Landscape Archaeology, Palaeolithic Survey and Coastal Change Along the Southern Red Sea of Saudi Arabia

Anthony Sinclair, Robyn H. Inglis, Andrew Shuttleworth,
Frederick Foulds, and Abdullah Alsharekh

Abstract

Since 2012, a new phase of landscape survey for archaeological remains from the Palaeolithic has been undertaken in the provinces of Jizan and Asir in Southwestern Saudi Arabia. This is the first Palaeolithic landscape survey in this area since the Comprehensive Survey of the Kingdom undertaken between 1977 and 1982. More than 100 Palaeolithic sites have been identified from the Early Stone Age to the Late Stone Age, evidencing a regular association between archaeological remains and the Harrat deposits of basalt. The analysis of two major newly discovered sites, Dhahaban Quarry and Wadi Dabsa, has demonstrated the quality of archaeological and behavioural information that can still be recovered through landscape surveys in this region. At the site of Dhahaban Quarry, the survey has confirmed that Middle Stone Age lithic artefacts can be found in situ in the preserved beach deposits of ancient shorelines suggesting the use of marine resources. At Wadi Dabsa the technological study of a large assemblage of lithic artefacts suggests variations in expertise in lithic technology, and possibilities for understanding the process of learning the skills of lithic technology.

A. Sinclair (✉)
Department of Archaeology, Classics and Egyptology,
University of Liverpool, 12–14 Abercromby Square,
Liverpool, L69 7WZ, UK
e-mail: a.g.m.sinclair@liverpool.ac.uk

R. H. Inglis
Department of Archaeology, University of York, King's Manor,
York, YO1 7EP, UK

R. H. Inglis
Department of Environmental Sciences, Macquarie University,
North Ryde, Sydney, NSW, Australia

A. Shuttleworth
Queen's University, Belfast, UK

F. Foulds
Northern Archaeological Associates, Marwood House, 28 Harmire
Enterprise Park, Barnard Castle, DL12 8BN, UK

A. Alsharekh
Department of Archaeology, King Saud University,
Riyadh, Saudi Arabia

1 Introduction

It is generally agreed that the first hominin species evolved in Central and Eastern Africa sometime after 7 million years ago (Senut et al. 2001; Brunet et al. 2005; Suwa et al. 2009; Brunet 2010). Following a long period of evolution within that continent, fossil evidence from Dmanisi in Georgia then indicates that hominins left Africa sometime before 1.8 million years ago (Garcia et al. 2010). As the closest landmass to Eastern Africa, Arabia must have been one of the first regions into which hominins dispersed when leaving Africa. We should therefore expect to find in Arabia archaeological evidence dating through most of the Pleistocene and indicative of the ways in which the first and later hominin migrations from Africa adapted to new environments. This simple understanding has led to a new wave of Palaeolithic archaeological research in the Arabian Peninsula since 2000 (see papers in Petraglia and Rose 2009 as an early example).

It is along the Red Sea coast where hominins entered the Peninsula either by land migration from the north, or, possibly, via a sea crossing at the southern end at times of lower sea level (Walter et al. 2000; Bailey 2009; Armitage et al. 2011; Lambeck et al. 2011; Groucutt and Petraglia 2012), and it is here that archaeological evidence is likely to be most abundant. Yet, despite the importance of the Red Sea coastal plains to an understanding of hominin dispersal, landscape surveys for evidence of Palaeolithic age have been limited, especially so at its southern end in the provinces of Asir and Jizan. An initial survey in the late 1970s identified archaeological sites with Palaeolithic evidence and, on the basis of typological similarity to the sites in Africa and the Levant, suggested that Arabia might have been colonised from 1.3 million years ago (Whalen et al. 1989; Whalen and Pease 1990). No further survey, however, happened until a more recent programme by

N. M. A. Rasul and I. C. F. Stewart (eds.), *Geological Setting, Palaeoenvironment and Archaeology of the Red Sea*,
https://doi.org/10.1007/978-3-319-99408-6_24

the authors started in 2012. This recent programme has significantly increased the number of Pleistocene age sites in the Red Sea coastal plain and greatly improved our knowledge of hominin landscape settlement, resource use and technological behaviours (Inglis et al. 2014; Bailey et al. 2015).

In this chapter, we shall give a brief overview of the results of landscape surveys conducted from 2012, and compare the evidence from the first archaeological survey to that gathered from recent work to assess the reliability of this earliest research. We shall also discuss in more detail the archaeological and sedimentary information gathered from two specific sites that give an indication of the quality of evidence that still survives. Recent archaeological work confirms some of the typological and anecdotal description recorded by the earliest survey teams, but advances in archaeological and landscape analysis indicate that there still remains a wealth of high-quality archaeological and environmental evidence to be found along the Red Sea that can inform us about a wide range of hominin behaviour, such as the relationships between hominins, changing coastal landscapes and potential marine resources at the coastline, and perhaps about less obvious behaviours such as the transmission of patterns of learning between generations. Even though these deposits and their associated archaeological remains have survived for many thousands of years, it is clear that the archaeological and associated sedimentary evidence, especially that related to the marine deposits preserved along the current Red Sea, is now very fragile and has become fragmented as a result of local development over the last thirty years. It faces imminent threat of destruction from further development. Without a proper appreciation of the evidence preserved and the sedimentary context in which such evidence may be found, including further research in the immediate future to record its distribution and quality, such evidence for the lives of the first human communities of the Arabian Peninsula along the Red Sea may soon be lost forever.

2 Landscape Survey in Archaeology

Interpretations of human behaviour based on evidence from landscape surveys rest on an understanding of the nature of the chronological, behavioural and taphonomic relationships between samples of archaeological material. First coherently described by David Clarke (1973), this may be the relationship between the sample of material that was discarded in the past out of the larger set that was made and used, or between the smaller sample that has been preserved from that which was discarded, or between the preserved sample and a smaller sample that remains visible to the survey team, or between that visible sample and a yet smaller sample that might be collected or recorded. When the focus of interpretation is the Palaeolithic, the interpretive problems are multiplied by the scales of temporal and environmental change involved and the difficulty of identifying discrete episodes of behaviour. Palaeolithic landscape surveys must balance an understanding of the effects of environmental change with the surviving evidence of hunter-gatherer activities distributed across a much wider range of spatial and temporal scales than is the case for the archaeology of post-Pleistocene settled communities. To be effective, investigation requires a knowledge of the taphonomy of archaeological materials—their differential preservation along with the various processes of destruction, burial and exposure in any landscape setting (e.g., Holdaway and Fanning 2014). It also requires an understanding of the ways in which mobile hunter-gatherers might exploit different plant and animal resources as environments change, recognising that the activities undertaken in one place during one environmental setting may be different from those undertaken in that same place at times of different environmental conditions (Binford 1982). In summary, the interpretation of survey data requires the disentangling of potential long-term archaeological palimpsests of discrete episodes of hominin life built up over different time scales and comprising many different activities (Rossignol and Wandsnider 1992; Stern 1993; Bailey 2007). Finally, it must be recognised that the potentially observable behaviour of hominins has changed considerably through the Pleistocene as physical, cognitive, and social capacities of different hominin species evolved.

In the southern Red Sea (Fig. 1), Palaeolithic landscape surveying is particularly difficult for a variety of reasons. A continuous history of changing sea level means that the location of the coast has been subject to considerable movement because of marine transgression and regression. Those coastal deposits which are currently accessible offer evidence from a short period of interglacial time, whilst deposits formed at other times are now submerged and lie many kilometres out from the modern shoreline (Lambeck et al. 2011). The coastal plain in the southern Red Sea has also been subject to episodes of deposition of aeolian, alluvial and colluvial sediments, whilst the lava flows and cinder cone deposits that are so prominent in this area and that have been thought to predate any Palaeolithic archaeology (Dabbagh et al. 1984) might not represent a physical remnant backdrop of ancient volcanic activity, but evidence of episodes of volcanic activity happening throughout the Pleistocene until quite recently (Bailey et al. 2007). Even though physical access to deposits at the coast and in parts of the coastal plain has become easier due to improvements in roads and vehicles, much of the coastal plain, the inner lava flows and the escarpment still remain very difficult to access and survey. Finally, the archaeological materials themselves are also difficult to see; the overwhelming majority are both made from and deposited on local volcanic lava flows.

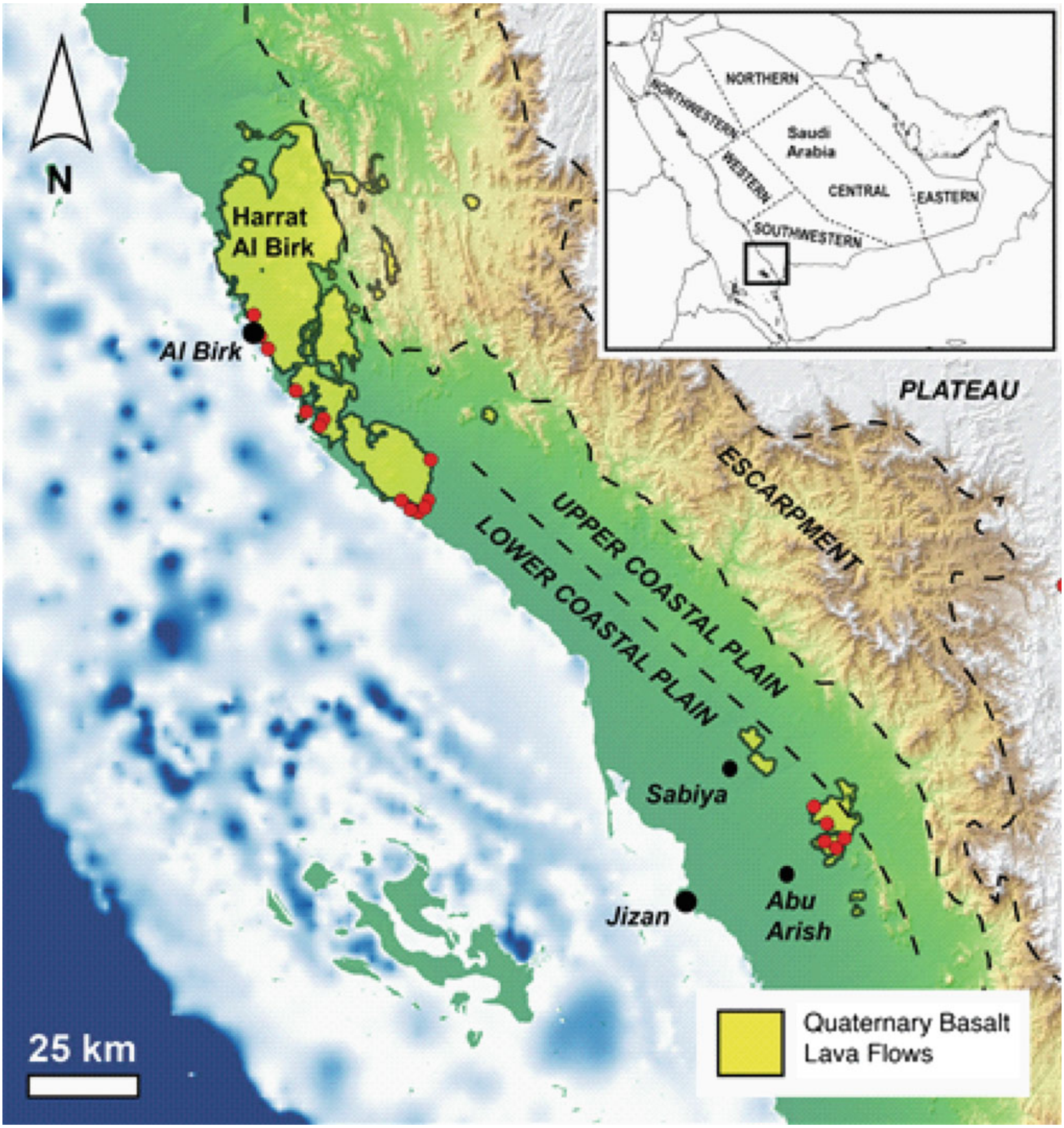

Fig. 1 Map of the location of the study area in Jizan and Asir Provinces, Southwestern Saudi Arabia. Major landscape zones defined by the DISPERSE project (following Devès et al. 2013). Red dots indicate findspots of Palaeolithic artefacts from the CASP survey of the Southwestern Province (Zarins et al. 1981). Elevation data © CGIAR-CSI SRTM 90 m v4.1 database; bathymetric data from GEBCO_08 One Minute Grid

geoff.bailey@york.ac.uk

3 Palaeolithic Survey of the Southern Red Sea Coast

3.1 The Comprehensive Archaeological Survey Program of the Kingdom

The first large-scale archaeological survey of Saudi Arabia, the "Comprehensive Archaeological Survey Program of the Kingdom", ran from 1977 to 1981. Sponsored by the Department of Antiquities and Museums and the Ministry for Education, it was planned as a response to a considerable growth in infrastructural development. The sponsors foresaw a potential threat posed to the Kingdom's antiquities if development continued without any prior understanding of the heritage assets that might be destroyed. The timing of the Comprehensive Survey was also significant; it was only from the mid-1970s that there were sufficient Saudi Arabian personnel trained in archaeology and heritage to work with foreign specialists to make such a survey possible (Adams et al. 1977; Potts 1998).

