Early Ordovician anoxia and biological extinction linked to a large seafloor-hydrothermal system at Løkken, Norway

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The Løkken volcanogenic massive sulphide (VMS) Cu-Zn-pyrite orebody is the largest (30 Mt) ophiolite-hosted VMS deposit known [1], having formed in an arc-related marginal basin near the eastern edge of Laurentia at 481.5±1.4 Ma based on U-Pb zircon geochronology of synvolcanic plagiogranite [2]. Laterally extensive beds of jasper (hematitic chert) up to 5 m thick occur below, along strike from, and above the orebody, suggesting deposition under generally oxic to suboxic bottom waters [3]. Directly above the orebody and extending laterally for at least 2 km are distinctive beds of iron formation, 0.5 to 2.0 m thick, consisting of silicate (stilpnomelane+chlorite±magnetite± minnesotaite) and sulphide (pyrite±pyrrhotite) facies. The presence of these iron formations implies, respectively, anoxic to euxinic bottom waters during VMS mineralization. We propose that this fundamental redox change, from suboxic/oxic to anoxic/euxinic conditions, was promoted by a large and sustained flux of hydrothermal reductants including H_2, H_2S, Fe^{2+}, and Mn^{2+}, which are well documented in vent fluids of modern seafloor-hydrothermal systems [4].

An Early Ordovician global marine extinction event involving mainly trilobites and brachiopods has recently been attributed to large-scale anoxia, based on positive $\delta^{13}C$ and $\delta^{34}S$ excursions and low (near-zero) I/Ca ratios in carbonate strata of Nevada and Utah that were deposited on the southern margin of Laurentia [5]. The age range for this early Stairsian (~482-481 Ma) event includes, within analytical uncertainty, the age of the Løkken orebody. We suggest that this extinction is linked to a large flux of reductants exhaled from seafloor vents of the Løkken hydrothermal system. In our model, these reductants were transported long distances by hydrothermal plumes, generating marine anoxia in deep and locally in shallow waters of the Laurentian margin.

[1] Grenne *et al.* (1999) *Min. Deposita* **34**, 422-471. [2] Slagstad *et al.* (2014) *Geol. Soc. London Spec. Publ.* **390**, 541-561. [3] Grenne & Slack (2005) *Econ. Geol.* **100**, 1511-1527. [4] Hannington *et al.* (2005) *Econ. Geol. 100th Ann. Vol.*, 111-141. [5] Edwards *et al.* (2018) *EPSL* **481**, 125-135.