beach deposits dated to the Last Interglacial at heights above the present sea level of c. 5 m (e.g. Gvirtzman 1994; Plaziat et al. 1998) close to the global norm, which strengthens the inference that for much of the Red Sea there has been little overall vertical movement of the rift flanks during the past 125,000 years. In contrast, the on-land portion of the Dead Sea Rift indicates a recurrence interval of 1500 years for earthquakes of M = 7.3 and 42 events of M = 6.7–8.3 in the past 2500 years (Ben-Menahem 1991; Marco et al. 1996). Episodic extension of the Red Sea, according to Drury et al. (2006), is well established on both its flanks on the basis of fault polarities and cooling histories. Evidently a single recurrence interval is unlikely to apply to the entire structure, but if one concludes that only large events are recorded geochemically in Red Sea cores, the available measurements may underestimate the rate of spreading. In other words, simple extrapolation on the basis of long-term extension rates suggests that the Bab al-Mandab could have opened as recently as 2 Myr ago. These arguments assume that the Bab al-Mandab Straits have always been directly connected to the main stretches of the Red Sea and the Gulf of Aden throughout the past 2 Myr. Deformation in the Afar should throw some light on this assumption, but here the tectonic history is more complex. The current depression that forms the Bab al-Mandab Straits exhibits no significant current activity, and motion has jumped to the highly active Danakil depression (e.g. Ayele et al 2007; Manighetti et al. 1997). When this occurred is poorly established, but is unlikely to have been much more recent than 2 Myr ago, suggesting that any tectonic activity in the region over that time span is minor with at most modest alterations to the coastlines due to tectonic activity. Absence of evaporite formation during the past 5 million years also indicates that some form of sea connection has been maintained over that period, although it does not rule out short-lived episodes when dry-land transit from Africa to Arabia was possible.

In conclusion, for the period of approximately the last 200,000 years, which encompasses the proposed dispersal of anatomically modern humans out of Africa, we are confident that tectonic effects would have had no major impact on the reconstructions of palaeoshorelines shown in Figure 5. For earlier periods of human dispersal, and especially for a postulated dispersal event at about 1.8 Myr, the position is much less clear. Further evaluation of the implications for ease of human transit in this period would require more detailed geological and seismic investigation of the straits region than are currently available, or extension of the Red Sea isotope record into earlier periods. In the absence of such detail, we can only point to possibilities in need of further exploration. Sea-levels may not have been lowered to the same extent as in the late Pleistocene, but conversely tectonic effects may have created a channel geometry that was narrower or shallower than today. At most, the southern crossing of the Red Sea during low sea level stands would probably have been comparable to the conditions that obtained during the Last Glacial (Figure 5b), while dry-land transit is unlikely to have been available except for very short-lived periods.

COASTAL HABITATS AND MARINE RESOURCES

Getting across the Red Sea is one issue, and the above discussion suggests that for much of the Pleistocene the Bab al-Mandab Straits posed little obstruction to at least intermittent movement between Africa and southern Arabia during long intervals of time. That raises the further question of whether the environments available in Arabia were sufficiently attractive to make the crossing worthwhile and to sustain human settlement and dispersal further eastwards. To answer that question we need to examine three closely related issues: (1) the nature of climatic conditions in coastal regions at the southern end of the Red Sea at different stages of the glacial-interglacial cycle and their likely impact on the availability of animal and plant foods on land; (2) the evidence for the exploitation of marine foods and the potential impact of such resources on the possibilities for settlement and dispersal; (3) local conditions of climate and resource availability on the emerged continental shelf during periods of lower sea level.

Climate change

With regard to climate, the preferred view is that wetter intervals in the arid zones of Arabia are correlated with interglacials, and hence that conditions were more arid than today during glacial periods (Derricourt 2005). Some support for this model comes from investigations in the Rub' al-Khali desert and elsewhere, which demonstrate the strengthening of the Indian Ocean Monsoon and the formation of lakes in now-dry inland areas between about 9000 and 7000 years ago (Parker et al. 2004, 2006). Deep-sea isotope records also indicate generally increased aridity on a global scale during glacial periods. However, the earlier conclusion of Deuser et al (1976) that the deep-sea oxygen isotope record of the Red Sea indicates more arid conditions during glacial periods should be discounted, since they inferred increased aridity from high rates of evaporation associated with high salinities, whereas Siddall et al. (2003) show that high salinities are primarily due to reduced inflow from the Gulf of Aden (see also Assaf 1977). In addition, it has been shown that Mediterranean cyclones brought increased winter rainfall to northern Arabia and the northern Red Sea region during the early Holocene. On the other hand wetter interludes have been identified during part of the last glacial, creating large lakes in the Nafud region in northern Arabia between about 34,000 and 24,000 years ago (Arz et al. 2003; Schultz and

