Blue Arabia: Palaeolithic and Underwater Survey in SW Saudi Arabia and the Role of Coasts in Pleistocene Dispersals

G.N. Bailey*[1], M.H. Devès[2], R.H. Inglis[1], M.G. Meredith-Williams[1], G. Momber[1, 3], D. Sakellariou[4], A.G.M. Sinclair[5], G. Rousakis[4], S. Al Ghamdi[6], A.M. Alsharekh[6]

Quaternary International (2015), http://dx.doi.org/10.1016/j.quaint.2015.01.002
(Green Arabia Special Issue)

* Corresponding author, email: geoff.bailey@york.ac.uk

1. Department of Archaeology, University of York, the King's Manor, Exhibition Square, York, YO1 7EP, UK
2. Institut de Physique du Globe de Paris, 1 rue Jussieu, 75238 Paris, Cedex 05, France
3. Maritime Archaeology Trust, Room W1/95, National Oceanography Centre, Empress Dock, Southampton, SO14 3ZH, UK
4. Hellenic Centre for Marine Research, 19013 Anavyssos, Athens, Greece
5. Department of Archaeology, University of Liverpool, Liverpool, 12–14 Abercromby Square, L69 7WZ
6. Department of Archaeology, King Saud University, P.O. Box 2627, Riyadh 12372, Saudi Arabia

Keywords: Submerged landscapes, Red Sea, Early Stone Age, Middle Stone Age, Late Stone Age, Shell mound

Abstract

The role of coastal regions and coastlines in the dispersal of human populations from Africa and across the globe has been highlighted by the recent polarisation between coastal and interior models. The debate has been clouded by the use of the single term 'coastal dispersal' to embrace what is in fact a wide spectrum of possibilities, ranging from seafaring populations who spend most of their time at sea living off marine resources, to land-based populations in coastal regions with little or no reliance on marine foods. An additional complicating factor is the fact of Pleistocene and early Holocene sea-level change, which exposed an extensive coastal region that is now submerged, and may have afforded very different conditions from the modern coastal environment.

We examine these factors in the Arabian context and use the term 'Blue' to draw attention to the fertile coastal rim of the Arabian Peninsula, and to the now submerged offshore landscape, which is especially extensive in some regions. We further emphasise that the attractions of the coastal rim are a product of two quite different factors, ecological diversity and abundant water on land, which have created persistently 'Green' conditions throughout the vagaries of Pleistocene climate change in some coastal regions, especially along parts of the western Arabian escarpment, and potentially productive marine environments around its coastline, which include some of the most fertile in the world.

We examine the interplay of these factors in the Southwest region of Saudi Arabia and the southern Red Sea, and summarise some of the results of recent DISPERSE field investigations, including survey for Palaeolithic sites on the mainland, and underwater survey of the continental shelf in the vicinity of the Farasan Islands.

We conclude that coastlines are neither uniformly attractive nor uniformly marginal to human dispersal, that they offer diverse opportunities that were spatially and temporally variable at scales from the local to the continental, and that investigating Blue Arabia in relation to its episodically Green interior is a key factor in the fuller understanding of long-term human population dynamics within Arabia and their global implications.

1. Introduction

The role of coastlines and marine resources in the grand narrative of human dispersal and colonisation of the globe has been widely canvassed over the past decade (Erlandson, 2001; Bailey and Milner, 2002; Bailey 2004a,b; Erlandson and Fitzpatrick, 2006; Evans et al., 2014). An earlier generation of thinking saw coastlines as of marginal relevance in the earlier stages of prehistory, and marine resources as too costly or inaccessible to be incorporated into the human economy until a very late period, typically associated with the Holocene explosion of shell-midden evidence around the world from about 7000 years ago onwards. The prevailing assumption was that human populations would only resort to coastal and marine resources when compelled to do so – by population pressure, climate change, decline in availability of mammal and plant resources on land, or some combination of all these processes (Childe, 1925; Washburn and Lancaster, 1968; Osborn, 1977). Although a bias against coastal and marine resources persists, the pendulum of opinion has begun to swing the other way, in some cases to the opposite extreme, with advocacy of marine adaptations invoked as the key stimulus to new patterns of Pleistocene settlement and dispersal, notably in the expansion of anatomically modern humans out of Africa. Here, the hypothesis of a coastal pathway of expansion has been proposed, involving supposedly rapid movement around the rim of the Indian Ocean over a distance of more than 15,000 km from southern Africa to northern Australia involving seafaring and dependence on marine resources, a process believed in some variations on this theme to have taken place at about 60,000 years ago (Stringer, 2000; Walter et al., 2000; Macaulay et al., 2005; Oppenheimer, 2003; Mellars, 2006; Mellars et al. 2013). Apart from the Australian end of the process, the field evidence in support of this hypothesis is almost non-existent. Rather, it takes most of its power from genetic models extrapolated from modern populations, producing results that have been strongly contested, and which have provoked alternative 'terrestrial' models of expansion in which coastlines play little or no role (e.g., Boivin et al., 2013; other papers in this issue).

There are two factors that can fundamentally compromise the validity of interpretation, if they are not taken into account, whether interpretation leans towards the marine or terrestrial extremes of the dispersal spectrum. The first is the overwhelming impact of Pleistocene sea-level change, which we now know has created a pattern in which global sea levels have persisted at depths of at least –40m below present for most of human existence on this planet, periodically reaching to –130m, punctuated by short-lived periods of high sea level like the present. The obvious visibility of coastal sites containing evidence of marine resources at periods of high sea level in comparison with preceding periods of low sea level risks giving this evidence an exaggerated significance, leading to the belief that it represents some revolution in behaviour – a 'postglacial revolution' in the case of mid-Holocene shell mounds, or a 'modern-human revolution' in the case of Last Interglacial (MIS5 and MIS4) African coastal sites – whereas it may indicate no more than the increased visibility of marine resources compared to earlier periods of low sea level with coastlines, marine subsistence and associated archaeological remains all now deeply submerged and lost to view (Bailey and Flemming, 2008). This factor is especially significant in the Arabian case, given the relatively shallow areas of continental shelf that would have been exposed at low sea level as extensive areas of terrestrial landscape in the southern Red Sea and the Arabian-Persian Gulf (FIGURE 1). Not only are the shorelines formed at lower sea level now deeply submerged and a long way off shore, but extensive areas of terrestrial landscape of potential significance to Pleistocene settlement and dispersal are also now submerged and hidden from view.

A second factor is the variable and often vague use of the term 'coastal'. This may be used to refer to the shoreline in its narrowest geographical sense – a littoral zone comprising the intertidal and the immediately adjacent beach – or to a larger region of indeterminate extent extending for some kilometres inland, subject to the influence of ecotones at the boundary of terrestrial and marine ecosystems, high water tables, and the ameliorating conditions of oceanic climate, conditions which may extend for tens or even hundreds of kilometres inland. Or it can include an area to seaward of the shoreline including offshore marine resources, islands, and opportunities for sea travel. Similarly, coastal economies may range at one extreme from 'boat economies', where people spend a large part of the year at sea living off fish and marine resources, to land-based economies in coastal regions, which make little or no use of the marine resources at the shore edge.

Between these extremes, there is a range of economic possibilities involving varying combinations of marine and terrestrial resources and varying arrangements for combining them, including sedentary settlements with terrestrial and marine resources within easy reach, seasonal movements between coast and hinterland, and trade or exchange between marine-based and inland communities. Moreover, the patterns of dispersal associated with these different economic patterns may be quite different. Maritime colonisation of newly exposed coastal territory along the Norwegian coastline 10,000 years ago, following the melting of the Scandinavian ice sheet, suggests that these pioneer marine specialists expanded over a distance of 3000 km within a period of 300 years or less (Bjerck, 2008), at least one order of magnitude greater than rates of dispersal associated with terrestrial-based hominin expansion (Van der Made, 2011). Lumping all these variants together as examples of 'coastal' economies, 'coastal' settlement or 'coastal' dispersal risks reliance on generalisations so broad as to be lacking in useful intellectual or analytical content.

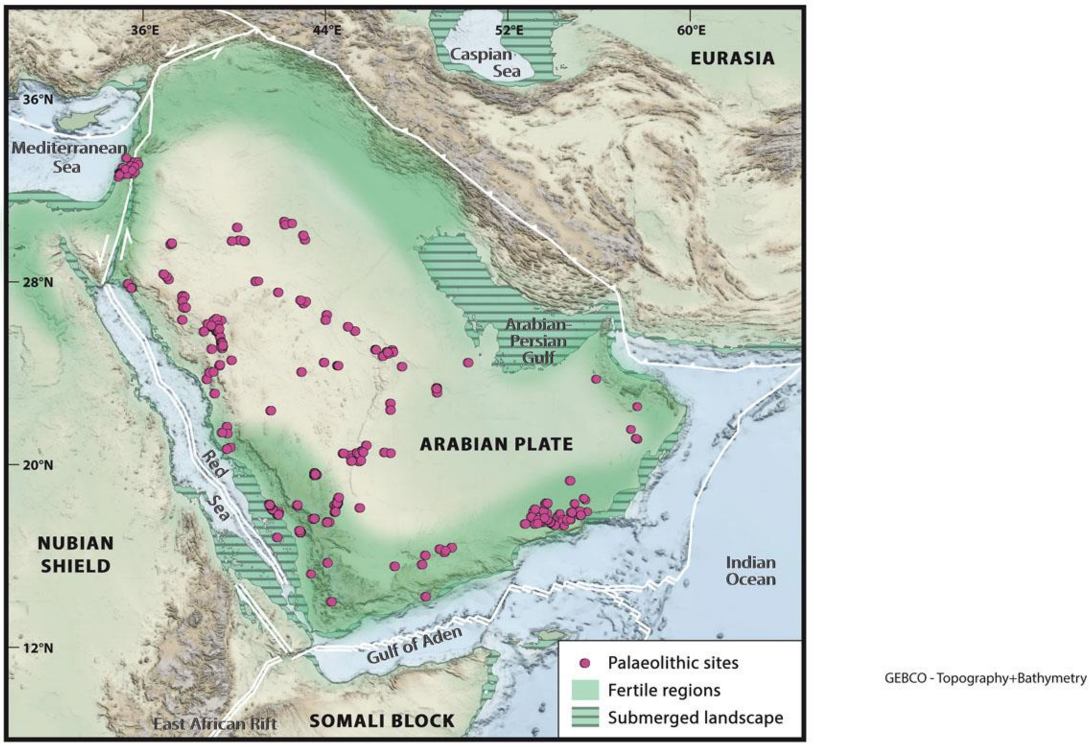

Figure 1. General map of the Arabian Peninsula and adjacent areas, showing the distribution of the most attractive areas for human settlement under present-day climatic conditions and the extent of the submerged landscape. The Red Sea opening is the result of counterclockwise rotation of Arabia with respect to the African plate. Sea-floor spreading during the last 5 million years has created a well-developed axial trough in the southern Red Sea, between 15°N and 20°N (Girdler and Styles, 1974; Roeser, 1975; Cochran, 1983; LaBreque and Zitellini, 1985; Bosworth et al., 2005; De Mets et al., 2010). Current total spreading rates determined from magnetic anomalies reach a maximum of 15–16 mm per year (Roeser, 1975; Chu and Gordon, 1998). South of 13°N, extension is 20 mm per year. In this region, opening is accommodated by the Danakil Depression (Mc Clusky et al, 2010). and has had no impact on the width of the narrow marine strait formed at lowest sea level between the Hanish Sill and the Bab al Mandab, as confirmed both by deep-sea isotope analysis (at least during the past half million years, Siddall et al., 2003) and modelling of palaeoshorelines (Lambeck et al., 2011).

In this paper we examine these issues in relation to recent fieldwork investigations in the coastal regions of SW Saudi Arabia (FIGURE 1) carried out as part of the DISPERSE Project (Bailey et al., 2012a). We have chosen this area because it is one of the more fertile regions of the Arabian Peninsula, with ecological diversity and relatively high rainfall, and because of its proximity to Africa across what would have been a relatively narrow sea channel dotted with islands for long periods of low sea level during the Pleistocene, creating a relatively easy pathway of movement across the southern end of the Red Sea (Lambeck et al., 2011). The region also has an extremely rich archaeological record of mid-Holocene marine sites on the Farasan Islands, which provide a point of reference for extrapolation back into earlier periods.

We present the background to the DISPERSE Project, its main objectives and the role of the Arabian work within its wider remit, summarize the principal environmental attractions of the SW region, present the preliminary results of recent Palaeolithic survey on land, and underwater exploration in the vicinity of the Farasan Islands, and consider the further implications for wider interpretation of dispersal patterns.