The Comprehensive Survey divided the Kingdom of Saudi Arabia into six large provinces: Northwestern; Northeastern; Western; Central; Eastern; and Southwestern. For each region, a team completed two or three seasons of field survey looking for archaeological sites of all periods. Preliminary reports were published in *Atlal,* then a new journal dedicated to Saudi Arabian archaeology and heritage. Major monographs for each province were planned, but, unfortunately, never came to fruition. Although entitled as a Comprehensive Archaeological Survey of the Kingdom, even at the time, it was recognised that the scale of the task made a total systematic survey impossible. Matters were also not helped by the absence of detailed topographic maps better than 1:500,000 scale (Petraglia 2003) with which to plan and record any work. To compensate, the Survey targeted areas where sites were already known, or areas close to known oases, shorelines, ancient wells and traditional travel routes and where access for survey teams was also possible. In doing so, the survey team recognised that their results would necessarily be affected by these constraints (Adams et al. 1977). The survey teams also clearly understood that any behavioural interpretations of the archaeology of the Pleistocene (the Palaeolithic record) would necessarily be tentative since the environmental constraints that have structured life in Saudi Arabia over the last few thousand years might have been considerably relaxed during earlier episodes with different climate regimes, allowing possible habitation and use of the landscape beyond the targeted survey areas (Adams et al. 1977). Recent research on changing palaeohydrology and landscapes in Arabia shows the wisdom of this observation (Parker 2009; Groucutt and Petraglia 2012; Bailey et al. 2015; Jennings et al. 2015, amongst others), confirmed by new archaeological finds on former wadis and lakes (e.g., Petraglia et al. 2011, 2012, and this volume; Delagnes et al. 2012; Crassard and Hilbert 2013). Despite these limitations, the Comprehensive Survey proposed some clear typological patterns and environmental associations for the Palaeolithic archaeology of Saudi Arabia (Petraglia 2003; Petraglia and Alsharekh 2003) which remain a testament to the observational skill of the original survey teams.

The Red Sea coastal plain in Jizan and Asir provinces lies within the Southwestern province of the Comprehensive Survey. Over six weeks in 1980, survey teams examined an area greater than 21,000 km^2, ranging from the Red Sea coastal plain to beyond the escarpment to the east, as well as including the Farasan Islands in the Red Sea as part of their second season of survey (Zarins et al. 1981, Plate 1A). They identified 20 sites that were typologically assigned to the Palaeolithic, with 4 sites in the coastal plain (Zarins et al. 1981). These sites were identified by stone tool typology as Lower Palaeolithic (including Oldowan and Acheulean), Middle Palaeolithic (including Mousterian) or Upper Palaeolithic by reference to typological or technological similarities to lithic materials discovered elsewhere in Europe or Africa. In Africa, archaeologists refer to these three periods as Early Stone Age (ESA), for Lower Palaeolithic, Middle Stone Age (MSA) for Middle Palaeolithic, and Later Stone Age (LSA) for Upper Palaeolithic. Presuming a colonisation route into Arabia primarily from Africa, these African chronological terms will be used here. This choice of name also indicates a need to look for parallels, where appropriate, in Africa rather than Europe as is often done by other researchers. Palaeolithic sites were located close to lava flows east of Abu Arish and in the Harrat al Birk (Fig. 1). Acheulean sites, within the ESA, were identified by the presence of handaxes, cleavers and a series of worked tools made on flakes that can be described as scrapers, knives and so forth that were always used as simple hand-held tools. Middle Stone Age sites were identified by the presence of prepared core technology in which a core is prepared in such a way so as to facilitate the removal of a flake of pre-determined shape and by tools that conformed to types observed in European sites of Mousterian age (Zarins et al. 1980, 1981). Prepared core technology, originally called "Levallois technique", results in flakes that can be broad and flat, or pointed and flat, that can be worked into a variety of tools of a more standardised shape, and that are also thin enough to haft into handles (see Debenath and Dibble 1994). Along the Red Sea coast, no discrete Palaeolithic localities younger than the MSA were discovered; indeed, it was noted that such materials were in fact difficult to identify in Arabia in general (Zarins et al. 1981).

From the context of sites and finds, the Survey suggested a relationship between hominin settlement and lithic raw material sources, water courses, coastal exploitation of marine resources and environmental or sea level change (Zarins et al. 1981, Plate 5b). Acheulean sites were found on the lava flows close to Al-Birk and Al Shukayk in Harrat al Birk, and these flows appeared to overlie remnant coral terraces approximately 10 m above modern sea level. The location of Acheulean sites was thought to indicate the exploitation of marine foods. For the MSA, the use of marine resources seemed even more certain; survey reports state that they had found tools embedded in remnant coral terraces approximately 2 m above sea level (Zarins et al. 1981). Away from the coast, Palaeolithic materials were found close to other lava flows, for example east of Abu Arish, and along old wadi courses. No absolute dates were produced, but it was suggested that Acheulean sites might date from 1,200,000 years ago, and MSA sites from 100,000 years ago, by comparison to dated sites in Africa, the Levant and Europe with typologically similar artefacts (Zarins et al. 1981). As was typical for Palaeolithic research at the time, the reports are also lacking in a detailed analysis of the techniques of working and the variability of working of stone materials within and between sites that might facilitate interpretations of movement of materials across a landscape.

Despite the real accomplishments of the Comprehensive Survey, the speed and the requirements of the geographical and chronological scale of the Survey meant that many questions remain. We have no idea of the real quantity of Palaeolithic archaeological materials surviving at the time. There are no absolute dates for any of these sites or for the lava flows with which stone tools were associated and which were reported to overlie remnant coral terraces. Aside from the statement that tools were associated with or embedded within coral terraces, no photographs were published to prove this relationship. The Survey reports provide no detail on the archaeological assemblages from the Red Sea coastal margin beyond their basic typological details; only one in the Hima region, east of the escarpment, has such detail. None of the sites found on the coastal plain was revisited for further excavation or analysis, unlike the Acheulean sites of the Wadi Fatimah and Dawadmi in the Western survey province (Whalen et al. 1981, 1983, 1989; Whalen and Pease 1990). As should be expected given the age and broad scope of the Survey, there is no detail on the techniques of working at any one site, how the raw material was exploited and how sites might have fitted into larger patterns of settlement as evidenced by their sequences of production. Such analyses were not common until the mid-1980s. Finally, no samples were collected to provide information on the sediments with which the archaeological materials were associated.

3.2 Palaeolithic Landscape Surveys in Jizan and Asir Provinces Since 2012

Following preliminary reconnaissance in 2004 and 2006 (Alsharekh and Bailey 2013), from 2012, the DISPERSE project has been conducting archaeological fieldwork along the coastal strip of southwestern Saudi Arabia in the provinces of Jizan and Asir as well as in the Farasan Islands, led by Geoff Bailey (University of York, United Kingdom), Geoffrey King (Institut de Physique de Globe de Paris, France) and Abdullah Alsharekh (King Saud University, Saudi Arabia). The broad aim of the Project has been to address the manner of and evidence for the dispersal of hominins, with a focus on dispersal from Africa into Arabia and beyond, recognising that (i) active tectonic and volcanic landscapes offer an attractive set of resources for hominins, and that (ii) much of the archaeological evidence relating to hominin dispersals is currently submerged (Bailey and King 2011; Winder et al. 2015). Fieldwork in Arabia has, therefore, included extensive research on the exploitation of marine resources on the Farasan Islands and on parts of the submerged shorelines, supported by detailed surveys of the topographical features of the sea bed between the mainland and the Farasan Islands to predict places which might have been used by hominins during periods of lower sea level, and where underwater surveys might find preserved archaeological evidence (Bailey et al. 2015, this volume; Momber et al., this volume; Sakellariou et al., this volume). Finally, the DISPERSE Project also initiated a new programme of landscape survey and, where appropriate, detailed site analysis along a 200 km by 100 km strip of the upper and lower coastal plain along the Red Sea from Jizan and Abu Arish in the south to north of the Harrat al Birk (Devès et al. 2013; Inglis et al. 2014). This is the first landscape survey for Palaeolithic archaeology in this region since the original Comprehensive Survey.

In the thirty years and more that have passed since the Comprehensive Survey, archaeological field surveys have been transformed by the availability of satellite imagery, GPS location and GIS mapping to investigate relationships between finds and landscape features. In Arabia, this has an even greater impact due to the continued absence of detailed paper maps. The availability of scalable high-resolution imagery transforms the speed and accuracy of survey planning, whilst accurate GPS location data, available from the late 1990s, allows the rapid recording and representation of survey findings in a graphical manner to facilitate immediate feedback into the planning process. Indeed, the availability of free, up-to-date imagery through Google Earth now makes it possible to observe and interrogate a landscape topographically to find potential types of deposit to be surveyed before entering the survey area, as well as transport routes to plan a series of locations and transects that can be accessed. Online access to Google Earth during the survey season makes it possible to modify plans in the light of daily survey results from an area, and to identify landform or sediment types that may be most profitable. Finally, regular updates to the available satellite imagery permit an examination as to how potential archaeological deposits are being damaged or destroyed by natural processes and human development. Despite these considerable technological developments, surveys are still ultimately dependent on the time-consuming process of walking across a landscape and being able to identify archaeological stone artefacts. This is further complicated in southwestern Arabia by the fact that identifying these pieces is not a case of spotting material anomalies in a landscape (as is often the case in regions where the materials used are not local) but one of looking over many thousands of possible pieces, many of which have been rolled and naturally flaked over time, to find a very much smaller number of real artefacts.

This recent programme of landscape survey initially focussed on re-visiting sites identified by the Comprehensive Survey to check on their current state of survival and the accuracy of their earlier observations. We also examined deposits of a similar type (remnant coral terraces, lava flows) to evaluate the proposed patterns in distributions of archaeological materials. Where possible we have examined naturally or artificially cut sections to look for archaeological materials that are buried by later sediments but exposed in section. We have also explored topographical locations that correspond to known hunter-gatherer patterns of landscape use, specifically examining old water courses and remnant tufa deposits that indicate the presence of ancient bodies of water, as well as locations with potential vantage points from which visual information about local animal and plant resources and other hominin groups might have been gained, and routes between. Recent research suggests that wayfaring and landscape legibility are significant factors in hominin behavioural evolution (Guiducci and Burke 2016; see also Kübler et al., this volume), and taking these factors into account has proven to be successful in landscape surveys elsewhere (Sinclair et al. 2003). Survey localities included small intensively surveyed areas (~200 m by 200 m) associated with specific resources or sediments, through to transects of perhaps 1 km length and 200 m width walked across the landscape. Survey locations were identified and planned from imagery available on Google Earth, and GPS data for all survey locations was recorded, whether archaeological materials were recovered or not. The resulting data was plotted as a layer on Google Earth and on smaller scale GIS-based models of the landscape. Archaeological samples, where found, had their locations recorded using a handheld GPS, were collected, typologically and technologically analysed and put into storage under the care of the regional antiquities service for Jizan and Asir provinces. Samples suitable for sedimentary analysis and for dating have also been collected where possible.

In four seasons of landscape surveys, more than 85 localities out of 110 visited yielded Palaeolithic artefacts (Table 1). From these locations, several relationships seem evident. There are three distinct concentrations of Palaeolithic materials, close to the lava flows at Abu Arish, Sabya and especially in the largest flows of Harrat al Birk (Fig. 2). Typologically, these localities include a few of predominantly ESA (Acheulean) character with handaxes, cleavers, large cutting tools and large flake tools (n = 9), a larger number of MSA character with evidence of prepared-core techniques and their retouched flake products (n = 18), and many localities with both (n = 47). Some localities could not be typologically diagnosed (n = 13), and a number of locations were surveyed without finding archaeological materials (n = 25). There are no localities that are specifically, and only, of LSA character, but there are either a small number, or just isolated pieces, in some places that are likely to be LSA (see below).

In general terms, recent landscape surveying has corroborated earlier findings by the original Comprehensive Survey. It has identified frequent concentrations of Palaeolithic material at Abu Arish and the Harrat al Birk, and supported the proposed association between lava flows and Palaeolithic archaeology by finding new localities close to the lava flows at Sabya. Comparing the quantities and character of evidence, we can now identify patterns with greater confidence than was possible from the original survey data. For example, there is a significant variation in the quantity of Palaeolithic lithics found at different localities; two sites (Dhahaban Quarry and Wadi Dabsa) have produced assemblages of 1000 or more pieces (Fig. 3), though the remainder have much smaller assemblages. Whilst most of the newly surveyed Palaeolithic localities contain lithics of both ESA and MSA typology, there are localities that are of a single typological period. This variability in quantity and quality indicates that it should be possible to examine changes in hominin behaviour through spatial data. There are clear associations between Palaeolithic hominins, water courses and lava flows in Harrat al Birk (Fig. 4), as well as possible evidence for movement of MSA hominins further into the lava fields. A reduced presence of LSA hominins is suggested by the reduced number of localities, and this will be clearer still when comparisons are made of absolute artefact numbers.

