Opening process of the Paleo-Tethys, based on geochemistry of a Devonian siliceous sequence in Northern Thailand

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The Paleo-Tethys, which opened in response to Devonian separation of the North China and Indochina blocks from Gondwana, occupied a large area around the equator from the Devonian to Triassic, where carbonates, chert, and basalt were deposited in a pelagic domain (e.g., Metcalfe, 1999). We reconstructed the opening of the Paleo-Tethys, including the depositional setting and redox conditions, based on an analysis of radiolarian fossils and the geochemistry of a Devonian siliceous sequence in the Chiang Dao area of northern Thailand.

The sequence is subdivided into the following five rock types (in ascending stratigraphic order): black shale (Early Devonian), siliceous shale (Middle Devonian), tuffaceous chert, tuff, and chert (Late Devonian). The black shale is dark black in color, and is 10 m thick. The shale is composed mainly of illite/smectite and quartz, with characteristic ramboidal pyrite. Rhythmic laminations are commonly observed with intervals of several millimeters. The siliceous shale is dark gray to black in color, 6 m thick, and consists of illite/smectite and quartz with abundant radiolarian fossils. The tuffaceous chert, which is light gray to light green in color and 40 m thick, is the dominant lithology within the Devonian siliceous sequence. The tuffaceous chert contains illite/smectite and quartz, being similar in lithology to the siliceous shale. The tuffaceous chert contains a 2-m-thick tuff layer. The tuff is acidic, light green in color, and weakly foliated. The tuff contains flattened pumice fragments (up to 2 cm in length) aligned parallel to bedding. The tuff consists of illite/smectite, chlorite, and quartz, with the chlorite being a characteristic feature. The chert is well bedded, usually dark green to dark gray in color, and 6 m thick, consisting entirely of cryptocrystalline to microcrystalline quartz, with no terrigenous material but containing radiolarian fossils.

For understanding of the depositional setting and redox conditions for the initial Paleo-Tethys, we determined the geochemistry of the sequence. The concentrations of major elements were determined by XRF (Philips PW-1404, Geological Survey of Japan), concentrations of trace elements and rare earth elements (REEs) were analyzed by XRF (Rigaku RIX3000) and ICP–MS (Agilent 7500a) at Niigata University. The total organic carbon (TOC) content, and Th and U concentrations were determined using a Thermo Finnigan Flash EA1112 and ICP–QMS (Agilent 7500cs) at Jamstec.

Based on analyses of land-derived elements (Al₂O₃, TiO₂, Rb, Zr, and Th) and mineral composition data, the black shale and tuff contain a large terrigenous input, whereas the chert contains no terrigenous material. We infer that the siliceous sequence (except for the chert) was deposited in a SiO₂-rich environment into which terrigenous material and volcanic ash were transported from the adjacent continent. Data on TOC, Th/U ratios and redox sensitive elements (V, Cr, Ni, Zn) indicate a gradual change from anoxic to oxic oceanic conditions between the black shale and chert, showing no influence by terrigenous material in the tuff.

Taking into account the interpreted depositional setting and redox conditions, the initial Paleo-Tethys developed as a small, closed anoxic–suboxic oceanic basin during the Early to Middle Devonian, located close to the continental margin. Black shale and siliceous shale were deposited in the basin at this time. Opening of the Paleo-Tethys started in the earliest Late Devonian, marked by voluminous volcanic activity. The tuffaceous chert was deposited under oxic conditions, suggesting that ash and pumice within the chert were derived from a continental source. After the Late Devonian, the Paleo-Tethys developed as a deep, broad ocean in which pelagic chert was deposited.