2. The DISPERSE Project

The DISPERSE Project builds on two strands of earlier investigation, one concerned with the impact of sea level change and submerged landscapes on the potential connections between Africa and Arabia (Bailey et al., 2007a, 2007b; Lambeck et al. 2011), the other with the impact of active tectonics on the early landscapes of human evolution (King and Bailey, 2006; Bailey and King, 2011; Bailey et al., 2011; Reynolds et al., 2011). Both focus on geological instabilities of different sorts, and their impact on the formation and deformation of the physical landscapes associated with early human activity, and the preservation and visibility of archaeological and fossil evidence. Both sorts of instabilities are dominating features of the regions of earliest human evolution in Africa and the main axes of early dispersal into western and southern Asia and southern Europe, an association that suggests a relationship that is more than mere coincidence, and more than a simple product of differential visibility of evidence.

The geological instabilities that we are interested in are typically associated in the popular imagination with destructive impacts. Earthquakes, volcanic eruptions and flooding associated with tsunamis or sea-level rise can all have devastating consequences both locally and in the short term, and over longer periods and larger areas, the latter especially so in the case of massive volcanic eruptions, which have been invoked in causing major climatic changes (Ambrose, 1998). Progressive sea level rise can also lead to cumulative long-term loss of very extensive territories where the continental shelf is shallow.

All these processes can also destroy or obscure archaeological evidence. Earthquakes and volcanic eruptions can bury material under sediments or lava flows or destroy it completely. Sea-level rise at the end of the Last Glacial period has played a major role in removing from view, and perhaps destroying, whole landscapes and their associated archaeological evidence, submerging not only shorelines and coastal sites but large areas of terrestrial hinterland. Indeed, given that so much of the evidence of the early stages in human evolution and dispersal is associated with tectonically active and coastal regions, one might be forgiven for doubting if any reliable spatial or geographical patterning can be inferred at all from the surviving evidence.

However, not all is destruction. All these processes have an obverse and potentially constructive effect. Repeating earthquakes on fault zones can create and accentuate basins that trap water and sediment, and activate or re-activate spring lines, concentrating and renewing conditions of localised fertility and water supply. They also create a complex topography of barriers, bottlenecks and enclosures of varying size that afford tactical advantage in pursuit of prey or escape from predators. Volcanic lava flows can have similar effects in trapping sediments, renewing soil nutrients and creating minor barriers. Even cumulative sea level rise, which would appear to be largely negative in terms of its human impact, may in the long run have positive effects on the marine fertility of inshore waters, creating shallow shelves and inlets in place of steeply shelving offshore topography, thereby facilitating the recycling of nutrients from the seabed to the photic zone at the surface and increasing the productivity of marine resources.

Also, the dynamic cycles of sedimentation and erosion that occur at coast edges and in regions of active tectonics can bury and thus preserve material, and subsequently re-expose it again, facilitating ease of discovery.

Nevertheless, the relationship between geological processes and the differential preservation and visibility of material remains is undoubtedly complex and does not lend itself to simple generalisation without detailed investigation of particular cases. Even so, the sea level rise at the end of the last glaciation should probably stand in a category of its own, since whatever evidence may have been preserved on or beneath the seabed is now mostly far removed from view or easy access, creating a very large gap in the archaeological record

These considerations have led us to formulate three working hypotheses as the basis for further investigation: (1) that geologically unstable landscapes have acted as a positive driver of the human evolutionary trajectory, selecting for or reinforcing many of the traits that characterise the evolution of the *Homo* lineage – the 'tectonic landscape model' or 'complex topography hypothesis' (Reynolds et al., 2011; Winder et al., 2013); (2) that marine and coastal resources have a much deeper history extending far back into the Pleistocene than conventionally allowed for; and (3) that the now submerged landscapes that occur in many parts of the world are hiding some of the most important evidence of human evolution and early prehistory, not only in relation to the question of early coastal and marine adaptations, but to the use of large areas of terrestrial landscape that were arguably amongst the most attractive for early human populations and likely to have supported some of the highest population densities.

3. Another Fertile Crescent?

For 100 years, the concept of a Fertile Crescent, a term first introduced by James Breasted in 1914 (Breasted, 1914: 56–57), has dominated thinking about the dynamics of Old World Civilization. This region of the Near East has been regarded as a uniquely favoured environmental zone of attractive climate and resources extending from the Levantine coastal regions bordering the Mediterranean around the foothills of the Taurus and Zagros Mountains as far as the head of the Arabian-Persian Gulf and including the floodplains of the Jordan and the Tigris-Euphrates Rivers – a focal centre of cultural innovation since at least the beginnings of plant and animal domestication (FIGURE 1). Even for earlier periods of human evolution, when the current evidence indicates Africa as the main centre of origin, the Fertile Crescent has been seen as continuing to exert a powerful gravitational pull as the primary conduit of population dispersal out of Africa into Europe and Asia.

In fact there is another Fertile Crescent, a southern version of its better known northern neighbour, extending around much of the rim of the Arabian Peninsula. Like its northern counterpart, this southern Crescent is characterised by high levels of orographic rainfall associated in particular with the mountains of the western Arabian escarpment, and sediment-filled intermontane valleys. As in the North, so in the South this green zone forms the perimeter of a desert core, and would periodically have expanded into this arid core during periods of Pleistocene climatic amelioration. In contrast to the north, the rainfall catchment was neither large enough nor the amount of rainfall sufficient to sustain permanent rivers like the Jordan, the Tigris and the Euphrates. Nevertheless, parts of this southern Fertile Crescent are permanently green under almost all climatic conditions, especially in the SW region, and especially in the inner coastal plain and foothills, which support a productive agriculture. Indeed, the SW region of Saudi Arabia is famous as the 'bread basket' of the Kingdom. During the unusually wet conditions of the winter of 2013–14, water flowed abundantly in the stream courses of the mountains and foothills, and the coastal plain was transformed into green pastures grazed by flocks of sheep as far as the eye could see. We surmise that this region would have maintained its attractions as a 'green zone' in the Arabian Peninsula under all climatic regimes including those periods of wetter climate when green conditions extended widely across the whole Peninsula (Rosenberg et al., 2013).

We note two other features of this Arabian Crescent. The first is that, particularly on its western arm, it is characterised by a mountain chain associated with volcanic and tectonic activity and complex topography in close proximity to smoother terrain capable of supporting large herds of large mammals. In this regard, it is very similar to much of the northern Crescent. As we have pointed out elsewhere, these conditions also characterise the landscapes and environments of early human evolution in East Africa, and we have argued that this combination of environmental conditions is a key factor in the early African evolutionary trajectory, and that its distribution can be mapped to identify the main pathways of human expansion out of Africa followed by the *Homo* lineage after about 2 million years ago (Winder et al. in press).

The second feature, which is in marked contrast to the northern Crescent, is the presence around the Arabian coastline of very fertile marine waters, supporting highly productive inshore fisheries, shellfish beds, and marine resources generally (FIGURE 2). Indeed the marine productivity of the region is amongst some of the highest in the world. In contrast, the Mediterranean as a whole is one of the least productive regions in the world because of limited tidal movement and poor circulation of nutrients, with the eastern Mediterranean at the lower end of the productivity gradient.

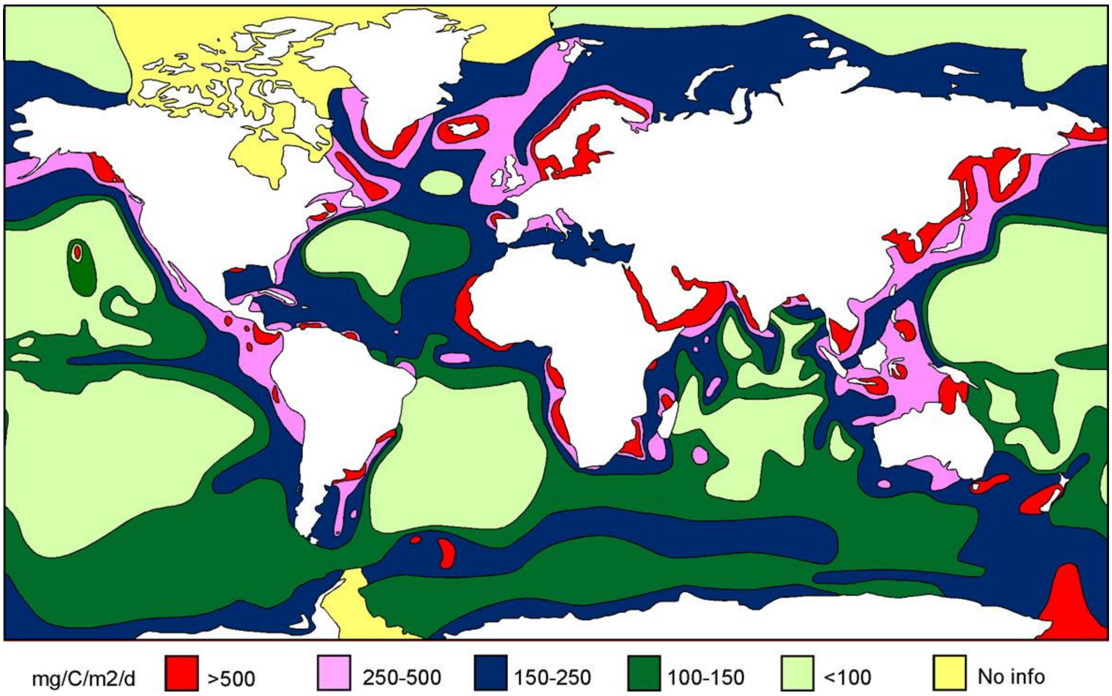

Figure 2. Differential fertility of the world's oceans under present-day conditions based on measurements of primary production. After Tait and Dipper (1998). Climatic changes associated with the glacial-interglacial cycle may have modified the pattern in some regions because of changes in ocean currents, but these changes are not relevant to the Arabian region, and the broad pattern of relative differences between ocean basins at a world scale is thought to be valid throughout the period under discussion here. Reduction in the extent of the shallow shelf at low sea level and restriction of inflow from the Indian Ocean possibly had some local and small-scale effects on Red Sea fertility particularly in the North (for further discussion see Bailey, 2009).

From the point of view both of climate and of complex topography, the SW region of the Arabian Peninsula is one that we would expect to be very high on the list of regions that first attracted hominin populations expanding out of Africa, an attraction further reinforced by its proximity to the Ethiopian Rift. We should expect early dates, long archaeological sequences indicating continuous settlement, and relatively high population densities, regardless of whether or not marine resources were part of the subsistence economy.

We do not rule out the possibility that the Arabian Peninsula and perhaps wider areas of Asia were part of the 'cradle' of human evolution (see also Dennell, 2009). As our maps of the southern Red Sea make clear, Africa and Arabia were separated by a long, narrow and shallow sea channel that persisted for tens of thousands of years at periods of low sea level, and represents no more of a barrier than a major river (Lambeck et al., 2011). The placing of a continental boundary here reflects an arbitrary concept open to challenge rather than an immutable physical fact, so too does the notion that dispersal across this boundary represents a qualitatively different type of process from dispersal within Africa or elsewhere.

The only potential inhibition to realising these attractions is the separation of the African and Arabian coastlines by the southern channel of the Red Sea, which at its narrowest under present-day conditions requires a sea crossing of nearly 30 km across the Bab al Mandab.

However, as we have also shown elsewhere (Bailey et al., 2007, Bailey, 2009; Lambeck et al., 2011), this crossing would have been much narrower for long periods of the Pleistocene, at almost any time when sea level was lower than about –40m in relation to the present day, forming a long and narrow channel and the shortest crossing point in the vicinity of the Hanish Sill, with intermediate islands that would have facilitated sea crossings over distances no greater than about 3–4 km. Of course, even without sea crossings the SW Arabian region could have been reached from Africa via the Nile Valley and the Sinai Peninsula to the North, albeit by a much longer route.

There is a paradox here, however, and that is that the very fact of sea level change that made the southern channel more easily crossable would also have exposed extensive lowland territories for colonisation by plants, animals and humans, which were then subsequently drowned. These submerged landscapes could represent a key zone for human settlement, and a fuller picture is unlikely to emerge without their investigation.

4. Palaeolithic Survey in SW Arabia

The starting point for any comprehensive discovery and interpretation of Palaeolithic archaeology at a regional scale must be a detailed investigation and understanding of the underlying geological processes that have shaped the physical landscape and its various geomorphological transformations over time. The major factor in our region is the opening of the Red Sea over the last 30 million years. This has been associated with deepening of the Red Sea graben and uplift of the Arabian escarpment, with successive episodes of tectonic deformation and magmatism, some of which have been active over the last 2 million years, with major impact on the evolution of the physical landscape during the timespan relevant to human occupation. Superimposed on this is the effect of changes in sea-level and climate, usually operating over shorter time scales. Together these processes have determined the differential availability of key resources for human occupation, including raw materials for stone tools, water supplies, and the differential productivity of different areas in terms of soil fertility and terrain and their capacity to support plant and animal life. These same processes also have a major bearing on the differential preservation and visibility of archaeological material.

