Source to sink (S2S) control on the deepwater depositional systems in Gulf of Papua: Insights from seafloor morphology, acoustic facies and turbidite sand provenance

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Summary

Two adjacent and contrasting deepwater systems, the Pandora and Moresby Troughs in the Gulf of Papua, have been investigated through C-14 dating of cores, sand provenance, sonar and seismic data in order to link sediment flux, sources, routing and the resultant morphology and facies.

Our studies reveal contrasting depositional stories due to interacting glacio-eustasy, coastal hydrodynamics, and tectonics. The Pandora Trough resembles a typical passive margin with sediments of dissected arc/recycled orogen provenance, whereas the Moresby Trough with a narrow shelf and mature canyons is a more typical active margin system with transitional to dissected arc sediment provenance.

The major implication for sediment delivery is timing. During the Holocene highstand, clastic delivery to the deep sea ceased in Pandora Trough, but has remained continuous in Moresby Trough via direct river transfer and shelf clinoform reworking via coastal currents, creating a unique highstand fan system.

Introduction

The GOP is a 400 km-wide embayment that contains excellent examples of adjacent passive and active terrestrial-oceanic margins with multiple sources of fluvial and neritic carbonate sediment input. Some of the main rivers, such as the Fly, Strickland, Turama, Kikori and Purari rivers, combine with smaller streams from the Papuan Peninsula to feed into the shelf, slope and deep water with annual sediment yields of greater than 1000 t/km^2. This region is an active convergent boundary between the Indo-Australian and Southwest Pacific plates with average tectonic uplift rates of 3-10 mm/y (Chappell, 1993)

The geology of the Papuan mainland consists of a southwest cratonic zone, a central collisional zone and Cenozoic volcanogenic terranes (Davies et al., 1996). Mainland volcanic activity peaked during Pliocene followed by mid-Tertiary uplifting caused by collision of Indo-Australian and Southwest Pacific plates, creating the Central Highlands. These highlands have consequently become sources for dissected arc provenance whereas on Papuan Peninsula to the southeast, the tectono-volcanic Bismarck and Owen Stanley ranges produced by the Papuan Orogen are more likely to deliver sediments of undissected to transitional arc provenance.

The Quaternary sediment dispersal system in GOP provides an excellent "natural laboratory" for comparative study of the dynamic processes associated with sources, timing and depositional product. This also endows us an opportunity to study the evolution of deepwater depositional system over approximately the last 45 ka.

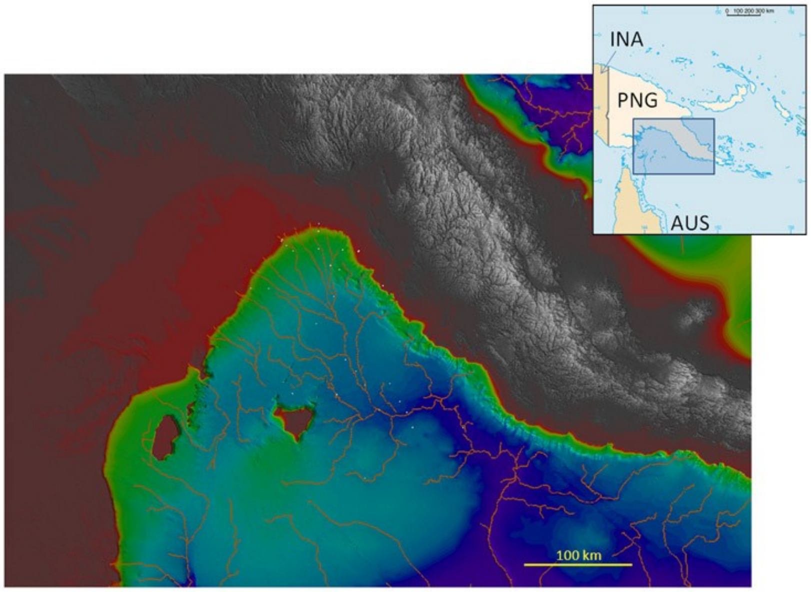

Figure1: Topography and bathymetry of the Gulf of Papua (based on the DEM of Daniell, 2008), including major deepwater channel systems determined from slope analysis. Inset map showing study area location, AUS= Australia, INA= Indonesia, PNG= Papua New Guinea

Methodology

This multi-scale study involves interpretation of seascape morphology derived from an extensive and high resolution multibeam bathymetric grid data combined with high resolution seismic profiles and jumbo piston cores, primarily acquired during cruises on the R/V Melville in 2004. Acoustic facies have been defined by the seafloor surface relief and roughness, reflective strength, sound penetration, sub-bottom reflector and internal reflector characteristic. Lithofacies have been defined based on gamma density and magnetic susceptibility curves, and sedimentary fabrics (physical and biogenic). Selected cores and been further sub-sampled for grain size, oxygen isotopes, radiocarbon and provenance analysis. Sand provenance (18 samples) was determined by quantitative detrital modes analysis assisted by scanning electron microscopy and mineral liberation analysis (SEM-MLA) with 3500-5000 particle counts per thin section. Provenance classifications were based on filtered criterion of >62.5 µm, with 60, 70 and 80 wt % minerals in each particle class.

