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The use of seabed scoured depressions as a proxy for near-seabed flow

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Background and Setting

The Oceanic Shoals Commonwealth Marine Reserve (CMR), situated in tropical northern Australia, incorporates extensive areas of carbonate banks and terraces. These are recognised by the Australian Government as potential biodiversity hotspots.

In September 2012, Geoscience Australia collected shallow seabed information to characterise the CMR and to better understand the carbonates banks and their role in supporting biodiversity.

The survey area is located on the widest part of the Continental Shelf (250 km) which is subject to a storm-influenced micro-tidal energy regime (mean range: <2 m). However, the coast immediately to the south is macro-tidal (~7 m). The net tidal direction is westerly and the sediment transport regime is flood-dominated (Porter-Smith et al., 2004).

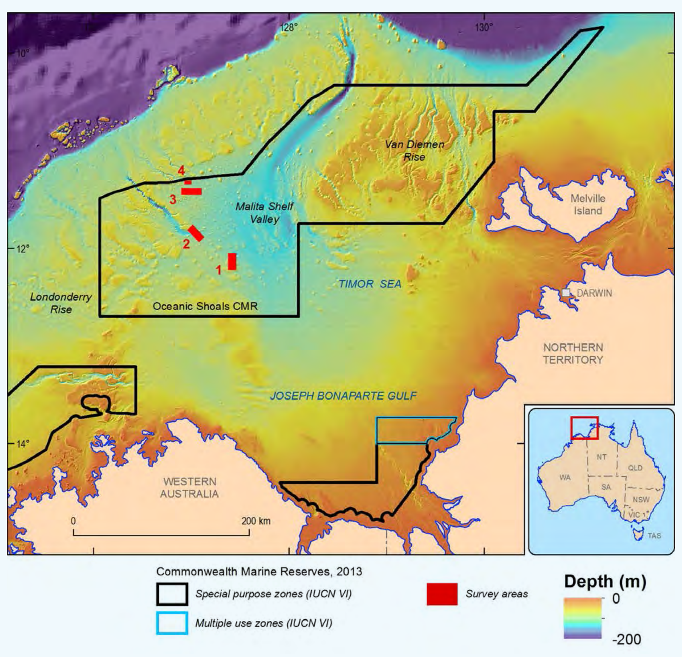


Figure 1. Location map showing the multibeam extent of the four grids surveyed in the Oceanic Shoals CMR

High-resolution mapping has revealed that the seafloor is characterised by multiple carbonate banks that rise tens of metres above otherwise vast soft-sediment plains. Moreover, the mapping and preliminary physical and chemical analyses have shown that: (Fig. 2).

- the size (length and height) of the banks reduces away from the coast (Fig. 3);
- sediments on the plains are amongst the muddiest sampled on the Australian continental shelf (Fig. 4);
- small depressions occur in large numbers over most of the plains. These depressions are likely pockmarks, which are the surface expression of focussed fluid flow, and;
- the amount of CO_2 relative to porosity was about twice as high in these pockmarked sediments compared to a compilation of other sediments from around Australia (Fig. 5). This signifies that metabolites from organic matter breakdown are in higher concentrations in these sediments compared to other known areas. This may contribute to the formation of the pockmarks.

It is noteworthy that many of the pockmarks in the deeper areas had scour marks that appear to be current-related.

