PART 1: FIELD EXPLORATION ON THE CORAL REEF STRUCTURES OF THE FARASAN ISLANDS AND THE JAZAN REGION, KINGDOM OF SAUDI ARABIA: THEIR IMPLICATIONS ON THE SEA-LEVEL CHANGE TECTONIC HISTORY, AND THE COASTAL ARCHAEOLOGY OF THE REGION

By

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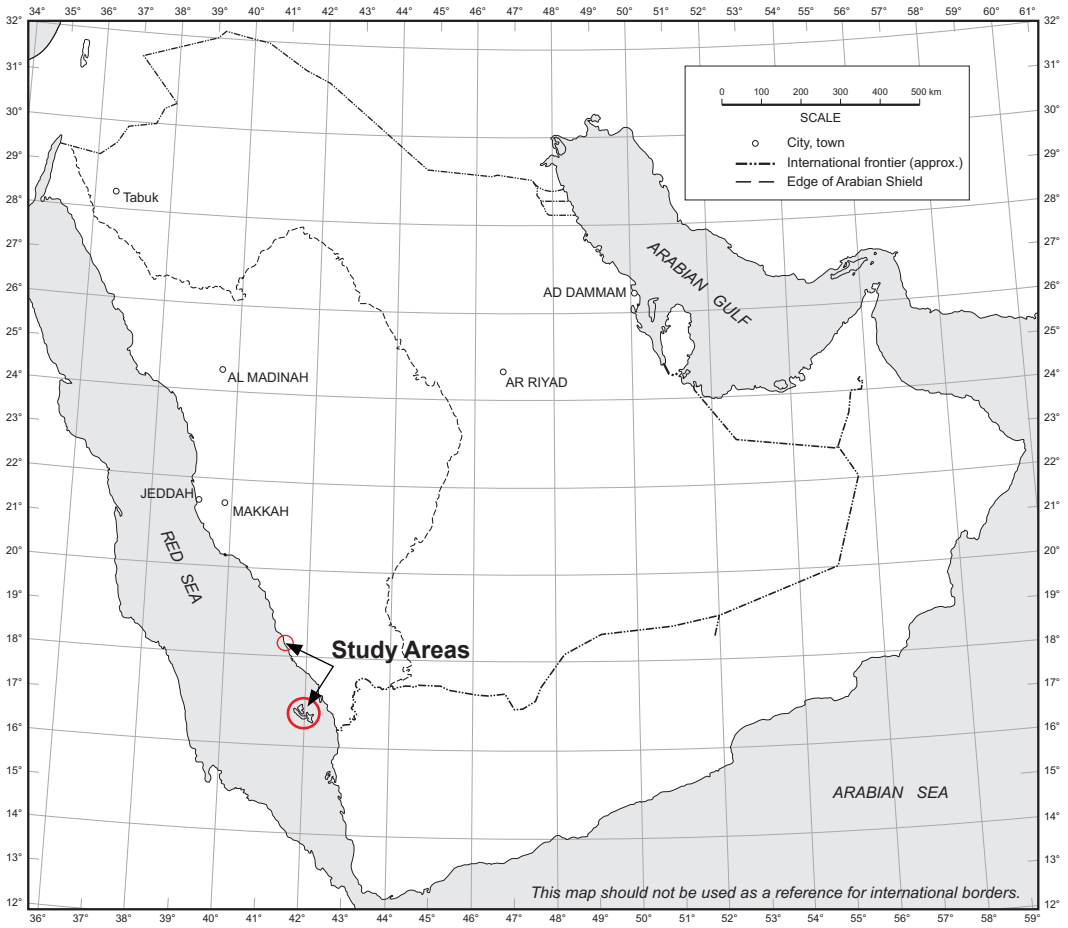

Index map of the Arabian Peninsula

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ABSTRACT

This report presents the initial results of a survey on the coastal features of the provinces of Asir and Jizan in SW Saudi Arabia and the Farasan Islands. This survey was prompted by the ongoing research on sea-level change, tectonic history, and coastal archaeology of the region, and it is concentrated on the cemented coral-reef structures that are now above the modern sea-level due to a change in sea levels, tectonic uplift, or a combination of both factors. Seventy-five locations were examined, with the collection of over 50 samples for geological, chronological, and palaeoecological analyses and 143 DGPS measurements of elevation.

Keywords: Sea-level changes, Raised coral terraces, Tectonics, Farasan Islands, Stone Age archaeology, Saudi Arabia

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الجزء الأول: الاستكشاف الميداني لهياكل الشعاب المرجانية في منطقة فرسان – جيزان، المملكة العربية السعودية: آثارها على تغير مستوى سطح البحر والتاريخ التكتوني والآثار الساحلية في المنطقة

إعداد

جيوف بيلي، نجيب رسول، روبين إنجليس، وليام بوسوورث، نواف ودينلي، علي الصعيدي

الملخّص

يعرض هذا التقرير النتائج الأولية لمسح المعالم الساحلية في محافظتي عسير وجيزان بجنوب غرب المملكة العربية السعودية وجزر فرسان. تم إجراء المسح من خلال البحث الجاري والمستمر حول تغير مستوى سطح مياه البحر والتاريخ التكتوني والآثار الساحلية للمنطقة. ركز المسح على متكونات الشعاب المرجانية الأسمنتية التي هي الآن فوق مستوى سطح ماء البحر الحديث بسبب ارتفاع مستويات سطح ماء البحر ، أو الحركات التكتونية أو كلاهما معا. تم فحص خمسة وسبعين موقعًا ، مع جمع أكثر من ٥٠ عينة للتحليل الجيولوجي والكرونولوجي والبيولوجي القديم و تم استخدام جهاز DGPS لعدد ١٤٣ موقعاً لقياس الارتفاعات عن سطح مياه البحر.

INTRODUCTION

The field survey took place between 28 November and 7 December 2014, with the time in the field divided between the surveys in the Farasan Islands and in the coastal mainland in the provinces of Jizan and Asir. The principal aim of the survey was to locate, measure, and date the ages of the cemented coral reef terraces, which are now elevated above the modern sea level (Fig. 1). It was also intended to document the structural geologic features of these areas, such as the faults and the fractures that are associated with the terraces. The resulting data should provide a better framework for modelling the relative sea-level changes and the crustal movements during the Late Pleistocene. An improved geochronological framework is also relevant to the understanding and interpretation of the many Stone Age archaeological sites that were discovered in these regions. The interpretation of the data presented in this report and its significance for a better understanding of the tectonic and the sea-level changes is presented in Inglis and others (2019a).

ARCHAEOLOGICAL RELEVANCE

The archaeological potential of the Farasan Islands and Jizan-Asir coastal mainland was first documented in the 1970s and 1980s by the Comprehensive Archaeological Survey Programme (CASP) (Zarins and others, 1981). The areas visited during the fieldwork had been intensively surveyed by the DISPERSE Project since 2011, a joint Saudi-UK initiative with the Saudi Commission for Tourism and Antiquities (SCTA), now known as the Saudi Commission for Tourism and National Heritage (SCTNH), and the Department of Archaeology of the King Saud University, with a focus on prehistoric archaeology, coastal geomorphology, and submerged landscapes (Alsharekh and Bailey, 2013; Bailey, 2015; Bailey and Alsharekh, 2018; Bailey and others 2007, 2015, 2019; Geraga and others, 2019; Hausmann and others, 2019; Inglis and others, 2013, 2014a, 2014b, 2019b; Kübler and others, 2019; Momber and others, 2019; Sakellariou and others, 2019; Sanderson and Kinnaird, 2019; Sinclair and others, 2019). The time span of human occupation in this region is at least 500,000 years. An improved understanding of these geological changes over this period, especially those associated with sea level changes and tectonic movements are, therefore, of great archaeological interest (see also Bosworth and others, 2019; Lambeck and others, 2011).

The geological changes in the region are likely to have major impacts on the preservation and the visibility of the archaeological evidence and on the varying attractiveness of the different areas of prehistoric human activities. Coastal uplift or subsidence and sea-level changes have also had major impacts on the visibility and preservation of coastal archaeological sites.

Figure 1. Multiple Late Pleistocene coral terraces in the Sulayn island group of the Farasan archipelago.

On the Jizan-Asir mainland, there are concentrations of Stone Age archaeological sites of all periods, many of them in the coastal areas that are in close proximity to elevated coral reefs, associated with periods of higher sea levels, especially along the edge of the Harrat Al Birk. Most of these sites are areas with surface scatters of stone artefacts, and these can only be dated in broad terms by their technological characteristics. Some artefacts were found in stratigraphic position within a wadi cobble unit in the Dhahaban quarry in association with the elevated coral and beach deposits and the basaltic lava flows (Inglis and others, 2014). This was a particular target of the present survey.

In the Farasan Islands, there are over 3,000 prehistoric shell middens, including an impressive series of shell mounds of up to 5 m tall (Fig. 2). These sites are the result of the collection of marine molluscs for food and the discard of the shells on favored locations used as camping sites. An excavation shows that these shell deposits include numerous other marks of human activities, including the presence of fish bones, mammal bones, such as those of the gazelle, numerous ashy lenses, representing the remains of fireplaces, and other artefacts. Usually, these deposits had built up as a result of the repeated use of the same location over long periods, ranging from decades to centuries. Majority of these sites, especially the mounds, fall in the period between 6,500 and 4,500 radiocarbon years BP (Bailey and others, 2013; Hausmann and others, 2019). There are also small middens and scatters of shells of more recent ages. The mounded sites are mostly located on the edge of a fossilized coral platform, which is the dominant landform of the Farasan Islands, and has been undercut by marine erosion at or close to the modern shoreline to form a characteristic notch. Some of these shorelines, especially those on which the larger mounds are located, appear to be higher than the present sea level. In some areas, these shorelines are now at some distance inland from the present-day shoreline around the edge of large bays that are now dry and sand-filled areas as a result of ongoing sedimentation and/or tectonic uplift.

TECTONIC RELEVANCE

The Saudi Geological Survey began a field program to study the uplifted Late Pleistocene coral terraces in December 2013. The purpose of this project is to document the relative sea-level changes along the coastlines of the country and, from this, to infer the magnitudes of the recent tectonic uplift or subsidence that occurred in the area. It is also intended to document the Late Pleistocene paleo-environments and the distribution of reefs through time. The first phase of

Figure 2. Series of shell mounds in the Janaba Bay, Farasan Kabir, showing a large mound in the foreground with the GPS measuring equipment used in the survey. Similar shell mounds are visible in the middle distance along the edge of a palaeoshoreline that is now ~1 km inland from the modern shoreline (visible on the far left).

this project covered the Saudi Arabian coast of the Gulf of Aqaba (Angeletti and others, 2019; Bosworth and others, 2019; Taviani and others, 2019), and the second phase reported here shifted the focus to the coast of the Red Sea.

The Late Pleistocene coral terraces in the southern Gulf of Suez in Egypt are known to have been tectonically uplifted by as much as 10–15 m during the past 125,000 years. This is almost entirely due to footwall uplift along several active extensional faults, at least one of which has been teleseismically active within the past 50 years (Bosworth and others, 2019). Our fieldwork with the SGS had confirmed that similar uplift rates are occurring in the northern Gulf of Aqaba at the Saudi margin. Along the southern part of the margin, particularly in the Midyan area, the rates are much lower.

The 2014 fieldwork reported here was intended to extend the documentation of the Late Pleistocene coral terrace to the southern part of the Red Sea margin, focusing on the area of Harrat Al Birk. This will provide important constraints on the tectonic evolution of the margin, which, unlike the Gulf of Aqaba, appears to be relatively stable or slightly subsident during the Late Pleistocene. Our fieldwork also included the offshore area of the Farasan archipelago, where the Pleistocene stratigraphy shows several overlying active salt domes, providing a different perspective on the neotectonics of the Red Sea basin. Though the situation here is much more complex than that of the coastal region.

OBJECTIVES OF THE SURVEY

The specific objectives of the survey were as follows:

a. to study the structural geology of the coastal landforms and the associated evidence of faulting, fracturing, and volcanism

b. to locate raised beaches that represent earlier periods of high sea level. Typically, these are composed of cemented corals or beach rock (cemented sands and shells)

c. to measure the elevations of these old beach terraces in order to track the local and the regional changes in the Earth's crust that resulted from rifting and salt tectonics and to collect new data on sea-level changes

d. to collect samples of corals or shells that are suitable for U-series dating from these elevated terraces

e. to collect samples of basalts that are suitable for Ar^{40}/Ar^{39} dating, wherever the ages of the basalts could help constrain the geologic evolution of the coral terraces themselves

f. to relate the geologic history of these coastal areas to the archaeological sites, which are frequently found at the coastal edges with the elevated coral terraces

METHODS

The fieldwork targeted a number of locations known from previous work to have good exposures of Pleistocene coral reefs. Locations visited were traversed by 4-wheel drive vehicles and on foot. Within the Farasan archipelago a small motorboat was also used to access the coastlines of several islands.

Particular attention was devoted to the collection of samples of corals and shells, which were embedded in the cemented coral or beach deposits for the U-series dating (Fig. 3). The degraded nature of the coral materials necessitated an intensive search for the suitable in-situ specimens. Moreover, the heavily cemented nature of the deposits required heavy-duty hammers and chisels and prolonged effort to remove the samples from their matrix.

Most of the corals are unsuitable for dating because of their fibrous open structures and diagenetic alteration. Many coral samples, when broken open, showed streaks of mineral staining, a sign of probable contamination. The most suitable materials for dating are the large coral heads with dense and uniform structures.

The shells of the *Tridacna* clam were also collected (Fig. 4). This is a very large mollusc, often 20 cm or more in length, and with a thick, dense shell several centimeters thick, with a better chance of preserving a closed geochemical system protected from contamination. Other types of shells, principally gastropods, were collected in some cases, being the only dateable materials that are present in the deposits. The shell materials of this type, as well as the coral, are also amenable to Amino Acid Racemization (AAR) dating, and the University of York BioArCh Laboratory, a leading center for this dating method, has established protocols in obtaining reliable dates from shells and corals, and sometimes, on materials, where the U-series dating has failed (Penkman and others, 2008, Hendy and others, 2012). The likelihood of success depends on the particular amino acids that are present in the shell or the coral matrix and their racemization rates, something that can only be established through experimentation, so that results are not guaranteed, even in unaltered samples.

