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Evidence for underwater current activity on the upper slope of the carbonate platform off western India using multibeam bathymetry

The carbonate platform examined in this study is on the outer continental shelf of the northwestern margin of India at water depths between 60 and 90 m (Figure 1). It is located off the Narmada and Tapi rivers, which debouch abundant terrigenous sediments and freshwater onto the coast. Despite abundant terrigenous material expected on the platform, it comprises <10% terrigenous sediments but abundant carbonate sediments. There may be strong surface or underwater currents preventing deposition of terrigenous material but no evidence for the same has been reported. The platform has been studied since 1971 for single-beam bathymetry, sediments and sedimentary rocks[1–7]. Recent studies on the platform revealed the presence of relict *Halimeda* bioherms, ranging in height from 2 to 20 m, faecal pellets, *Halimeda* and ooid–peloid associated sediments and sedimentary rocks formed during the Early Holocene[6,7]. The importance of *Halimeda* bioherms is that they produce abundant carbonate sediments, and during carbonate production abundant CO_2 is released to the atmosphere[8]. Thus, the study of the growth/demise of bioherms on the platform is helpful to better understand the contemporary climatic and oceanographic conditions. The *Halimeda* bioherms of the Early Holocene and Recent occur in the Indo-Pacific region[9–15]. A few bioherms of the Palaeozoic and Miocene have also been reported[16–18]. *Halimeda* bioherms produce both fine- and coarse-grained carbonate sediments[19–21]. The platform off western India comprises abundant coarse carbonate sediments. The fine-grained sediments (lime muds) produced on the platform were partly deposited in some lagoons and partly transported and deposited on the slope[22–24]. It was assumed that strong bottom currents or tidal currents that prevailed on the platform transported fine-grained carbonates to the slope during the Early Holocene.

Bathymetry data based on widely spaced single-beam echosounder profiles collected on the carbonate platform are available[7]. Single-beam echo-sounding data offer two-dimensional view of the seafloor features, and to know their lateral continuity close-interval data have to be obtained. Multibeam bathymetric data, on the other hand, offer larger aerial view of the morphological features on the seafloor and enable researchers to

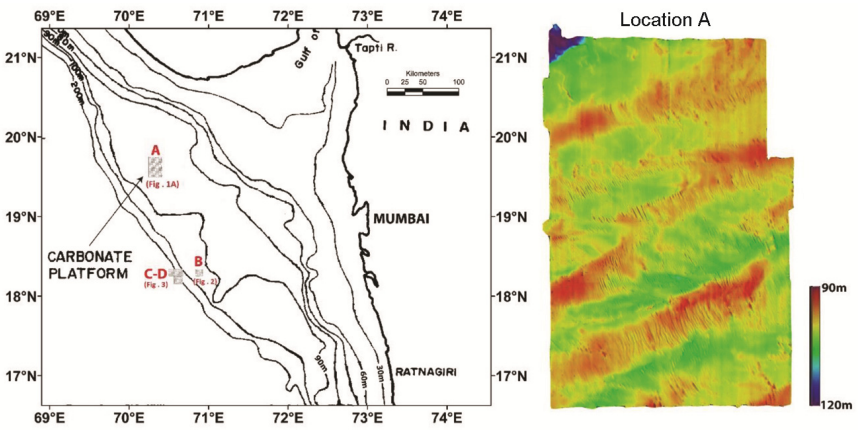

Figure 1. The carbonate platform off western India. (Left) Three boxes (A, B, C-D) shown on the platform are locations where multibeam bathymetry was carried out. (Right) Multibeam bathymetry at location A showing linear ridges and their lateral coalescence, suggesting the presence of algal bioherms.

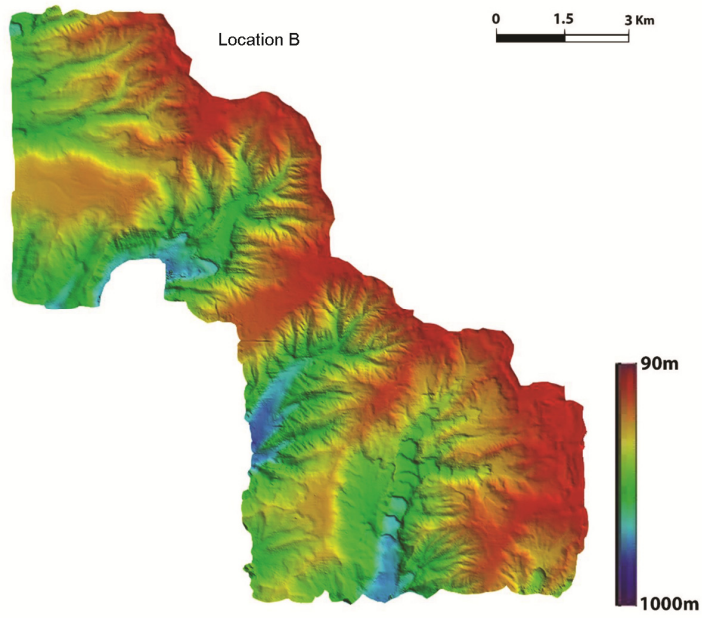

Figure 2. Multibeam bathymetry at location B (see Figure 1). The platform is dissected into small blocks and the channels that formed joining the main streams directed to the slope.

