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# Internal Stress Fields of a Large-Scale Submarine Debris Flow

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Detailed analysis of a submarine debris-flow deposit exposed as a nearly1.6 km continuous outcrop reveals existence of a compressional stress field during transportation and deposition. Deposit of gravelly mudstone, containing large deformed sedimentary blocks (long axis up to 100 m), occurs in the Upper Cretaceous (Maastrichtian) to Paleocene Akkeshi Formation, Hokkaido Island, northern Japan. This mass-transport exposure exhibits three facies, based on size and spatial arrangement of accumulated blocks. Facies A consists of relatively small blocks (long axes approximately 1 to10 m), supported by a gravelly mudstone matrix. Facies B consists of clast-supported moderate blocks (long axes ?30 m). Generally, blocks in Facies B are deformed significantly. Facies C mainly comprises large blocks with long axes up to 100 m. Facies A and B alternate downcurrent, while Facies C occurs only at the more distal end of the exposure. Usually, long axes of blocks are oriented parallel to the bedding surface, suggesting a laminar state of flow. Application of the multiple inverse method to meso-scale faults observed in the blocks reveals possible internal paleostress fields that existed before deposition. This analysis suggested two different stress fields: (1) a uni-axial compressional stress field, where maximum principal compression axis is normal to bedding surface, and (2) a tri-axial compressional stress field, where orientation of maximum principal compression axis is parallel to paleocurrent direction. Numerical simulation of a submarine debris flow using the bi-linear rheology model indicates that this mass-transport deposit experienced the first stress field when it moved downslope, thereby expanding its surface area. It then experienced the second stress field as it decelerated, because of compression parallel to paleocurrent direction. Although the second stress field caused by deceleration of the flow occurs in any conditions, the first stress field that is related to the initial flow expansion occurs depending on the initial flow geometry and yield strength of the flow matrix. Thus, the result of this study implies that (1) a horizontal compression paleo-stress field can be an indicator of the paleocurrent direction of the debris-flow, which is generally difficult to be reconstructed from the outcrop data. In addition, it is also suggested that existence of a vertical compression paleo-stress field can be a clue for the initial conditions of the submarine landslide.

Keywords: submarine debris flow, paleostress analysis, paleocurrent analysis, gravelly mudstone, submarine landslide