Prior to survey, satellite imagery (LandsatGeoCover 2000/ETM+ Mosaics and imagery accessed through Google Earth imagery) and DEMs (ASTER GDM v2 and SRTM 90m v4.1) were used to define broad-scale landscape zones, followed by four spells of more detailed ground survey (Devès et al., 2012, 2013; Bailey et al., 2012b; Inglis et al., 2013; 2014a, b). Offshore, we have conducted localised diving exploration in the Farasan Islands to search for underwater shorelines and shell middens (Bailey et al., 2007a, 2007b, Alsharekh and Bailey, 2014; Momber et al. 2014), and more extensive mapping over larger areas using remote sensing and coring (Sakellariou et al., 2013). On this basis, we have identified seven broad landscape zones within the study region, with differing potentials for early human occupation (Devès et al., 2013, FIGURE 3). These are distributed across the provinces of Jizan and Asir and their offshore territories and comprise the following:

(1) The Lower Coastal Area, a relatively flat area with blanket cover of Quaternary sediments.
(2) The Upper Coastal Area, comprising steeper slopes and basement rock overlaid in places by alluvial fans.
(3) The ‘magmatic line’, a ridge of low hills comprised of schists and Quaternary volcanics with some Miocene dyke intrusions, which separates zones (1) and (2).
(4) The Harrat Al Birk, to the NW of the Lower Coastal Area, dominated by volcanic cones and basaltic lavas extending to the coast, and penetrated by wadis with alluvial sediments connecting the coast to the remoter hinterland.
(5) The mountain escarpment and its foothills, with steep valleys and eroded hillsides, and a geology dominated by schists with smaller outcrops of sandstone and granite.
(6) The Arabian Plateau, sloping gently to the East from the watershed of the escarpment

(7) The now-submerged offshore landscape including the Farasan Islands, with bedrock composed of limestone, evaporites and cemented coral, but with little known in detail about its geology or topography.

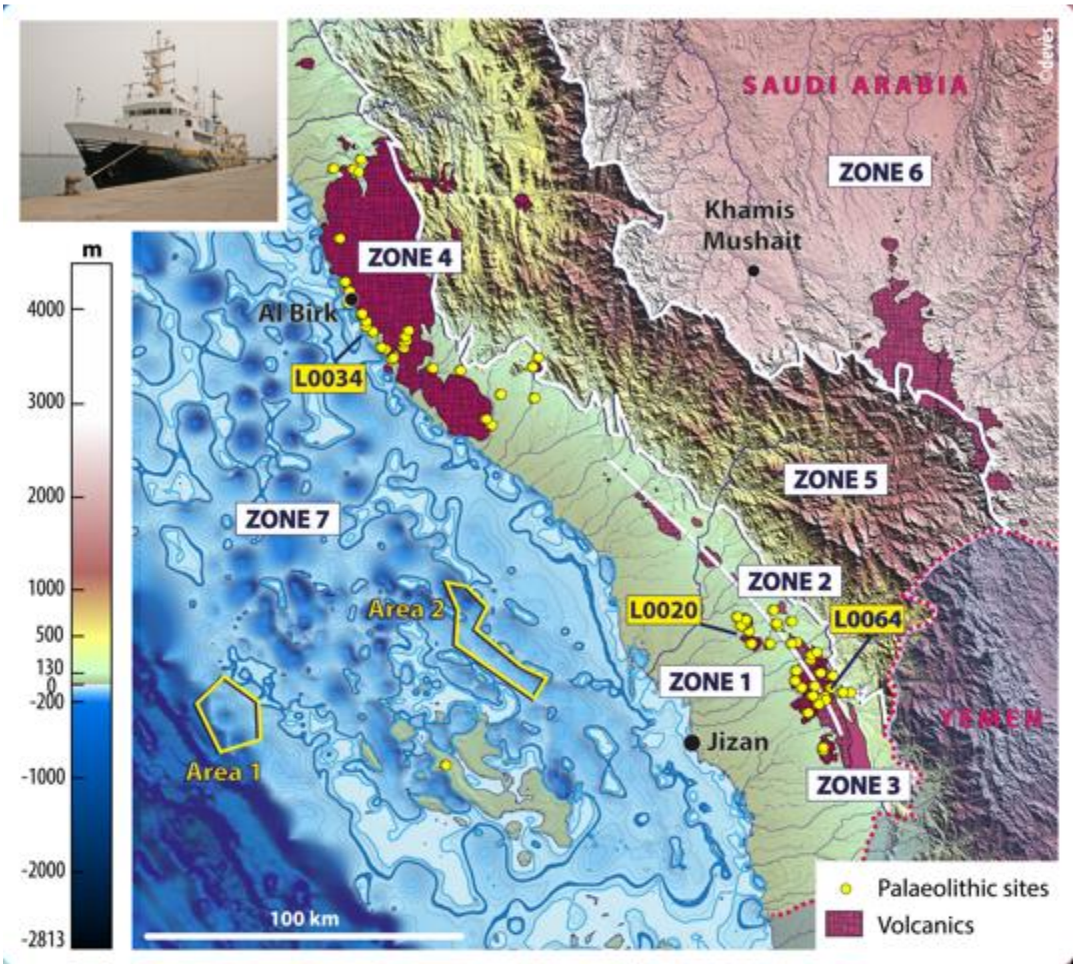

Figure 3. Map of SW Saudi Arabia, showing principal landscape zones, distribution of archaeological localities, general overview of shelf bathymetry, targets for underwater survey and other features mentioned in the text. The light blue area offshore shows the area exposed at sea levels of -120m, and the dark blue line encloses areas of land at -20m. Terrestrial elevation data from CGIAR-CSI SRTM 90m v4.1 database and ASTER-GDEMv2, bathymetry from GEBCO_08 30 arc-second grid. ASTER-GDEM is a product of METI and NASA. Inset photo: R/V AEGAEO birthed in Jizan port, 2013. Photo by D. Sakellariou.

We have sampled all seven zones in our survey strategy, though with most emphasis so far on Zones (1), (2) and (3) on land because of time and access constraints, and Zone (7). We have also used as a starting point the results of the Comprehensive Archaeological Survey Progamme (CASP) of the 1970s (Zarins et al., 1979, 1980, 1981), which first highlighted the potential richness and time depth of the Palaeolithic record in the region.

4.1. Palaeolithic Survey on Land

A primary objective of our survey is to map the differential distribution of human activities across the landscape at a regional scale and through time. Of necessity, this objective must rely on the distribution of stone artefacts as a proxy. Understanding the relationship between the two types of distributions poses formidable challenges – of differential preservation, visibility, chronological resolution and survey intensity. Our survey strategy has been designed to highlight these issues and control for them where we can, while also producing information on broad trends.

4.1.1. Survey Strategy and Methods

In seeking geographical patterning, the major problem we face is that the great majority of discovered artefacts are surface finds that can be dated only in very broad terms. We are mindful of the fact that we are dealing with a regional palimpsest with much loss or mixing of material through a time depth of 1 million years or more, and with a record that is generally of low resolution (Rossignol and Wandsnider, 1992; Bailey et al., 1997; Bailey, 2007; Fanning et al., 2009, Holdaway and Fanning, 2010; Holdaway and Douglass, 2011). The technological and typological character of the tools themselves may provide chronological clues, but these depend on assumed correlations with stratified and dated material elsewhere, and provide only very broad indications of date. The date of the geological or sedimentary surfaces on which stone tools sit may provide another set of clues, but will only provide at best a maximum possible date. Archaeological material buried in sediments that can be dated provides an important control on chronology, and the search for stratified sites is an important objective of our survey strategy. But these sites are rare, and subject to the chance discovery of artefacts in sections exposed through buried deposits.

Another problem is the geomorphological controls on the accessibility of the record. Large areas of Palaeolithic land surface in our survey region are buried under thick Holocene sediments, particularly in the Lower Coastal area. Equally, this area is also subject to a massive multi-billion dollar investment by the Saudi government in new cities, roads and infrastructure, resulting in extensive quarrying and earth removal, which has exposed earlier land surfaces and sediments in numerous geological sections, but has probably destroyed many sites as well. Sections exposed by wadi-erosion through the overlying sediments provide another window into the Palaeolithic land surface.

Areas with extensive outcrops of volcanic material may also bias the geographical distribution, since these are likely to provide a focus for survey and easily discovered artefacts because of the attractions of basaltic lava for stone-tool manufacture. At the same time, other raw materials are widely available in the region including andesite, quartzite, and fine-grained sedimentary rocks, so that raw material does not seem to be an overall limiting factor at the regional scale on where artefacts are likely to be found (Inglis et al., 2014a). As a counterbalance to this potential bias, we have also deliberately targeted other types of geological substrate, notably the schists, which are extensive in the region. The time available to sample the whole region to gain an overview, and the search-time and search-intensity devoted to individual locations, represent conflicting requirements in the design of any survey strategy and additional sources of potential bias.

Some of these confounding variables can be untangled by carefully designed search strategies, using a mix of judgemental and systematic sampling of different landscape zones. We are also combining satellite imagery, DEMs and field observations of different geomorphological settings and landforms within individual landscape zones to refine understanding of taphonomic processes affecting the record, to guide survey, and to aid interpretation of site distributions.

In selecting target areas, we concentrated on areas of low sedimentation and high potential for visible surface archaeology, areas that have previously yielded evidence of early stone artefacts, and areas that have potentially attractive geological, geomorphological and topographic conditions for human occupation and the preservation and visibility of archaeological evidence. We also briefly sampled landforms assessed as low in archaeological potential (e.g., areas of Holocene sedimentation). Within these areas we targeted exposed bedrock on a variety of geologies, as this has high potential for the preservation of surface artefacts in relatively undisturbed position, and elevated terrain providing a good view over the surrounding landscape, as previous experience in this region and elsewhere has shown that this affords attractive vantage points for prehistoric people. We also targeted key geomorphological features for dating landscape evolution, such as raised beach terraces and sections in quarries, and scanned accessible sections for the presence of stratified artefacts. To access these areas, we used a four-wheel drive vehicle and then slowly traversed the terrain on foot with team members spaced at 5–10m intervals walking along transects of 100–500m distance, sometimes further depending on local circumstances.

4.1.2. Preliminary Results

We have visited over 90 localities in the Jizan and Asir Regions, and have recorded and analysed 1800 stone artefacts (FIGURE 3; Inglis et al., 2013; 2014a,b). Given the sources of potential bias discussed above, here we attempt only a very broad characterisation of the material. We use the term 'locality' to refer to any recorded location, whether or not it yielded artefacts. Localities with larger numbers of artefacts most likely represent time-averaged palimpsests of material, and may indicate preferred locations repeatedly used over long periods of time associated with attractive concentrations of resources. But we do not attempt at this stage any further interpretation of the function of a locality or the specific behaviour implied by the number and type of artefacts observed there

In terms of geographical distribution, survey centred on the inland wadis and volcanic areas of the Lower and Upper Coastal Plains and on the coast in the Harrat Al Birk region. Little time was spent in the heavily-eroded interior of the escarpment and its foothills, where archaeological material was not expected to survive in situ. Likewise, little time was spent investigating the areas of Holocene sedimentation on the Lower and Upper Coastal Plains, except around low jebels and lava flows rising above the blanket of sedimentation, and in quarries and wadi cuts.

Analysis of the archaeological information from the localities visited is ongoing, but preliminary observations can be made. Out of 89 localities visited between 2012 and 2014, 67 yielded lithic artefacts, with only 11 of these lacking diagnostic pieces. We have used very broad characterisations of the material based on the close similarities in appearance to artefacts in Eastern and Southern Africa. Early Stone Age is identified by the presence of cleavers, handaxes and large cutting tools, Middle Stone Age by prepared cores including Levallois and discoidal types and their retouched products, Late Stone Age by bladelets and small blade cores. Localities with MSA artefacts had the most widespread distribution (47), with ESA and LSA artefacts at 31 and 11 localities respectively.

The Jizan and Asir regions possess abundant materials suitable for lithic reduction in the form of volcanic basalts and andesites, such that access to raw materials is almost never a significant factor necessitating careful economy of resources or transport over long distances. The exception is some obviously non-local materials such as cherts, which indicate extensive maintenance and transport, and these are usually LSA in character. The vast majority of the ESA and MSA artefacts and accompanying debitage indicate the preparation of core forms using nodules or clasts selected carefully from the range of shapes available to facilitate easy reduction. Prepared cores show little evidence of regular maintenance prior to discard. Retouch of flake blanks is also minimal, but there is a full range of retouched tool types including burins, piercers and points in MSA assemblages.

Although most artefact-bearing localities are associated with volcanics and lava flows, geomorphological factors are not the sole determinant of their distribution. Around Wadi Jizan, localities in the centre of the lava flows yielded very few, if any, artefacts, whereas localities at the edge yielded more, especially in locations commanding views over water and the surrounding plains (Inglis et al., 2014a). L0006 is located on a flow above the Wadi Jizan dam lake with good views over the convergence of the five wadis that feed the lake, and which flowed through this area in the past. Over 80 MSA and LSA lithics on basalt, chert, andesite and quartz were collected from the locality, more than any other locality in the lava fields of this region, indicating a persistent attraction.

