The Archaeology of Pleistocene Coastal Environments and Human Dispersals in the Red Sea: Insights from the Farasan Islands

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Abstract

This chapter examines the different sources of evidence—phylogenetic, palaeoclimatic and archaeological—that have been used to investigate the hypothesis that early human dispersals from Africa during the late Pleistocene were facilitated by exploitation of marine resources and seafaring abilities and followed a predominantly coastal route including a crossing of the southern end of the Red Sea. We examine critically the current evidence and arguments for and against such a hypothesis and highlight the need for a more sophisticated understanding of the taphonomic factors that determine the formation, preservation and distribution of coastal archaeological deposits such as shell mounds. We present new data on the mid-Holocene shell mounds of the Farasan Islands and examine their spatial and temporal distribution in relation to a coastal environment that has been subject to rapid changes of sea level, geomorphology and ecological potential. We demonstrate that substantial shell mound deposits can accumulate rapidly over a matter of decades, even in a dynamic shoreline environment undergoing changes in relative sea level, that the ecological conditions that provide an abundant supply of marine molluscs as food are highly episodic in time and space, and that the resulting archaeological record is extremely patchy. We highlight the problem of dealing with negative evidence in the archaeological record and the need for a more detailed investigation and understanding of the various factors that determine the survival and visibility of archaeological deposits.

1 Introduction

Over the past decade, worldwide interest has focussed on the Red Sea region, and especially on the western escarpment and coastal regions of Saudi Arabia, because of the unusually favourable conditions that it offers for the understanding of Quaternary sea-level change and the earliest human dispersals out of Africa over the past 2 million years. A number of different sources of evidence have contributed to this new interest:

1. New archaeological field projects and new finds of early Stone Age archaeology in many parts of the Arabian Peninsula, including the desert interior, the western escarpment of Saudi Arabia and the coastal hinterland of Yemen, Oman and the UAE (Petraglia and Rose 2009; Armitage et al. 2011; Bretzke et al. 2013; Inglis et al. 2014; Bailey et al. 2015; Petraglia et al., this volume; Sinclair et al., this volume)
2. Phylogenetic inference, which has led some authors to argue for a pattern of rapid dispersal of early human populations around the Indian Ocean rim from the Horn of Africa to the shores of Australia, taking in a crossing of the southern Red Sea and the coastlines of southern Arabia (Macaulay et al. 2005; Mellars et al. 2013)
3. Renewed interest in the likely early significance of marine resources such as shellfish and fish in the palaeodiets of early human populations and the possibilities of early sea travel (Erlandson 2001; Bailey and

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Milner 2002; Anderson et al. 2010; Marean 2010; Jerardino 2016)

4. A growing realisation that the low sea levels that have persisted throughout much of the Quaternary period have dramatically altered the palaeogeography of the Arabian coastline by (a) creating extensive areas of now-submerged terrestrial landscape attractive to earlier human settlement, particularly in the southern Red Sea, and (b) narrowing sea channels, in particular in the region of the Hanish Sill and Bab al Mandab, which would have made them more easily crossable than today (Siddall et al. 2003; Lambeck et al. 2011; Bailey et al. 2015)
5. New data on climate change (Parker 2009; Drake et al. 2013; Rohling et al. 2013; Rosenberg et al. 2013)

Particular interest in the past decade has focussed on the hypothesis of a major dispersal of modern humans (*H. sapiens sapiens*) out of Africa at about 70 ka (70,000 years ago) or perhaps earlier, accompanied by new adaptations involving seafaring abilities and intensified marine exploitation, with the main pathway of dispersal across the southern Red Sea, around the rim of the Indian Ocean and into New Guinea and Australia.

This idea has taken powerful hold of the scientific and popular imagination, but is largely speculative, deriving support primarily from phylogenetic inference and other indirect clues. Supporting field evidence for or against this hypothesis of an early coastal dispersal is almost non-existent, arguably because the relevant areas and time periods in question are now submerged below modern sea level.

Our aim in this chapter is, firstly, to summarise the arguments for and against the suitability of a dispersal pathway across the southern end of the Red Sea and around the shorelines of the Arabian Peninsula, and secondly, to examine the sorts of archaeological evidence that currently exist for the use of early shorelines and marine resources, or that we need to look for and might expect to find in support of such a proposition. Since so little archaeological evidence is currently available before the establishment of modern sea level at about 6 ka, we focus on the shell mounds of the Farasan Islands, which date from about this time. These are typical of the types of highly visible archaeological deposits that are associated with exploitation of marine foods and sea-travel in a hunter-gatherer setting, and are the type of evidence that we might expect to find in earlier periods and in other coastal regions as markers of a coastal pattern of settlement and dispersal associated with substantial reliance on marine resources. We will present new field evidence relating to the Farasan shell mounds, and use this evidence to examine the ecological and geological circumstances associated with their formation, the ways in which their formation interacts with dynamic changes in shoreline position during the Holocene period, and the likelihood of finding similar deposits at other times and places, in particular during earlier periods of low sea level.

The basis of our approach is that we need to understand the variable processes that determine the differential accumulation, preservation, destruction and visibility of archaeological deposits, before we can draw reliable inferences about past patterns of human demography and dispersal from archaeological site distributions in time and space. Deposits of stone tools, especially in large numbers, usually accumulate very slowly and acquire their archaeological visibility from repeated visits to the same location over long periods (decades to millennia). Once established, the stone tools are resistant to decay but are vulnerable to processes of burial under later sediments, or to displacement and dispersal by erosion. Shell mounds, in contrast, can accumulate very rapidly (days to decades) but only under quite restricted ecological conditions; they are also highly sensitive to burial or removal by small changes in sea level and coastline geomorphology. Both types of deposits are vulnerable to destruction by human impact from modern land use and industrial development. It is these processes that we seek to highlight in the following investigation.

2 Expansion Out of Africa

Both fossil evidence of human remains and phylogenetic data point to Africa as the homeland of our ancient ancestors, with at least two waves of expansion out of Africa: an early one after about 2 Ma by the early members of the genus *Homo* (most likely *H. ergaster* or *H. erectus*), and a later one by anatomically modern humans (*H. sapiens sapiens*). The date of the later dispersal is unclear. The earliest known and dated specimens of anatomically modern *H.s.s.* come from the Kibish formation in Ethiopia dated at 196 ± 2 ka (Fleagle et al. 2008), but the earliest human fossil specimens of *H.s.s.* outside Africa are much younger with dates ranging from, at earliest, about 120 ka in SW Asia, 70 ka or later in SE Asia and Australia, and 40 ka in Europe.

Whether any of these broad dates are representative of the earliest dates of entry of *H.s.s.* populations into their respective continents is a matter of conjecture, subject to all the vagaries of differential preservation and discovery of fossil human remains that are inherently rare. The European dates are quite well constrained thanks to the presence of numerous well-dated remains of Neanderthals (*Homo sapiens neanderthalensis*), who evolved separately in Europe from an earlier common ancestor, and who are reliably associated with distinctive Mousterian tool assemblages

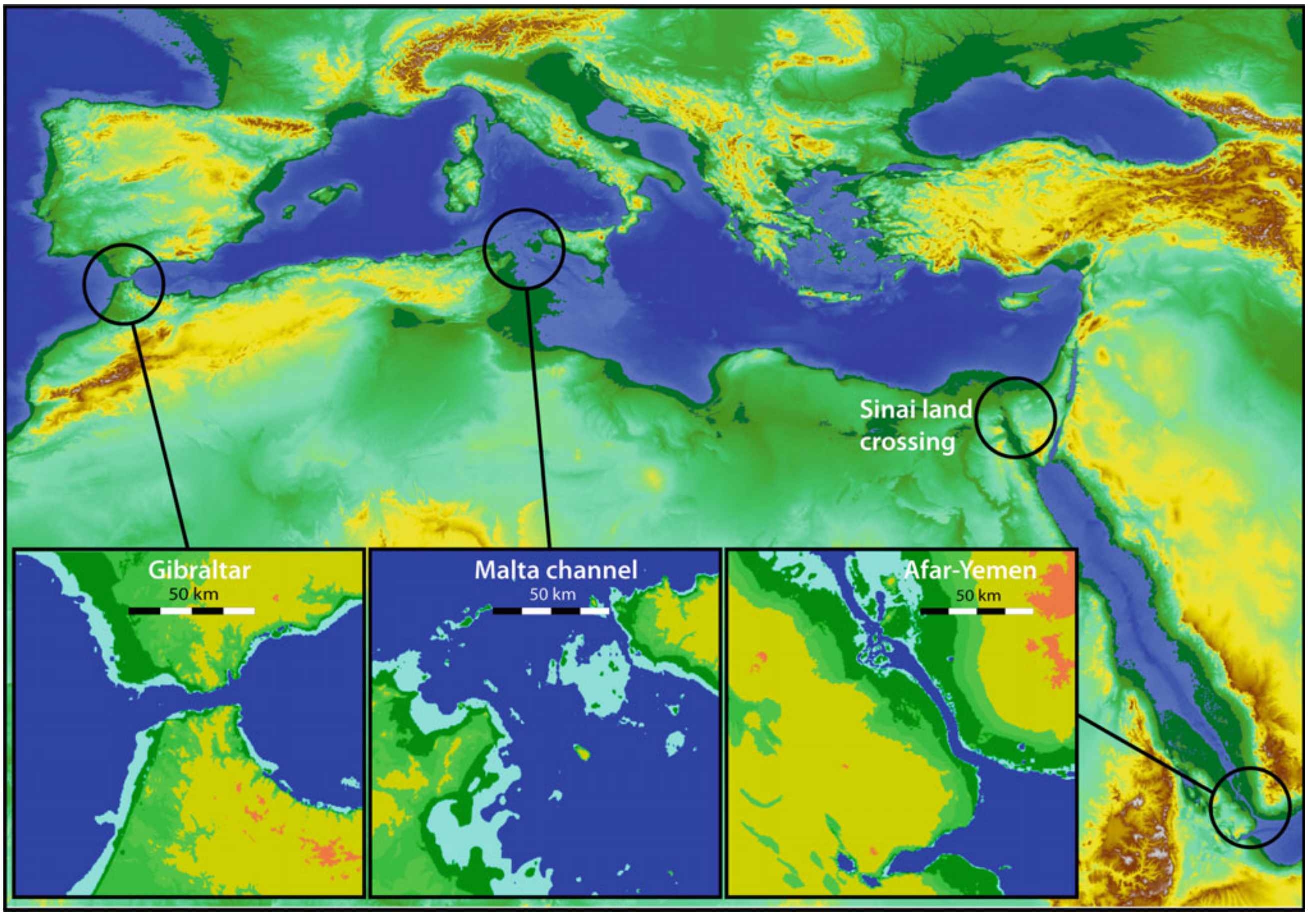

Fig. 1 Map of North Africa and the Mediterranean Basin showing major potential exit points for human dispersal out of Africa. Insets show the distance of sea crossings at the present day and when sea-levels were at −130 m (light blue shading). Courtesy of Maud Devès and the DISPERSE project

quite different from those associated with incoming *H.s.s.* populations. In Asia the picture is much less clear with few human fossil finds, huge gaps in time and space between them, and no characteristic stone-tool assemblages that can be used as reliable proxies for different hominin taxa.

