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Long-shelf sediment transport and storm-bed formation by Cyclone Winifred, central Great Barrier Reef, Australia

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ABSTRACT

Three major sediment facies belts occur on the Great Barrier Reef shelf: an inner shelf prism of Holocene terrigenous sand and mud, a patchy middle shelf veneer of palimpsest muddy shelly calcsand (<1 m thick) above a weathered Pleistocene erosion surface, and an apron of modern carbonate mud and sand around reefs of the main reef tract. These sediments were mobilized and strongly affected by the passage of severe tropical Cyclone Winifred (central pressure 958 hPa), which traversed the central Great Barrier Reef shelf on February 1, 1986.

Re-surveys after the passage of Cyclone Winifred showed that (i) a storm-induced shell lag and/or a normally graded bed of terrigenous fine sand-mud had been deposited at depths down to 20 m; (ii) middle shelf longitudinal bedforms were widespread at depths of 28–35 m, and comprised a furrowed substrate of palimpsest muddy shell gravel surmounted by 40–150 m wide ribbons of quartzose and bioclastic sand up to 15 cm thick; (iii) fields of northward-facing, 1–2 m wavelength megaripples were present adjacent to zones of ribbons, and in the alleys between ribbons; (iv) five days after the cyclone, mud was still settling from suspension, and large parts of the inner shelf were bathed in muddy hypopycnal river plumes, some of which reached 30 km seaward to the inner edge of the reef tract; and (v) suspended mud, derived in part by unmixing of the seabed, was present throughout the shelf water column, and a seaward-thinning mud drape up to 40 cm thick had accumulated on and seawards of the inshore sediment prism, tapering seawards to a few mm thick only over most of the middle shelf.

It is inferred that storm-waves and currents associated with the passage of Cyclone Winifred caused widespread unmixing of bottom sediments. Offshore, long-shelf transport of bedload sand ribbons and megaripples was affected by powerful shelf-parallel currents of velocity 1–3 m/s. As the storm passed, the graded, seaward-thinning sand–mud bed was deposited over the inner-middle shelf. On the middle shelf, bioturbation and downward mixing of the mud drape started immediately after the passage of the cyclone, and was well advanced after 3 months. In this way, the ephemeral seabed features produced by passage of a cyclone are gradually degraded, and the storm-layer stratigraphy becomes incorporated within a thin middle shelf veneer of muddy shelly calcsand.

1. Introduction

Cyclone Winifred crossed the central Great Barrier Reef coast at Innisfail, near latitude 17° 30′ S, on February 1, 1986 (Fig. 1). The cyclone ranked as a category 3 tropical cyclone, with a 50–70 yr recurrence interval (Puotinen et al., 1997). Minimum central barometric pressure was 957 hPa, maximum measured wind gusts were 55 m/s, and the associated storm surge reached 1.6 m in height (Gagan et al., 1990). Modelling predicts deep water waves up to 9.0 m high and of 11.6 s period for a cyclone of this intensity (Bretschneider tropical cyclone model; Young, 1985). Landfall occurred at 7 p.m. on February 1st, 1986, and was followed by intense rainfall as the cyclone degenerated into a rain depression, causing the North and South catchments of the Johnstone River to flood and produce its highest recorded instantaneous flow of 5715 m^3/s (Table 1).

Serendipitously, the area of shelf traversed by the cyclone was at the time subject to detailed sedimentological study, funded by the Australian Marine Science and Technologies Grants Scheme. A moderately extensive pre-cyclone database therefore existed, which included two cross-shelf transects of sidescan sonar and 3.5 kHz seismic, 40 short cores taken from undisturbed van Veen frame-supported-grab samples (most along two the cross-shelf transects), and 8 vibrocores at other significant locations. Shortly after Cyclone Winifred had passed, a rapid response dataset was collected that