Figure 3. Sampling a Pleistocene coral terrace on Farasan Kabir west of Mursa al Hesen. Both corals and *Tridacna* clam shells (shown here) were sampled. Note the staff with a GPS receiver, mounted the sample, used for both precision measurement of position and elevation.

Figure 4. The *Tridacna* clam and the labelled bag.

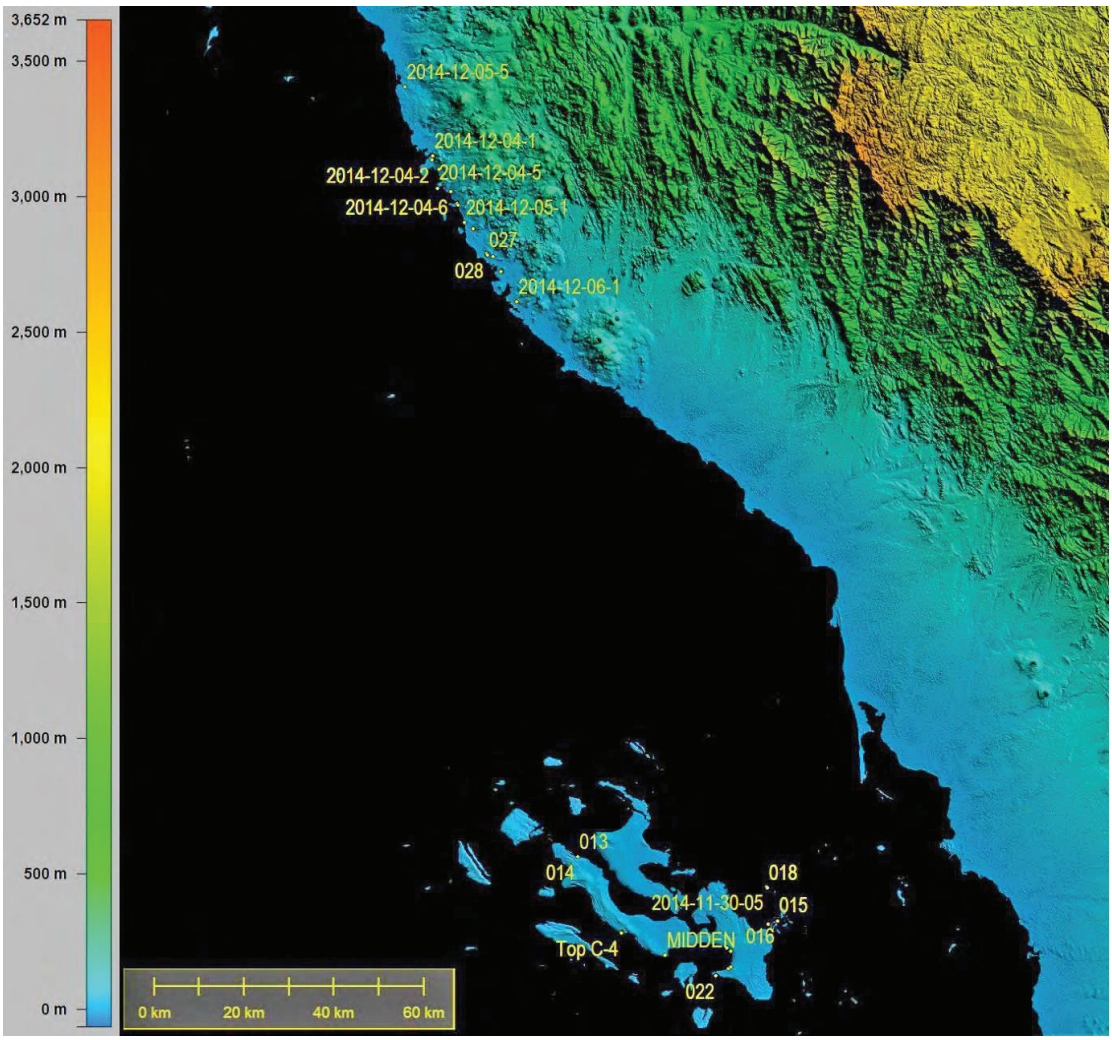

Figure 5. Locations of the stations on the Farasan archipelago and along the Red Sea coastline at Harrat Al Birk. The digital elevation model used is from the US National Oceanic and Atmospheric Administration.

All of the samples for dating were separately bagged in canvas bags. Each sample was labelled with a unique catalogue number, prefixed with FA for Farasan or HAB for Harrat Al Birk, tagged with the dates of collection, and other relevant details (Fig. 4).

Over 70 samples for age dating were collected this way. All sample locations and elevations were measured with a Trimble differential GPS instrument, utilizing survey reference points or local base stations. Post-acquisition data processing was conducted by the survey team at the SGS. Additional traverses and spot elevations of specific features were made with the same equipment. In some locations, additional elevation data were also obtained by tape measure, referenced to the sea level. The locations of the outcrop stations are shown in Figure 5. The full details of the samples for age dating and the DGPS measurements are tabulated in Appendices 1 and 2. A map of the DGPS positions in Farasan Station 3 is presented in Appendix 3.

In some locations, archaeological artefacts were identified, such as the flaked stone artefacts or the broken ceramics. The shell middens, usually more or less extensive scatters of shells left by humans, were also identified in some of the areas visited, including those sites that were not recorded in previous surveys. These were described in the field with brief notes on their extent, principal mollusc species, and the presence or absence of artefacts. Several artificial stone structures were also encountered in some areas, and were briefly measured and described, including an important series of stone mounds in the southern area of Al Qamah in the Harrat Al Birk, which are clearly human burial mounds but of unknown age (Fig. 6). We also observed a group of interesting structures, one of which is associated with a midden of pearl-oysters (Fig. 7) on one of the Abalat islands. All archaeological data will be submitted to the SCTA for their records, so that these sites, which are at risk of being damaged or destroyed, will be flagged for their attention and needed action to preserve them.

In the coastal region of Asir and Jizan Provinces, all archaeological materials are at risk because of the intensive development taking place in these areas, with extensive earth moving, bulldozing, and construction

Figure 6. A stone mound south of Al Qamah in the Harrat Al Birk, resting on a Pleistocene terrace, which is now located several kilometers from the present shoreline. More than a dozen of these mounds are present in this location and were built for human burials.

Figure 7. Shell midden located on one of the Abalat islands within the Farasan archipelago. The shells are predominantly pearl oysters and are associated with the remains of a nearby stone structure. This site probably represents a pearl fishermen's camp of relatively recent age.

activities. We have, therefore, collected the materials in areas, where the likelihood of their loss or destruction is high. These materials comprise a small number of artefacts, including mostly individual flaked stone artefacts but also some ceramic materials. These materials were bagged separately and will be added to the materials collected previously by the DISPERSE project staff, which are currently stored in the SCTA storage in the Sabiya Museum (Jizan).

PRELIMINARY RESULTS

FARASAN ISLANDS

On the Farasan Islands, we spent three days of intensive survey and targeted three principal areas during the successive days: 1) Mursa Al Hesen in the north of Farasan Kabir, the largest island of the Farasan group, and also, the area that shows most obvious signs of tectonic uplift associated with salt tectonics on the satellite images; 2) the Sulayn and Abalat group of islands, north of the main port on Farasan Kabir; and 3) Ras Shida at the southern extremity of Farasan Kabir. A plan to visit the island of Qumah was aborted because of bad weather and a halt to all boating activities on this particular day.

Mursa al Hesen

This is a fisherman's harbor in a small bay (Fig. 8), backed by a partly eroded cliff, forming an impressive sequence of uplifted white biogenic/bioclastic marine sediments and capped by a 2-m thick coral reef terrace. The top of the terrace is about 30 m high. The terrace is bounded by a NW-SE striking extensional fault on its southwest side. Numerous coral and *Tridacna* samples were collected from the lower lying terraces to the west of the harbor.

Sulayn and Abalat Islands

We visited a number of islands to the north of the modern port of Farasan and collected samples from Murrabaah Island within the main Sulayn group (Fig. 9), and from one of the larger islands of the Abalat group to the northwest (Fig. 10). The upper coral terrace in Abalat lies at an elevation of 9 m, as determined using a tape measure to the sea level in the afternoon of November 30.

Ras Shida

Ras Shida itself shows an interesting four-fold sequences of uplifted coral platforms. The highest and oldest is Jabal Shida, with an elevation of 26 m (DGPS measurement in December 1 at 11:44 AM) (Fig. 11).

Below this highest terrace is a terrace, now tilted and with sinkholes, most probably formed by wave action acting on the minor faults or joint fractures in the bedrock, before the surface was uplifted (Fig. 12).

Figure 8. A fishing village in Mursa al Hesen on Farasan Kabir. This photograph was taken from the top of a coral terrace that was up-thrown relative to the plain below, with a topographic offset of about 30 m.

Figure 9. Coral terraces and small fishing village in the Murrabaah Island.

Figure 10. Massive coral reef section, capped by 9-m terrace in the large island within the Abalat group.

Figure 11. The highest coral terrace in Ras Shida.

Figure 12. Upper terrace in Ras Shida, showing a sinkhole and a surface joint fracture.

Skirting this is a lower terrace, and below this is a 3-m terrace that abuts the present shoreline. The three upper units provided samples for age dating. However, we were unable to find suitable dateable materials in the 3-m terrace around the headland, because the reef materials here, as elsewhere along the Janaba Bay shoreline, are mostly composed of beachrock rather than corals. Some of the shell mounds sitting on the edge of this coral terrace yielded radiocarbon age dates in the range of 6,000–4,000 cal BP, but this can only be interpreted as a minimum age for the underlying terrace, which could be very much older. The preliminary height measurements suggest that this lower terrace has variable elevations along its length, suggesting the effect of a differential uplift/subsidence along this stretch of the coast (Figs. 13 and 14).

Figure 13. Shell mound of mid-Holocene, age sitting on the 3-m terrace, with the Ras Shida headland visible from a far distance. The edge of the coral terrace was undercut by marine erosion.

Figure 14. The Farasan 3-m coral terrace, showing the degree of undercutting by marine erosion.

JIZAN MAINLAND

We spent four days on the mainland, concentrating on the localities along the coastal edge of the Harrat Al Birk (Fig. 5) within the Province of Asir: 1) the Dhahaban quarry, 2) the Al Birk area to the north, and 3) the Al Qamah area to the south.

Dhahaban Quarry

The Dhahaban Quarry is a complex series of deposits, partially exposed by quarrying and by the down-cutting of a wadi that grades to the present sea level, which has incised the earlier deposits. The deposits represent at least four different episodes: 1) a volcanic cinder cone with associated basaltic lava flows; 2) a unit comprising large water-rolled cobbles of basaltic lava and isolated corals and marine shells; 3) a marine deposit of cemented sands, beach rocks, and corals, which formed during a period, when the sea level was ~8 m higher than the present level; and 4) an upper cross-bedded deposit, believed to be wind blown that is banked up against the volcanic cinder cone. This site is also archaeologically significant, since it has yielded a large number of Early and Middle Stone Age artefacts lying on the surface of the marine terrace, and a smaller number of artefacts embedded in unit (2) (Inglis and others, 2014a,b) (Fig. 15 and 16).

Samples for new age dating were obtained from all four units, including the basalts, for Ar^{40}/Ar^{39} dating of the basaltic lavas to derive a maximum date for the overlying deposits. The samples for OSL dating were recovered from the upper sand unit in 2014 and are currently being processed at the Scottish Universities Environmental Research Centre, UK. The combination of the dating methods and the dating samples from this site offers a good prospect of unravelling its geologic history.

Al Birk Region

A number of localities were visited in the Al Birk region. These include the shell midden site to the north of Al Birk town, which were visited and sampled during the previous archaeological surveys (Fig. 17). The site is of particular interest, because it comprises a cemented coral terrace, most likely of last interglacial date, that is situated immediately behind the modern beach with Middle Stone Age artefacts on its surface and probably of similar age (Inglis and others, 2014b), and a scatter of food shells that were dated to be 5,560±70 BP (Beta-191460) using radiocarbon, which was an age obtained from one of the shells (Bailey and others, 2007; Alsharekh and Bailey 2013). In other words, the area is an archaeological palimpsest, comprising a mixture of materials of very different ages that cannot

Figure 15. Unit 2, comprising a debris flow conglomerate within the wadi, cutting through the Dhahaban quarry. The clasts include cobbles of both the basalt and the Pleistocene corals that crop out in other parts of the quarry. Stone artefacts were also recovered from this same deposit (see Fig. 16).

be stratigraphically disentangled. The coral terrace on which the deposit sits yielded a radiocarbon age of 38,380 1290 BP (Beta-191459), in effect, an infinite age. New samples for the age dating of corals and shell were obtained from the eroded section of the cemented coral unit.

Two other locations in the northern area of Al Birk town were sampled, one with a cemented coral deposit banked up against a volcanic lava flow on the west of the main road opposite a gas station, and a second locality in the eastern side of the main road and further south, where a coral beachrock deposit is exposed, with a single

Figure 16. The debris flow in the Dhahaban quarry, showing two basalt artefacts embedded in the deposit (immediately to the right of the measuring scale).

Figure 17. The shell midden at Al Birk. The midden comprises a relatively thin and superficial deposit, spread over quite a large area. The stone tools that were scattered across the surface are made from the local basalt and belong to a much earlier period than the shells. Large boulders of basalt are clearly visible around the edge of the area as can be seen in this image.

Figure 18. Extensive coral terrace that was banked up against a volcanic cinder cone on the east side of the coast guard radar station south of Al Birk. The corals in this location are very highly altered and generally unsuitable for U-series age dating.

struck basalt flake recovered from within the beachrock deposit.

In the town of Al Birk itself, there is a prominent peninsula projecting out to sea, comprising a lava flow. Coral deposits occur on its flank but the best exposures are inaccessible behind a tall security fence.