Two inland localities contained stratified artefacts. At L0020, a quarry near Wadi Sabiya, a worked shale clast with three long, soft-hammer blade removals indicating MSA technology, was found in a section through wadi channel deposits (FIGURE 4(a). A date for a volcanic tuff overlying these deposits of 0.44±0.26 mya is considered unreliable (Dabbagh et al., 1984a), and the results of new OSL and Ar/Ar dating are awaited.

At L0064, in a quarry adjacent to a tributary of Wadi Jizan, a single discoidal flake on reddish coarse chert was discovered protruding from fine grained floodplain sediments underlying a lava flow (FIGURE 4 (b). Ar/Ar dating samples have been taken and results are awaited to see whether they are comparable to nearby flows in the Wadi Jizan dated to 0.8±0.3mya (Dabbagh et al., 1984a).

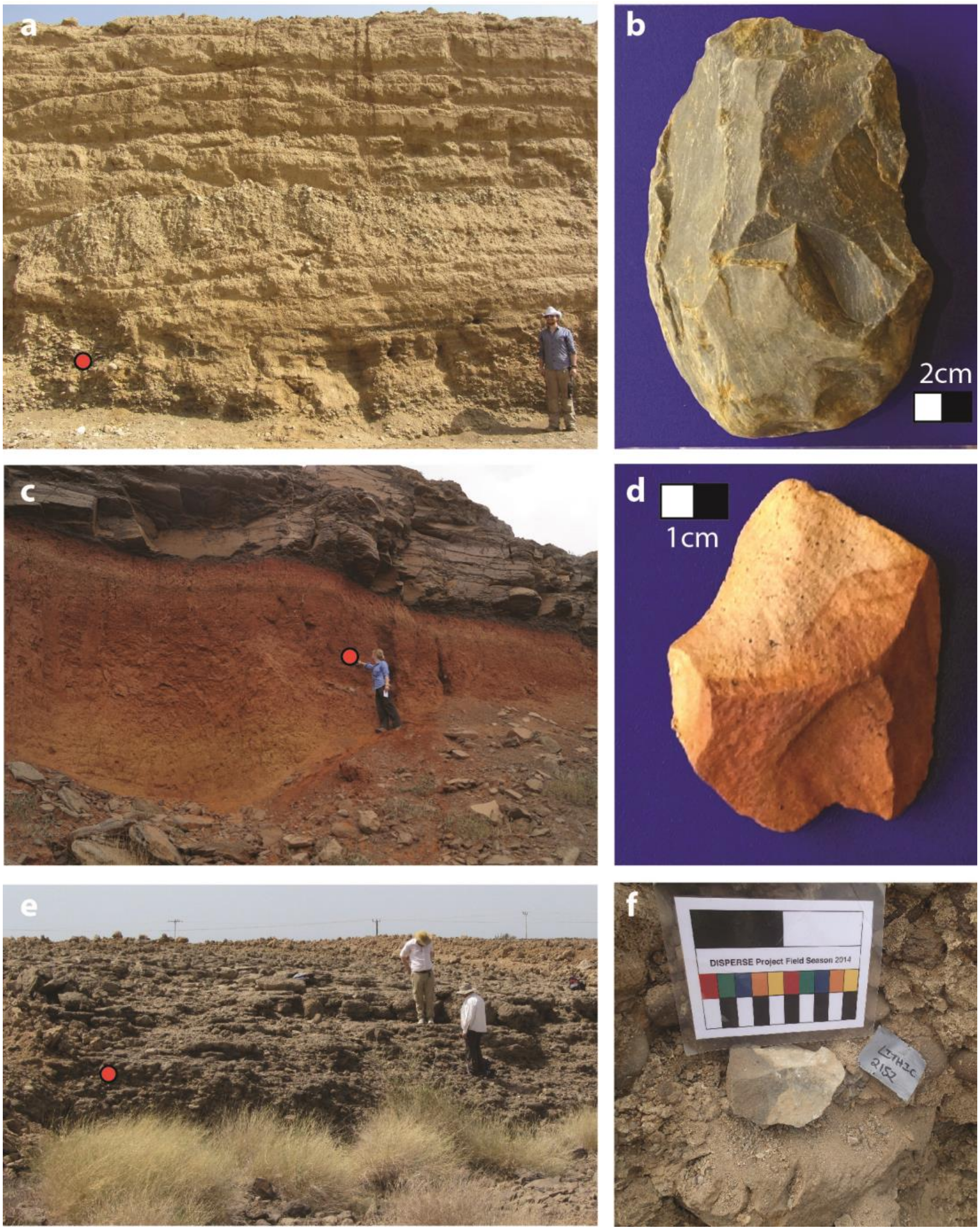

Figure 4: Locations with stratified artefacts discovered by DISPERSE survey. (a) Section through wadi channel deposits at L0020, Wadi Sabiya showing location of worked shale clast (b) (Photos: R. Inglis and A. Shuttleworth); (c) Section through wadi floodplain deposits below lava at L0064, Wadi Jizan tributary, showing location of chert discoidal flake (d) (Photos G. Bailey and A Shuttleworth); (e) Section through beach deposits and underlying wadi cobble unit at L0034, Dhahaban Quarry, showing location of one (f) of 19 andesite flakes removed from within cobble unit (Photos: R. Inglis and A. Sinclair).

On the coastline of the Harrat al Birk, we have recorded 10 localities with ESA and MSA artefacts on coral terraces and raised beaches, replicating the results of the CASP survey

(Zarins et al 1981). Of these, the Dhahaban Quarry locality (L0034) on the modern coastline is of particular importance. Here there is an aeolianite, fossil beach and coral terrace complex, much damaged by quarrying, that extends for c. 1 km along the base of lava flows. At +8m asl, the raised beach complex is consistent with an MIS 5 date (Lambeck *et al.* 2011), and dating samples are under analysis to check this. The locality yielded ~400 more lithic artefacts from the surface of the quarry and surrounding lava flows, with ESA, MSA and LSA characteristics. In one area of the quarry, in a section exposed by a small wadi draining the lava flows, a cemented cobble unit deposited as an alluvial fan or small delta is overlain by layers of fine beach shell sand grading into aeolianite, indicating a high sea stand (FIGURE 4 (c). A total of 19 andesite lithics with MSA affinities, relatively sharp, were recovered from within the cobble unit, indicating their deposition close to or within the wadi prior to inundation by sea level rise. This site therefore potentially acts as evidence for exploitation of the immediate coastal environment, even if it stops short of providing evidence for the use of marine resources.

4.2. The Submerged Landscape of the Southern Red Sea

We have drawn on a variety of sources of evidence for this phase of investigation, including available bathymetry as a first order characterisation of the buried land surface, diver inspection, acoustic survey and coring of sediments. The area involved is extensive, at least 30,000 km^2, and even on the basis of available low-resolution bathymetry indicates a complex topography (FIGURE 3). This is the result of extensive diapirism (upward movement) of massive Middle to early Late Miocene evaporites, salt deposits formed when the Red Sea was a closed basin, along with extensional, rift-related faulting (Purser & Bosence, 1999). Regional uplift due to salt diapirism, and solution of near-surface salt domes to create deep sinkholes, are widespread processes in the southwest Saudi Arabia lowland (Jizan area), the Farasan archipelago (Bantan, 1999) and the Saudi Arabian continental shelf, as well as on the opposite Dahlak Archipelago on the Eritrean continental shelf (Carbone et al, 1999, see also Hudec and Jackson (2007) for a general description of the processes involved).

4.2.1. Survey Strategy and Methods

Organising more detailed survey over such an extensive area of variable seabed topography poses formidable logistical challenges, and we have been constrained by the variable availability of suitable equipment and vessels. In our earliest investigations (in 2006) we used diver inspection to establish the presence of submerged palaeoshorelines at a variety of depths, easily recognisable as low cliffs of cemented coral with an undercut notch formed by marine erosion, very similar to features visible at the modern shoreline (Bailey et al., 2007a,b). We have continued shallow-water diving in 2008, 2009 and 2014 to explore these features and to search for archaeological traces of activity in the form of shell deposits comparable to the mid-Holocene shell middens present on the modern shoreline, but so far without definitive results (Sakellariou et al., 2013; Alsharekh and Bailey, 2014; Momber et al., 2014).

In 2013, the presence of the R/V AEGAEO in the Red Sea, purpose built for underwater survey, offered the opportunity to undertake more extensive investigations including coverage of deeper areas of the shelf. Targets of particular interest selected for investigation are the shorelines that would have been formed at different sea-level stands during the glacial cycle, major valley systems and drainage channels, areas of topographic complexity that might have trapped sediment and water and provided ecological diversity and tactical advantage, and deep solution hollows resulting from the withdrawal or solution of salt diapirs, which would have formed potential traps for sediment and freshwater when exposed on the pre-inundation land surface.

We chose two target areas with the aim of sampling a number of different types of geological and environmental features on the seabed, and with an eye to locations suitable for the discovery of archaeological material based on our knowledge of archaeological site locations on the mainland and on the Farasan Islands discovered in our previous fieldwork campaigns (FIGURE 3).

Area 1 is on the outer edge of the shelf. Here we expected to find relatively limited cover of later marine sediments over the original terrestrial land surface, with the possibility of identifying the shoreline formed at the Last Glacial Maximum (at c. –120 m and 20,000 BP), and of finding spring lines – often located at the foot of low cliffs and fault scarps – and sediment-filled basins that show the transition from marine to terrestrial sediments in the early stages of sea-level rise. Area 2 on the inner shelf is an area with a major valley system and complex topography that appears to drain into a deep solution hollow. This could have been a freshwater trap at lowered sea level, and may contain a sediment sequence showing the transition from marine to terrestrial/lacustrine conditions with changing sea levels.

The marine survey conducted in the Farasan area aboard R/V AEGAEO comprised a wide variety of geological-geophysical techniques. Swath bathymetry (multi-beam) mapping was performed by using two hull-mounted multi-beam systems (20kHz and 180 kHz) operating simultaneously. High-resolution sub-bottom profiles were acquired with a 3.5 kHz pinger to obtain precise images of the structure and stratigraphy at shallow depths (<20m) below the seafloor. Mapping of the acoustic character of the seafloor was implemented by using a deep-towed, 110/410 kHz, digital side scan sonar. Acoustic images (sonographs) of the seafloor helped to better understand the various structures exposed on or developed on the seafloor. Deep penetrating seismic profiles were recorded with a 10 cubic inches airgun. Penetration of the profiles reached locally >500–800m below the seafloor and provided insight into the geological and tectonic structure of the surveyed area. Gravity cores, 3–5m long, were used for coring and sampling the sub-seafloor sedimentary layers. A box core, 40 x 40 x 60 cm, was used to take undisturbed samples of the topmost seafloor sediments. A CTD device was used to obtain vertical profiles of the physical parameters of the seawater column (sound velocity, temperature, salinity, density, conductivity). A remotely operated vehicle (ROV) was used for underwater missions at sites identified from the bathymetric, acoustic and profiling data, aimed at inspecting visually seafloor structures of morphological or archaeological interest.

4.2.2. Preliminary Results

An area of about 500 km^2 of the seafloor in Areas 1 and 2 (FIGURES 5 and 6) was covered with multi-beam bathymetry during the 12 days of the cruise. A total length of 170 nautical miles (315 km) of airgun seismic profiles, 250 nautical miles (460 km) of 3.5kHz sub-bottom profiles and 140 nautical miles (260 km) of side-scan sonar tracks were acquired, 20 gravity and box cores recovered, and 5 dives of the ROV Max Rover accomplished.

Area 1 indicates two prominent terraces at about 75–80m (FIGURE 7) and 38–40m depth on the shelf and one more, locally preserved terrace at 120m depth on the slope. The outer edge of the continental shelf is controlled by normal faults trending NW–SE, parallel to the rifting axis of the Red Sea. Elongate ridges, running parallel to and off the shelf edge, are characterized by steep faulted slopes and flat, 80–90m shallow tops. They were exposed above sea-level during Pleistocene low sea-level stands, forming a series of flat-topped islands, the ‘prehistoric Farasan Archipelago’, separated from the palaeo-coastline of the mainland by deep troughs. Holocene sediment deposition on the shelf is very limited. Sedimentological description of cores indicates Late Pleistocene, lacustrine-type sedimentation below the Holocene marine deposits in the isolated depressions formed on the 80m-deep terrace,

Area 2 comprises a 120m deep, elongate basin bounded by NW–SE trending normal faults and incised on a prominent 70–75m terrace of the inner shelf. One other morphological terrace has been mapped along the flanks of the basin at about 112m depth. Gravity coring in the basin penetrated the Holocene marine drape and recovered gypsum fragments from the substrate at about 2–2.5m below the seafloor. A narrow gorge on the seafloor, at the north-western tip of the valley-like basin (FIGURE 8), connects it with a >200m deep, circular depression, which hosts a >250m thick sedimentary sequence. Preliminary laboratory analyses on sediment cores from the deep depression reveal lacustrine-type sedimentation below the 1–2m thick marine silt. This observation indicates that the numerous, circular or elongate depressions, which occur on the shelf along NW–SE trending faults and have formed due to the withdrawal or solution of Miocene salt domes, may have been lakes during Pleistocene low sea-level stands. This type of landscape might have served both as an attractor of human settlement and as a location for the preservation of archaeological evidence.

