Relationships between erodibility and fine-grained seabed properties on tidal to seasonal time-scales, York River estuary, Virginia, USA

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Appropriate parameterization of time-dependent erodibility of muddy seaboards is a significant barrier to improved understanding and accurate modeling of sediment dynamics in estuaries and coastal seas. An ongoing sedimentological study at the MUDBED observatory in the middle reaches of the York River estuary investigates controls on cohesive bed erodibility by assessing changes in hydrodynamic and seabed properties over varying timescales. During April and May of 2010, multiple GOMEX box cores were collected over a five-week period chosen to correspond with the annual post-freshet dissipation of the York’s secondary turbidity maximum (STM) while also resolving the relatively strong spring-neap cycle. Once a week for five weeks, box cores were subsampled for near-surface profiles of sediment water content, 7Be activity, disaggregated grain size, and, based on gentle sieving, resilient pellet concentration and size distribution. In addition, images of internal layering were collected via digital x-radiography, and erodibility of the surface of the cores was determined via a Gust microcosm.

Over the observational period, bed erodibility (depth-limited eroded mass divided by bed stress) varied from about 0.5 to 1.2 kg/m²/Pa. In terms of external forcings, erodibility was seen to generally decrease in time from April through May, following the annual post-freshet dispersal of the STM. In addition, bed erodibility fluctuated with the spring-neap cycle, with a maximum positive correlation found between erodibility and the averaged tidal range from the previous five days. Time since the end of the freshet combined with tidal range accounted for 80% of the observed temporal variation in bed erodibility. In terms of internal bio-geo-physical properties, bed erodibility was not significantly correlated with organic content (which varied from 6 to 12% dry weight), sand content (from 0 to 30% dry weight), or water content (from 60 to 80% by volume). Bed erodibility was, however, negatively correlated to pellet abundance (from 3 to 15% of total mud), positively correlated to 7Be activity (from 0.8 to 3 dpm/g), and positively correlated to the degree of physical layering apparent in x-radiographs. Resilient pellet abundance alone accounted for 90% of the observed temporal variation in bed erodibility.

Together, these observations are consistent with the following conceptual model for the control of erodibility for biologically active, physically energetic muddy beds: Bioturbation and/or physical disturbance prevents dewatering of the uppermost (~ 1 to 2 cm) of the seabed to such a degree that bulk water content no longer plays its classically dominant role in determining erodibility. Rather, it is the fabric and aggregation state of the muddy bed that provides a better proxy for erodibility. Active trapping of flocculated mud particles results in a poorly aggregated and very easily eroded uppermost seabed. In terms of bio-geo-physical properties recovered by box cores, this state is more clearly identified by layered fabric in x-radiographs, high 7Be activity, and an absence of pellets, rather than by percent water, sand, mud or organics. Conversely, under conditions of floc dispersal, resilient pellets are left behind and cohesion increases with time, which, in turn, lead to progressively reduced bed erodibility. Although active bioturbation and cyclical resuspension prevents a notable decrease in bulk water content within the upper few cm, the resultant churning of the bed and concentration of resilient pellets are clearly seen in box cores. Spring-neap cycles are superimposed on the above seasonal trend, with more intense physical disturbance at spring tide tending to break apart resilient pellets and cohesive bonds, increasing erodibility. Neap tide, in contrast, favors the net production pellets and increased cohesion, reducing erodibility.