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Theory and Inverse Analysis of Equilibrium Profile of Submarine Canyons

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This study aims to calculate the theoretical equilibrium profile of submarine canyons. Submarine canyons are distributed along submarine slopes throughout the world and are channels through which turbidity currents deposit sandy sediments in submarine fans. Thus, the development process of submarine canyons is closely related to that of submarine fans.

A geomorphology with equilibrium state is a region where the rate of sedimentation or erosion is equal to zero. In other words, an equilibrium profile indicates that sediment laden flows (turbidity currents in this case) bypass submarine canyons. It is very important to consider theoretical equilibrium profiles in the modeling of geomorphological and stratigraphic developments, although such perfect profiles are rarely observed in natural environments. For example, the equilibrium profile of a canyon slope can be used as a criterion to predict the regions of erosion and deposition in submarine depositional systems.

In this study, we propose a method to calculate the equilibrium profile of submarine canyons. First, we begin with the three equation model of turbidity currents. For the case of an equilibrium (bypass) profile, everywhere, the volume transport rate per unit width of suspended sediment, qs, must be (a) constant, (b) equal to a specified upstream value qsu, and (c) equal to the capacity value qse. Thus, we can define three equations in three unknowns, i.e., U, H, and S, which are the layer averaged values of velocity, flow height, and slope inclination, respectively. These variables define an equilibrium (bypass) profile of submarine canyons. We have obtained a first order ordinary differential equation that can be solved downstream from some specified upstream value, Uu, along with other specified parameters (e.g. qsu). Once the value of U is known everywhere, the elevation profile of an equilibrium submarine canyon is obtained from the calculated hydraulic variables.

Finally, we apply our model to carry out an inverse analysis of hydraulic conditions of the Kushiro Submarine Canyon. Turbidity currents generally bypass submarine canyons; hence, the profiles of most canyons can be regarded to be in the semi equilibrium state. Therefore, we calculate equilibrium profiles using different possible combinations of parameters and compare them to the real geomorphologies. Thus, we obtain the parameter sets of turbidity currents that best explain the geomorphology of the Kushiro Submarine Canyon. The average velocity of turbidity currents, bulk Richardson number of turbidity currents, and grain size of the sediments in the submarine canyon estimated from the inverse analysis are 0.4 m/s, 0.270, and approximately 2.9 phi, respectively. Although our inverse analysis method is based on a crude approximation, it appears to be useful for roughly characterizing submarine depositional systems.