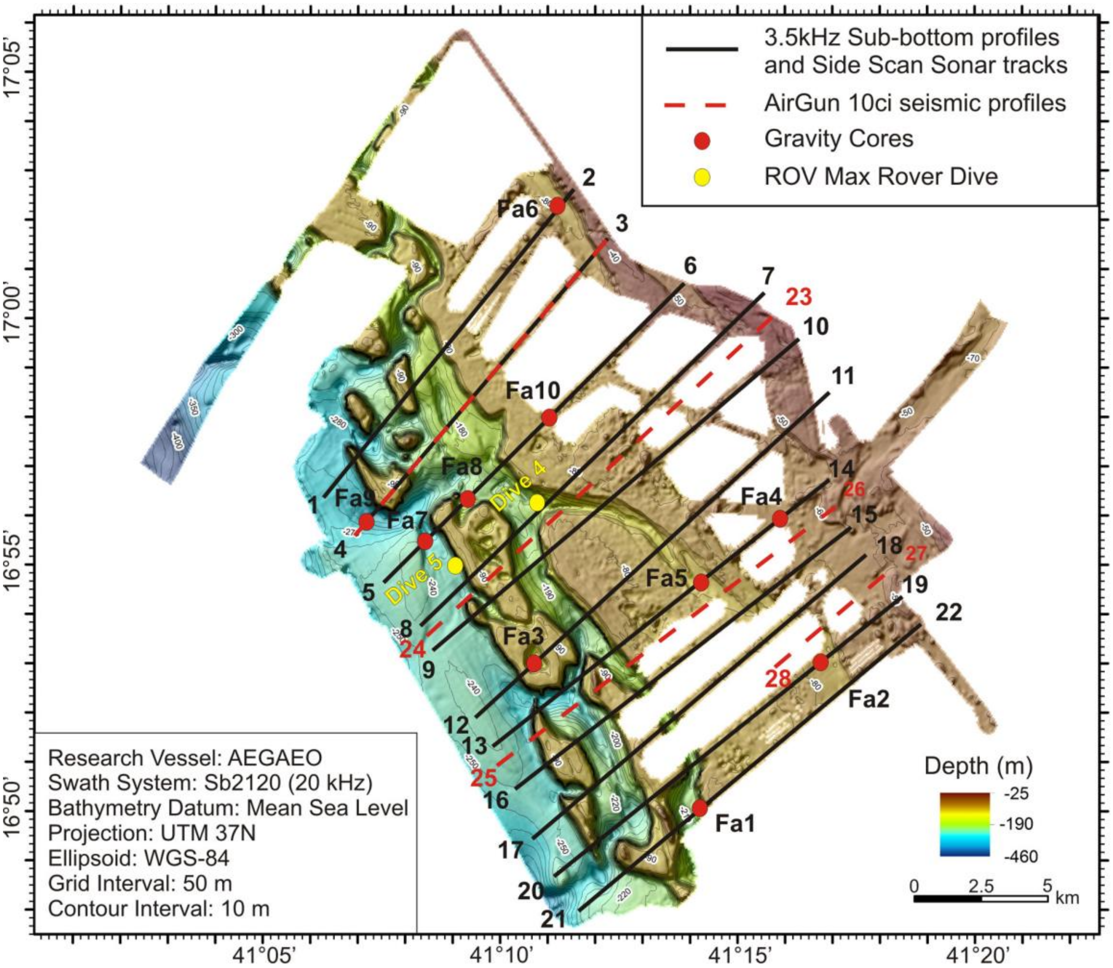

Figure 5. Swath bathymetry, airgun and high-resolution seismic profiles and location of coring sites and ROV dives in Area 1 in the outer shelf area.

Our preliminary results show that a very large part of the Farasan continental shelf is occupied by a prominent, gently seaward-dipping morphological terrace, which can be mapped at depths of 70–75 m on the inner shelf and 85–90 m on the outer shelf. This terrace has developed on Plio-Quaternary marine limestones (Dabbagh et al, 1984b; Bantan, 1999), intruded by salt diapirs derived from the underlying Upper Miocene evaporites in the lower stratigraphic levels (Purser and Bosence, 1998 and papers therein). Dullo and Montaggioni (1998) suggest that, in accordance with observations in the Indian Ocean, this prominent terrace may have formed during MIS 3, about 37–28 ka BP, and was certainly exposed during the last low sea-level stand (MIS 2).

The areas that we have surveyed so far cover a relatively small portion of the total available shelf and our analysis of the results and especially of the sediment cores is still at an early stage. Nevertheless, two features stand out as of particular interest. The first is the large number of fault-bounded basins, associated with salt tectonics, which were potentially water-filled lakes. The nature and duration of the water-fill remains to be established, but at first sight our preliminary results suggest the hypothesis that this extended shelf area available at lowered sea level was a veritable lake district, with all that this implies for attractive conditions for animal life and human exploitation (compare Faure et al., 2002). The second is the presence of offshore islands on the glacial maximum shoreline. A similar suite of small islands has been identified in the Hanish Sill region associated with sea levels lower than about –40m (Lambeck et al., 2011). How extensive these islands were and whether we can describe them as characteristic of an archipelago environment that periodically existed at certain periods of the sea level cycle and in particular regions of the palaeo-coastline will depend on further analysis.

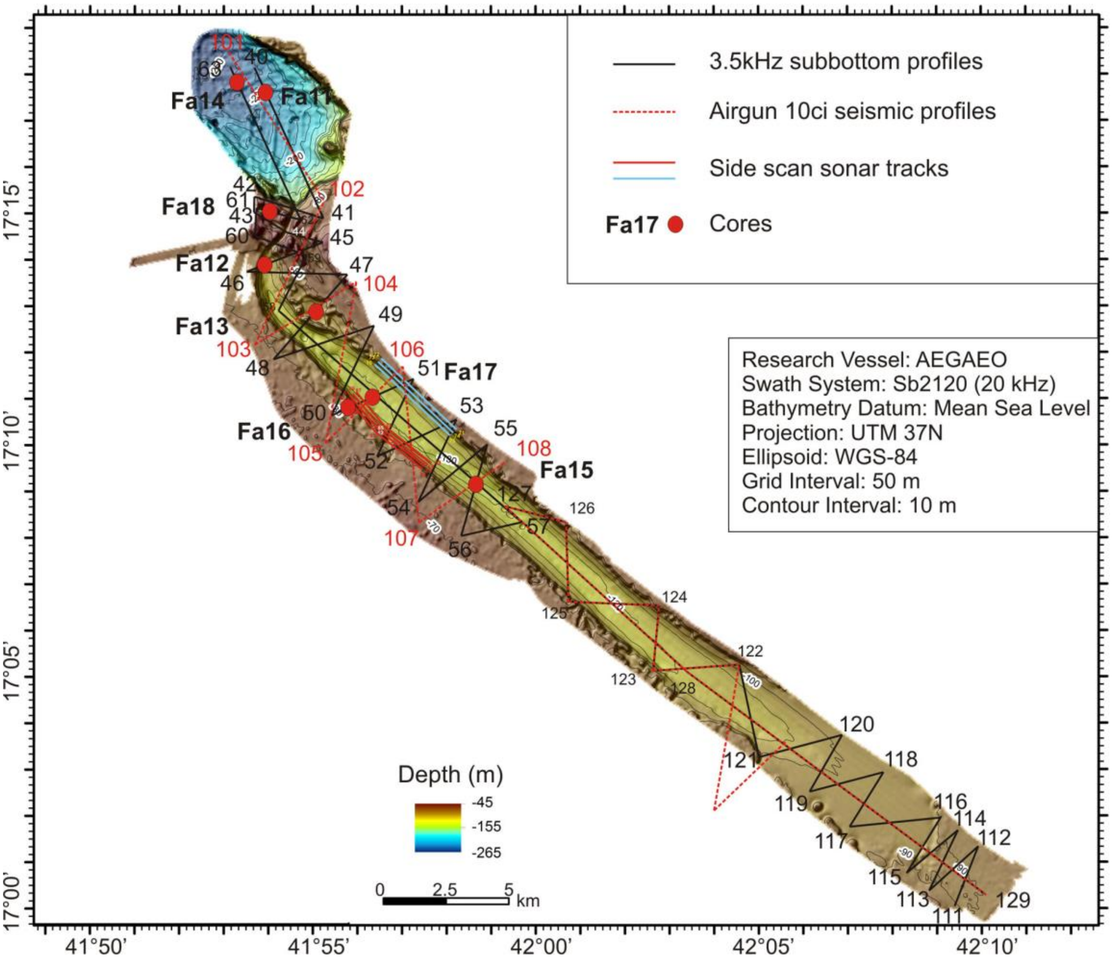

Figure 6. Swath bathymetry, airgun and high-resolution seismic profiles and location of coring sites in Area 2.

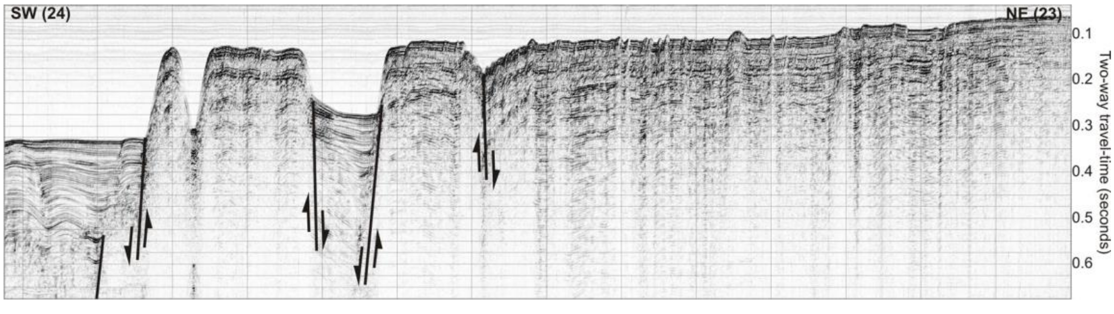

Figure 7. Air Gun 10ci seismic profile across the edge of the outer shelf, Area 1. Note the prominent, 80–90m deep terrace on the shelf and the ridges off it, which is displaced by SW-facing normal faults and antithetic NE-facing normal faults, compatible with the rifting process of the Red Sea.