Several other localities were visited and sampled south of Al Birk town, including exposures of an old coral terrace in the inner edge of the modern sabkha, and the radar station site, the CASP site 216-208, also known as DISPERSE Locality L0084 (Zarins and others, 1981), comprising a volcanic cinder cone with a coral terrace on its northern and eastern flanks (Fig. 18). This site is well known in published archaeological literature and has been visited on several occasions, yielding Early and Middle Stone Age artefacts and a K/Ar age of 1.3 Ma, based on the materials from the cinder cone (Bailey and others, 2007). Boulders engraved with writing in South Arabic scripts are also present on the eastern slope of the cinder cone immediately below the radar station and in the nearby shallow tunnels that were excavated into the side of the cinder cone within a defined area of the SCTA protection (Fig. 19).

Since this site was first visited in the 1980s and again in 2004 and 2013, the whole area has been seriously disturbed by construction works, road building, and extensive quarrying of sediments. The coral terrace on the eastern side of the cinder cone is still reasonably intact, but finding samples of corals that are suitable for dating proved elusive, and only shell samples were recovered from this location.

Al Qamah

In the southern area of Al Qamah, we visited a lava flow and a coral beachrock complex, similar to the other exposures in this region. This location is of archaeological interest because of the number of stone-built burial mounds that are located on the edge of the terrace (Fig. 6) and a nearby scatter of archaeological materials, including incised ceramics. The top of the terrace was surveyed.

CONCLUSIONS

This report presents data of coastal landforms, principally elevated coral terraces and exposures of beachrock, and associated archaeological evidence in the form of shell middens and stone artefacts. The approximate age date of the materials is at least 130,000 kyr or may be more. The geological features were formed at or close to their contemporaneous sea-level, and their present elevations are evidence either of sea level changes or vertical tectonic movements since the time of their formation, or a combination of both. They, therefore, provide important indicators of these processes during the late Quaternary period.

Figure 19. Boulders with south Arabic scripts were found on the eastern slope of the cinder cone.

The archaeological data provide insights into the potential significance of coastal environments and marine resources to the Stone Age populations that lived in the region over the same time range. The data were collected from 13 locations along the 100 km coastline adjacent to the volcanic province of the Harrat Al Birk in the provinces of Asir and Jizan, and from three areas in the Farasan Islands: the north of Farasan al Kabir, the headland of Ras Sheida in the south of Farasan al Kabir, and the Sulayn and Abalat group of islands. All locations and features were photographed, and their positions and elevations were measured with DGPS equipment. Over 70 samples for dating were collected for Uranium series, Argon-Argon and Amino Acid Racemization analysis. The data on the archaeological features or artefacts were recorded in situ. The Al Birk coastal features lie in the range of 3–8 m above the modern sea level, which is consistent with the elevation of the features, dated elsewhere in the Red Sea region, to the last interglacial high sea-level stand at c. 130,000 ka. The features of the Farasan Island have much more variable elevations due to the locally variable effects of salt doming. The archaeological features mostly comprise shell middens that are known to be of mid-Holocene age based on radiocarbon determinations. These cannot be used to date the underlying coral terraces or other geological formations, which may precede the middens by an unknown time interval. In rare cases, notably at the Dhahaban quarry site in the Al Birk region, stone artefacts are stratified in deposits that were linked to an elevated coral terrace.

RECOMMENDATION

Additional data might be required to date the samples, and as such, future trips are recommended, so that a full geochronological interpretation could be determined.

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REFERENCES

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

Angeletti, L., Rasul, N.M.A., and Taviani, M., 2019, Mollusc fauna associated with Late Pleistocene coral reefs of the Saudi Arabian side of the Gulf of Aqaba: *in*: Rasul, N.M.A., and Stewart I.C.F. (eds.), Geological setting, palaeoenvironment, and archaeology of the Red Sea: Springer, Cham, p. 367–387.

Bailey, G.N., 2015, The evolution of the Red Sea as a human habitat during the Quaternary period: *in*: Rasul, N. M. A., and Stewart, I. C. F. (eds.), The Red Sea: The formation, morphology, oceanography, and environment of a young ocean basin: Springer Verlag, Heidelberg, p. 595–610.

Bailey, G.N., and Alsharekh, A.M., (eds.), 2018, Palaeolithic archaeology, coastal prehistory, and submerged landscapes in southwest Saudi Arabia and the Farasan Islands: DISPERSE Field Reports, 2012–2015, Saudi Commission for Tourism and National Heritage, Riyadh.

Bailey, G.N., Williams, M.G.M., and Alsharekh, A., 2013. Shell mounds of the Farasan Islands, Saudi Arabia: *in*: Bailey, G., Hardy, K., Camara, A. (eds.) Shell Energy: Mollusc Shells as Coastal Resources. OxBow, Oxford, p. 241–54.

Bailey, G.N., Alsharekh, A., Flemming, N., Lambeck, K., Momber, G., Sinclair, A., and Vita-Finzi, C. 2007, Coastal prehistory in the southern Red Sea Basin: Underwater archaeology and the Farasan Islands: Proceedings of the Seminar for Arabian Studies, v. 37, p. 1–16.

Bailey, G.N., Devès, M.H., Inglis, R.H., Meredith-Williams, M. G., Momber, G., Sakellariou, D., Sinclair, A. G. M., Rousakis, G., Al Ghamdi, S., and Alsharekh, A.M., 2015, Blue Arabia: Palaeolithic and underwater survey in SW Saudi Arabia and the role of coasts in Pleistocene Dispersal: Quaternary International, v. 382, p. 42–57.

Bailey, G.N., Meredith-Williams, M., Alsharekh, A., and Hausmann, N., 2019, The archaeology of Pleistocene coastal environments and human dispersal in the Red Sea: Insights from the Farasan Islands: *in*: Rasul, N. M. A., and Stewart, I. C. F. (eds.), Geological setting, palaeoenvironment, and Archaeology of the Red Sea: Springer, Cham, p. 587–608.

Bosworth, W., Taviani, M., and Rasul, N.M.A., 2019, Neotectonics of the Red Sea, Gulf of Suez, and Gulf of Aqaba: *in*: Rasul, N. M. A., and Stewart, I. C. F. (eds.), Geological setting, palaeoenvironment, and archaeology of the Red Sea: Springer, Cham, p. 11–35.

Geraga, M., Sergiou, S., Sakellariou, D, and Rohling E., 2019. Results of micropalaeontological analyses on sediment core FA09 from the southern Red Sea continental shelf: *in*: Rasul, N. M. A., and Stewart I.C.F., (eds.), Geological setting, palaeoenvironment, and archaeology of the Red Sea: Springer, Cham, p. 709-723.

Hausmann, N., Kokkinaki, O., and Leng, M. J., 2019, Red Sea palaeoclimate: Stable isotope and element-ratio analysis of marine mollusc shells: *in*: Rasul, N. M. A., and Stewart I. C. F., (eds.), Geological setting, palaeoenvironment, and archaeology of the Red Sea: Springer, Cham, p. 725–740.

Hausmann, N., Meredith-Williams, M., Douka, K., Inglis, R., and Bailey, G., 2019. Quantifying spatial variability in shell midden formation in the Farasan Islands, Saudi Arabia. *PLoS ONE* 14(6): e0217596. https://doi.org/10.1371/journal.pone.0217596.

Hendy, E., Tomiak, P., Collins, M.J., Hellstrom, J., Tudhope, A., Lough, J., and Penkman, K.E.H., 2012, Assessing amino acid racemization variability in coral intra-crystalline protein for geochronological applications: Geochimica et Cosmochimica Acta, v. 86, p. 338–353.

Inglis, R.H., Sinclair, A.G.M., Shuttleworth, A., Alsharekh, A.M., and Al Ghamdi, S., 2013, Preliminary Report on 2013 fieldwork in southwest Saudi Arabia by the DISPERSE Project: (2) Jizan and Asir Provinces, February–March 2013:

Unpublished Report to the Saudi Commission for Tourism and Antiquities. http://www.disperse-project.org/field-reports.

Inglis, R.H., Sinclair, A.G.M., Shuttleworth, A., Al Maamary, A., Budd, W., Hausmann, N., Meredith-Williams, M. G., Alsharekh, A. M., Al Ghamdi, S., and Bailey, G. N., 2014a, Preliminary report on 2014 fieldwork in southwest Saudi Srabia by the DISPERSE Project: (1) Jizan and Asir Provinces: Unpublished Report to the Saudi Commission for Tourism and Antiquities. http://www.disperse-project.org/field-reports.

Inglis, R.H., Sinclair, A., Shuttleworth, A., Alsharekh, A., Al Ghamdi, S., Devès, M., Meredith-Williams M.G., and Bailey. G.N., 2014b, Investigating the Palaeolithic landscapes and archaeology of the Jizan and Asir Regions, southwest Saudi Arabia: Proceedings of the Seminar for Arabian Studies, v. 44, p. 193–212.

Inglis, R., Bosworth, W., Rasul, N.M.A., Al Saeedi, A., and Bailey, G.N., 2019a, Investigating the fossil coral terraces and coastal archaeology of the southern Red Sea: *in* Rasul, N. M. A., and Stewart I.C.F. (eds.), Geological setting, palaeoenvironment, and archaeology of the Red Sea: Springer, Cham, p. 553–581.

Inglis, R.H., Fanning, T. C., Stone, A., Barfod, D.N., Sinclair, A., Chang, H.S., Alsharekh, A., and Bailey, G., 2019b, Paleolithic artifact deposits at Wadi Dabsa, Saudi Arabia: A multiscalar geoarchaeological approach to building an interpretative framework: Geoarchaeology: An International Journal, v. 34, p. 272–294.

Kübler, S., King, G.C.P., Devès, M.H., Inglis, R.H., and Bailey, G.N., 2019, Tectonic geomorphology and soil edaphics as controls on animal migrations and human dispersal patterns: *in*: Rasul, N.M.A., and Stewart, I.C. F. (eds.), Geological setting, palaeoenvironment, and archaeology of the Red Sea: Springer, Cham, p. 653–673.

Lambeck, K., Purcell, A., Flemming, N., Vita-Finzi, C., Alsharekh, A., and Bailey, G.N., 2011, Sea level and shoreline reconstructions for the Red Sea: Isostatic and tectonic considerations and implications for hominin migration out of Africa: Quaternary Science Reviews, v. 30, no. 25–26, p. 3,542–3,574.

Momber, G., Sakellariou, D., Rousakis, G., and Bailey, G.N., 2019, The multi-disciplinary search for underwater archaeology in the southern Red Sea: *in*: Rasul, N.M.A., and Stewart, I.C. F. (eds.), Geological setting, palaeoenvironment, and archaeology of the Red Sea: Springer, Cham, p. 609–632.

Penkman, K.E.H., Kaufman, D.S., Maddy, D., and Collins, M.J., 2008, Closed-system behaviour of the intra-crystalline fraction of amino acids in mollusc shells: Quaternary Geochronology, v. 3, no. 1–2, p. 2–25. 10.1016/j.quageo.2007.07.001

Sakellariou, D., Rousakis, G., Panagiotopoulos, I., and Bailey, G.N., 2019, Geological structure and geomorphological evolution of the Farasan Islands continental shelf, southern Red Sea, SW Saudi Arabia: *in*: Rasul, N.M.A., and Stewart, I.C.F. (eds.), Geological setting, palaeoenvironment, and archaeology of the Red Sea: Springer, Cham, p. 633–656.

Sanderson, D.C.W., and Kinnaird, T.C., 2019, Optically stimulated luminescence dating as a geochronological tool for late Quaternary sediments in the Red Sea region: *in*: Rasul, N.M.A., and Stewart, I.C.F. (eds.) Geological setting, palaeoenvironment, and archaeology of the Red Sea: Springer, Cham, p. 685–707.

Sinclair, A., Inglis, R., Shuttleworth, A., Foulds, F., and Alsharekh, A., 2019, Landscape archaeology, palaeolithic survey and coastal change along the southern Red Sea of Saudi Arabia: *in*: Rasul, N.M.A., and Stewart, I.C.F. (eds.), Geological setting, palaeoenvironment, and archaeology of the Red Sea: Springer, Cham, p. 533–552.

Taviani, M., Montagna, P., Rasul, N.M.A., Angeletti, L., and Bosworth, W., 2019, Pleistocene coral reefs on the Saudi Arabian side of the Gulf of Aqaba, Red Sea: *in*: Rasul, N.M.A., and Stewart, I.C.F. (eds.), Geological setting, palaeoenvironment, and archaeology of the Red Sea: Springer, Cham, p. 341–365.

Zarins, J., Al-Jawad Murad, A., and Al-Yish, K.S., 1981, The comprehensive archaeological survey program, a. The second preliminary report on the southwestern province: Atlal, the Journal of Saudi Arabian Archaeology, v 5, p. 9–42.

