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COMMENTARY

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Comment on Baas, J.H., Hewitt, W., Lokier, S. and Hendry, J. (2025) Coming to light: How effective are sediment gravity flows in removing fine suspended carbonate from reefs? *The Depositional Record*, 11, 583–598. doi: 10.1002/dep2.319

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1 | DISCUSSION THEMES

The sediment gravity flow experiments of Baas et al. (2025) are among the first to explore the differences between carbonate-dominated and siliciclastic-dominated sediment gravity flows. Two themes addressed in this study, however, need further discussion:

(i) Carbonate powder in the experiments: Baas et al. (2025) used fine-grained crushed limestone as a first-order approximation of natural mud-grade calcite. However, this sediment cannot be considered as an analogue for carbonate mud in natural carbonate systems due to significant differences in composition and in the cohesive properties of aragonite- and high-magnesium-calcite-dominated muds in shallow-water carbonate settings.

(ii) Carbonate mud threat to reef health: Baas et al. (2025) argue that mud-grade calcite (or, more accurately, aragonite) poses a threat to reef development. They highlight that the export of fine-grained $CaCO_3$ out of the reef environment situated at the platform margin is essential for reef survival, and that without it, reef existence would be severely compromised. However, substantial evidence indicates that carbonate mud does not inherently threaten carbonate reefs.

2 | INTRODUCTION

Gravity flows are important agents of sediment transport in both siliciclastic and carbonate submarine sedimentary systems throughout geological time as well as today (e.g. Schlager et al., 1994; Talling et al., 2015 and references therein). In carbonate settings, sediment production not only varies over time but also depends on the type of carbonate factory, for example tropical, cool-water, microbial, pelagic (e.g. Reijmer, 2021). Understanding the sediment production in these systems therefore is an essential prerequisite as it influences the type of sediment transport through gravity flows.

2.1 | Sand and mud analogues

Experimental studies using artificial and natural siliciclastic sediments have a long research history (e.g. Baas et al., 2004, 2013; Baker et al., 2017; Cartigny et al., 2013; Eggenhuisen & McCaffrey, 2012; Kuenen & Migliorini, 1950; Postma et al., 1988). Variations in the composition of sand mud mixtures have highlighted the balance between cohesive strength and flow mobility in sediment gravity flows (e.g. Baas et al., 2009). Other flume experiments have explored variability in turbidity current velocity in response to bed roughness, sediment load and density stratification (e.g. Cartigny et al., 2013; Eggenhuisen & McCaffrey, 2012). A range of sediment types has been used in these experiments, including natural pebbles and sand mixed with chalk powder (Postma et al., 1988); glass ballotini (Baas et al., 2004); glass ballotini mixed with kaolinite clay (Amy et al., 2006); non-cohesive silica flour and a range of weakly to strongly cohesive kaolinite clay mixtures (Baker et al., 2017); and glass ballotini mixed with bentonite clay (Baker & Baas, 2023).

Hodson and Alexander (2010) were the first to experimentally explore sedimentation processes in carbonate-dominated gravity flows, using mixtures of silicon carbide and glass ballotini as substitutes for natural carbonate sediment to mimic variations in grain size, shape, texture and density of carbonate grains. More recent flume experiments investigating sediment segregation in carbonate-dominated gravity flows have used natural carbonate sand (Slootman et al., 2023) and mixtures of natural carbonate-dominated sand and mud (Nworie et al., in revision). The study of Baas et al. (2025) therefore represents a valuable contribution to this underexplored field of research. However, there are some issues with the very poorly sorted sandy mud, with modal grain sizes at 2.5 μm (clay) and 60 μm (coarse silt), as an analogue for carbonate mud.