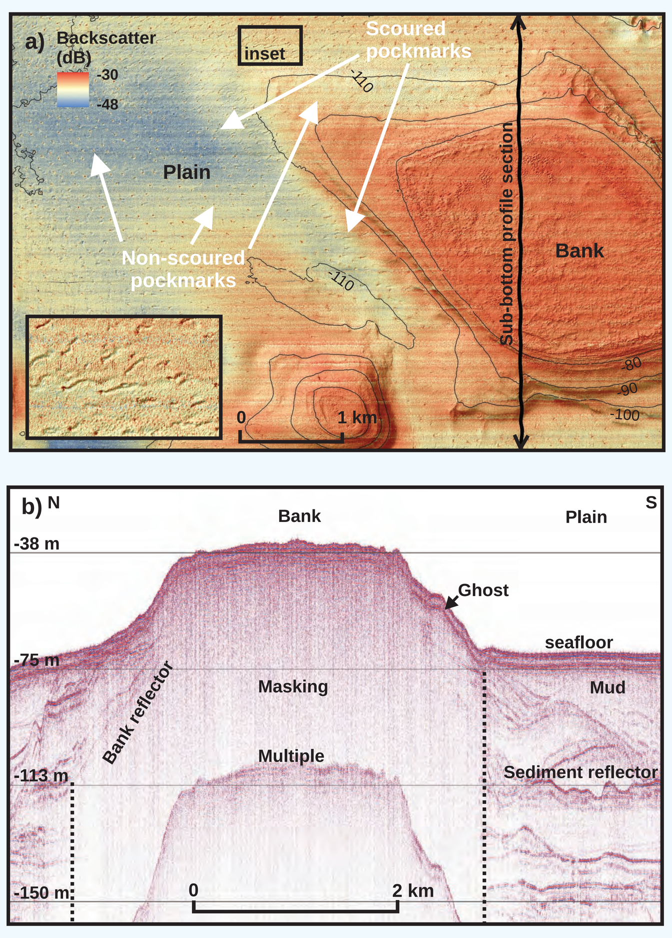


Figure 2. a) Inset from Grid 1 showing pockmarks around the banks highlighted using multibeam backscatter strength over hillshaded bathymetry (grid resolution 2 m). b) Sub-bottom profile showing the sub-surface relationship between the banks and plains

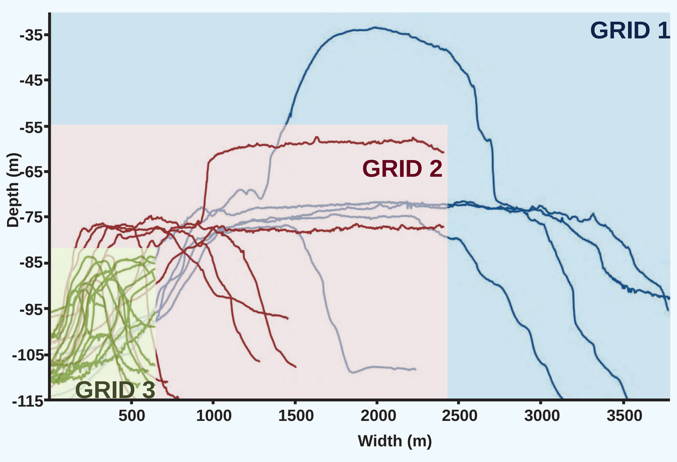


Figure 3. Cross-section profiles of carbonate banks mapped in Grids 1, 2, and 3

Objective

In this preliminary study, we quantify and further characterise the pockmarks using a series of ArcGIS spatial analyst tools, and explore the alignment of the scour marks as proxy for near-seabed flow.

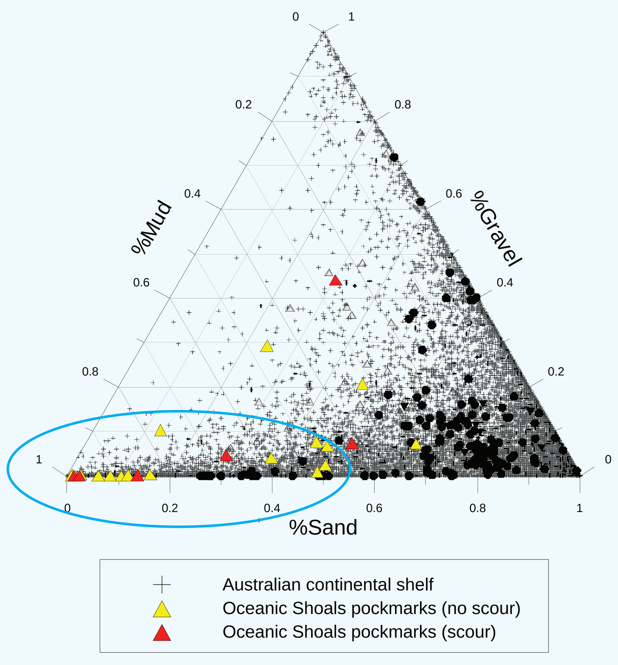


Figure 4. Ternary diagram showing mud, sand and gravel content of Oceanic Shoals sediment in relation to all samples for the Australian continental shelf held by Geoscience Australia

