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Application of the XRF-core scanning technique in the study of late Quaternary palaeoclimatic changes within the southern Red Sea

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Introduction and Objectives

Non-destructive techniques provide a continuous analysis of sediment cores and constitute an essential tool in the reconstruction of past environmental and climatic conditions. XRF-core scanning in particular can provide a high-resolution record of element intensities, the ratios of which can be used in order to decipher palaeoenvironmental characteristics. One of the main aims of this research, which was carried out within the framework of the ERC-funded DISPERSE project (Bailey et al., 2012), was the application of the XRF-core scanning technique in order to investigate the palaeoceanographic and palaeoclimatic conditions that prevailed in the southern Red Sea during the late Quaternary. The Red Sea, one of the youngest oceanic basins on earth also described as an 'ocean in the making', presents a strong significance for both earth scientists and archaeologists alike. One of the reasons the Red Sea has received much attention in the last decades can be attributed to the fact that the basin is viewed as an archive of past sea-level changes (e.g., Trommer et al., 2010 and references therein). These sea-level fluctuations played an important role in controlling the environmental conditions developed within the basin on a glacial-interglacial timescale (e.g., Rohling et al., 2008a). The Red Sea and especially its southern corridor, has also been a subject of study in the field of archaeology as it is considered to have been a pathway for the dispersal of the modern human (*H. Sapiens Sapiens*) out of Africa during the Pleistocene (Bailey et al., 2019 and references therein). This study presents the preliminary results revealed through the various elemental ratios of two sediment cores retrieved from the continental shelf off the Farasan Islands (Saudi Arabia).

Materials and methods

Two distinct areas within the continental shelf off the Farasan Islands were surveyed during the DISPERSE-Farasan cruise on board the R/V Aegaeo in 2013. The first core (FA09) was retrieved from survey area 1, which is located on the upper slope-outer continental shelf, whereas the second one (FA14) from the inner continental shelf, located between the Farasan Islands and the Arabian Peninsula (Sakellariou et al., 2019). Both cores were retrieved via gravity coring with 3-5m long barrels, photographed and sedimentologically described. The cores were afterwards scanned with the use of the AVAATECH XRF core scanner system at the CORELAB laboratory of the University of Barcelona, at 2mm resolution, in three runs at 10, 30 and 50kV in an X-ray tube. Six samples were also retrieved from specific depth intervals in both cores for chronological dating via ^{14}C AMS analysis. Five samples of about 10 mg of hand-peaked *Gs ruber* individuals were taken from core FA09, while one sample of benthic *Cibicides sp* specimens were retrieved from the FA14 core due to a lack of planktonic foraminiferal assemblages. Samples were analysed at the Scottish Universities Environmental Research Centre laboratories (SUERC).

Results and discussion

Preliminary results were drawn from the relative changes of the elemental profiles observed in both cores, the ratios of which are used as proxies of environmental and hydrological conditions. The 266 cm long FA09 core presents two visually distinct parts separated by a sharp interface at 129.5 cm b.s.f., or 15332 BP. Within the upper 0-120 cm b.s.f there is an increase in the Ca/Fe ratio (Figure 1), which is used as a proxy of marine Ca in comparison to terrigenous Fe (Richter et al., 2006); and can therefore suggest a transition from a glacial period of low biogenic production and high terrigenous inputs (downwards of 120 cm b.s.f) to an interglacial period of higher biogenic productivity (upwards of 120 cm b.s.f). This observation is further supported by a decrease in the Sr/Ca (Figure 1) log-ratio within the same depth interval which is also a proxy of biogenic Ca inputs. Ratios of the terrigenous elements K, Si, Fe to the carbonate Ca (Figure 1) have been used as proxies for aeolian dust input (Hanebuth and Henrich, 2009) and show increased values below 130 cm b.s.f supporting the theory that the sediments below 130 cm b.s.f were deposited during the arid Last Glacial Maximum (LGM). In terms of proxies for palaeoproductivity, according to Thomson et al. (2006) Br/Cl (Figure 1) may reveal increased organic matter inputs. Within this core, Br/Cl shows an increase between 110-130 cm b.s.f, which also coincides with the visually identified sapropel layer between 115-130 cm b.s.f. Finally, increased amounts of Sr, which is used as a proxy of high salinity by Arz et al. (2001b), were found below 130 cm b.s.f. The 293 cm long FA14 core also presents two visually distinct units separated by a 7cm thick transition layer. The upper layer is found between 0-225 cm b.s.f while the lower one below 230.5 cm b.s.f or 9027 BP. Within this core the Ca/Fe ratio (Figure 2) slightly increases from about 240 cm b.s.f upwards with a broad peak at about 210 cm b.s.f indicating increased marine productivity in the upper interglacial part. The Br/Cl ratio (Figure 2) exhibits increasing values from around 230 cm b.s.f upwards therefore, indicating a higher input of biogenic matter. Similarly to FA09, increased amounts of Sr (Fig. 2) are also present within the lower glacial unit of this core, below 230 cm b.s.f.