APPENDICES

Appendix 1: Dating Samples

Location 1	Code	U-series		Date	Information on the Bag	Additional Comments
		Yes	No			
Farasan Islands series						
Mursa al Hesen, 1st stop	FA0001	Y		29/11/2014	Sample for age dating	Bill Bosworth's notes
Mursa al Hesen, 1st stop	FA0002	Y		29/11/2014		Bill Bosworth's notes
Mursa al Hesen, 1st stop	FA0003	Y		29/11/2014	Coral for age dating	Bill Bosworth's notes
Mursa al Hesen, 2nd stop	FA0004		N	29/11/2014	Sample missing	Large Tridacna collected by Geoff
Mursa al Hesen, 2nd stop	FA0005		N	29/11/2014	Sample missing	Spondylus shell collected by Geoff
Mursa al Hesen, 2nd stop	FA0006	Y		29/11/2014		Another clam
Mursa al Hesen, 2nd stop	FA0007		N	29/11/2014	Dec	Adel's clam
Mursa al Hesen, 2nd stop	FA0008		N	29/11/2014	Sample for palaeoecology	Not a sample for dating
Mursa al Hesen, 2nd stop	FA0009	Y		29/11/2014		Najeeb's fan-shaped coral
Mursa al Hesen, 2nd stop	FA0010		N	29/11/2014		Shell for palaeoecology
Murrabaah Island	FA0011		N	30/11/2014	No samples collected	Record of shell midden
Murrabaah Island	FA0012		N	30/11/2014	Palaeoecology terrace surface	
Murrabaah Island	FA0013	Y		30/11/2014		From the tallest section on the island
Murrabaah Island	FA0014	Y		30/11/2014		From dropped cliff - Robyn and Geoff
Murrabaah Island	FA0015	Y		30/11/2014	Coral for age dating, on small island	Bag contains FA0015a and FA0015c
Murrabaah Island	FA0015a	Y		30/11/2014	80 cm below 15	Must be below 15c
Murrabaah Island	FA0015c	Y		30/11/2014	Tridacna	All FA0015 from the other side of the dropped cliff
Abalat Islands	FA0016	Y		30/11/2014	Sample for dating	Coral
Abalat Islands	FA0017		N	30/11/2014	Palaeoecology	Not for age dating
Ras Shida	FA0018	Y		01/12/2014	Bill and Najeeb samples	Highest terrace; Bill Bosworth's notes
Ras Shida	FA0019	Y		01/12/2014	Bill and Najeeb samples	Highest terrace; Bill Bosworth's notes
Ras Shida	FA0020	Y		01/12/2014	Geoff and Bill sample	Highest terrace; Bill Bosworth's notes
Ras Shida	FA0021	Y		01/12/2014	Sample for the SGS	Upper terrace, with sinkholes; NB 2 bags with the same number
Ras Shida	FA0021	Y		01/12/2014	Coral for age dating	Upper terrace, with sinkholes; NB 2 bags with the same number
Ras Shida	FA0022	Y		01/12/2014	Tridacna (bag, 1 Nov) [sic]	Lower terrace
Ras Shida	FA0023A	Y		01/12/2014	Coral for age dating	Lower terrace
Ras Shida	FA0023B	Y		01/12/2014	Tridacna	Lower terrace
Janaba Bay East	FA0024	Y		01/12/2014	Tridacna	Lowest terrace in the Janaba Bay, NW of Ras Shida
Janaba Bay North	FA0025	Y		01/12/2014	Coral	Lowest terrace surface near the power station and Janaba 4 shell mound
Harrat Al Birk series						
Dhahaban Quarry	HAB0001		N	03/12/2014	Vesicular basalt	Basalt block in the plastic bag (Bill)
Dhahaban Quarry	HAB0002		N	03/12/2014	Robyn sediments	Cross-bedded unit from the 'aeolianite' section

Appendix 1: Dating Samples--CONTINUED

Location 1	Code	U-series		Date	Information on the Bag	Additional Comments
		Yes	No			
Dhahaban Quarry	HAB0003		N	03/12/2014	Robyn sediments	Pebble unit from the 'aeolianite' section
Dhahaban Quarry	HAB0004		N	03/12/2014	Robyn sediments	Cross-bedded unit from the 'aeolianite' section
Dhahaban Quarry	HAB0005		N	03/12/2014	Robyn sediments	Unconsolidated unit below the cross-bedded unit, 'aeolianite' section
Dhahaban Quarry	HAB0006		N	03/12/2014	Robyn sediments	Modern dune surface
Dhahaban Quarry	HAB0007		N	03/12/2014	Basalt in calc. sandstone	Basalt cobbles from below/within the aeolianite unit
Dhahaban Quarry	HAB0008		N	03/12/2014	Vesicular basalt, base volcano	Basalt from the base of volcanic Jebel
Dhahaban Quarry	HAB0009		N	03/12/2014	No sample	Top of sst/aeolianite
Dhahaban Quarry	HAB0010	Y		03/12/2014	Coral, top of the flow	Large flake removed from the section
Dhahaban Quarry	HAB0011		N	03/12/2014	No sample	Spot height, no sample collected
Dhahaban Quarry	HAB0012	Y		03/12/2014	Large coral head	From the debris flow
Dhahaban Quarry	HAB0013	Y		03/12/2014	Small coral head	From the debris flow
Dhahaban Quarry	HAB0014	Y		03/12/2014	Large oyster shell	Base of the debris flow
Dhahaban Quarry	HAB0015	Y		03/12/2014	Coral	Coral in the section below the HAB0011 flake
Dhahaban Quarry	HAB0016	Y		03/12/2014	Coral	Coral in the section below HAB0015
Dhahaban Quarry	HAB0017		N	03/12/2014	Basalt, wadi bed	Basalt block in the plastic bag (Bill)
Dhahaban Quarry	HAB0018		N	03/12/2014	Cement, wadi base	Cement and pebbles from the wadi base
Dhahaban Quarry	HAB0019		N	03/12/2014	Basalt within the wadi flow (cobble)	
Dhahaban Quarry	HAB0020	Y		03/12/2014	Marine unit, bulldozer tracks	North side of the wadi and west, shells on the surface
Dhahaban Quarry	HAB0021		N	03/12/2014	Marine unit, top of the wadi section	North side of the wadi and west, shell
Dhahaban Quarry	HAB0022	Y		03/12/2014	Marine unit, top of the wadi section	West of HAB0021, shell
Dhahaban Quarry	HAB0023	Y		03/12/2014	Tridacna, shell unit surface	North side of the wadi and west, Tridacna embedded on the surface
Dhahaban Quarry	HAB0024	Y		03/12/2014	Tridacna	Similar location, loose on the surface
Dhahaban Quarry	HAB0025		N	03/12/2014	Surface coral	Coral in poor condition, not worth for age dating
Dhahaban Quarry	HAB0026	Y		03/12/2014	Coral from the terrace	In-situ brain coral from the area north of the small wadi
Dhahaban Quarry	HAB0027	Y		03/12/2014	Coral from the debris flow	No details in GB notes
Dhahaban Quarry	HAB0028	Y		03/12/2014	Coral cobble from the debris flow	No details in GB notes
Dhahaban Quarry	HAB0029		N	03/12/2014		No information
Dhahaban Quarry	HAB0030		N	03/12/2014	Basalt from the peak	Basalt block in plastic bag (Bill)
Dhahaban Quarry	HAB0031		N	03/12/2014	Vesicular basalt from the Jebel notch	Basalt block in plastic bag (Bill)
Dhahaban Quarry	HAB0032		N	03/12/2014	Calc. for petrography, highest position	
Al Birk North shell midden	HAB0033	Y		04/12/2014	Coral beneath the shell midden	
Al Birk North shell midden	HAB0034	Y		04/12/2014	Shell scatter north of Al Birk	
Al Birk North shell midden	HAB0035	Y		04/12/2014	Shell scatter terrace north of Al Birk	

Appendix 1: Dating Samples--CONTINUED

Location 1	Code	U-series		Date	Information on the Bag	Additional Comments
		Yes	No			
Al Birk North shell midden	HAB0036	Y		04/12/2014	Tridacna, Al Birk north, midden site	-
Al Birk North shell midden	HAB0037		N	04/12/2014	Shells from the reef, Al Birk	Presumed to be a palaeoecology sample
Al Birk North Gas Station	HAB0038	Y		04/12/2014	Coral for age dating	-
Al Birk North, Gas Station	HAB0039	Y		04/12/2014	Tridacna (broken) and bivalve + Tridacna (whole)	
Al Birk North, E of main road	HAB0040	Y		04/12/2014	Coral from the beachrock	-
Al Birk North, E of main road	HAB0041		N	04/12/2014	Struck flake	Not a sample for age dating
Al Birk headland	HAB0042		N	04/12/2014	Shell midden	Not a sample for age dating
Al Birk South	HAB0043	Y		04/12/2014	Tridacna from the reef remnant	By the main road south of Al Birk
Al Birk South	HAB0044A	Y		04/12/2014	1 of 2. Coral from large block (moved)	Massive coral next to track
Al Birk South	HAB0044B	Y		04/12/2014	2 of 2	Same as above
Al Qahma radar station	HAB0045A	Y		04/12/2014	Tridacna + Bivalve	Coral terrace E of volcanic cone
Al Qahma radar station	HAB0045B	Y		05/12/2014	Tridacna + other shell	Coral terrace E of volcanic cone
Al Qahma radar station	HAB0046	Y		05/12/2014	Tridacna	Coral terrace E of volcanic cone
Al Qahma radar station	HAB0047		N	05/12/2014	Gastropod shell	Coral terrace E of volcanic cone
Al Qahma South	HAB0048		N	06/12/2014	Pottery	Archaeological site near burial mounds
Totals	-	**47**	**32**	-	-	-

Appendix 2. GPS2 Farasan St1

Sample No.	UTM		Elevation (m)	Deg	Min	Sec	Deg	Min	Sec	Start Time	End Time
	East	North									
bas-1	808558.8040	1850349.6120	3.59	16	42	56.602660	41	53	36.415460	-	-
cos-1	808561.1970	1850335.2710	0.29	16	42	56.135430	41	53	36.489150	11/29/2014 01:20:11 PM	11/29/2014 01:20:18 PM
cos-2	808559.4900	1850333.4660	0.28	16	42	56.077570	41	53	36.430700	11/29/2014 01:20:34 PM	11/29/2014 01:20:36 PM
cos-3	808559.4900	1850333.4650	0.28	16	42	56.077560	41	53	36.430720	11/29/2014 01:21:00 PM	11/29/2014 01:21:02 PM
cos-4	808552.0220	1850340.1210	2.84	16	42	56.297390	41	53	36.182090	11/29/2014 01:23:16 PM	11/29/2014 01:23:18 PM
cos-5	808548.2790	1850346.0540	3.01	16	42	56.491990	41	53	36.058760	11/29/2014 01:24:18 PM	11/29/2014 01:24:20 PM
cos-6	808548.6890	1850345.1190	3.31	16	42	56.461430	41	53	36.072130	11/29/2014 01:24:54 PM	11/29/2014 01:24:56 PM
cos-7	808554.5280	1850329.1930	2.89	16	42	55.941040	41	53	36.261250	11/29/2014 01:26:33 PM	11/29/2014 01:26:35 PM
cos-8	808554.3240	1850329.7380	2.86	16	42	55.958860	41	53	36.254650	11/29/2014 01:27:00 PM	11/29/2014 01:27:02 PM
cos-9	808541.4450	1850348.7630	4.96	16	42	56.583260	41	53	35.829580	11/29/2014 01:32:43 PM	11/29/2014 01:32:45 PM
cos-10	808545.9210	1850340.4430	4.95	16	42	56.310730	41	53	35.976490	11/29/2014 01:33:11 PM	11/29/2014 01:33:13 PM
cos-11	808550.1210	1850330.5690	4.26	16	42	55.987850	41	53	36.113300	11/29/2014 01:33:35 PM	11/29/2014 01:33:37 PM
cos-12	808557.0450	1850321.5090	3.57	16	42	55.690090	41	53	36.342360	11/29/2014 01:34:01 PM	11/29/2014 01:34:03 PM
cos-13	808520.2840	1850403.7770	3.95	16	42	58.381310	41	53	35.142860	11/29/2014 01:37:13 PM	11/29/2014 01:37:15 PM
stm-7	808482.3850	1850409.5940	4.02	16	42	58.588300	41	53	33.867500	11/29/2014 01:43:24 PM	11/29/2014 01:43:26 PM
stm-8	808485.2980	1850410.9080	3.00	16	42	58.629620	41	53	33.966380	11/29/2014 01:44:13 PM	11/29/2014 01:44:15 PM

Appendix 2. GPS 2 Farasan St2--CONTINUED

Sample No.	UTM		Elevation (m)	Deg	Min	Sec	Deg	Min	Sec	Start Time	End Time
	East	North									
base 1	191899.8480	1842808.0020	5.45	16	38	51.703330	42	6	42.737180	-	-
BASE_1	191899.8480	1842808.0020	5.45	16	38	51.703330	42	6	42.737180	-	-
s-lev-1	191681.7260	1842856.6180	-0.02	16	38	53.180930	42	6	35.359440	12/01/2014 09:20	12/01/2014 09:20
s-lev-2	191673.9490	1842842.9560	0.00	16	38	52.733230	42	6	35.103900	12/01/2014 09:21	12/01/2014 09:21
s-lev-3	191663.4460	1842826.0510	0.01	16	38	52.178860	42	6	34.758020	12/01/2014 09:21	12/01/2014 09:21
top-1	191898.0050	1842806.0810	5.39	16	38	51.640040	42	6	42.675980	12/01/2014 09:27	12/01/2014 09:27
top-cor-1	191905.6920	1842823.6940	3.19	16	38	52.216110	42	6	42.926560	12/01/2014 09:25	12/01/2014 09:25
top-cor-2	191914.4760	1842830.0030	3.19	16	38	52.425270	42	6	43.219660	12/01/2014 09:26	12/01/2014 09:26
top-cor-3	191927.7540	1842841.5100	3.21	16	38	52.805530	42	6	43.661700	12/01/2014 09:26	12/01/2014 09:26