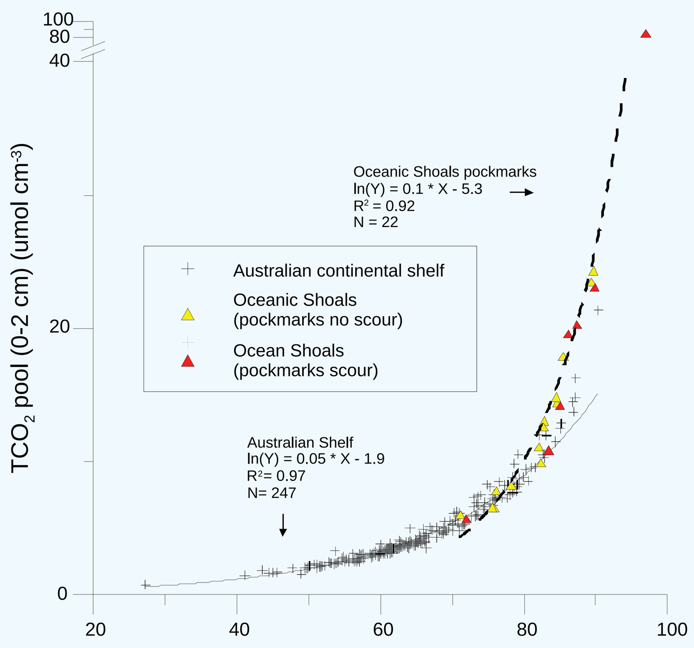
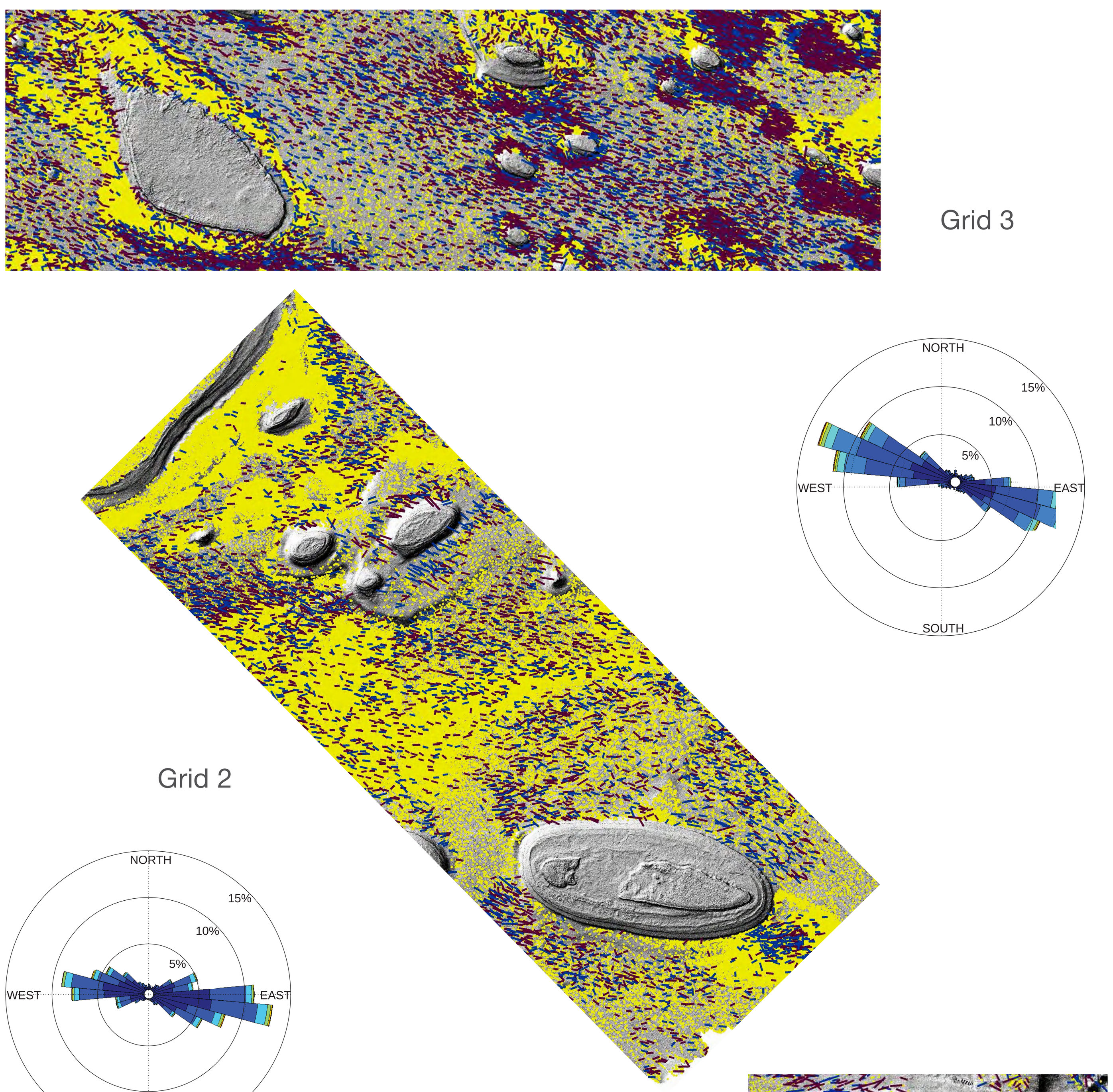
