The Multi-disciplinary Search for Underwater Archaeology in the Southern Red Sea

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Abstract

During the height of the last glacial maximum about 20,000 years ago, the sea-level was 120–130 m lower, making movement out of Africa into Arabia relatively easy. The Hanish Sill at the southern end of the Red Sea would only have been a few metres deep, less than 10 km wide and interspersed with small islands. Extensive evidence of archaeological artefacts dating to the Middle Palaeolithic has been found on the southern Arabian Peninsula demonstrating an earlier hominin presence. These movements might well have been facilitated by former periods of low sea level, as for the last million years or so, sea levels have averaged 40–60 m lower than today. These were times when large areas of continental shelf around the Farasan Islands would have been exposed as a terrestrial landscape, providing a coastal environment that would have been attractive for animals and humans. This paper looks at a series of fieldwork projects that have helped characterise the submerged landscape and assess the potential for human occupation of the drowned lands around the Farasan Islands. Significant submerged wave-cut notches, platforms and lacustrine features were recorded, evidence for tectonic realignments was identified and areas with the potential for human occupation were investigated. The fieldwork has provided new information on the nature of the drowned landscape, characterised potential sites of human occupation and identified the challenges that need to be addressed by archaeologists as the investigations continue.

1 Introduction

At the beginning of the millennium, a series of field projects led by the University of York was initiated in southwest Saudi Arabia to develop an understanding of the early prehistory of the region. A Palaeolithic sequence of considerable time depth but consisting mainly of surface finds of artefacts of Lower, Middle and Upper Palaeolithic type had already been established in earlier surveys (Zarins et al. 1979, 1980, 1981). New work was structured around the investigation of the potential role of the southern Arabian route for human dispersal out of Africa and across the southern end of the Red Sea. From an early stage, an underwater component was incorporated into the research strategy, initially under the aegis of the Africa-Arabian Connections Project—AFRAC, or AFRAC MAR referring specifically to the offshore work (2003–2009), and later (2011–2015) as part of the DISPERSE Project (Dynamic Landscapes, Coastal Environments and Human Dispersals) (Bailey et al. 2007a, b; Alsharekh and Bailey 2013; Bailey et al. 2015, 2018; Bailey and Alsharekh in press). The aim of this chapter is to review the different types of underwater work that have informed the evolution of the research strategy over a period of more than ten years, with particular reference to the Farasan Islands and surrounding areas of the submerged continental shelf, to highlight the technical and logistical factors that constrain offshore and underwater research, and to summarise the results.

From high above the Earth, the Farasan archipelago emerges as a patchwork of turquoise and sand coloured islands surrounded by dark blue water. These reefs and irregular rocky outcrops break the tranquillity of the Red Sea

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today, but this was not always the case. Past climatic changes caused fluctuations in the sea level, which dropped to reveal an extensive, flat landscape dotted with deep fault-bounded basins and occasional low hills. When the globe was at its coldest and the ice caps were most extensive around 21,500 years ago the sea-level was 120–130 m lower (Chappell and Shackleton 1986; Lambeck and Chappell 2001; Bailey 2009; Lambeck et al. 2011; Harff et al. 2017). This revealed a coastal plain stretching over almost 1000 km north to south and 50 km east to west, doubling the width of the current coastal plain.

A review of seabed bathymetric data recorded on the Admiralty charts compiled by the UK Hydrographic Office and collected by the Saudi Geological Survey showed that the seabed generally dipped gently toward the west and the edge of the continental shelf. However, the dip is not consistent as it is interrupted by elevated areas of bedrock and submarine pinnacles while being interspersed with deep circular and oval hollows (see Sakellariou et al. 2018). These circular features are particularly interesting as they measure 10–20 km across with many dropping to over 500 m below the surrounding sea floor, making them ideal potential reservoirs of fresh water

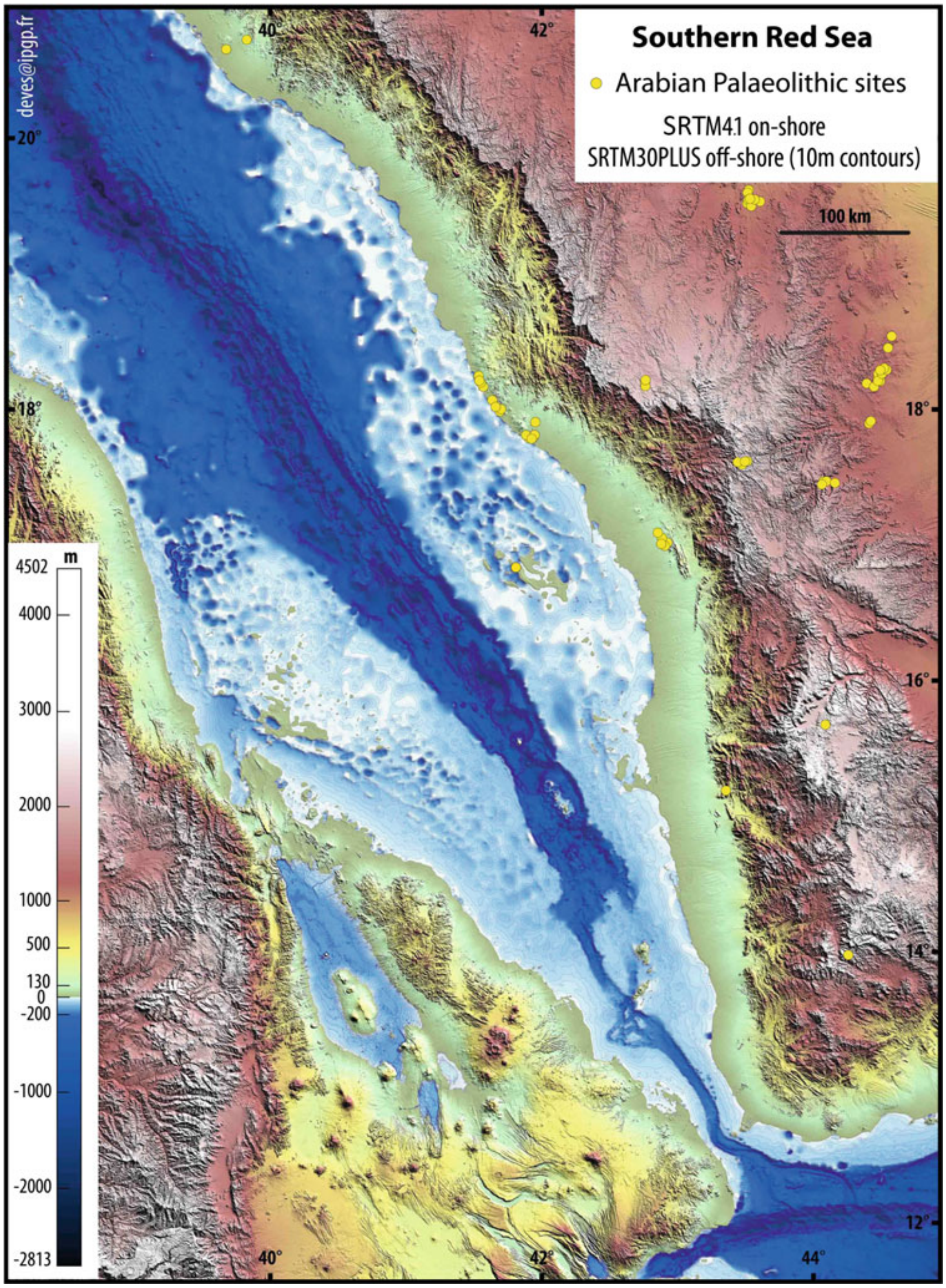

Fig. 1 Location map of Red Sea and Farasan Islands showing exposed land at lower sea level and Palaeolithic sites

when they were free from marine influence. If this was the case and an extensive landscape with lakes and springs existed (see also Faure et al. 2002), this would have been an attractive region for large mammals and human hunters. Furthermore, these environments could have presented ideal conditions for preservation where archaeological and organic materials could survive, and often in better condition than their terrestrial counterparts. In addition, the area is only 500 km north of the Hanish Sill (Fig. 1).

This is the narrowest point of the Red Sea between the Arabian Peninsula and Africa, and it could have been crossed by *Homo sapiens* (or earlier hominins) with relative ease during glacial maxima, when sea levels were at their lowest (Ambrose 1998; Rohling et al. 1998; Lambeck and Chappell 2001; Siddall et al. 2003; Bailey 2009; Lambeck et al. 2011). Clearly, the Farasan Islands, being easily accessible and containing dynamic and complex landscapes with varied ecological opportunities for human exploitation, had the potential to answer significant archaeological questions concerning human dispersal out of Africa (Walter et al. 2000; Oppenheimer 2003; Bailey 2004a, b, 2009; King and Bailey 2006; Armitage et al. 2011; Bailey and King 2011; Mellars et al. 2013; Winder et al. 2013). However, to achieve this, interpretation of the palaeoclimatic, palaeoenvironmental and geomorphological variability of the ancient land surface was necessary (Dullo and Montaggioni 1998; Purser and Bosence 1998; Bantan 1999; Sakellariou et al. 2013, 2018). Evidence for these changes is found in the geology and the sediments. Accordingly, there was a need to visualise the submerged landscape, collect sedimentary samples and physically inspect the seabed. Here we review the multi-disciplinary investigations that have been used to interpret the drowned landscape and the search for archaeological remains.

2 Investigating the Drowned Landscape of the Farasan Region

The Farasan Islands were visited by the project team in 2004. During a season of terrestrial fieldwork, they recorded hundreds of shell middens that demonstrated past coastal exploitation dating back at least 7000 years (Bailey et al. 2007a, b, 2012, 2013, 2018). These discoveries paved the way for a diving project on board Saudi Aramco's 70-m long vessel MV Midyan to search below the water (Fig. 2), followed by three further seasons of underwater diving fieldwork and a two-week marine geophysical survey (Fig. 3). However, before any underwater investigations were conducted information was gathered from the land surveys and assessments of the hydrographic charts helped to identify areas that had the potential to act as occupation sites for early human populations. The location that offered the greatest promise was a 120-m deep depression in the bay to the south of Qumah Island. Here the depression was surrounded by a shallower seabed that is now only 50–60 m below sea level; therefore, when sea levels dropped lower than this during the last glacial cycle there would have been a basin up to 60 m deep. If the basin was filled with fresh water it would have been a very attractive place for wild fauna and human hunters and gatherers.