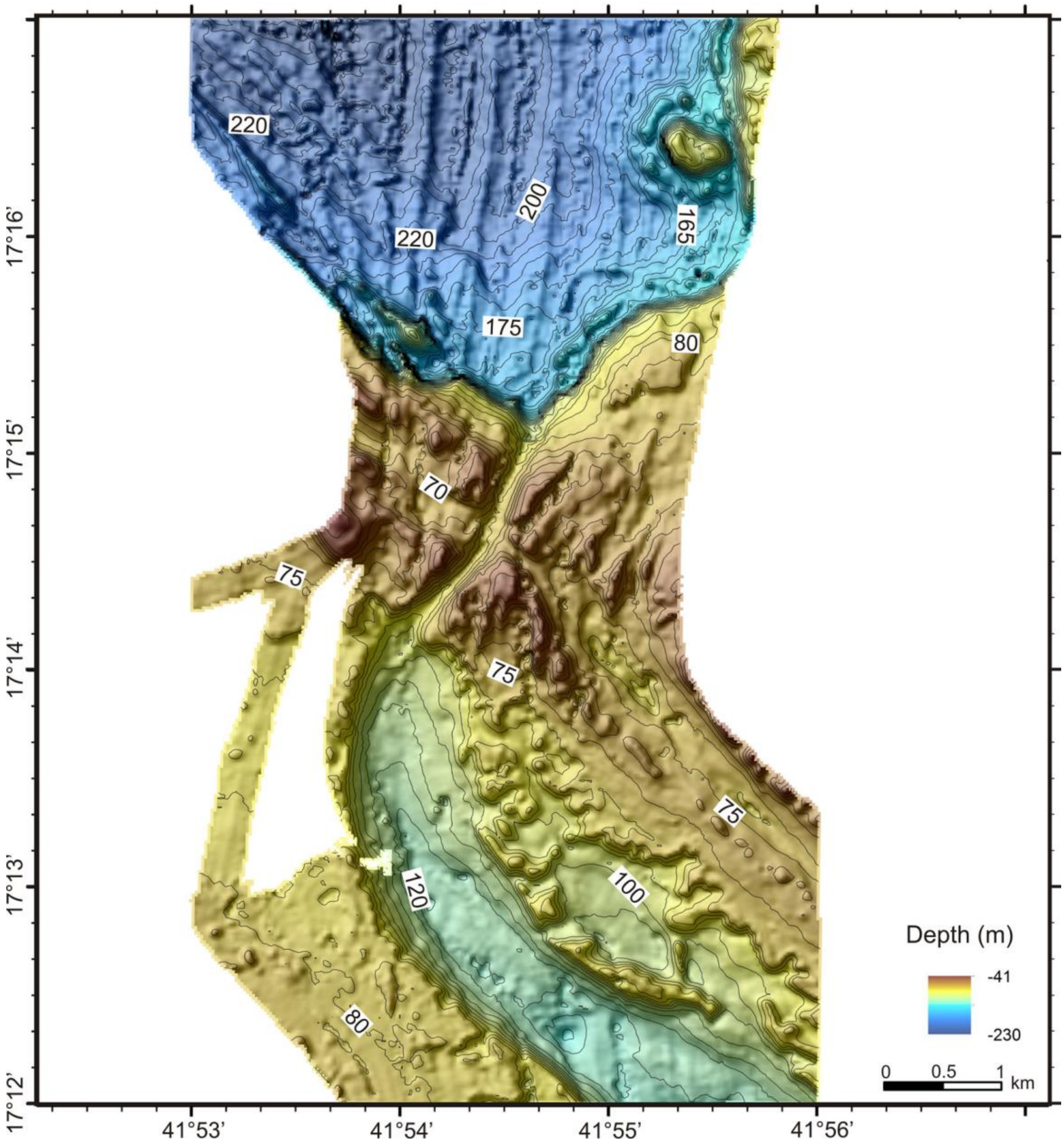

Figure 8. Detailed, hill-shaded bathymetry of the narrow gorge connecting the valley-like basin with the deep depression in the northern part of Area 1 on the inner Farasan shelf. Swath system: SB2120; bathymetry datum: mean sea-level; projection: UTM 37N; Ellipsoid: WGS-84; grid interval: 25m; contour interval: 5m.

5. Discussion

Given the preliminary nature of our investigations, the large areas that we are attempting to cover in developing a regional perspective, and the patchy and incomplete nature of the data currently available, it would be premature to arrive at over-detailed conclusions. There are, however, some interesting general patterns beginning to emerge. In the first place, there is a substantial Palaeolithic record in our region. The majority of the archaeological material comprises artefacts of ESA and MSA type, but LSA artefacts are also present in smaller numbers, suggesting a persistent, if not necessarily continuous, human presence in the region. The currently available dates for lava overlying artefact-bearing sediments in Wadi Jizan suggest a potential time depth of human occupation of nearly 1 million years. All of this indicates a substantial archaeological record comparable to the evidence found further to the north along the Arabian escarpment and in the desert interior (Petraglia et al., 2009, 2011), and to the south and east in the Yemen, Oman and the United Arab Emirates (Armitage et al., 2011; Rose et al., 2011; Delagnes et al., 2012). Tufa deposits in the Wadi Najla in the Harrat

Al Birk zone indicate perennial water flow at certain periods during the Pleistocene (Inglis et al., 2013), consistent with evidence of periodically wetter climatic conditions than at present (Parker, 2009; Rosenberg et al., 2013).

In terms of geographical distribution, the material is centred on the inland wadis and volcanic areas of the Lower and Upper Coastal Plains and on the coast in the Harrat Al Birk region. The inland sites are associated with locations that provide commanding views over adjacent wadi valleys, affording corridors of movement for animals moving between the coast and the hinterland, good water supplies, and abundant sources of lithic raw material, often in association with topographic constrictions affording tactical advantage at the confluence of wadis or lava flows.

The Dhahaban coastal site is of particular interest, given uncertainties about earlier claims for association between Palaeolithic artefacts and beach deposits in the region (Bailey, 2009), and suggests a parallel with the Abdur site in Eritrea (Walter et al., 2000). However, the fossilised coral and beach deposits on the Arabian coast are heavily weathered, bone is not preserved, and shells, though present in small numbers, are not demonstrably food remains as opposed to natural death assemblages. The question of whether, or to what extent, marine resources were exploited during this earlier period of high sea level therefore remains unclear.

Shell middens, comparable to the large concentration on the Farasan Islands, where over 3000 have now been recorded dating from about 7000 years ago (Bailey et al., 2013; Meredith-Williams et al., 2014a), are unknown at any earlier period. They are not present on elevated shorelines belonging to earlier periods of high sea level, for example at the Dhahaban site. Nor have we found any underwater examples associated with submerged palaeoshorelines, although investigation of such a possibility is still at a very early stage. At the site of Al Birk, further to the north, an extensive scatter of densely packed shells discarded as food remains is interspersed with MSA artefacts on an elevated coral terrace. However, the shells are dated to the 6th millennium BP (Bailey et al., 2007b, p. 7), and have nothing to do with the makers of the MSA artefacts, indicating the dangers of interpreting archaeological palimpsests comprising materials of many different ages without independent dating of the individual components.

However, the absence of shell mounds is not in itself evidence for an absence of marine exploitation. Many examples are known from around the world of postglacial coastal sites with evidence of sea fishing and other maritime activities, which are not shell mounds. In Denmark alone, where the Mesolithic shell mounds of the Ertebølle period represent one of the largest and most famous groups in the world, there are as many Mesolithic coastal sites without shells as there are shell mounds (Andersen, 1993). Moreover, where accurate measurements can be taken, it is clear that marine molluscs represent a much smaller proportion of the food supply than is suggested by the bulk of their surviving shell remains (Bailey and Milner, 2002).

It is also probably the case that shell middens, even large shell mounds, are much more vulnerable to weathering, deflation and destruction than is generally admitted, especially very old shell middens formed on ancient shorelines dating from the MIS 5 period of high sea level or earlier, which would have been exposed to prolonged sub-aerial weathering. Shell deposits associated with now-submerged shorelines would have been exposed to the attrition of wave action and marine currents during the process of inundation, perhaps dispersing the material to the point where it is no longer recognisable as an archaeological deposit.

We also think it likely that shell mounds are associated with relatively short-lived ecological and geomorphological windows of opportunity: shallow offshore topography conducive to the creation of very extensive mudflats capable of generating large quantities of molluscs, and a stable sea level position that enables repeated harvesting and accumulation of shells in the same place over a long enough period to generate a visible archaeological deposit (Meredith-Williams et al., 2014b). All the evidence is that such conditions are quite patchily distributed in space and time, even within a period of relatively stable sea level as during the mid-to-late Holocene, and very much more so during a period of sustained sea-level rise or rapidly fluctuating sea-level change.

All of these factors mean that it may be very difficult to find decisive evidence for or against marine exploitation associated with Pleistocene or early Holocene palaeo-shorelines, except in coastal rock overhangs that have preserved deposits associated with earlier periods of high sea level, or in underwater rock overhangs associated with submerged shorelines where the original terrestrial infill has survived the erosive effects of subsequent sea-level rise. As for the submerged landscape, preliminary mapping indicates the presence of a significant extension of land dotted with stream channels, fault-bounded basins developed by withdrawal and solution of salt domes, and potential lakes. More work is needed to provide detail and to constrain over-generalisation. However, if this general characterisation proves correct, the added increment of land would have provided very attractive conditions for plant and animal life and for human hunters and gatherers. Because of the fluctuating pattern of sea-level change, these conditions would have been episodic, each episode lasting from as little as 1000 years to a maximum possible duration of 60,000 years, amounting in total to about 50 per cent of the glacial-interglacial cycle (FIGURE 9). In this respect the submerged landscape suggests an analogy with the Arabian hinterland – an attractive and extensive territory for human occupation, but one that was only periodically available, the principal difference being that the greening of the hinterland occurred less often and for shorter periods, representing periods lasting from about 3000 to 20,000 years and amounting to about 30 percent of the glacial-interglacial cycle.

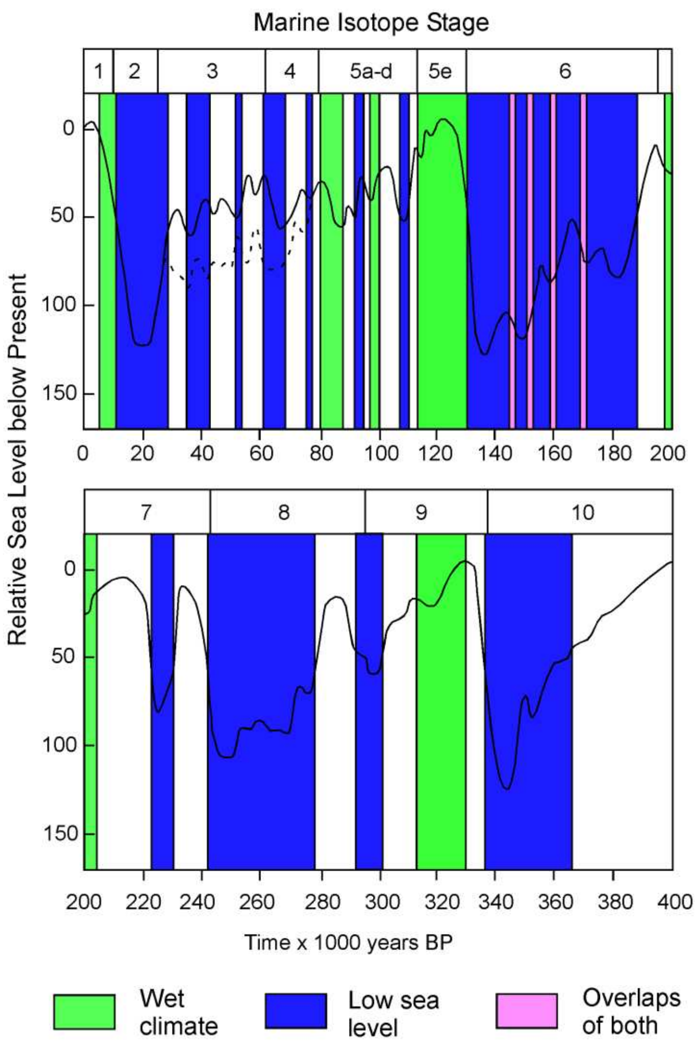

Figure 9. A comparison of climatic and sea level variation over the past 350,000 years. Blue: periods when sea level was between –40 m and –120m, exposing new land on the continental shelf. Green: periods of wetter climate. Pink: overlap of wetter climates and lower sea level. Climate data are from Parker (2009) and Rosenberg et al. (2013); data on sea-level change from Lambeck et al. (2011).

An attempt to examine in more detail the relationship between fluctuating sea levels and climate is shown in FIGURE 9. The general pattern and dating of the sea level curve is well established, the climatic sequence less so, especially in periods earlier than MIS 5, with new research still ongoing, so that the picture may change. Nevertheless, there appears to be a very clear pattern with almost no overlap between periods of low sea level and periods of climatic greening. When climate change opened up the desert interior, facilitating human expansion over extensive new territory, the configuration of the coastline would have been close to that of the present-day, with sea level rapidly rising to its present position. When increasing aridity closed down the occupation of the interior, new and attractive territory would have become available on the continental shelf. Optimum conditions for demographic expansion and interaction would have occurred with the coincidence of wetter climates and low sea levels, but that combination seems to have occurred very rarely or persisted only for very short periods – no more than four episodes each of about 1–2000 years during the past 200,000 years. Maximum pressure on populations and resources would have occurred when arid climates coincided with high sea levels, as today, and typically during some part of previous interglacial periods such as the latter part of MIS 5.

The western escarpment and coastal plain of SW Arabia gain a heightened interest from this perspective, providing a core region of relatively stable conditions for human occupation, and a reservoir of human and animal populations able to expand rapidly into the interior with wetter climates, or onto the extended coastal shelf when sea level dropped. The resulting model that emerges is one of a pulsating core of humanly occupied territory, periodically expanding and contracting in relation to these diverse and dynamic environmental processes. Factoring marine resources into this model would of course change the balance of demographic pressures and opportunities, but there is insufficient data at present to pursue this further.

This raises the question of how far our new survey data can shed light on the issue of Pleistocene seafaring and exploitation of marine resources. Given the preliminary nature of our results, our contribution on the matter can hardly be decisive at this stage, but the following are relevant points. In the first place, we have an extensive distribution of material indicating exploitation of terrestrial resources in the hinterland, as well as a group of sites along the present-day coast, at least one of which is contemporaneous with an ancient coastline. Poor preservation conditions mean that we do not know what sort of resources were being exploited on the coastline, or to what extent, if at all, marine resources played a role. Even if they were present, it seems that they were part of a regional pattern involving extensive use of the hinterland and terrestrial resources.