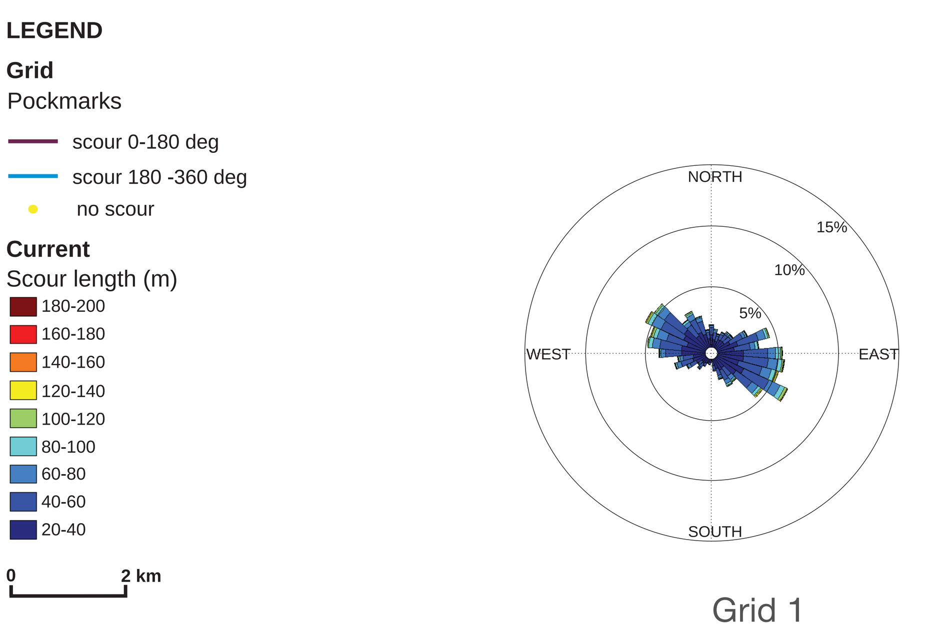


