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Late Quaternary geomorphology, seabed evolution, and terrigenous sediment delivery to the Pandora and Moresby Troughs, Gulf of Papua

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ABSTRACT

An integrated geology and geophysics investigation has been carried out to study the late Quaternary deepwater depositional system in the Gulf of Papua (NSF-MARGINS focus area) focusing on two contrasting depocentres, Pandora and Moresby troughs. The studies incorporate multi-beam bathymetry, sub-bottom sonar, and core data in order to define and map acoustic and lithofacies; and relate depositional processes, sediment routing, timing and geomorphic products that have developed since Marine Isotope Stage (MIS) 3, ca. 40 cal ka. 3D seafloor visualisation is used to infer sedimentary processes responsible for observed morphology, which are then placed into a chronostratigraphic framework using recently published age models of sediment cores.

The peak depositional period in Pandora Trough occurred during MIS 2. At that time a large deep-sea channel network linked the Pandora and Moresby troughs, allowing long-distance sediment transport by large turbidity currents from the Papuan mainland to the Coral Sea Basin. Near the LGM, shelf-edge failure led to emplacement of mass-transport deposits on the floor of the Pandora Trough, blocking this pathway for large turbidity currents. Intermittent turbidity currents continued to feed minibasins upslope of the MTD complex until early MIS 1 (earliest Holocene).

Along the shelf edge of the Papuan Peninsula, substantial sediment delivery by turbidity currents continued until middle Holocene and perhaps later; combined with bottom currents, these flows contributed to the formation of large sediment waves of Moresby Fan. However, this Holocene turbidite sedimentation does not extend much farther into the Moresby Trough, based on negligible Holocene sediment accumulation deeper in the basin.

This study has shown that sediment delivery from fluvial sources to deep basins in the GoP is controlled by a complex interplay of changing sea level, evolving basin bathymetry (influenced by depositional and tectonic processes), and oceanic transport of sediment from shelf to slope. These conditions have created highly localised conduits for shelf to slope sediment delivery that respond both to global forcing (eustatic sea level) as well as local conditions (shelf gradient, mass wasting, currents, and source proximity), resulting in a complex network of deep-sea depositional morphologies active from the Last Glacial Maximum to Holocene time.

1. Introduction

The study of seabed morphology can provide valuable insights regarding formative sedimentary processes. Deep-sea sedimentary processes operate over a range of temporal and spatial scales, and morphological analysis is a valuable tool to assess relevant processes via their sedimentary products. This study presents 3D visualisation, analysis and interpretation of seabed morphology, stratigraphy, and sediment acoustic characteristics derived from sub-bottom sonar data and sediment cores collected during the 2004 PANASH cruise of the R/V Melville in the Gulf of Papua (GoP) (Dickens et al., 2006), and a bathymetric grid based in part on multibeam data collected by the R/V Melville in 2004 (Daniell, 2008).

The GoP (Fig. 1), with associated large river systems and deep ocean basins was selected as a focus area for the US-NSF MARGINS Source to Sink (S2S) Program (NSF-MARGINS, 2004, 2009), owing to the large terrigenous sediment flux, the presence of active sedimentary processes in fluvial, shelf, and deep-sea settings, and the relatively closed nature of the system over millennial timescales. This continental margin receives large terrigenous sediment flux (331 million tonnes/year) (Milliman, 1995) from rivers that have low anthropogenic impacts in their catchments. The shelf and slope exhibit morphological gradients from the wide and gentle shelf–slope setting adjacent to the Pandora Trough to the narrow-steep shelf–slope