Whitney 1986). Sanlaville (1992), in summarising evidence in the form of alluvial sediments, travertines, tufas, calcretes, and lake deposits indicating higher levels of precipitation than today, also identified evidence for four wet phases since the Last Interglacial. The first, well-dated and corresponding to MIS Stage 5e suggests higher levels of precipitation than during the wettest phase of the Holocene, under the influence of a northward movement of the Indian Ocean Monsoon, and the mechanisms underlying such fluctuations seem to be of general application during interglacial periods (Rohling et al. 2002). A second and wetter phase represents a renewal of extended monsoon conditions corresponding to Stage 5a, followed by renewed aridity in Stage 4 after about 80,000 years ago. A third and prolonged phase of increased precipitation extended from at least 30,000 years ago, and possibly from as early as 45,000 years, to about 20,000 years ago. These conditions were less wet than in the previous two phases, but were widespread throughout the Peninsula, and included the formation of extensive lakes in the Rub' al-Khali (McClure 1976). Sanlaville attributes this episode to the southward movement of Mediterranean cyclones bringing winter rainfall. There then followed more arid conditions, with widespread dune building, but with brief intervening phases of increased humidity, until the onset of the early Holocene wet period referred to earlier.

To sum up the above climatic sequence, there have been wet-dry fluctuations during both glacial and interglacial periods, though of varying amplitude and periodicity. The wettest and presumably most favourable conditions for plant and animal life on land occurred during periods of relatively high sea level, typically at sea levels slightly below the present on the evidence of the early Holocene and MIS 5a phases, but an extended and relatively humid period also coincided with a large part of MIS stage 3 when sea levels were between about –40 m and –60 m. Only during the very maximum of the glacial period, when sea levels reached their maximum regression and crossing the southern end of the Red Sea was easiest, does it seem that arid conditions might have restricted further movement.

There is, however, one very important qualification to this assessment, and that is the nature of the environmental conditions in the enlarged coastal region exposed by a drop in sea level. Faure et al. (2002) have presented cogent arguments to suggest that as sea level dropped, the flow of groundwater from the enormous underground aquifers of the Arabian Peninsula, as in many other coastal regions, would have increased. There are many examples of submarine freshwater springs in the Mediterranean, the Red Sea, and the Persian Gulf, some of which are well known to local fishermen and used to replenish drinking supplies. Faure et al. suggest that this flow of freshwater would have been greatly increased at lowered sea level because of the increased hydrostatic head, and the removal of the downward pressure inhibiting stream flow imposed by the overlying column of sea water during high sea levels, and that this effect would have transformed the emerged shelves into extensive areas of well-watered land with springs and wetlands. Thus as sea levels dropped and conditions became more arid inland, so refugia for plant and animal life became available in the newly emerged coastal zone. If this argument is correct, then the period when local conditions of water supply and plant and animal life were at their most favorable in coastal regions would also have coincided with periods when dispersal across the southern end of the Red Sea and around the coastal margins of the Arabian Peninsula would have been easiest.

Marine resources

In considering the additional impact of marine resources on human dispersal, our first task is to consider the available evidence that they were actually exploited for food during the Pleistocene, or that they were available for exploitation. We begin with the recently reported material from Abdur in Eritrea (Figure 1, Bruggeman et al 2004; Walter et al. 2000). Here artifacts have been found stratified within a series of elevated marine coral terraces, and well dated to c. 125,000 years (MIS 5e). Finds include Acheulean bifacials, vertebrate bone fragments, including hippopotamus, crocodile, elephant, rhinoceros and bovid, and oyster shells. Taken at face value the material suggests a mixed diet that included a substantial dependence on land mammals. Walter et al. (2000) originally suggested that the oyster shells were very early evidence of a significant use of marine resources that helped to facilitate the dispersal of anatomically modern humans out of Africa, and cited in support the evidence of marine resources from deposits in South African caves of similar date. These sites, which include caves such as Die Kelders, Klasies River Mouth and Blombos Cave, and open air sites such as Sea Harvest and Hoedjies Punt (Avery et al. 1997; Henshilwood and Marean 2003; Henshilwood et al. 2001; Klein et al. 2004) date between about 130,000 and 75,000 BP, and contain variable quantities of marine shells, mostly rocky shore species of limpets and mussels, often forming layers of quite dense shell midden, and bones of seals, penguins, and fish.