Figure 5. Summary graph of TCO_2 pools in relation to sediment porosity for sediments collected by GAaround Australia. TCO_2 pools are calculated from the first 2 cm of sediments from the grab sample surface

The length of scour marks and modelled bottom shear stress (Fig. 7) were not correlated. However, the hydrodynamic model resolution was not high in the study area. More detailed analysis of other physical variables, such as sediment grain-size, may yield further hydrodynamic information.





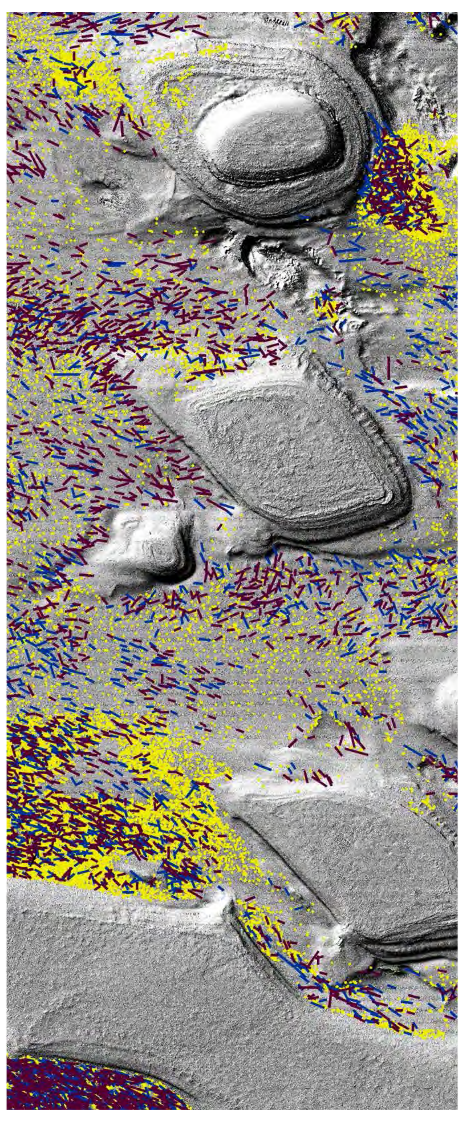
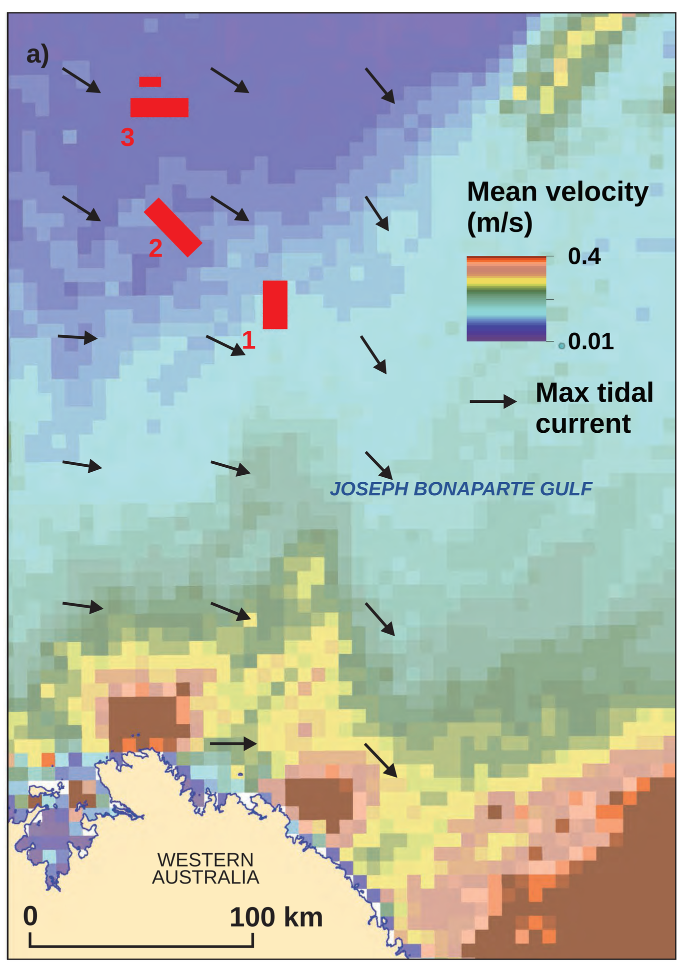


Figure 6. Distribution of pockmark with and without scour marks within survey grids. Each grid is accompanied by current roses displaying the direction and length of all scour marks. Pockmarks and scours were mapped using ArcGIS spatial analyst and hydrology tools and excludes features less than 25 m²



