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Interpretation of sedimentation mechanism of Miocene siliceous rocks by high-resolution analytical method using X-ray microscope

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High-resolution quantitative reconstructions of paleoenvironmental changes become increasingly important to understand the dynamics of environmental variations. Especially, it is essential to understand the mechanism of material recycling by reconstructing high-resolution burial flux variations. Chemical compositions of fine-grained sedimentary rocks provide biogenic matter content and detritus content, and in conjunction with measurements of dry bulk densities and linear sedimentation rates, it enables us to estimate burial fluxes of each components. Therefore, quantitative micro-scale chemical analyses and dry bulk density measurements of sedimentary rocks are necessary. However, conventional methods are too time-consuming. In this study, firstly, a rapid, high-resolution, quantitative method for chemical analysis and dry bulk density measurement was developed using X-ray analytical microscope. Secondly, this method was applied to interpret the sedimentation mechanism of siliceous rocks of the Onnagawa Formation.

XGT-2700 is an instrument designed for non-destructive, rapid, high-resolution, semi-quantitative, chemical mapping of rocks, but its application to quantitative analysis is not yet attempted. But area scanning analysis for 0.5x0.5 to 100x100mm size region of rocks within 100 seconds by XGT enables us to obtain the cumulative elemental spectral and transmission X-ray image at the same time. Therefore, XGT analysis has possibility to achieve quantitative measurement of chemical composition and dry bulk density at the same time. First, the calibration lines were constructed for Mg, Al, Si, S, K, Ca, Ti, Mn, Fe. Analyses of standard fine-grained rock samples whose compositions were measured by conventional XRF method revealed strong positive correlations between the element concentrations(wt%) and X-ray peak intensities(cps*keV) measured by XGT. Si content can be measured within the precision of 9wt%(2sigma), other elements within 2.0wt%. Next, the transmission X-ray intensities measured by XGT showed the negative correlation with dry bulk densities of standard fine-grained rock samples, which were measured by mercury pycnometer. Regression curve for this relation was expressed by exponential function. If we use this regression curve as a calibration line, dry bulk density for small region of the sample can be measured within the precision of 0.14(g/cm3)(2sigma) by XGT. These results mean XGT can measure chemical compositions and dry bulk densities at the same time. The speed of this analytical method is about ten times faster than conventional method.

The siliceous rocks of middle Miocene Onnagawa Formation have centimeter- to decimeter-scale rhythmical alteration of dark and light layers, which may represent centennial- to millennial-scale paleoenvironmental variation. Especially, the Onnagawa Formation in Gojohme area has micrometer-scale lamina couplets that are considered as varves. In this study, in order to clarify the sedimentation mechanism with high time resolution, about 2.5m interval of the Onnagawa Formation in Gojome area was sampled continuously and analyzed with 5mm resolution by XGT. As a result of chemical analysis, it was revealed that the Onnagawa Formation was mainly composed of biogenic silica, terrigenous detritus and dolomite. The variations of biogenic silica flux and detritus flux were estimated from dry bulk density measured by XGT and linear sedimentation rate measured by lamina thickness. Detritus flux was relatively constant in contrast with centimeter-scale variations of biogenic silica flux in light-dark pairs. And the variation of biogenic silica flux was in harmony with cm-scale variation of bottom water oxygenation level. This results indicate the possibility that centimeter-scale variations of biogenic silica flux is attributed to centennial-scale surface productivity cycle.