However, there are unresolved questions about the taphonomy of the Abdur material. Bruggeman et al. (2004) indicate that the oysters are a natural death assemblage and are not therefore certainly food remains. The artifacts associated with the shells could have been used for activities near the shoreline quite unrelated to shellfish gathering and consumption, and then discarded in the shallow water nearby, or on the exposed reef flat during a period of sea-level regression. In any case, as in South Africa, the Abdur evidence is at best the earliest *visible* expression of shoreline activity in this region, made visible by proximity to the coastline during a period of high sea level, rather than the earliest actual evidence. In short, the Abdur evidence is an important indication of visits to the Last Interglacial shoreline, and reinforces the significance of similar finds in the Afar (Faure and Roubet 1968). However, there is currently no clear evidence for shellfish consumption, let alone a significant dependence on it, and certainly no evidence that it formed the basis for a new adaptation to the exploitation of marine resources or the key to dispersal of anatomically modern humans.

Similar sites have been recorded along the Saudi Red Sea coastline in association with raised marine terraces and lava fields, with finds of Lower and Middle Palaeolithic stone tools, particularly near Al Qahmah and Al Birk (Figure 1, Zarins et al. 1981). All the sites and artifacts we have examined in the field are surface finds. None of them are stratified within the underlying deposits, and extensive inspection of exposed sections in marine beach deposits and alluvial sediments has so far failed to reveal any artifacts in a stratigraphic context that might provide some means of dating and preservation of associated food remains. Two basalt samples from the lava cone at site 216-208 near Al Qahmah (Zarins et al. 1981: 18, fig. 5/A) gave K/Ar ages of 1.37±0.02 million years (KSA04/AR1) and 1.25±0.02 million years (KSA04/017), which are maximum ages for the Acheulean artifacts in the vicinity, and Middle Palaeolithic artifacts occur on the surface of a nearby coral beach terrace some 3–4 m above present sea level, presumed to be of Last Interglacial date (Bailey et al. 2007). So far, we have found no convincing in situ deposits or shell middens clearly associated with beach deposits dated earlier than 6000 years ago.

From this evidence, the scale and time depth of exploitation of marine resources in the Red Sea area remains unclear. There is an added problem in some parts of the Red Sea that during extreme low sea level stands salinities would have been high enough to prevent plankton growth (Hemleben et al. 1996; Fenton et al. 2000) and marine resources dependent on the plankton food chain. Even if some marine resources, such as intertidal molluscs, were able to persist during these aplanktonic episodes because of adaptability to high salinities and an ability to subsist on detrital material, the opportunities for human subsistence on marine resources during these periods would seem to be very limited, at least within the main body of the Red Sea. No such problems would have affected the narrow channel south of the Hanish Sill because the salinity of the inflowing water would have been identical with that in the adjacent Gulf of Aden and Indian Ocean, and that moderating effect may have extended some distance into the main basin, sufficient to permit biological production in the region of the Farasan and Dahlak archipelagos.

In any case it is unclear whether marine resources by themselves and especially molluscs could be relied on as a major source of subsistence in the absence of complementary food supplies derived from terrestrial plants or animals. All the marine taxa recorded as food remains in sites such as the Middle Stone Age caves of South Africa referred to earlier could have been obtained on the seashore — molluscs in the intertidal zone, fish trapped in rock pools by the receding tide, and sea mammals and marine birds scavenged as carcasses beached by storms or trapped on land in the case of seals. None of them presuppose the existence of a specialised technology or the use of boats. Molluscs are valuable in providing a predictable and relatively accessible supply of food (cf. Meehan 1982), but even in the largest shell mounds of the mid- to late Holocene, the molluscs demonstrably supply much less food than the bulk of their remains might otherwise suggest, are almost always associated with exploitation of terrestrial resources as well as marine, and rarely show the sort of evidence of catastrophic overexploitation that might be caused by over-dependence on molluscs or overwhelming human impact (Bailey and Milner 2002, in press).

Our analysis suggests that resources on the coastal shelf may have been more abundant and more easily available during periods of lowered sea level than today, particularly on the landward side of the shoreline, although the precise combination of circumstances evidently fluctuated with changes in climate and sea level and from region to region. There is certainly no basis for arguing for a persistent barrier, whether physical or climatic, to dispersal via the southern route on Pleistocene time scales. At the extreme lowering of sea level at the glacial maximum it may have been well-watered conditions on the emerged coastal shelf, together with ease of transit in regions such as the Bab al-Mandab and Hormuz that was the key attraction to human settlement and dispersal. What both climatic and archaeological considerations emphasize is the importance of the emerged continental shelf during periods of lowered sea level, and the need to undertake explorations both on land and under water in search of relevant archaeological and paleoenvironmental evidence.

THE FARASAN ISLANDS

The Farasan Islands today are some 40 km from the mainland and are composed of coral platforms uplifted and deformed by salt tectonics, resulting in a complex onshore and offshore topography (Dabbagh et al. 1984; Macfadyen 1930). Indigenous resources include the Arabian gazelle, a rich inshore and intertidal marine environment with fish, molluscs, turtles and sea mammals, and migratory birds. The sea area around the Farasan Islands supports the largest fishery in Saudi Arabia. The Islands offer a number of advantages for underwater survey. The seabed between the Islands and the mainland is relatively shallow and at sea levels between about 20 and 50 m they would have formed a single land mass accessible to human settlement at intervals throughout the Pleistocene without requiring sea crossings (Figure 8).