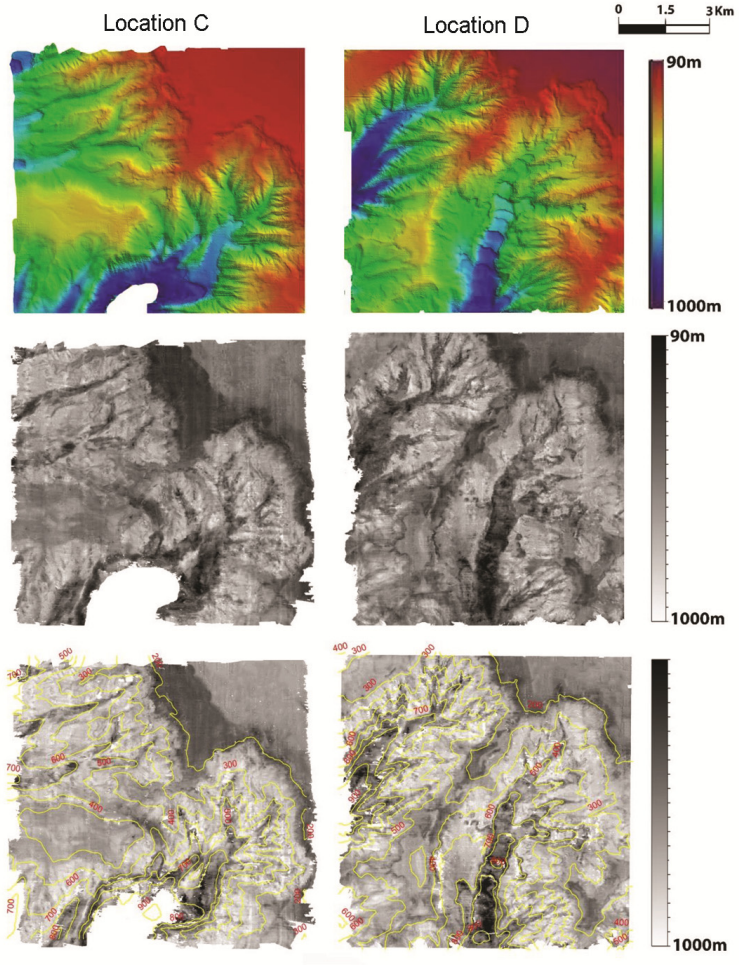

Figure 3. Multibeam bathymetry at locations C and D (see Figure 1). Channels and subchannels eroding the slope of the platform and joining streams at the deeper slope indicate the impact of underwater currents on the slope.

better interpret the features. A multibeam bathymetry echo-sounding system (EM 1002 of Kongsberg AS, Norway) was installed in the National Institute of Oceanography Coastal Research Vessel *Sagar Sukti*. This system has 111 receiving beams and each beam is narrow covering 2° over a 150° sector. The operating frequency of the system is 95 kHz. Using the amplitude (inner beams) and phase (outer beams) detection methods, the multibeam system is capable of achieving depth resolution (2–8 cm) and is helpful to characterize the seafloor features. Post-processing corrections include removal of tide effects and depth outliers and gridding of the bathymetric data. Dandapath *et al.*[25] mapped pockmark features of the seafloor using multibeam bathymetry and reported modifications in the seafloor pockmark morphology by bottom current activity. In the present study the multibeam bathymetry data were acquired, especially on the carbonate platform during four cruises of *CRV Sagar Sukti* in 2007. Figures 1–3 show the bathymetric features at three locations – one on the platform and two on the upper slope in the southern portion of the platform.

Figure 1 shows multibeam bathymetry of the platform exhibiting ridges and furrows, and coalescence of ridges. In an earlier study we have described platform bathymetry in 11 E–W profiles showing linear ridges across the platform, mounds and lens-shaped structures, and reported them as algal biohermal structures[7]. The second location (Figure 2) is at ~90 m depth contour, and shows that the platform is being scoured and dissected into small portions at its edge, and several small and narrow channels eroding the platform are merged into streams that are directed downslope. The third location is at ~200 m contour and further downslope (Figure 3). Here we found a network of several narrow channels and subchannels distributing from 200 m contour eroding the slope and finally joining the deeper and wider stream at 700 m contour that extends further down the slope. The network of channels cutting or scaring of the platform evidence the activity of underwater currents or gravity currents on the slope of the platform. The steep walls of the main stream at 700 m depth indicate strong current activity. Surface and underwater currents have been reported on the western margin of India, both during the southwest (SW)

and northeast (NE) monsoons[26–31]. Some studies have also indicated the prevalence of strong SW monsoon during the Early Holocene[32–34]. A southerly coastal surface current[26] about 150 km wide[29] occurs at water depth of 50 m on the continental shelf of western India during the SW monsoon (June–September). This current may have transported river-borne suspended sediments to the south of the platform, keeping the platform free of terrigenous sediments. During the NE monsoon (November–February), the southerly surface current is replaced by a northerly surface current. An undercurrent ~40 km wide in the depth interval of 100–250 m (ref. 29) characteristic of the Bay of Bengal waters, prevails during both the SW and NE monsoons[30,31]. However, it becomes progressively weaker from south to north, and is not detected north of ~20°N. Since the study region is between 18°N and 19°N on the upper slope in the southern part of the platform, the seafloor might have been influenced by this current, which scoured portions of the upper slope. This study thus provides evidence on the impact of strong bottom current scouring the upper slope of the platform; these currents act as agents transporting sediments to the lower slope and/or deep sea.

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