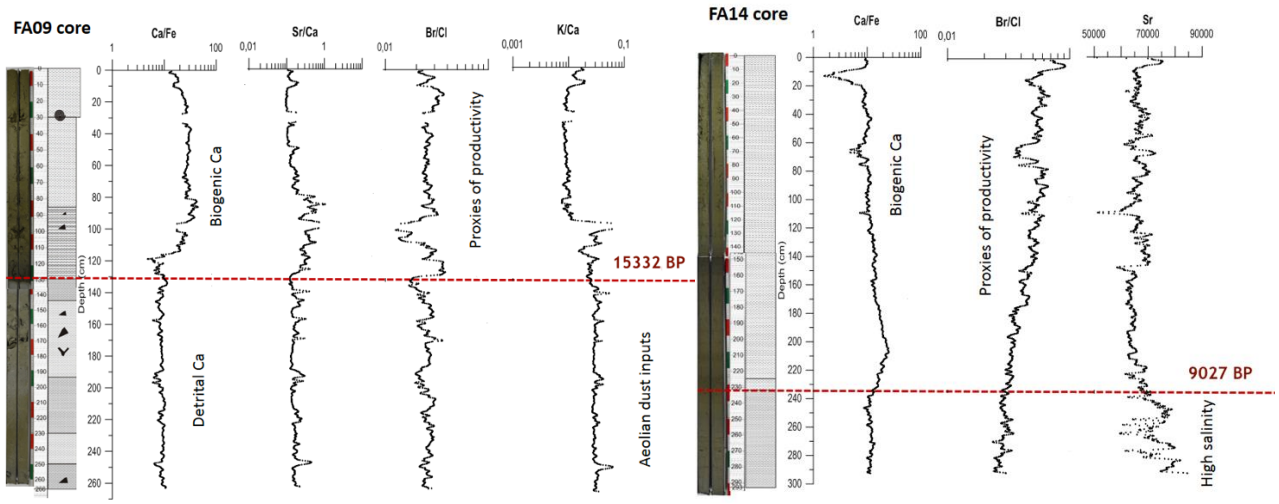

Figure 1, 2. Diagnostic elemental ratios for FA09 and FA14 cores. The dotted red lines depict the presumed transition between the Last Glacial Maximum (LGM) and interglacial sedimentation.

Conclusions

Application of the XRF-core scanning technique resulted in a preliminary qualitative description of the palaeoenvironmental conditions that prevailed during the sediment deposition in the upper slope (FA09 core) and inner shelf (FA14 core) of the Farasan Islands. One of the main conclusions drawn was that the transition from the LGM environment to the current interglacial marine setting did not happen simultaneously in both locations due to the distinct morphological characteristics of each basin. Both basins presented increased salinity during the LGM as well as decreased marine productivity and biogenic carbonates. The basin within survey area 2 (FA14 core) presented higher salinity values and as a result it can be presumed that during the low sea levels of the LGM it was completely isolated. Transitioning into the interglacial period marine productivity and biogenic carbonates increased whereas salinity decreased. It is apparent that through the vertical distribution of various diagnostic elemental ratios many conclusions can be drawn concerning depositional environments. Ongoing geochemical studies will assist in the calibration and establishment of this non-destructive technique in palaeoenvironmental research.

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