Whilst it would be reasonable to have expected the identification of a greater number of Palaeolithic localities in the recent programme of fieldwork when compared to the original survey, given the greater length of time devoted to surveying, the abundance of localities confirms the presence of a rich archaeological record in this region that is still no

Table 1 Survey localities 2012–2017. Latitude/Longitude in WGS1984. ESA/MSA/LSA counts are defined as number of diagnostic techno-typological pieces. Numbers in brackets include possible identifications of broad categories, e.g. ESA/MSA, or MSA/LSA. Undiagnostic artefacts are those lithics that cannot be tentatively assigned to a broad period based on their typological form

Locality	Latitude	Longitude	Province	Description	Lithic artefacts				
					Total	ESA	MSA	LSA	Undiagnostic
L0001	17.187926	42.725637	Jizan	Basalt flow, Jebel Akwah (South)	1	0 (0)	0 (0)	0 (0)	1
L0002	17.288010	42.791759	Jizan	Undulating hills near Al Kadami	2	0 (0)	0 (0)	0 (0)	2
L0003	17.007015	42.926441	Jizan	Basalt flow, Wadi Jizan	20	5 (5)	2 (3)	0 (1)	12
L0004	17.027127	43.039292	Jizan	Escarpment foothills near Al Aridah	0	0 (0)	0 (0)	0 (0)	0
L0005	16.878146	42.939741	Jizan	Cinder cone, Jebel Umm Al Qummam (North)	1	0 (0)	0 (0)	0 (0)	0
L0006	17.055552	42.963629	Jizan	Basalt flow, Wadi Jizan Dam	66	0 (0)	8 (8)	5 (21)	35
L0007	17.113061	42.940373	Jizan	Wadi Jizan Tributary	0	0 (0)	0 (0)	0 (0)	0
L0008	17.083452	42.847372	Jizan	Basalt flow, near Abu Arish (Lower flow)	0	0 (0)	0 (0)	0 (0)	0
L0009	17.076882	42.856067	Jizan	Basalt flow, near Abu Arish (Upper flow)	12	2 (2)	10 (10)	0 (0)	0
L0010	16.869092	42.940231	Jizan	Basalt flow, Jebel Umm Al Qummam (North)	67	31 (33)	17 (26)	1 (8)	10
L0011	16.887337	42.986865	Jizan	Alluvial fan East of Al Wahmah	0	0 (0)	0 (0)	0 (0)	0
L0012	16.874363	42.994776	Jizan	Alluvial fan East of Al Wahmah	0	0 (0)	0 (0)	0 (0)	0
L0013	17.267884	42.683631	Jizan	Basalt flow, Jebel Akwah (North)	8	3 (3)	3 (4)	0 (1)	1
L0014	17.259316	42.708638	Jizan	Wadi draining Jebel Akwah (North)	9	1 (3)	3 (5)	0 (0)	3
L0015	17.241765	42.695073	Jizan	Basalt flow, Jebel Akwah (North)	7	1 (1)	4 (4)	0 (0)	2
L0016	17.248540	42.800845	Jizan	Alluvial deposits, Wadi Nakhlan	2	0 (0)	0 (0)	0 (0)	2
L0017	17.240254	42.804980	Jizan	Hills above Wadi Nakhlan	28	1 (6)	20 (24)	0 (0)	2
L0018	17.193206	42.782904	Jizan	Incised deposits in Wadi Sabiya Quarry	0	(0)	0 (0)	0 (0)	0
L0019	17.219985	42.713273	Jizan	Wadi Nakhlan between Jebel Akwah cinder cones	0	0 (0)	0 (0)	0 (0)	0
L0020	17.187597	42.781249	Jizan	Wadi Sabiya Quarries	13	0 (0)	0 (0)	4 (5)	8
L0021	17.189416	42.800086	Jizan	Wadi Sabiya—Incised deposits	0	0 (0)	0 (0)	0 (0)	0
L0022	17.193590	42.809743	Jizan	Wadi Sabiya Quarries	0	0 (0)	0 (0)	0 (0)	0
L0023	17.188525	42.845222	Jizan	Basalt exposed along Wadi Sabiya	2	0 (2)	0 (2)	0 (0)	0
L0024	17.191863	42.860800	Jizan	Hills above Wadi Sabiya	63	2 (5)	4 (16)	10 (30)	24
L0025	17.254514	42.845795	Jizan	Wadi Nakhlan, escarpment foothills	5	0 (0)	0 (0)	0 (0)	5
L0026	16.981653	42.894690	Jizan	Basalt flow, SW of Abu Arish lava flows	13	1 (6)	3 (5)	0 (1)	3
L0027	17.032474	42.908738	Jizan	Basalt flow, North of Wadi Jizan	11	1 (5)	1 (2)	1 (1)	4

(continued)

Table 1 (continued)

Locality	Latitude	Longitude	Province	Description	Lithic artefacts				
					Total	ESA	MSA	LSA	Undiagnostic
L0028	17.061549	42.914820	Jizan	Centre of Abu Arish lava flows	3	1 (1)	0 (0)	1 (1)	1
L0029	17.056896	42.875615	Jizan	Basalt flow, Western edge of Abu Arish fields	10	0 (0)	9 (9)	0 (0)	1
L0030	17.042681	42.998008	Jizan	Schist hills above Wadi Jizan	3	2 (2)	0 (0)	0 (0)	1
L0031	17.039973	42.981798	Jizan	Alluvial sediments, Wadi Jizan Dam Lake	0	0 (0)	0 (0)	0 (0)	0
L0032	17.858012	41.935777	Asir	Volcanic cone with flat top	91	2 (68)	16 (84)	0 (0)	5
L0033	17.931643	41.978747	Asir	Granite Outcrops E of Harrat Al Birk	80	11 (17)	14 (27)	0 (0)	41
L0034	18.071406	41.623357	Asir	Wadi Dhahaban Quarry	711	14	398	1	138
L0035	18.172324	41.565232	Asir	Coral terrace over basalt, Al Birk coastline	35	6 (6)	8 (13)	0 (0)	16
L0036	18.167809	41.566148	Asir	Coral terrace over basalt, Al Birk coastline	18	14 (14)	3 (3)	0 (0)	1
L0037	18.148964	41.577697	Asir	Coral terrace over basalt, Al Birk coastline	2	0 (0)	1 (1)	0 (0)	1
L0038	18.134898	41.577301	Asir	Coral terrace over basalt, Al Birk coastline (CASP 216-208)	48	11 (30)	8 (27)	0 (0)	10
L0039	18.121848	41.704216	Asir	Hill in headwater basin of Wadi Najla	31	6 (6)	11 (23)	0 (0)	2
L0040	18.104065	41.694961	Asir	Head of gorge, Wadi Najla	23	13 (13)	6 (7)	0 (0)	5
L0041	18.093014	41.698197	Asir	Base of gorge, Wadi Najla	2	0 (0)	0 (1)	0 (0)	1
L0042	18.084579	41.692803	Asir	Gorge base, Wadi Najla	12	3 (3)	3 (3)	0 (0)	5
L0043	18.065674	41.674188	Asir	Hill at coastal mouth of Wadi Najla	0	0 (0)	0 (0)	0 (0)	0
L0044	18.605248	41.480481	Asir	Area of rock art on basalt flow, Al Moalmat	4	0 (0)	2 (2)	0 (0)	2
L0045	18.595227	41.555002	Asir	Basalt flow, Wadi Shafqah	11	0 (0)	2 (11)	0 (0)	0
L0046	18.602847	41.539418	Asir	Alluvium and Basalt, Wadi Shafqah	3	0 (0)	2 (2)	0 (0)	1
L0047	18.632677	41.561697	Asir	Alluvium and Basalt, Wadi Shafqah	5	1 (1)	1 (1)	0 (0)	3
L0048	18.634902	41.544491	Asir	Area of carbonate deposits, Wadi Shafqah	0	0 (0)	0 (0)	0 (0)	0
L0049	18.070333	41.690620	Asir	Young basalt flow, Wadi Najla	20	2 (2)	2 (5)	0 (0)	13
L0050	18.002664	41.858373	Asir	Alluvial fan near Wadi Urayk/Wadi Nahab	2	0 (0)	0 (0)	0 (0)	2
L0051	18.009341	41.776442	Asir	Rockshelters in volcanic Jebel Hashahish	26	0 (0)	0 (14)	0 (0)	12
L0052	17.920381	42.079484	Asir	Linear schist outcrops cut by Wadi Aramram	1	0 (0)	0 (0)	0 (0)	1
L0053	18.041980	42.090410	Asir	Escarpment foothills, Wadi Aramram	21	0 (0)	5 (5)	0 (0)	16
L0054	18.013357	42.074013	Asir	Jebel Bagarah volcanic cone, Wadi Aramram	10	0 (1)	4 (7)	0 (0)	3
L0055	16.862098	42.954549	Jizan	Dune abutting Jebel Umm Al Qumam (North)	0	0 (0)	0 (0)	0 (0)	0
L0060	17.212833	43.031100	Jizan	Escarpment foothills	0	0 (0)	0 (0)	0 (0)	0

(continued)

Table 1 (continued)

Locality	Latitude	Longitude	Province	Description	Lithic artefacts				
					Total	ESA	MSA	LSA	Undiagnostic
L0061	17.249880	42.705320	Jizan	Sediment on basalt flow, Jebel Akwah North)	2	0 (0)	0 (0)	0 (0)	2
L0062	17.249610	42.709800	Jizan	Colluvial slopes of cider cone, Jebel Akwah (North)	11	0 (0)	0 (0)	6 (6)	5
L0063	17.243605	42.704993	Jizan	Basalt surface, Jebel Akwah (North)	13	0 (0)	1 (1)	4 (4)	8
L0064	17.019560	42.946990	Jizan	Quarry adjacent to Wadi Jizan	32	3 (3)	4 (4)	4 (1)	24
L0065	17.035400	42.529430	Jizan	Deflated shell midden, North of Jizan	0	0 (0)	0 (0)	0 (0)	0
L0066	17.184389	42.780317	Jizan	Wadi Sabiya quarry sections	1	0 (0)	0 (0)	0 (0)	1
L0067	17.018126	42.923189	Jizan	Quarries through basalt flows and sediments, Wadi Jizan	14	1 (1)	1 (1)	0 (5)	7
L0068	17.022422	42.929729	Jizan	Quarries through basalt flows and sediments, Wadi Jizan	1	0 (0)	0 (0)	0 (0)	1
L0069	17.041193	43.020466	Jizan	Area of schist bedrock close to Wadi Jizan Dam	1	0 (0)	0 (0)	0 (0)	1
L0070	17.027626	42.974781	Jizan	Area of schist bedrock close to Wadi Jizan Dam	0	0 (0)	0 (0)	0 (0)	0
L0071	17.030012	42.944420	Jizan	Basalt terraces below Wadi Jizan Dam	12	0 (0)	4 (4)	0 (0)	8
L0072	17.162252	42.919970	Jizan	Alluvial terrace, Wadi Dhamad	4	1 (1)	0 (0)	0 (0)	3
L0073	17.153165	42.904202	Jizan	Linear shist hills above Wadi Dhamad	2	1 (1)	0 (0)	0 (0)	1
L0074	17.106895	42.859326	Jizan	Basalt flow, distal end, near As Shugayri	15	1 (2)	3 (4)	6 (6)	4
L0075	17.137263	42.881558	Jizan	Sediment sections beneath basalt	0	0 (0)	0 (0)	0 (0)	0
L0076	17.140631	42.902273	Jizan	Basalt flow and alluvial terrace at base of wadi	2	0 (0)	1 (1)	0 (0)	1
L0077	17.225168	42.717739	Jizan	Sediment and basalt flows between Jebel Akwah North and South cones	3	0 (0)	0 (0)	1 (1)	2
L0078	18.267436	41.515297	Asir	Shell scatter on coral terrace	16	1 (4)	6 (11)	0 (0)	9
L0079	17.100630	42.931879	Jizan	Centre of Abu Arish basalt flows	3	0 (0)	1 (1)	0 (0)	3
L0080	17.092157	42.968446	Jizan	Linear schist hills above Wadi Jizan Dam	11	0 (0)	3 (3)	3 (3)	5
L0081	17.217560	42.965900	Jizan	Escarpment foothills, Al Henaya	0	0 (0)	0 (0)	0 (0)	0
L0082	17.204495	42.990423	Jizan	Escarpment foothills, Al Henaya to N of Wadi Dhamad Dam	0	0 (0)	0 (0)	0 (0)	0
L0083	17.206003	43.019666	Jizan	Escarpment foothills, Al Henaya	0	0 (0)	0 (0)	0 (0)	0
L0084	17.173910	42.734090	Jizan	Basalt flow south of Jebel Akwah (South) cut by road	0	0 (0)	0 (0)	0 (0)	0
L0085	17.165620	42.738590	Jizan	Basalt flow south of Jebel Akwah (South) cut by road	0	0 (0)	0 (0)	0 (0)	0
L0087	18.396523	41.499354	Asir	Basalt flow above wadi confluence, near Markaz as Shurtah	17	1 (2)	5 (6)	0 (1)	9
L0088	18.040502	41.658652	Asir	Volcanic hill on coast at mouth of Wadi Najla	1	0 (0)	0 (0)	0 (0)	1
L0089	18.036455	41.653339	Asir	Coral terraces around northern edge of volcanic cone at mouth of Wadi Najla	14	1 (1)	9 (9)	0 (0)	4
L0090	18.202787	41.524803	Asir	Coral terrace on basalt, Al Birk headland	1	0 (0)	1 (1)	0 (0)	0
L0091	18.066465	41.635032	Asir	Coral and lava terraces on S side of basalt hill adjacent to L0034	2	1 (1)	0 (0)	0 (0)	1