Appendix 2. GPS3: Farasan St3--CONTINUED

Sample No.	UTM		Elevation (m)	Deg	Min	Sec	Deg	Min	Sec	Start Time	End Time
	East	North									
base 1	188784.1730	1840961.6120	11.22	16	37	50.222600	42	4	58.601060	-	-
BASE_1	188784.1730	1840961.6120	11.22	16	37	50.222600	42	4	58.601060	-	-
cave	188691.8420	1840959.6340	15.35	16	37	50.114550	42	4	55.489440	12/01/2014 12:03	12/01/2014 12:03
cor-elv-1	188504.0910	1840790.0920	4.63	16	37	44.515210	42	4	49.243530	12/01/2014 13:26	12/01/2014 13:26
cor-elv-2	188503.5390	1840788.3300	4.64	16	37	44.457670	42	4	49.225800	12/01/2014 13:28	12/01/2014 13:28
cor-elv-3	188632.5680	1840755.3060	2.16	16	37	43.445560	42	4	53.591730	12/01/2014 13:36	12/01/2014 13:36
cor-elv-4	188654.8780	1840755.2740	2.48	16	37	43.455090	42	4	54.343830	12/01/2014 13:37	12/01/2014 13:37
crl tp 1	188807.6430	1840866.2860	26.02	16	37	47.135540	42	4	59.439140	12/01/2014 11:44	12/01/2014 11:44
gb arche	188555.1080	1841009.8630	10.24	16	37	51.682190	42	4	50.855250	12/01/2014 13:57	12/01/2014 13:57
mid t 1	188840.7300	1841254.3900	10.04	16	37	59.765040	42	5	0.363760	12/01/2014 14:10	12/01/2014 14:10
mid t 2	188810.7850	1841250.4700	10.08	16	37	59.623430	42	4	59.356180	12/01/2014 14:11	12/01/2014 14:11
mid t 3	188781.6970	1841224.9330	10.26	16	37	58.779680	42	4	58.388150	12/01/2014 14:12	12/01/2014 14:12
mid t 4	188753.4980	1841207.1670	10.55	16	37	58.188900	42	4	57.446220	12/01/2014 14:12	12/01/2014 14:12
mid t 5	188742.2350	1841197.1660	11.08	16	37	57.858520	42	4	57.071450	12/01/2014 14:13	12/01/2014 14:13
mid t 6	188741.7880	1841194.9510	12.10	16	37	57.786290	42	4	57.057470	12/01/2014 14:13	12/01/2014 14:13
mid t 7	188728.6210	1841187.0770	12.50	16	37	57.524140	42	4	56.617480	12/01/2014 14:13	12/01/2014 14:13
mid t 8	188726.6880	1841194.5260	12.31	16	37	57.765330	42	4	56.548650	12/01/2014 14:14	12/01/2014 14:14
mid t 9	188718.0390	1841196.5140	12.19	16	37	57.825840	42	4	56.256080	12/01/2014 14:14	12/01/2014 14:14
profile 1	188810.3450	1840740.3950	1.31	16	37	43.045220	42	4	59.592120	12/01/2014 13:42	12/01/2014 13:42
profile 2	188810.6340	1840747.5850	2.12	16	37	43.279040	42	4	59.598340	12/01/2014 13:42	12/01/2014 13:42
profile 3	188812.0490	1840756.7370	2.08	16	37	43.577140	42	4	59.641520	12/01/2014 13:43	12/01/2014 13:43
profile 4	188812.2760	1840764.8220	2.85	16	37	43.840030	42	4	59.645210	12/01/2014 13:43	12/01/2014 13:43
profile 5	188813.1010	1840773.1900	3.86	16	37	44.112390	42	4	59.668900	12/01/2014 13:44	12/01/2014 13:44
profile 6	188813.5500	1840779.9220	5.28	16	37	44.331400	42	4	59.680740	12/01/2014 13:44	12/01/2014 13:44
profile 7	188813.4900	1840787.1490	6.77	16	37	44.566270	42	4	59.675170	12/01/2014 13:44	12/01/2014 13:44
profile 8	188813.9860	1840794.9690	7.62	16	37	44.820640	42	4	59.688020	12/01/2014 13:45	12/01/2014 13:45
profile 9	188814.6920	1840803.6340	8.01	16	37	45.102620	42	4	59.707590	12/01/2014 13:45	12/01/2014 13:45
profile 10	188816.5580	1840812.6650	8.38	16	37	45.397010	42	4	59.766040	12/01/2014 13:45	12/01/2014 13:45
profile 11	188818.9360	1840823.2290	8.64	16	37	45.741480	42	4	59.841020	12/01/2014 13:46	12/01/2014 13:46
profile 12	188821.3160	1840831.6320	8.93	16	37	46.015730	42	4	59.917120	12/01/2014 13:46	12/01/2014 13:46
profile 13	188823.0900	1840838.2970	9.92	16	37	46.233170	42	4	59.973660	12/01/2014 13:46	12/01/2014 13:46
profile 14	188824.8610	1840843.8270	12.05	16	37	46.413760	42	5	0.030610	12/01/2014 13:47	12/01/2014 13:47
profile 15	188824.8600	1840848.4540	13.99	16	37	46.564120	42	5	0.028310	12/01/2014 13:47	12/01/2014 13:47
profile 16	188825.0940	1840852.8930	15.30	16	37	46.708520	42	5	0.034040	12/01/2014 13:47	12/01/2014 13:47
profile 17	188825.0770	1840855.4790	16.34	16	37	46.792570	42	5	0.032200	12/01/2014 13:48	12/01/2014 13:48
profile 18	188822.5830	1840858.4930	17.71	16	37	46.889320	42	4	59.946620	12/01/2014 13:48	12/01/2014 13:49

Appendix 2. GPS3: Farasan St3—CONTINUED

Sample No.	UTM		Elevation (m)	Deg	Min	Sec	Deg	Min	Sec	Start Time	End Time
	East	North									
samp-22	188961.0090	1841144.7600	8.52	16	37	56.258920	42	5	4.472480	12/01/2014 14:21	12/01/2014 14:21
samp-23	188827.9730	1841300.5820	9.07	16	38	1.260290	42	4	59.911000	12/01/2014 14:30	12/01/2014 14:30
s-lev-1	188611.0600	1841650.4050	-1.70	16	38	12.527050	42	4	52.426310	12/01/2014 11:08	12/01/2014 11:08
s-lev-2	188629.8770	1841650.7100	-1.73	16	38	12.545890	42	4	53.060520	12/01/2014 11:10	12/01/2014 11:10
s-lev-3	188639.0880	1841656.0790	-1.64	16	38	12.724760	42	4	53.368390	12/01/2014 11:11	12/01/2014 11:11
smp-18	188629.1260	1840830.0230	22.95	16	37	45.872310	42	4	53.438940	12/01/2014 11:33	12/01/2014 11:33
smp-19	188652.0510	1840839.3970	19.99	16	37	46.187860	42	4	54.207180	12/01/2014 11:36	12/01/2014 11:36
smp-21	188658.2650	1840957.1660	15.59	16	37	50.018420	42	4	54.358730	12/01/2014 12:22	12/01/2014 12:22
smpl 20	188863.1540	1840897.9840	20.81	16	37	48.192070	42	5	1.294920	12/01/2014 11:48	12/01/2014 11:48
topo coral 1	188408.9470	1840848.6500	6.27	16	37	46.373280	42	4	46.007300	12/01/2014 13:08	12/01/2014 13:08
topo coral 2	188443.6280	1840864.8570	6.82	16	37	46.916460	42	4	47.168470	12/01/2014 13:09	12/01/2014 13:09
topo coral 3	188464.3270	1840870.6500	7.09	16	37	47.114570	42	4	47.863380	12/01/2014 13:10	12/01/2014 13:10
topo coral 4	188485.1880	1840875.5070	7.88	16	37	47.282330	42	4	48.564240	12/01/2014 13:10	12/01/2014 13:10
topo coral 5	188502.5390	1840877.2550	8.53	16	37	47.347380	42	4	49.148320	12/01/2014 13:11	12/01/2014 13:11
topo coral 6	188524.7060	1840868.6650	8.67	16	37	47.078690	42	4	49.899810	12/01/2014 13:12	12/01/2014 13:12
topo coral 7	188554.6700	1840867.9140	9.61	16	37	47.068490	42	4	50.910320	12/01/2014 13:13	12/01/2014 13:13
topo coral 8	188586.3250	1840870.1030	10.19	16	37	47.154670	42	4	51.976350	12/01/2014 13:13	12/01/2014 13:13
topo coral 9	188595.2560	1840887.4710	10.98	16	37	47.723380	42	4	52.268890	12/01/2014 13:14	12/01/2014 13:14
topo coral 10	188589.0950	1840918.3680	11.32	16	37	48.724660	42	4	52.046000	12/01/2014 13:15	12/01/2014 13:15
topo coral 11	188583.2240	1840931.9960	10.46	16	37	49.164780	42	4	51.841390	12/01/2014 13:15	12/01/2014 13:15
topo coral 12	188558.7120	1840935.7660	8.96	16	37	49.275680	42	4	51.013190	12/01/2014 13:16	12/01/2014 13:16
topo coral 13	188521.9170	1840926.4010	8.41	16	37	48.953850	42	4	49.777390	12/01/2014 13:17	12/01/2014 13:17
topo coral 14	188491.1550	1840921.9350	7.91	16	37	48.794100	42	4	48.742560	12/01/2014 13:17	12/01/2014 13:17
topo coral 15	188444.2690	1840904.7030	7.12	16	37	48.211810	42	4	47.170440	12/01/2014 13:18	12/01/2014 13:18
topo coral 16	188414.1440	1840899.1570	6.60	16	37	48.017260	42	4	46.157620	12/01/2014 13:19	12/01/2014 13:19
topo coral 17	188383.0210	1840888.6750	5.92	16	37	47.661830	42	4	45.113600	12/01/2014 13:20	12/01/2014 13:20
topo coral 18	188378.0520	1840880.2140	5.57	16	37	47.384480	42	4	44.950270	12/01/2014 13:20	12/01/2014 13:20
topo coral 19	188367.7940	1840870.2880	5.15	16	37	47.056990	42	4	44.609320	12/01/2014 13:21	12/01/2014 13:21
topo coral 20	188366.5750	1840865.0660	5.38	16	37	46.886680	42	4	44.570810	12/01/2014 13:21	12/01/2014 13:21
topo coral 21	188364.1760	1840856.6140	5.12	16	37	46.610860	42	4	44.494110	12/01/2014 13:22	12/01/2014 13:22
topo coral 22	188381.7880	1840850.8580	5.79	16	37	46.432140	42	4	45.090660	12/01/2014 13:22	12/01/2014 13:22

Appendix 2. GPS3: Farasan St3—CONTINUED

Sample No.	UTM		Elevation (m)	Deg	Min	Sec	Deg	Min	Sec	Start Time	End Time
	East	North									
topo coral 23	188392.7640	1840850.6580	6.10	16	37	46.430840	42	4	45.460750	12/01/2014 13:23	12/01/2014 13:23
topo coral 24	188399.1430	1840860.1870	6.55	16	37	46.743580	42	4	45.671110	12/01/2014 13:23	12/01/2014 13:23
topo coral 25	188420.6640	1840868.7080	6.87	16	37	47.030740	42	4	46.392410	12/01/2014 13:23	12/01/2014 13:23

Appendix 2. GPS4: Farasan St4—CONTINUED

Sample No.	UTM		Elevation (m)	Deg	Min	Sec	Deg	Min	Sec	Start Time	End Time
	East	North									
base 1	191788.4450	1842690.9560	5.26	16	38	47.846760	42	6	39.038260	-	-
BASE_1	191788.4450	1842690.9560	5.26	16	38	47.846760	42	6	39.038260	-	-
farasan st 2 bas	191903.0770	1842808.6630	7.07	16	38	51.726350	42	6	42.845720	12/01/2014 15:57	12/01/2014 15:57
old crs ln 1	191693.9140	1842868.4340	1.86	16	38	53.570700	42	6	35.764580	12/01/2014 16:37	12/01/2014 16:37
prof 2-1	191786.5520	1842694.5690	5.08	16	38	47.963320	42	6	38.972650	12/01/2014 16:01	12/01/2014 16:01
prof 2-2	191784.9660	1842697.0810	4.97	16	38	48.044230	42	6	38.917960	12/01/2014 16:02	12/01/2014 16:02
prof 2-3	191783.7100	1842699.9460	4.94	16	38	48.136740	42	6	38.874230	12/01/2014 16:02	12/01/2014 16:02
prof 2-4	191783.5250	1842700.2470	4.91	16	38	48.146450	42	6	38.867840	12/01/2014 16:04	12/01/2014 16:04
prof 2-5	191783.4310	1842700.4620	4.79	16	38	48.153380	42	6	38.864560	12/01/2014 16:06	12/01/2014 16:06
prof 2-6	191783.0960	1842701.1360	4.71	16	38	48.175130	42	6	38.852940	12/01/2014 16:08	12/01/2014 16:08
prof 2-7	191782.8890	1842701.5210	2.90	16	38	48.187560	42	6	38.845790	12/01/2014 16:09	12/01/2014 16:09
prof 2-8	191779.2920	1842708.4280	2.66	16	38	48.410340	42	6	38.721140	12/01/2014 16:10	12/01/2014 16:10
prof 2-9	191778.5810	1842710.3700	2.59	16	38	48.473130	42	6	38.696230	12/01/2014 16:12	12/01/2014 16:12
prof 2-10	191778.5880	1842711.1700	2.83	16	38	48.499130	42	6	38.696060	12/01/2014 16:13	12/01/2014 16:13
prof 2-11	191776.5630	1842713.3500	2.65	16	38	48.569020	42	6	38.626720	12/01/2014 16:14	12/01/2014 16:14
prof 2-12	191774.0640	1842718.3210	2.79	16	38	48.729420	42	6	38.540070	12/01/2014 16:14	12/01/2014 16:14
prof 2-13	191773.1520	1842719.5790	2.44	16	38	48.769880	42	6	38.508690	12/01/2014 16:14	12/01/2014 16:14
prof 2-14	191771.0780	1842723.1220	2.48	16	38	48.884060	42	6	38.437030	12/01/2014 16:15	12/01/2014 16:15
prof 2-15	191769.5480	1842726.7180	2.88	16	38	49.000230	42	6	38.383710	12/01/2014 16:15	12/01/2014 16:15
prof 2-16	191766.7340	1842731.1530	2.86	16	38	49.143050	42	6	38.286660	12/01/2014 16:16	12/01/2014 16:16
prof 2-17	191764.4890	1842735.8040	2.98	16	38	49.293180	42	6	38.208700	12/01/2014 16:16	12/01/2014 16:16
prof 2-18	191762.7840	1842740.4190	3.02	16	38	49.442350	42	6	38.148970	12/01/2014 16:17	12/01/2014 16:17
prof 2-19	191758.6820	1842746.9400	3.00	16	38	49.652360	42	6	38.007490	12/01/2014 16:17	12/01/2014 16:17
prof 2-20	191754.9960	1842754.2930	2.96	16	38	49.889620	42	6	37.879640	12/01/2014 16:18	12/01/2014 16:18
prof 2-21	191748.6740	1842766.0290	2.85	16	38	50.268100	42	6	37.660780	12/01/2014 16:19	12/01/2014 16:19