With regard to seafaring, the presence of groups of islands offshore of the glacial-maximum shoreline in one of our survey areas described above, and in the Hanish Sill region (Lambeck et al., 2011) provides our best clue as to the possibility of early offshore activity. Both would be worth closer investigation. However, preliminary ROV inspection of the former has not so far identified relevant features or targets suitable for diver inspection; while geopolitical factors currently make the Hanish Sill region difficult of access. Indications from other parts of the world are that conditions suitable for early experiments in simple seafaring and offshore exploitation of marine resources are most often associated with archipelago environments like these. They offer sheltered conditions protected from the full force of bad weather in the open sea, mixing of marine currents conducive to high levels of marine fertility, and relative ease of access to offshore locations. Examples include the late Pleistocene occupation of the region between SE Asia and Australia (O'Connor et al., 2011), and the early postglacial occupation of regions as diverse as the Aegean (Ammerman, 2014), the Norwegian coastline (Bjerck, 2008), the western islands of Scotland (Tolan-Smith, 2008), the Channel Islands of California (Erlandson et al., 2011), and Tierra del Fuego (Orquera and Piana, 2009). All the indications are that these archipelago environments have played a significant role in permitting or accelerating human dispersal in a variety of geographical circumstances. Where conditions are favourable, populations can expand rapidly along these marine corridors, as is demonstrated by the Norwegian example cited earlier (Bjerck, 2008).

Equally, these archipelago environments have a patchy distribution around the world's coastlines, and their configuration and distribution at periods of lower sea level may have been quite different from that visible on the modern coastline. Moreover, if the worldwide ethnographic record of recent coastal hunters and gatherers is any guide, coastal societies that hug the coast and have patterns of mobility organised along the coastline tend to occur in coastal regions that are not only archipelagos highly productive in marine resources, but are also on coastlines with limited or non-existent hinterland resources, because of mountainous terrain, impenetrable forest vegetation, ice sheets or desert. On more open coastlines with an accessible hinterland, patterns of movement and economy are oriented between coast and hinterland, whether through mobility or exchange, so as to achieve integration of the widest range of economic options. We suggest that a model of dispersal that accommodates both coastal and hinterland patterns of dispersal, with seafaring as an additional but intermittent option, according to the opportunities of each region, is best suited to capturing the realities of Pleistocene dispersal patterns.

Conclusions

Our field investigations are still at an early stage, but a number of significant avenues of future investigation are opening up. The importance of investigating the now submerged landscape, especially where it is extensive, as in the southern Red Sea, cannot be overemphasised. Not only does this region hide the shorelines that may have been significant in fostering the earliest experiments in marine exploitation and sea travel. It also represents a significant extension of terrestrial territory, territory moreover that offered attractive environments for human settlement and terrestrial exploitation. In addition, these attractions expanded and contracted with cyclical changes in sea level, creating a long-term dynamic that must have had consequences for patterns of occupation further inland. Whether this underwater world harbours the missing evidence required to fill the gaps in currently popular theories of Pleistocene coastal dispersal remains to be seen. We have not so far found unequivocal archaeological material under water, and that goal may be slow to achieve until we learn better where to focus the search and how to read the traces of what has survived. Giving greater precision to the landscapes and environments that were available during periods of lower sea level is a necessary step towards archaeological discovery as well as an important goal in its own right. All the early indications are that these submerged landscapes offered quite different opportunities and challenges for their prehistoric inhabitants compared to the contemporaneous hinterland, and that their study brings an entirely different perspective to the study of Pleistocene dispersal.

Equally important is the investigation of the on-land archaeological record, especially given the threats to its preservation by the currently massive scale of industrial development in our region. Above all, our results point to the importance of treating the archaeological record above sea level and below it as an integrated whole, and to the limitations of relying on simple models of dispersal. Simple models tend to be a function of limited data, where the data points are so few and far between that the only connections between them are straight lines. As field investigations in Saudi Arabia intensify, so the pattern of data will become more complex, opening up opportunities for more subtle and varied interpretations. We suspect that patterns of dispersal in, through and around the Arabian Peninsula will turn out to be neither solely 'green' – following well-watered environments wherever they may occur – nor solely 'blue' in following the coastline, but a combination of the two, the emphasis varying according to a highly dynamic set of ever-changing palaeogeographical and climatic circumstances.

6. Acknowledgements

We thank the Saudi Commission for Tourism and Antiquities (SCTA) for permission to undertake fieldwork, and the President, HRH Prince Sultan bin Salman bin AbdulAziz al Saud, the Vice-President, Professor Ali Al-Ghabban, and the Director General, Jamal al

Omar, for their continued support of our research. We also thank HRH Crown Prince Salman bin Abul Aziz Al Saud and the Department of General Survey of the Ministry of Defense for permission to undertake the cruise of R/V AEGAEO. We also thank Lt Fahad Al Shwish, Observer from the Hydrographic Department of the Saudi Ministry of Defense, for his support and valuable assistance in overcoming unexpected logistical difficulties during the cruise, and Captain Theodoros Kanakaris and the crew of R/V AEGAEO for their untiring efforts to ensure the smooth running of the scientific operation during the offshore survey work. We thank two anonymous assessors for comments that have helped to improve the text and Bill Bosworth and Geoffrey King for discussions of geological issues. The research is funded by the European Research Council through Advanced Grant 269586 DISPERSE under the 'Ideas' Specific Programme of the Seventh Framework Programme. This paper is DISPERSE contribution no. 21 and IPGP contribution no. 2604.

7. References

Alsharekh, A.M., Bailey, G.N. (Eds). 2014. Coastal Prehistory in Southwest Arabia and the Farasan Islands 2004–2009 Field Investigations. Riyadh: Saudi Commission for Tourism and Antiquities.

Ambrose, S.H. 1998. Late Pleistocene human population bottlenecks, volcanic winter and differentiation of modern humans. Journal of Human Evolution 34: 623–651.

Ammerman, A. (Ed.). 2014. Island Archaeology and the Origins of Seafaring in the Eastern Mediterranean. Journal of Eurasian Prehistory 10.

Andersen, S.H. 1993. Coastal adaptations and marine exploitation in Late Mesolithic Denmark – with special emphasis on the Limfjord region. In: A. Fischer (ed.) Man and Sea in the Mesolithic. Oxford: Oxbow, pp. 41–66.

Armitage, S.J., Jasim, S.A., Marks, A.E., Parker, A.G., Usik, V.I., Uerpmann, H.P. 2011. The southern route "Out of Africa": evidence for an early expansion of modern humans into Arabia. Science 331: 453-456.

Bailey, G.N. 2004a. World prehistory from the margins: the role of coastlines in human evolution. Journal of Interdisciplinary Studies in History and Archaeology 1(1): 39–50.

Bailey, G.N. 2004b. The wider significance of submerged archaeological sites and their relevance to world prehistory. In: N.C. Flemming (ed.) Submarine Prehistoric Archaeology of the North Sea: Research Priorities and Collaboration with Industry. CBA Research Report 141. York: Council for British Archaeology, pp. 3–10.

Bailey, G. N. 2007. Time perspectives, palimpsests and the archaeology of time. Journal of Anthropological Archaeology 26: 198–223.

Bailey, G.N. 2009. The Red Sea, coastal landscapes and hominin dispersals. In: M.D. Petraglia, J.I. Rose (eds) The Evolution of Human Populations in Arabia. Dordrecht, Netherlands: Springer, pp. 15–37.

Bailey, G.N., Flemming, N.C. 2008. Archaeology of the continental shelf: marine resources, submerged landscapes and underwater archaeology. Quaternary Science Reviews 27: 2153–2165.

Bailey, G.N., Milner, N.J. 2002. Coastal hunters and gatherers and social evolution: marginal or central? Before Farming: the Archaeology of Old World Hunter-Gatherers 3–4(1): 1–15.

Bailey, G.N., King, G.C.P. 2011. Dynamic landscapes and human dispersal patterns: tectonics, coastlines and the reconstruction of human habitats. Quaternary Science Reviews 30: 1533–1553.

Bailey, G.N., Reynolds, S.C., King, G.C.P. 2011. Landscapes of human evolution: models and methods of tectonic geomorphology and the reconstruction of hominin landscapes. Journal of Human Evolution 60(3): 257–80.

Bailey, G., Cadbury, T., Galanidou, N., Kotjabopoulou, E., 1997. Open-air sites and rockshelters: survey strategies and regional site distributions. In: G. Bailey (ed.) Klithi: Palaeolithic Settlement and Quaternary Landscapes in Northwest Greece, Volume 2: Klithi in its local and regional setting. McDonald Institute for Archaeological Research, Cambridge, pp. 521–37.

Bailey, G.N., King, G.C.P., Flemming, N.C., Lambeck, K., Momber, G., Moran, L.J., Al-Sharekh, A.M., Vita-Finzi, C. 2007a. Coastlines, submerged landscapes and human evolution: the Red Sea Basin and the Farasan Islands. Journal of Island and Coastal Archaeology 2: 127–160.

Bailey, G.N., Al-Sharekh, A.M., Flemming, N.C., Lambeck, K., Momber, G., Sinclair, A.G.M., Vita-Finzi, C. 2007b. Coastal prehistory in the southern Red Sea Basin, underwater archaeology and the Farasan islands. Proceedings of the Seminar for Arabian Studies 37: 1–16.

Bailey, G.N., King, G.C.P., Devès, M., Hausmann, N., Inglis, R., Laurie, E., Meredith-Williams, M., Momber, G., Winder, I., Alsharekh, A., Sakellariou, D. 2012. DISPERSE: dynamic landscapes, coastal environments and human dispersals. Antiquity 86 (334). http://antiquity.ac.uk/projgall/bailey334/

Bailey, G.N, Williams, M.G., Alsharekh, A.M. 2013. Shell mounds of the Farasan Islands, Saudi Arabia. In: G.N. Bailey, K. Hardy, A. Camara (eds) Shell Energy: Mollusc Shells as Coastal Resources. Oxford: OxBow, pp. 241−254.

Bailey, G.N., Inglis, R.H., Meredith-Williams, M., Hausmann, N., Alsharekh, A.M., Al Ghamdi, S. 2012. Preliminary Report on Fieldwork in the Farasan Islands and Jizan Province by the Disperse Project, November–December, 2012. Available at <http://www.disperse-project.org/field-reports>.

Bantan, R.A., 1999. Geology and Sedimentary Environments of Farasan Bank (Saudi Arabia) Southern Red Sea: A Combined Remote Sensing and Field Study. Ph.D. Thesis, Department of Geology, Royal Holloway, University of London.

Bjerck, H.B. 2008. Norwegian Mesolithic trends: a review. In: G. Bailey, P. Spikins (eds) Mesolithic Europe. Cambridge: Cambridge University Press, pp. 60–157.

Bosworth, W., Huchon, P., McClay, K. 2005. The Red Sea and Gulf of Aden Basins. Journal of African Earth Sciences 43: 334–378

Boivin, N., Fuller, D.Q., Dennell, R., Allaby, R., Petraglia, M.D. 2013. Human dispersal across diverse environments of Asia during the Upper Pleistocene. Quaternary International 300: 32–47.

Breasted, J.H. 1914. Outlines of European History. Part I. Earliest Man: The Orient, Greece and Rome. Boston: Ginn.

Carbone, F., Matteucci, R., Angelucci, A. 1998. Present-day sedimentation on the carbonate platform of the Dahlak Islands, Eritrea. In: B.H. Purser, D.W.J. Bosence (eds) Sedimentation and Tectonics in Rift Basins: Red Sea-Gulf of Aden. London: Chapman & Hall, pp. 523–536.

Childe, V.G., 1925. The Dawn of European Civilization. London: Kegan Paul.

Chu, D., Gordon, R.G. 1998. Current plate motions across the Red Sea. Geophysical Journal International 135: 313–328.

Cochran, J.R. 1983. A model for development of Red Sea. American Association of Petroleum Geologists Bulletin 67: 41–69.

Dabbagh, A., Emmermann, R. Hötzl H., Jado A.R., et al. 1984a. The development of Tihamat Asir during the Quaternary. In: A.R., Jado, J.G. Zötl (eds) Quaternary Period in Saudi Arabia Volume 2: Sedimentological, Hydrogeological, Hydrochemical, Geomorphological, Geochronological and Climatological Investigations in Western Saudi Arabia. Vienna: Springer, pp. 150–73.

Dabbagh, A., Hoetzl, H., Schnier, H. 1984b. Farasan Islands. In: A.R. Jado, J.G. Zötl (eds) Quaternary Period in Saudi Arabia Volume 2: Sedimentological, Hydrogeological, Hydrochemical, Geomorphological, Geochronological and Climatological Investigations in Western Saudi Arabia. Vienna: Springer, pp. 212–220

De Mets, C., Gordon, R.G., Argus, D.F. 2010. Geologically current plate motions. Geophysical Journal International 181: 1–80.

Delagnes, A., Tribolo, C., Bertran, P., Brenet, M., Crassard, R., Jaubert, J., Khalidi, L., Mercier, N., Nomade, S., Peigné, S., Sitzia, L., Tournepiche, J-F., Al-Halibi, M., Al-Mosabi, A., Macchiarelli, R. 2012. Inland human settlement in southern Arabia 55,000 years ago. New evidence from the Wadi Surdud Middle Paleolithic site complex, western Yemen. Journal of Human Evolution 63: 452–474.

