Mapping of the recent sediment and relict features in the area between Jizan and Farasan Islands southeastern Red Sea, Saudi Arabia

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Project

The project is a joint venture between various international and national organizations. The first stage of research is currently under way in the vicinity of the Farasan Islands and Jizan in the Saudi Arabian sector of the Red Sea, run by the Saudi Geological Survey and by a joint Saudi-UK geo-archaeological project forming part of the ERC-funded DISPERSE project (Dynamic Landscapes, Coastal Environments and Human Dispersals) (Bailey et al, 2012) .

Objectives

In February and June 2014 the *R/V COASTAL SURVEYOR II* of the Saudi Geological Survey conducted two cruises to understand the sedimentary characteristics of the basin from an environmental perspective, the influence of the wadis draining into the basin, and the role of islands and shoals controlling sediment dispersal.

In May–June 2013, the *R/V AEGAEO* of the Hellenic Centre for Marine Research conducted a survey (Bailey et al, 2013; Sakellariou et al, 2013) to explore systematically the submerged landscapes down to –120 m revealed by Late Pleistocene (~100ka to 6 ka) low sea-level stands. Targets of interest are features that might have been attractive to human settlement: stream channels, lake basins, rockshelters and caves, palaeoshorelines, cliff lines, and complex topography where prehistoric hunters could easily monitor and trap animals.

Study Area

The study area is the southeastern Red Sea of Saudi Arabia between the Farasan Islands in the west and Jizan coastal areas in the east (Figure 1a, b) The Farasan Islands are ~ 45 km west of the coastal city of Jizan and were low hills in a terrestrial landscape when sea level was lower. They are composed typically of reef (coralline) limestone with over 120 islands and associated shoals of various dimensions. In general. The largest islands are Farasan al-Kabir and Sajid. The topography is low (10–15 m) with a maximum altitude of over 70 m, spread over an area of ~ 3000 km2. The islands were formed by progressive uplifting by salt diapirism, based on dating by strontium and radiocarbon isotopes, continuing into the Holocene and the present day.

The area between the Farasan Islands and the Jizan coast is relatively flat with varying depths of up to 100 m. Several wadis (seasonal streams) drain into a wide continental shelf as compared to the northern Saudi Red Sea where the shelf is narrow or absent. Input from wadis influences the depositional environment and is veneered mostly with terrigenous materials and subordinate foraminiferal sand.

The region is of special interest for two reasons. First, recent human activities have profoundly affected sedimentation, notably in the past decade in Jaafirah Bay (Figure 1a), and more generally between Jizan and Farasan because of bottom trawling at least twice a year and the regular ferry service between the Islands and Jizan. Secondly, the region is regarded as one of the primary pathways of dispersal for early human populations expanding out of Africa during the Pleistocene.