(continued)

Table 1 (continued)

Locality	Latitude	Longitude	Province	Description	Lithic artefacts				
					Total	ESA	MSA	LSA	Undiagnostic
L0092	18.119056	41.597420	Asir	Beachrock exposure (1 km) on basalt	8	0 (0)	6 (6)	0 (0)	2
L0093	18.239446	41.528332	Asir	Coral terrace over basalt	4	0 (0)	1 (4)	0 (0)	0
L0094	17.839722	41.952032	Asir	Hajambar Quarry	7	1 (1)	0 (0)	0 (0)	6
L0095	17.652420	42.688550	Jizan	Terraces above Wadi Bayish Dam Lake	2	0 (0)	0 (0)	0 (0)	1
L0096	18.004440	41.882770	Asir	Dykes rising out of alluvium in tributatries of Wadi Urayk	26	0 (5)	0 (5)	0 (0)	21
L0100	18.465869	41.473108	Asir	Basalt escarpment parallel to coast	8	5 (7)	0 (2)	0 (1)	0
L0101	18.463013	41.492603	Asir	Basalt terrace above Wadi Amq	18	3 (4)	1 (4)	11 (11)	0
L0102	18.476082	41.492370	Asir	Basalt terrace above Wadi Amq	0	0 (0)	0 (0)	0 (0)	0
L0103	18.406560	41.461806	Asir	Beachrock exposure south of Amq (correlated with L0105)	23	6 (10)	3 (10)	5 (7)	2
L0104	18.406078	41.482014	Asir	Basalt ridge 3 km inland from present day coastline	28	20 (21)	2 (4)	3 (4)	1
L0105	18.417158	41.464038	Asir	Beachrock exposure south of Amq (correlated with L0103)	16	4 (5)	2 (6)	5 (8)	1
L0106	18.306375	41.563742	Asir	Wadi Dabsa Tufa Exposure—Main Grids	2847	175 (67)	478	0 (13)	2194
L0107	18.313622	41.559729	Asir	Wadi Dabsa Tufa Exposure—Transect up basalt flow	20	7 (8)	9 (11)	0 (0)	2
L0108	18.305406	41.551689	Asir	Wadi Dabsa—Tufa downstream from main exposure	4	4 (4)	0 (0)	0 (0)	0
L0109	18.301462	41.536807	Asir	Wadi Dabsa—basalt flow	6	1 (4)	1 (5)	0 (0)	0
L0110	18.196402	41.555418	Asir	Wadi terraces next to Al Birk Baladiyah	12	7 (9)	0 (2)	0 (0)	3
L0111	18.212968	41.585135	Asir	Wadi and tufa deposits inland from L0111	3	2 (2)	0 (1)	0 (1)	0
L0112	18.177545	41.596737	Asir	Terraces above Wadi Dahin	4	1 (1)	2 (2)	1 (1)	0
L0113	17.948380	41.749505	Asir	Terrace above Wadi Hamidah	58	1 (1)	0 (2)	55 (57)	0
L0114	17.920450	41.780271	Asir	Wadi draining Jebel Huwwah	30	6 (11)	0 (4)	19 (19)	0
L0115	17.895032	41.799279	Asir	High basalt terrace above wadi draining Jebel Khurmah	6	6 (6)	0 (0)	0 (0)	0
L0116	17.884521	41.795242	Asir	Low undulating basalt c. 1 km to SW of L0115	13	4 (5)	0 (1)	8 (8)	0
L0117	18.369736	41.456772	Asir	Low lying undulating basalt hills close to coast	2	0 (0)	0 (1)	1 (2)	0
L0118	18.132236	41.640305	Asir	Basalt terraces above Wadi Dhaban dam lake	0	0 (0)	0 (0)	0 (0)	0
L0119	18.116808	41.631170	Asir	Isolated basalt jebel in Wadi Dhahaban floodplain	12	0 (0)	3 (3)	7 (7)	2
L0120	18.084993	41.630403	Asir	Low basalt rise 3 km from present-day coastline	6	5 (6)	0 (1)	0 (0)	0
L0121	18.308182	41.485023	Asir	Beachrock exposure overlying low basalt peninsula	40	7 (21)	4 (22)	5 (10)	4
L0122	18.141990	41.585491	Asir	Basalt terrace where Wadi Dahin flows into sea	9	4 (5)	0 (1)	2 (2)	2

(continued)

Table 1 (continued)

Locality	Latitude	Longitude	Province	Description	Lithic artefacts				
					Total	ESA	MSA	LSA	Undiagnostic
L0123	17.851005	41.816456	Asir	Basalt and coral/beachrock terrace next to Moath bin Jebel	8	3 (3)	0 (0)	0 (0)	5
L0124	17.831206	41.834735	Asir	Low lying, undulating basalt hills	0	0 (0)	0 (0)	0 (0)	0
L0125	17.812721	41.845927	Asir	Southern/eastern slopes of Jebel ar Raqabah	4	1 (3)	0 (2)	1 (1)	0
L0126	18.307269	41.568197	Asir	Wadi Dabsa Tufa Exposure—tufa transect	32	5 (21)	3 (20)	5 (8)	0
L0127	18.308949	41.559993	Asir	Wadi Dabsa Tufa Exposure—basalt flow transect	5	3 (5)	0 (2)	0 (0)	0
L0128	17.974918	41.684844	Asir	Raised beach deposits S of Al Qahma	1	1 (1)	0 (0)	0 (0)	0
L0130	18.306375	41.563742	Asir	Wadi Dabsa Tufa Exposure—Main Grids	399	43	121	0	235

more than partially explored. For example, the apparent absence of localities along much of the eastern edges of the lava flows in Harrat al Birk arises from an absence of surveys, resulting from the difficulty of access, and not from a known absence of archaeology. If access were to make surveys possible, there is no reason to think that further Palaeolithic localities would not be found. With one exception, we have also found it very difficult to access and survey potential places going inland toward and into the escarpment. Finally, finds of ESA materials (including a worked shale clast, and a flake from a discoidal core) from artificially-exposed, deep sections below the lava flows (see Bailey et al. 2015) suggest a younger date for some of the lava flows, and the probable presence of many more archaeological remains now covered by overlying sediment.

Beyond these general observations, the two sites found in this survey programme with the largest archaeological assemblages, Dhahaban Quarry and Wadi Dabsa, indicate the extraordinary quality of archaeological and environmental evidence that remains in the Red Sea coastal plain, as well as the potential that exists for addressing more specific questions about marine resource use and the ways of life of past hunter-gatherer communities.

3.3 Dhahaban Quarry and the Evidence for the Use of Coastal Environments

South of the town of Dhahaban, about 1 km inland from the present shoreline, a complex series of coral terraces and marine sediments have been preserved adjacent to the remnants of a heavily-eroded cinder cone and its associated basalt lava flows (Inglis et al. 2014, and this volume; Bailey et al. 2015). From north to south, the deposits, all overlying the basalt flows, include exposures of coral terrace and overlying beachrock, a deep section through shallow marine sediments, potentially formed in a lagoonal environment, and beach sediments, capped by aeolianite at the southernmost extent. Toward the centre of the site, a wadi flowing from east to west has cut through the shallow marine/beachrock sediments (Fig. 5), exposing a unit of rounded cobbles of basalt and coral (for further stratigraphic detail, see Inglis et al., this volume). Absolute dating of the sediments (optically stimulated luminescence), basalt (^{39}Argon/^{40}Argon) and coral (Uranium series) at Wadi Dhahaban is a complex process and still ongoing (Inglis et al., this volume; Sanderson and Kinnaird this volume). However, the elevation of this complex of deposits, about 7 m above current sea level, is broadly consistent with a Last Interglacial high sea stand, suggesting that the artefacts buried below in the cobble unit pre-date MIS 5e (see discussion in Inglis et al., this volume). Examination of the conditions of deposition of the cobble unit is also ongoing,

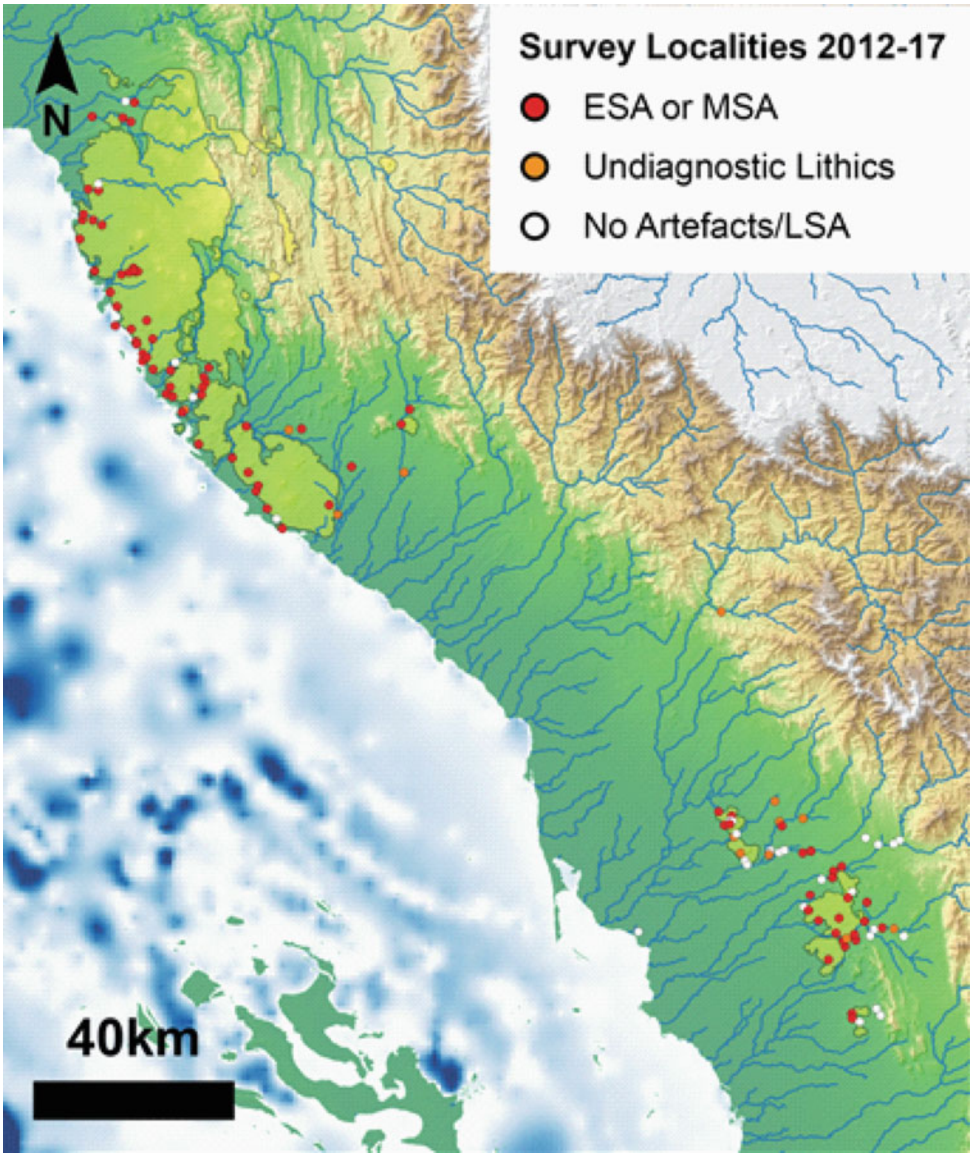

Fig. 2 Palaeolithic localities identified by recent landscape surveys in the southern Red Sea coastal region from 2012 to 2017. Red circles show localities where Lower Palaeolithic/Early Stone Age and/or Middle Palaeolithic/Middle Stone Age artefacts were identified; orange circles show localities where only undiagnostic lithic artefacts were observed; white circles show locations surveyed that yielded no artefacts, or only those of post-Palaeolithic character, i.e., those whose typologies were assigned to the LSA

but the presence of rounded cobbles of coral may suggest reworking of an earlier coral deposit, potentially from an earlier high sea stand, within a terrestrial debris flow, which also incorporated the artefacts.

The deposits at Dhahaban Quarry show the range and complexity of marine deposits that remain in patches along this coast and attest to the complex development and later reworking of marine deposits at times of changing sea level (see Inglis et al., this volume). It also highlights the threats facing these deposits today. This site was first identified because a large area in the central and southern part of the site, possibly equivalent to 50% of the total area of the marine deposits, has been extensively bulldozed, removing the upper deposits of aeolianite and beach rock and forming sections through these deposits. The western edge of the site has also been extensively quarried, removing much more of the same deposit and leaving a large exposed section 6–7 m high. Much of this extraction of sediment presumably occurred to provide aggregate material for building the coastal highway that runs close to the western edge of the site, or perhaps for new housing that has been built in local towns.