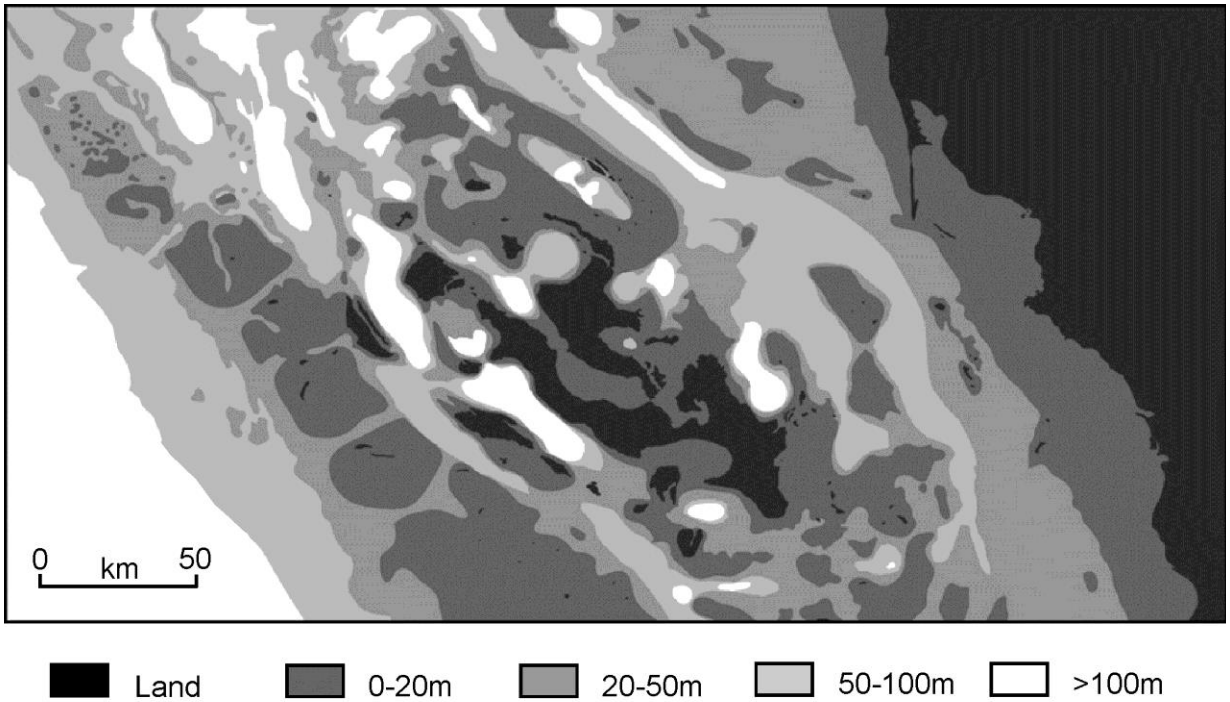

Figure 8. *The Farasan Islands showing offshore bathymetry (bathymetric data from Hydrographic Office (2000): British Admiralty Chart No.15, drawn by G. Momber)*

In the other direction, the shelf slopes more steeply towards the axial trough of the Red Sea, offering the possibility of discovering shorelines associated with different stages of the sea level cycle. At all but the lowest sea levels, the complex configuration of coastlines, islands, and archipelagos would have created shore areas protected from the full destructive force of wave action during sea level rise, with a greater likelihood that landscape features and archaeological material have survived inundation. The offshore location also means that the seabed is less likely to have been covered with thick sediments washed into the sea from the mainland. Many inshore areas are also unsuited to coral growth, which would otherwise obscure the underlying surface. The complex topography of the seabed apparent from the bathymetric contours, and in particular the deep depressions scattered across the underwater landscape, also suggest the possibility of numerous locations that would have trapped freshwater when the landscape was uncovered during periods of lower sea level. Here we report on our strategy of investigation and the results of our first season's work in 2006 (see also Bailey et al. 2007).

Farasan Archaeology

Almost nothing has been reported previously on the archaeology of the Farasan Islands apart from the results of brief surveys published in Zarins et al. (1981) and Zarins and Zahrani (1985), two Latin inscriptions, some Islamic material, and an unreadable but supposedly pre-Islamic inscription on a traditional building. Zarins et al. noted the presence of shell middens in Janaba Bay (Figure 9), the remains of structures of probable pre-Islamic age made from blocks of coral, and the presence of ceramics typical of the Islamic period, the pre-Islamic South Arabian Civilization, dated on the mainland between about 1200 BC and the 6^{th} century AD, and the 'Neolithic' period. No excavations were undertaken as part of these early surveys apart from a small test excavation of one of the shell middens to provide some radiocarbon dates. We thus have only the outlines of an archaeological sequence and a basic chronology extending back to about 5400 radiocarbon years BP (Table 1).