2.2 | Carbonate mud and artificial substitutes

Baas et al. (2025) used crushed limestone (calcite) without significant intra-particle porosity, manufactured by Omya (C.A.S. number 1317-65-3) and supplied as 'Calcium Carbonate Powder' by Elixir Garden Supplies (UK), as a first-order approximation of natural mud-grade calcite. The authors refer to this material as 'calciclastic, fine-grained sediment', 'fine-grained $CaCO_3$' and 'mud-grade calcite'. They appropriately avoid the term 'carbonate mud', as crushed limestone differs significantly from the muds that characterise present-day carbonate sedimentary environments. These differences have been discussed in detail by Schieber et al. (2013); see their figures 1 and 3 itemising the variations in carbonate mud. For settling variations of carbonate grains, De Kruijf et al. (2021) provided a detailed overview.

The study of sediments from the Bight of Abaco (Little Bahama Bank) by Neumann and Land (1975) shows that carbonate mud can have multiple origins: (i) mechanical disintegration of shells, rock and ooids; (ii) bioerosion by scrapers and excavators; (iii) disaggregation of calcareous algae; and (iv) chemical or biochemical precipitation. In a comprehensive assessment of mud from modern reefs and carbonate platforms (e.g. Belize, the Bahamas, Florida, the Maldives, French Polynesia, Great Barrier Reef), Gischler et al. (2013) demonstrated that these carbonate muds either originate from (i) the breakdown of skeletal grains and the disintegration of codiacean algae or (ii) inorganic precipitation (so-called whitings; Shinn et al., 1989). Gischler et al. (2013) further showed that for carbonate mud from the Atlantic, Pacific and Indian Oceans the 4–20 μm and 20–63 μm fractions consist predominantly of skeletal and algal carbonate debris derived from molluscs, foraminifera, tunicates, corals and codiaceans such as *Halimeda* sp., whereas the <4 μm fraction of all their samples comprised short needles, nanograins and coccoliths. Consequently, natural muds differ markedly from the crushed limestone (mud-grade calcite) used by Baas et al. (2025) in terms of grain shape, mineralogy and specific gravity.

2.3 | Shear strength of carbonate mud

Kenter and Schlager (1989) showed that the shear strength of marine carbonate mud (clay to silt) is more variable but consistently higher than that of siliciclastic equivalents. Microbial binding, mud cohesion and flocculation are probably additional processes contributing to these differences (e.g. Eberli et al., 2019; Schieber et al., 2013). Recent settling experiments with natural marine carbonate mud and sand further underscore this contrast (Reijmer et al., 2025), demonstrating that grain-size segregation becomes less efficient with increasing sediment concentration and/or cohesive mud proportion, and at substantially lower thresholds than in comparable experiments using siliciclastic muds (kaolinite clay) and artificial substitutes (glass ballotini) (Amy et al., 2006).

Natural carbonate sediments also differ fundamentally from artificial analogues in terms of (i) aragonite-dominated mineralogy (Milliman, 1974); (ii) sediment export via hyperpycnal density flows (Betzler et al., 2014; Wilber et al., 1990); (iii) glacial–interglacial variations in sediment export (Schlager et al., 1994); (iv) sediment-sorting processes (Counts et al., 2021); and (v) environmental controls (e.g. leeward versus windward settings).

This range of controls gives rise to considerable sediment diversity, requiring careful selection of experimental analogues. Non-natural calcite-based muds may not adequately represent natural aragonite-dominated carbonate mud in settling experiments and laboratory gravity flows; the same limitation holds for carbonate sands. Hence, the use of non-natural analogues may yield results that differ substantially from those observed in carbonate sedimentary environments, including flat-topped carbonate platforms, shelves, ramps and atolls.

3 | CARBONATE MUD AS A THREAT TO CORAL REEF HEALTH

3.1 | Flat-topped carbonate sedimentary systems

In carbonate depositional environments, especially in the vicinity of flat-topped carbonate platforms, two principal modes of sediment export are recognised: (i) the export of carbonate mud (e.g. Schlager & James, 1981; Wilber et al., 1990) and (ii) the export of carbonate silt to sand and even boulder-sized blocks (e.g. Mullins & Cook, 1986). This distinction not only aligns with the different sediment production sites within these systems but also reflects the relatively short source-to-sink pathways characteristic of carbonate depositional systems compared to siliciclastic counterparts.