3 Mixed Gas Diving and Maritime Archaeology

In 2006, the first marine archaeological project was conducted in the area to investigate deeply submerged palaeo-landscapes. The objectives were to characterise geological and geomorphological formations, notably

Fig. 2 MV Midyan demonstrating its fire hoses on site (Photo: Garry Momber)

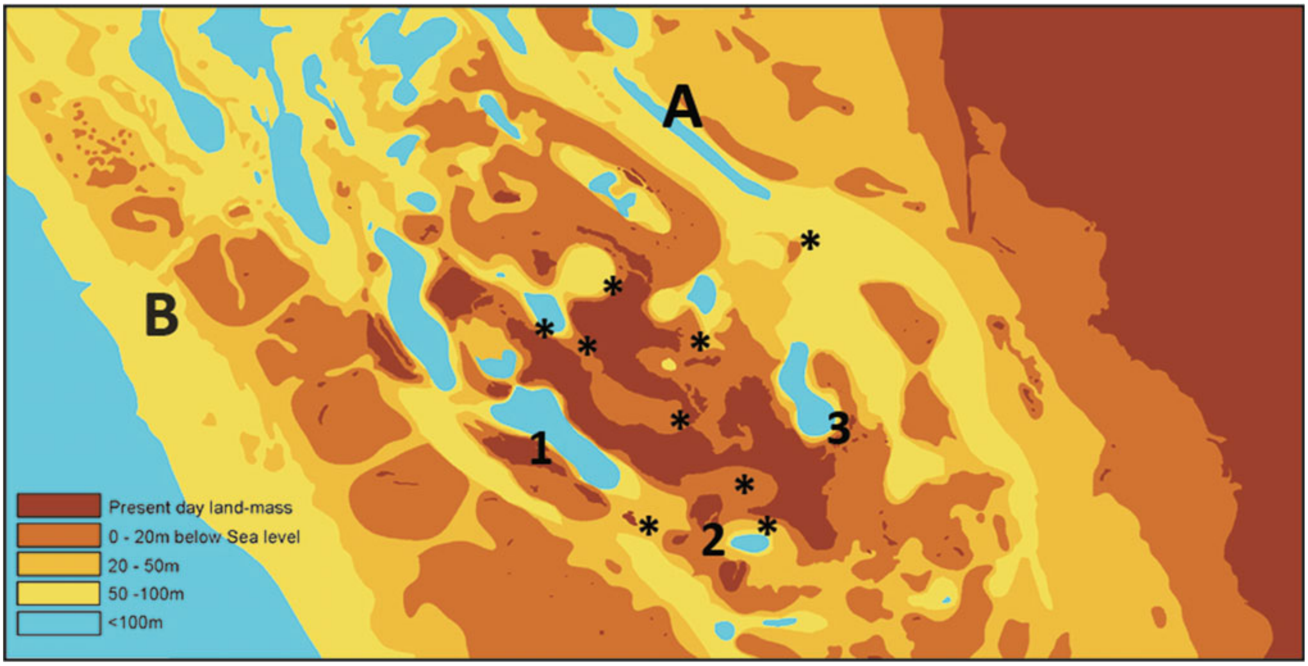

Fig. 3 Map of the Farasan Islands showing the bathymetry coloured at 20, 50 and 100 m depths. When the sea level dropped below 100 m the shelf was largely exposed while the sink holes formed by collapsed diapirs were probably filled with water. The asterisks indicate locations inspected by the dive team in shallow water. The numbered areas are (1) Zufāf Island, (2) Qumah Island and (3) the Sulayan archipelago. A and B indicate the areas of geophysical survey represented in Figs. 18 and 19 respectively (image courtesy R Smith, adapted by J Gillespie)

submerged palaeoshorelines, basaltic formations and possible springs, with the aim of locating areas with the greatest potential for human occupation. This necessitated the use of technical diving. The MV Midyan provided the perfect platform from which to run the diving operation. It was of sufficient size to host an air compressor, a gas blender, dive cylinders to provide mixed gas for the dive team, plus dive equipment, underwater archaeological equipment and all the tools required to maintain a smooth-running project. Different gases had to be mixed and blended for diving purposes that required space for dozens of 50 L J-bottles containing pure oxygen and pure helium, to be managed on the back deck (Fig. 4).

The use of mixed gas is ideal for deep diving but it is technologically and logistically challenging. This imposes constraints on the diver's actions and increases the task load faced by the project manager, dive supervisor and participants. Accordingly, the logistical considerations should be taken into account as a key element of an archaeological project. There are many training manuals and publications describing the detailed methods used for mixed gas diving and books describing the physiological effects of the different gases (Joiner 2001; Brubakk and Neuman 2003; Gerth 2006; Mitchell 2007). However, for this report, a short outline of the practice is given as a backdrop against which this and future operations have to be planned.

All gases used are derivations of air, which is approximately 21% oxygen, 78% nitrogen and 1% other gases. It is the most convenient gas as it can be taken straight from the atmosphere and compressed. It can be breathed underwater for limited periods without harm; however, at depth, high concentrations of compressed gases become toxic. Problems can arise when they enter the cardiovascular system and circulate within the body for extended periods. The longer a diver is under pressure, the greater the amount of gas absorbed. When air is breathed at 10 m underwater it is compressed to half the volume of air at the surface, meaning that the lungs need twice as much gas to fill them. Therefore, the 21% of oxygen per unit of air in the lungs will double, effectively increasing the relative percentage to 42%; this percentage is otherwise referred to as a partial pressure, in this case being 0.42. The pressure increases proportionally with depth; at 20 m it is tripled, at 30 m it is quadrupled, and so on. When oxygen reaches a partial pressure concentration of 1.4, it becomes poisonous and the diver can have a fit or become unconscious. This can occur at a depth of around 65 m.

Nitrogen can also be toxic in high concentrations, causing disorientation and confusion known as nitrogen narcosis or the 'Narcs'. This can affect a diver from around 30 m. In addition, when the diver returns to the surface the pressure is released allowing the gas to expand. If the ascent is too fast,

Fig. 4 Pure oxygen on the back deck of the MV Midyan to be mixed with helium and air to form Nitrox (Photo: Garry Momber)

nitrogen in the body comes out of solution and forms bubbles that can block blood flow, thereby cutting off circulation and starving tissues of oxygen. This is decompression sickness, commonly known as the bends, and is the greatest threat to divers. The most common method used to reduce the amount of nitrogen taken on by a diver is to enrich the gas with oxygen and reduce the amount of nitrogen; this mixture is Nitrox. When Nitrox is breathed by a diver, the amount of nitrogen absorbed by the blood is reduced and the problems of nitrogen narcosis and decompression sickness are lessened. This allows the diver to stay underwater safely for longer. However, the risk of oxygen poisoning at increased partial pressure remains. Due to these constraints, in practice, the value of enriched air Nitrox is limited to depths of no more than around 40 m.

To go deeper without oxygen becoming toxic while limiting nitrogen loading in the blood within the body's tissues, a harmless, inert gas can be added, such as helium. By introducing helium and halving the concentration of oxygen breathed by a diver, the diver can go to twice the depth before oxygen becomes poisonous. Therefore, with 10% oxygen in the mix rather than the normal 21%, an average diver could go to 120 m and beyond without inducing a detrimental 'oxygen hit'. Similar benefits are seen when nitrogen is reduced. When helium is added to air or Nitrox it becomes Trimix. The relatively small proportions of oxygen in the mix make it perfect for breathing at depth; however, if you reduce the amount to less than 17% it will be too weak to breathe at the surface and will cause oxygen starvation. To manage this, the concentrations must be adjusted to suit the best depth and different mixes have to be taken underwater. As a result, a deep diver will normally carry one cylinder with enriched air Nitrox to breath on the way down, two cylinders with Trimix to breathe near and on the bottom, and one with 100% oxygen to breathe while decompressing near the surface (Fig. 5).

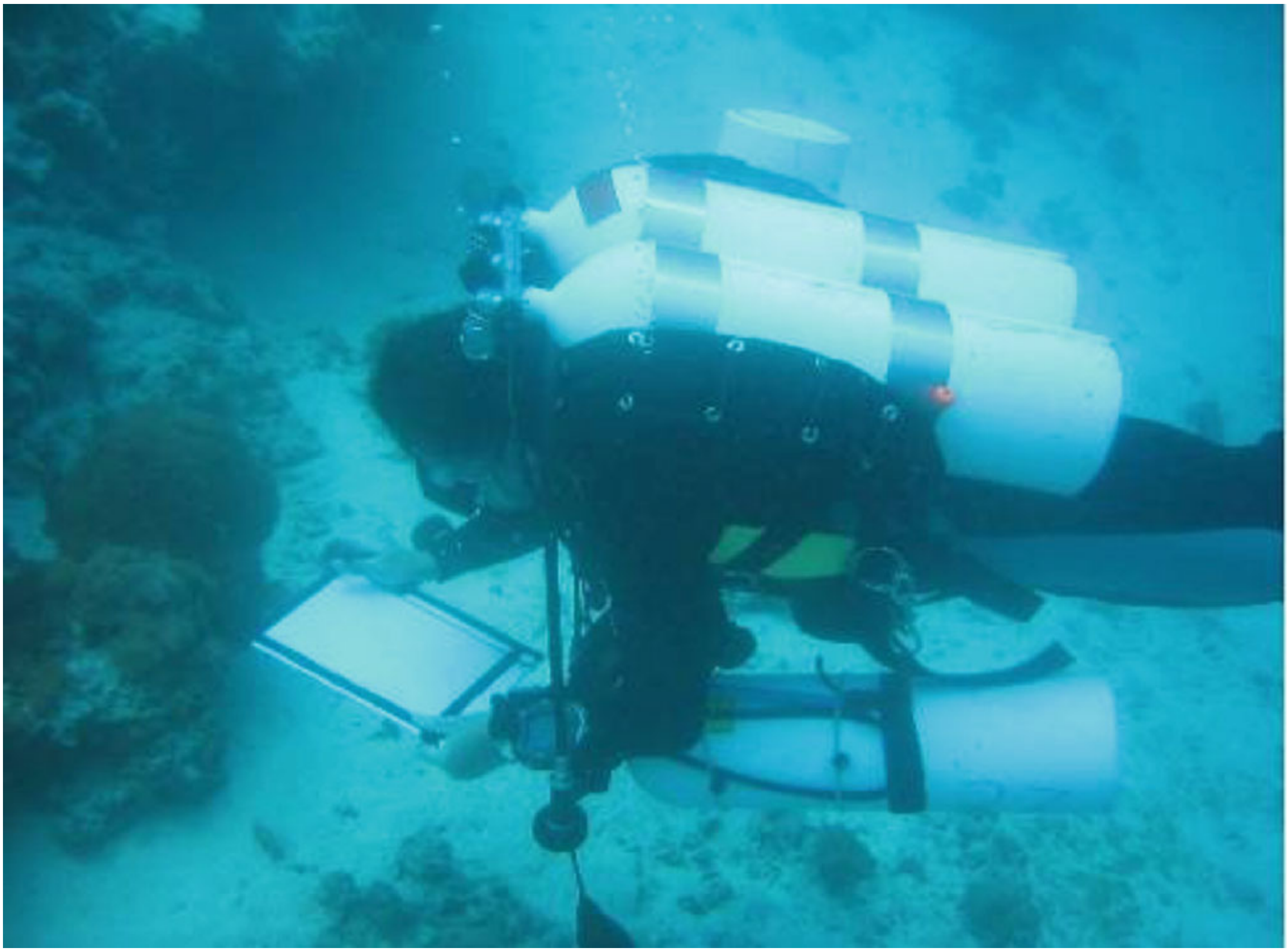

Fig. 5 Heavily laden Trimix diver working underwater (Photo: Garry Momber)

The implications of mixed gas diving for archaeological investigations are the limitations on time and mobility when underwater. The need for tight control during a dive operation restricts the actions of the marine archaeologist when compared with their terrestrial counterparts; therefore, diving fieldwork will inevitably take much longer. This is necessary to ensure safety but arguably is worth it when uncovering data that cannot be found elsewhere.

