Deformed sediment gravity flow deposits associated with bypassing slides: an example from the Miocene Ushikiri Formation, Southwest Japan

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The Middle Miocene Ushikiri Formation in Shimane Peninsula, southwest Japan, is interpreted to have been deposited on the shelf margin to the middle continental shelf, and is known to contain unique sediment gravity flow deposits, similar to hybrid sediment gravity flow deposits (turbidite + debrite). Intensely deformed mud clasts have been described from this formation. However, their formation has not been focused on previous studies. The present study aims to characterize the deformation of sandstone beds and mud clasts contained within the sediment gravity flow deposits and to discuss of the deformation process of the sediments.

Many of the sandstone beds in the upper Ushikiri Formation (averaging 0.6 m thick) are bipartite, with lower parts showing characteristics similar to Ta or Ta-b turbidites with rich mud clasts. The upper parts of the sandstone beds are represented by poorly-sorted muddy sand with scattered mud clasts having debrite-like features. The small mud clasts in the lower part show features different from those in ordinary turbidites: some are subject to injection of surrounding sand and some scattered in sands show jigsaw-puzzle patterns, suggesting in situ mud clast fragmentation. Some mud clasts are intensely stretched. The beds also host large mud clasts (maximum length: ca 3 m), in which deformation structures, such as slump folds, are well developed. Mud clast shapes are not consistent with internal deformation structures and the most of them have sharp margins. The sand around some large mud clasts shows local liquefaction. Local grading is also found above the large mud clasts and does not continue beyond the edge of the mud clasts.

The injection of sand into mud clasts and their in situ fragmentation into jigsaw-puzzle patterns can be explained by liquefaction of beds with overburden pressure. A possible pressure source is slides that passed over a freshly deposited turbidite bed. When a slide bypassed the sand bed, the bed once deposited as turbidite easily liquefied under the moving slide mass, having led overburden pressure in the bed that caused injection and in situ fragmentation. On the contrary, the large mud clasts may have been fragments ripped from a major sliding body that bypassed the studied locality. Local liquefaction around large mud clasts indicates they sank or were forced into the bed from above. The presence of local grading above the mud clasts can be explained by local resuspension of sand around the mud clasts when they sank into the sand. The above mentioned sediment deformation process is supported by beds with a slide deposit above a sandy part having similar mud clast deformation.
The bypassing of the slide may have been due to hydroplaning of the slide mass. The slide deposits are represented by up to 2 m thick of large mud block rich sediments with variety of deformation structures, which grades from an underlying debrite-like bed that consists of poorly-sorted muddy sand with rich mud clasts with injection of surrounding muddy sand. Some mud clasts in the muddy sandstone beds are intensely stretched, implying that shear stress exerted within the beds. The poorly-sorted muddy sand is thus interpreted as a fluid layer, which has been existed below the moving landslide mass, having

triggered the hydroplaning.

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