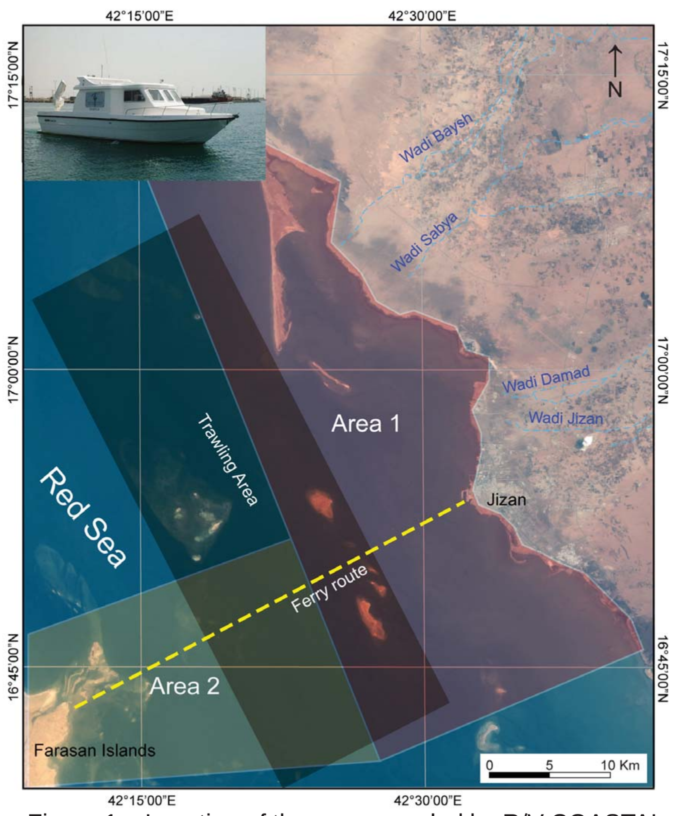

Figure 1a: Location of the area sampled by R/V COASTAL SURVEYOR II .

Data Acquisition and Processing

We used Peterson and Ponar grab samples (upper 15 cm) on R/V COASTAL SURVEYOR II, and on R/V AEGAEO gravity and box core samples (up to 5 m) and geophysical equipment – dual frequency echo-sounding, multi-beam swath bathymetry (20 kHz and 180 kHz), airgun seismic profiler (10 cubic inches), high resolution sub-bottom profiler (3.6 kHz pinger), deep-towed (110/410 kHz) side-scan sonar, and an ROV (Max Rover).

R/V COASTAL SURVEYOR II focused on the processes responsible for sediment transport and possible contamination and degradation of the marine environment, incorporating wide-ranging studies of sediment veneer, water quality, bathymetric survey, circulation pattern and physical properties of the water, producing 118 surficial sediment samples and data on various physical and chemical parameters from an area of ~ 1100 km2.

R/V AEGAEO concentrated on two areas (FARASAN 1 and FARASAN 2) and two seismic transects (TRANSECT 1 and TRANSECT 2), and mapped ~500 km2 with multi-beam systems, 170 nautical miles of airgun seismic profiles, 250 nautical miles of 3.5 kHz sub-bottom profiles, and 140 nautical miles (260 km) of sidescan sonar. The cruise also acquired 18 gravity cores and 2 box cores and conducted 5 dives of the Max Rover (Figure 1b) (Bailey et al, 2013; Sakellariou et al, 2013).

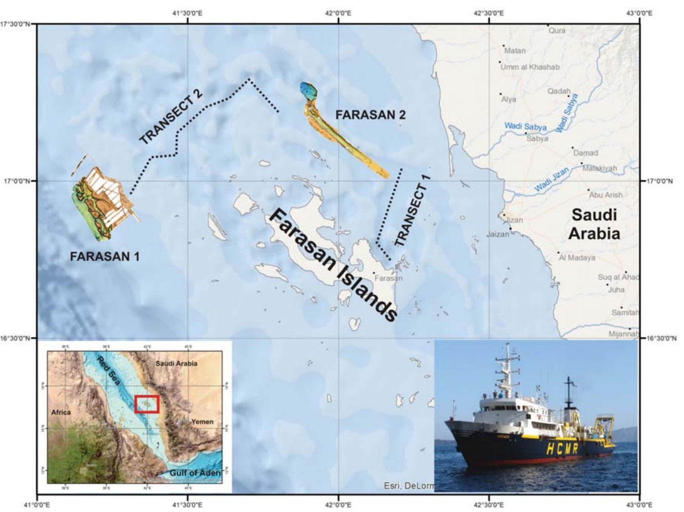

Figure 1b: Location of area surveyed by R/V AEGAEO.

Discussion

Present-day submarine sediment distributions and sources play a vital role in understanding the evolution of the Arabian coastal zone. They also play an important role in understanding the submerged continental shelf and the way it has evolved under varying conditions of sea-level changes. The texture map shows the sediment veneer is mostly sandy mud of terrigenous origin, whereas the coarser materials are mostly biogenic (Figure 2).

In the Jizan coastal belt rapid development along with natural factors has caused significant environmental degradation and loss of critical habitat (coral reefs and living resources). Jaafriyah Bay is a catchment for contaminants mostly from a shrimp farm, and anthropogenic input has caused severe deterioration in the quality of the sedimentary environment. Pollutant discharge and surface drainage has also greatly affected water quality in many ways, e.g. foul smell and high TOC levels in water and sediment. The shrimp farm has been shut down because of bacterial contamination (Figure 3, insert a,b,c). Since the closure of the farm, the Bay is under environmental stress because of limited exchange of water with the open sea.