Africa is a very difficult continent from which to escape. All the possible exit routes represent narrow bottlenecks. It has been generally assumed that the most likely exit for all early movements out of Africa is the narrow land corridor of the Sinai Peninsula connecting the Nile Valley to the Levant, on the assumption that land routes would have been the only viable ones for early human populations. The possibility of sea crossings of the Mediterranean during the Palaeolithic era has also been raised. The narrowest crossing at any position of sea level is about 12 km across the Strait of Gibraltar between opposing shores that are clearly inter-visible (Fig. 1). But neither here nor elsewhere in the Mediterranean is there decisive evidence for sea crossings based, for example, on indisputably dated human presence on islands, until a relatively late date from about 13 ka onward, despite claims for earlier evidence (Alimen 1975; Derricourt 2005; Strasser et al. 2010; Ammerman 2013, 2014). In any case, if the land exit via the Sinai is a bottleneck difficult to get through, sea crossings are likely to have been even more so.

2.1 The Southern Dispersal Route

A crossing at the southern end of the Red Sea, with or without a land bridge, has also periodically been proposed, most notably by Lahr and Foley (1994), who first raised this possibility as an alternative pathway for human populations moving out of Africa and into SE Asia. This particular pathway has gained new popularity from a variety of genetic, palaeogeographical and archaeological inferences, often coupled with the idea of new adaptations involving sea travel and use of marine resources as distinctive features of *H.s.s.* that gave them an evolutionary advantage and opened up new environments for colonisation and new migration

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pathways involving sea crossings (Beyin 2006, 2011; Mellars 2006; Oppenheimer 2012a, b; Mellars et al. 2013).

2.2 Phylogenetic Evidence

Genetic inferences about the dates of human dispersals have been derived from the construction of phylogenetic trees based on genetic variations in present-day human populations and mutation rates of DNA. These give patterns of divergence that suggest a date of 70–60 ka for the *H.s.s.* dispersal out of Africa (Macaulay et al. 2005; Soares et al. 2012; Oppenheimer 2012a, b; Mellars et al. 2013). In some cases, even the geographical routes of dispersal between Africa and SE Asia have been inferred from this evidence.

However, the assumptions on which these conclusions are based and their accuracy have been challenged and remain uncertain (Bailey 2009; Boivin et al. 2013; Field and Lahr 2005; Field et al. 2007; Groucutt et al. 2015). The mutation rates on which the DNA clock is based are uncertain and likely to have varied over time, and some studies indicate that during genetic bottlenecks the rate can actually increase (e.g., Ho et al. 2011). Divergence dates estimated from genetic modelling are subject to very large margins of error, with confidence intervals amounting to many tens of thousands of years. Divergence times also depend on anchoring the extrapolation to independently dated events. By their very nature, these are rare, and comprise a limited number of identifiable and dated migrations of genetically-known modern human populations splitting from their source populations and moving into new territory, for example the expansion of Bantu populations within Africa at 3.5 ka, the entry of anatomically modern humans into Australia supposedly at 50 ka, and the first colonisation of remote Pacific Islands within the past millennium. Other difficulties are that the genetic signature of earlier population expansions may be erased or swamped by later ones, and that nothing in the genetic relationships between modern populations living in Africa and on the Indian subcontinent can possibly specify a preference for a coastal pathway as opposed to a hinterland pathway for the expansion of the common ancestral populations out of Africa. The genetic data are equally compatible with an expansion out of Africa at 130 ka rather than 70 ka or indeed with a yet earlier date, and with a variety of alternative geographical pathways including crossings of the Arabian deserts during periods of wetter climate (Drake et al. 2013; Groucutt et al. 2015).

As often when dealing with investigations that take place in the no-man's-land at the intersection of different disciplinary boundaries, the risk of circular argument is high. For example, geneticists may depend on dates for human fossils and their archaeological proxies in the form of stone-tool assemblages to calibrate the DNA clock; and archaeologists may rely on the inferences of geneticists to provide dates for the fossil and archaeological record; both are inclined to rely on global climatic records of low geographical resolution derived from ice cores, speleothems and marine or lacustrine sediments to reinforce a preferred hypothesis.

Recovery of ancient DNA from fossil bone, though still rare—and likely to remain so because of the limited chronological range and temperature conditions in which ancient DNA is preserved—offers another source of genetic data. If anything, however, this seems likely to complicate rather than simplify the evolutionary narrative, since recent data suggest genetic mixing across taxonomic boundaries, for example between Neanderthals and anatomically modern humans (Green et al. 2010). Similar complications are emerging from DNA analysis of other mammalian taxa, for example mammoths (Enk et al. 2016).

Many genetic interpretations produced by independent analyses of different modern populations appear to be mutually reinforcing, but since they all depend on a similar set of assumptions about rates of genetic change and dates of divergence that are difficult to test independently, they need to be treated with caution and a critical eye when used to examine or reinforce archaeological interpretations about the demography and dispersal patterns of prehistoric human populations. As genetic studies extend more widely amongst modern human populations, so the patterning is becoming more complex, with evidence for two-way migrations and multiple dispersals, some much earlier than the original estimates (Malispinas et al. 2016; Pagani et al. 2016; Bohlender et al. 2016).

Another indirect source of genetic information of relevance to the southern dispersal route is the evidence from DNA analysis of modern baboon populations (*Papio hamadryas*) (Kopp et al. 2014). *Papio* evolved in Africa, splitting from *Theropithecus* according to fossil evidence at about 5 Ma, a date which provides a chronological anchor for phylogenetic reconstruction based on DNA analysis of modern populations. Baboons are present today in Arabia and in northeast Africa with major concentrations in SW Arabia, Eritrea and Ethiopia. DNA analysis shows that these populations form different genetic clades with evidence that the Arabian populations are derived from the African ones, together with some evidence of back migration from Arabia to Eritrea. Kopp et al. (2014) conclude from an analysis of the geographic distribution of genetic diversity and estimates of divergence times and population expansion that the most parsimonious interpretation of these data is that baboons dispersed across the southern end of the Red Sea on at least two occasions: At a mean date of about 150 ka with a range of 222–88 ka; and at 31 ka with a range of 55–11 ka (both ranges at the 95% confidence interval). These results are of considerable interest both in providing a transparent analysis and interpretation of modern genetic data that highlights the margins of error associated with inferred dates, and also in highlighting the likelihood of movement across the southern end of the Red Sea by non-human primates. If baboons were able to make the crossing, seemingly on more than one occasion, why not early humans?

2.3 Palaeogeographical and Palaeoclimatic Variables

The first question to address is the nature of the sea crossing at the southern end of the Red sea. At the present day, the shortest sea crossing is across the Bab al Mandab Strait, a sea-distance of about 30 km. Although it would be possible in principle for an endurance swimmer to cross this distance, a 30 km-wide sea channel is likely to have been an effective barrier to population movements without the use of seaworthy water craft. We know that Neolithic communities on the Arabian side used artefacts made of obsidian derived from sources in Ethiopia from as early as 8 ka (Khalidi 2009; Khalidi et al. 2010, 2012), so that sea crossings must have been taking place at that time. What sort of sea craft were used is not known for certain, but remains of barnacle-encrusted reeds and bitumen from the Gulf coast of Kuwait dated at about 7 ka suggest that boats made from bundles of reeds were in use at this time, and possibly boats made from sewn wooden planks (Lawler 2002; Carter 2010; Boivin et al. 2009). As with evidence from elsewhere in the region and from more recent periods, boats made from bundles of reeds are the most obvious candidate.

How much earlier such a technology was in use is impossible to say with any certainty. Isolated surface finds of obsidian artefacts have been found in surveys in SW Arabia, which could be from earlier periods (http://www.disperse-project.org/field-reports). However, we do not know their date or the source of the obsidian—there are sources in the Yemen as well as in Ethiopia—nor is the absence of obsidian or lack of evidence for its movement across the Red Sea an argument against the presence of boat technology or sea crossings.

A more relevant consideration, and one for which we do have some evidence is the effect of lowered sea level on the distance across the southern Red Sea (Fig. 2). At the maximum lowering of the Red Sea during the last glacial maximum at about 25–20 ka, global sea levels were 120–130 m lower than present because of the amount of sea water locked up in the continental ice sheets. The southern Red Sea was reduced to a relatively long, narrow and shallow sea channel extending for about 100 km from the Bab al Mandab to the Hanish Sill and no more than about 10 km wide (Siddall et al. 2003; Rohling et al. 2010, 2013). Palaeogeographic reconstructions of palaeoshorelines in the region taking account of global seawater volumes as well as isostatic and tectonic movements of the Earth's crust show that at the shallowest point of this channel, in the vicinity of the Hanish Sill, there was a group of islands in mid channel (Fig. 3). These reduce the sea distances to 4 km or less by island hopping from one side of the channel to the other (Lambeck et al. 2011).

In addition, the geometry of the channel is such that, although it is very wide at present sea-level, over 100 km, below a depth of about 40 m it narrows to a channel with quite steep sides, meaning that the possibility of short crossings would have persisted for any period when sea level was lower than about 50 m below present. Given the chronology of sea level change, this means that short sea crossings would have been available for as much as 40 kyr during the last 100-kyr-sea-level cycle and for some 140 kyr during the past 400 kyr (Lambeck et al. 2011).

Rohling et al. (2013) incorporating climatic proxies have further suggested that the most favourable windows of opportunity for sea crossings would have been narrowed to periods when climatic amelioration and low sea level coincided (see also Fig. 6 in Bailey et al. 2015). Other authors have also used the evidence of broad Pleistocene climatic cycles that periodically opened up the deserts of Arabia and the Sahara to the spread of grasslands and surface water to further constrain the timing of human dispersal (e.g., Drake et al. 2013; Kopp et al. 2014; Breeze et al. 2015, 2016). However, it should be remembered that the key for animal and human populations on the ground is the availability of soil nutrients, vegetation and water, and these are often highly variable at the sub-regional and local scale depending on local factors of topography, tectonic activity and hydrology (see Kübler et al., this volume). Human populations are likely to be attracted to combinations of environmental features that are atypical of the broader environmental or climatic zone within which they occur, and which afford a measure of insensitivity to fluctuations in rainfall or other regional climatic parameters. These especially occur in geological unstable regions where faulting and other tectonic or geomorphological processes rejuvenate soils and soil nutrients, create spring lines, and trap sediments and water in local basins (King and Bailey 2006; Bailey and King 2011; Winder et al. 2015; Kübler et al. this volume).