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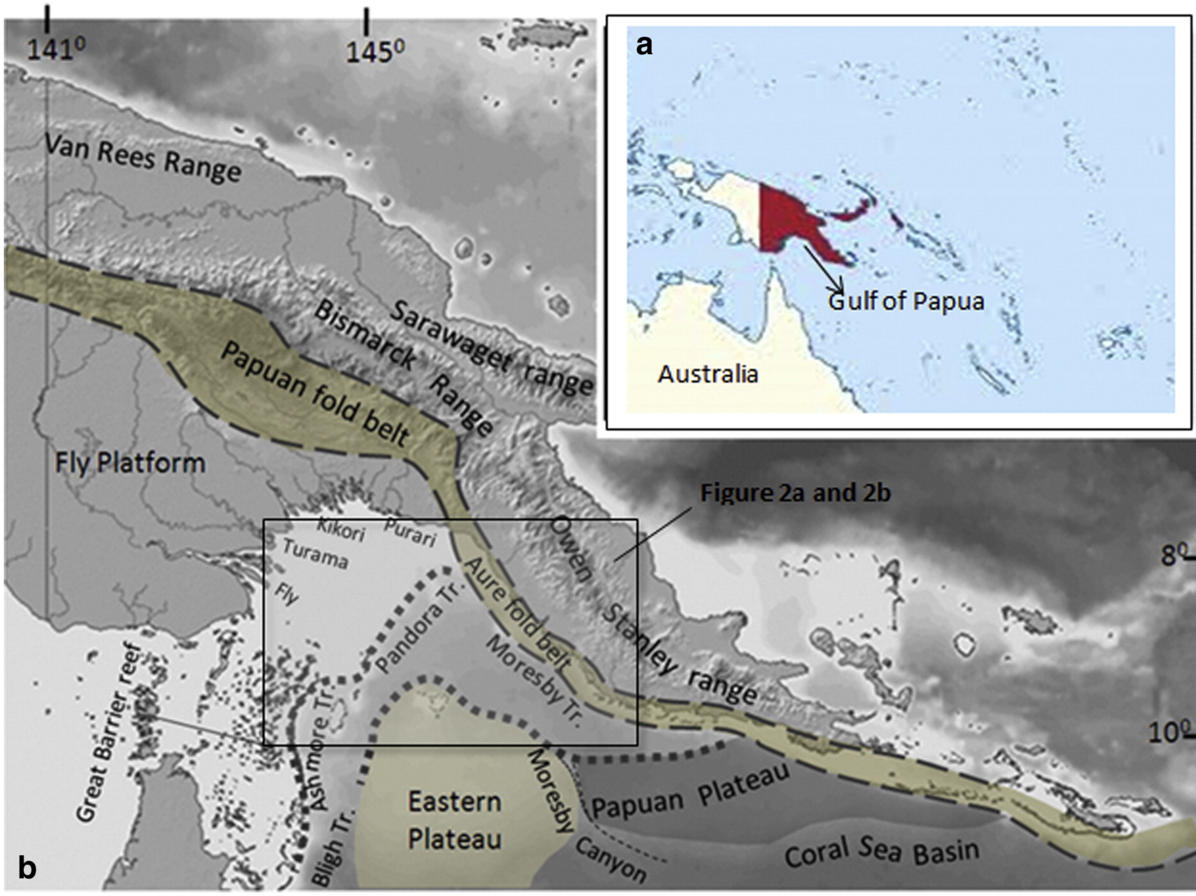

Fig. 1. (a) Inset shows Papua New Guinea highlighted in red; (b) physiographic and tectonic elements of the Gulf of Papua and Papua New Guinea (modified after Pigram and Davies (1987)).

setting adjacent to the Moresby Trough, which have all been progressively drowned since the Last Glacial Maximum (LGM) (23–19 cal ka). The shelf–slope depositional complex built extremely rapidly during the Neogene, and contains hydrocarbon systems that are presently being exploited (Tcherepanov et al., 2008).

This area has been intensively sampled and investigated with multibeam swath bathymetry, 3.5 kHz seismic profiling, and core sampling, and thus provides an excellent place to study dynamic processes associated with sediment delivery and deposition. This rich data archive (Dickens et al., 2006) allows a rare opportunity to study the evolution of a regional deepwater depositional system at fine temporal and spatial resolution (centennial–millennial time scale, centimetre to metre sedimentary thickness) over approximately the last 40 cal ka (Septama, 2015; Septama et al., 2016). Our main objectives are to study seabed and shallow subsurface morphology, stratigraphy, and sediments, so as to infer sedimentary processes over space and time. These observations will allow identification of primary pathways, timing, and mode of sediment delivery across the study area.

This study will first assess the descriptive morphology of the two major contrasting depocentres in the GoP (Pandora and Moresby troughs), with their associated canyons, channels and slopes, by integrating a published bathymetric grid (Daniell, 2008) with 3.5 kHz seismic data to generate a general acoustic facies classification and distribution map. Core data (Septama, 2015; Septama et al., 2016) will then be used to calibrate acoustic facies, and elucidate detailed depositional processes in the area. Previous studies have concentrated on linking seafloor geomorphology with broad inferred patterns of sediment delivery and accumulation (Francis et al., 2008). This study will build on the morphological analysis of Francis et al. (2008) by use of a more extensive chronostratigraphic framework, more detailed documentation of lithofacies distributions, geochemical proxies, and other sources.

There are five morphological basins in the modern Gulf of Papua and adjacent northern Coral Sea (Figs. 1, 2a and b) (Francis et al., 2008; Daniell, 2008):

(1) The Bligh Trough forms the southwestern boundary of the study area, and is the eastern border of the Great Barrier Reef and the southwestern terminus of the Pandora Trough and southern terminus of the Ashmore Trough. It is oriented North-South with water depths ranging from 1500 to 2300 m.
(2) The Coral Sea Basin is a wide abyssal plain covering an area of 100,000 km^2, with water depths ranging from 2500 to more than 4500 m. It is the most distal and deepest area of the Gulf of Papua and is interpreted as the ultimate depositional sink, connected to the Papuan mainland and peninsula by the Moresby Channel.
(3) The Ashmore Trough to the west is the smallest basin (2009 km^2) and has water depths of 500–900 m. This depocentre is surrounded by elongated semi-drowned carbonate platforms (Tcherepanov et al., 2008) that grew on the top of northeast-southwest oriented structural ridges (Ashmore Reef to the east, Boot Reef and Portlock Reef to the north-northwest, and the Great Barrier Reef to the west).
(4) The Pandora Trough is the largest basin and depocentre in the northern GoP, covering 17,350 km^2, located parallel to the toe of the slope of the Gulf of Papua's continental shelf margin. It is elongated south-southwest–north-northeast, with water depths of 1500–2000 m, with an extensive continental shelf adjacent to the basin.