Dredging and land reclamation along the Jizan coastal belt has also led to shoreline erosion and loss of pristine environment people used to enjoy (Figure 3, insert d,e).

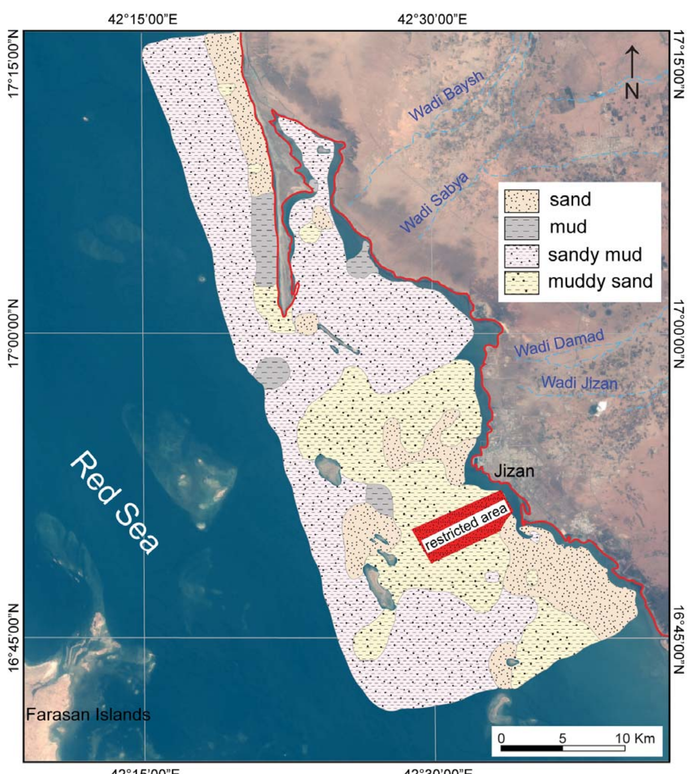

Figure 2: Sediment distribution map in the Jizan offshore area.

The area between Jizan and the Farasan Islands is regarded as the sediment pathway (Figure 4). Most sediments empty into the Red Sea north of Jizan in the Al-Shuqaiq region from wadis (seasonal streams) and are transported to the South by prevailing northwesterly winds. Wind generated surface water currents transport and disperse terrigenous material especially the micas to deeper waters. Longshore drift also transports sediments along the coast resulting in a wider shelf in the southern Red Sea. During transit, terrigenous materials are transported to the East by tidal currents, resulting in deposition of sediments on the beach. Some sediments are blown inland, forming sand dunes along the coast (Figure 5 a, b). The tide is diurnal with a maximum height of 0.9 m, with limited effect in the Bay as compared to the open sea. Small-scale sand bars have been formed by tidal currents. The sediment cover ranges from medium to fine sand to clay size material of fluvial origin (Figure 6 a). Forams and biogenic (Figure 6 b) materials are present in limited amounts in shallow waters but their abundance in deeper waters (~ 50 m) confirms that the sediment pathway is parallel to the coast.