Dhahaban Quarry is the source of the second largest assemblage of Palaeolithic materials recovered during this

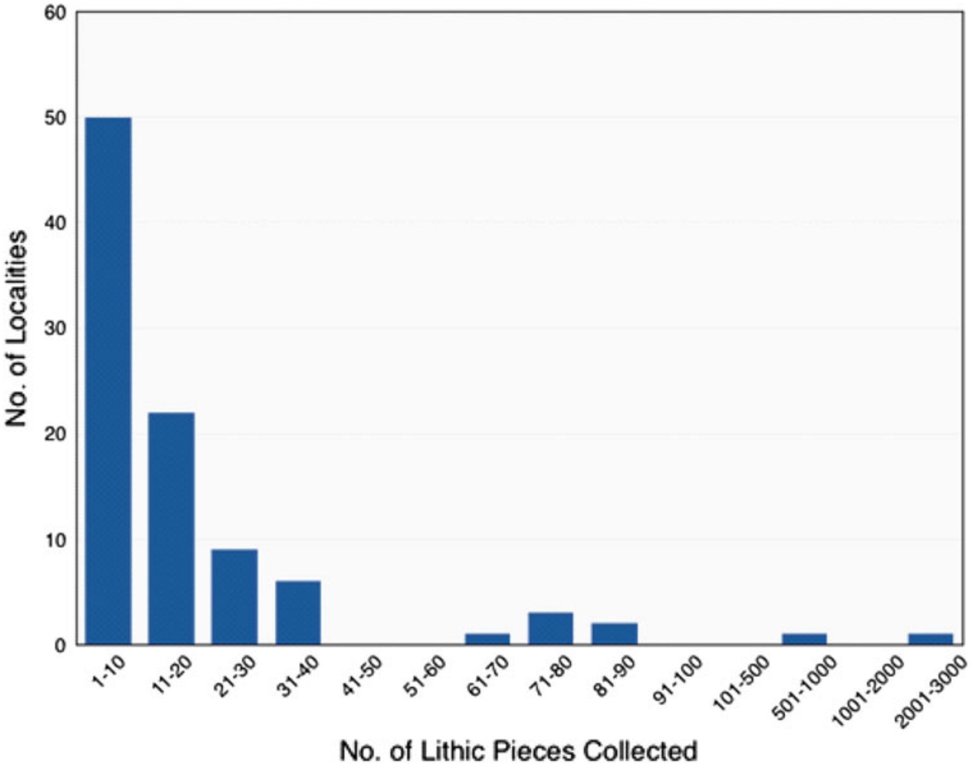

Fig. 3 The variability in numbers of artefacts found at Palaeolithic localities through field surveys from 2012 to 2015

survey. Across the preserved coral and beachrock deposits, more than 900 MSA and ESA basalt artefacts have been collected, containing a range of retouched tool forms (hand axes, picks, scrapers, large cutting tools from the ESA, prepared cores, retouched points, burins and retouched flake blades from the MSA), and other types of prepared and non-prepared cores and unretouched flakes. Most importantly, still embedded within the shallow marine and beachrock deposits that were cut by the wadi, we have found 19 sharp basalt flakes of MSA character with another lithic embedded within a lump of beach rock displaced by the bulldozing activity, suggesting that bulldozing has probably removed many other embedded lithics (Fig. 5c). Spatial analysis is ongoing, but broadly-speaking, the geographical spread of diagnostic and typologically identified stone tools suggests that the ESA materials are to be found at the southern and northern ends of the site, often closest to the lava flows, from where they may have moved downslope onto the surface of the younger marine and aeolian sediments. MSA materials are more common in the central part of the site, and within the marine deposits. Dhahaban Quarry, therefore, confirms the report of the Comprehensive Survey team that MSA period artefacts can be found embedded in marine deposits along this part of the Red Sea coast, as well as on their surface, raising the possibility of finding more embedded stone tools where other deposits of the same type are preserved in other places along the coast. Whilst the lithic evidence indicates that ESA and MSA communities exploited the local lithic resources available here at the coast, the taphonomic complexity of marine deposits, lava flows, and the mixture of depositional and erosional processes at Dhahaban Quarry, make it difficult at present to determine whether they were also here for the specific purpose of exploiting its marine resources. This highlights the necessity of being able to study other similar deposits in the future (Inglis et al., this volume).

3.4 Wadi Dabsa and Technological Evidence for Cultural Transmission

The Wadi Dabsa basin is about 6 km inland from the present-day shoreline. The basin is approximately 1 km^2 in area, and filled by a complex series of tufa carbonate deposits, deposited by the flowing and pooling of carbonate-rich water during periods of increased humidity. Its limits are defined by basalt flows emanating from numerous adjacent cinder cones (Inglis et al. 2015, 2017). The date and sequence of development of these tufa deposits, and that of emplacement of the basalt flows

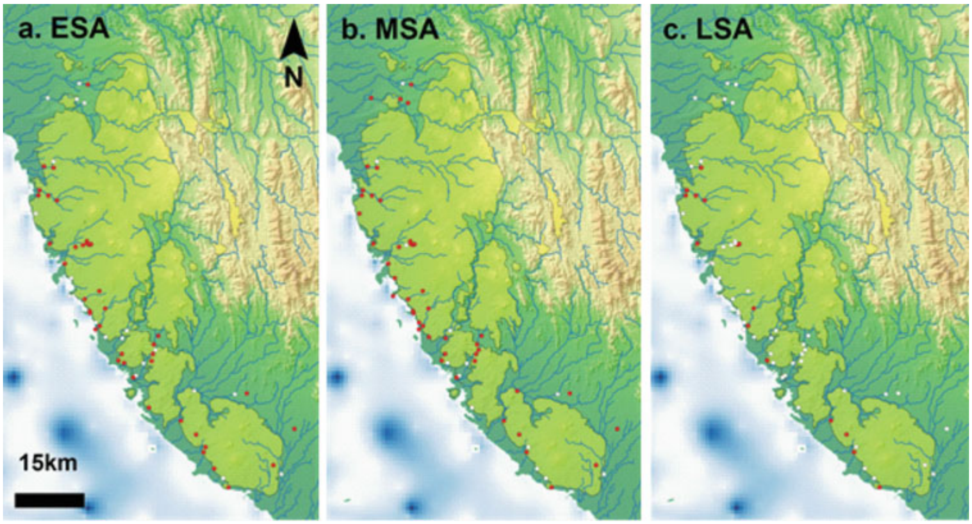

Fig. 4 The distribution of Palaeolithic localities in the Harrat al Birk mapped by typological age against potential modern water courses mapped from the SRTM DEM. Red dots show observation of artefacts of given typological age, white dots show localities where artefacts of given age were not observed

surrounding the basin, is the subject of ongoing investigation (Inglis et al. in prep.).

In 2015, numerous Palaeolithic artefacts were found during an initial survey of the surrounding basalt flows at the limits of the basin, leading to the discovery of a much larger concentration of Palaeolithic artefacts located on the top of a tufa spur overlying a basalt outcrop in the centre of the basin (Inglis et al. 2015; Foulds et al. 2017). The tufa spur is bordered on its southern and western side by a drainage depression filled with sandy-silt sediment. Artefacts of ESA and MSA character were identified and recorded across two 50 × 60 m grids (localities L0106 and L0130) in 2015 and 2017 (Fig. 6). All artefacts identified from L0106 were collected for later technological study, but those from L0130 were typologically recorded, photographed and left in situ. The density of artefacts across the grids (Fig. 7) suggests that their numbers are controlled by geomorphological processes that are deflating an artefact-bearing unit that overlies the tufa (Inglis et al. 2017, in prep.). The artefacts would therefore post-date tufa formation. However, a handaxe encased in tufa (Fig. 8) found on the surface of the drainage depression in 2017 suggests a longer, more complex history for both tufa deposition and hominin activity.

Palaeoenvironmental and dating evidence from the tufa deposits and lava flows will contribute significantly to an understanding of the complexity of local environments inland from the Red Sea coast, but it is the quality of the technological information accessible from this site that is more surprising. Wadi Dabsa has produced an assemblage of more than 2900 artefacts of both ESA and MSA character. ESA artefacts include large cutting tools, scrapers, notched and denticulated pieces, as well as a number of handaxes, and one unusually large handaxe (Foulds et al. 2017). The MSA assemblage contains a variety of retouched flake tools including scrapers, burins, and point forms amongst others. Two small test pits excavated in L0106 in 2017 have produced examples of small shatter flakes that typically result from in situ core working, and demonstrate that the archaeological deposits are not completely deflated and offer potential research gains through archaeological excavation in the future.

The MSA assemblage is particularly well preserved and appears to offer the possibility for refitting pieces making it possible to reconstruct sequences of technological activity (Fig. 9). It contains an extensive sample of prepared cores and prepared-core flakes across all stages of reduction. The production of good flakes through prepared-core technology requires a knowledge of the way in which this technique balances the volume and angles of stone above and below a middle “horizon” (Boëda 1995). It also requires sufficient prior individual experience to be able to adjust the exact placing and weight of any striking of the core to respond to the individual qualities of the nodule being worked and the success or failure of prior blows (see van Peer 1992 for examples from Egypt). At Wadi Dabsa, the lithic evidence for prepared-core reduction has examples of cores that are worked with knowledge and experience, as well as others found in a restricted, but central, part of the site grid (B3-4, C3-4) that show technological mistakes typical of individuals learning to work stone. Specifically, these cores show repeated attempts to strike and remove preparation flakes from the same place, where previous strikes have been

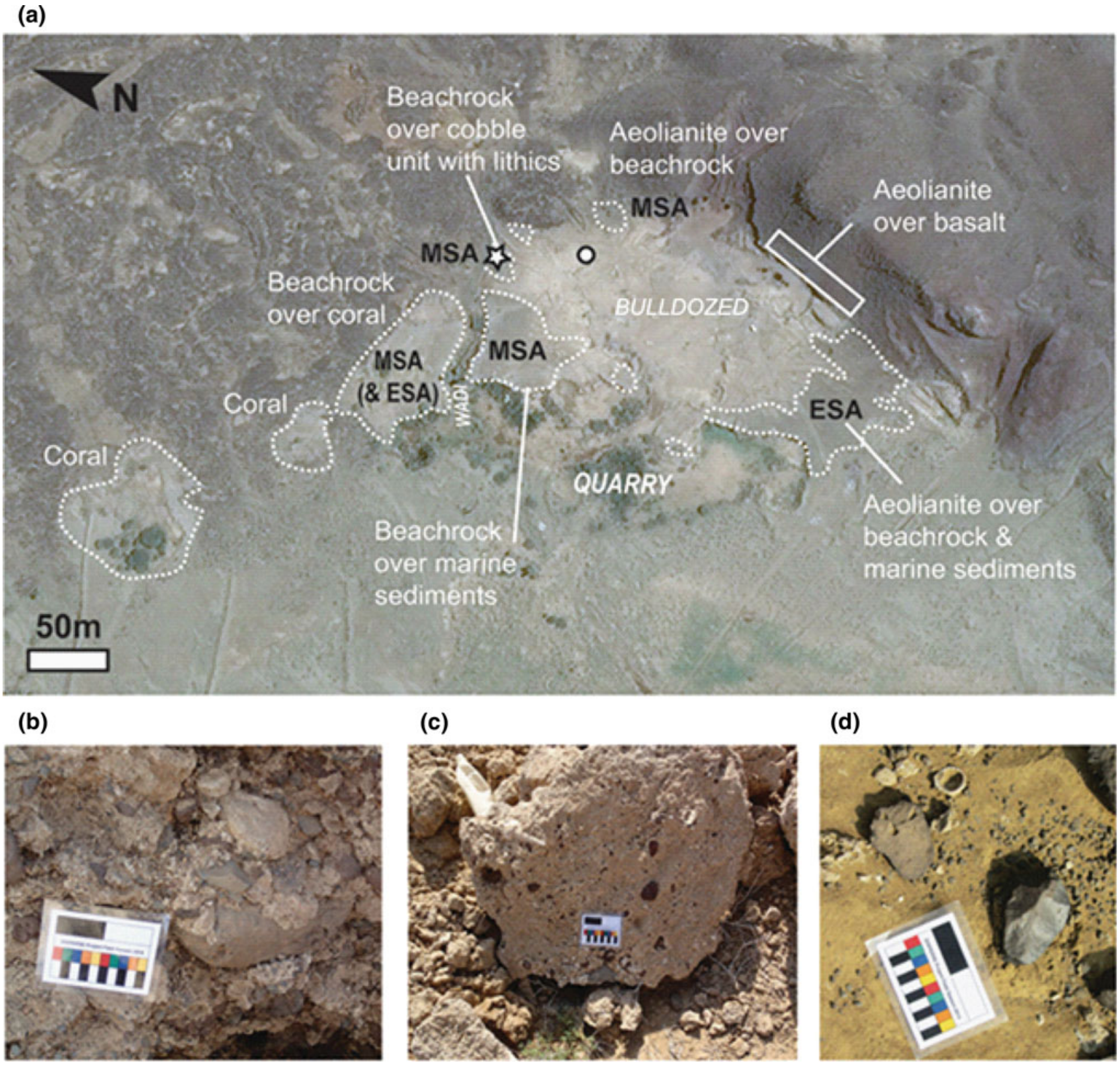

Fig. 5 **a** Overview of geomorphological units at Dhahaban Quarry (after Inglis et al., this volume) and summary of artefact technotypological characteristics found (Imagery © Google Earth, imagery date 19/1/2014); **b** basalt flake embedded within cobble unit, location marked by star on (**a**); **c** basalt flake embedded in bulldozed block of beachrock, location marked by circle on (**a**); **d** example of basalt MSA artefact (prepared core) found on surface of deposits at Dhahaban Quarry. Photos: A. Sinclair

unsuccessful, resulting in cores that must be discarded before the preparation process is complete. These unsuccessful cores demonstrate a knowledge of what needs to be done, the “recipe” for working, but a lack of experience with which to adjust the process when faced by problems. A detailed study of this evidence is ongoing (Sinclair et al. in prep.) with the hope that refitted sequences of reduction will support the technological interpretation derived from the examination of single artefacts.