Results

Acoustic facies classification defines seabed morphological provinces, sediment type and depositional geometry. With ground-truthing from core data, the classification incorporates lithology and sedimentary structure. Core analysis reveals four microfacies based on sediment properties. The ternary diagram using Gazzi-Dickinson fields (e.g. Ingersoll et al., 1984) is shows variation of source terranes ranging from transition arc to dissected arc to recycled orogen (Figure-2a)

Pandora Trough: The ^{14}C age model for jumbo piston cores MV-54 and MV-23, supported by ^{210}Pb multicore analyses of Muhammad et al. (2008), suggests that most of the slope system was inactive since sea level rise at the end of Marine Isotope Stage (MIS)-2, either because the underlying morphology retains sediment near the shelf edge or that the major input is shifting landward. In the toe of slope, a strong continuous sub-bottom reflector in seismic profiles was observed, which corresponds to thin turbidite beds observed in cores, interpreted as by-pass channel-fan system. The age model of this fan shows a period of rapid sedimentation (41.3 cm/ka) from 44 -19 Ka Bp, decelerating to 20 cm/ka afterward. The turbidite succession observed in core and seismic profiles, suggests multiple point sources for the fan system, which appears to have shifted oceanward during periods of falling sea level. Sand provenance in this core ranges from dissected arc to isolated deposits of recycled orogen provenance that probably document several time intervals of intense fluvial incision during the MIS-3 to MIS-2 interval (Fig. 2b). The compositional trend of quartz and litho-volcanic proportion increases upward, suggesting increased supply of extrusive volcanic terranes in the Central Highlands.

Moresby Trough: The basin floor is dominated by undulatory sloping deposits with echo character dominated by regular overlapping hyperbolae. We interpret these deposits as originally transported to the basin floor by mass transport processes, possibly triggered by eustatic sea level fall in MIS-3 (57-29 Ka). The relict morphology of the pressure ridge at the depositional head of the mass transport deposit created an undulatory pre-existing topography that promoted the deposition of turbiditic sediment waves that now blanket the seafloor (Figs. 3a&b). Radiocarbon ages from core MV-22 show moderate depositional rates of 28 cm/ka over the PAST 41 Ka, most likely delivered via shelf-incising canyons to the basin floor. The 3D morphology visualization shows that the canyon processes were periodically plugged and avulsed anti-clockwise by right-lateral faulting which scraped and uplifted seafloor sediment. Core MV-22 contains thin sheet sands, with provenance varying from transitional to dissected arc resembling sources from the Bismarck and Owen Stanley ranges of the Papuan Peninsula. The upward-increasing textural maturity in the cores suggests additional more recent allochthonous input from the Fly Highlands to the northwest.

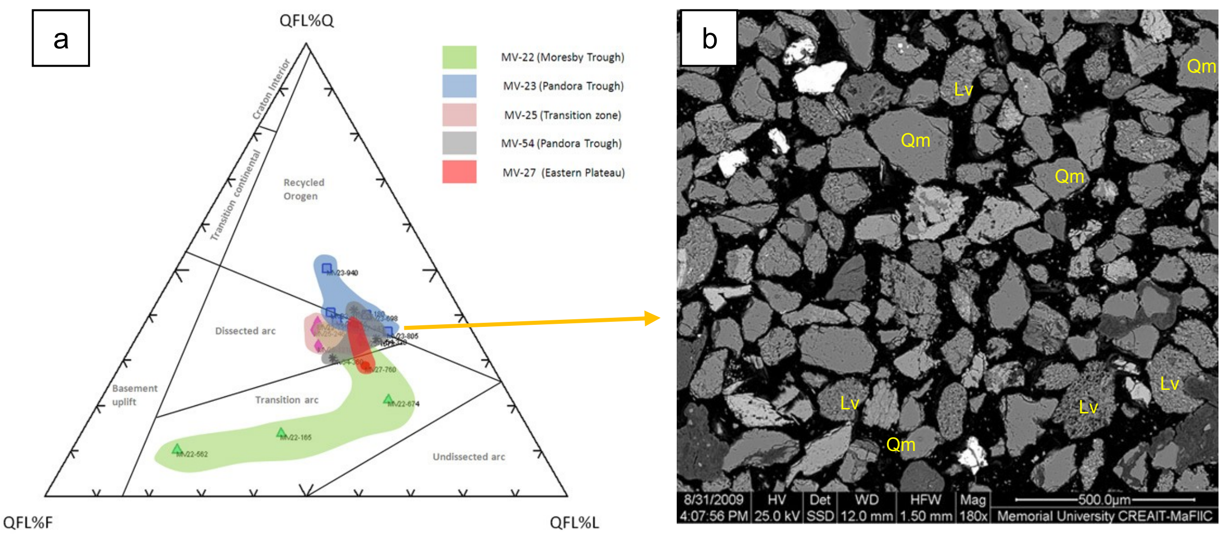

Figure 2: a) Ternary diagram using provenance fields of Gazzi-Dickinson (Ingersoll et al., 1984) showing the turbidite sources range from dissected arc to recycled orogen. b) Example of the backscatter SEM image from turbidite sand samples in core MV-23 (Pandora Trough) interval 805 cm (borderline between dissected arc and recycled orogen), showing the predominant composition of volcanic lithic (Lv) and monocrystaline Quartz (Qm).