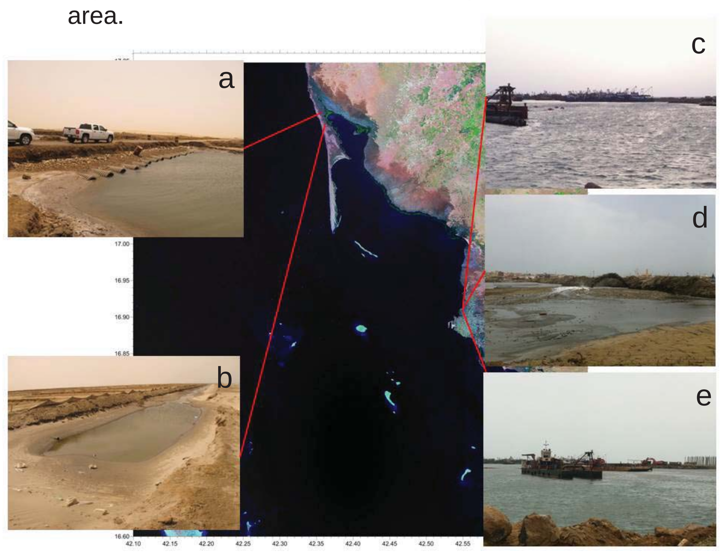

Figure 3: a) the outfall from the shrimp farm: pipelines redirected the water into the Jaafirah Bay; b) reminence of drainage path; c) organic material is covered with aeolian material; d) dredger in action; e) the pumped water is composed mostly of fine-grained terrigenous material and organic debris.

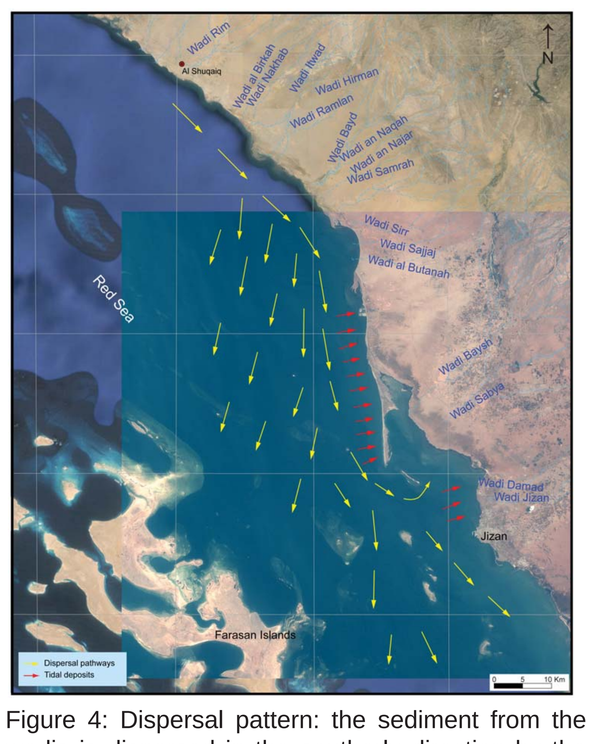

Figure 4: Dispersal pattern: the sediment from the wadis is dispersed in the southerly direction by the surface water current.

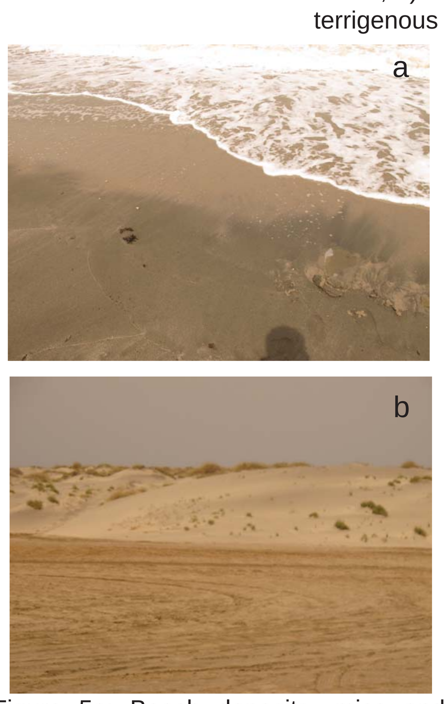

Figure 5a: Beach deposits- mica and heavy minerals are deposited on the beach by tidal currents; b) sand dunes are formed from blown sand-composed mostly of quartz, mica and heavy minerals.