4 Deep Water Investigations off Zufāf and Qumah Islands

Deep diving operations were carried out off the coast of Zufāf Island, on the western side of the archipelago and off the south of Qumah Island, next to the main Farasan Island. Zufāf Island was identified as a suitable dive site by merit of the steep drop-offs plotted on Admiralty Chart "Approaches to Jījān no.15. 2000". These were verified by an echo sounder survey that recorded a steep incline averaging about 33° which levelled off at just over 50 m below modern sea level to form a gently sloping terrace, inclined at 6° for 165 m to the east until it reached 80 m. At this point it dropped almost vertically. The depth in the centre of the channel has been sounded at about 140 m. Investigation of the deep drop-offs and terrace was conducted with mixed gas diving.

The diving operation used Trimix to reach the wave cut terrace at a depth of 56–60 m. The descent down the slope recorded little change in the seabed type although the occasional outcrop of old grey coral rising from under the sand was noted. This suggested that the underlying geology is close to the surface, offering the potential to find areas of the old land surface. At −56 m the seabed levels off and drops continually toward the deep. A blanket of sand covers this terrace making it impossible to see the bedrock below. This continued for over 100 m to the northeast as the seabed dropped to −62 m. A small sondage was excavated 40 cm into the sand by hand fanning but the underlying substrate was not detected as the blanket of sand was too deep at this location.

At the mouth of Qumah Bay, Trimix diving was used to follow a wave cut platform from the Slick Point Peninsula underwater toward the centre of the depression. The divers traced the platform down slope for over 300 m to a depth of 30 m where it runs beneath the sandy sea floor. The divers continued to a depth of 38 m. It was apparent that the rock formation continues below the seabed as occasional exposures of the reef were recorded; however, by −40 m the area became dominated by silty sand. Beyond this point, the flat seabed dips gently to the south. As with the diving off Zufāf Island, the deeper surfaces could not be examined by divers without excavation and it was concluded that a geophysical survey would be necessary to calculate the thickness of the sand. In the shallows, however, reefs, terraces and rock formations were exposed, so the next phase of the fieldwork was to focus on the accessible submerged coastal features at 10–20 m depth.

5 Shallower Water Evidence of Wave Cut Notches and Deformation

The diving confirmed the existence of wave cut and erosional notches at varying depths, and that most of the visible geological features were in the shallower waters; accordingly, this was where the next phase of activity was concentrated. In Qumah Bay, the notches are generally located within cliff sides or steep slopes, particularly toward the entrance in the south. Many of these notches measure around 1 m in height although some measured up to 2 m.

At the eastern entrance to Qumah Bay the area investigated was marked by a west-facing cliff that forms the edge of the wave cut platform as it passes below and adjacent to Slick Point. The cliff is 10 m high with a laterally consistent row of notches running toward its base (Fig. 6). The depth to the back of the largest notch averages around 3–4 m while the entrance is 1.5–2 m high. The platform reef at the base of the notch forms a ledge that protrudes 1–1.5 m beyond the mouth of the cave. Studies of wave cut notches in the Mediterranean show that the height of the average wave cut notch is invariably higher than the mean tidal range but less than the maximum tidal range (Antonioli et al. 2015). The tidal range at Jizan, being the closest mainland port immediately to the east of the Farasan Islands, is 1.69 m (see Inglis et al. 2018). This maximum tidal range is slightly less than the height of the notch suggesting some of them are too large to have been formed by tidally controlled wave action alone. However, it should also be noted that the Farasan Islands are on a relatively shallow shelf and the arrangement of islands within the archipelago can channel water to create a funnel effect that creates a larger tidal range, although long term observations have yet to be collected near the site to confirm this.

Mechanical erosion could be another factor that contributed to the formation of notches at the base of the cliff if this occurred prior to a regression and at a time when this part of the seabed might have been able to retain pebbles. Mechanical erosion would not have had the same impact when the sea level transgressed the site as the platform reef ledge that the notches now sit above is truncated to seaward by a reef step. Beyond this, the seabed drops off steeply into the sand filled bay below. This means that while pebbles could have contributed to erosion when they were being moved by the energy of relatively powerful intertidal waves, once the forces diminished as the sea level rose, the pebbles would be washed off the platform downslope. It is also

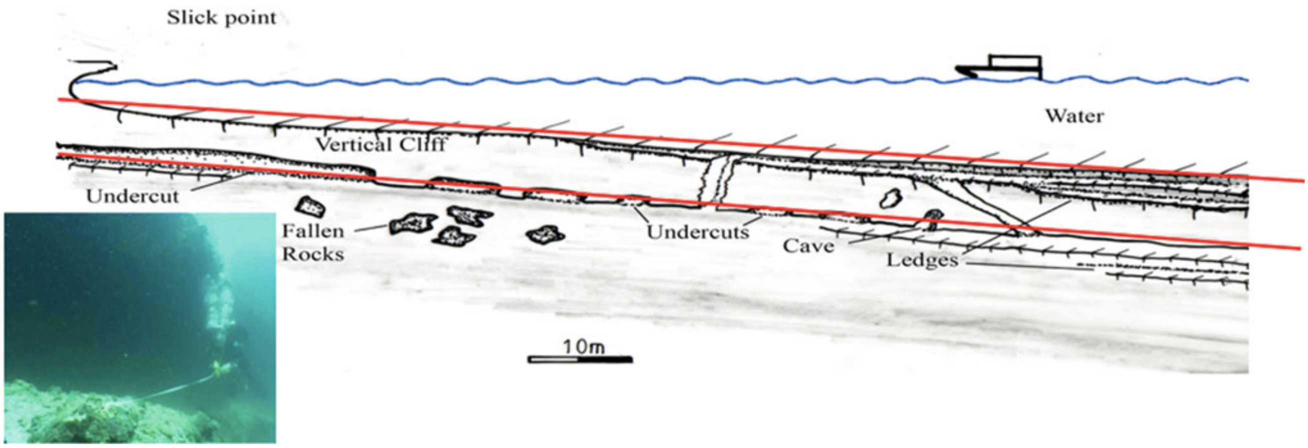

Fig. 6 Plan of submerged cliff, terraces and wave cut notches off Slick Point. The laterally consistent linear features are indicated with red lines. The notches at the foot of the cliff sit above a ledge that is truncated by a vertical drop-off. Sand covers the seabed in front of this rock face, masking much of the underlying seabed. Intermittent, exposures of this smaller cliff were measured at 0.6–0.7 m. The erosion features at the top and within the cliff are parallel and dip toward a collapsed diapir to the south (Drawn by G Momber)

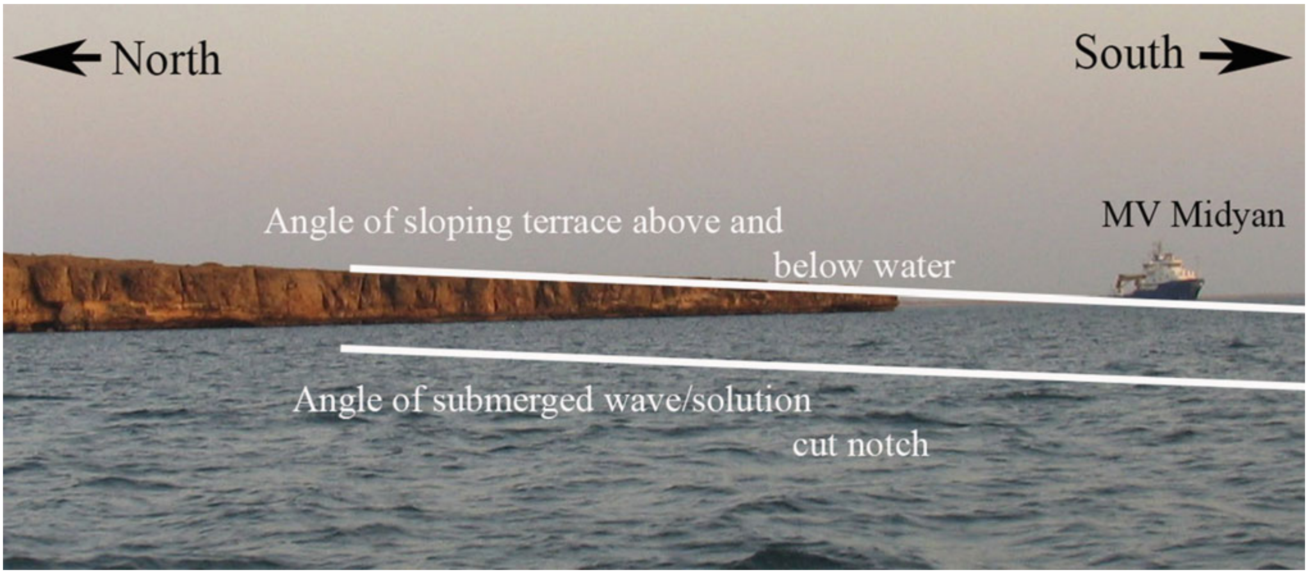

Fig. 7 Slick Point from the west. The white line indicates the approximate position of a stratigraphic break which continues underwater as a wave cut platform and which has been tilted by subsequent tectonic uplift. An equivalent feature has been identified at a lower level, from a depth of 9.6 m below sea level, recorded to a depth of 20 m. It runs in a north–south direction and is believed to relate to a period when sea level was 20–22 m below present (Photo: Garry Momber)

probable that the ledge in front of the cliff was less prominent when the notches were formed as the bay is part of the subsidence associated with salt tectonics. This vertical step in front of the platform reef now protrudes through the sand toward the northern end of the submerged notches where it is 0.6–0.7 m in height.