The southwest region of Arabia is persistently 'green' under most climatic conditions that have been experienced during the late Pleistocene, including those of the present day (Bailey et al. 2015). These attractions are likely to have been further enhanced when sea levels were low by the increased availability of water supplies on the exposed continental shelf because of the presence of fault-bounded basins, and the increased hydraulic head from groundwater

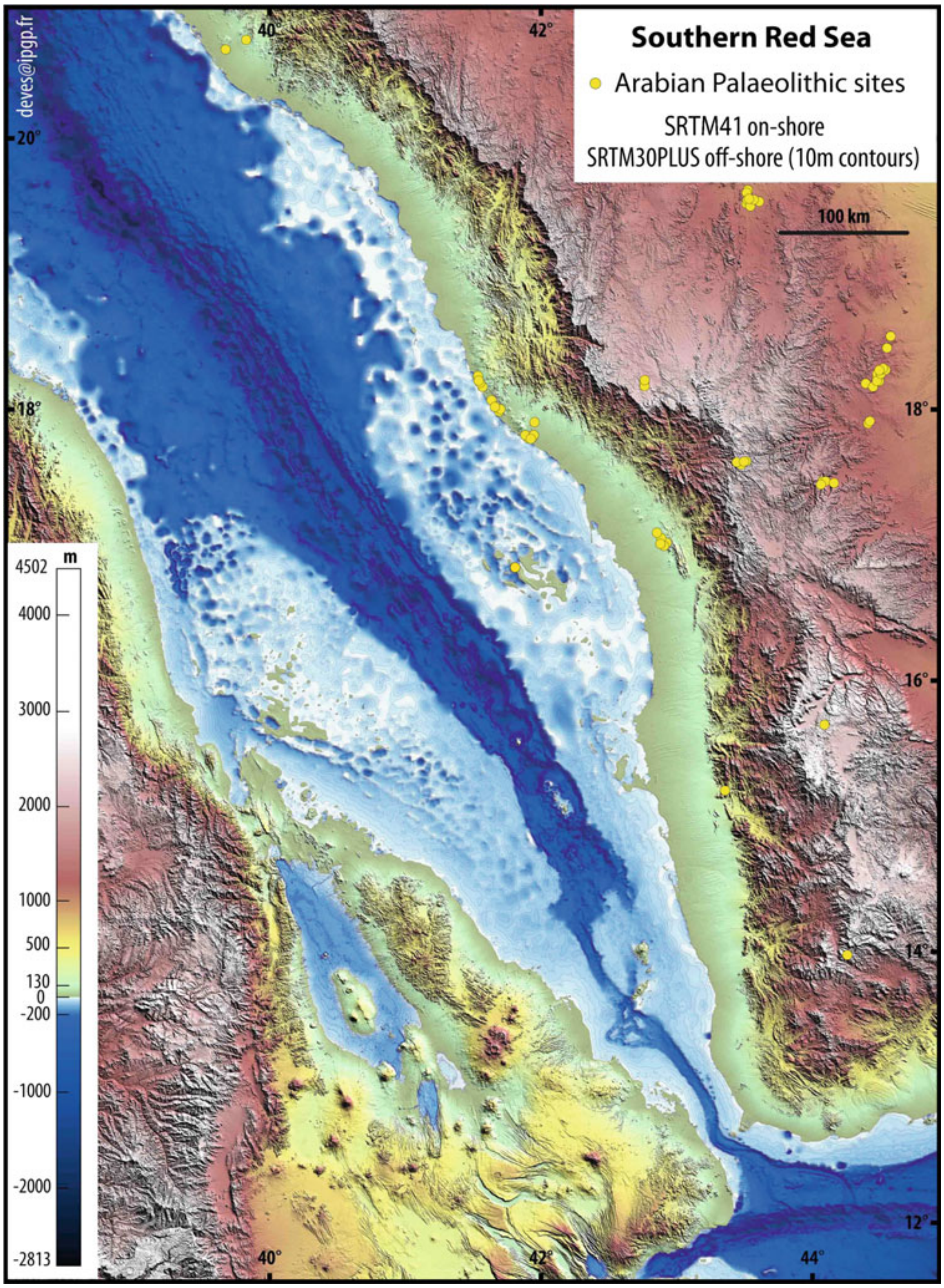

Fig. 2 Enhanced satellite imagery of the southern Red Sea showing the position of the Farasan Islands, and the extent of the submerged landscape at maximum sea-level regression during glacial periods, and the general nature of the seabed topography. ASTER GDEM is a product of METI and NASA. Courtesy of Maud Devès and the DISPERSE project

reservoirs, creating groundwater springs and relatively attractive local conditions regardless of climatic aridity at the continental scale (Faure et al. 2002; Bailey et al. 2015; Sakellariou et al., this volume).

In addition, the isotope data from deep sea cores from within the Red Sea and the evidence of what is known or can be inferred about crustal movements associated with rifting indicate that these palaeogeographical and palaeoclimatic scenarios are likely to have persisted for at least the past half million years. Before that time, the position is less clear because of lack of data from deep-sea sediments extending that far back in time, and because of uncertainties associated with the separation of the Arabian and African plates.

The key point is that opportunities for short sea crossings would have persisted for relatively long periods of thousands of years at a time, if not tens of thousands, over the past half million years. Given some degree of inter-visibility between opposing shores and availability of vegetation and water on

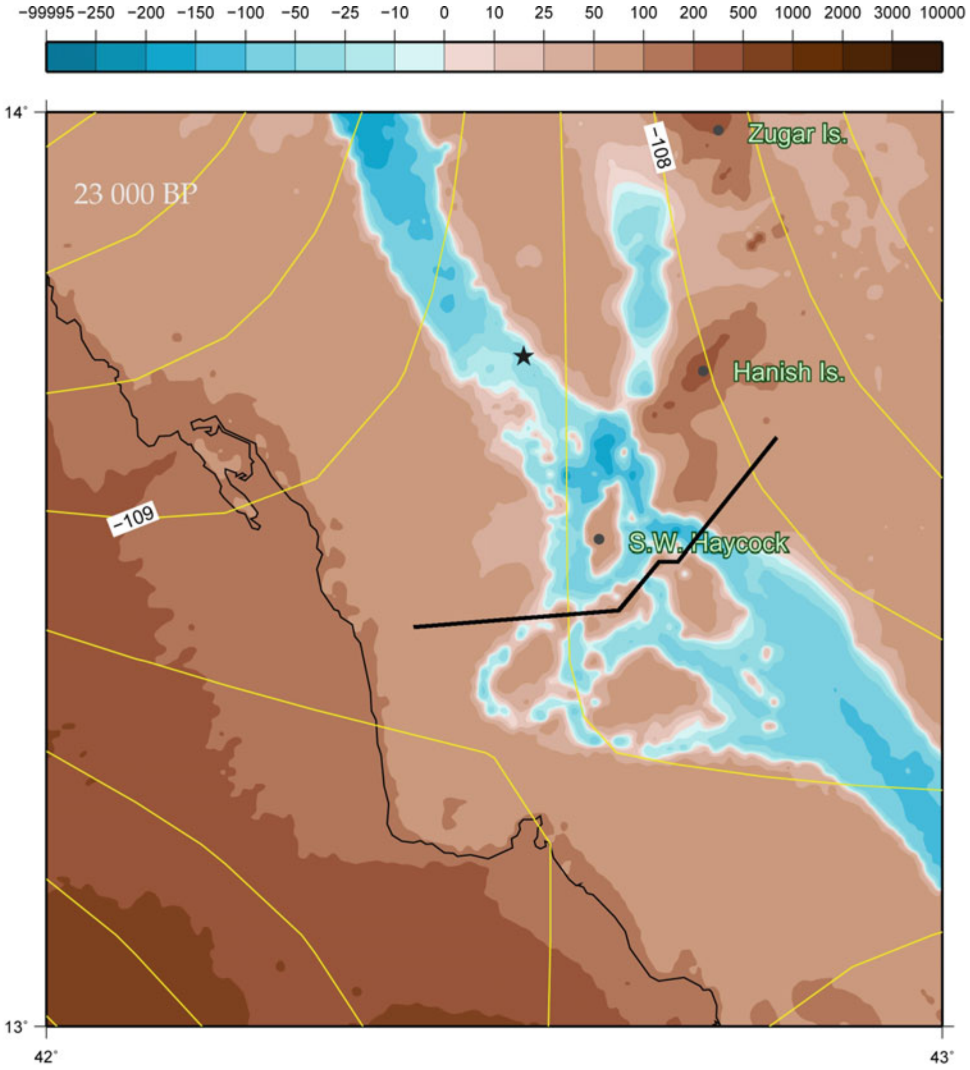

Fig. 3 Palaeoshorelines at the southern end of the Red Sea during the maximum sea-level low-stand at the Last Glacial Maximum. The present-day coastline is indicated by the thin black line. The black star shows the location of the Hanish Sill and the yellow lines represent contours of equal sea level position relative to the present at 23 ka. The shortest sea crossings at this period would have been in the region of the Hanish Sill as shown by the thick black line. After Lambeck et al. 2011

both sides, distances would have been short enough and the windows of opportunity long enough to suggest a high probability of crossings by swimming, floating or rafting on natural mats of vegetation whether by chance or by design. However, the distances are not so large that they require any need to invoke the construction of water craft or seafaring abilities as practised during the Holocene period. The fact that baboons, as noted above, appear to have colonised SW Arabia from NE Africa across the southern channel on at least two occasions between about 220 ka and 11 ka reinforces this conclusion. It should be added that many other terrestrial mammals including hippopotami, elephants, cervids, bovids, equids, ursids and some carnivores are capable of swimming over relatively short distances whether by choice or compulsion. We see no need in any of this evidence to suppose that short sea crossings during favourable windows of opportunity could not have been accomplished by human populations at any time in the past half million years or indeed earlier.

2.4 Archaeological Evidence

Palaeogenetic, palaeoclimatic and palaeogeographical information offer, at best, indirect clues as to the pattern of human settlement and dispersal. The ultimate test must lie in archaeological field data. Here the available evidence for late Pleistocene coastal sites around the southern shores of the Red Sea, especially in shore-edge settings, is meagre. Only one site is unquestionably on the shore edge, and that is the site of Abdur in Eritrea (Walter et al. 2000). Here, artefacts of Middle Stone Age (MSA) type including flakes made on obsidian have been found stratified within beach deposits associated with reef corals which have been dated to about 125 ka. Also present in these deposits are mammal bones and mollusc shells of edible species including oysters and mussels, which the authors have interpreted as evidence of subsistence activity on the beach, the marine foods indicating a novel adaptation comparable to the fish bones and mollusc shells found at a similar date in the caves of South

Africa, such as Blombos Cave and Klasies River Mouth (Henshilwood et al. 2001; Van Niekerk 2011; Langejans et al. 2017).