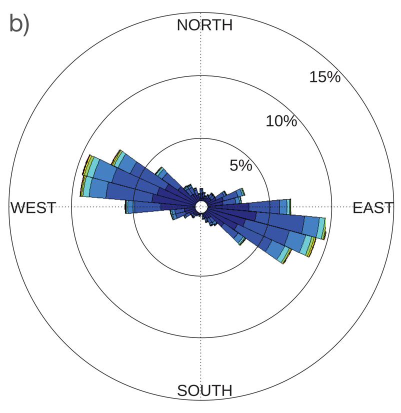


Figure 7. a) Modelled bottom shear velocity (square-root of bottom stress divided by water density) for the Timor Sea averaged over the year (modified from Condie 2011), with survey grids plotted. Black arrows represent the direction of maximum tidal current vectors (modified from Porter-Smith et al., 2004). b) Summary rose of the scour mark directions for all survey grids

Results and Discussion

Over 200 000 pockmarks were identified in the study areas. This density of pockmarks is unusually high, even on a global scale.

Pockmarks occurred in particularly high density in part of Grid 2 and around the banks, which are considered a source of reactive organic matter. These pockmarks (yellow dots: Fig. 6) generally lacked scour features.

About 40 000 pockmarks had distinct scour marks. The scoured pockmarks, which mainly occurred at water depths >90 m in unconsolidated plain sediments, had higher %TOC and Al concentrations than the non-scoured pockmarks.

The current rose diagrams show that the scours are bi-directional, ESE – WNW, and up to 200 m in length. However, most are <100 m long. The orientation of the scour marks correlated with the general tidal flow (Fig. 7). There is more directional variability in Grid 1 compared to Grid's 2 and 3, which we interpret as mainly due to steering by local bathymetric features. The coastward increase of bottom shear stress across the shelf (Fig. 7) and bank size (Fig. 3) may be particularly important variables influencing the extent and direction of scouring.

Future work

- How do pockmarks relate to the underlying geology and the shelf evolution, including carbon production on the banks?
- Does the local bathymetric steering of currents influence the distribution and composition of benthic communities?
- How do pockmarks influence the infauna?
- How representative are the surveyed banks of the broader carbonate terrace and bank ecosystem of the Timor Sea?

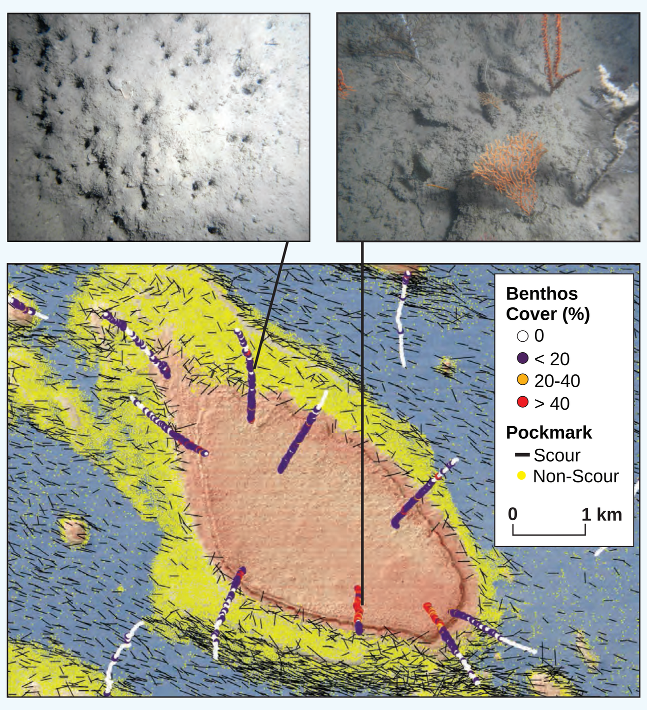


Figure 8. Benthos coverage analysed from underwater video stills around a bank in Grid 3. The base map shows backscatter strength with pockmarks indicated

References

S. Condie, 2011. Modeling seasonal circulation, upwelling and tidal mixing in the Arafura and Timor Seas. Continental Shelf Research, 31, 1427-1436

R. Porter-Smith, Harris, P.T., Andersen, O.B., Coleman, R., Greenslade, D., Jenkins, C.J., 2004. Classification of the Australia continental shelf based on predicted sediment threshold exceedance from tidal currents and swell waves. Marine Geology, 211, 1-20

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