The system of notches and reefs runs parallel to the platform at the top of the cliff and follows the angle of dip to the south. The submerged notches also continue into the bay to the north where these become shallower as they mirror the strike of the land above water (Fig. 7). Our understanding of the formation processes is essential if we wish to establish a relationship between these features and sea level. However, in doing so we recognise the value of the notches as indicators of a changing land-sea relationship and our attention turned to these submerged exposed reefs where they were free from sediment cover and therefore accessible.

The height of the land above modern sea level across the Farasan Islands is commonly around 2–5 m. The elevation of this landscape may equate to the formation of coral reefs around 125 thousand years ago, during MIS Stage 5e when eustatic sea levels were 5–7 m higher (Rohling et al. 1998; see Inglis et al.2018). However, this can vary across the islands where many areas are subject to localised uplift and downwarping caused by the salt tectonics (Hudec and Jackson 2007). This is particularly the case on Qumah Island where linear scars traversing the land surface indicate faulting and fracturing. Fortunately, the deformation is localised and clearly identifiable. This is the process evident at the entrance to Qumah Bay by Slick Point (see above and Fig. 7). Despite the tilting of the land, the surface is relatively flat, providing a point of reference against which to record submerged notches.

It was noted that the distance between the land surface and the first sequence of notches is consistently in the order of 15–17 m depth. This equates to around 20–22 m below the MIS Stage 5e sea level. Periods when the sea level was stable for long enough to impact the coastline by eroding or dissolving features have been calculated by a number of researchers (Shackleton 1987; Rohling et al. 1998; Lambeck and Chappell 2001; Siddal et al. 2003; Bailey 2009; Lambeck et al. 2011). The research has identified these still stands at 20–25 m depth around 110,000 and 80,000 years ago, at 40–60 m depth 30–45,000 years ago, at 30 m depth 39–44,000 years ago, and 40–50 m depth about 12,000 years ago (Fig. 8).

The still stand at 20–25 m depth is particularly significant for the archaeologist as this would have occurred about 80,000 years ago (when calibrated against the elevated marine terraces in New Guinea as presented in Fig. 8). Notches or undercuts formed at these times, being before a regression, would have dried out and remained above water level as the sea dropped. This would have provided a habitable shelter for over 70,000 and probably 100,000 years while the sea level was lower. Diver surveys along the −10 and −15 m contours confirmed that wave cut notches can be found running along both sides of Qumah Bay and also around the adjacent shoreline of Qumah Island.

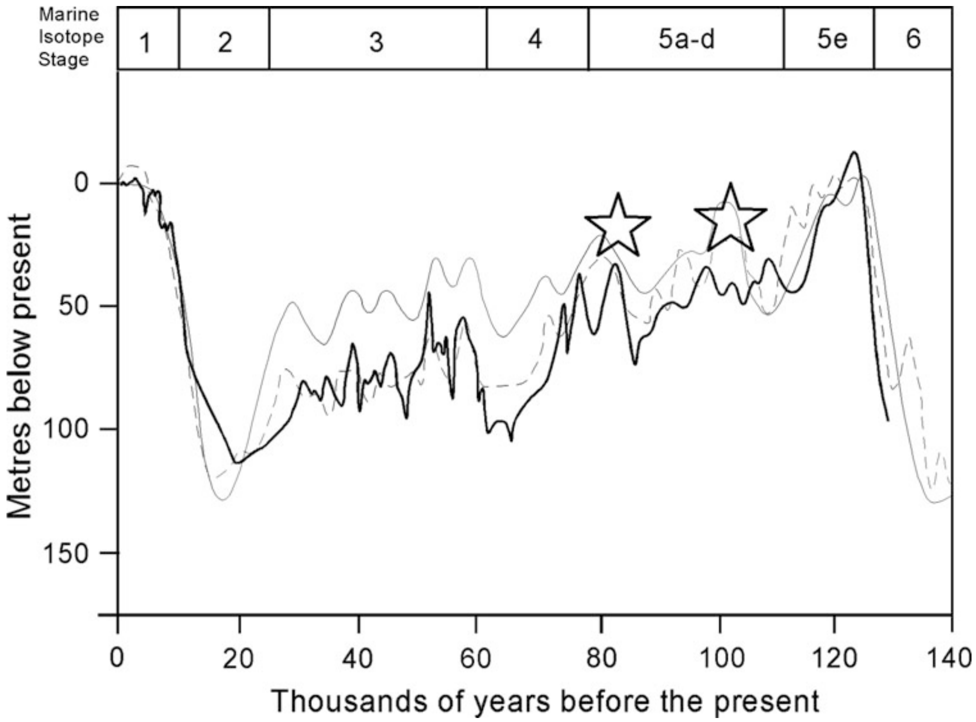

Fig. 8 Global sea-level change over the past 140 kyr. The dashed grey line is based on deep-sea isotope records of planktonic and benthonic fauna, the solid grey line shows the same curve corrected for temperature effects using dated and elevated marine terraces in New Guinea, the dark solid line is based on isotope records of planktonic fauna from the Red Sea. Stars show the probably dates when some of the larger submerged notches were formed around Qumah Island. Modified from Chappell and Shackleton (1986), Shackleton (1987), Lambeck and Chappell (2001), Siddall et al. (2003)

6 Shallow Water Diving to Identify Archaeological Potential Around the Islands

The insights into the submerged landscape features identified in 2006 informed the research questions for 2008, which aimed to gather more data about the submerged terraces around the islands and assess the viability for associated human occupation. Firstly, it was necessary to identify the suitability of a site to provide shelter near possible sources of food and water, and secondly there was a need to qualify the potential for survival of material.

When determining the possibility for preservation of material at a particular location, we should address the implications of morphological changes that occur when the sea level fluctuates. A consequence of rising sea level can be the displacement and dispersal of archaeological material. Alternatively, material can be buried and protected in areas that act as a sedimentary sink. Both scenarios create challenges for the archaeologist, but the biggest threat is physical erosion. Degradation and deflation of deposits will be particularly acute when they are within the surf zone. During this phase, archaeological artefacts are likely to get dispersed. The chances of finding such dispersed sites are minimal unless material remains trapped in crevices. Where the currents and waves are weaker, the possibility exists for artefacts, such as stone axes, to remain in their original position with only finer material removed. This would be good for the archaeologist but it is very rare. A more likely scenario is where sheltered sites are protected from wave energy, enabling sediment to fall from the water column. This can bury large areas of palaeo-landscapes, sealing them for many tens of thousands of years (Andersen 1993; Flemming 2004; Momber 2011, 2014; Peeters and Momber 2014; Momber and Peeters 2017; Flemming et al. 2017). The problem occurs when trying to find such sites as they may be buried beneath many metres of sediment.

It is therefore the case that if areas of sedimentation or erosion are known to be extensive, they do not warrant exploration by divers. Areas that do provide the greatest possibilities for the discovery of archaeological material exist where there is a transition between the two systems, at a point where erosion and sedimentation meet. If cover is thin enough, artefacts are more easily accessible but the challenge is to find these areas. However, the seabed is not static and opportunities can open up following storm events or changes in currents that can disturb the seabed or cause

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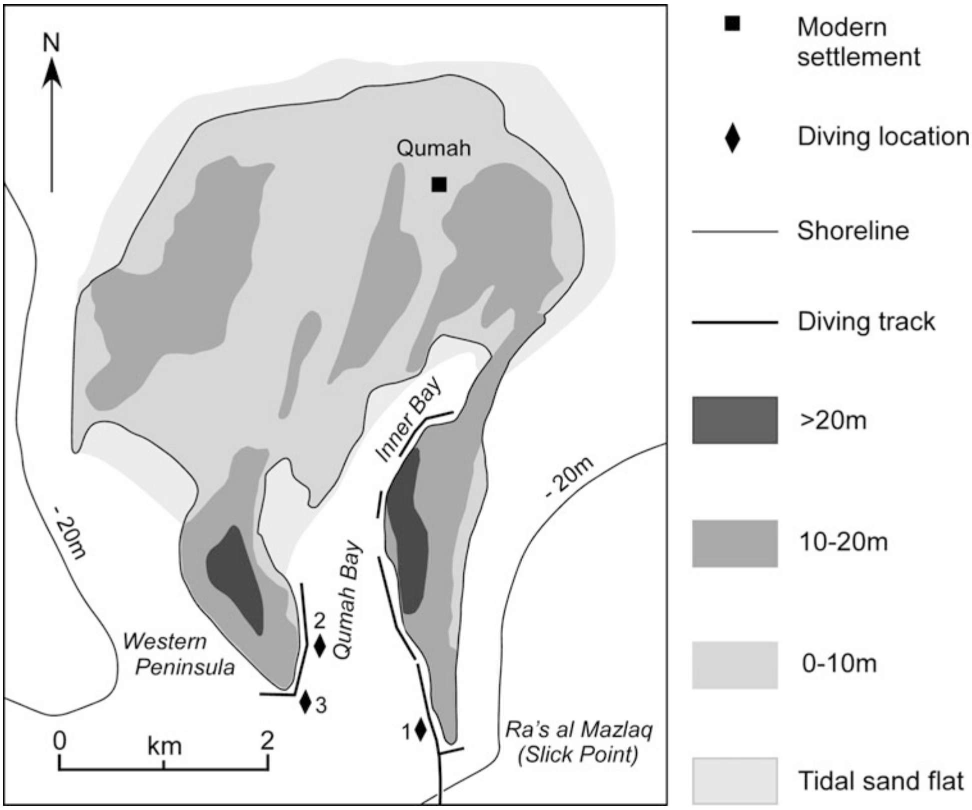

Fig. 9 Map of Qumah Island, showing diving locations and places mentioned in the text. Diving locations are: (1) Slick Point; (2) Western peninsula; (3) Shark Point; the site of RS QB01 is at location 2 (Drawn by G. Bailey)

scouring of sediment. Here, submerged landscapes that have been protected by silt since inundation may become subject to erosion and exposed.

7 Survey Strategy and Methods

With the aid of bathymetric charts and the experience gained during the previous expedition, near-shore palaeo-coastlines were targeted. The archaeological potential for each site was evaluated against a set of criteria that looked at the cultural nature of material (i.e., whether it had characteristics such as a shell midden that suggested longer term occupation or an isolated artefact such as a worked stone tool of local or exotic material), the date of the artefacts or ecofacts and the proximity of the archaeological evidence to the coastal feature of interest. This evidence was considered along with the potential for life sustaining resources nearby, primarily being sources of fresh water. This assessment was coupled with a consideration of coastal geomorphological processes that would have enabled archaeological material to survive the last transgression without burying it below metres of marine sediment (Flemming 2004; Flemming et al. 2017).

During the 2008 season, the dive team inspected 15 new sites around the Farasan Islands including extensive visual searches across large tracts of Qumah Bay (Fig. 9). Notches and wave cut platforms were recorded at all the coastal sites, most of which compare favourably in depth with the 80,000-year still stand. Of the 15 different areas investigated, no archaeological or palaeo-environmental material was uncovered, but two sites were identified as offering the greatest potential for the discovery of archaeological material. One site on the western peninsula of Qumah Bay is associated with overhangs that could offer shelter to early humans, while the other site in the Sulayn Islands compared favourably with the adjacent terrestrial landscape that supports many shell middens.