There is no reason to doubt the age or stratigraphic associations of the Abdur deposit, and the connection to *H.s. s.* is plausible, given the date and the geographical region. The rest of the interpretation, however, is open to challenge. Since the deposit as a whole is a beach deposit including shell and coral-reef material that is clearly the debris of natural death assemblages, including whole oysters described as in growth position, the question of what is food shell and what is natural shell needs to be posed and investigated. Distinguishing between the two types of shell material when both are present in the same deposit is notoriously difficult and has given rise to an extensive literature on diagnostic criteria (e.g., Attenbrow 1992; Rowland 1994; Watters et al. 1992; Rosendahl et al. 2007). The fact that artefacts were found next to edible marine mollusc shells is not necessarily evidence that the shells were eaten as food, nor does the sharp condition of the artefacts rule out post-depositional movement and displacement. A reef flat is not the most obvious place for people to butcher large mammals or for that matter to process and consume locally collected marine foods. Without a thoroughgoing taphonomic analysis that examines the source and condition of all these various materials and the possible agencies of transportation and deposition, including natural as well as cultural ones, the palaeoconomic interpretation must remain in doubt. This evidence remains a very slender basis on which to hypothesise the exploitation of marine resources, coastal environments and the crossing of the southern Red Sea as significant factors in human dispersal out of Africa.

Elevated coral reefs of presumed similar age associated with an MIS 5 high sea-level have been extensively surveyed on the SW Saudi Arabian coastline of the Red Sea (Inglis et al., this volume), but so far with no evidence comparable to Abdur. Middle Stone Age or Middle Palaeolithic artefacts have been found on the surface of some of these coral terraces, but almost none in demonstrable stratigraphic association with them. The exception is Dhahaban Quarry, where stone artefacts are embedded in a water-laid cobble unit beneath a series of shallow marine and beach deposits, and associated with a coral platform ~6.5 m above modern sea level (Inglis et al. 2014, and this volume; Sinclair et al., this volume). Isolated shells of oyster, giant clam and mangrove whelk and pieces of coral are in the same depositional unit, but the shells are not food remains

Otherwise, artefacts of Middle Stone Age type, and in many cases Early Stone Age type, have been recovered in many areas in the Arabian Peninsula. Many are surface finds where dating is impossible except by reference to typological and technological comparisons with better studied and dated material in the neighbouring regions of Africa and southwest Asia. MSA material is typically identified by the presence of prepared core technologies of discoid or Levallois type. At Jebel Faya, material of this type is dated at 125 ka (Armitage et al. 2011; Bretzke et al. 2013), but initial claims that this was evidence for the presence of anatomically modern humans have not been supported by finds of associated human fossil material. Since prepared core technologies have been widely used over at least the past 250 ka and are associated with hominins such as Neanderthals as well as early anatomically modern humans such as the Skhul and Qafzeh remains in Israel, they are clearly unreliable proxies for the presence of anatomically modern humans. Other recently investigated material in the Nefud dates back to about 100 ka (Petraglia et al. 2011), and some of the Arabian material includes bifacially worked flakes of Acheulean type that very likely date back to the Middle Pleistocene, perhaps as early as 0.8 Ma (Petraglia et al. 2009; Bailey et al. 2015).

Most of this material is in the Arabian hinterland and much of it in the Arabian deserts, associated with periods of climate change when hydrological corridors with lakes or wetlands and grasslands were extensively distributed across the deserts of the Rub al ‘Khali and the Nefud (Breeze et al. 2015, 2016; Petraglia et al., this volume). None of this material can be described as coastal except in the very broad sense that some of the sites are in coastal regions broadly defined, such as the recently discovered site of Wadi Dabsa in the Harrat Al Birk region of southwest Saudi Arabia (Foulds et al. 2017; Inglis et al. 2017; Sinclair et al. this volume), with an extensive palimpsest of material of many different periods in an inland basin about 10 km from the present-day coastline.

At first sight the distribution of the archaeological material suggests an overwhelming preference for hinterland locations and little or no interest in the coastline or its marine resources until the mid-Holocene. However, we should beware of taking this at face value.

For example, Usik et al. (2013) have cast doubt on the hypothesis that there was a rapid coastal dispersal of modern humans around the Indian ocean coastline at 60 ka on the grounds that sites of this date are absent on coastlines where we should expect to find them if the hypothesis is correct. On the Oman coastline, for example, MSA (MIS5 or earlier) and Neolithic (mid-Holocene) sites are present but none of Upper Palaeolithic or Late Stone Age type that could be assigned to the intervening period (MIS 4–2). One could argue against this that 60 ka coastal sites would now be on submerged coastlines, but Usik et al. (2013) note that sites of this period are absent even on the uplifted coastline of the Musandam Peninsula. One difficulty here is that sites of this period are rare or absent everywhere in the Arabian

Peninsula. Either there was a prolonged period of human absence, or the archaeological sites of this period are generally of very low archaeological visibility.

How then, are we to deal with negative evidence, that is the absence of archaeological material on or near coastlines, even in areas where the conditions for preservation or visibility on the coastline appear to be good? One place to start investigating this relationship in more detail is to look at more recent coastlines where archaeological material with clear evidence of marine exploitation is well preserved, and to examine the relationship between the formation processes of archaeological deposits, and their spatio-temporal distribution in relation to variations in the geomorphology and ecology of the contemporaneous coastline.

3 Shell Mounds of the Farasan Islands

The Farasan Islands have several advantages for such an examination. In the first place they have one of the largest concentrations of shell mounds known anywhere in the world, comparable to the better known and studied concentrations of shell mounds in Europe, Japan, the Americas, South Africa, West Africa and Australia (Bailey et al. 2013a). This concentration is in part the product of the high ecological fertility of the surrounding inshore waters, and in part due to the remoteness of the islands, the small population size, and the lack of modern development. Shell mounds are notoriously vulnerable to destruction by quarrying activities to exploit the shell for building material or simply as obstacles in the way of road building or other construction activities, often accompanied by the belief that they are natural deposits with no cultural significance. The Farasan Islands have witnessed very little of these developmental impacts until recently, offering a near-pristine distribution of archaeological material along the coastline. Also, the islands are located on a salt dome, with quite rapid uplift of some shorelines because of salt tectonics, and down warping of others (Inglis et al., this volume). In this respect the Islands offer an unusual insight into the impact of changing relative sea levels on the coastal geomorphology of shorelines, molluscan habitats and the occurrence and distribution of shell mounds.

The Farasan shell mounds are often described as 'Neolithic' in the Arabian context, mainly because of their date. Elsewhere shell mounds of similar form in Europe are described as 'Mesolithic', in North America as 'Archaic', or in other parts of the world by some other label according to the local nomenclature. The great majority of the larger shell mounds and concentrations of open air shell middens found all across the world first appear in the mid-Holocene at about 7–6 ka. The implication of these labels is that the shell mounds are a relatively late cultural stage in the broader history of human development, a rung on the ladder of human progress. However, this is also the period when sea level stopped rising from a low sea-level stand of −120 m at the Last Glacial Maximum. There is no reason to suppose that earlier concentrations of shell mounds could not have existed at earlier periods during the Last Glacial on shorelines that are now submerged. Earlier evidence for the exploitation of marine molluscs is certainly present, back to at least 160,000 years ago (Jerardino and Marean 2010), and is especially prominent in deposits dating to the Last Interglacial period (MIS 5) when sea levels stood at heights generally similar to the present day. But the evidence is mostly in caves on the present-day coastline, and none of the deposits is on the scale of the mid-Holocene mound concentrations. This is most likely because these earlier sites are on rocky coastlines that are much less productive of marine molluscs than the bays and estuaries where the mid-Holocene mounds are concentrated.

We make no assumptions here about whether or not the Farasan shell mounds are a cultural phenomenon unique to their particular time and place. That is possible, but we maintain an open mind as to the possibility that similar shell mounds existed on earlier coastlines that are now submerged. Rather our intention here is to use the Farasan example as a high-resolution case study to examine the relationship between the variable preservation and visibility of shell-dominated coastal archaeological deposits and the variable ecology and geomorphology of the coastlines where they occur. In this way, the case study can serve as a benchmark against which to assess the significance of the more sparsely distributed evidence from earlier periods.

3.1 General Features

Over 3000 shell midden deposits have been recorded on the Farasan Islands (Williams 2010; Alsharekh et al. 2013; Bailey et al. 2013a, b; Meredith-Williams et al. 2013, 2014a, b; Hausman and Meredith-Williams 2016a, b). The largest are 5 m tall and roughly oval in plan, forming highly visible features of the landscape (Fig. 4). The largest may contain as much as 1000 m^3 of deposit, representing 1000 tonnes of shell and over 100 million molluscs. Not all deposits are so impressive in size; many are low mounds less than 1 m in thickness and some are surface scatters of shell less than 5 m in diameter with little accumulation of deposit. Nevertheless, the larger mounds are striking and highly visible features in the present-day landscape, sometimes forming a quasi-continuous line of mounds of varying size along the shoreline that are easily identifiable on satellite images (Fig. 5; Meredith-Williams et al. 2014b). Many of these larger mounds form clusters with mounds of varying size and smaller deposits nearby. These are usually lined up

Fig. 4 Line of shell mounds in Janaba Bay West, looking south. The shell mounds are sitting on a coral platform which has been eroded by marine action to form a low undercut cliff at a time when the sea penetrated further inland than today. The height of the cliff is c. 2 m Photo by Abdullah Al Zahrani

along the shoreline or else they are clustered in groups with the larger mounds along the shoreline and smaller mounds and shell scatters extending up to several hundred metres inland from the shoreline.

Nineteen shell mounds of varying size and location have been excavated with systematic exposure of sections, removal of bulk shell samples, collection of faunal and artefactual material where present, and recovery of individual specimens of charcoal and shell from the sections for radiocarbon dating (Table 1; see also Meredith-Williams et al. 2013). The bulk of the mounded shell deposits were formed between about 6.5 and 4.5 ka. Some younger-dated shell deposits are present, some as recent as the Islamic period, but these all have the form of shell scatters, or deposits <50 cm thick.