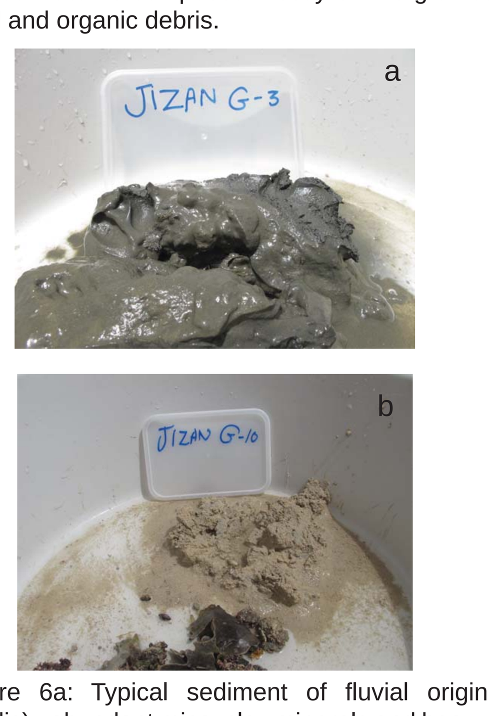

Figure 6a: Typical sediment of fluvial origin (wadis) - abundant mica, clay minerals and heavy minerals are found in a low energy environment; b) well-sorted coral debris in very coarse sand-product of erosion and breaking of coral either by fish and/or human activities.

However, the presence of micas and clay minerals along with biogenic sand in deeper water indicates that these minerals have drifted offshore and settled down in a quiescent environment (Figure 6 a). The seabed seems somewhat flat between the Farasan Islands and Jizan, which could be due to bottom trawling.

The salinity of the surface water ranges between 35 and 38 ‰, with higher values close to the Farasan Islands especially in sheltered small lagoons and bay-like environments. There are lower values along the Jizan coastal area because of dilution from wadis and effective mixing by wind generated currents.

Area 1, Outer Farasan Shelf

Preliminary interpretation of the geophysical data in Area 1(Sakellariou et al 2014) indicates two prominent terraces at depths of ~70–80m (Figure 7) and 38–40m, and a locally preserved terrace at 120m depth. The outer edge of the continental shelf is controlled by normal faults trending NW-SE, parallel to the rifting axis of the Red Sea (Figure 8). Elongate ridges, running parallel to and off the shelf edge are characterized by steep faulted slopes and flat 80–90m shallow tops (Figure 9, 10). They were exposed above sea-level during Pleistocene low sea-level periods, forming a series of flat islands, the "prehistoric Farasan Archipelago", separated from the palaeo-coastline by deep troughs. Holocene sediment deposition on the shelf is very limited. Cored sediments indicate lacustrine-type material below the Holocene marine drape in the isolated depressions on the 80m terrace.

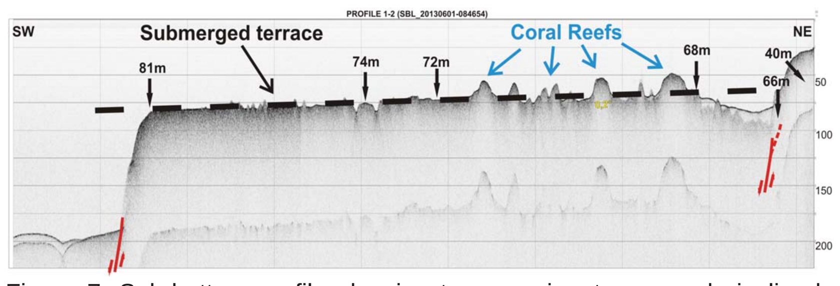

Figure 7: Sub-bottom profile showing two prominent, seawards inclined terraces at 70–80m and 38–40m depth on the shelf. Shallow mounds on the shelf are coral reefs (Sakellariou et al 2014).

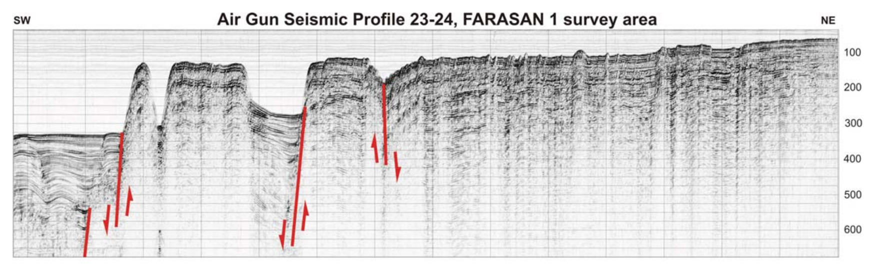

Figure 8: Air Gun seismic profile across edge of outer shelf, Area 1. Note the prominent, 70–80m deep terrace on the shelf (Sakellariou et al 2014).

