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Classification of flood- and slope-failure induced lacustrine sediment gravity-flow deposits using depositional processes and lateral facies changes: Case study of the Middle Pleistocene Hiruzenbara and Miyajima formations, Japan

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Sediment gravity flow deposits in lakes and deep seas are used to unravel flood and earthquake-events archives. Distinguishing these deposits in thin cores is difficult and despite reports in several studies, clear identification criteria for flood and earthquake-induced sediment gravity-flow deposits remains elusive. In this study, we conducted a sedimentological analysis on river-inflow (flood) and slope-failure (earthquake) deposits of the Middle Pleistocene lacustrine deposits of the Hiruzenbara and Miyajima formations. Data from well-exposed outcrops was employed to discuss sedimentary processes associated with these deposits and propose classification criteria.

The Hiruzenbara Formation, outcropping in Hiruzenbara, Okayama Prefecture, southwest Japan is a lacustrine deposit dominated by varved diatomites. The varves consist of light and dark layers of fossil diatoms ($\geq$ 90 %). The river-inflow (flood) deposits are typical clastic deposits while the slope-failure (earthquake) deposits consist of rip-up varve clasts. The river-inflow deposits were classified into very thin (a few mm) hypopycnites or homopycnites without an erosional base and hyperpycnites with an erosional base. The hyperpycnites contain inverse grading units and a normal grading units separated by internal erosion surfaces. Lateral facies changes are characterized by minor changes in thickness and quantity of organic matter in downstream. The river-inflow deposits are proximal facies attributed to deposition from sustained sediment gravity-flow. Slope-failure deposits were partitioned into those with abundant rip-up varve clasts and those that are structureless with finely crushed varves. Slope-failure deposits showed lateral facies changes with pinch out over several meters. The slope-failure deposits are distal facies ascribed to deposition from surge sediment gravity-flow.

The Miyajima Formation, exposed in Nasushiobara, Tochigi Prefecture, northeast Japan is another lacustrine deposit dominated by varved diatomites. The varves consist of light laminae dominated by fossil diatoms and dark laminae of inflow deposits. Because sediment gravity-flow deposits of the formation contain silt and sand from inflow, some sediment-gravity flow deposits are classified as flood-induced, while slope-failure is assigned to deposits with abundant diatomites. Some slope-failure deposits including slump-fold structures and many diatomaceous blocks were likely induced by floods. Paleocurrents data associated with the deposits indicate they were derived from a fan delta at the west coast of the paleo-Shiobara lake. Flood deposits of the formation are classified into those with an erosional base, those without an erosional base, and those with inverse grading. Deposits with erosional bases and those with inverse grading were deposited as hyperpycnites, while those with no erosional base were deposited as hypopycnites or homopycnites. Lateral facies changes are minor for the flood deposits but significant for slope-failure deposits including the flood-induced type.

The use of depositional processes and lateral facies changes associated with the flood and slope failure deposits improved identification of the deposits and the unravelling of event records.