The dominant mollusc species in all the mounded deposits is the lineated conch, *Conomurex fasciatus*, a small gastropod 4–6 cm in length (Hausmann et al., this volume; Fig. 6). A variety of other species are present in varying proportions. These include the large gastropods, *Chicoreus ramosus* (the branched murex shell), and *Pleuroploca trapezium* (the horse conch). All the gastropod species are found on reef flats, usually on sandy substrates. Bivalve species include *Chama reflexa* (jewel box clam), *Pinctada* cf. *radiata* (pearl oyster), *Arca avellana* (hazelnut ark shell), *Plicatula plicata* (plicate kittens paw), *Spondylus marisrubri* (spiny oyster), *Beguina gubernaculum* (rudder cardita) and *Modiolus auriculatus* (eared horse mussel). These mostly occur on coral reefs and attach themselves to a hard surface with byssus threads or cement-like secretions. All of these species are present today, but the *Conomurex* shells are quite rare, in contrast to their obvious abundance in the prehistoric period. It is not clear whether this is due to temporary and episodic population collapse or long-term habitat degradation. In 2009 we found large quantities of live specimens on one of the smaller offshore islands in a sheltered sandy bay where they could be scooped up by the bucket-full. However, on returning in 2015, there was no trace of them.

The species that is most commonly used as food today is the large strombid gastropod, *Strombus tricornis* (Queen conch). The shells of this species are often found in small scatters near the modern shoreline where they have been left by modern picnickers, along with other typical modern artefacts such as empty drink cans. This species is relatively rare in the prehistoric shell mounds, but is certainly present and occasionally the dominant mollusc in some layers.

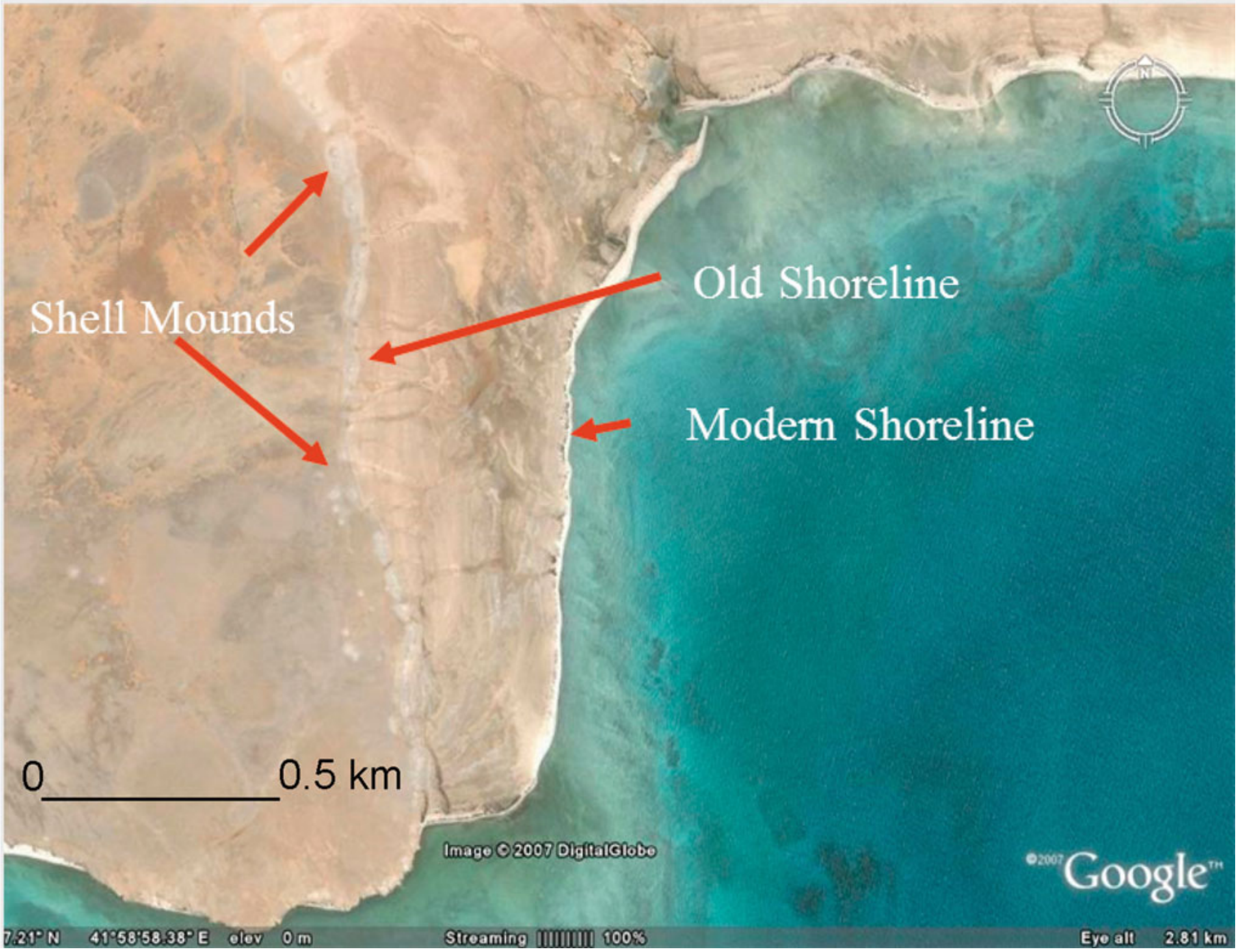

Fig. 5 Google Earth image showing aerial view of Janaba Bay West. Large shell mounds, including the mounds shown in Fig. 4, are clearly visible on a now-abandoned shoreline

Table 1 Radiocarbon dates for shell mounds in Janaba West. See Figs. 9 and 10 for location of sites. Calibration according to Reimer et al. (2013)

Lab Number	Site	Layer	Radiocarbon Age BP	Material	Species	Modelled age 2σ range Cal BP
OxA-31168	JW1705	1	3411 ± 31	marine shell	*C. fasciatus*	3325–2980
OxA-31166	JW1705	6	4842 ± 32	marine shell	*C. fasciatus*	5209–4836
OxA-31167	JW1705	4-basal	6870 ± 38	marine shell	*C. fasciatus*	7413–7172
OxA-27890	JW1727	17	4202 ± 29	charcoal	unknown	4844–4627
OxA-27889	JW1727	23	4287 ± 29	charcoal	unknown	4958–4825
OxA-28617	JW1727	23	4701 ± 28	marine shell	*C. fasciatus*	4970–4630
OxA-28009	JW1727	2	4851 ± 31	marine shell	*C. fasciatus*	5217–4842
OxA-34098	JW1727	8 Top	4759 ± 31	marine shell	*C. fasciatus*	5041–4712
OxA-34099	JW1727	8 Base	4539 ± 33	marine shell	*C. fasciatus*	4786–4433
OxA-31169	JW1727	27-basal	5044 ± 35	marine shell	*Brachidontes variabilis*	5444–5064
OxA-31170	JW5694	3	2767 ± 30	marine shell	*C. fasciatus*	2573–2177
OxA-30870	JW5694	4-basal	2902 ± 29	marine shell	*C. fasciatus*	2700–2365
OxA-31171	JW5697	3-basal	2220 ± 27	marine shell	*C. fasciatus*	1845–1555
OxA-31172	JW5719	basal	2500 ± 29	marine shell	*C. fasciatus*	2199–1870
OxA-31173	JW5719	upper	2554 ± 27	marine shell	*C. fasciatus*	2283–1955

Fig. 6 *Conomurex fasciatus* shell. Photo by Niklas Hausmann

The variable presence in the mounds of these different mollusc species most likely reflects differences in the intertidal and offshore habitats within reach of a given mound or on different parts of the coastline, and to some extent long-term changes in habitat availability, particularly for the *Conomurex* and *Strombus* species of the Strombidae family

Excavations show fairly uniform conditions of shell deposition, with a dominant matrix of whole or broken shells, variable proportions of fine ashy sediment, occasional interleaved ash lenses and scattered small pieces of charcoal (Fig. 7). Fish bones are present, mostly of small specimens most likely caught by net. The most common species are reef fish such as parrotfish (Scaridae), sea bream (Sparidae), emperors (Lethrinidae), trevallies (Carangidae) and groupers (Serranidae) (Beech 2018). There are also occasional bones of gazelle (*Gazella gazella*). Stone artefacts are rare, and include a ground stone axe and a worked flake, both made of volcanic rock only available on the mainland, manuports of coralline limestone of uncertain function, and occasional pieces of worked *Tridacna* (giant clam) shell. Potsherds are very rarely present. A human burial, comprising pits with the remains of two individuals, is present in the top of one of the excavated shell mounds, and is of the same date as the surrounding midden deposit.

The inhabitants of this period were clearly capable of regular sea travel, judging by the presence of shell mounds on smaller offshore islands and the contacts with the mainland, most likely using sea craft made of bundles of reeds as discussed earlier. Seasonality analyses of the mollusc shells also indicate that molluscs were exploited throughout the year, which rules out the hypothesis that the Islands were visited only for seasonal activities (Hausmann and Meredith-Williams 2016a).

3.2 Interpretation of Shell Quantities

It is important at this point to dispel two myths that commonly grow up around the existence of shell mounds on this scale. The first is that the quantities of shell are so vast that they must have been accumulated by natural agencies as natural shell banks or storm deposits rather than by human action. The second is that they represent the remains of people who lived mainly on shellfood.

The first hypothesis is refuted by a number of lines of evidence. First, there is no known natural agency that could dump shells in the form of discrete and mound-like structures at regular intervals along a shoreline or at distances of up to several hundred metres inland. Natural shell banks tend to form long low sub-parallel banks parallel to the modern shoreline and contain layers with large quantities of crushed shell, a very wide-range of molluscan species, beach sand and gravel, evidence of water abrasion and shell specimens of every size and age. The shell mounds we are talking about are dominated by a relatively restricted range of molluscan species, all of which are edible, whole and broken shells of mature-size specimens, ash lenses representing fire places used for cooking, artefacts, and bones of fish and terrestrial mammals.

It is true that artefacts are rare but this is the result of several factors, the scarcity of suitable stone material on the islands for making flaked or ground stone artefacts, the relatively rapid rates of accumulation of the shell deposits due to the bulk of the shell in comparison with other deposited materials, and, most likely, the specialised nature of the shell mounds as locations for the processing and consumption of marine mollusc shells and fish, rather than as settlement sites. The latter may be represented by some of the thinner shell mounds and shell scatters that are located inland from the bigger shell mounds on the immediate shoreline. Some of these have blocks of coral embedded in the shell deposit representing the remains of simple structures, and more abundant surface remains of broken potsherds.