4 The Research Potential of Archaeological Deposits Along the Southern Red Sea Coast

A new programme of landscape surveying along the southern Red Sea coast has confirmed the basic typological observations of the Comprehensive Survey in this area more than 30 years previously concerning surviving

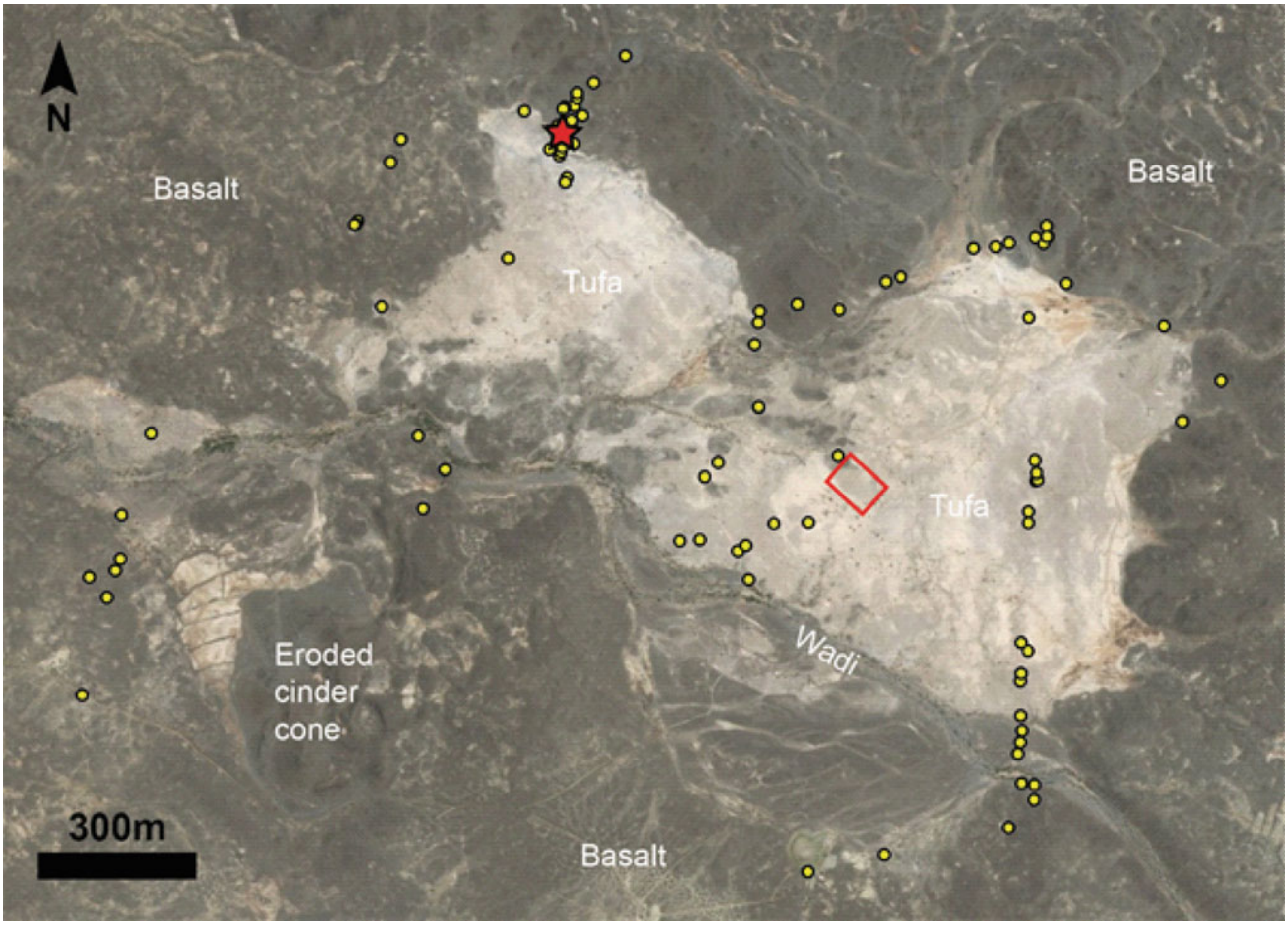

Fig. 6 An aerial view of the Wadi Dabsa showing the main geomorphological units and the locations of observed artefacts in 2015 and 2017. Red box indicates location of L0106/L0130 grids (see Fig. 7), and red star marks find of large handaxe reported in Foulds et al. (2017). Satellite Imagery © CNES/Astrium, imagery date 15/11/2015

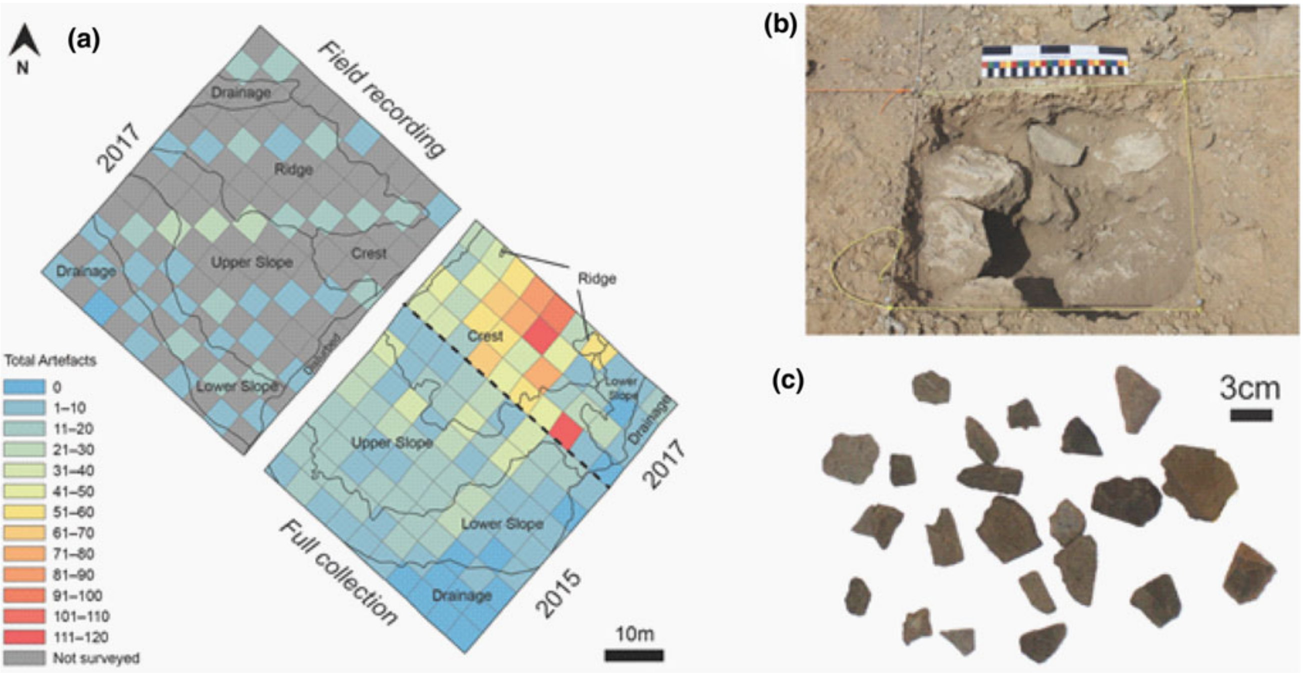

Fig. 7 Artefact survey grid at Wadi Dabsa (L0106/L0130). **a** artefact counts across the grid, showing geomorphological units; **b** basalt artefacts uncovered in situ in Test Pit 1, Photo: G. Bailey; **c** basalt shatter flakes from test pit 2

Fig. 8 ESA handaxe encased in tufa recovered from surface of L0130. Photo: H. Robson

archaeological material of Palaeolithic age. It has identified extensive concentrations of sites close to lava flows at Abu Arish, Sabya and especially in the Harrat al Birk. It has also been able to show, at Dhahaban Quarry, that there are still Palaeolithic artefacts embedded in preserved marine deposits along the coastline, even though the complexity of their depositional history makes it difficult to prove directly the earlier claims for the exploitation of Red Sea marine resources by hominins. Finally, the quality of behavioural information still recoverable from the lithic artefacts of a largely surface deposit at Wadi Dabsa is convincing evidence that considerable future research potential for understanding hominin behaviour remains in the surviving sedimentary deposits along the Red Sea.

Realising the full research potential of other remaining archaeological localities will be challenging. The typological descriptions that have been given to this material are too broad as evidence of date, particularly when more than half of the localities contain palimpsests of different-age materials. A comprehensive programme of dating associated sediments will be necessary. The clear association between Palaeolithic artefacts and lava flows, alongside the

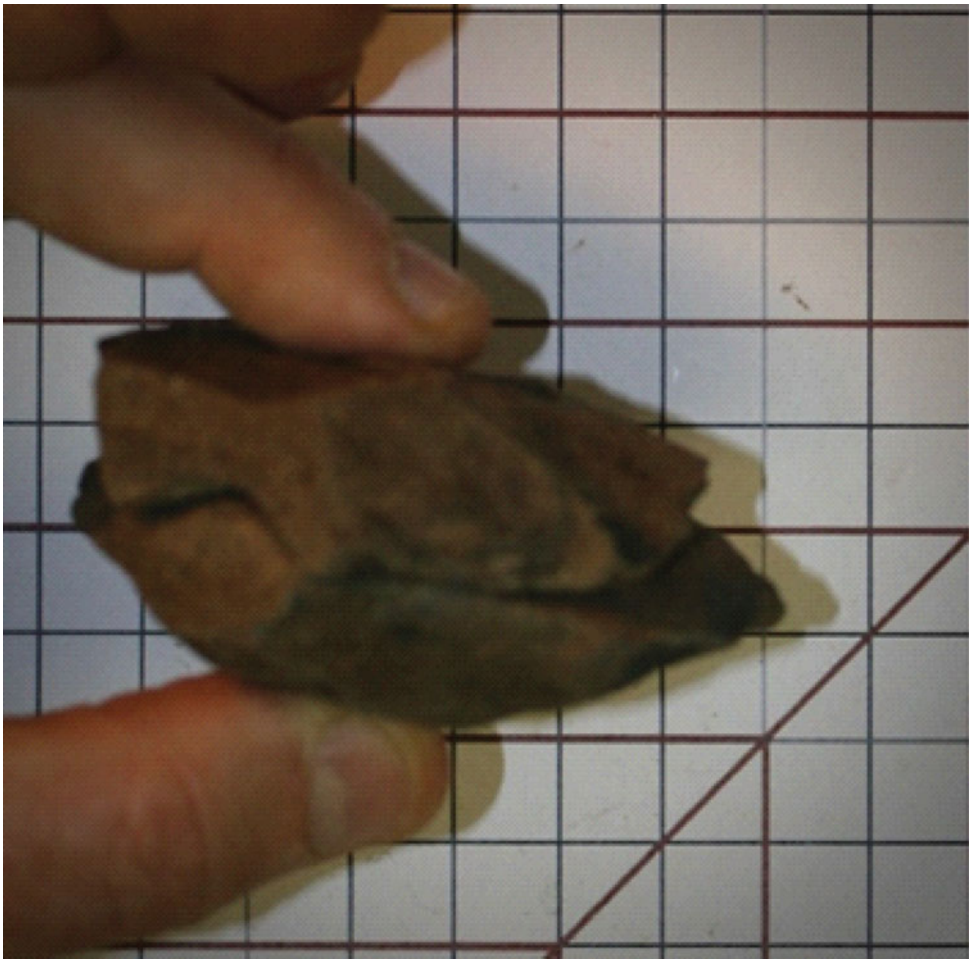

Fig. 9 A prepared core flake (upper) fitting into the negative flake scar of a prepared core (lower) both collected at the Wadi Dabsa indicating the continuity of technological activity at this site. The grid squares behind are 1 × 1 cm

recognition that volcanic activity might have generated new lava flows until quite late in the Pleistocene, indicates that a programme of dating of the lava flows is necessary to provide a series of dates to bracket the upper age of certain localities. Likewise, the presence of tufa deposits and marine deposits with associated archaeological remains that may be dated by OSL (See Sanderson and Kinnaird this volume) also offers great potential for narrowing down the time range of hominin behaviour.

The considerable time depth and geographical scale of hominin life and the spatial distribution of different activities means that we require archaeological assemblages from many different localities if we wish to interpret the dispersal, migration and colonisation of hominins into Arabia. Landscape surveys for Palaeolithic materials have demonstrated that there is genuine potential for this evidence in the southwestern Red Sea. The original Comprehensive Survey began as an essential first step to map the surviving heritage assets across the Kingdom that were faced with potential destruction through development. There are, however, likely to be more sedimentary deposits, as yet undiscovered, with research potential. It is these deposits that need proper mapping and assessment. The recent damage to the deposits at Dhahaban Quarry confirms that the threat from development remains as great as ever. In the case of the Red Sea coast, there is still a (short?) window of opportunity made possible by the availability of aerial imagery and digital mapping to map these deposits, with the potential to inform future development proposals.