8 Seabed Excavation and Sampling at Qumah Bay

The submerged notches on the western peninsula of Qumah Bay were selected for excavation and sampling during the 2009 expedition. These possible shelters are opposite Slick Point and are positioned at a favourable vantage point overlooking the depression off the south-east of Qumah Island that could have offered an attractive terrestrial environment when sea levels were lower. The wave cut notches are relatively free from sand cover as the location sits around the interface between deep sediment and scoured exposures.

One particular notch forms a small cave that would have made an ideal rock shelter. The site lies in 10 m of water half way along the inner side of the western peninsula. It has a 2-m-high opening and is 3.5 m deep, with a sloping roof that tapers to the back of the cave (Fig. 10). There are flat areas inside and above the cave that are covered by thin layers of sand and these would have provided suitable platforms for activities such as flint knapping or shell processing. These areas were searched, the sand was cleared and samples were recovered from crevices at the back of cave but no archaeological material was found. The lack of material suggests that if it was present it must have been removed by the waves as the sea level rose during the transgression. We therefore looked below the shelter to see if any objects had found their way into deeper water.

The rock shelter sits above a steep 7-m-high slope that has a small outcropping rocky reef at its base. If artefacts had washed down from the shelter, the more resistant items could have been caught in the reef below. Here, a metre-high notch forms a perfect trap that was full of accumulated sand and shells. It was excavated to record the stratigraphy and recover samples.

Excavations in front of the notch created an 85 cm section (Fig. 11). The top is capped with sand above layers of shell. These form distinct layers with different shell types and become sandier at the bottom. In the entrance to the notch, the remains of a coral reef were uncovered that form a ledge. It appears that the coral did not grow within the small cave-like feature, most probably due to the lack of direct sunlight. Beyond this, toward the back of the notch, was a deeper area that retained material in a well stratified deposit. Five samples were collected vertically from within the section and analysed to look for concentrations of edible shells by comparing them with midden sites on land. The shells were mainly unsuitable for human consumption although

Fig. 10 Garry Momber evaluating south facing entrance to the possible shelter on the western side of Qumah Bay. It offered a view over a low-lying area to the southwest when sea level was lower (Photo: Julie Satchell)

Fig. 11 The small cave filled with layers of shells was revealed following excavations below the wave cut arch in 17 m of water. The relic coral reef can be seen outcropping in the bottom right hand corner (Photo: Garry Momber)

there was one distinct horizon, 45 cm from the top, which was dominated by an assemblage of edible bivalves (Fig. 12). There was also an anomalous piece of stone that contrasted to the lightly coloured calcareous material evident in the rest of the section, but there were no cut marks on the shells and the stone was not sufficiently diagnostic to prove the sample is an artefact. This evidence is inconclusive but the distinct stratigraphic units established that there were areas where material could remain undisturbed following deposition. It is within these shallow sedimentary sinks that we are most likely to find archaeological artefacts (Flemming 2004).

Above water, it is worth noting that the terrestrial cliff over the submerged rock shelter reaches the 10-m contour (Fig. 13). It is slightly domed due to salt tectonic uplift. If the coral platform above the cliff dates to MIS 5e, when it would have been covered by a sea level that was about 2–5 m higher than today, it would suggest the land has risen in the order of 10 m. The depth of the submerged rock shelter from the top of the cliff is 20 m, presenting a likelihood that it could have formed during the last −20-m still stand. This again dates to about 80,000 years ago, so the overhang would have offered welcome shelter for tens of thousands of years before becoming inundated during the last transgression.

9 Seabed Excavation and Sampling at Sulayn al Janub Archipelago

The second site excavated was in a sheltered, shallow water channel south of Sulyan Island. The Sulayn al Janub archipelago is situated on large shallow plateaux that would have been largely dry land 7,000 years ago when sea levels were 5–6 m lower than today (notwithstanding local uplift or submergence). Shell middens visible on the islands demonstrate occupation and the availability of marine resources (Fig. 14).

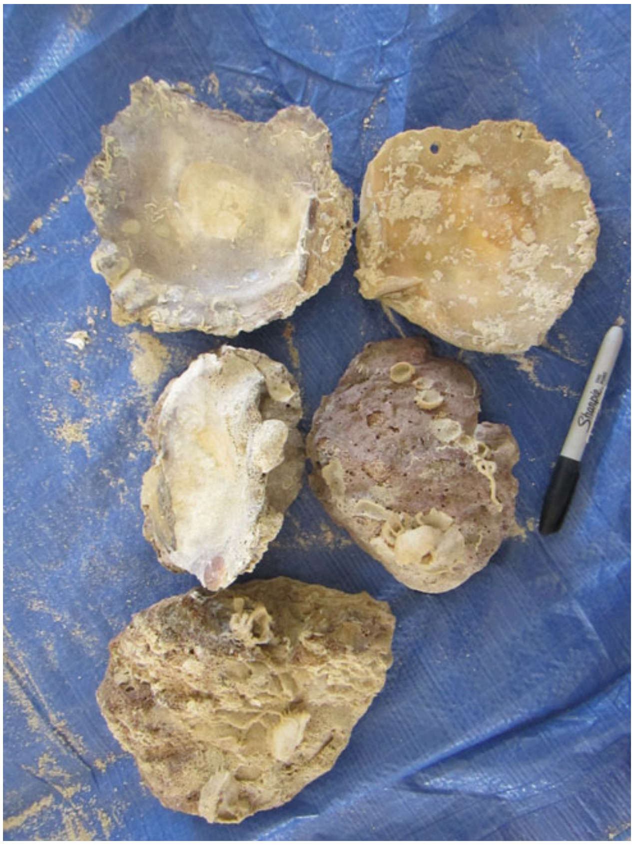

Fig. 12 The sorted finds included an assemblage of edible shells from Qumah that were found alongside an anomalous lithic (Photo: Garry Momber)

The area under investigation is a drowned valley surrounded by three islands with three entrances (Fig. 15). The entrance to the southwest is wide and shallow, only a metre or two deep. The channel to the north is narrow and a little deeper at 2–3 m. In the east, the channel is recorded at 5 m deep and is fairly wide. Interpretation of the modern bathymetry shows that this eastern channel saw the first ingress of water into the basin. A break-through in the north would have followed and finally the wide western channel would have been inundated.

The north and west channels would have been dry land 7,000 years ago. This was a time when the harvesting for molluscs was prolific and several large middens can be seen along the shores today (Bailey and Flemming 2008; Bailey et al. 2013; Meredith-Williams et al. 2014a; Hausmann et al. 2015). Any that were built nearer the water's edge 7,000 years ago would now be underwater. Searching across the centre of the drowned basin proved futile as the seabed is covered with sand; however, where water movement is sufficiently strong the sand has been prevented from settling or has been removed, and the underlying surface is accessible. This occurred when the new channels were opened to the west and north, particularly the northern channel, which is narrower and deeper. Therefore, the northern channel was chosen for excavation as it is near an inshore environment rich in marine molluscs. Also scour caused by the current passing through the channel has resulted in a thinner layer of

Fig. 13 Cliff inside west peninsula and above submerged wave/solution cut features (Photo: Garry Momber)

Fig. 14 Shell midden on South Sulayn Island near the area of underwater excavation (Photo: Garry Momber)

sand toward its centre and a large deposit of shells was recorded at this location during the 2008 fieldwork (Fig. 16).

10 Excavation at Sulayn al Janub

A 10 m long evaluation trench was excavated down-slope from west to east. The working depth was shallow. The west end was recorded at about 2 m below mean high water while the eastern end was just under 3 m. On completion of the trench, sections were recorded and five samples were recovered. Three contexts were noted. From top to bottom these are sand, fine grey organic silty clay and a sandy shell mix. The total thickness of the sediments was recorded as 0.7 m in the west and 0.35 m in the east. The relative concentrations of shells increased to the east as the sand became thinner.

Samples recovered from the trenches were dried and sorted. Mollusc shells were removed from the deposit and the species typical of those found in the on-land middens (see Bailey et al. 2018) were separated. The sub-samples were weighed and the proportional relationship recorded. The shells were densely packed in the lower context but the vast majority were too small to be edible and the wide spectrum of species was too broad to represent a midden deposit. It was concluded that the material from all the contexts was natural rather than archaeological. However, the results have helped to inform our understanding of the depositional process. A layer of fine grey silts below the mobile sandy sediment shows that the underlying deposits are stable in the sheltered waters around the islands. In addition, the presence of the fine silt along the entire length of the trench indicates that protective sediments, which could create anaerobic conditions, accumulate even in the shallower water.

Archaeological items were not recovered but a fragment of charcoal was discovered that suggested human activity. This result warranted further investigation and in 2014 a larger excavation and sampling programme was conducted. During this phase, a new trench running parallel to the initial

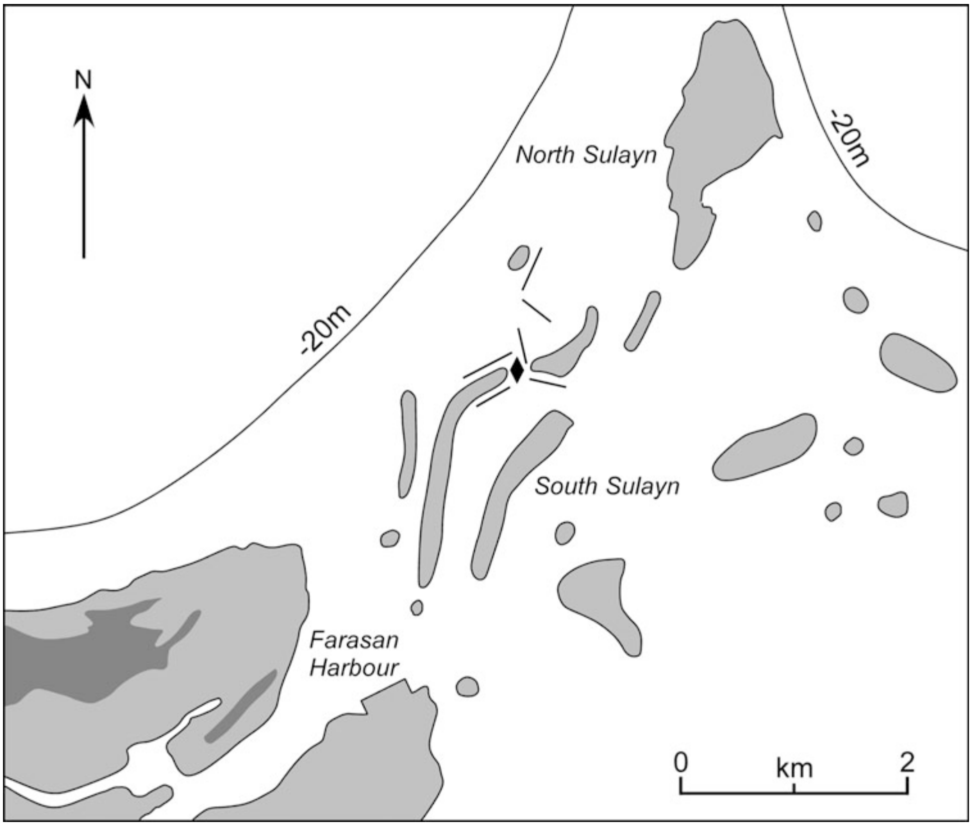

Fig. 15 Chart showing the 20 m contour around the Sulayn al Janub archipelago. The shaded areas are the islands with the darker areas indicating higher ground above 20 m. The location of diver inspections and excavation are indicated by the lines and the diamond respectively (Drawn by G. Bailey)

Fig. 16 The north channel investigated in Sulayn al Janub archipelago. Diving operations were conducted from left to right below the water (Photo: Garry Momber)

evaluation trench was opened. It was widened and extended to form an arm from north to south nearer the centre of the channel. The methodology focussed on increased lateral and horizontal sampling.