Appendix 2. GPS4: Farasan St4--CONTINUED

Sample No.	UTM		Elevation (m)	Deg	Min	Sec	Deg	Min	Sec	Start Time	End Time
	East	North									
prof 2-22	191745.3620	1842772.3670	2.80	16	38	50.472540	42	6	37.546010	12/01/2014 16:20	12/01/2014 16:20
prof 2-23	191736.1830	1842783.2990	2.56	16	38	50.823540	42	6	37.231230	12/01/2014 16:20	12/01/2014 16:20
prof 2-24	191730.6290	1842792.5760	2.40	16	38	51.122460	42	6	37.039440	12/01/2014 16:21	12/01/2014 16:21
prof 2-25	191728.0240	1842805.1480	2.75	16	38	51.529840	42	6	36.945490	12/01/2014 16:23	12/01/2014 16:23
prof 2-26	191726.3380	1842826.1750	2.74	16	38	52.212450	42	6	36.878380	12/01/2014 16:23	12/01/2014 16:23
prof 2-27	191711.1920	1842837.2450	2.60	16	38	52.565130	42	6	36.362350	12/01/2014 16:24	12/01/2014 16:24
prof 2-28	191705.4510	1842848.0590	2.45	16	38	52.913900	42	6	36.163500	12/01/2014 16:25	12/01/2014 16:25
prof 2-29	191704.1800	1842850.0620	2.53	16	38	52.978410	42	6	36.119670	12/01/2014 16:26	12/01/2014 16:26
prof 2-30	191703.3160	1842851.8150	2.60	16	38	53.034970	42	6	36.089670	12/01/2014 16:27	12/01/2014 16:27
prof 2-31	191702.3030	1842853.8420	1.54	16	38	53.100390	42	6	36.054540	12/01/2014 16:28	12/01/2014 16:28
prof 2-32	191700.8340	1842856.4740	1.52	16	38	53.185250	42	6	36.003730	12/01/2014 16:28	12/01/2014 16:28
prof 2-33	191699.6050	1842858.4970	2.25	16	38	53.250420	42	6	35.961320	12/01/2014 16:29	12/01/2014 16:29
prof 2-34	191699.7120	1842861.2000	2.32	16	38	53.338320	42	6	35.963610	12/01/2014 16:30	12/01/2014 16:30
prof 2-35	191696.8110	1842864.1970	3.11	16	38	53.434380	42	6	35.864320	12/01/2014 16:31	12/01/2014 16:31
prof 2-36	191696.8020	1842864.2000	3.11	16	38	53.434450	42	6	35.864030	12/01/2014 16:31	12/01/2014 16:31
prof 2-37	191695.0980	1842867.5200	2.03	16	38	53.541560	42	6	35.804970	12/01/2014 16:32	12/01/2014 16:32
prof 2-38	191692.8760	1842871.7710	1.49	16	38	53.678680	42	6	35.727970	12/01/2014 16:33	12/01/2014 16:33
prof 2-39	191692.5030	1842872.4690	1.42	16	38	53.701200	42	6	35.715040	12/01/2014 16:33	12/01/2014 16:33
prof 2-40 crs	191692.5000	1842872.4800	1.42	16	38	53.701540	42	6	35.714950	12/01/2014 16:34	12/01/2014 16:34
prof 2-40 crt	191689.1780	1842878.8600	1.32	16	38	53.907360	42	6	35.599820	12/01/2014 16:35	12/01/2014 16:35
smpl 24	191790.7920	1842709.1670	4.50	16	38	48.439760	42	6	39.108510	12/01/2014 16:49	12/01/2014 16:50
wcn 1	191951.3140	1842856.3180	4.78	16	38	53.297860	42	6	44.448850	12/01/2014 16:56	12/01/2014 16:56
wcn 2	191947.7690	1842857.8720	3.50	16	38	53.346700	42	6	44.328570	12/01/2014 16:57	12/01/2014 16:57
wcn 3	192012.8590	1842945.5220	4.78	16	38	56.226080	42	6	46.480390	12/01/2014 17:01	12/01/2014 17:01
wcn 4	192008.9570	1842948.0000	4.00	16	38	56.304800	42	6	46.347630	12/01/2014 17:01	12/01/2014 17:01
wcn 5	192061.0900	1843029.2140	4.71	16	38	58.968880	42	6	48.065770	12/01/2014 17:02	12/01/2014 17:02

Appendix 2. GPS5: Solan--CONTINUED

Sample No.	UTM Zone37		Elevation (m)	Deg	Min	Sec	Deg	Min	Sec	Start Time	End Time
	East	North									
bas-1	201970.7520	1852803.0290	6.48	16	44	21.239880	42	12	17.569040	-	-
bas-1	201970.3280	1852798.8360	5.70	16	44	21.103400	42	12	17.556720	-	-
m-s-lv-1	201910.0970	1852823.0560	-0.01	16	44	21.863120	42	12	15.513410	11/30/2014 12:03:12 PM	11/30/2014 12:03:14 PM
m-s-lv-2	201895.3780	1852809.9270	0.01	16	44	21.429650	42	12	15.023110	11/30/2014 12:03:50 PM	11/30/2014 12:03:52 PM
sampl-13	201977.9900	1852875.8270	9.22	16	44	23.609450	42	12	17.778680	11/30/2014 11:42:55 AM	11/30/2014 11:43:12 AM
sampl-14	201958.7780	1852878.3820	6.15	16	44	23.683700	42	12	17.129370	11/30/2014 11:46:53 AM	11/30/2014 11:46:55 AM
sampl-15	201956.8700	1852897.5930	8.20	16	44	24.307270	42	12	17.055890	11/30/2014 11:52:18 AM	11/30/2014 11:52:20 AM

Appendix 2. GPS6: Dahban St1--CONTINUED

Sample No.	UTM Zone37		Elevation (m)	Geologic Code	Deg	Min	Sec	Deg	Min	Sec	Start Time	End Time
	East	North										
1	777333.3160	2000525.3370	6.72	BR	18	4	32.394120	41	37	12.448960	03/12/2014 12:03	03/12/2014 12:03
2	777343.9830	2000513.5480	6.66	BR	18	4	32.005990	41	37	12.805770	03/12/2014 12:05	03/12/2014 12:05
3	777350.7190	2000507.0100	6.55	B	18	4	31.790350	41	37	13.031570	03/12/2014 12:06	03/12/2014 12:06
4	777369.2070	2000483.5080	6.53	B	18	4	31.017880	41	37	13.648510	03/12/2014 12:07	03/12/2014 12:08
5	777376.6570	2000469.2640	6.05	D	18	4	30.551460	41	37	13.894850	03/12/2014 12:08	03/12/2014 12:09
6	777395.6120	2000449.8090	5.68	D	18	4	29.910350	41	37	14.529630	03/12/2014 12:10	03/12/2014 12:10
7	777408.9070	2000433.2660	5.77	B	18	4	29.366460	41	37	14.973490	03/12/2014 12:11	03/12/2014 12:11
8	777421.6660	2000417.2870	5.90	B	18	4	28.841200	41	37	15.399370	03/12/2014 12:12	03/12/2014 12:12
9	777430.9770	2000405.8480	5.96	B	18	4	28.465060	41	37	15.710290	03/12/2014 12:13	03/12/2014 12:13
10	777435.8290	2000399.8200	5.94	C	18	4	28.266910	41	37	15.872290	03/12/2014 12:13	03/12/2014 12:14
11	777448.6990	2000384.7370	5.95	C	18	4	27.770700	41	37	16.302400	03/12/2014 12:15	03/12/2014 12:15
12	777480.3970	2000344.6480	6.14	C	18	4	26.452990	41	37	17.360290	03/12/2014 12:17	03/12/2014 12:17
13	777486.8540	2000336.7980	6.31	C	18	4	26.194820	41	37	17.575920	03/12/2014 12:18	03/12/2014 12:18
14	777488.2310	2000334.6440	6.42	B	18	4	26.124180	41	37	17.621690	03/12/2014 12:18	03/12/2014 12:18
15	777496.9440	2000323.3560	6.58	B	18	4	25.753250	41	37	17.912340	03/12/2014 12:19	03/12/2014 12:19
16	777508.0100	2000310.7590	6.70	B	18	4	25.338670	41	37	18.282350	03/12/2014 12:20	03/12/2014 12:20
17	777522.8120	2000288.8550	6.64	B	18	4	24.619880	41	37	18.774810	03/12/2014 12:22	03/12/2014 12:22
18	777528.6410	2000278.1550	6.25	C	18	4	24.269380	41	37	18.967730	03/12/2014 12:22	03/12/2014 12:22
19	777546.6600	2000262.5620	6.20	C	18	4	23.754190	41	37	19.572580	03/12/2014 12:24	03/12/2014 12:24
20	777555.5130	2000251.7850	5.74	C	18	4	23.399810	41	37	19.868250	03/12/2014 12:24	03/12/2014 12:24
21	777557.0330	2000249.0620	5.62	B	18	4	23.310600	41	37	19.918600	03/12/2014 12:25	03/12/2014 12:25
22	777560.9770	2000243.4030	5.24	B	18	4	23.124850	41	37	20.049880	03/12/2014 12:26	03/12/2014 12:26
23	777562.0050	2000242.0220	5.15	C	18	4	23.079490	41	37	20.084150	03/12/2014 12:26	03/12/2014 12:26

Appendix 2. GPS6: Dahban St1--CONTINUED

Sample No.	UTM Zone37		Elevation (m)	Geologic Code	Deg	Min	Sec	Deg	Min	Sec	Start Time	End Time
	East	North										
24	777565.0350	2000237.2750	5.09	C	18	4	22.923780	41	37	20.184820	03/12/2014 12:27	03/12/2014 12:27
25	777585.7500	2000238.3660	5.61	BR	18	4	22.949680	41	37	20.889340	03/12/2014 12:30	03/12/2014 12:30
26	777587.0230	2000239.5740	5.62	B	18	4	22.988350	41	37	20.933210	03/12/2014 12:30	03/12/2014 12:30
27	777600.4180	2000232.0510	5.71	B	18	4	22.737640	41	37	21.384780	03/12/2014 12:31	03/12/2014 12:31
28	777605.5550	2000215.8550	5.88	BR	18	4	22.208800	41	37	21.551550	03/12/2014 12:32	03/12/2014 12:32
29	777611.0550	2000205.9150	5.73	BR	18	4	21.883160	41	37	21.733650	03/12/2014 12:33	03/12/2014 12:33
30	777613.8450	2000198.5020	5.29	D	18	4	21.640920	41	37	21.824890	03/12/2014 12:34	03/12/2014 12:34
31	777616.1240	2000190.0540	5.45	BR	18	4	21.365270	41	37	21.898260	03/12/2014 12:35	03/12/2014 12:35
32	777617.0770	2000181.8510	5.53	LSS	18	4	21.098220	41	37	21.926690	03/12/2014 12:36	03/12/2014 12:36
33	777618.2510	2000176.5520	5.12	LSS	18	4	20.925430	41	37	21.964030	03/12/2014 12:36	03/12/2014 12:36
34	777617.2240	2000176.2390	2.92	D	18	4	20.915720	41	37	21.928980	03/12/2014 12:39	03/12/2014 12:39
35	777622.8210	2000167.9390	1.43	D	18	4	20.643340	41	37	22.115170	03/12/2014 12:40	03/12/2014 12:40
36	777630.5030	2000158.8140	2.85	D	18	4	20.343190	41	37	22.371850	03/12/2014 12:42	03/12/2014 12:42
37	777631.8090	2000156.0490	5.42	LSS	18	4	20.252700	41	37	22.414890	03/12/2014 12:43	03/12/2014 12:43
38	777632.4460	2000151.3630	5.67	LSS	18	4	20.100090	41	37	22.434270	03/12/2014 12:44	03/12/2014 12:44
39	777632.6340	2000150.8530	5.92	WSS	18	4	20.083440	41	37	22.440420	03/12/2014 12:44	03/12/2014 12:44
40	777643.8080	2000141.9550	6.36	WSS	18	4	19.789050	41	37	22.815850	03/12/2014 12:45	03/12/2014 12:45
41	777656.1170	2000126.1080	6.41	WSS	18	4	19.268250	41	37	23.226510	03/12/2014 12:46	03/12/2014 12:46
bas-1	777697.3130	2000024.3760	6.82		18	4	15.942480	41	37	24.577380	03/12/2014 10:38	03/12/2014 10:41
BM-638	773181.9940	2008155.5290	5.98		18	8	42.319190	41	34	54.998480	03/12/2014 09:08	03/12/2014 09:08
BM 651	777234.6470	2000649.1090	12.88	WSS	18	4	36.462800	41	37	9.155390	03/12/2014 13:49	03/12/2014 13:49
BM 652	777357.9490	2000127.8200	3.00	WSS	18	4	19.461600	41	37	13.094280	03/12/2014 13:58	03/12/2014 13:58
BM 652	777357.9490	2000127.8200	3.00	WSS	18	4	19.461600	41	37	13.094280	03/12/2014 13:50	03/12/2014 13:50
BM 654	778044.3690	1999233.7100	11.54	WSS	18	3	50.081820	41	37	35.989490	03/12/2014 14:06	03/12/2014 14:06
BM 654-1	778044.3680	1999233.7190	11.58	WSS	18	3	50.082120	41	37	35.989450	03/12/2014 14:09	03/12/2014 14:09
C SPT H	777548.2440	2000209.0700	4.03		18	4	22.014740	41	37	19.600590	03/12/2014 16:50	03/12/2014 16:50
CORAL	777659.1570	2000185.9880	3.25		18	4	21.213250	41	37	23.358760	03/12/2014 17:32	03/12/2014 17:32
CORAL-1	777659.1540	2000185.9810	3.25		18	4	21.213010	41	37	23.358660	03/12/2014 17:33	03/12/2014 17:33
END L	777657.0480	2000125.6530	6.43		18	4	19.253040	41	37	23.257950	03/12/2014 11:49	03/12/2014 11:49
GMN-538	773202.0830	2008172.8610	7.36		18	8	42.873380	41	34	55.689770	-	-
GREFLA	777771.7740	1999982.6100	14.35	SS	18	4	14.550480	41	37	27.087720	03/12/2014 14:52	03/12/2014 14:52
HAB002	777739.3320	1999928.6740	12.44	SS	18	4	12.812320	41	37	25.959150	03/12/2014 14:44	03/12/2014 14:44
HAB003	777739.2990	1999929.9700	10.18	D	18	4	12.854470	41	37	25.958650	03/12/2014 14:39	03/12/2014 14:39
HAB004	777739.3020	1999930.2840	9.56	D	18	4	12.864640	41	37	25.958900	03/12/2014 14:38	03/12/2014 14:38
HAB005	777756.8310	1999955.4180	11.48	D	18	4	13.673520	41	37	26.566760	03/12/2014 14:36	03/12/2014 14:36
HAB008	777692.0280	1999797.7880	10.03	B	18	4	8.579780	41	37	24.288360	03/12/2014 14:28	03/12/2014 14:28