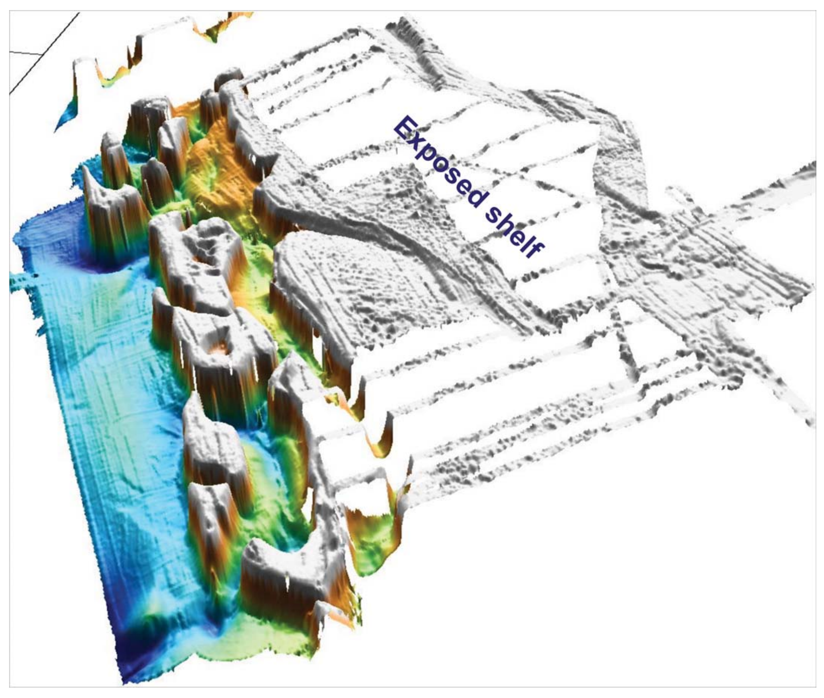

Figure 9: 3D view of outer Farasan shelf. Areas shallower than 120m in gray, deeper areas in colour. Shallow ridges off the shelf were exposed during the Last Glacial Maximum (LGM) (Sakellariou et al 2014).

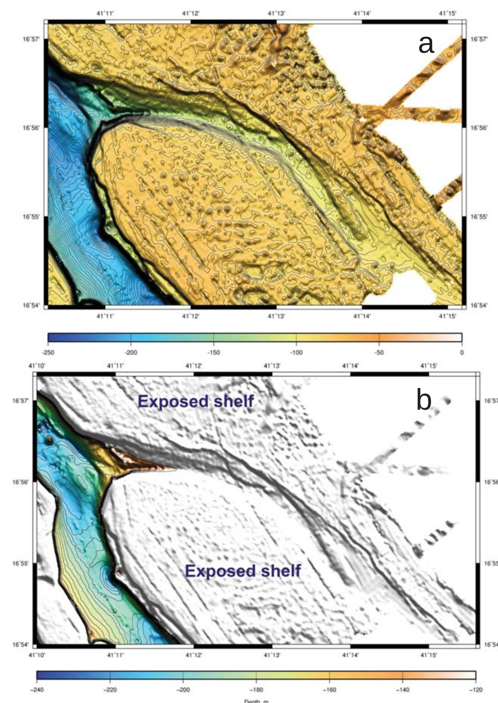

Figure 10: a) High-resolution shaded bathymetry of central Area 1; b) the same area with exposed part (<120 m depth) not coloured (Sakellariou et al 2014).

