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NOTE

Stabilisation of intertidal cobbles and gravels by *Goniastrea aspera*: an analogue for substrate colonisation during marine transgressions?

Chris T. Perry · Scott G. Smithers

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Abstract There is a widespread perception that coral larvae require stable (lithified) rock substrates to settle during reef initiation, and that these substrates are typically carbonate. However, reef core data show that reef establishment can also occur directly above a wide range of unlithified, non-carbonate sediment substrates, including relict alluvial sands and gravels. The mechanisms by which these lithic substrates are colonised and stabilised are not, however, well documented. Here, we describe such processes from an intertidal setting on the inner-shelf of the Great Barrier Reef, in a setting directly analogous to that which would have existed around many inner-shelf high islands during the post-glacial marine transgression when mid-Holocene reef initiation was taking place.

Keywords Coral colonisation · Lithic substrates · Terrigenous inner-shelf · Great Barrier Reef

The initiation of coral communities during periods of rising (transgressionary) sea levels is an important phase in the post-lowstand reestablishment of coral reefs along continental margins and offshore carbonate platforms. For many Holocene reefs, this initiation occurred directly above lithified limestone substrates—typically relict Pleistocene reef substrates that were exposed (and often sub-aerially weathered) during the previous sea-level lowstand. Based on these observations, it is widely assumed that coral larvae require stable rock (normally carbonate) substrates to settle. However, a review of reef data from both Holocene and fossil reef systems shows that reef establishment can also occur directly above a wide range of unlithified, non-carbonate sediment substrates, including clays, relict alluvial sands and gravels, and intertidal and subtidal sands and muds (see Martin et al. 1989; Braga et al. 1990; Piller and Riegl 2003; Smithers et al. 2006). These sediment substrates were clearly unconsolidated at the time of initial coral settlement and would have been subjected to varying degrees of physical reworking. The mechanisms by which corals are able to settle and persist to form reefs in such environments are not, however, well documented.

Here, we illustrate the colonisation and stabilisation of unconsolidated lithic substrates by the coral *Goniastrea aspera* at Stingaree Reef, located on the south–west side of Dunk Island (146° 09′ E, 17° 56′ S), on the inner-shelf of the Great Barrier Reef (GBR). The NW margins of Stingaree Reef abut a steep rocky headland, along the intertidal margins of which (at about Lowest Astronomical Tide level) is a fringe of rounded to sub-angular clasts that range in size from pebbles up to medium-sized boulders (size range ~50–500 mm; Fig. 1a). The boulders are interpreted as corestones weathered from bedrock during lowstands and winnowed from regolith, prior to reworking and deposition as boulder beaches during sea-level highstands (Hopley 1971). These deposits were most active during the Holocene high-energy window (~8–6.5 K years BP), when the outer barrier had not yet reached sea level and higher energy swells penetrated further inside the GBR lagoon (Hopley 1984), although the

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C. T. Perry (✉)
Department of Environmental and Geographical Sciences, Manchester Metropolitan University, John Dalton Building, Chester Street, Manchester M1 5GD, UK
e-mail: c.t.perry@mmu.ac.uk

S. G. Smithers
School of Earth and Environmental Sciences, James Cook University, Townsville, QLD 4811, Australia

Fig. 1 **a** View looking across the lithic boulder dominated intertidal zone at Stingaree Reef, Dunk Island. Note the clear elevational control on the colonisation of lithic substrates by *G. aspera* and the imbricated nature of many of the clasts. Photo taken at close to LAT. **b** Detail showing initial colonisation of lithic substrates by *G. aspera*. Note that partial over-growth of adjacent lithic clasts is already occurring. **c** More complete overgrowth of boulders and cobbles by *G. aspera* and the meniscus bridge-type structures that develop between adjacent clasts. **d** Extensive overgrowth of lithic boulders such that the thin *G. aspera* colonies form a veneer of skeleton over the clasts. Scale bars in cm

imbricated nature of many of the clasts may suggest more recent reworking has also occurred.

The corals, which have settled on a wide range of clast sizes in this environment, grow laterally to form thin veneers of skeleton over the substrate, eventually coalescing with those corals established on adjacent clasts, such that they become joined by meniscus-type bridges (Fig. 1b, c). Over time, the result is the development of a highly stable substrate with adjacent lithic clasts bound together by a thin veneer of coral (Fig. 1d). The setting in which this process is occurring is directly analogous to that experienced during marine transgressions when rising sea levels were flooding terrigenoclastic-substrate dominated shorelines and island margins, and provides an insight into the processes by which unconsolidated lithic substrates can be settled by coral larvae and stabilised prior to subsequent reef accretion. The process is, in effect, a modern analogue, for that inferred from the basal facies of reefs in many other areas of the GBR, including well-documented examples at Cape Tribulation (Partain and Hopley 1989) and Iris Point (Hopley and Barnes 1985).

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