Acknowledgements We thank HRH Prince Sultan bin Salman bin Abdul Aziz, President of the Saudi Commission for Tourism and National Heritage (SCTH) and Dr. Ali Al-Ghabban, Vice-President, for granting permission for the archaeological fieldwork reported here (or on which this research is based) and for their ongoing support. We also thank the President of the Saudi Geological Survey, Dr. Zohair Nawab and his staff, in particular Dr. Najeeb Rasul, for additional support and for their invitation to participate in the Jeddah Workshop.This work was supported between 2011 and 2015 by the European Research Council through ERC Advanced Grant 269586 'DISPERSE: Dynamic

Landscapes, Coastal Environments and Human Dispersals'. Fieldwork from 2015 to 2017 was funded by grants from the British Academy (Arthur Reckitt Fund), the Gerald Averay Wainwright Fund for Near Eastern Archaeology at the University of Oxford, and the British Foundation for the Study of Arabia, with additional funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 660343, "SURFACE: Human-Landscape-Interactions and Global Dispersals: The Surface Record of Palaeolithic Arabia". This is DISPERSE contribution number 41.

References

Adams RMcC, Parr P, Ibrahim M, Al-Mughannum AS (1977) Saudi Arabian archaeological reconnaisance 1976. The preliminary report on the first phase of the comprehensive survey program. Atlal 1:21–40

Alsharekh AM, Bailey GN (eds) (2013) Coastal prehistory in southwest Arabia and the Farasan Islands: 2004–2009 field investigations. Saudi Commission for Tourism and Antiquities, Riyadh

Armitage SJ, Jasim SA, Marks AE, Parker AG, Usik VI, Uerpmann H-P (2011) The southern route "Out of Africa": evidence for an early expansion of modern humans into Arabia. Science 331:453–456

Bailey GN (2007) Time perspectives, palimpsests and the archaeology of time. J Anth Archaeol 26(2):198–223

Bailey GN (2009) The Red Sea, coastal landscapes, and hominin dispersals. In: Petraglia MD, Rose JI (eds) The evolution of human populations in Arabia: paleoenvironments, prehistory and genetics. Springer, Netherlands, pp 15–138

Bailey GN, King GCP (2011) Dynamic landscapes and human dispersal patterns: tectonics, coastlines, and the reconstruction of human habitats. Quatern Sci Rev 30:1533–1553

Bailey GN, Flemming NC, King GCP, Lambeck K, Momber G, Moran LJ, Al-Sharekh AM, Vita-Finzi (2007) Coastlines, submerged landscapes, and human evolution: the Red Sea Basin and the Farasan Islands. J Island Coast Archaeol 2(2):127–160

Bailey GN, Devès MH, Inglis RH, Meredith-Williams MG, Momber G, Sakellariou D, Sinclair AGM, Rousakis G, Al Ghamdi S, Alsharekh AM (2015) Blue Arabia: palaeolithic and underwater survey in SW Saudi Arabia and the role of coasts in Pleistocene dispersals. Quat Int 382:42–57

Bailey GN, Meredith-Williams M, Alsharekh A, Hausmann N (this volume) The archaeology of Pleistocene coastal environments and human dispersals in the Red Sea: insights from the Farasan Islands

Binford LR (1982) The archaeology of place. J Anth Archaeol 1(1):5–31

Boëda E (1995) Levallois: a volumetric construction, methods, a technique. In: Dibble HL, Bar-Yosef O (eds) The definition and interpretation of Levallois technology. Prehistory Press, Madison, Wisconsin, pp 41–68

Brunet M (2010) Two new Mio-Pliocene Chadian hominids enlighten Charles Darwin's 1871 prediction. Phil Trans R Soc B 365:3315–3321

Brunet M, Guy F, Pilbeam D, Lieberman Likius A, Mackaye HT, Ponce de León MS, Zollikofer CP, Vignaud P (2005) New material of the earliest hominid from the Upper Miocene of Chad. Nature 434:752–755

Clarke DL (1973) Archaeology: the loss of innocence. Antiquity 47:6–18

Crassard R, Hilbert YH (2013) A Nubian complex site from central Arabia: implications for Levallois taxonomy and human dispersals during the Upper Pleistocene. PLoS One 8(7):e69221. https://doi.org/10.1371/journal.pone.0069221

Dabbagh A, Emmermann R, Hötzl H, Jado AR, Lippolt HJ, Kollman W, Moser H, Rauert W, Zötl JG (1984) The development of Tihamat Asir during the Quaternary. In: Jado AR, Zötl JG (eds) Quaternary period in Saudi Arabia volume 2: sedimentological, hydrogeological, hydrochemical, geomorphological, geochronological and climatological investigations in Western Saudi Arabia. Springer, Vienna, pp 150–173

Debenath A, Dibble H (1994) Handbook of palaeolithic typology: lower and middle palaeolithic of Europe, vol 1. Philadelphia, University Museum of Archaeology and Anthropology

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

Devès MH, Inglis RH, Meredith-Williams MG, Al Ghamdi S, Alsharekh A, Bailey GN (2013) Palaeolithic survey in southwest Saudi Arabia: methodology and preliminary results. Adumatu 27:7–30

Foulds F, Shuttleworth A, Sinclair A, Alsharekh A, Al Ghamdi S, Inglis RH, Bailey G (2017) A large handaxe from Wadi Dabsa and early hominin adaptations within the Arabian Peninsula. Antiquity 91(360):1421–1434

Garcia T, Féraud G, Falguères C, de Lumley H, Perrenoud C, Lordkipanidze D (2010) Earliest human remains in Eurasia: new ^{40}Ar/^{39}Ar dating of the Dmanisi hominid-bearing levels, Georgia. Quat Geochronol 5(4):443–451

Groucutt HS, Petraglia MD (2012) The prehistory of the Arabian Peninsula: deserts, dispersals, and demography. Evol Anth 21(3):113–125

Guiducci D, Burke A (2016) Reading the landscape: legible environments and hominin dispersals. Evol Anth 25:133–141

Holdaway S, Fanning PC (2014) Geoarchaeology of Aboriginal Landscapea in Semi-arid Australia. CSIRO Publishing, Collingwood

Inglis RH, Sinclair A, Shuttleworth A, Alsharekh A, Al Ghamdi S, Devès M, Meredith-Williams MG, Bailey GN (2014) Investigating the Palaeolithic landscapes and archaeology of the Jizan and Asir regions, southwest Saudi Arabia. Proc Sem for Arab Stud 44:193–212

Inglis RH, Foulds F, Shuttleworth A, Alsharekh AM, Al Ghamdi S, Sinclair AG, Bailey GN (2015) The Palaeolithic occupation of the Harrat Al Birk. Preliminary Report on the 2015 Fieldwork in Asir Province, Southwest Saudi Arabia. University of York/Saudi Commission for Tourism and Antiquities. http://eprints.whiterose.ac.uk/84382/

Inglis RH, Sinclair AG, Alsharekh AM, Barfod DN, Chang HC, Fanning PC, Al Othaibi DT, Robson HK, Shuttleworth A, Stone A, Bailey GN (2017) Preliminary report on UK-Saudi 2017 fieldwork at Wadi Dabsa, Asir Province, Saudi Arabia. University of York/Saudi Commission for Tourism and National Heritage. http://eprints.whiterose.ac.uk/119267/

Inglis RH, Bosworth W, Rasul NMA, Al Saeedi A, Bailey GN (this volume) Investigating the palaeoshorelines and coastal archaeology of the Southern Red Sea

Jennings RP, Singarayer J, Stone EJ, Krebs-Kanzow U, Khon V, Nisancioglu KH, Pfeiffer M, Zhang X, Parker P, Parton A, Groucutt HS, White TS, Drake NA, Petraglia MD (2015) The greening of Arabia: multiple opportunities for human occupation of the Arabian Peninsula during the Late Pleistocene inferred from an ensemble of climate model simulations. Quat Int 382:181–199

Kübler S, Devès MH, Bailey GN, King GCP (this volume) Tectonic geomorphology and soil edaphics as controls on animal migrations and human dispersal patterns

Lambeck K, Purcell A, Flemming NC, Vita-Finzi C, Alsharekh AM, Bailey GN (2011) Sea level and shoreline reconstructions for the Red Sea: isostatic and tectonic considerations and implications for hominin migration out of Africa. Quat Sci Rev 30(25–26):3542–3574

Momber G, Sakellariou D, Bailey GN, Rousakis G (this volume) The multi-disciplinary search for underwater archaeology in the southern Red Sea

Parker AG (2009) Pleistocene climate change in Arabia: developing a framework for hominin dispersal over the last 350 ka. In: Petraglia MD, Rose JI (eds) The evolution of human populations in Arabia. Springer, Dordrecht, Netherlands, pp 39–49

Petraglia MD (2003) The Lower Palaeolithic of the Arabian Peninsula: occupations, adaptations, and dispersals. J World Prehist 17:141–179

Petraglia MD, Alsharekh A (2003) The Middle Palaeolithic of Arabia: implications for modern human origins, behaviour and dispersals. Antiquity 77(298):671–684

Petraglia MD, Rose JI (eds) (2009) The evolution of human populations in Arabia. Springer, Dordrecht, Netherlands

Petraglia MD, Alsharekh AM, Crassard E, Drake NA, Groucutt H, Parker AG, Roberts RG (2011) Middle Paleolithic occupation on a marine isotope stage 5 lakeshore in the Nefud Desert, Saudi Arabia. Quat Sci Rev 30(13–14):1555–1559

Petraglia MD, Alsharekh AM, Breeze P, Clarkson C, Crassard R, Drake NA, Groucutt HS, Jennings R, Parker AG, Parton A, Roberts RG, Shipton C, Matheson C, Al-Omari A, Veall M-A (2012) Hominin dispersal into the Nefud Desert and Middle Palaeolithic settlement along the Jubbah palaeolake, northern Arabia. PLoS One 7(11):e49840

Potts DT (1998) The Gulf Arab states and their archaeology. In: Meskell L (ed) Archaeology under fire: nationalism, politics and heritage in the Eastern Mediterranean and the Middle East. Routledge, London, pp 189–199

Rossignol J, Wandsnider L (eds) (1992) Space, time and archaeological landscapes. Plenum, New York

Sakellariou D, Rousakis G, Panagiotopoulos I, Morfis I, Bailey GN (this volume) Geological structure and Late Quaternary geomorphological evolution of the Farasan Islands continental shelf, south Red Sea, SW Saudi Arabia

Sanderson D, Kinnaird I (this volume) Optically stimulated luminescence dating as a geochronological tool for Late Quaternary sediments in the Red Sea region

Senut B, Pickford M, Gommery D, Mein P, Cheboi K, Coppens Y (2001) First hominid from the Miocene (Lukeino Formation, Kenya). Compt Rend de l'Acad de Sci 332(2):137–144

Sinclair A, McCraith L, Nelson E (2003) Understanding hominid landscapes at Makapansgat, South Africa. In: Mitchell P, Haour A, Hobart J (eds) Researching Africa's past: new contributions from British archaeologists. Oxford University School of Archaeology, Oxford, pp 11–24

Sinclair A, Inglis RH, Shuttleworth A et al (in prep) Technological errors, practical experience and informal learning in the Middle Stone Age at Wadi Dabsa, Saudi Arabia

Stern N (1993) The structure of the Lower Pleistocene archaeological record. Curr Anth 34(3):201–225

Suwa G, Asfaw B, Kono RT, Kubo D, Lovejoy CO, White TD (2009) The Ardipithecus ramidus skull and its implications for hominid origins. Science 326(5949):68e1–7

Van Peer P (1992) The Levallois reduction strategy. Prehistory Press, Madison, Wisconsin

Walter RC, Buffler RT, Bruggemann JJ, Guillaume MMM, Berhe SM, Negassi B, Libsekal Y, Cheng H, Edwards RL, von Gosel R, Neraudeau D, Gagnon M (2000) Early human occupation of the Red Sea coast of Eritrea during the last interglacial. Nature 405:65–69

Whalen N, Pease D (1990) Variability in developed Oldowan and Acheulean bifaces of Saudi Arabia. Atlal 13:43–48

Whalen N, Killick A, James N, Morsi G, Kamal M (1981) Saudi Arabian archaeological reconnaissance: preliminary report on the western province. Atlal 5:43–58

Whalen N, Sindi H, Wahida G, Siraj-Ali JS (1983) Excavation of Acheulean sites near Saffaqah in ad-Dawadmi 1402–1982. Atlal 7:9–19

Whalen N, Davis WP, Pease D (1989) Early Pleistocene migrations into Saudi Arabia. Atlal 12:59–75

Winder I, Devès M, King G, Bailey G, Inglis RH, Meredith-Williams MG (2015) Evolution and dispersal of the genus homo: a landscape approach. J Hum Evol 87:48–65

Zarins J, Whalen N, Ibrahim M, Al-Jawad Mursi A, Khan M (1980) Comprehensive archaeological survey program. Preliminary report on the Central and Southwestern provinces survey. Atlal 4:9–36

Zarins J, Al-Jawad Murad A, Al-Yish KS (1981) The comprehensive archaeological survey program: the second preliminary report on the southwestern province. Atlal 5:5–42

Investigating the Palaeoshorelines and Coastal Archaeology of the Southern Red Sea

Robyn H. Inglis, William Bosworth, Najeeb M. A. Rasul, Ali O. Al-Saeedi, and Geoff N. Bailey

Abstract

Numerous palaeoshoreline features including coral platforms, beachrock and wave-cut notches are present on the Red Sea coastline of SW Saudi Arabia and on the Farasan Islands. Some are associated with prehistoric archaeological material, which has been the focus of ongoing archaeological investigations over the past decade. Dating and interpretation of these features are therefore of considerable interest and relevance to the deep history of human coastal adaptation and colonization in a key zone for the understanding of early human expansion out of Africa, as well as to the study of relative sea-level changes and tectonic movements. This chapter provides details of a field survey carried out in 2014 and presents new information on the location, geological setting, geochronological sampling and archaeological associations of these palaeoshoreline features. The results of dating are still awaited, so that some of our interpretations are still hypotheses in need of further testing. At this stage, it is clear that the most prominent shoreline features on the mainland coast are at elevations similar to those dated elsewhere in the Red Sea as belonging to MIS 5e, and that in at least one exposure Middle Stone Age artefacts can be stratigraphically linked with this period of high sea level. On the Farasan Islands, coral platforms have undergone more variable and localised rates of movement associated with salt tectonics. We set out the field data in support of these interpretations and consider their wider archaeological and tectonic implications.

