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Sedimentary facies and depositional processes of flood-induced lacustrine sediment gravity flow deposits intercalated within diatomites in Japan

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Lacustrine sediment gravity flow deposits (L-SGFDs) originate from flood inflows and slope failures triggered by earthquakes. Previous studies have mainly focused on sandy L-SGFDs and have described these deposits as hyperpycnites. However, very few studies exist concerning fine-grained L-SGFD, therefore the detailed sedimentary processes associated with these deposits remain unclear. In addition, homopycnal flows and hypopycnal flows are also expected to occur but clear descriptions of these deposits are not available in the literature. In this study, microscopic internal structures in flood-induced L-SGFDs within several diatomite formations in Japan were examined and a model of the sedimentary processes associated with these deposits is established.

The middle Pleistocene Hiruzenbara Formation is a diatomite deposit from a paleo-dammed lake and includes a wide variety of intercalated L-SGFDs. The L-SGFDs in this formation may be classified as deposits induced by floods and slope failure. For comparison, we also examined L-SGFDs within the middle Pleistocene Miyajima Formation, a caldera fill deposit in northeast Japan, and the middle Miocene Choujabaru Formation on Iki Island in the Japan Sea. Flood-induced L-SGFDs in this study may be further sub-classified as a thicker erosional type (>1 mm) and a thinner non-erosional type (=<1 mm). Most L-SGFDs classified as the thicker erosional type show graded bedding, occasionally including an internal erosion surface. L-SGFDs that show an internal erosion surface consist of a lower inversely graded unit and an upper graded unit, separated by the internal erosion surface. This type are suggested to be hyperpycnites deposited from the increasing and decreasing discharge stages of a hyperpycnal flow. As the lower unit in some L-SGFDs of this type is observed to be structureless with many rip-up clasts, there is a possibility that the lower unit was deposited from a debris flow eroding the underlying layer. In that scenario, a dilute turbulent flow may evolve into a concentrated laminar flow by entraining material from the underlying layer, which is then deposited as a massive structureless unit from a freezing debris flow during the increasing discharge stage. The upper graded unit may then have formed from a more dilute flow over the lower unit. Some L-SGFDs interpreted as hyperpycnites were draped by very thin clay-rich layers. The origin of these capping clay-rich layers is suggested to be related to deposition from a dilute homopycnal or hypopycnal flow separated from a main flow, and which spread on the lake water surface or along the thermohaline boundary. The thinner non-erosional type of L-SGFD deposit may include a graded unit and constitute very thin deposits with no clear grain size trend. These types of deposits show good lateral continuity and may be correlated over 1-2 km, although the thickness of these layers is typically thinner than 1 mm. L-SGFDs of this type are suggested to be homopycnites or hypopycnites. These deposits are thought to originate from homopycnal and hypopycnal flows spreading on the surface or the thermocline of a lake, with sediments subsequently settling on the lake floor.