**Research Advances**

# Influence Factors on the Distribution of Tidal Bar in Tide-Dominated Estuary: Insight from Deposition Numerical Simulation

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## Objective

The Mcmurray Formation oil sands in the Athabasca region of Canada are mainly a deposit of tide-dominated estuary and an important target of oil and gas exploration of CNPC. However, the outcrop and the subsurface reservoir of tide-dominated estuary are few, and the formation mechanisms and distribution of estuarine sand bar are ambiguous due to the interaction of fluvial and tide process in opposite direction, which has posed challenge for the efficient exploration and development of oil sands. The depositional numerical simulation method is a focused topic in the study of sediment process, which can reveal the interaction between hydrodynamic force and sediments of river, delta and turbidite fan. The main objective of this study is to reveal the formation mechanisms and influence factors of the distribution of tidal bar in tide-dominated estuary.

## Methods

To observe the formation mechanisms and controlling factors of estuary deposits, the depositional numerical simulation software Delft3D is used to simulate and reveal the hydrodynamic process of estuary. In the flow module and tide module, the fluvial hydrodynamic parameters can be set and in tide module the tidal range can be set. The bi-directional flow characteristics can be calculated by the Navier-Stokes function to reveal the formation of the estuarine sand bar. The typical modern Fitzroy estuary was selected to conduct numerical simulation. The average sediment grain size is 0.2 mm. Hydrodynamic parameters including river discharge, velocity of flow, acceleration of gravity and maximum tidal range were extracted from the published hydrologic data of Fitzroy estuary, which is $1000m^3/s$, 0.8–2.2m/s, 9.81 $m/s^2$, 4 m, respectively. The modeling grid size is 29×650 and the bed slope is 0.005°.

## Results

The modeling result is shown in Fig. 1. As can be seen from the flow field, the bidirectional flow of the ebb and flood tide decide the formation and geometry of estuarine sand bar. The migration direction of the estuarine sand bar is a competition of the energy of the ebb and flood tide. When the energy of flood tide is dominant, the migration is landward, otherwise the seaward. The formation process of estuarine sand bar is step by step. When the simulated step length is smaller than 1000 m, the river will carry sands to estuary, and meanwhile, the sand in the bed of river mouth will gradually pile up by tides. The point bars are formed in river while sand bar cannot be seen in estuary. Fresh water brought by rivers will quickly blend with sea water, and sea water with a high salinity will invade the estuary from the bottom, thus making water in upper and lower levels flow in the opposite directions. With the increasing of simulated step length and continuous alteration of ebb and flood tide, there will be changing bimodal currents within the river way and the estuary to segment sand and form tidal bars. Tidal bars can be easily found when the simulated step length reaches to 1500 m. Tidal bar will continue to grow and the thickness will gradually increase when simulation continues (Leuven et al., 2016). Meanwhile, big tidal currents will erode sandbar edges, thus forming sand sheets around the sandbar edges. In later stages of the simulation, parts of tidal bars will be abandoned and filled in by mud sediment and parts will connect and form an integral whole (Guo Leicheng et al., 2015). The simulation revealed the forming process of tidal bars, which can be corresponded to the practically observed formation and distribution of sand within modern Fitzroy estuary. Thus, it indicated that sedimentary numerical simulation can reveal the formation mechanisms and distribution of tidal bars in tide-dominated estuary. Then the single factor analysis method is adopted to observe the influence of the controlling parameters on tidal bars. A number of simulations are executed and some phenomenon can be found. A

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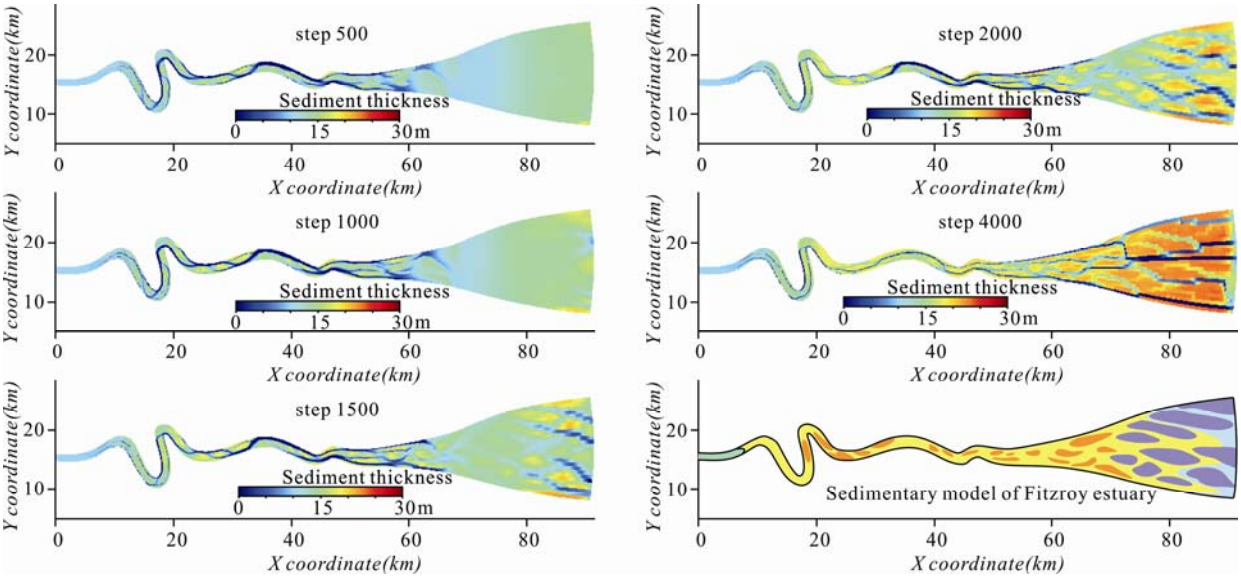


Fig. 1. Numerical simulation process of the Fitzroy estuary.
(a), Bi-modal flow and the formation of tidal sand bar; (b), Simulation process and its comparison with geological facts.

preliminary conclusion is that tidal range and increase of mud are the main factors on the formation and distribution of tidal bars (Chen Min et al., 2016).

## Conclusion

The depositional numerical simulation is taken to reveal the formation mechanisms and distribution of tidal bars in tide-dominated estuary. From the Fitzroy estuary test, the simulation result is similar to the real world. A single factor analysis method is used to test each parameter influence on the tidal bars to give the conclusion that the main influence factors are tidal range and increase of mud.

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### References

Chen Min, Qi Hongshuai, Lan Dongzhao, Lan Binbin and Fang Qi, 2016. Paleoenvironmental evolution of the Beilun River Estuary, Northwest South China Sea, during the past 20,000 years based on diatoms. *Acta Geologica Sinica* (English edition), 90(6): 2244–2257.

Guo Leicheng, Van der Wegen, M., Roelvink, D.J., Wang Zhengbing and He Qing, 2015. Long-term, process-based morphodynamic modeling of a fluvio-deltaic system, part I: the role of river discharge. *Continental Shelf Researc*h, 109: 95–111.

Leuven, J.R.F.W., Kleinhans, M.G., Weisscher, S.A.H., and Van der Vegt, M., 2016. Tidal sand bar dimensions and shapes in estuaries. *Earth-Science Reviews*, 161: 204–223.