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A novel 4D-view on sediments: insights to sedimentation processes and post-sedimentary mineral formation

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Lake sediment archives are well studied around the globe and contribute greatly to our understanding of past environments and climates. Yet, traditional sedimentological analyses are either limited to a 2D study of the sediment core surface, or volumetric analysis, for which the sedimentological structure needs to be destroyed. To overcome these limitations, we combined high-resolution 3D-microCT-scanning (μm-scale) of fresh lake sediment with XRF-scanning, micro-XRF mapping, and traditional thin section analysis. MicroCT-scanning facilitates the observation of sedimentary structures at the mm-scale in 3D prior to analysis, while high-resolution mapping in 2D aids characterisation of the observed structures once the fragile sample is embedded in resin.

We present a study of sediments from Lake Towuti (2.75°S, 121.5°E), one of the oldest and deepest lakes in Indonesia. Cores of the entire sediment infill have been recovered in the ICDP Towuti Drilling Project in 2015, including lacustrine sediments covering several glacial-interglacial cycles. Located in the ultramafic East Sulawesi Ophiolite, the lake is highly ferruginous but poor in sulphur and among the least productive tropical lakes on Earth (ultra-oligotrophic). In the cores, high density contrasts between the clay-rich sediment matrix and postdepositional alteration products such as siderite ($FeCO_3$) provide an ideal setting for microCT analysis on characteristic sediment core sections. Geochemical information from the embedded sections is provided by high-resolution XRF-scanning (200 μm spacing) and micro-XRF mapping (50 μm spacing) of the samples.

MicroCT scans reveal μm-thick vertical voids filled with high-density mineral precipitates related to post-depositional fluid circulation, as well as coatings of high-density material (mainly siderite), around low-density centres. We also observe beds of siderite, which appear continuous in 2D, but prove to be separated structures in 3D space. A crack showing vertical displacement in the sediment is, in 3-D space, visualised as a plane of higher density material, which points towards a rupture, perhaps seismically induced, that promoted precipitation of siderite on the newly-formed surface. The combination of high-resolution imaging with XRF element scans allows a novel, very detailed 4D-view of sedimentary structures that identifies processes involved in authigenic mineral formation and their relation to paleoenvironmental changes in the lake and its catchment.