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Current and sea-level signals in periplatform ooze (Neogene, Maldives, Indian Ocean)

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ABSTRACT

Periplatform ooze is an admixture of pelagic carbonate and sediment derived from neritic carbonate platforms. Compositional variations of periplatform ooze allow the reconstruction of past sea-level changes. Periplatform ooze formed during sea-level highstands is finer grained and richer in aragonite through the elevated input of material from the flooded platform compared to periplatform ooze formed during the episodes of lowered sea level. In many cases, however, the sea floor around carbonate platforms is subjected to bottom currents which are expected to affect sediment composition, i.e. through winnowing of the fine fraction. The interaction of sea-level driven highstand shedding and current impact on the formation of periplatform ooze has hitherto not been analyzed. To test if a sea-level driven input signal in periplatform ooze is influenced or even distorted by changing current activity, an integrated study using seismic, hydroacoustic and sedimentological data has been performed on periplatform ooze deposited in the Inner Sea of the Maldives. The Miocene to Pleistocene succession of drift deposits is subdivided into nine units; limits of seismostratigraphic units correspond to changes or turnarounds in grain size trends in cores recovered at ODP Site 716 and NEOMA Site 1143. For the Pleistocene it can be shown how changes in grain size occur in concert with sea-level changes and changes of the monsoonal system, which is thought to be a major driver of bottom currents in the Maldives. A clear highstand shedding pattern only appears in the data at a time of relaxation of monsoonal strength during the last 315 ky. Results imply (1) that drift sediments provide a potential target for analyzing past changes in oceanic currents and (2) that the ooze composition bears a mixed signal of input and physical winnowing at the sea floor.

1. Introduction

Carbonate periplatform ooze is an admixture of pelagic and neritic platform-derived carbonates. It records sea-level highstands, i.e. flooding of the carbonate platforms, through the higher contents of material shed from the platform, such as fine-grained aragonite mud (Droxler and Schlager, 1985; Glaser and Droxler, 1991; Schlager et al., 1994). Highstand shedding has proven as a solid tool for the reconstruction of the sea-level history of different platforms (Droxler et al., 1983; Droxler and Schlager, 1985; Reymer et al., 1988; Glaser and Droxler, 1991, 1993; Schlager et al., 1994; Rendle and Reijmer, 2002; Rendle-Bühring and Reijmer, 2005; Paul et al., 2012). Although there is growing evidence for the occurrence of bottom currents affecting periplatform areas (Isern et al., 2004; Betzler et al., 2009; Bergmann et al., 2010; Eberli et al., 2010), such currents or fluctuations of the bottom-current regime were not identified as a major agent controlling the deposition of periplatform carbonate ooze. Bottom currents, however, are known to winnow carbonate ooze, and grain-size variations of such sediments are used as an index of bottom current variations elsewhere (Gardner et al., 1986; House et al., 1991; Kastanja and Henrich, 2007). Based on planktonic foraminiferal associations, Lidz and McNeill (1995) showed the admixture of fresh and reworked periplatform ooze at the Bahamas.

This study uses seismic, hydroacoustic and sedimentological data to address the question, of how fluctuations of sea level and of bottom-current intensity interact. We analyze Pleistocene periplatform deposits from the Maldives that have been deposited in a current-affected setting. Deconvolution of the various factors will allow us to gauge their relative contributions to the periplatform depocenter.