Carbonate muds, dominated by aragonite with minor high-magnesium calcite, have various origins, primarily: (i) picoplankton-derived aragonite needles from lagoonal whitings (Lopez-Gamundi et al., 2024; Macintyre & Reid, 1992; Schieber et al., 2013), and (ii) aragonite needles produced by the disintegration of *Halimeda* sp. occurring in the inner lagoon or on the deeper slope (Geyman et al., 2022; Gischler & Zingeler, 2002; Macintyre & Reid, 1992; Trower et al., 2019). Other possible mud production includes (iii) grain-size reduction through bioerosion (e.g. by parrotfish; Salter et al., 2012; Yarlett et al., 2021), and (iv) microbial-mediated precipitation (Dupraz & Visscher, 2005; Visscher & Stolz, 2005).

In contrast, the platform margin itself is dominated by reefs and associated sediments as pointed out in early classification schemes of carbonate facies distribution along the shallow-water carbonate platforms of the Bahamas and Florida Bay (Dunham, 1962; Folk, 1974; Ginsburg et al., 1958). In these early studies, the parting of carbonate mud-free sediments at the platform margin and carbonate mud-dominated sediments within the platform interior were extensively discussed. These studies further noted that mud-dominated facies prevailed in areas sheltered from the wave and current action affecting the edge of the platform.

Early studies of the Florida Keys detailed that the keys themselves separated the mud-dominated lagoon from the reefs fringing them (Ginsburg et al., 1958). A similar spatial division is observed at Andros Island and along its northern extension at the Joulters Ooid Shoal (Harris, 1979). Hence, the carbonate sediment classification schemes of Dunham (1962) and Folk (1974) are grounded in this fundamental distinction between grainstone–packstone-dominated platform margins and back-reef to lagoonal environments dominated by mudstone, wackestone and packstone. More recent studies of Great Bahama Bank confirm that this facies partition persists at the platform scale (Harris et al., 2015; Reijmer et al., 2009).

In this context, the assertion by Baas et al. (2025) that reef development is threatened by mud input is not supported by observations from modern carbonate systems. Carbonate mud, dominated by aragonite rather than calcite, is either produced in areas spatially separated from reef environments or is efficiently removed by waves and currents acting at the platform margin. Lopez-Gamundi et al. (2024) showed that mud export out of the lagoon of Great Bahama Bank is a continuous process, driven by tidal currents on the windward (eastern) side and by wind- and wave-induced currents on the leeward (western) side. Hence, mud removal from shallow-water carbonate platforms is highly effective and by no means is a threat to the corals and overall reef development.

Exceptions may occur in reefs located in highly turbid settings, such as off Mozambique (Perry, 2003), within the Great Barrier Reef (Kleypas, 1996; Morgan et al., 2016; Perry et al., 2012, 2013), and near Singapore (Morgan et al., 2020). Yet even then coral communities show remarkable accretion rates (Morgan et al., 2020) or adapt by increasing their heterotrophic feeding level to survive such hostile environments (Travaglione et al., 2023). Furthermore, recent studies by Pisapia et al. (2016, 2026) and Pancrazi et al. (2026) demonstrate that repeated bleaching events, as well as other environmental disturbances (e.g. tsunami impacts and crown-of-thorns starfish outbreaks), lead to shifts in community structure from delicate branching and tabular *Acropora* to more robust massive and encrusting forms as a survival strategy. These observations underscore the resilience of coral ecosystems to significant environmental stress.