We are pursuing a joint strategy of archaeological investigation above and below modern sea level. On land or below the water, our interest is in the prehistoric landscape as a seamless whole and the human activities and archaeological materials associated with it.

Survey Results

In our first season of survey, our objectives were to survey more widely for archaeological materials on land, to obtain more radiocarbon dates, to examine the relationship between archaeological sites on land and local geomorphological features as clues to where to search under water for earlier sites, and to undertake preliminary underwater survey.

Our initial surveys on land have revealed an immensely rich archaeological landscape comprising some 1000 archaeological sites. Most are shell mounds of substantial size, up to 4 m thick, sometimes forming a virtually continuous line of deposits along stretches of the shoreline, and many others have marine shells associated with them (Figure 9). The sites often form clusters, with thicker mounds on the beachfront and shallow shell deposits or shell scatters situated further back from the shoreline. Some are associated with potsherds of Islamic and pre-Islamic age. Others appear to be older prehistoric deposits without ceramics. Small test trenches through the larger mounds show that they have the characteristic features of a midden deposit, with stratified layers of broken marine shells, ash lenses, occasional imports of stone material and fish bone. The taxonomic composition of the molluscs varies from area to area, and includes reef, sand, and rock dwelling species, with conch (*Strombus fasciatus*) and pearl oyster (*Pinctada nigra*) especially well represented. The number of artifacts recovered from these text excavations is currently too small to provide any useful clues to cultural affiliation or chronology.

Further radiocarbon dates are awaited from our own investigations. In the meantime it is clear that there is an abundant archaeological record extending back to at least the mid Holocene. Since the shorelines have undergone localized uplift as well as downwarping, we may also find shell middens of significantly earlier date above sea level. Our survey strategy is also directed to the discovery of material of earlier date deposited on land when the Islands formed part of an extensive hinterland on the emerged continental shelf, as well as to the discovery of sites associated with the now submerged hinterland. There is also a possibility of discovering coastal archaeological middens from the Last Interglacial, since there are traces of an extensive fossil coral terrace that formed an ancient shoreline at the inner edge of the modern shore platform.