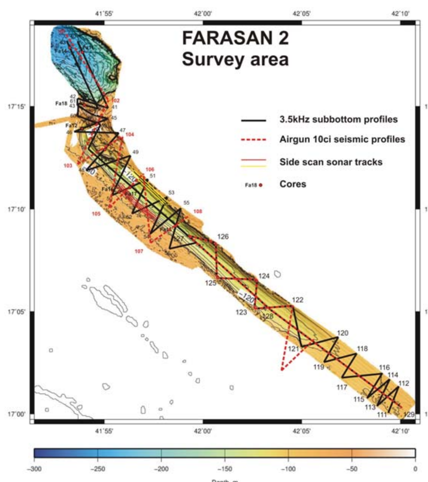

Figure 11: Swath bathymetry and location of seismic profiles, coring sites and ROV dives on inner Farasan shelf (Sakellariou et al 2014).

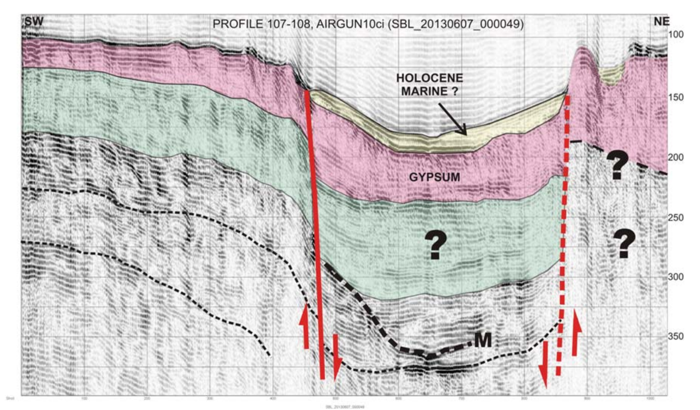

Figure 12: Airgun profile across elongate basin in Area 2, The basin has been formed from subsidence between two opposing NW-SE trending faults (Sakellariou et al 2014).

Area 2, Inner Farasan Shelf

Area 2 comprises a 120m deep, elongate basin (Figure 11) bounded by NW–SE trending normal faults (Figure 12) and incised on the prominent 70–75m terrace of the inner shelf (Sakellariou et al 2014). Another terrace has been mapped along the flanks of the basin at about 112m depth. Gravity coring penetrated the presumably Holocene, marine drape and recovered gypsum fragments from about 2–2.5m below the seafloor. A narrow gorge at the NW tip of the valley-like basin (Figure 13) connects it with a >200m deep, circular depression with a >250m thick sedimentary sequence. Preliminary analysis of sediment cores reveals lacustrine-type sedimentation below the 1–2m thick marine silt (Figure 14). This indicates that the numerous deep and shallow depressions formed by evaporite solution on the shelf along NW–SE trending faults were probably lakes during Pleistocene low sea-level stands (Figure 15). This landscape would have been attractive for human settlement and for the preservation of archaeological evidence.

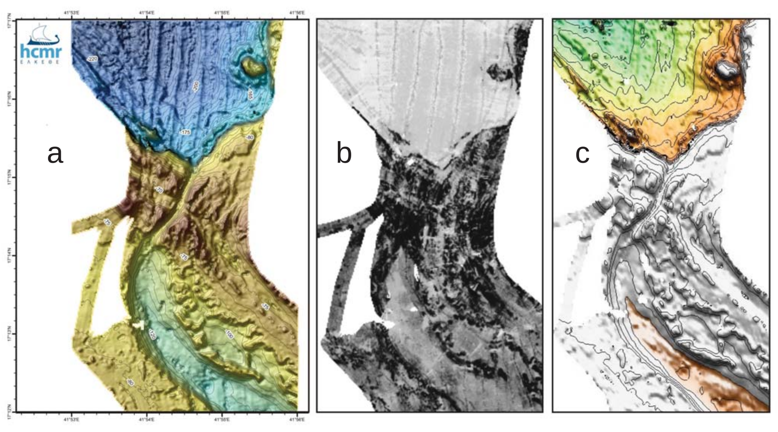

Figure 13: Detailed maps of gorge between the valley-like basin and the deep depression in Area 2: a) High-resolution shaded bathymetry; b) backscatter (reflectivity) map; c) shaded bathymetry. Different reflectivity patterns in (b) coincide with the submarine topography and indicate the differences in deposition character. The gorge was exposed above the sea-level during the LGM while the two depressions at both ends were filled with water (c) (Sakellariou et al

