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Depositional cycle and flood and slope-failure events in an 8,000-yr varve of Pleistocene Hiruzenbara Formation, Japan

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Paleoenvironmental changes can be reconsructed from varve deposits. The Middle Pleistocene Hiruzenbara Formation, which is distributed in the Hiruzen Highland, Maniwa city, Okayama Prefecture in Japan, is composed of mostly pure lacustrine diatomite that contains finely-laminated varves. From these varves, researchers have found decadal-scale depositional cycles that are thought to correspond to solar activities (Ishihara and Miyata, 1999), and intercalated flood- and slope-failure events have been detected. However, the relationship between the solar cycles and hydrogeological events remains unclear. In the present study, we sampled the finely laminated varves in the Hiruzenbara Formation, and obtained an 8,000-yr time-series of varve-thickness, gray-values for each lamina, variance of the gray-values, and deposits of flood- and slope-failure events using image analysis methods. Wavelet analysis and a fast Fourier transform (FFT) were applied to these time-series data to evaluate event-cyclicities.

In the time-series of varve-thickness, a long-term cyclicity of 1,000 - 2,000 yr was recognized. The upper parts of varves were light-green in color, and these were likely deposited during the winter season. Clear increases in thicknesses of the light-green parts were observed from the lower to upper parts of the analyzed section. Results from frequency analyses using the FFT and wavelet analysis of the time-series of varve-thickness data suggest that periods of 8 to 12 yr, 20 yr, and 30 to 35 yr dominate in this region. These periods were also found by Ishihara and Miyata (1999) and Masuda et al. (2004) in other sections of the formation. The periods in varves of 8 - 12 yr and around 20 yr correspond to solar activity, and a 35-yr periodicity of lake environmental change has been reported previously. In this study, however, these periods were not stable in the analyzed section, which is similar to the results obtained by Ishihara and Miyata (1999) and Masuda et al.(2004) who measured varve-thickness using a microscope.

One hundred-forty seven flood deposits were identified in the 8,000-yr record. Portions of the high-frequency parts and low-frequency parts were repeated in the analyzed section. Mean thickness of the flood beds was around 2 mm. Thirty-three deposits from slope failures were found in the section. These deposits were rare in the upper and lower most parts of the section, but were dominant in the lower part. There was no repetition of domination for the deposits that were observed during the flood events. Mean thickness of the slope-failure deposits was around 5.5 mm.

In the sections where flood deposits dominated, the mean varve-thickness tended to thinner without exception. In the upper part of the analyzed section, which lacked flood event signatures, the mean varve-thickness was generally greater. These trends suggest that climate conditions and the frequency of flood events might have affected the productivity of diatoms (thickness of the lamina). In addition, the periods detected by frequency analyses were not clear in the flood-deposit dominated sections. Results showing that dominations of slope-failure deposits were not related to the varve-thickness and the gray-values suggest that the slope-failure events were influenced by local phenomena related to lake development.

Keywords: Banded diatomite, Varve, Image analysis, flood deposit, slope-failure deposit, Solor activity