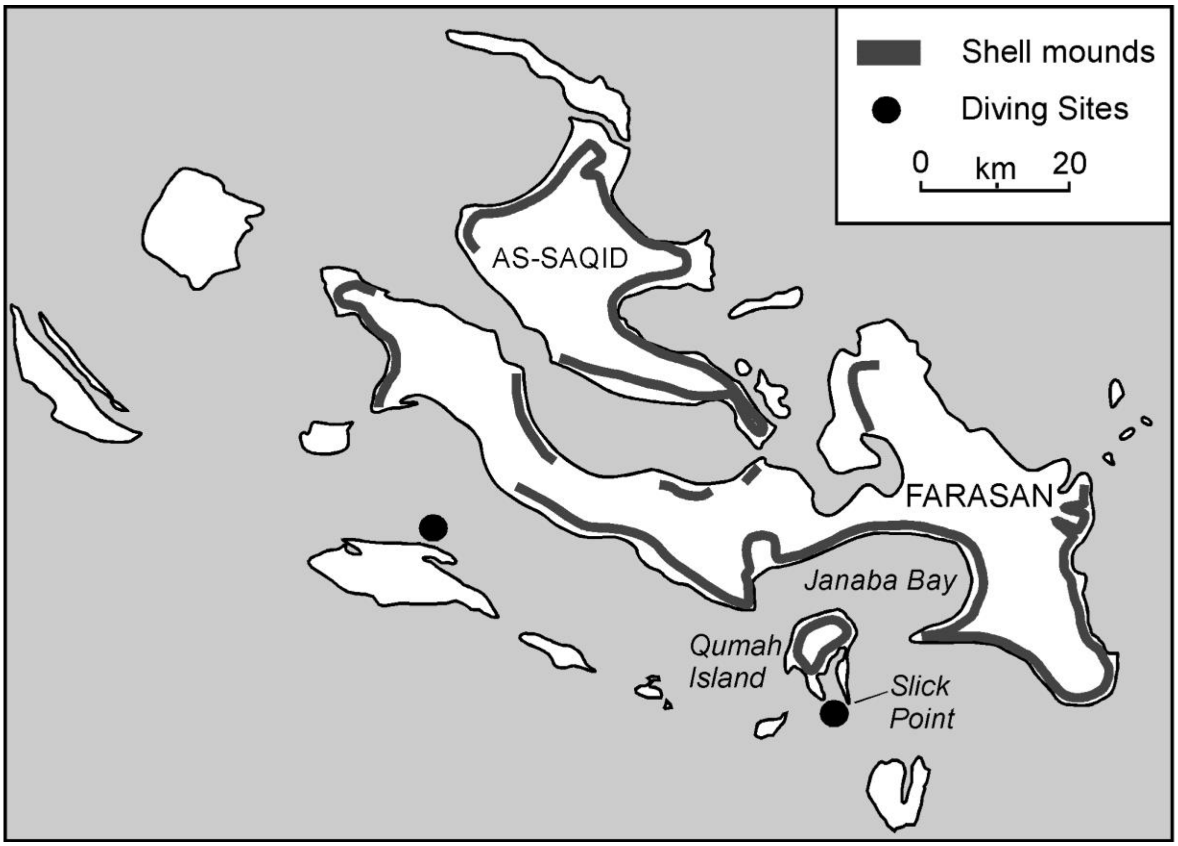

Figure 9. *General distribution of shell mounds on the Farasan Islands (drawn by G. Bailey).*

Underwater archaeological sites could be shoreline sites like the shell middens on the present-day coast, or 'inland' sites associated with freshwater springs or lakes. We suspect that shoreline sites are likely to be easier to locate given their probable association with shell deposits. Hence, our initial strategy for underwater exploration is to use the location of the shell mounds and other archaeological features on the present-day shoreline, and their relationship to local geological and topographic features, to predict the types of surface features that we should be targeting underwater. A characteristic feature is the association of shell mounds with a wave-undercut coral platform resulting primarily from the chemical solution of the coral material at the shore edge (Figure 10). In some cases these undercut coral platforms on land are now separated from the modern shoreline by a shallow sand-filled embayment, which was formerly an extensive intertidal zone with productive conditions for the molluscs whose shells form the main constituent of the archaeological deposits. This infilling is the result of cumulative deposition of sediments in very shallow conditions, accentuated in some cases by localised tectonic warping resulting from salt movement, and highlights the fact that the ecological conditions for abundant intertidal shell beds may have been relatively short lived and quite variable on different shorelines.

Figure 10. *Shell mound and undercut coral platform on Qumah Island (photo G. Bailey, 2006).*

Preliminary underwater survey has been directed to locating similar shoreline features associated with earlier periods of sea level, using a combination of diving, video, and remote sensing. We have placed particular importance on the diving work, because video and remote sensing by themselves are insufficient to evaluate underwater features in the early stages of exploring unfamiliar terrain, and cannot make drawings or collect dating samples from cemented coral. An important part of the initial survey was therefore to establish the feasibility of prolonged and deep dives using mixed gas technology and to solve the logistics of doing so in a remote location. The diving program was facilitated by the use of a large vessel (the MV Midyan) as a mobile offshore base for a six-strong diving team, diving equipment, and two small boats to provide access to dive sites. For short and shallow exploratory dives we used normal scuba tanks with compressed air and for prolonged diving at greater depth, nitrox (oxygen and nitrogen) and trimix (oxygen, nitrogen, and helium), which enable divers to work with greater mental acuity, reach deeper locations that would otherwise be inaccessible, to work there safely for extended periods, and to explore underwater features to a maximum depth of about 90 m.

Diving was concentrated in near-shore locations with relatively steep drop-offs and good potential for exposure of wave-cut coral platforms representing shorelines formed during periods of lowered sea level. Preliminary acoustic (single-beam echo-sounder) transects were conducted to identify breaks of slope elsewhere that might indicate similar features, and to help focus the selection of diving locations. Work was concentrated on the north side of Zufaf Island and on the southern side of Qumah Island in the vicinity of Slick Point.

At Zufaf, well-defined coral terraces were identified at depths of 60 m and 6 m, but smothering of sand obscured detail, and more detailed work was concentrated at Slick Point. Here there was little overburden of obscuring sediment or recent coral growth, and it was possible to identify coral reefs representing old shoreline terraces at approximately 6 m and 20 m depth and to map their features over a considerable distance (Figure 11). These features are typical of those associated with the present-day shoreline and represent a beach line at a sea level about 20 m below the present, which could have formed at about 80–90,000 years ago and been re-occupied when sea level reached the same level about 12,000 years ago (see Figure 2). This former shoreline feature is now tilted in a north-south direction at an angle of about 1 in 20 as a result of salt tectonics, and rises to a level some 9 m below the present sea level within Qumah Bay. Within the Bay itself, there are shell mounds above the modern sea level that are located