Excavations to the underlying bedrock were conducted in selected areas to investigate variations in colouration and with the intent of investigating any taphonomy, to see if any palaeo-soils remained, and to find the source of the charcoal. The new excavations concurred with the results from the first trench, but this time the trench revealed larger areas of bedrock which exposed a layer of buried coral on top of a hard, basal coral terrace. An airlift was used to remove overburden and collect samples from gullies within the coral basement rocks.

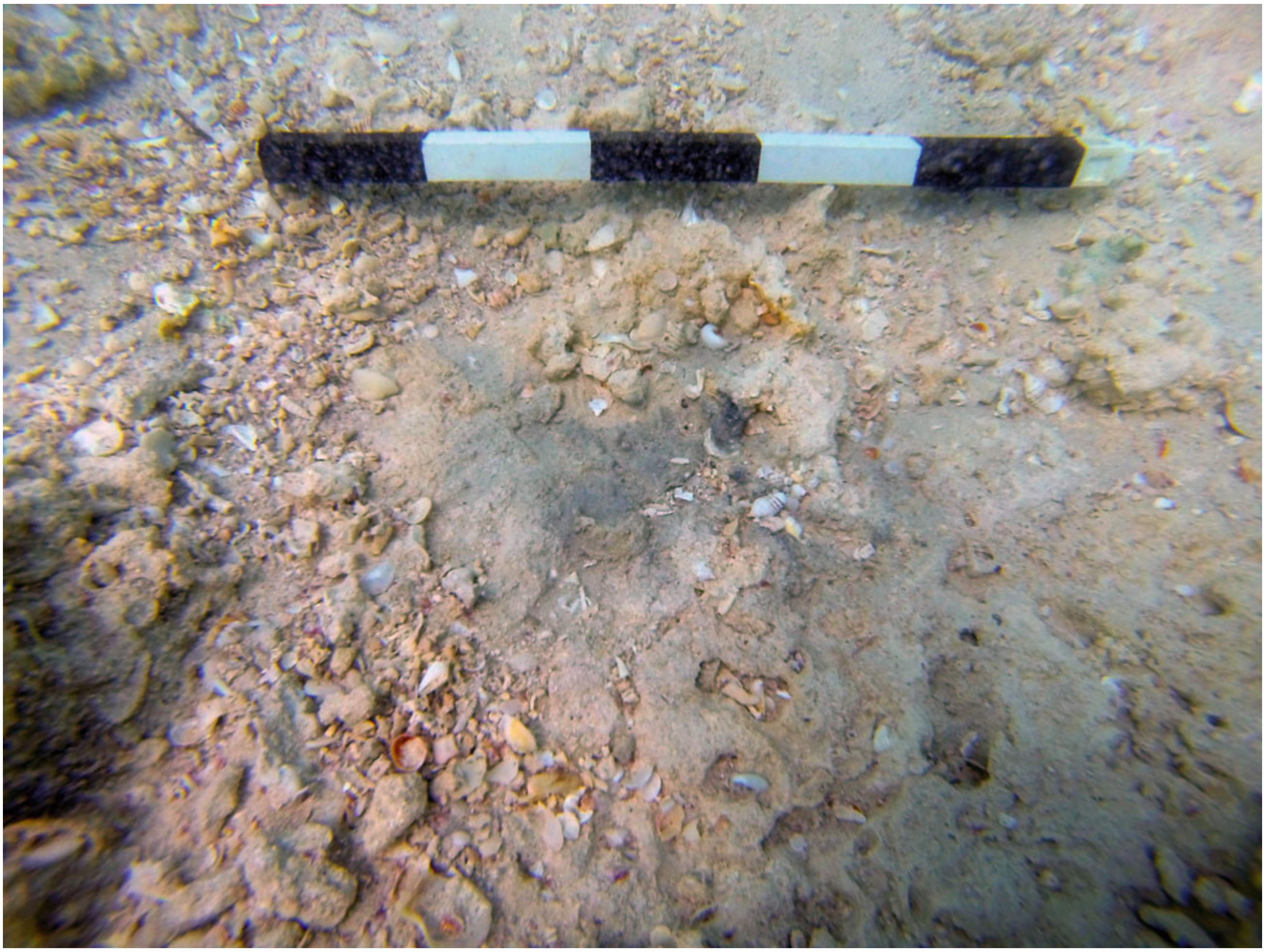

Fig. 17 Area of dark staining being uncovered on the coral bedrock (Photo: Garry Momber)

In the deeper water, to the east of the surveyed area, the sediment cover of sand and shell was thinnest, while the horizon of broken coral below the shell but above the basement/bedrock was thickest. On the northern-most baseline, dark grey stains or patches were recorded that extended below heads of coral that must have grown after the 'stains' were formed. Samples of the seabed surface were collected for analysis, but rather than burn marks, it was concluded they were caused by organic decomposition (Fig. 17).

The 98 samples recovered from the excavation were processed and sampled. Another small piece of charcoal was identified although, yet again, it was not possible to confirm any anthropogenic patterns within the shell collections.

The underwater work conducted by the dive team has provided a great deal of geological and geomorphological information about the coastal waters around the Farasan Islands. We are now much better informed about the elusive nature of the archaeological signature in the area and recognise that middens will deflate as they go through the tidal zone while coral hand tools will degrade when in the sea. However, we have identified submerged shorelines, wave cut platforms and solution notches. By recording these features, we have located sites suitable for habitation by prehistoric peoples and found areas with stable stratified units that could hold material. For the geologist, we have identified markers for relative sea level change and helped interpret the geomorphological effects of salt tectonics as it deforms the landscape. We have also learnt that there are no outcrops of basaltic material around the islands, which is unfortunate as field-walking on the mainland showed these were the main targets of human activity and provided the most distinct indicators of an early human presence.

As the project progressed and understanding increased, it was recognised that there was a growing need to collect more information about the submerged landscape so we could further investigate the hypothesis that the basins formed by salt tectonics held fresh water during periods of lowered sea level. There was also a need to better understand the geomorphological processes across the wider shelf exposed around the Farasan Islands during lower sea level and locate nodes of activity, ideally near basalt outcrops, with a greater potential to find evidence of human activity. To achieve this, we needed to cover a much larger area than we could do with divers, so a multidisciplinary geophysical survey was conducted.

11 Acoustic, Geophysical and Coring Equipment Used in the Farasan Islands

In June 2013, an opportunity arose to conduct a geophysical and acoustic survey to investigate the underlying geological processes and the presence of sediments. These were tools that had not been used around the Farasan Islands for geo-archaeological reasons before but they are becoming increasingly important to the maritime archaeologist when trying to interpret the palaeo-landscape.

Enormous technological progress has been made in recent decades in marine geophysical survey methods and a large spectrum of techniques is available for the systematic mapping of seafloor and sub-seafloor of the continental shelf at various scales, allowing the reconstruction of submerged landscapes and terrestrial palaeo-environments and the evaluation of possible locations for prehistoric archaeological sites. The main advantages of using marine geophysical techniques are: (i) large areas can be surveyed in high resolution (decimetre to metre resolution) and over a relatively short time, (ii) deep seafloor areas can be easily and systematically surveyed, (iii) information on the shallow sub-seafloor structure and stratigraphy can be collected without the need to excavate the seafloor, and (iv) geophysical sub-bottom profiles can be calibrated by coring.

Multibeam echo sounders (MBES) are designed to acquire simultaneously co-registered bathymetric and backscatter (acoustic reflectivity) data covering a swath of the seafloor along the survey track. They are fairly complex systems requiring sophisticated motion sensor units in order to rectify vessel pitch, roll and heave when positioning the data relative to the seafloor (Le Bas and Huvenne 2009). The coverage on the seafloor is proportional to the water depth. Since MBES are usually surface-towed or hull-mounted systems, the resolution of the seafloor decreases as the water-depth increases.

Unlike MBES, side scan sonars (SSS) are deep-towed systems designed to map the acoustic reflectivity of a swath of the seafloor acquired along the survey track. SSS typically consist of an underwater vehicle (“tow-fish”) with two transducers mounted on either side (port-starboard). The tow-fish is deployed via a “tow-cable” behind the vessel to maintain constant height (about 20 m) above the seafloor during the survey. Thus, SSS provide high resolution mapping of the seafloor’s acoustic reflectivity throughout the survey, both in shallow and deeper depths.

Multibeam echo sounders (MBES) and side scan sonars are powerful tools in surveying, in particular in areas where submerged landscape features are exposed on the seafloor. This is not the case in many areas, where marine sediment deposition has led to the burial of the submerged palaeo-landscape and any remaining prehistoric features below a blanket of marine deposits, the thickness of which may vary between a few decimetres and a few tens of metres. For these cases, a wide range of sub-bottom profilers (SBP) are designed to provide information from below the seafloor, on the structure and stratigraphic pattern of the sub-seafloor. According to the sound source and the frequency (wavelength) and strength of the emitted sound, SBPs are distinguished as “pingers”, “chirps”, “parametric echosounders”, “sparkers”, “boomers” and “air guns”. In general, higher frequencies provide higher resolution but limited penetration while lower frequencies can penetrate deeper below the seafloor at compromised resolution. Sub-bottom profilers can be either towed behind the survey vessel or be hull- or pole-mounted. Conventional SBPs provide a 2D profile of the stratigraphy along the survey track. Recent technological advances have led to the development of 3D profilers, which can provide three-dimensional imaging of the sub-seafloor but require extensive and complex processing (Missiaen et al. 2017a, b).