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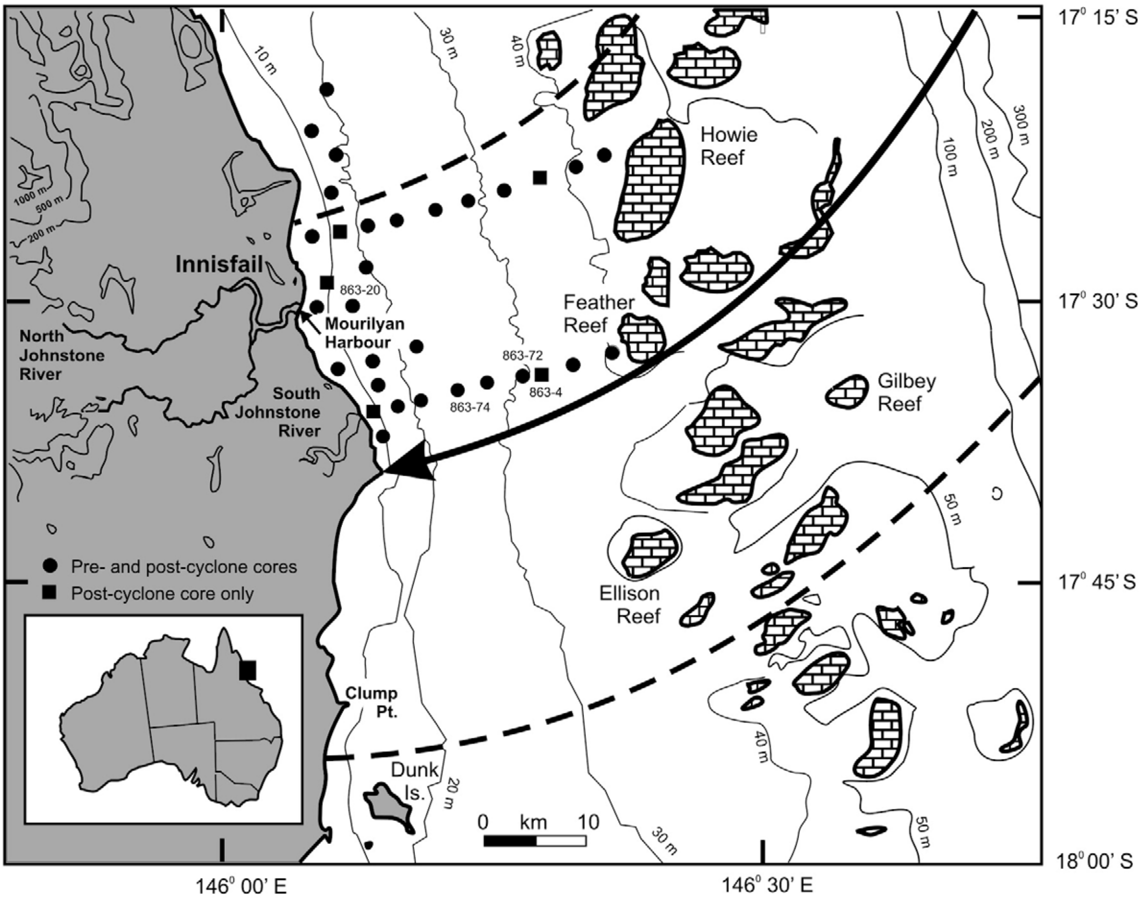

Fig. 1. Locality map of the Innisfail area, central Great Barrier Reef. The path of the eye of Cyclone Winifred (bold, solid line) and the adjacent swathe of shelf waters that were affected by strong winds (bold, dotted lines) are indicated.

included replicate profiles along the sidescan and 3.5 kHz lines, 6 new sidescan and 3.5 kHz lines, 19 repeat grab samples, 6 new grab samples, 9 vibrocores, 14 camera stations, 6 video-camera stations, salinity profiles and water samples. These samples and observations were collected on r.v. *James Kirby* cruises KG 846, 854, 861, 862 863, 865 in 1984–86; cruise reports and samples are archived at James Cook University, Townsville. In addition, the locations of sediment-laden flood plumes were mapped along the coast by aerial observation on February 4, two days after Cyclone Winifred made landfall.

Based on this dataset, it has been shown that Cyclone Winifred caused major sedimentary effects (Gagan et al., 1987, 1988, 1990). Extensive sediment remobilisation occurred from the inshore sediment prism, from the middle shelf substrate and from the offshore reef tract, and new sediment was also delivered to the shelf system via settling of fine-grained material from river flood plumes and the reef tract. As the storm subsided, an extensive fining-upward storm bed up to 15 cm thick was deposited in waters up to 43 m or more deep, and extended at least 30 km offshore and 50 km along-shelf (Gagan et al., 1988). In total, the Winifred storm bed probably covered an area greater than 3000 km^2 and contained an approximate volume of 140×10^6 m^3 sediment, of which perhaps only 40×10^6 m^3 represented new terrigenous material. Carbon isotope studies of pre- and post-Winifred samples (Gagan et al., 1987) indicate that most of the new riverine sediment contributed after the cyclone was deposited near river mouths, with little moving more than 15 km offshore. Erosion by wave and wind-forced currents eroded more than 14.4 cm from the middle shelf seabed, and significant portions of the resuspended sediment were advected alongshelf and at least 15 km shorewards before being deposited within the storm bed.

Published observations of cyclone-induced currents are rare from Australian seas, though Church and Forbes (1983) recorded wind-forced residual currents of up to 0.5 knots (25 cm/s) from the Gulf of Carpentaria. Further west, on the Northwest Shelf, Hearn and

Table 1
Estimated water motions for cyclones of different intensity on the Great Barrier Reef shelf off Townsville, including storm surge and shallow and deep water wave-orbital velocities (after Young, 1985).

Saffir–Simpson		NQ return	Pressure	Max. wind gust		WD current	Surge	Wave Hs	Wave Ts	Wave L	Umax	Umax
Scale	Magnitude	(Yr)	(hPa)	(Knots)	(m/s)	(cm/s)	(m)	(m)	(s)	(m)	(cm/s (deep))	(cm/s (shallow))
1	Mild	5	>990	40–60	20–30	40–60	0.0–1.0	8.3	11.2	193	204	75
2	Moderate	10	970–985	70–90	35–45	70–90	1.5–2.5	8.5	11.3	197	212	77
3	Severe	50	950–965	100–120	50–60	100–110	3.0–4.0	9.0	11.6	207	234	81
3	Severe	100	945–950	120–130	60–65	120–130	4.0–4.5	9.2	11.8	214	245	83
4	Very severe	500	930–945	130–150	65–75	130–150	4.5–5.5	9.7	12.1	225	269	88
5	Catastrophic	1000	<925	160–180	80–90	160–180	6.0–7.0	10.0	12.2	229	280	90

The wind-driven current is also shown, calculated at 2% of the wind strength.