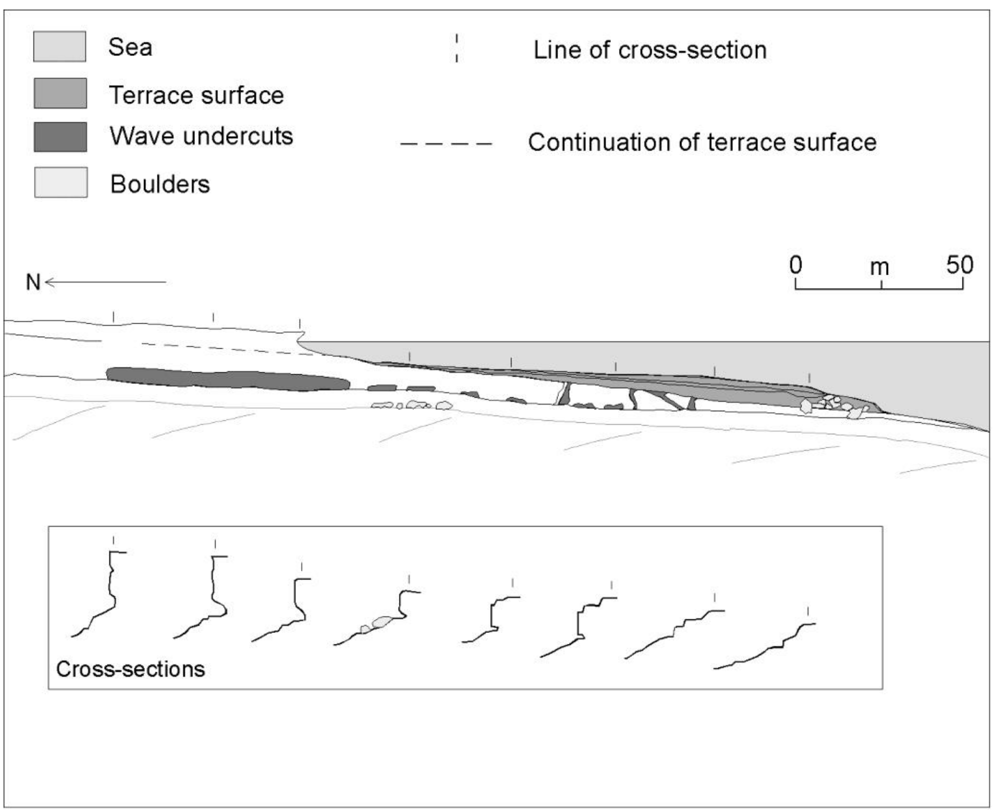

Figure 11. *Mapping of the underwater palaeoshoreline at Slick Point on Qumah Island, showing underwater features. The cross-sections show the profile of the terrace viewed from south to north. The wave-undercut notches at the base of the terrace indicate the position of the paleoshoreline and both the longitudinal profile and the cross-sections show the extent of warping resulting from salt tectonics (compiled and drawn by G. Momber).*

directly over wave undercut platforms, and other mounds located further inland on an undercut coral platform fronted by a dry, shallow sandy bay. Similar topography has been identified in association with the underwater shoreline, including notches and undercuts (Figure 11). Such undercuts occur above modern sea level and provide sheltered and shady locations at the present-day, often used as modern campsites with a typical archaeological signature of bottles, cans, and remains of fireplaces. We would expect to find prehistoric artifacts associated with the equivalent features that are now submerged, as well as shell midden accumulations above the wave cuts in ecologically favorable conditions. Slick Point provides an example of a submerged shoreline where coastal geomorphological processes can result in clearly defined platforms and underlying notches, some of which extend up to 4 m into the cliff (Figure 11). Unfortunately, the exposed nature of the headland reduces the chance of discovering archaeological material in situ at this location. However, reconnaissance further into the bay led to the discovery of another series of wave cut notches in 10 m of water. These possible overhanging 'shelters' are fronted by a gentle sandy slope into Qumah Bay and would have been protected from the full force of the sea to the south. These tranquil conditions increase the chances for survival of archaeological material, which, even if disturbed, may not have been dispersed far from its original position. Further exploration on this occasion was curtailed by logistical constraints, but we shall extend this work in future with more detailed investigation of archaeological sites on land, and more extensive underwater survey using multi-beam bathymetry, sub-bottom profiling, shallow coring and diving.

CONCLUSION

In reviewing the evidence of paleogeographical and paleoclimatic change, we conclude that human transit across the Bab al-Mandab Straits would have been relatively easy during the lower sea levels that prevailed throughout most of the Pleistocene, and that neither the physical barrier of a water channel nor climatic disincentives of arid climate can be invoked to reject the likelihood of human settlement and dispersal in the southern corridor over the time span of the Pleistocene as a whole. Occasionally, unfavorable paleogeographical and climate conditions may have combined to reduce the attractions of this region, but probably only for relatively short periods. Extreme high sea levels would always have posed a more significant barrier to crossing at the Bab al-Mandab before the invention of seaworthy boats.

