Depth-limiting resistant layers tune the shape and tidal bar pattern of Holocene alluvial estuaries

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Holocene fluvial and estuarine systems are commonly assumed to be entirely alluviated, which means that channels freely move in erodible substrates. This implies that the shape and tidal bar patterns are self-formed. Data analysis for estuaries and deltas worldwide, however, proves presence geological depth constraints in many, if not most systems. This potentially constrains estuary channel dimensions and planform shape. In this study we compare detailed historical bathymetry maps of the last two centuries and depths of resistant Pleistocene clays and tills in the Eems-Dollard estuary, located on the Dutch-German border. Based on this new historical and geological data we show how resistant layers forced bar patterns and channel dimensions in an estuary that was hitherto considered autogenically-formed. Resistant layers limit channel depth and consequently cause widening and mid-channel bar formation, increasing channel curvature over at least one bar length in both seaward and landward direction (Figure 1). Furthermore, channel confluences preferentially form where resistant layers are absent. These combined effects determine the position of confluences and bars on the scale of the entire estuary; they are tuned to the presence of the resistant layers. Our results challenge the view that bar-filled estuaries are predominantly self-formed. They show that apparently local obstacles have estuary-wide implications: they can, for example, force bar formation and increased channel curvature that may favor the stability a two channel system. Future sea-level rise may cause tidal prisms and consequently the channel volumes to increase. As a result, the resistant layers are expected to be more exposed on the bases and edges of estuary channels, leading to potentially unexpected channel behavior when their effects are not taken into account. This strongly highlights the need to incorporate inherited resistant layers into morphological models.

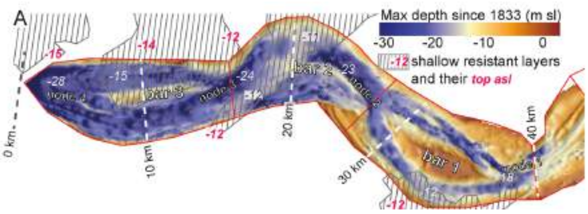

Figure 1. Maximal channel depth over 200 years. Where shallow resistant layers occur (hatching), channels are persistently shallower and bars occur here preferentially.