Appendix 2. GPS6: Dahban St1--CONTINUED

Sample No.	UTM Zone37		Elevation (m)	Geologic Code	Deg	Min	Sec	Deg	Min	Sec	Start Time	End Time
	East	North										
HAB010	777709.7670	2000171.4670	4.32		18	4	20.717840	41	37	25.071680	03/12/2014 15:43	03/12/2014 15:43
HAB011	777710.0020	2000170.8810	5.30	C	18	4	20.698690	41	37	25.079400	03/12/2014 15:39	03/12/2014 15:39
HAB012	777699.4430	2000172.5140	3.34		18	4	20.756660	41	37	24.721350	03/12/2014 15:49	03/12/2014 15:49
HAB013	777698.8570	2000172.7960	3.57		18	4	20.766090	41	37	24.701570	03/12/2014 15:49	03/12/2014 15:49
HAB014	777699.3910	2000173.0900	3.26		18	4	20.775410	41	37	24.719860	03/12/2014 15:50	03/12/2014 15:50
HAB015	777710.5760	2000170.7850	4.62		18	4	20.695320	41	37	25.098850	03/12/2014 16:01	03/12/2014 16:01
HAB016	777710.3010	2000171.1430	4.21		18	4	20.707070	41	37	25.089700	03/12/2014 16:02	03/12/2014 16:02
HAB017	777735.5020	2000187.3990	4.63		18	4	21.223810	41	37	25.953960	03/12/2014 16:22	03/12/2014 16:22
HAB018	777733.4850	2000185.3640	4.45		18	4	21.158620	41	37	25.884450	03/12/2014 16:24	03/12/2014 16:24
HAB020	777647.3050	2000192.8550	4.28		18	4	21.441910	41	37	22.959300	03/12/2014 16:37	03/12/2014 16:37
HAB021	777621.5650	2000175.8760	4.90		18	4	20.901930	41	37	22.076340	03/12/2014 16:45	03/12/2014 16:45
HAB022	777578.5600	2000177.4690	3.67		18	4	20.973560	41	37	20.615600	03/12/2014 16:47	03/12/2014 16:47
HAB023	777346.5870	2000516.4250	6.82		18	4	32.098310	41	37	12.895670	03/12/2014 17:00	03/12/2014 17:00
HAB024	777461.0340	2000340.1830	5.03		18	4	26.316790	41	37	16.700080	03/12/2014 17:07	03/12/2014 17:07
HAB024-1	777462.4140	2000336.1640	5.97		18	4	26.185520	41	37	16.745040	03/12/2014 17:08	03/12/2014 17:08
HAB025	777507.1110	2000263.7880	5.96		18	4	23.812310	41	37	18.229110	03/12/2014 17:11	03/12/2014 17:11
HAB026	777557.0090	2000236.8950	5.13		18	4	22.915130	41	37	19.911880	03/12/2014 17:24	03/12/2014 17:24
HAB027	777702.6070	2000172.2580	3.82		18	4	20.746880	41	37	24.828730	03/12/2014 17:36	03/12/2014 17:36
HAB028	777701.4700	2000171.8410	4.27		18	4	20.733860	41	37	24.789900	03/12/2014 17:39	03/12/2014 17:39
HAB-007	777710.7850	1999820.8220	15.29	WSS	18	4	9.319810	41	37	24.936920	03/12/2014 14:23	03/12/2014 14:23
OALD-	777845.5990	2000199.3000	9.97	SS	18	4	21.559790	41	37	29.701310	03/12/2014 15:19	03/12/2014 15:20
OALD-	777744.0140	2000168.3860	8.74	SS	18	4	20.601890	41	37	26.234070	03/12/2014 15:23	03/12/2014 15:23
ORGFLA	777741.2460	1999930.7900	13.64	SS	18	4	12.880210	41	37	26.025210	03/12/2014 14:47	03/12/2014 14:47
SEA LVL 1	776785.1360	1999161.5600	0.03	WSS	18	3	48.317550	41	36	53.162420	03/12/2014 13:23	03/12/2014 13:23
SEA LVL 2	776772.3120	1999164.9240	-0.01	WSS	18	3	48.432810	41	36	52.728260	03/12/2014 13:23	03/12/2014 13:23
SEA LVL 3	776772.3030	1999164.9320	-0.02	WSS	18	3	48.433050	41	36	52.727930	03/12/2014 13:24	03/12/2014 13:24
SEA LVL 4	776755.0860	1999169.8200	0.01	WSS	18	3	48.599860	41	36	52.145200	03/12/2014 13:24	03/12/2014 13:24
SST1	777711.6400	1999823.3240	17.31	SS	18	4	9.400740	41	37	24.967170	03/12/2014 14:25	03/12/2014 14:25
SSTSMPL1	777771.6740	1999944.2770	21.04	SS	18	4	13.304530	41	37	27.065810	03/12/2014 14:49	03/12/2014 14:49
START L	777323.3990	2000538.9850	7.06	B	18	4	32.842290	41	37	12.118520	03/12/2014 11:59	03/12/2014 11:59
TPSST1	777773.1580	1999929.3360	24.14	SS	18	4	12.818190	41	37	27.108990	03/12/2014 14:56	03/12/2014 14:56
WAD FL B	777735.5030	2000187.4030	4.62		18	4	21.223970	41	37	25.954010	03/12/2014 16:20	03/12/2014 16:20

Appendix 2. GPS7: AlBirk St1--CONTINUED

Sample No.	UTM		Elevation (m)	Geologic Code	Deg	Min	Sec	Deg	Min	Sec	Start Time	End Time
	East	North										
ctot-1	771320.2920	2011198.7240	3.30	C	18	10	22.087630	41	33	53.145460	12/04/2014 15:29	12/04/2014 15:29
ctot-2	771325.7340	2011185.3700	3.43	C	18	10	21.651080	41	33	53.324150	12/04/2014 15:30	12/04/2014 15:30
ctot-3	771334.2730	2011202.7310	3.60	C	18	10	22.211520	41	33	53.622780	12/04/2014 15:30	12/04/2014 15:30
GMN-538	773202.0830	2008172.8610	7.46		18	8	42.873380	41	34	55.689770	-	-
HAB043	771358.2400	2011297.2870	2.29	CLAM	18	10	25.274270	41	33	54.482710	12/04/2014 15:34	12/04/2014 15:34
Hab044	771307.8080	2011199.6760	3.19	C	18	10	22.124230	41	33	52.721370	12/04/2014 15:28	12/04/2014 15:28
INSCRIPTION	772883.9790	2007168.5970	13.67		18	8	10.374440	41	34	44.395520	12/04/2014 16:49	12/04/2014 16:49
SLVL-1	770930.8330	2011103.0720	0.02		18	10	19.155100	41	33	39.856370	12/04/2014 16:22	12/04/2014 16:22
SLVL-2	770926.1550	2011097.5930	0.00		18	10	18.979150	41	33	39.694690	12/04/2014 16:22	12/04/2014 16:23
SLVL-3	770915.7230	2011090.1180	-0.02		18	10	18.740890	41	33	39.336400	12/04/2014 16:23	12/04/2014 16:23
TOTC-1	771366.6050	2011290.6040	3.20		18	10	25.053210	41	33	54.764010	12/04/2014 15:35	12/04/2014 15:35
TOTC-2	771371.8630	2011302.1890	3.20		18	10	25.427420	41	33	54.948290	12/04/2014 15:35	12/04/2014 15:35
TOTC-3	771380.7830	2011305.0200	3.50		18	10	25.515390	41	33	55.252990	12/04/2014 15:36	12/04/2014 15:36
TOTC-4	771509.4440	2010766.3690	4.69	C	18	10	7.947690	41	33	59.372100	12/04/2014 16:11	12/04/2014 16:11
TOTC-5	771526.5020	2010779.1870	4.85	C	18	10	8.356600	41	33	59.958260	12/04/2014 16:12	12/04/2014 16:12
TOTC-6	771520.7070	2010757.8600	4.82	C	18	10	7.665980	41	33	59.751070	12/04/2014 16:13	12/04/2014 16:13
TOTC-7	771511.1320	2010744.0650	4.53	C	18	10	7.221930	41	33	59.418890	12/04/2014 16:13	12/04/2014 16:13

Appendix 2. GPS8: AlBirk St2--CONTINUED

Sample No.	UTM		Elevation (m)	Geologic Code	Deg	Min	Sec	Deg	Min	Sec	Start Time	End Time
	East	North										
bas-1	765808.6390	2020724.1570	11.59		18	15	34.207560	41	30	50.161500	04/12/2014 11:17	04/12/2014 11:20
BR-1	767339.1420	2018598.1580	4.87	BR	18	14	24.412580	41	31	41.234170	04/12/2014 12:28	04/12/2014 12:28
BR-2	767339.3870	2018624.2720	5.97	BR	18	14	25.261360	41	31	41.254760	04/12/2014 12:30	04/12/2014 12:30
BR-3	767316.3400	2018639.3790	6.27	BR	18	14	25.762790	41	31	40.477830	04/12/2014 12:31	04/12/2014 12:31
HAB033	765906.6810	2021678.1660	3.17	BR	18	16	5.175400	41	30	53.944030	04/12/2014 12:58	04/12/2014 12:58
HAB034	765906.8790	2021679.2960	2.36	BR	18	16	5.212050	41	30	53.951290	04/12/2014 12:59	04/12/2014 12:59
HAB035	765907.0830	2021679.3490	2.66	BR	18	16	5.213680	41	30	53.958240	04/12/2014 13:00	04/12/2014 13:00
HAB038	765866.4040	2020796.1550	2.04		18	15	36.522140	41	30	52.160560	04/12/2014 12:12	04/12/2014 12:12
HAB039	765872.4290	2020798.8540	1.35		18	15	36.607180	41	30	52.366830	04/12/2014 12:14	04/12/2014 12:14
HAB040	767392.7240	2018580.2290	4.22	BR	18	14	23.805710	41	31	43.048570	04/12/2014 12:45	04/12/2014 12:45
HAB041	767391.4690	2018581.3420	4.20	BR	18	14	23.842440	41	31	43.006370	04/12/2014 12:48	04/12/2014 12:48
SL-1	765897.1570	2021680.3600	0.01		18	16	5.250990	41	30	53.621000	04/12/2014 13:01	04/12/2014 13:01
SL-2	765907.5230	2021690.5400	0.00		18	16	5.577250	41	30	53.978480	04/12/2014 13:02	04/12/2014 13:02
SL-3	765916.6630	2021700.3670	-0.02		18	16	5.892610	41	30	54.294070	04/12/2014 13:03	04/12/2014 13:03
TOCT-1	767049.2000	2014604.2560	3.45		18	12	14.714650	41	31	29.496990	04/12/2014 13:43	04/12/2014 13:43
TOCT-2	767060.1390	2014606.1530	3.88		18	12	14.771430	41	31	29.869940	04/12/2014 13:43	04/12/2014 13:43
TOP_COR-1	765903.9910	2021670.5410	3.45		18	16	4.928720	41	30	53.848930	04/12/2014 10:52	04/12/2014 10:52
TOT-1	765873.8080	2020789.2240	3.44		18	15	36.293550	41	30	52.409220	04/12/2014 12:11	04/12/2014 12:11
TOT-2	765875.5160	2020788.1600	3.57		18	15	36.258180	41	30	52.466840	04/12/2014 12:11	04/12/2014 12:11

