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Geochemical Proxies as an Effective Tool for Determining Depositional Environments for Burgess Shale-Type Fossil Localities

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A variety of models have been presented to account for the arrest of decay processes in Burgess Shale-type (BST) fossil beds. These models include sustained anoxia, fluctuating oxyclines, and hypersaline brines. Despite being questioned in the published literature, patterns in redox-sensitive metals may differentiate between these chemical environments of deposition. Accordingly, the redox indices V versus Al, V/Sc, Ni/Al, Ni/Co, and Mo were applied to two well-documented North American BST localities: 1) the Wheeler Formation (Utah, USA) with palaeontological characteristics indicating deposition within a fluctuating oxycline; and 2) the Burgess Shale (British Columbia, Canada) with field evidence indicating an association of fossil deposits with hypersaline brine pools. In addition, the chemical characteristics of the Kinzers Formation (Pennsylvania, USA), a BST fossil locality in which details of depositional environment are unclear due to limited outcrop exposure, were compared to those of the Wheeler and Burgess Shale formations.

A set of eighty-four Wheeler Shale samples yielded a range of Ni/Co values from 0.6 to 10.5, and V/Sc values up to 27.9. Barren shales cluster along the line that defines the lithogenic maximum for V, whereas fossiliferous samples yielded a scattered distribution of V versus Al values above the lithogenic maximum. Molybdenum content was <1ppm in all Wheeler Shale samples. These data are consistent with deposition under a range of redox conditions, with fossils (both BST and trilobites) correlating with low-oxygen environments. In contrast, a set of 53 samples from the Burgess Shale and associated units yielded a restricted range of both Ni/Co (<6.3; all but two <5.0), and V/Sc (<7.2). Vanadium values correlate with aluminum. Molybdenum content is below the 2ppm detection limit in all but two samples (2 and 3 ppm). Geochemical signatures for barren, trilobite-bearing, and soft-bodied-fossil-bearing samples are indistinguishable. These data are consistent with deposition of Burgess Shale strata beneath an oxygenated water column. Geochemical palaeo-redox proxies are consistent with field relationships and palaeontological data. This demonstrates that geochemical proxies can be applied effectively to BST fossil-bearing strata.

Two units within the Kinzers Formation were studied: 1) the Olenellus and BST-fossil-bearing Emigsville Member; and 2) the Longs Park Member which includes black shale strata that host abundant Ogygopsis trilobites but lack BST preservation. The BST-bearing strata of the Emigsville Member yield geochemical patterns similar to those of the Burgess Shale: correlation of V with Al, limited range of Ni/Co (<6.0) and V/Sc (<6.0), and non-detectable Mo (<2ppm). In contrast, the Ogygopsis beds are distinct from both the Burgess and Wheeler Strata: elevated V with respect to Al, anomalous V/Sc (20.9 to 35.2), and consistently detectable Mo concentrations (3-10ppm). These data suggest that BST preservation in the Kinzers occurred under oxic conditions, whereas the Ogygopsis beds were deposited in an anoxic environment. Non-oxygen-related environmental factors, such as salinity, must account for soft-tissue preservation in the Kinzers Formation.