Similarly, under varying eutrophication levels, as documented for reef environments at La Réunion (Indian Ocean), a differentiation in sediment production and export persists and the grain-size spectrum remains dominated by fine sand and coarser fractions, with only minor contributions of silt (Chazottes et al., 2008). Thus, even substantial variations in eutrophication do not result in enhanced production of carbonate mud.

Baas et al. (2025) cite two studies to support the proposition that 'the presence of large volumes of suspended mud is detrimental to carbonate producers and, thus, to sediment production and reef growth'. These are as follows: (i) Rogers and Ramos-Scharrón (2022), discussing a conceptual approach for sediment input in land-attached carbonate systems in the north-eastern Caribbean, where reefs are located close to terrestrial sediment delivery points entering nearshore waters; and (ii) Tuttle and Donahue (2022), presenting a literature study on the effects of sediment stress, but also exposure duration, on corals. Thus, both references address very specific environmental settings in which terrigenous mud or sediment input in general threatens carbonate sedimentary systems. Further references (e.g. Jones et al., 2020; Lokier, 2023; Lokier et al., 2009; Mallela & Perry, 2007) are also invoked to discuss the impact of suspended sediment on carbonate producers, although the latter focusses specifically on interactions between volcanic input and carbonate systems.

In summary, it can be stated that, contrary to the interpretation of Baas et al. (2025), the impact of terrigenous sediment influx is not the main threat to carbonate-producing ecosystems. This observation is further supported by recent work in the northern Red Sea (Rendall & Mutti, 2025, and references therein).

3.2 | Carbonate ramp sedimentary systems

In carbonate ramp systems, such as those of the present Persian Gulf, carbonate muds may influence the overall distribution of coral-dominated facies. Purser and Evans (1973) documented the muddy character of facies belts adjacent to coral reefs along the Trucial Coast of the southern Persian Gulf (see their figures 4 and 5). However, a recent study by Steuber et al. (2026) documented the near absence of mud in the shallow-water areas of the SE Persian/Arabian Gulf. Subsequent carbonate ramp models (Burchette & Wright, 1992) further demonstrated facies zonation as a function of the interaction between tides, waves and storms.

In the mud threat context, of particular importance is the inner-ramp zone, characterised by recurrent wave agitation of the sea floor, and which hosts high-energy shoal-barrier complexes positioned at the transition between the open marine environment and the lagoon to tidal flat-sabkha environment. In this arid carbonate setting, sediment transport by longshore currents, together with tides and waves, ultimately determine the distribution of the individual facies zones. This pattern is illustrated by contrasts between the shoreline-parallel facies zonation of the Trucial Coast and the shoreline-perpendicular organisation observed in the Al Dakirah lagoon (Billeaud et al., 2014).

Studies of the modern carbonate ramp near Kuwait (Gischler & Lomando, 2005) documented a sharp transition from grain-supported textures in shallow water to mud-supported textures at depths of 15–20 m. This clear facies partitioning further indicates that, also in this carbonate ramp setting, the proposed mud threat for reef development is not a major issue.

4 | SUMMARY

In summary, (i) the use of crushed limestone mud (calcite) introduces a significant source of uncertainty in the experiments of Baas et al. (2025). Sediment properties, including size, shape, texture, density and mineralogy, differ fundamentally from those of natural carbonate muds. As a result, the cohesive behaviour and settling dynamics also diverge markedly from those of the siliciclastic muds to which the mud-grade calcite experiments are compared. This difference includes both the dissimilarities in (non-)skeletal mud content as well as shear strength. (ii) The claim that carbonate mud represents a threat to reef development, and that its export out of the reefs at the platform margin, or from within the reefs themselves, is essential for reef survival is not supported by an extensive body of facies-based studies from present-day carbonate platforms, shelves, atolls and patch reefs.

Future flume-tank experiments should therefore be grounded in a rigorous evaluation of sediment composition and settling behaviour for both mud and sand fractions. Given their intrinsic diversity, carbonate sediments cannot be adequately replaced by a single non-natural analogue.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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