2. Setting

The Maldives archipelago in the central equatorial Indian Ocean is a series of isolated tropical carbonate platform constituting the central and largest part of the Chagos–Laccadives Ridge, which is located southwest of India (Fig. 1). In the central part of the archipelago, a north–south oriented double row of atolls encloses the Inner Sea of the Maldives. The atolls are separated from each other by inter-atoll channels, which deepen towards the Indian Ocean (Purdy and Bertram, 1993). The Inner Sea is a bank-internal basin with water depths of up to 550 m. The Maldives cap an almost 3-km thick carbonate sedimentary succession which accumulated since the Eocene,

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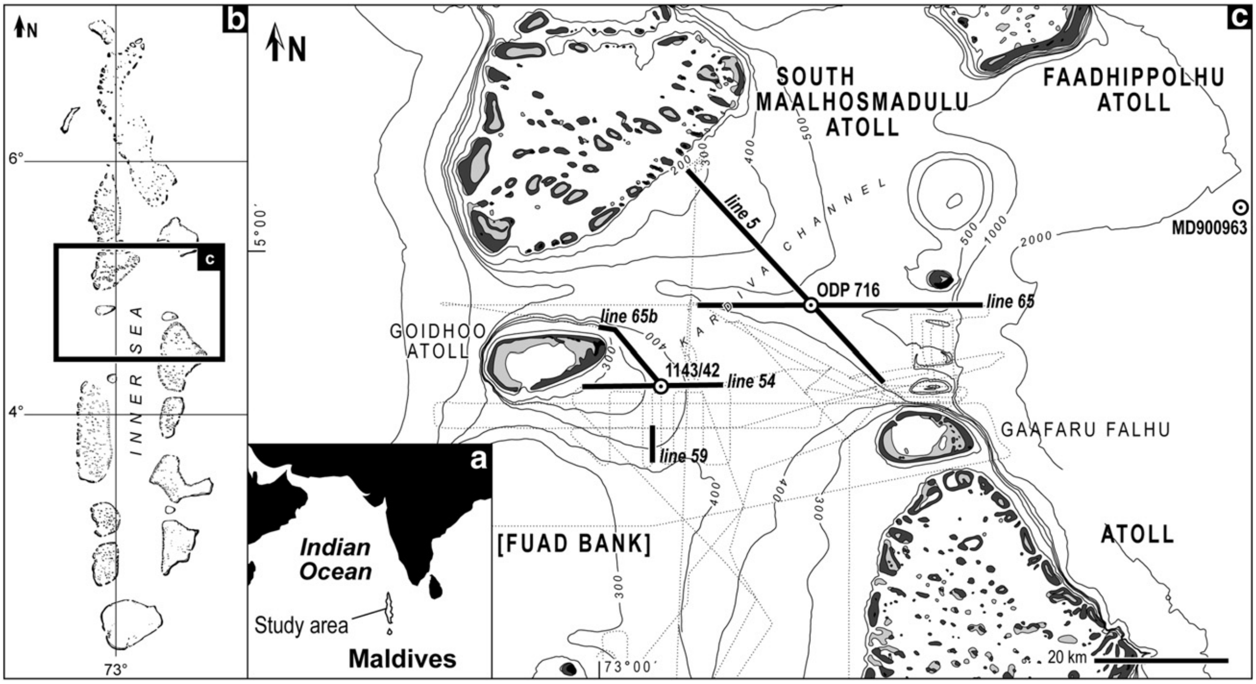

Fig. 1. Location map of the Maldives. (a) The Maldives are situated in the central equatorial Indian Ocean. (b) The box shows the outline of the study area. (c) Closer view of the study area. The position of Parasound and seismic lines respectively is indicated. The thin dotted line traces the complete R/V Meteor leg M74/4 vessel track.

and consists of neritic carbonates and periplatform ooze (Aubert and Droxler, 1992; Purdy and Bertram, 1993).

The ocean-facing margins of the archipelago are inclined 20–30°, down to water depths of 2000 m. On the Inner Sea side, atoll slopes have the same inclination angles, but reach down to water depths of only 150 m (Anderson, 1998; Fürstenau et al., 2010), where the gradient rapidly declines (Aubert and Droxler, 1996). Since the late Middle Miocene, the Inner Sea basin has accumulated periplatform ooze deposits (Droxler et al., 1990; Malone et al., 1990), which are subject to re-deposition by bottom currents (Betzler et al., 2012; Lüdmann et al., 2013) (Fig. 2).