Conclusions

Our preliminary observations reveal that in the Pandora Trough, turbidite sedimentation was active during MIS-3 and MIS-2, and diminished when the sea level began to rise at the end of MIS-2. This pattern contrasts with that of the Moresby Trough, where the basin is still receiving terrigenous sediment supply through the canyon system during the present sea level highstand. The factors influencing this variation include shelf width, proximity of sediment sources, and the orientation and intensity of shelf current systems. This study demonstrates how such depositional processes and stratigraphic successions can vary within a regional embayment. This detailed understanding of geologic processes and products can be used as an analog to better understand the evolution of other deep sea systems, modern and ancient, over centennial-millennial time scales.

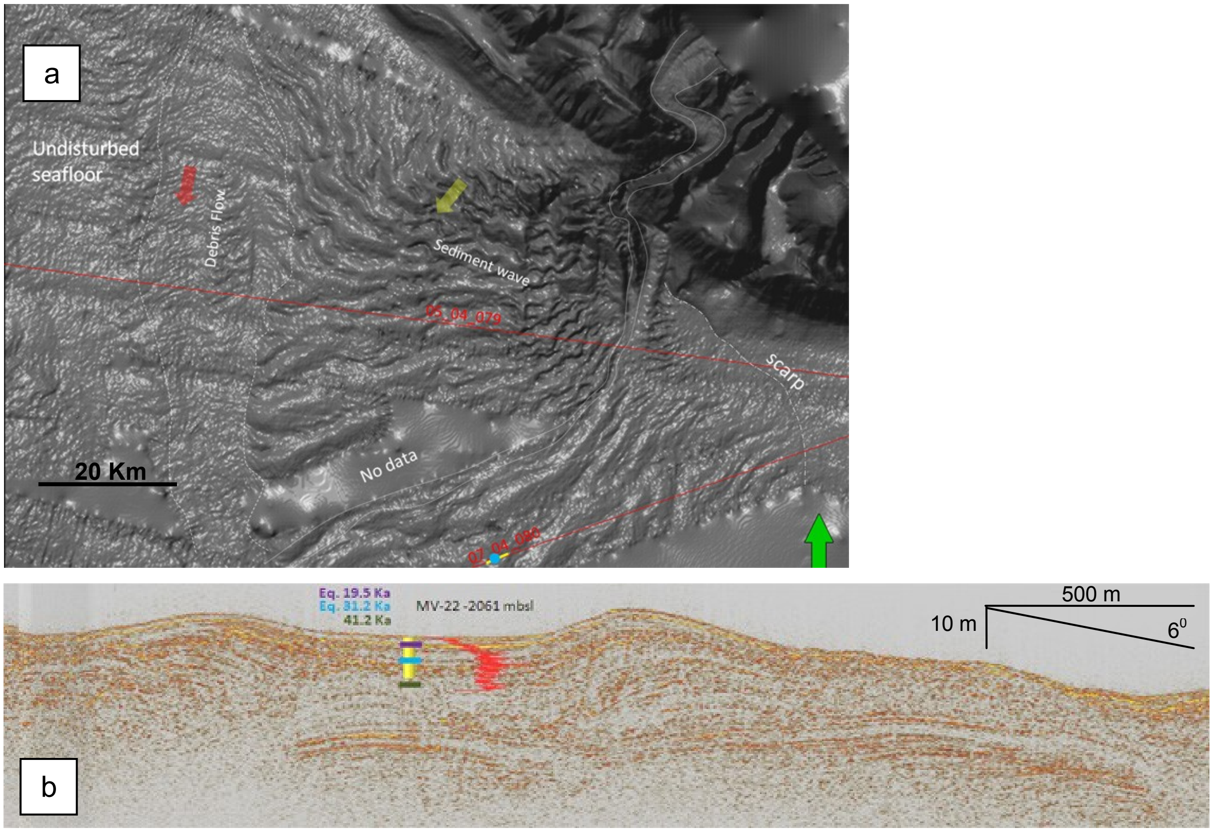

Figure 3: a) Gridded bathymetric data showing fan-shaped sediment waves observed in the Moresby Trough, with depositional dimensions of 2 km wavelength and 160-230 m height in the inner fan and 15-26 m in the outer fan. The origin of these depositional elements is interpreted as mass transport deposits overlain by thin turbidite layers.
b) 3.5 Khz seismic profiles of section 07-04-080 (yellow lines in Figure 3.a), showing continuous parallel sub-bottom reflectors, tied with jumbo piston core MV-22, for which the serrated gamma density curve (red) illustrates thinly layered turbidite sands.

Acknowledgements

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