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Siderite in ferruginous sediments: spatially explicit Identification of temporally variable mineral formation

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Understanding the temporal and spatial context of authigenic and diagenetic mineral formation in sedimentary environments is critical to utilize them as recorders of past environmental changes. Here we provide detailed insight into spatiotemporal formation relationships of siderite in ferruginous sediments of 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 the last ~1 Myr, continuously.
We combined high-resolution 3D-μCT-scanning (μm-scale) of fresh lake sediment with XRF-scanning, micro-XRF mapping, and traditional thin section analysis. μCT-scanning facilitates the observation of sedimentary structures at the μm-scale in 3D prior to analysis, while high-resolution mapping in 2D aids characterisation of the observed structures once the fragile sample is conserved in resin. Siderite and other high density authigenic phases, such as millerite, produce high density contrasts in the clay-rich Towuti sediment matrix thus facilitating spatial analysis of their formation contexts.
While the formation of siderite is dependent on the chemical and redox environment in the water column and sediment, our μCT analyses reveal a wide variety of both synsedimentary and postdepositional structures in which siderite formed in Towuti sediments. These include: 1) discontinuous laminae composed of micritic siderite along the synsedimentary bedding; 2) vertical voids filled with siderite related to postdepositional fluid circulation, 3) siderite precipitates on micro-fault planes; 4) up to cm-diameter large siderite nodules with lower density centres suggesting continued postdepositional growth. All structures occur repeatedly in the 100 m long soft sediment record and sometimes in close, or even overlapping relation to each other, suggesting that siderite in these sediments contains a mixed signal of different mineral formation generations and processes. Our results thus emphasise the importance of careful identification and characterization of different authigenic mineral formation modes in sedimentary records, prior to utilizing them as recorders of the chemical environment in which they formed.