As for the second hypothesis, a simple calculation shows that despite the impressive quantities of shell involved, the amount of food they represent is actually quite small. At a conservative estimate the known shell mounds on the Farasan Islands represent about 500,000 tonnes of shell

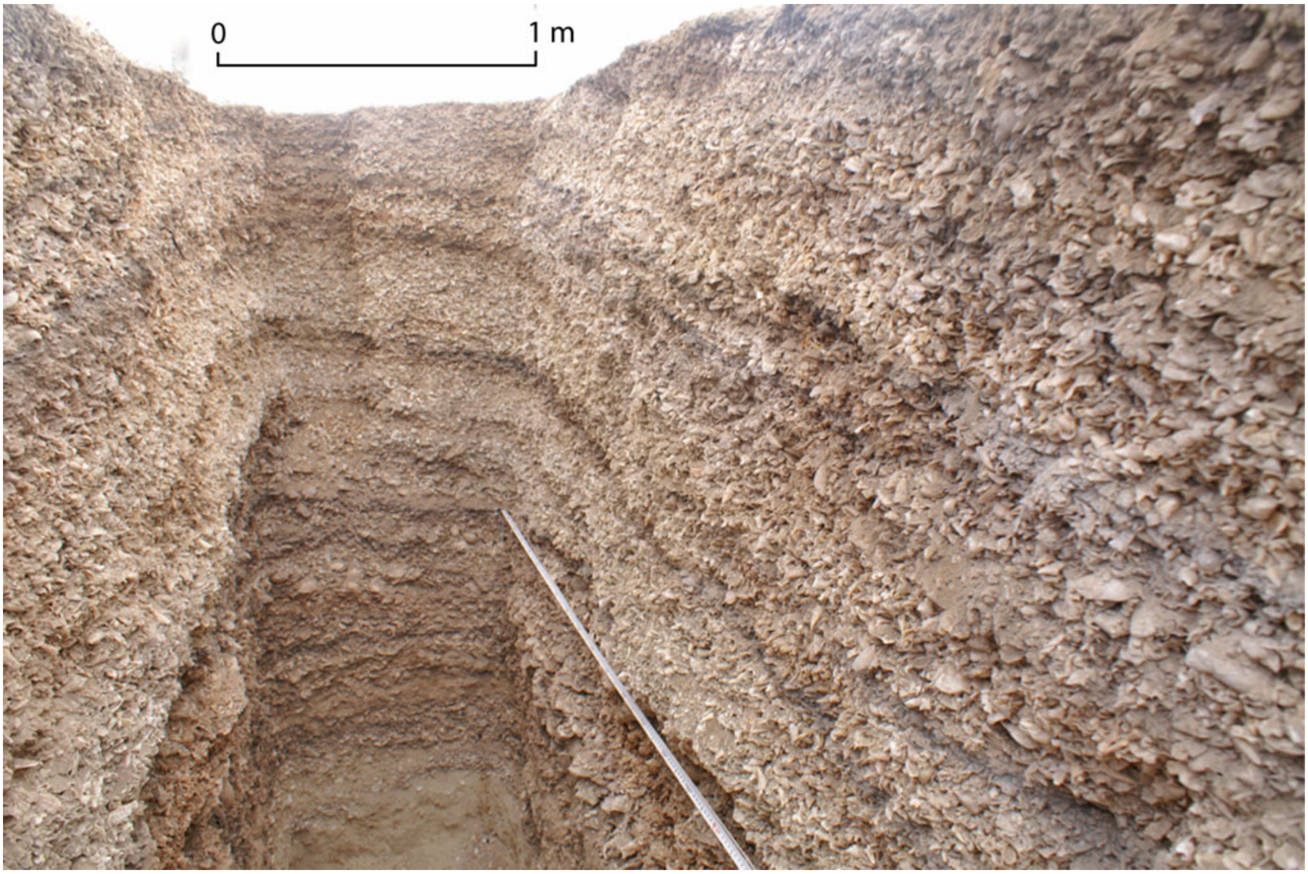

Fig. 7 Excavated trench showing section through a large shell mound, JE0087, in Janaba Bay East

material. Taking a shell-weight to meat-weight ratio of 5:1, a calorie content of 50 kcal per 100 g of meat, and a daily human individual requirement of 2000 kcal, this gives a total quantity of 25 million person-days of food or 68,500 person-years. Assuming a total duration of the Farasan shell mounds of 2000 years, this figure in its turn represents enough food to feed 34 people, assuming that they ate nothing but shellfood. Of course a diet of nothing but shellfood would rapidly lead to protein poisoning (Noli and Avery 1988), and these figures are not intended to represent an economic reality. Rather, they indicate parameters that are compatible with a relatively small resident population on the islands—of the order of hundreds rather than thousands of people—and a diet in which shellfood played an important but by no means dominant role. The belief in the dominant role of shellfood results from the great bulk of discarded shell relative to the meat content and the greater resistance of the discarded shells to decay and destruction compared to the material remains of animal and plant food. Nevertheless, here as in other regions of the world (Meehan 1982) the mollusc meat clearly played an important role in the subsistence economy. In particular, seasonality data show an increase of mollusc consumption during the more arid times of the year when other food sources would have been more limited (Hausmann and Meredith-Williams 2016a). Ethnographic observations of living people also show that the converse situation can arise, namely one where people collect large quantities of shellfood but do not necessarily deposit the discarded shells in the form of impressive shell mounds (Hardy et al. 2016).

One other point to comment on is the dominant presence of *Conomurex fasciatus*. This small gastropod at first sight does not look a promising source of food compared to the larger molluscs. It would need some form of mass capture using a bag or basket, and heat to kill the animal and loosen the meat from the shell. Since small gastropods requiring similar techniques of collection and processing are widely used today as food, for example as observed in the markets of China (pers. obs., 2012) and recorded in Australian Aboriginal ethnography (Rowland 1994), there is no reason to consider their small size and processing requirements as an argument against their collection as food.

3.3 Spatial Distribution

The first point to make is that the shell mounds are not uniformly distributed around the shorelines of the islands and the largest mounds and the largest concentrations of mounds are highly restricted in their distribution.

A closer examination shows that the large clusters of shell mounds are limited in their distribution compared to the smaller deposits and shell scatters, which are distributed more extensively around the coastlines of the Islands (Fig. 8). These large clusters are associated with very large shallow bays and this almost certainly reflects the fact that the extensive intertidal and subtidal sand flats hosted by these shallow bays provide the optimal habitat for molluscs, particularly the gastropods, and the most extensive habitat, with vast quantities of living shell. Along the more open shorelines, shell mounds are smaller, exist only as small surface scatters, or are completely absent over long stretches of shoreline, reflecting much less suitable local habitats for large quantities of molluscs, and also on some shorelines greater difficulties of access to the shore because of more irregular terrain and the presence of low cliffs created by marine erosion.

3.4 Chronological Distribution, Rates of Deposition and the Impact of Coastal Change

The chronology of the mounds indicates that the main concentrations, and especially the larger mounds are not only clumped in space, but they are also clumped in time, with a major concentration in the period between 6.5 ka and 4.5 ka. The principal reason for this appears to be the

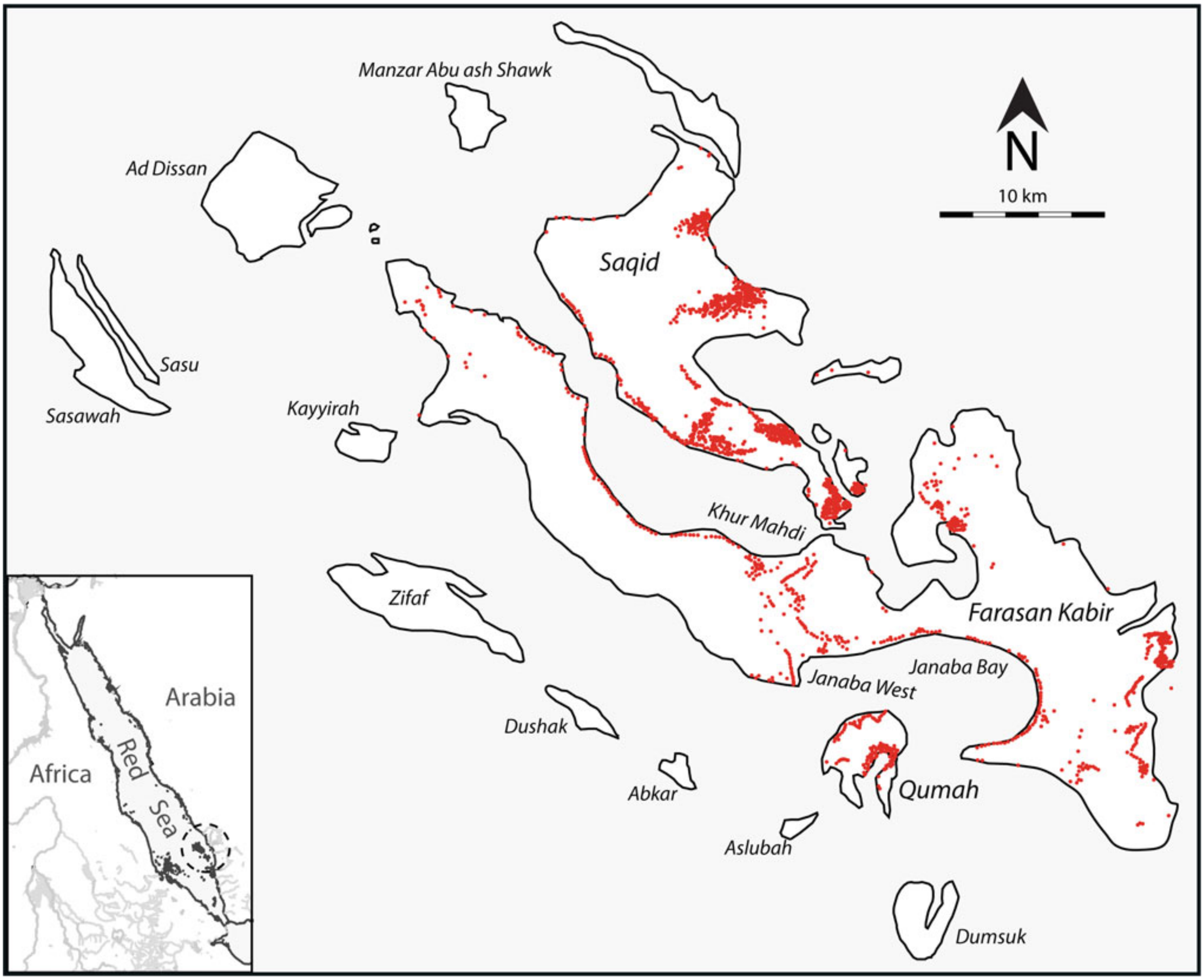

Fig. 8 Distribution of shell mounds (red dots) in the Farasan Islands. Drawn by Niklas Hausmann

