Large Submarine Landslide Discovered on the Outer Shelf and Slope of the Great Barrier Reef; A New Local Mechanism Capable of Generating Significant Tsunamis Along the Northeast Australian Coastalline

1. INTRODUCTION & METHODOLOGY

Submarine landslides have not been well studied compared to their terrestrial counterparts. They can be on a massive scale and have been seen to destroy underwater infrastructure, dramatically change the geomorphology of a region and create devastating tsunamis (Masson et al., 2006). This paper describes a large-scale landslide on the outer Great Barrier Reef (GBR) (Fig. 1). This is the first landslide discovered in the GBR. We will present the geomorphology of the submarine landslide (2), describe the formation of the feature (3), suggest the age of the landslide (4) and then calculate the size of a tsunami created by the movement (5).

All data was taken on the R/V Southern Surveyor between September and October 2007. Bathymetry and backscatter data was collected using the EM3800 system. These were processed in Caris HIPS/SIPS and FM Geocoder respectively and brought into Fledermuam and ArcGIS for analysis. Seven seismic lines were run parallel to the shelf edge over the feature using the Total IS-28 system. A subset sample was taken within the landslide debris and carbonate algae on the sample was dated as ANS1473. Surface complexity was calculated (Ardron 2002) and analysed with backscatter to locate areas of hard rock and soft, fine sediment. Thickness and volume were determined using a technique similar to that used by Völker (2010). A Ward and Day (2003) formula was used to estimate run up on the Australian coastline at the time of the mass movement.

3. FORMATION

The shelf debris is a contiguous, transparent face. Although there are three separate escarpments and associated debris, there is no evidence of settling within the faces. This suggests that the mass movement was near simultaneous. These would be adjacent successive flows, where by the collapse of one escarpment leads to the weakening and fall of another (Mulder and Cochonat, 1979). The toe of the current escarpment is 350 m deep and has two subaerial peaks that are 150 m deep. Offshore there is a shelf with no more than 100 m depth, as well as a bedded deposit to the west. In places the landslide has eroded the shelf surface to expose the underlying carbonate support. As a result, the shelf edge is stepped and suggests that there has been a rotational submarine landslide.

4. TIMING

The shelf edge samples show that the landslide occurred at least 15,000 years ago. No other landslides has occurred since. The sea level on the GBR from transgression to regression has no current between 128 m - 124 m. Due to the age of the landslide (in the area) the escarpment appears to be subaerial rather than subaerial or partially subaerial. The debris has travelled over a relatively large distance and it forms a V-shape with a nose and has a progression of debris sorted from large blocks near the source to fine sediment at the toe. 15,000 years ago the sea level was around 100 m below the present state. Therefore, to have formed at least 15,000 ya and at time when the current landlisde area was submarine it would have occurred at 90,000 ya during the transgression.

5. TSUNAMI

The volume calculations show that 2.5 x 10^6 m^3 of material was lost whilst 3.9 x 10^5 m^3 was gained. This is comparable to the smaller submarine landslides measured by McAdoo et al. (2000) on the American continental shelf edge. The average and total area of the debris was also measured using the volume calculation. The area covered by the landslide was 18.7 km^2 with a maximum thickness of 264 m and average of 6 m. These variables were entered into the Ward and Day (2003) formula. Adopting the assumption that the slide occurred at a high stand similar to current sea level the tsunami with a run up of 11 m and the Australian coastline up to 180 m away could have been created. The ability of the GBR to attenuate a wave has been described (Baba et al., 2008) and would warrant further investigation in relation to this event. Movement tsunami deposits have previously been discovered inside the Great Barrier Reef (Bryant and Nott, 2001). No evidence as yet has been supplied as to the source of these tsunami. Landslides such as this one should be considered.

6. CONCLUSIONS

A submarine landslide measuring 7 km wide and 5.5 km long is found on the shelf edge of the GBR. Coral reef terrace and unconsolidated sediment from the shelf edge is deposited on the upper slope. Facing upslope, the debris contrasts to the fine sediment of upper slope. The feature is 7 km wide and stretches out 5.5 km from the debris head. Hard, rocky intervals dominate. These intervals are surrounded by hard, rocky debris which appears to trap the sediment (Fig. 4A).

This feature is the largest area, cutting back into the slope 400 m and is 1.2 km wide. It has 7 km and from the head to the toe it is 5.5 km. The landslide is a culmination of three adjacent near simultaneous movements. The feature is an example of a rotational slide with stepped formations and erosion into the shelf edge. The toe of the current escarpment is 350 m deep and has two subaerial peaks that are 150 m deep. Offshore there is a shelf with no more than 100 m depth, as well as a bedded deposit to the west. In places the landslide has eroded the shelf surface to expose the underlying carbonate support. As a result, the shelf edge is stepped and suggests that there has been a rotational submarine landslide.

Figure 1. The submarine landslide. A collapse of the continental shelf edge, with coral reef limestones and unconsolidated sediments deposited onto the upper slope. At its widest point the landslide is 7 km and from the head to the toe it is 5.5 km. The inset map of the Queensland and Australia coastlines shows the location of the landslide 10 km from the modern coastline suggesting the landslide is 15,000 ya old. (A) The seven seismic images looking upslope. (B) Interpretation of the seismic data from the landslide. The position and the visual direction of the surrounding features are plotted on the main image.

Figure 2. (A) A plan view of the landslide coloured by depth. Boundaries of surface classification are labeled. (B) A plan view of the landslide with the surface coloured by the results of bathymetry and surface complexity analysis. The position of the dredge and of the 7 seismic lines are also shown. The 7th line is parallel with line 6 downstream on an undisturbed slope.

Figure 3. Close up of the 3 escarpment features cutting into the shelf edge. The escarpment on the left is 300 m wide and 1.2 km wide. The escarpment on the right is 1.6 km wide. The total width of the landslide is 7 km.

Figure 4. (A) Two soft fine sediment areas in the rocky debris. (B) The stepped feature.

Figure 5. Surface showing debris mounded from the shelf edge on to the upper slope facing upslope, the debris contrasts to the fine sediment of upper slope. Facing upslope, the debris contrasts to the fine sediment of upper slope. Facing upslope, the debris contrasts to the fine sediment of upper slope.

Figure 6. (A) The seven seismic images looking upslope. (B) Interpretation of the seismic data from the landslide. The position and the visual direction of the surrounding features are plotted on the main image.