Investigation of numerical forward model toward inverse analysis of ancient turbidities: Comparison between results of numerical simulation and grain-size analysis of the ancient turbidite bed in the Pliocene Kiyosumi Formation, Boso Peninsula, Japan

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Turbidity currents are considered as a main mechanism of sediment-transport toward deep-seas, and deposits of turbidity currents, i.e. turbidite sandstones, can be reservoir rocks of petroleum. Therefore it is important to understand the behavior of turbidity currents not only from the perspective of earth sciences, such as sedimentology and stratigraphy, but also resource geology. However, it is quite difficult to observe turbidity currents directly because of their high-velocity and intermittency of occurrences, so that the detailed mode of sediment transport and depositional processes remain unclear. To this end, the methods for inverse analysis to reconstruct flow conditions of turbidity currents from thickness and grain-size distribution of ancient deposits have been developed. However, previous studies have difficulty in feasibility of application to natural examples because of calculating costs of their forward model (2D DNS model). Here we examine that applicability of the forward model of turbidity currents based on the non-steady 1D shallow-water equation for inverse analysis of ancient turbidites. The 1D shallow-water equation model of turbidity currents is superior to the DNS model from the viewpoint of calculation costs, but it is not fully tested for flows that contain sediments of multiple grain-size classes.
First, this study investigated thickness and grain-size distribution of the ancient turbidite bed in the Mio-Pliocene Kiyosumi Formation, Boso Peninsula, Japan. The Formation is composed of sand-rich alternating beds of sandstone and mudstone, which have been interpreted as deposits of the submarine fan. This study focused on the turbidite sandstone G1, which is sandwiched between two characteristic tephra and therefore it can be traced over 40 km. We measured thickness of the sandstone bed and collected samples for grain size analysis by using the settling-tube method. As a result, it was revealed that (1) bed thickness decrease downcurrent non-linearly. There are points where volume per unit area of each grain-size class decrease remarkably. (2) Locations of the points where sediment volume per unit area decrease vary depending on grain size classes. Then, we conducted numerical experiments to reproduce geometrical features of the turbidite bed described above. We employed 1D shallow water equation model with sediment conservation equations of each grain-size class and active-layer approximation of grain-size distribution of the basal surface. In this study, grain-size distribution is approximated to the two grain-size classes: medium sand (2 phi) and silt (8 phi). As a result, distribution pattern of sediment volume per unit width was well reproduced by our model. Sand-sized sediments pinched out downcurrent, whereas silt-sized sediments show continuous thickness distribution downcurrent. This result imply that the inversion model using the forward model based on shallow-water equation could be applicable for ancient turbidites that have 10s km in spatial scale.

Keywords: Kiyosumi Formation, numerical simulation, turbidity currents