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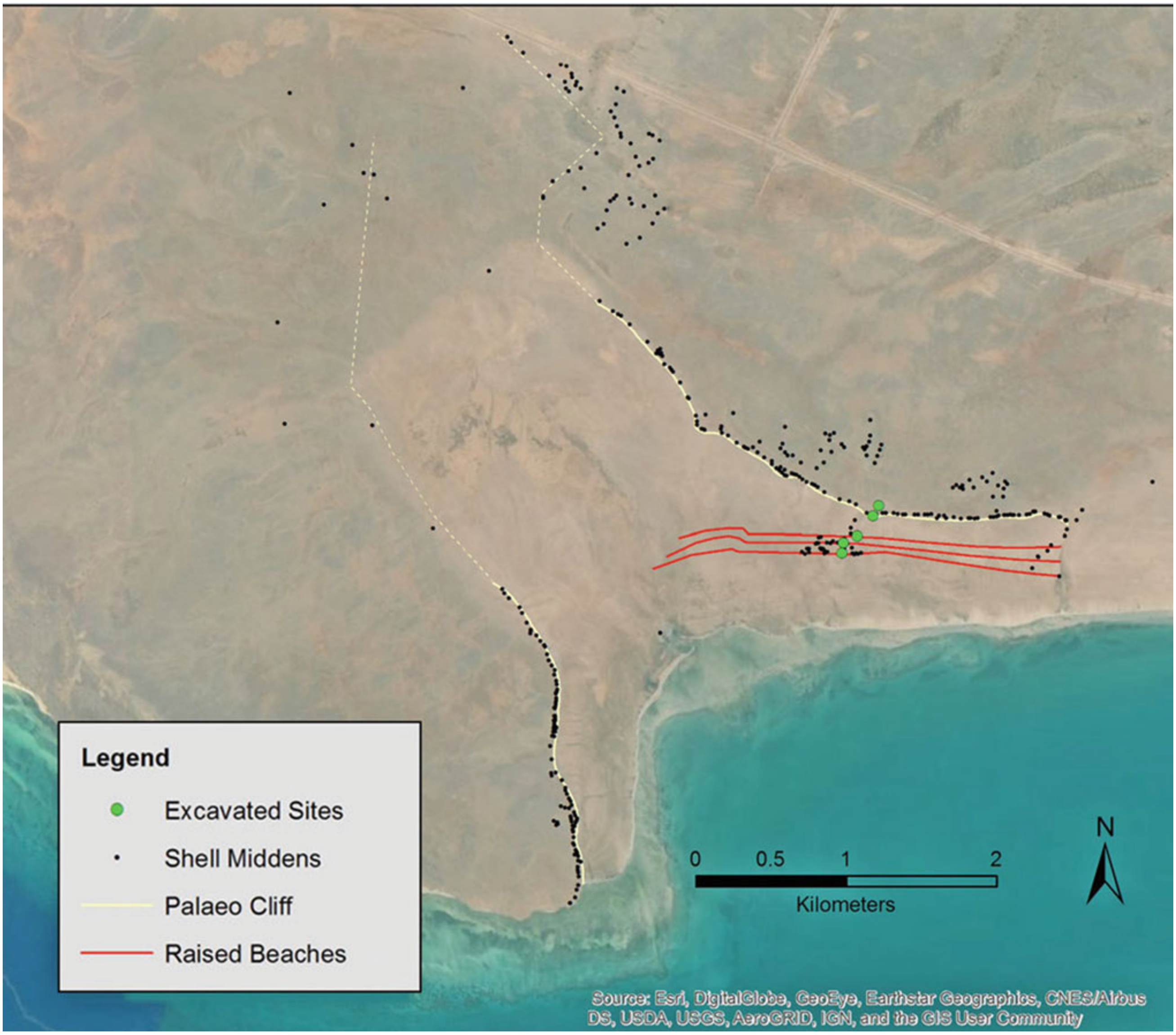
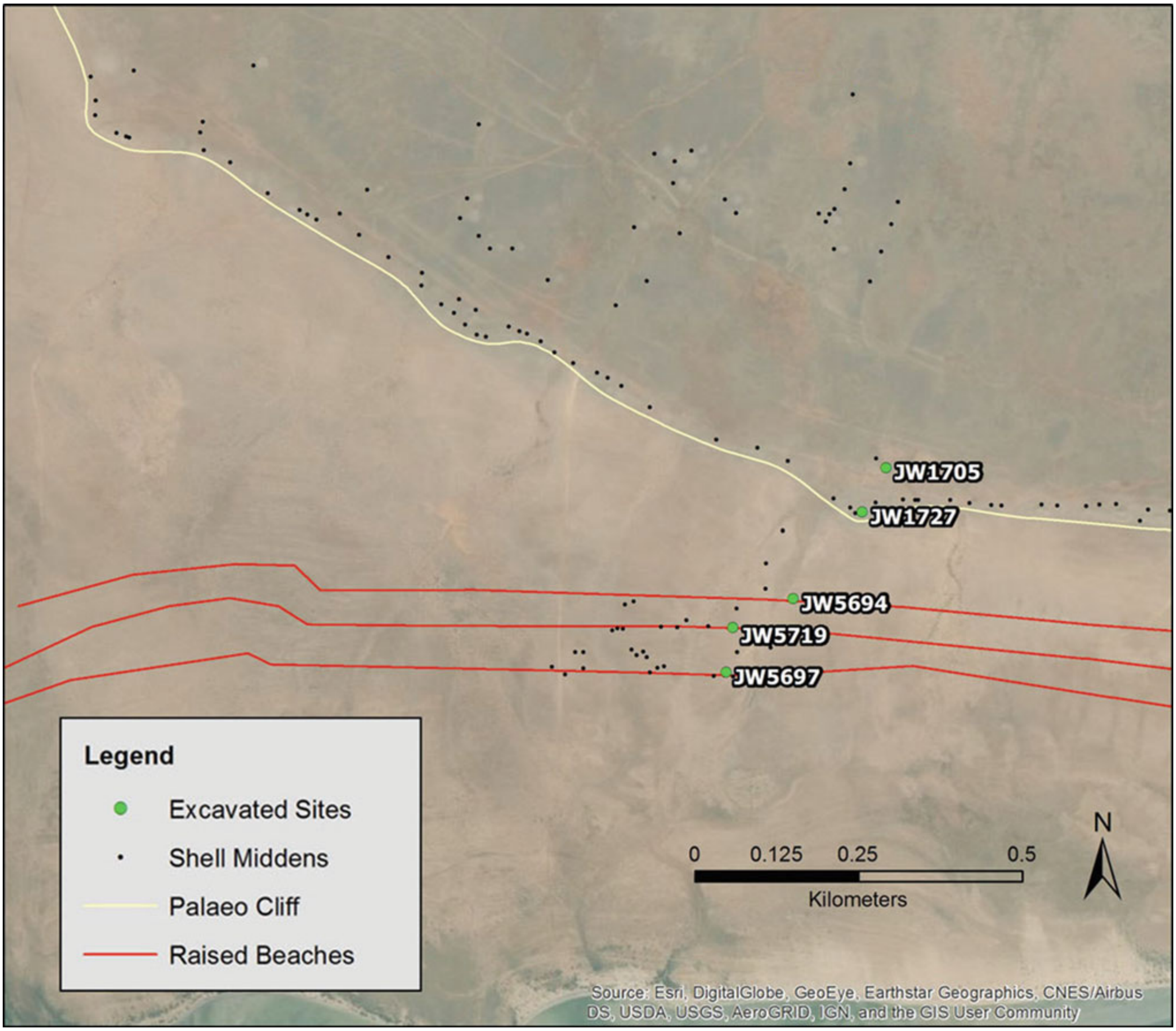
relatively short-lived nature of the shallow habitats that generated large supplies of *C. fasciatus*. Before about 6–7 ka, sea level was significantly lower than today, and any shallow sandy intertidal habitats and associated shell mounds must now be under water. After about 4.5 ka, progressive geomorphological and ecological changes removed the extensive areas of *C. fasciatus* habitat.

Today, the shallow bays associated with all the major clusters of large shell mounds are now dry terrestrial surfaces filled with sand. This effect is most dramatically visible at Janaba West, where the original bay and the shorelines and shell mounds that originally lined the inner edge of the bay are clearly visible on satellite imagery (Fig. 5). At some point between the active accumulation of the major shell mounds and the situation visible today, these bays must have begun to dry out, either because of tectonic uplift associated with the Farasan salt dome, or more simply because of progressive accumulation of marine sand and progradation of the beach front, or possibly both processes acting together, amplified by accumulations of wind-blown sand removed from the newly exposed seabed. The result is the transformation of these pre-existing shallow intertidal



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Fig. 9 Satellite image showing detailed distribution of shell middens in Janaba Bay West (see also Figs. 4 and 5). The largest shell mounds are on the original palaeoshoreline (shown in white) which partially circumscribes a now-dry bay. Red lines indicate palaeoshorelines formed during the regression of the shoreline toward the present-day position. For further detail see Fig. 10



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Fig. 10 Satellite image showing detail of shifting shorelines and location of excavated shell mounds in Janaba Bay West

marine embayments into terrestrial surfaces comprising supratidal sand flats, or exposed coral reef surfaces covered with a thin veneer of mobile sand that forms windblown drifts and dunes. These effects are clearly visible in the bays associated with the other major clusters of shell mounds.

A more detailed insight into these processes is afforded by a sequence of shell mounds on the inner margin of the Janaba West Bay. Here there are numerous shell mounds of varying size forming distinctive patterns of distribution. A majority of the sites, including the largest shell mounds in the group, are located along the former shoreline of a major embayment, both clearly visible on satellite images (Figs. 5 and 9). This shoreline was static for long enough to form a low cliff created by marine erosion.

Inland of this major feature are small shell mounds and shell scatters that form a less regular pattern. These include site JW 1705, a shell scatter, dated to about 7300 cal BP, with a younger date of about 5000 cal BP (Fig. 10, Table 1). Their distribution suggests an earlier shoreline or series of shorelines formed at a time, probably quite short-lived, when the sea penetrated yet further inland and then retreated again, either because of slight tectonic uplift, or because of a mid-Holocene high sea level.

The shell mounds formed along the major shoreline are typical deposits dominated by *C. fasciatus*, and are clearly associated with the large embayment when it was an inter-tidal basin providing a suitable habitat for very extensive beds of shellfish (Fig. 10). Site JW 1727 is typical of the

Fig. 11 Excavated trench of site JW 5694, showing shallow depth of shell deposit

mounds formed along this shoreline, and consists of an oval mound about 30 m long with a maximum thickness of 2 m, a total volume of 163 m^3, and a radiocarbon date of about 4850 cal BP (Hausmann and Meredith-Williams 2016b).

Seaward of this major shoreline are shell deposits of progressively younger date, formed on sandy beach ridges which formed a sequence of shorelines that moved progressively seaward with the retreating shoreline. JW 5694 is a deposit of *Chicoreus* shells and is about 5 m in diameter and 30 cm thick, dated to about 2500 cal BP (Fig. 11, Table 1). Vertebrate remains are also present including bones of fish and gazelle. JW 5719 (Fig. 12) and JW 5697 are scatters of *Chicoreus* shells 5 m in diameter, dated respectively to about 2000 cal BP and about 1700 cal BP (Table 1). These are clearly short-lived deposits associated with a rapidly changing shoreline. Not only are the shell species different, indicating changes in the available molluscan habitat, but the character and function of the deposits appear to be quite different from the larger mounds, suggesting ephemeral camp sites used for a variety of subsistence practices.