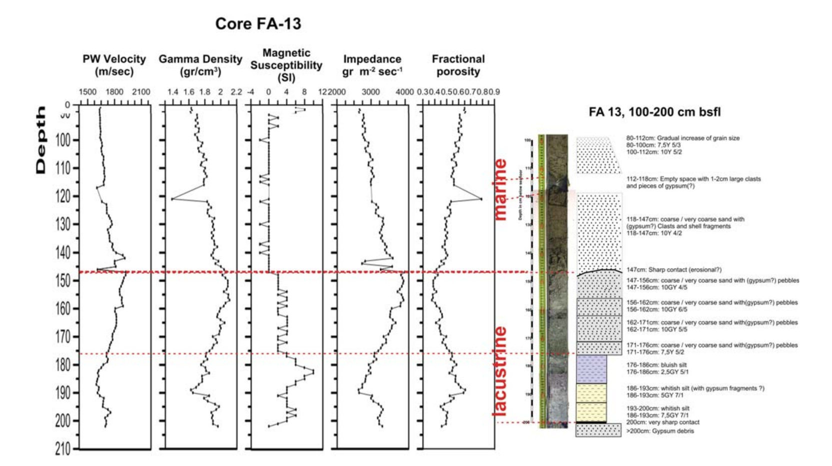

Figure 14: Sedimentological description and down-core multi-logger measurements of sediments physical properties. The abrupt change in sediment colour and properties at 147cm below seafloor marks the transition between lacustrine and marine sedimentation (Sakellariou et al 2014).

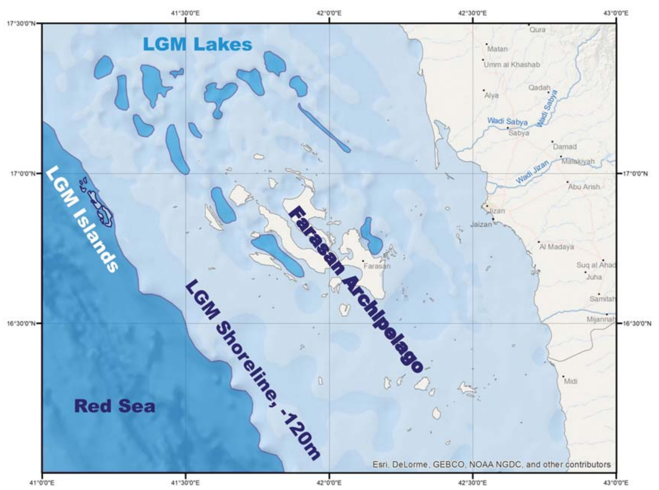

Figure 15: GEBCO bathymetry of Farasan area with the assumed LGM shoreline at –120m. Note palaeoshoreline, emerged offshore islands and lake basins on inner shelf (Sakellariou et al 2014).

Conclusions

Sedimentation rate in the study area has not been reported but initial results from R/V COASTAL SURVEYOR II show that the most recent sediments originated from wadis along the eastern stretch of the Red Sea ~150 km from the area of deposition. The presence of fine sediments and floccules in deeper water on the shelf and in shallow sheltered water (Jaafriyah Bay) indicates calmer conditions. However, strong tidal currents move sediments to the beach, and strong winds move some material on land to form sand dunes mostly of aeolian quartz, with heavy minerals from the wadis.

The R/V AEGAEO survey is one of the first attempts to apply underwater techniques to the systematic geo-archaeological exploration of a submerged land surface across the whole depth range of the continental shelf. It demonstrates that a landscape with interpretable features of geological structure, geomorphology, topography, and potential for human settlement lies now submerged on the extensive shelf region surrounding the Farasan Islands, and forms a promising basis for future investigations.

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