Appendix 2. GPS9: AlBirk St3--CONTINUED

Sample No.	UTM		Elevation (m)	Geologic Code	Deg	Min	Sec	Deg	Min	Sec	Start Time	End Time
	East	North										
BR-1	774792.7900	2005626.2040	6.49		18	7	19.365860	41	35	48.550550	12/05/2014 09:56	12/05/2014 09:56
BR-2	774806.6520	2005658.8240	6.87		18	7	20.419820	41	35	49.037430	12/05/2014 09:57	12/05/2014 09:57
BR-3	774808.9610	2005706.4200	6.84		18	7	21.965870	41	35	49.138750	12/05/2014 09:59	12/05/2014 09:59
BR-4	774778.3050	2005712.0350	6.62		18	7	22.162440	41	35	48.099320	12/05/2014 10:00	12/05/2014 10:00
BR-5	774781.4950	2005689.1770	6.43		18	7	21.417980	41	35	48.196770	12/05/2014 10:02	12/05/2014 10:02
BR-6	774778.9080	2005651.8910	6.33		18	7	20.207190	41	35	48.090950	12/05/2014 10:03	12/05/2014 10:03
BR-7	774741.3950	2005597.5480	3.57		18	7	18.457960	41	35	46.789650	12/05/2014 10:07	12/05/2014 10:07
BR-8	778970.6600	1999513.6580	6.58		18	3	58.752310	41	38	7.602980	12/05/2014 10:48	12/05/2014 10:48
BR-9	778956.5960	1999517.5390	6.63		18	3	58.884990	41	38	7.126920	12/05/2014 10:51	12/05/2014 10:51
BR-10	778932.6030	1999514.4780	5.93		18	3	58.796630	41	38	6.310110	12/05/2014 10:52	12/05/2014 10:52
BR-PPROF-1	780902.3680	1996655.8820	7.89	SS	18	2	24.964250	41	39	11.852780	12/05/2014 11:43	12/05/2014 11:43
BR-PPROF-2	780896.1590	1996655.0830	8.05	SS	18	2	24.941180	41	39	11.641420	12/05/2014 11:45	12/05/2014 11:45
BR-PPROF-3	780881.8080	1996650.0240	7.82	SS	18	2	24.783400	41	39	11.151350	12/05/2014 11:45	12/05/2014 11:45
BR-PPROF-4	780874.6560	1996649.0390	7.40	BR	18	2	24.754730	41	39	10.907880	12/05/2014 11:46	12/05/2014 11:46
BR-PPROF-5	780859.6050	1996645.4140	7.15	BR	18	2	24.643930	41	39	10.394710	12/05/2014 11:46	12/05/2014 11:47
BR-PPROF-6	780835.3970	1996639.2300	6.97	BR	18	2	24.454220	41	39	9.569160	12/05/2014 11:47	12/05/2014 11:47
BR-PPROF-7	780810.6890	1996631.8980	6.24	BR	18	2	24.227430	41	39	8.726090	12/05/2014 11:48	12/05/2014 11:48
BR-PPROF-8	780799.1090	1996627.4310	5.95	BR	18	2	24.087610	41	39	8.330440	12/05/2014 11:48	12/05/2014 11:48
BR-PPROF-9	780797.7650	1996627.5770	5.81	D	18	2	24.093000	41	39	8.284860	12/05/2014 11:49	12/05/2014 11:49
BR-PPROF-10	780771.1320	1996623.2360	4.83	D	18	2	23.964330	41	39	7.377810	12/05/2014 11:49	12/05/2014 11:50
BR-PPROF-11	780751.4870	1996618.4230	4.69	D	18	2	23.817030	41	39	6.707970	12/05/2014 11:50	12/05/2014 11:50
BR-PPROF-12	780729.0860	1996614.0370	4.47	D	18	2	23.684910	41	39	5.944710	12/05/2014 11:51	12/05/2014 11:51
BR-PPROF-13	780706.9690	1996629.5950	4.24	C	18	2	24.200930	41	39	5.200830	12/05/2014 11:52	12/05/2014 11:52
BR-PPROF-14	780699.9440	1996635.3190	4.03	C	18	2	24.390240	41	39	4.964910	12/05/2014 11:52	12/05/2014 11:52
BR-PPROF-15	780689.8750	1996639.8760	3.14	C	18	2	24.543060	41	39	4.625030	12/05/2014 11:53	12/05/2014 11:53
BR-PPROF-16	780689.6000	1996639.8510	3.15	D	18	2	24.542370	41	39	4.615670	12/05/2014 11:53	12/05/2014 11:53
BR-PROF-1	780796.7070	1996477.6630	7.16		18	2	19.220680	41	39	8.175850	12/05/2014 11:26	12/05/2014 11:26
BR-PROF-2	780813.3890	1996495.5100	7.54		18	2	19.793020	41	39	8.751350	12/05/2014 11:27	12/05/2014 11:27
BR-PROF-3	780834.1650	1996526.0680	7.52		18	2	20.776590	41	39	9.472140	12/05/2014 11:27	12/05/2014 11:27
BR-PROF-4	780864.6630	1996549.9990	7.09		18	2	21.540200	41	39	10.520050	12/05/2014 11:29	12/05/2014 11:29
BR-PROF-5	780870.3980	1996605.2260	7.23		18	2	23.332610	41	39	10.741820	12/05/2014 11:30	12/05/2014 11:30
BR-PROF-6	780874.0590	1996654.2150	7.55		18	2	24.923260	41	39	10.890100	12/05/2014 11:32	12/05/2014 11:32
BR-PROF-7	780872.0450	1996670.5800	7.73		18	2	25.456110	41	39	10.829650	12/05/2014 11:32	12/05/2014 11:32
BR-PROF-8	780851.9080	1996706.6890	7.55		18	2	26.639180	41	39	10.163070	12/05/2014 11:33	12/05/2014 11:33
BR-PROF-9	780844.9940	1996736.0260	7.65		18	2	27.595980	41	39	9.942440	12/05/2014 11:34	12/05/2014 11:34
BR-PROF-10	780819.0590	1996774.7210	7.24		18	2	28.865820	41	39	9.080110	12/05/2014 11:35	12/05/2014 11:35

Appendix 2. GPS9: AlBirk St3--CONTINUED

Sample No.	UTM		Elevation (m)	Geologic Code	Deg	Min	Sec	Deg	Min	Sec	Start Time	End Time
	East	North										
BR-PROF-11	780792.5640	1996841.3690	7.32		18	2	31.044490	41	39	8.212370	12/05/2014 11:37	12/05/2014 11:37
C-TER-1	780800.4160	1996154.9550	3.96	D	18	2	8.729700	41	39	8.144600	12/05/2014 12:13	12/05/2014 12:13
C-TER-2	780832.9690	1996149.7520	4.54		18	2	8.545390	41	39	9.248100	12/05/2014 12:20	12/05/2014 12:20
C-TER-3	780849.3550	1996207.5350	6.57		18	2	10.415930	41	39	9.832990	12/05/2014 12:22	12/05/2014 12:22
C-TER-4	780860.0340	1996226.2030	7.50	BR	18	2	11.017720	41	39	10.204940	12/05/2014 12:23	12/05/2014 12:23
C-TER-5	780853.1960	1996239.3960	7.41	BR	18	2	11.449760	41	39	9.979030	12/05/2014 12:23	12/05/2014 12:23
C-TER-6	780826.2170	1996278.6640	7.08	BR	18	2	12.738700	41	39	9.081500	12/05/2014 12:25	12/05/2014 12:25
C-TER-7	780805.5560	1996264.6450	5.82	BR	18	2	12.292650	41	39	8.372680	12/05/2014 12:26	12/05/2014 12:26
C-TER-8	780754.7290	1996238.3410	4.50	C	18	2	11.461370	41	39	6.632920	12/05/2014 12:28	12/05/2014 12:28
C-TER-9	780701.8240	1996256.7340	3.53	C	18	2	12.083880	41	39	4.844360	12/05/2014 12:29	12/05/2014 12:29
C-TER-10	780667.7730	1996251.6500	3.44	C	18	2	11.934470	41	39	3.684920	12/05/2014 12:30	12/05/2014 12:30
GMN-538	773202.0830	2008172.8610	7.32		18	8	42.873380	41	34	55.689770	-	-
SLVL-1	780121.0270	1997233.1930	0.00		18	2	44.093160	41	38	45.585560	12/05/2014 12:46	12/05/2014 12:46
SLVL-2	780103.3000	1997219.4470	0.00		18	2	43.654630	41	38	44.976520	12/05/2014 12:51	12/05/2014 12:51
SLVL-3	780094.1140	1997210.0270	0.00		18	2	43.352690	41	38	44.659800	12/05/2014 12:51	12/05/2014 12:51
SS	780889.1220	1996655.2950	8.61	SS	18	2	24.951320	41	39	11.402430	12/05/2014 11:42	12/05/2014 11:42
toct-1	772822.0370	2007012.6390	3.33		18	8	5.333170	41	34	42.215280	12/05/2014 09:00	12/05/2014 09:00
toct-2	772859.0800	2007028.7830	2.96		18	8	5.841070	41	34	43.482350	12/05/2014 09:01	12/05/2014 09:01
toct-3	772879.5720	2007053.6510	3.68		18	8	6.640070	41	34	44.190880	12/05/2014 09:02	12/05/2014 09:02
toct-4	772901.3640	2007092.5710	3.85		18	8	7.895250	41	34	44.950340	12/05/2014 09:03	12/05/2014 09:03
toct-5	772951.7650	2007133.2800	3.87		18	8	9.195550	41	34	46.683260	12/05/2014 09:04	12/05/2014 09:04
toct-6	772715.1810	2007052.1860	4.75		18	8	6.667330	41	34	38.601280	12/05/2014 09:25	12/05/2014 09:25
toct-7	772728.6540	2007064.0620	5.27		18	8	7.047240	41	34	39.065000	12/05/2014 09:26	12/05/2014 09:26

Appendix 2. GPS10: North OMG--CONTINUED

Sample No.	UTM		Elevation (m)	Geologic Code	Deg	Min	Sec	Deg	Min	Sec	Start Time	End Time
	East	North										
BASE-1	759876.8180	2036813.4840	4.64		18	24	19.860120	41	27	35.732590	-	-
OMG-1	759868.0050	2036805.2100	4.58	BR	18	24	19.595030	41	27	35.428650	12/05/2014 14:36	12/05/2014 14:37
OMG-2	759854.3140	2036778.7170	4.54	BR	18	24	18.739850	41	27	34.950180	12/05/2014 14:37	12/05/2014 14:38
OMG-3	759890.6240	2036750.9360	5.07	BR	18	24	17.820760	41	27	36.173840	12/05/2014 14:39	12/05/2014 14:39
OMG-4	759902.5710	2036779.1850	4.85	BR	18	24	18.733770	41	27	36.593730	12/05/2014 14:40	12/05/2014 14:40
OMG-5	759921.1380	2036792.8900	5.09	BR	18	24	19.171100	41	27	37.232320	12/05/2014 14:41	12/05/2014 14:41
OMG-6	759938.4430	2036803.5410	5.19	BR	18	24	19.509720	41	27	37.826530	12/05/2014 14:42	12/05/2014 14:42
OMG-7	759957.7290	2036839.6770	5.22	BR	18	24	20.675920	41	27	38.500000	12/05/2014 14:43	12/05/2014 14:43
OMG-8	759929.6880	2036867.6660	5.08	BR	18	24	21.598120	41	27	37.558030	12/05/2014 14:44	12/05/2014 14:44
OMG-9	759939.4850	2036894.1020	5.19	BR	18	24	22.453190	41	27	37.903870	12/05/2014 14:45	12/05/2014 14:45
OMG-10	759944.0500	2037019.8320	5.02	BR	18	24	26.538350	41	27	38.117410	12/05/2014 14:47	12/05/2014 14:47
OMG-11	759936.0510	2036996.7580	5.22	BR	18	24	25.791800	41	27	37.834360	12/05/2014 14:48	12/05/2014 14:48
OMG-12	759930.6220	2036966.2900	5.34	BR	18	24	24.803730	41	27	37.635390	12/05/2014 14:49	12/05/2014 14:49
OMG-13	759920.4710	2036945.9420	5.29	BR	18	24	24.146760	41	27	37.280330	12/05/2014 14:49	12/05/2014 14:49
OMG-14	759912.0290	2036915.1370	5.33	BR	18	24	23.149080	41	27	36.978590	12/05/2014 14:50	12/05/2014 14:50
OMG-15	759904.4460	2036883.3860	5.26	BR	18	24	22.120260	41	27	36.705710	12/05/2014 14:51	12/05/2014 14:51
OMG-16	759891.3500	2036858.2950	5.07	BR	18	24	21.310420	41	27	36.248140	12/05/2014 14:52	12/05/2014 14:52
OMG-17	759883.3340	2036834.3070	5.03	BR	18	24	20.534150	41	27	35.964090	12/05/2014 14:52	12/05/2014 14:53
OMG-18	759876.3790	2036818.6910	4.85	BR	18	24	20.029590	41	27	35.720050	12/05/2014 14:53	12/05/2014 14:53
SLVL-1	758350.0790	2037090.5790	-0.01		18	24	29.539150	41	26	43.868700	12/05/2014 15:02	12/05/2014 15:02
SLVL-2	758274.4020	2037022.8370	-0.01		18	24	27.370170	41	26	41.260460	12/05/2014 15:04	12/05/2014 15:04
SLVL-3	758271.8650	2037019.5390	0.01		18	24	27.264060	41	26	41.172550	12/05/2014 15:05	12/05/2014 15:05
SLVL-4	758269.5590	2037016.1180	0.01		18	24	27.153870	41	26	41.092440	12/05/2014 15:05	12/05/2014 15:05

difference in location by ±0.5 m

Appendix 2. GPS11: Qamah--CONTINUED

Sample No.	UTM Zone37		Elevation (m)	Geologic Code	Deg	Min	Sec	Deg	Min	Sec	Start Time	End Time
	East	North										
BASE-1	784336.452	1989567.456	11.80025		17	58	32.95636	41	41	5.041		
BR-T-1	784274.446	1989522.34	5.19625	BR	17	58	31.5191	41	41	2.91284	12/06/2014 09:18	12/06/2014 09:18
BR-T-2	784285.677	1989510.492	5.34725	BR	17	58	31.12873	41	41	3.28848	12/06/2014 09:19	12/06/2014 09:19
BR-T-3	784298.769	1989500.858	5.40325	BR	17	58	30.80942	41	41	3.72838	12/06/2014 09:19	12/06/2014 09:20
BR-T-4	784312.81	1989490.913	5.68425	BR	17	58	30.47958	41	41	4.20038	12/06/2014 09:20	12/06/2014 09:20
BR-T-5	784330.995	1989480.568	5.88425	BR	17	58	30.13478	41	41	4.81295	12/06/2014 09:21	12/06/2014 09:21
BR-T-6	784355.942	1989469.332	6.09125	BR	17	58	29.75784	41	41	5.65471	12/06/2014 09:22	12/06/2014 09:22
BR-T-7	784349.212	1989453.621	5.50225	BR	17	58	29.25034	41	41	5.41841	12/06/2014 09:22	12/06/2014 09:22
BR-T-8	784372.875	1989449.818	6.25925	BR	17	58	29.11561	41	41	6.22024	12/06/2014 09:23	12/06/2014 09:23
BR-T-9	784383.158	1989439.285	6.32225	BR	17	58	28.76841	41	41	6.56433	12/06/2014 09:23	12/06/2014 09:23
BR-T-10	784374.838	1989420.35	5.54525	BR	17	58	28.15688	41	41	6.27241	12/06/2014 09:24	12/06/2014 09:24
BR-T-11	784405.489	1989413.374	5.93225	BR	17	58	27.91569	41	41	7.31001	12/06/2014 09:25	12/06/2014 09:25
BR-T-12	784394.82	1989399.232	5.58225	BR	17	58	27.46108	41	41	6.9407	12/06/2014 09:25	12/06/2014 09:25
HAB048	784281.963	1989517.569	5.36525	POTTERY	17	58	31.36049	41	41	3.1658	12/06/2014 09:16	12/06/2014 09:16
HOL ST MD	784374.766	1989449.616	6.10425		17	58	29.10814	41	41	6.28437	12/06/2014 09:30	12/06/2014 09:30
SLVL-1	782067.279	1990855.726	-0.03675		17	59	15.89317	41	39	48.59807	12/06/2014 09:50	12/06/2014 09:50
SLVL-2	782058.123	1990849.425	-0.00375		17	59	15.69265	41	39	48.284	12/06/2014 09:51	12/06/2014 09:51
SLVL-3	782049.673	1990845.146	-0.00475		17	59	15.55752	41	39	47.99486	12/06/2014 09:51	12/06/2014 09:51
SLVL-4	782038.669	1990840.791	0.04525		17	59	15.42109	41	39	47.61897	12/06/2014 09:52	12/06/2014 09:52

Appendix 3. Farasan Station 3 (Ras Shida) DGPS measurements located on a Google Earth map