One other feature of interest in this group of shell deposits is the evidence that even the larger mounds accumulated very rapidly, perhaps over a matter of decades. Bayesian analysis (Bronk Ramsey 2009) of the radiocarbon dates at JW 1727 demonstrates that this mound accumulated over a period of between 16 and 88 years (65.4% and 95.4% confidence interval respectively), a rate of accumulation further reinforced by detailed analysis of seasonality estimates of the mollusc shells (Hausmann and Meredith-Williams 2016b). This is of particular importance because it refutes the belief that, during a period of rising sea level or a short-lived still-stand, the shoreline would have been moving fast enough that it was never located in one place long enough for accumulations of shell to form archaeologically visible deposits before the shoreline moved to a new position (Fischer 1995, p 382; Bailey 2011, p 322). The above data clearly indicate that this is not a valid argument in the Farasan case, and that substantial archaeological deposits can accumulate over a very short time span. Whether similar arguments can be applied elsewhere will depend on the abundance and stability of the available molluscan supply, and the rate of shoreline displacement. Certainly examples are now coming to light in other parts of the world of equally rapid shell mound growth based both on ethnographic observations (Hardy et al. 2016) and on

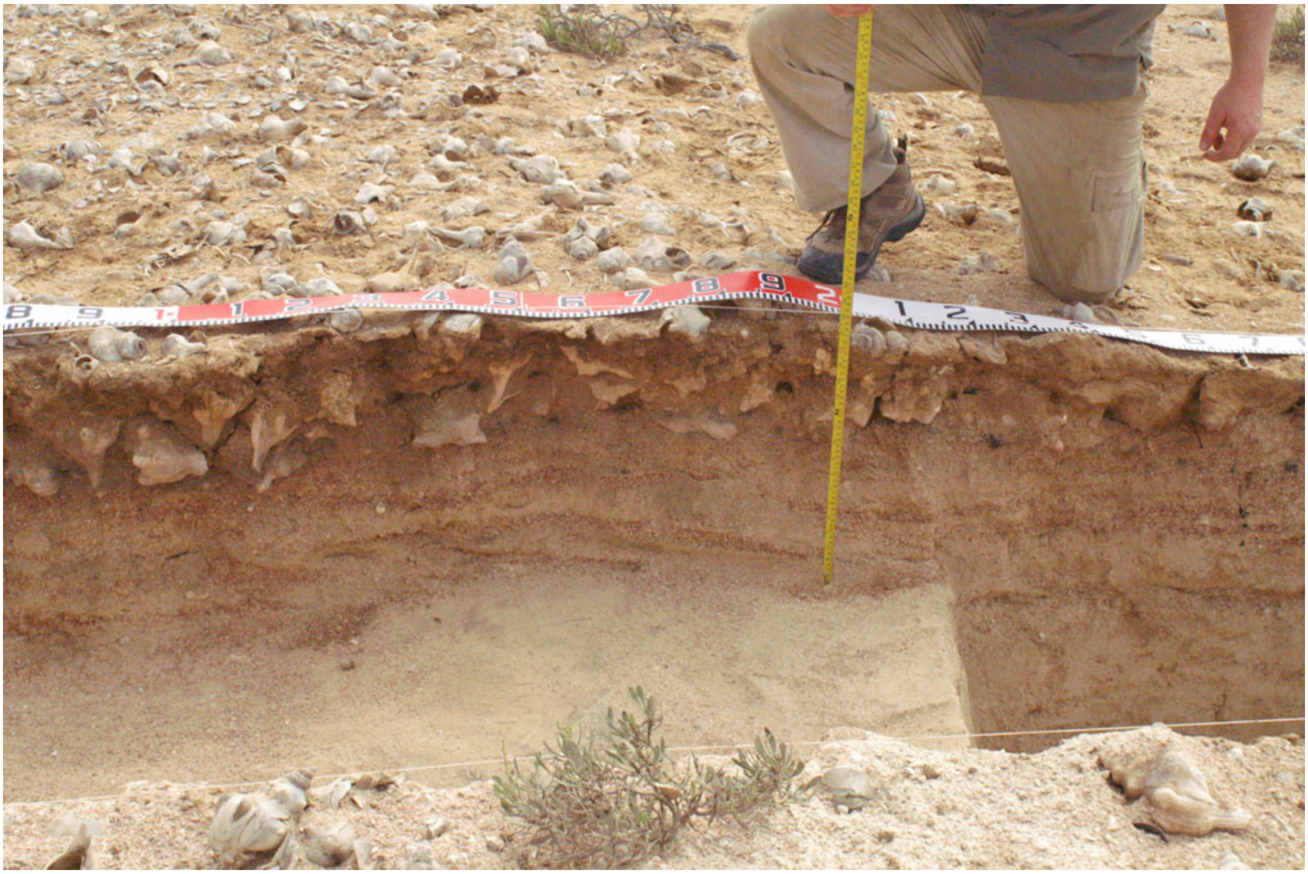


Fig. 12 Excavated trench of site JW 5719. The shell matrix is dominated by shells of *Chicoreus ramosus*, clearly visible in the section

multiple radiocarbon dating of archaeological mounds (Holdaway et al. 2017).

4 Discussion

The Farasan example demonstrates that in a dynamically changing shoreline environment subject to changes in relative sea level or other geomorphological changes such as sedimentation and erosion, the habitats and abundance of molluscs may change quite rapidly. Molluscan species such as *C. fasciatus* that provide the very large quantities of shellfood necessary to generate rapid growth of shell mounds are especially vulnerable to these sorts of changes. This is because they depend on very shallow intertidal conditions to thrive in large numbers, and it is precisely these conditions that are most sensitive to minor changes in coastal geomorphology or sea level. Our results demonstrate that shell mounds can grow very quickly to create archaeologically significant and substantial deposits, even when shoreline conditions are changing quite rapidly. But, equally, the conditions that sustain rapid shell-mound growth represent short-lived windows of ecological opportunity, opportunities that may be widely spaced in the geographical dimension as well as the temporal dimension.

The Farasan example therefore has important implications in the search for similar sorts of deposits in earlier periods, whether on submerged shorelines associated with lower sea-levels, or on the emerged shorelines associated with earlier periods of high sea level. Underwater investigation in the Farasan Islands has demonstrated that submerged shorelines are present and have the characteristic undercut notch formed by marine erosion, but so far, the only shell deposits discovered in association with these shorelines are natural death assemblages and not food remains (Bailey et al. 2007, 2013a; Alsharekh et al. 2013; Momber et al., this volume). Destruction of shell mounds by inundation during sea-level rise, subaerial erosion on exposed coastlines, or lack of interest in coastal and marine resources by earlier human populations, are typically invoked to account for the absence of shell mounds in earlier periods. Analysis of the Farasan shell mounds on the present-day coastline suggests another major factor, and that is that the ecological and geomorphological preconditions for rapid shell-mound growth are very limited both spatially and temporally. Much more intensive investigation of taphonomic factors, and in particular more extensive underwater surveys taking advantage of remote-sensing techniques to identify potential diving targets, will be needed before we can be sure that 'absence of evidence' is indeed 'evidence of absence'.

5 Conclusion

Coastlines have always been attractive places for human settlement and the concentration of human populations and human activities at all periods of the past up to and including the modern era, and at all levels of technology, whether Stone Age or Oil Age in character. Just as today a very large proportion of the world's human population is concentrated in coastal lowland regions on or close to the coastline, so this is likely to have been the case in the past. Coastal regions offer diversity of food resources, including marine foods at the shore edge and offshore, often better soils and sediments to support plant and animal life, and better water supplies and more equable climate conditions than hinterland regions, a variety of raw materials for technological production, ranging, in the Arabian case, from basaltic lavas for making stone tools to rare minerals valuable in many modern industrial processes, and generally better opportunities for population movement, and for social contact and interaction. The rim of the Arabian Peninsula as a whole represents a 'fertile crescent' equivalent to the more famous Fertile Crescent to the north comprising the Levantine coastal region and the foothills of the Taurus and Zagros ranges circumscribing the upper reaches of the Rivers Jordan, Tigris and Euphrates. The Arabian Fertile Crescent has the added advantage of abundant marine resources around much of its coastline. Moreover, these advantages are likely to have persisted throughout the climatic fluctuations of the Pleistocene (Bailey et al. 2015).

This concentration of population at the coast edge, also, of course, adds an increasingly powerful anthropogenic imprint to the dynamic changes of the coast edge, modifying many natural processes through modification of land surfaces and pollution, and obscuring or destroying the archaeological evidence of earlier human presence. It is no surprise that some of the most easily accessible and largest concentrations of Stone Age archaeology are to be found in the desert interior, where earlier evidence has suffered relatively little disturbance or destruction by later land use processes and industrial development, whereas areas closer to the coast, where we would expect to find the largest concentrations of Stone Age remains, are also the areas where the risk of burial or destruction of earlier evidence is greatest.

In addition, coastlines are the most dynamic and changeable parts of the wider landscape because of tectonically and climatically induced changes in relative sea level. Also, much of the most attractive terrain, available for long periods of the Pleistocene climatic cycle as noted earlier, is now submerged because of sea-level change, and underwater exploration of this hidden world has scarcely begun (see Sakellariou et al., this volume; Momber et al., this volume, 2018).

The interlinked nature of all these processes is both a distinctive feature of coastal regions and a formidable challenge for the future, not only for archaeologists but for all the scientific disciplines interested in the history of coastal regions. An interest in the 'taphonomy' of landscape change—the processes that have variously buried, obscured, removed, destroyed, modified or preserved different sorts of evidence—is emerging as a new and unifying research focus. These problems are especially obvious in the underwater realm, but they are no less important on dry land. Here an equally powerful array of factors has affected the distribution of archaeological material. These include agricultural development, changes in land-use practices that have variously exposed or obscured archaeological material, the impact of wind and rain, and the growing impact of modern development through large-scale infrastructural developments, including the building of new towns and roads and the quarrying away of large parts of the landscape to provide the raw materials for new developments. Given the many different factors of deposition, site formation, preservation, exposure and destruction that affect archaeological remains, we should be very wary of assuming that the distribution of archaeological remains that have survived and are visible today are in any way an accurate reflection of the distribution of past human populations. These are not simply negative factors that impede archaeological interpretation, but ones that are amenable to investigation, and need to be built into archaeological research design and interpretation at every scale if the discipline is to progress, and such investigations are likely to grow in importance in the coming decades.

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