Inverse analysis to reconstruct hydraulic conditions of non-steady turbidity currents considering multiple grain-size classes

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Turbidity currents emplace turbidite sandstones that are characterized by graded bedding. In spite of their significance in the paleoenvironmental researches and the resource geology, the flow properties of turbidity currents in deep-sea environments remain unclear because in-situ measurements have been disturbed by their highly destructive nature and infrequent occurrences. Therefore, in order to understand the behavior of actual turbidity currents, this study aims to develop a new method of the inverse analysis to reconstruct the paleo-hydraulic conditions of turbidity currents from ancient turbidites. There have been a few studies of inverse modeling of turbidity currents; however, several problems in their studies have been pointed out. For instance, the previous study employed the oversimplified forward model that assumes temporally steady flows, which cannot produce graded bedding. Normal grading and other successive transition of sedimentary structures (i.e. the Bouma sequence) is typical features of ancient turbidites, so that their steady-flow assumption is not suitable for analysis of natural turbidity currents. In contrast, the author inverse model employed two-dimensional Navier-Stokes equations for the forward model, but the calculation cost of their method is too high to apply it to the field-scale data. To this end, this study proposes a new forward model of non-steady turbidity currents with consideration of mixed grain-size sediment, which can describe the behavior of a turbidity current that deposits a typical turbidite showing graded bedding. Our model employs the one-dimensional shallow water equation, which is applicable to the field-scale problems. The “lock-exchange” type condition is assumed as the initial setting in this model. For inverse analysis, the objective function is defined as sum of squares of deviations between the results of the observation and the numerical calculation. In our inverse calculation, the initial hydraulic conditions that minimize the objective function are explored by the genetic algorithm. Tests of our inversion method using the artificial data provided reasonable results, suggesting adequacy of the optimization methodology. We then applied our method to a turbidite in the Kiyosumi Formation, Boso Peninsula, Japan. The Kiyosumi Formation is composed of sand-dominated alternations of turbidite sandstone and hemipelagic mudstone, which are considered to be deposits of the submarine fan lobe. In this study, the individual turbidite bed intercalated between the two key-tuff layers was correlated over 20 km, and thickness and grain-size distribution of the bed were measured at the seven sampling localities. As the result of the inverse analysis, the hydraulic conditions of the turbidity current that had emplaced the turbidite bed was estimated. When the flow reached at the downstream end of the study area, the flow thickness, velocity, and total sediment concentration were reconstructed to be 334.55 m, 0.98 m/s, and 0.0058% respectively at the downstream end of the sampling area. Although the verification of this result will be discussed as a future issue, these reconstructed values are in agreement with the hydraulic conditions of turbidity currents monitored by the previous studies.

Keywords: inverse analysis, turbidity current , turbidite, the Kiyosumi Formation