Coring can provide physical access to sedimentary layers of the seafloor’s substrate and physical constraints for the interpretation of the seismic sub-bottom profiles. Gravity and piston corers can theoretically reach several tens of metres beneath the seabed, but in most cases they rarely exceed 5–10 m penetration. The deployment and recovery of corers require powerful winches and therefore they are used from purpose-built vessels.

12 Deep Seabed Inspection: Methods, Results and Limitations

Manned submersibles (or Human Operated Vehicles, HOVs) and remotely operated vehicles (ROVs) have been used for the inspection of the deep seabed for over 40 years. During recent years, the use of autonomous underwater vehicle (AUV) technology for the survey of the seafloor has become increasingly available and efficient (Missiaen et al. 2017a, b). The most commonly used sensors mounted on ROVs, HOVs and AUVs include navigation sensors for positioning, optical sensors (video, photographic, stereoscopic still cameras), sonar sensors for mapping the seafloor and its features (multibeam, side scan sonar, subbottom profiler) and chemical/environmental sensors for quantifying the oceanographic environment.

Submersibles are best suited for direct-observation mapping and sampling rather than fine-resolution systematic surveys. They are not tethered and thus can move freely and independently from the ship. The bottom time is relatively short, depending on the consumption of power and the need for recharging of the batteries. ROVs are tethered to the survey vessel through an umbilical which provides power and commands to the vehicle and transmits data from the vehicle to the vessel. ROV dives are not constrained on bottom time; however, the tethered configuration restricts their mobility, as the vehicle and the surface ship have to move in concert. AUVs have recently emerged as stable, near-bottom survey platforms. They are not tethered and are designed to run pre-programmed missions by flying along survey lines at constant altitudes from the seabed (Bingham et al. 2010).

13 The Farasan Islands Research Cruise: Survey Methodology and Results

The large-scale imaging of the Farasan continental shelf was carried out by the HCMR survey vessel, R/V Aegaeo. The marine survey was designed to collect as much data as possible and integrate the different data sets in order to map important palaeo-morphological features on the seafloor and its substrate, including palaeo-shorelines and terraces, river-valleys and lakes, and to reconstruct the submerged, terrestrial landscape of the Last Glacial Maximum (Sakellariou et al. 2018).

During the 12 days of the cruise two areas were surveyed systematically, in the inner and the outer continental shelf, northeast and west of the Farasan archipelago respectively. Swath bathymetry and backscatter mapping of the seafloor were performed with the use of two hull-mounted, multibeam systems (20 and 180 kHz), while certain areas were surveyed in more detail with a deep-towed side scan sonar. A 3.5 kHz pinger was used for the high-resolution survey of the seafloor's shallow substrate while a 10 ci airgun seismic profiler provided information on the deeper geological structure and the seismic stratigraphy (see Sakellariou et al. 2018). Coring with a 5-m-long gravity corer and a box corer was performed on sites selected on the basis of the on-board preliminary interpretation of the acoustic and geophysical recordings. Finally, ROV dives were scheduled to inspect visually specific sites of potential palaeo-environmental interest.

The wide continental shelf off southwestern Saudi Arabia and around the Farasan Islands comprises a 70–80 m deep terrace, dipping very gently toward the Red Sea, which was exposed during the Last Glacial Maximum. Post-LGM marine sedimentation has been negligible on the shelf of the surveyed areas. Marine deposits with a maximum thickness not exceeding a few metres occur only in local depressions of the shelf. Thus, the primarily terrestrial landscape with its main morphological features is preserved and exposed on the seafloor. The survey area in the outer shelf is incised by well-preserved river valleys, developed along fault scarps and outflowing at the LGM shoreline. The latter has been identified at about 120 m below present depth (Fig. 18). A series of flat-topped ridges surrounded by steep, faulted slopes has been mapped at a short distance off the shelf edge and separated from it by deep troughs. The top of the ridges lies at depths comparable to the depth of the shelf; thus, they were exposed during the last low sea-level stage, forming an archipelago at a short distance off the shoreline. The survey area on the inner shelf comprises a 120–130-m-deep valley incised in the 70-m-deep terrace, which connects to a sub-circular 250-m-deep depression through a narrow gorge. Both the valley and the sub-circular depression were probably filled with water and formed lakes during the last glacial maximum, when the surrounding shelf was exposed (Fig. 19). The results of the Farasan Islands research cruise are presented in detail by Sakellariou et al. (2018).

14 Does it Give Clues About Areas with Archaeological Potential?

The seabed surface and sub-surface categorization provided by the geophysical data gives a baseline of anomalies that can be explored in detail by divers. It shows that a great deal of the pre-submergence morphology remains. It also reveals that the thickness of sediment covering the submerged terrestrial surface is relatively thin (see Sakellariou et al. 2018), although it would mask prehistoric archaeological artefacts. This was something that was apparent from the diver and ROV inspections. However, close up human examination by an experienced diving archaeologist would increase understanding and enhance our ability to interpret the character of the seabed. Visual inspection as a method of ground truthing the geophysical data is essential to help determine subtle geo-morphological features, short term erosive or depositional processes, along with indications of palaeo-land surfaces or signatures of human activity. These include any stone artefacts or outcrops of underlying deposits that could indicate buried landforms.

15 Discussion: What Have We Learnt and Where Next?

The AFRAC MAR and DISPERSE projects have provided unique insights into the drowned landscape around the Farasan Islands (Momber et al. 2014). Diving investigation inspected over 20 km of seabed in eighteen distinct areas of coastal waters at different locations over four seasons of fieldwork. The work resulted in a broad understanding of the near-shore submerged landscape around the present-day

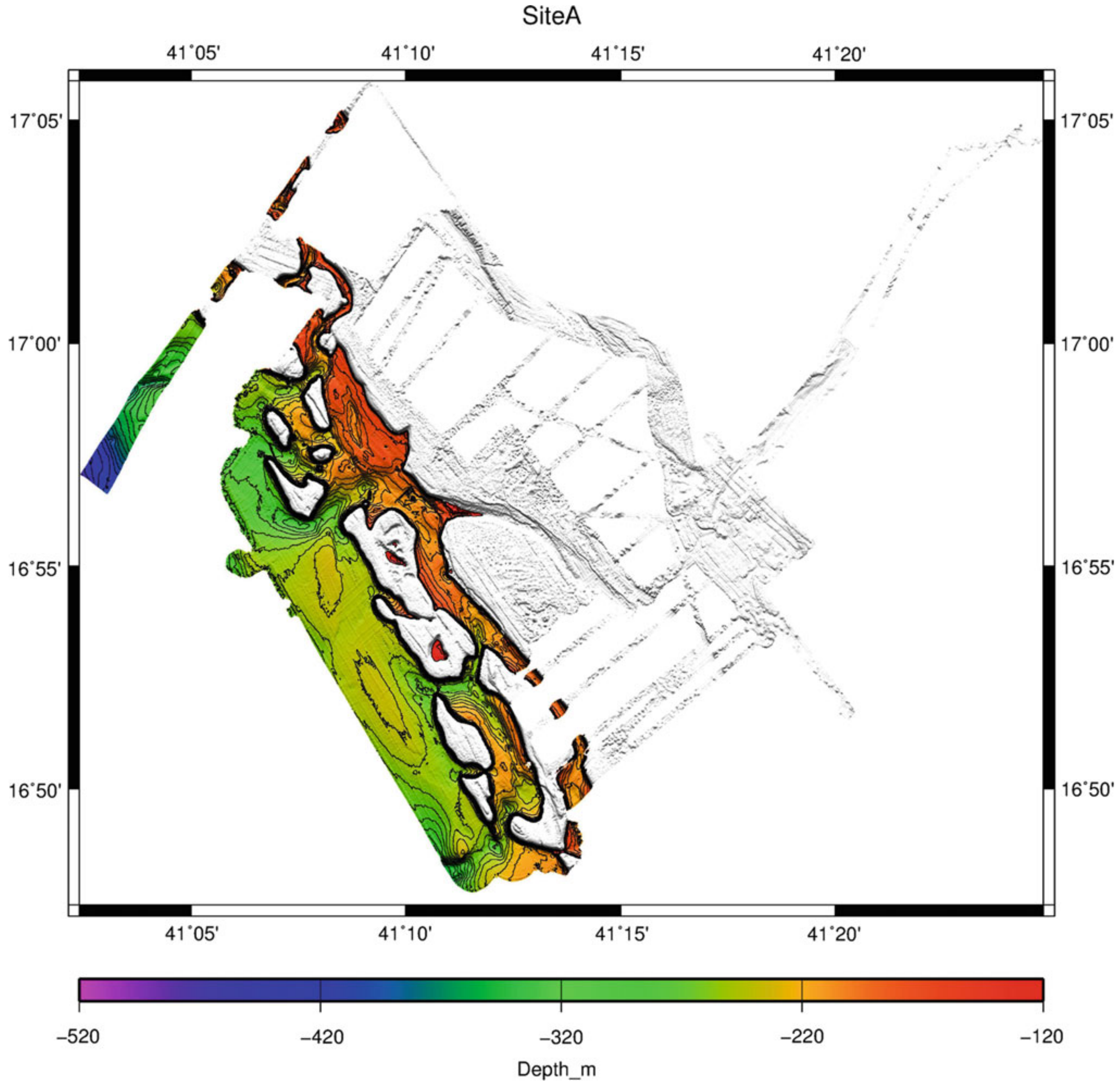

Fig. 18 This series of submerged outcrops off the west end of the continental shelf would have been islands during the LGM. The colours signify contours and the depths below Ordnance Datum (OD) are annotated on the scale. Core samples from within the hollows in the centre of one of the islands identified possible lacustrine deposits (see Sakellariou et al. 2018)

Farasan archipelago where wave cut platforms and notches indicate past shorelines. Attractive sites for human occupation that would have provided shelter and vantage points looking out over resource-rich environments were also identified. Excavation of the sea bed at selected locations revealed stratified units of marine deposits above palaeo-land surfaces, demonstrating that deposits could remain stable following deposition and inundation.