If coastlines were especially attractive places for human settlement, either because they represented primary corridors for initial population dispersal, or because they offered additional attractions in the form of marine resources and better-watered and more fertile conditions on land, it is clear that settlement was not confined to coastal zones. During climatically favorable intervals, lake basins developed in inland depressions and attracted human settlement from an early period in the Pleistocene.

Nor should we overstate the relative attractions of the southern route in comparison with others. Lowered sea levels would probably have enhanced the attractions of the northern route via Suez, Sinai, and the Tigris-Euphrates catchment, as well as in the south, while high sea levels would have had rather less impact in the north. The loss of a coastal plain at high sea levels along the eastern coastline of the Mediterranean would have posed no serious obstacle to movement. It may even have heightened the attractiveness of caves and shelters, such as those of Mt. Carmel, by providing easier access to marine resources as well as the added security of complex and protective topography in a coastal setting (Vita-Finzi and Stringer 2007). Conversely the steep topography and aridity of the Makran Coast may have posed a serious barrier to movement during periods of high sea level. This region today is mountainous and arid with annual rainfall of 150 mm, and is famous as the location where the army of Alexander the Great came to grief from lack of food and water on their return from India in 325 BC. It is, however, a region that would have become more attractive and easily traversable with a relatively narrow but significant addition of low-lying and potentially well-watered coastal plain when sea levels were lower, and Middle Stone Age surface finds from the Konarak Peninsula show a human presence there at some point in the later Pleistocene (Vita-Finzi and Copeland 1980).

The case for the influence of marine resources in facilitating dispersal along Pleistocene coastlines remains uncertain in the absence of clear evidence for their exploitation. On the other hand, the exposure of relatively well-watered coastal lowlands around the coastlines of the Arabian Peninsula and the Makran may well have been a more decisive factor in opening up easier pathways for movement to the east. One of the biggest uncertainties in assessing the paleogeographical possibilities in more detail is our ignorance of conditions on the now submerged coastal plain. All the indications are that when sea levels were lower this was a key refugium for plants, animals, and humans during the more arid episodes of the glacial periods. Survey of this submerged landscape for relevant paleoenvironmental and archaeological evidence is now essential if such hypotheses are to be tested.

ACKNOWLEDGMENTS

We acknowledge funding from the Natural Environment Research Council (NERC), UK, through its EFCHED programme (Environmental Factors in Human Evolution and Dispersal), *the British Academy, and the Leverhulme Trust, and additional funding and assistance in kind for the underwater work from Saudi ARAMCO, the Saudi British Bank (SABB) and Shell Companies Overseas. For the issue of permits we are grateful to the following Saudi governmental organisations and individuals: HRH Crown Prince Sultan Bin Abdul Aziz Al Saud, Minister of Defence and Aviation; HRH Prince Sultan Bin Salman Bin Abdul Aziz, Secretary General to the Supreme Commission for Tourism; the Deputy Ministry of Antiquities and Museums; the Military Survey Department of the Ministry of Defence and Aviation; the Saudi Border Guard; Prof. Saad Al-Rashid and Dr. Ali S. Al-Moghanam, former Deputy Ministers of Antiquities and Museums; Dr. Ali Al-Ghabban, Supreme Commission for Tourism; Major General Muraya Al-Sharani and Admiral Abdulrahman Al-Shihiri, Military Survey Department, Ministry of Defence and Aviation; and Dr. Dhaifallah AlTalhi, Deputy Ministry of Museums and Antiquities. We also gratefully acknowledge the help of HM British Ambassador to Saudi Arabia, Sir Sherard Cowper-Coles, Dr. Ali Al-Muhana, Public Relations Advisor to the Minister of Petroleum and Mineral Resources, the Governor of Farasan, Abdulrahman Mohammed Abdulhak, the Captains of Saudi ARAMCO's oil vessel, the Midyan, Yusuf Dukak, Al-Amin Gizani and Salem Enazi and their crew; Captain Ahmed Mirdad and Mohammed Saber of Saudi ARAMCO, Jeddah, and our representatives in the field, Faisal Tamaihi, Deputy Ministry of Antiquities and Museums, Sabiya, and Lt. Cdr. Abdulla M. Ahmari, Ministry of Defence and Aviation, General Staff Headquarters, Military Survey Department, Riyadh. We also thank the Hampshire and Wight Trust for Maritime Archaeology for provision of survey equipment and additional support, Eva Laurie, Department of Archaeology, University of York, for the identification of molluscan taxa, Eliyahu Biton, Department of Environmental Sciences, Weizmann Institute, for information on current flows in the Hanish Channel, and two anonymous assessors for their comments.*

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