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A Carboniferous iron formation and its implications for episodic ferruginous conditions

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Iron formations (IFs) are iron-rich chemical sediments that were widespread throughout the Precambrian. The deposition of IFs has provided key evidence about the prevalence of anoxic and ferruginous marine conditions throughout Earth's history. Here, we describe the Shikebutai IF, hosted in a Late Carboniferous volcano-sedimentary sequence in the Western Tianshan region of northwest China.

The Shikebutai IF is mainly composed of hematite, quartz, and minor siderite with distinct alternating iron-rich and silica-rich bands. The chemical composition of the IF is dominated by Fe_2O_3 and SiO_2, and very low concentrations of Al_2O_3, TiO_2, Th, Nb, and Sc were observed, indicative of an authigenic origin. The hematite shows $\delta^{18}O$ values in the range of +2.2‰ to +7.0‰, and the jasper yields $\delta^{30}Si$ values of -1.90‰ to -1.20‰. In addition, the IF also shows high Fe/Ti, Fe/Al, Co/Zn, and Ni/Zn ratios, along with positive Eu anomalies ($Eu/Eu^* = 1.26$ to 2.16) and $\varepsilon_{Nd}(t)$ values (-0.2 to +4.3), which points to a significant submarine volcanic and hydrothermal contribution. The absence of negative Ce anomalies and heterogeneous $d^{56}Fe$ values suggest progressive oxidation of hydrothermally sourced Fe(II) and deposition in an anoxic to low oxygen basin. Low P/Fe ratios in the Shikebutai IF, comparable to those found in the Precambrian, are consistent with Si inhibition of P sorption and P drawdown with high hydrothermal inputs.

The intimate association of this Late Carboniferous IF with submarine volcanic activity suggests an origin that is analogous to Precambrian Algoma-type IFs. Further, the Shikebutai IF provides evidence for an episode of basin-scale anoxic, ferruginous conditions coinciding with the generally well-oxygenated deep oceans of the Phanerozoic, with deposition driven by enhanced submarine volcanic and hydrothermal activity in the Western Tianshan region during the Late Carboniferous. This demonstrates how, even with near modern surface oxygen levels, enhanced hydrothermal activity can shape the marine redox landscape and cause the development of ferruginous conditions without quantitative sulfate drawdown.