1 Introduction

The purpose of this chapter is to present the results of a field excursion conducted in November and December 2014 to examine palaeoshoreline features in the southern Red Sea along the mainland coastline of Asir Province in SW Saudi Arabia and on the Farasan Islands in Jizan Province (Fig. 1), and to set out the intellectual and scientific issues that have informed our fieldwork.

Cemented coral platforms and beach deposits indicating the presence of palaeoshorelines are widely distributed above present sea level around the Red Sea, and some have been recorded below sea level (Faure et al. 1980; Dullo 1990; Hoang and Taviani 1991; El Moursi et al. 1994; Gvirtzman 1994; Hoang et al. 1996; Plaziat et al. 1998, 2008; Walter et al. 2000; Lambeck et al. 2011; Manaa et al. 2016; Bosworth et al., this volume; Sakellariou et al., this volume). Those on land mostly represent earlier periods of high sea level during Pleistocene interglacials. They occur at varying elevations above present sea level, up to 100 m in the Gulf of Aqaba, reflecting differences of age, variations in eustatic sea level in different interglacials, and vertical crustal movements associated with tectonic processes of various sorts.

Similar palaeoshoreline features are present in our region. In particular, exposures of cemented coral platforms or terraces and beach deposits at least 4 m above the present sea level, and assumed to relate to higher sea-level stands of the

---

R. H. Inglis (✉) · G. N. Bailey
Department of Archaeology, University of York, The King's Manor, YO1 7EP York, UK
e-mail: robyn.inglis@york.ac.uk

R. H. Inglis
Department of Environmental Sciences, Macquarie University, North Ryde, Sydney, NSW 2109, Australia

W. Bosworth
Apache Egypt Companies, 11 Street 281, New Maadi, Cairo, Egypt

N. M. A. Rasul
Center for Marine Geology, Saudi Geological Survey, Jeddah, Saudi Arabia

A. O. Al-Saeedi
Survey Department, Saudi Geological Survey, Jeddah, Saudi Arabia

G. N. Bailey
College of Humanities, Arts and Social Sciences, Flinders University, GPO Box 2100 5001 Adelaide, SA, Australia

N. M. A. Rasul and I. C. F. Stewart (eds.), *Geological Setting, Palaeoenvironment and Archaeology of the Red Sea*,
https://doi.org/10.1007/978-3-319-99408-6_25

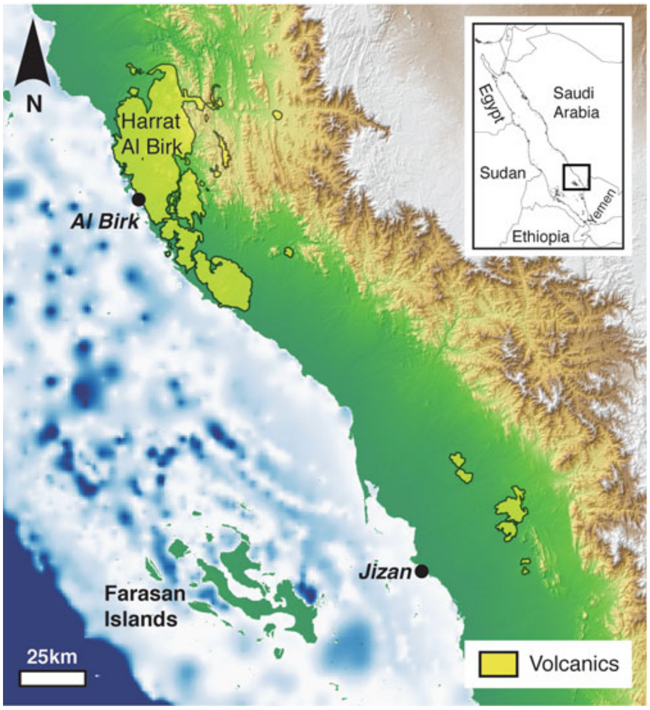

Fig. 1 The southwestern Saudi Arabian Red Sea coastline showing the Harrat al Birk and Farasan Islands. Area of Fig. 4 outlined in black. Pale blue areas show the continental shelf exposed when sea level is lowered to 120 m. The dark blue circular patches on the shelf are deep depressions resulting from solution of Miocene evaporites. Data from GEBCO 08 and SRTM 4.1

Last Interglacial period (MIS 5e) or older, have been noted during earlier archaeological expeditions in the region (Zarins et al. 1980, 1981; Alsharekh and Bailey 2013; Bailey et al. 2007a, b; Inglis et al. 2013, 2014a, b). However, they had not received systematic or extensive geological investigation or geochronological sampling before our 2014 expedition. As such, the region is one of the least well studied in this respect compared to most other coastlines of the Red Sea. It is also the focus of ongoing research on coastal prehistory (Bailey et al. 2012, 2015; Devès et al. 2013; Inglis et al. 2013, 2014a, b, 2015; Meredith-Williams et al. 2013, 2014; Bailey and Alsharekh, in press; Bailey et al., this volume; Hausmann et al., this volume; Sinclair et al., this volume), and this provides an additional incentive for more detailed geological research. Moreover, many coastal features are under threat of destruction by intensifying pressures of development, road-building, other infrastructural projects and tourism, adding urgency to the collection of field data.

For most published studies, the primary interest of these palaeoshoreline features is their contribution to an understanding of sea-level change, and that is often taken to be the main goal of their investigation. Together with evidence from deep sea cores (Siddall et al. 2003; Rohling et al. 2013), this makes the Red Sea an important study region for the wider understanding of global sea level change and its relationship to climate change. However, palaeoshoreline features also have relevance to a wider range of geological, geoarchaeological and archaeological interests, and it is important to be clear about the different aims, data requirements and assumptions that different disciplines bring to shoreline studies. We identify here broadly three different themes:

1. Measurement and modelling of sea-level change in relation to global climate change, often with the ultimate goal of producing better predictions of future sea-level change.
2. Understanding of regional tectonic effects associated with rifting, plate motions and other processes of crustal deformation and their contribution to the wider understanding of Earth deformation processes and geodynamics
3. Charting the role of coastlines in the global expansion of human populations out of Africa during the Pleistocene period and the deeper history of human interest in coastal and marine resources and their exploitation.

These three themes are, of course, interlinked. Shoreline features cannot be interpreted as sea-level indicators without taking into account the interplay between eustatic variations of sea level and vertical crustal movements associated with rifting, plate motions, changes of mass loading and other tectonic effects. This is especially important in the Red Sea, which has a complex geotectonic history. Palaeoshorelines in their turn provide sensitive measures of tectonic movements that can be calibrated against independent evidence of eustatic sea level change. Eustatic changes of sea level also have effects on the mass loading of the Earth's crust in coastal regions and on the erosion or submergence of geological features. In relation to archaeological issues, both tectonic and sea-level changes alter the physical landscape setting within which past human populations made their living; they can alter the nature and accessibility of the plants, animals and water supplies available for subsistence, pathways of movement and communication, and the preservation and visibility of archaeological evidence. Geological studies can also provide chronological control on the archaeology. Geologists and sea-level specialists in their turn are interested in the potential of archaeological data to provide independent age-constraints on geological processes, and are increasingly interested in the relevance of their research to the study of human evolution and the scale of human activities (e.g., Lambeck et al. 2011; Rohling et al. 2013; Benjamin et al. 2017; Kübler et al., this volume).

Shoreline features are viewed differently in each of these types of investigation—as sea-level indicators, as measures of tectonic movement, and as evidence of human exploitation of shorelines, respectively. The measurement accuracy differs accordingly. For sea-level studies, measurements of the highest possible accuracy are required—metre to decimetre scale—with clear specification of measurement errors and other sources of uncertainty, and calibration to a uniform spatial and temporal framework. This is to facilitate differentiation of eustatic sea levels in different interglacials or interglacial sub-stages that may differ by only a small amount, and to facilitate interregional and global comparisons. For tectonic studies, a coarser scale—metres to tens of metres—may be sufficient to distinguish between stable conditions and long-term vertical movements. For archaeological purposes, the absolute height of a shoreline is less important than stratigraphic evidence that the archaeological material can be directly associated with an elevated shoreline feature at the time when sea level was high, rather than representing material deposited on the surface at a later date. For example, stone tools found on the surface of Last Interglacial coral terraces could have been deposited during the subsequent glacial stage, when sea level was far lower than present and the shoreline many tens of kilometres distant.

Despite these inter-relationships and the widely acknowledged virtues of interdisciplinary research, the investigation of these three themes is often pursued by scientific communities working within separate disciplinary or subdisciplinary compartments with poor communication across the boundaries between them or even mutual incomprehension. As a multi-disciplinary group with combined expertise in geoarchaeology, marine science, coastal prehistory, geophysics and tectonic geology, we are interested in all three of these themes and the relationships between them, and our approach to field surveying has been shaped accordingly.

In this chapter, we set out the wider geological and archaeological issues that inform our fieldwork, define our field objectives and methods, present our preliminary results, and discuss their wider implications.

2 Geological and Archaeological Issues

2.1 Geological Context

The Red Sea has a geotectonic setting involving the interaction of several different processes, including: continental rifting involving crustal extension, normal faulting and volcanism; seafloor spreading; plate motions; isostatic changes of mass loading; and more localised tectonic movements resulting from the mobility of Miocene salt deposits, also referred to as evaporites or halites. The basin began to take its present form as a continental rift at about 30 Ma as a northward extension of the East African Rift system, and this whole rift structure was probably triggered at least in part by the eruption of the 4 km-thick flood basalts that occurred over the Ethiopian hot spot—a swelling and thinning of the Earth's crust over a hot plume rising from deep within the Earth's mantle—acting on pre-existing weaknesses in the lithosphere (Hubert-Ferrari et al. 2003; Bonatti et al. 2015; Bosworth 2015). The central Red Sea basin has the typical features and asymmetric cross-section of a rift, with the main faulting running through the centre of the basin. Ongoing extension and normal faulting have resulted in progressive uplift of the rift flanks and deepening of the rift floor. The footwall of the main rift is on the eastern margin, comprising the western Arabian escarpment, which reaches a maximum height of ~3000 m above sea level (asl) in the south; the lower, hanging wall is on the western margin of the Red Sea; and the deepest part of the axial trough in the centre of the basin is ~2800 m below present sea level.

By 19 Ma, seafloor spreading had commenced in the Gulf of Aden. The Arabian Peninsula continued separating from the African Plate, moving to the north, with extension in the Afar region of Ethiopia and the widening of the 'Proto Red Sea'. The Red Sea remained isolated from the world oceans, apart from intermittent incursions of seawater from the Mediterranean, and filled with thick deposits of evaporite because of high rates of evaporation in a closed basin. By 5 Ma, a connection with the Indian Ocean was established, with the onset of seafloor spreading and formation of oceanic crust within the Red Sea Basin. The whole process has been accompanied by episodes of magmatism on land on the Arabian side with extensive areas of volcanic cinder cones and basaltic lava flows, notably during the Miocene (>5 Ma) and the Quaternary (<2 Ma and extending in some regions into the Holocene), although it remains unclear to what extent these originate from shallow sources in the mantle associated with local extension and faulting or from deeper mantle sources associated with the Ethiopian plume.

Many of the details of these processes including their timing and the nature of ongoing deformation are still a matter for debate. An active oceanic spreading centre is present along the basin axis, with the Arabian Plate separating from Africa/Nubia at ~1.7 cm/yr (ArRajehi et al. 2010), and continuing to slide along the large transform faults that define its western and eastern boundaries and to collide with the Eurasian continent to the north. However, there is debate concerning when the transition from continental rifting to seafloor spreading began (Girdler and Styles 1974; Girdler and Whitmarsh 1974; Cochran 1983; Coleman 1993; Cochran and Karner 2007; Mohriak 2015). Plate reconstructions and extrapolation of spreading rates suggest that the tectonic regime has been fairly constant over about the past 11 Myr (McQuarrie et al. 2003; Reilinger et al. 2015).