Dennell, R.W. 2009. The Palaeolithic Settlement of Asia. Cambridge: Cambridge University Press.

Devès, M., Inglis, R., Meredith-Williams, M., Alsharekh, A., Al Ghamdi, S., Bailey, G. 2012. Preliminary Report of Reconnaissance Fieldwork in Southwest Saudi Arabia, May–June, 2012. Available at < http://www.disperse-project.org/field-reports>.

Devès, M.H., Inglis, R.H., Meredith-Williams, M.G., Al Ghamdi, S., Alsharekh, A.M., Bailey, G.N. 2013. Palaeolithic survey in southwest Saudi Arabia: methodology and preliminary results. Adumatu 27: 7–30.

Dullo, W.C., Montaggioni, L. 1998. Modern Red Sea coral reefs: a review of their morphologies and zonation. In: B.H. Purser, D.W.J. Bosence (eds): Sedimentation and Tectonics in Rift Basins: Red Sea-Gulf of Aden. London: Chapman & Hall, pp. 583–594.

Erlandson, J.M. 2001. The archaeology of aquatic adaptations: paradigms for a new millennium. Journal of Archaeological Research 9: 287–350.

Erlandson, J.M., Fitzpatrick, S.M. 2006. Oceans, islands, and coasts: current perspectives on the role of the sea in human prehistory. Journal of Island and Coastal Archaeology 1, 5–33.

Erlandson, J.M., Rick, T.C., Braje, T.J., Casperson, M., Culleton, B., Fulfrost, B., Garcia, T., Guthrie, D.A., Jew, N., Kennett, D.J., Moss, M.L., Reeder, L., Skinner, C., Watts, J., Willis, L. 2011. Paleoindian seafaring, maritime technologies, and coastal foraging on California's Channel Islands. Science 331: 1181–1185.

Evans, A., Flemming, N.C., Flatman, J. (Eds). 2014. Prehistoric Archaeology of the Continental Shelf: a Global Review. New York: Springer.

Fanning, P. C., Holdaway, S. J., Rhodes, E. J. Bryant, T. G. 2009. The surface archaeological record in arid Australia: geomorphic controls on preservation, exposure, and visibility. Geoarchaeology 24(2): 121–146.

Girdler, R.W., Styles, P. 1974. Two stage sea-floor spreading. Nature 247: 7–11.

Faure, H., Walter, R.C., Grant, D.R. 2002. The coastal oasis: ice age springs on emerged continental shelves. Global and Planetary Change 33: 47–56.

Holdaway, S., Douglass, M., 2011. A twenty-first century archaeology of stone artifacts. Journal of Archaeological Method and Theory 19: 101–131.

Holdaway, S., Fanning, P. 2010. Geoarchaeology in Australia: understanding human-environment interactions. In: P. Bishop, B. Pillans (eds) Australian Landscapes. Geological Society, London, Special Publications, 346, pp. 71–85.

Hudec, M.R., Jackson, M.P.A. 2007. Terra infirma: understanding salt tectonics. Earth-Science Reviews 82: 1–28.

Inglis, R.H., Sinclair, A.G.M., Shuttleworth, A., Alsharekh, A.M. 2013. Preliminary Report on 2013 Fieldwork in Southwest Saudi Arabia by the Disperse Project: (2) Jizan and Asir Provinces, February–March 2013. Available at <http://www.disperse-project.org/field-reports>

Inglis, R.H., Sinclair, A.G., Shuttleworth, A., Alsharekh, A., Devès, M.H., Meredith-Williams, M., Al Ghamdi, S., Bailey, G. 2014a. Investigating the Palaeolithic landscapes and archaeology of the Jizan and Qunfudah regions, Southwestern Saudi Arabia. Proceedings of the Seminar for Arabian Studies 44: 193–212.

Inglis, R.H., Sinclair, A.G.M., Shuttleworth, A., Al Maamary, A., Budd, W., Hausmann, N., Meredith-Williams, M.G., Alsharekh, A.M., Al Ghamdi, S., Bailey, G.N. 2014b. Preliminary Report on 2014 Fieldwork in Southwest Saudi Arabia by the Disperse Project: (1) Jizan and Asir Provinces. Available at < http://www.disperse-project.org/field-reports>

King, G.C.P., Bailey, G.N. 2006. Tectonics and human evolution. Antiquity 80: 265–86.

LaBreque, J.L., Zitellini, N. 1985. Continuous sea-floor spreading in Red Sea, an alternative interpretation of magnetic anomaly pattern. American Association of Petroleum Geologists Bulletin 69: 513–524.

Lambeck, K., Purcell, A, Flemming, N., Vita-Finzi, C., Alsharekh, A., Bailey, G.N. 2011. Sea level and shoreline reconstructions for the Red Sea: isostatic and tectonic considerations

and implications for hominin migration out of Africa. Quaternary Science Reviews 30: 3542–3574.
Macaulay, V., Hill, C., Achilli, A. et al. 2005. Single, rapid coastal settlement of Asia revealed by analysis of complete mitochondrial genomes. Science 308: 1034–1036.
McClusky, S., Reilinger, R., Mahmoud, S., Ben Sari, D., Tealeb, A., 2003. GPS constraints on Africa (Nubia) and Arabia plate motions. Geophysical Journal International 155: 126–138.
Mellars, P.A. 2006. Going east: new genetic and archaeological perspectives on the modern human colonization of Eurasia. Science 313: 796–800.
Mellars, P.A., Gori, K.C., Carr, M., Soares, P.A., Richards, M.B. 2013. Genetic and archaeological perspectives on the initial modern human colonization of southern Asia. Proceedings of the National Academy of Science. 110: 10699–10704.
Meredith-Williams, M. G., Hausmann, N., Bailey, G.N., Inglis, R.H. 2014a. 4200 new shell mound sites in the southern Red Sea. Internet Archaeology 37, doi:10.11141/ia.37.2.
Meredith-Williams, M.G., Hausmann, N., Bailey, G.N., King, G.C.P., Alsharekh, A., Al Ghamdi, S. 2014b. Mapping, modelling and predicting prehistoric coastal archaeology in the southern Red Sea using new applications of digital imaging techniques. World Archaeology 46(1): 10–24.
Momber, G., Gillespie, J., Mason, B., Mason, C., Tidbury, L., Mozayen, W., Hamzi, F., Al Sadiq, J., Al Haiti, A., Meredith–Williams, M., Hausmann, N., Aqeeli, A., Mofta, M., Bailey, G. 2014. Preliminary Report on 2014 Fieldwork in Southwest Saudi Arabia by the DISPERSE Project: (2) Underwater Research in the Farasan Islands. Available at: < http://www.disperse-project.org/field-reports>
O'Connor, S., Ono, R., Clarkson, C. 2011. Pelagic fishing at 42,000 years before the present and the maritime skills of modern humans. Science 334: 1117–1121.
Oppenheimer, S. 2003. Out of Eden: the Peopling of the World. London: Constable.
Osborn, A.J., 1977. Strandloopers, mermaids, and other fairy tales: ecological determinants of marine resource utilization – the Peruvian case. In: L.R. Binford (ed.) For Theory Building in Archaeology. New York: Academic Press, pp. 157–205.
Parker, A.G. 2009. Pleistocene climate change in Arabia: developing a framework for hominin dispersal over the last 350 ka. In: M.D. Petraglia, J.I. Rose (eds) The Evolution of Human Populations in Arabia. Dordrecht, Netherlands: Springer, pp. 39–49.
Petraglia M.D., Drake, N.A., Alsharekh, A.M. 2009. Acheulean landscapes and large cutting tools assemblages in the Arabian Peninsula. In: M.D. Petraglia, J.I. Rose (eds) The Evolution of Human Populations in Arabia. Dordrecht, Netherlands: Springer, pp. 103–116.
Petraglia, M.D., Alsharekh, A.M., Crassard, E., Drake, N.A., Groucutt, H., Parker, A.G., Roberts, R.G. 2011. Middle Paleolithic occupation on a Marine Isotope Stage 5 lakeshore in the Nefud Desert, Saudi Arabia. Quaternary Science Reviews 30 (13–14): 1555–1559.
Piana, E.L., Orquera, L.A. 2009. The southern top of the world: the first peopling of Patagonia and Tierra del Fuego, and the cultural endurance of the Fuegian sea-nomads. Arctic Anthropology 45: 103–117.
Purser, B.H., Bosence, D.W.J. (Eds). 1998. Sedimentation and Tectonics in Rift Basins: Red Sea-Gulf of Aden. London: Chapman & Hall.
Reynolds, S.C., Bailey, G.N., King, G.C.P. 2011. Landscapes and their relation to hominin habitats: case studies from *Australopithecus* sites in eastern and southern Africa. Journal of Human Evolution 60 (3): 281–98.
Roeser, H.A. 1975. A detailed magnetic survey of the southern Red Sea. Geologisches Jahrbuch 13: 131–153.
Rose, J., Usik, V., Marks, A., Hilbert, Y., Galletti, C., Parton, A., Geiling, J.M., Cerný, V., Morley, M., Roberts, R.G. 2011. The Nubian complex of Dhofar, Oman: an African Middle Stone Age industry in southern Arabia. PLoS ONE 6(11), e28239.
Rosenberg, T.M., Preusser, F., Risberg, J., Plikk, A., Kadi, K.A., Matter, A., Fleitmann, D. 2013. Middle and Late Pleistocene humid periods recorded in palaeolake deposits of the Nafud desert, Saudi Arabia. Quaternary Science Reviews 70: 109–123.

Rossignol, J., Wandsnider, L. (Eds.), 1992. Space, Time and Archaeological Landscapes. New York: Plenum.

Sakellariou, D., Bailey, G.N., Momber, G., Meredith-Williams, M. G., Alsharekh, A., Rousakis, G., Panagiotopoulos, I., Morfis, I., Stavrakakis, S., Pampidis, I., Renieris, P., Georgiou, P., Kalogirou, S., Mantopoulos, P., Stasinos, V., Kallergis, M., Manousakis, L., Al Nomani, S.M., Devès, M. 2013. Preliminary Report on Underwater Survey in the Farasan Islands by the R/V Aegaeo, May–June 2013. Available at <http://www.disperse-project.org/field-reports>.

Siddall, M., Rohling, E.J., Almogi-Labin, A., Hemleben, C., Meischner, D., Schmelzer, I., Smeed, D.A. 2003. Sea-level fluctuations during the last glacial cycle. Nature 423: 853–858.

Tait, R.V., Dipper, F.A. (4th ed.) 1998. Elements of Marine Ecology. Oxford: Butterworth-Heinemann.

Tolan-Smith, C. 2008. Mesolithic Britain. In: G. Bailey, P. Spikins (eds) Mesolithic Europe. Cambridge: Cambridge University Press, pp. 60–106.

Van der Made, J. 2011. Biogeography and climatic change as a context to human dispersal out of Africa and within Eurasia. Quaternary Science Reviews 30: 1353–1367

Walter, R.C., Buffler, R.T., Bruggemann, J.J., Guillaume, M.M.M., Berhe, S.M., Negassi, B., Libsekal, Y., Cheng, H., Edwards, R.L., von Gosel R., Neraudeau, D., Gagnon, M. 2000. Early human occupation of the Red Sea coast of Eritrea during the Last Interglacial. Nature 405: 65–69.

Washburn, S.L., Lancaster, C.S. 1968. The evolution of hunting. In: R.B. Lee, I. DeVore (eds) Man the Hunter. Chicago: Aldine, pp. 293–303.

Winder, I., King, G.C.P., Devès, M., Bailey, G.N. 2013. Complex topography and human evolution: the missing link. Antiquity 87: 333–49.

Winder, I.C., Devès, M.H., King, G.C.P., Bailey, G.N., Inglis, R.H., Meredith-Williams, M.G. In press. Dynamic landscapes and complex topography as agents in human evolution: the dispersals of the genus *Homo*. Journal of Human Evolution.

Zarins, J., Ibrahim, M., Potts, D., Edens, C. 1979. Saudi Arabian archaeological reconnaissance 1978. The preliminary report on the third phase of the Comprehensive Archaeological Survey Program – the Coastal Province. Atlal, The Journal of Saudi Arabian Archaeology 3: 9–42.

Zarins, J., Whalen, N., Ibrahim, M., Mursi, A.J., Khan, M. 1980. The Comprehensive Archaeological Survey Program. Preliminary report on the Central and Southwestern provinces. Atlal, The Journal of Saudi Arabian Archaeology 4: 9–36.

Zarins, J., Al-Jawad Murad, A, Al-Yish, K.S. 1981. The Comprehensive Archaeological Survey Program, a. The second preliminary report on the Southwestern province. Atlal, The Journal of Saudi Arabian Archaeology 5: 9–42.