Climate, oceanographic setting and current activity at the Maldives nowadays is dictated by the seasonally reversing Indian monsoon system (Tomczak and Godfrey, 2003). Southwestern winds prevail during northern hemisphere summer (April–November), whereas northeastern winds prevail during winter (December–March). Winds generate and interact with oceanic currents, which are directed westwards in the winter and eastwards in the summer. Interseasonally, a band of Indian Ocean Equatorial Westerlies is established, forcing strong, eastward-flowing surface currents showing velocities of up to 1.3 m s^{-1}. Monsoon-generated currents reach to great depth with only slightly reduced velocities (Tomczak and Godfrey, 2003). According to Shankar et al. (2002), data deduced from an Oceanic General Circulation Model show that the Ekman drift controls circulation in the uppermost 20 m of the water column, and geostrophy dominates in deeper water. The Winter Monsoon current primarily is a geostrophic current with an Ekman drift modulation. The stronger summer monsoon winds induce a dominance of Ekman drift at the surface, leading to a more complex vertical current pattern than during the winter monsoon. Float data corroborate that the circulation patterns around 900 m of water depth resemble those at the surface (Davis, 2005).

3. Methods and material

Data from two cores (NEOMA 1143, 4°49.50′N, 73°05.04′E; ODP Site 716, 4°56.00′N, 73°17.00′E) are integrated with multi-channel reflection seismic data, sub-bottom profiler (Parasound) and Multibeam data acquired during R/V Meteor cruise M74/4 in 2007. Grain-size measurements of core samples were performed using a Sympatec HELOS/KF MAGIC laser diffraction particle-size analyzer with wet dispersing system QUIXEL. Data were processed with the software Windox 5 and GRADISTAT (Blott and Pye, 2001) with the calculations following the logarithmic graphical method by Folk and Ward (1957). Comparison of grain-size data generated by laser diffraction with data from conventional sieving shows that the absolute values differ around 5% and up to 10%. Carbonate mineralogy was measured by x-ray diffraction with a Philips Diffractometer PW1830/00 on smear mounts with 0.02° 2θ steps and 2 s of scanning time. The carbonate mineralogy was calculated based on a calibration curve for aragonite and the aid of the free peak fitting software MacDiff 4.2.5 (Rainer Petschick, Department of Geosciences, Johann Wolfgang Goethe University, Frankfurt/Main, Germany). The carbonate content data from core NEOMA 1143 were performed with a LECO SC-144 DRPC and are based on the measurements of carbon content and stoichiometric re-calculation of the carbonate content assuming 10% being present as organic carbon. Stable isotope measurements of samples from core NEOMA 1143 were performed on 10–15 tests of the planktonic foraminifer *Globigerinoides ruber* (white) cleaned ultrasonically prior to analysis. The isotope measurements were performed with a Finnigan MAT 251 mass spectrometer at the Leibniz-Laboratory for Radiometric Dating and Isotope Research in Kiel, Germany. Analysis precision is about 0.07‰. The results are reported relative to the PDB standard. U/Th dating has been carried out at the Marine Biogeochemistry department of IfM-GEOMAR in Kiel, Germany. Pieces of the solitary living coral *Caryophyllia* spp. from core NEOMA 1143 were measured by multi-static MIC-ICP-MS (Fietzke et al., 2006). For the correction of detrital 230Th a 230Th/232Th activity ratio of 0.6 ± 0.2 was used.

The seismic data of the NEOMA cruise were collected with a 144-channel digital streamer array. Seismic signals were generated by two clustered GI-Guns, each with a volume of 45 in^3 for a 105-in^3 generated injector volume. The dominant frequencies center around 100–120 Hz. The shot point distance was 12.5 m. Processing of the data was done with the Promax software package (Halliburton-Landmark). The data are processed to a zero phase, filtered in time