Further offshore, the comprehensive geophysical survey and coring over significant areas of the submerged shelf in 2013 helped us to understand the submerged geology and the geomorphological processes that shaped the wider landscape around the Farasan Islands (See Sakellariou et al. 2018). The data collected is helping to reconstruct a complicated palaeo-landscape interspersed with lakes that would have been fed by wadis or springs when sea levels were

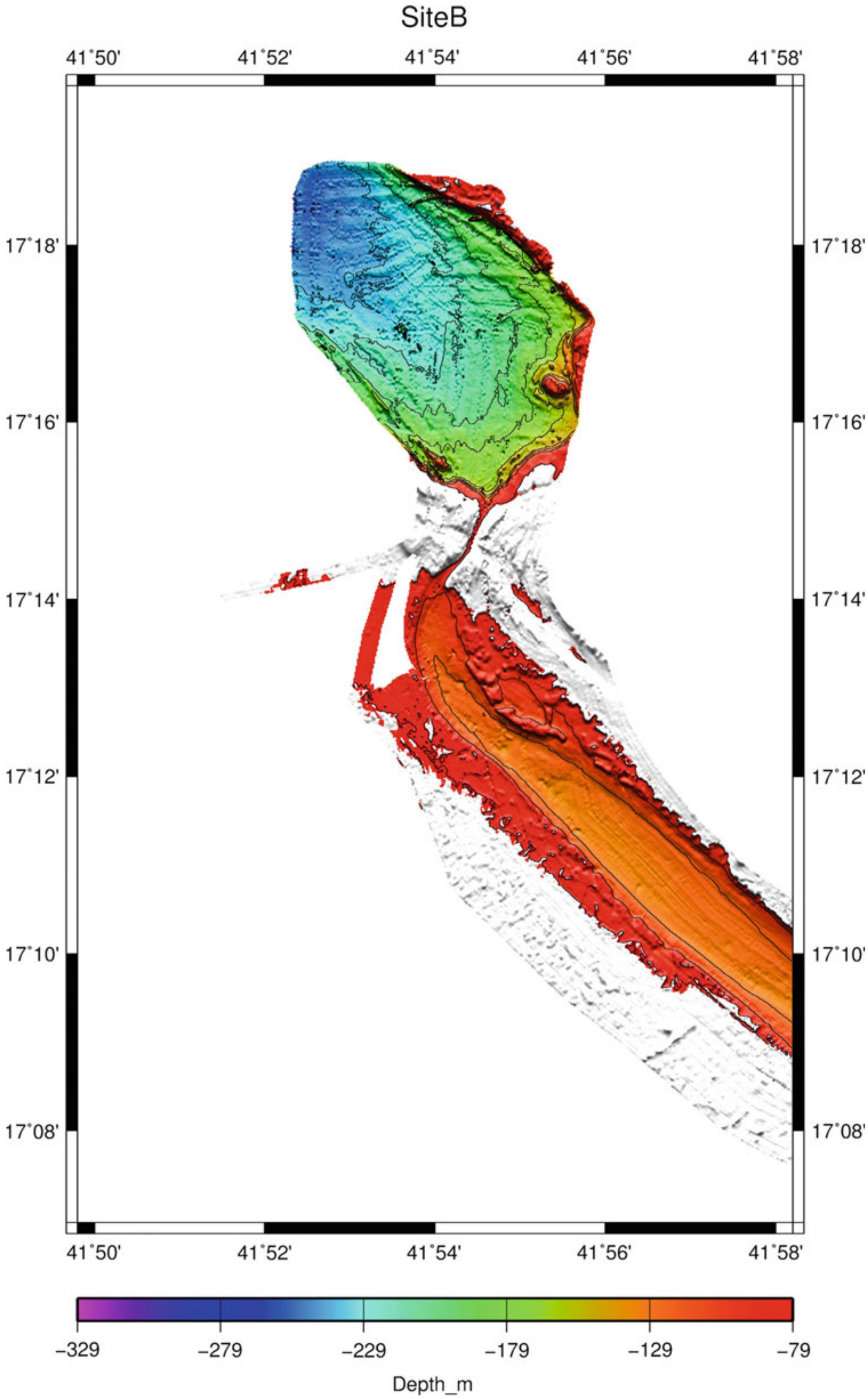

Fig. 19 3D bathymetric relief of interesting submerged landscape features northeast of the Farasan Islands. Survey collected by Hellenic Centre for Marine Research (HCMR) from R/V Aegaeo. The coloured contours begin at −79 m below OD. The large linear feature to the south east was identified as a fault. The orange colour indicates a depth of around 130 m, being approximately 50 m deeper than the surrounding landscape and the narrow gorge to the north. At the last glacial maxima, sea-level was approximately 120–130 m below OD. During this time and until the sea level was high enough to pass through the gorge, the fault was isolated from marine influences and could have contained fresh water. The dark blue area is the southern edge of a circular sinkhole; this formed when a subterranean salt dome or diapir collapsed, and it is over 350 m deep (Courtesy D Sakellariou)

lower. This is of particular importance given the relatively more arid climates that persisted throughout much of the global cycle in this region (see Petraglia et al. 2018). More importantly it is giving us a better understanding of the potential for human exploitation of the now-submerged landscape and environment and its value that is helping to address the issue of human dispersal into and through Arabia.

What we have yet to find underwater is unequivocal archaeological evidence of occupation. Unfortunately, sedimentation, erosion, and the processes of dispersal make archaeological discovery much more challenging under water than on land. The dominant archaeological features surviving today on the present-day land surface that relate to coastal exploitation on the Farasan Islands are the mounded shell middens, of which over 3000 have now been discovered. The midden building began about 7,000 years ago and lasted a couple of thousand years. The excavated structures show accumulations of marine molluscan species that were harvested during different seasons and from different localities (Meredith-William et al. 2014a; Hausmann et al. 2015; see also Bailey et al. 2018, and Hausmann et al. 2018). Some of the shellfish were recovered from a few metres underwater, demonstrating that the islanders had to take to the water and dive, while others came from the intertidal zone. It is most probable that some of the earliest shell middens would have been built on land that is now underwater. Unfortunately, our work has shown that the drowning process would have caused these to deflate and mix with natural assemblages making their signature on the seabed very unclear.

Lithic artefacts recorded during field-walking included small ground stone implements made from fine-grained volcanic material that would have been imported from the mainland as volcanic material has not been identified in or around the Farasan Islands. In contrast, surveys on the mainland between 2013 and 2014 identified rich assemblages of stone tools. Some 119 localities in the Jizan, Asir, and Harrat al Birk basaltic regions resulted in the recording of over 3000 artefacts (Alsharekh and Bailey 2013; Devès et al. 2013; Inglis et al. 2014a, b; Meredith-Williams et al. 2014b; see also Sinclair et al. 2018). On the Farasan Islands, the larger tools discovered were fashioned out of the local coral limestone. These are not as durable as basalt and are prone to weathering, particularly underwater where salt water and marine boring organisms will degrade them beyond recognition.

Although the underwater excavations to date have yet to produce any archaeological material, only a very small section of the submarine landscape has been investigated. A main challenge is the widespread deposition of sand and shell that blankets the seabed. However, a great deal of information about the archaeology and geology of the submerged palaeo-landscape around the Farasan Islands has been generated over the past decade and many lessons have been learnt. The combination of research on land and underwater has helped to identify the nature of stone tools in the region, areas where concentrations are greatest and the conditions that would allow for the greatest chance of preservation. It has demonstrated that the potential to discover stratified archaeological deposits within underwater sites that were protected during the last transgression remains high, but the probability of finding worked lithics would he greatest nearer outcrops of basaltic lava. These outcrops are to be found further north in the vicinity of Harrat Al Birk, where abundant stone tools have been discovered on land, and where volcanic deposits appear to occur also offshore from the present coastline. Here, any stone tools present on the submerged seabed would be more abundant and their darker colour would make them easier to identify against a backdrop of coral terrace or yellow sand.

16 Conclusion

In some respects, purposeful underwater archaeological surveying for prehistoric material is very different from an archaeological survey on dry land and is subject to very different challenges and constraints. Notwithstanding the huge technological and technical advances in recent decades in underwater acoustic surveys, photography and remote sensing and the development of underwater vehicles and robotics, there remain severe limitations on how large an area of the seabed can be explored in a given project.

The financial costs are also much greater than on land, especially where ship time is involved, although these can be mitigated in some cases, as in our work in Saudi Arabia, by collaboration with industrial partners. Diving in shallow water with SCUBA and normal air mixtures is a cheaper option, but issues of health and safety, the provision of logistical support, and the unpredictability of weather conditions and underwater visibility impose their own constraints on the area of seabed that can be examined. In any case, the depths accessible to divers are for the most part in the shallower areas of the continental shelf exposed at low sea level.

Also, features of the original terrestrial land surface and especially archaeological deposits are liable to dispersal and destruction or burial under sediment during and after inundation by sea level rise. We know from the many underwater prehistoric finds that have been discovered that archaeological material can survive and can be exposed and discovered under favourable circumstances. Nevertheless, finding those favourable locations remains a challenge, given the other constraints on underwater surveys.

If the discovery of archaeological sites, often taken to be the primary objective of an archaeological survey, were the sole test of success, our underwater work in the Red Sea would have to be judged, so far, as a failure. However, archaeological surveying should involve much more than the opportunistic discovery of a well stratified and dateable site. What we have learned from our research is the importance of two additional objectives that should inform archaeological surveys over and above the discovery of archaeological sites. The first is the need for a much more detailed understanding of the bigger geological picture of landscape evolution and dynamics within which human occupation took place. This provides the framework for defining the environmental conditions that may have variously attracted or deterred human activity, the geomorphological conditions of erosion or sedimentation that may have destroyed or buried archaeological material, and the basis for predictive models aimed at identifying suitable targets for more careful archaeological investigation.

The second lesson, which follows from the first, is the importance of understanding the taphonomic conditions that determine the preservation, visibility, exposure and destruction of archaeological sites and archaeological material. And that in its turn depends on an understanding of the geological processes of formation and deformation operating in different parts of the landscape. No archaeological survey—and no map of archaeological sites and findspots—can be said to be complete or even in any way meaningful without addressing these two objectives. And this applies as much on land as under water. If anything, the situation on land is as bad if not worse. Archaeological material on land is subject to severe degradation and destruction by subaerial weathering, and is just as liable to burial or exposure and dispersal by erosion or accumulation of sediment as underwater material. To this must be added the increasingly powerful impact of human activity in the form of industrial development, agricultural land-use practices, road-building, quarrying, land fill, and other infrastructural developments.

What is different about underwater archaeological surveying is that the geomorphological evolution and dynamics of the landscape and the complexities involved in determining archaeological site taphonomies are more obvious. However, they are no less present on land. Archaeologists who conduct surveys, whether on land or under water, tend to regard the discovery of a big site or sites as the prime objective, investing much time and resources in excavation of such sites once discovered, and only working outward to the wider landscape at a later stage and then rarely progressing very far away from the primary site. Geologists involved in archaeological surveys, in contrast, tend to start at the other end of the spectrum, wanting to gain an overall understanding of the regional geology and geomorphological processes first, and only later working inward to individual locations. Successful archaeological surveying requires both approaches. Only when sites can be placed in their wider geomorphological and taphonomic setting can the project be judged a success. Surveys that produce sites without that wider understanding are as incomplete as surveys that fail to produce sites. In this respect archaeological surveys on land and underwater have much to learn from each other.

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