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THE EARLY TRIASSIC CARBON, SULFUR AND NITROGEN ISOTOPE RECORD

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At the aftermath of the end-Permian mass extinction, Panthalassan ocean chemistry underwent profound changes, as outlined by geochemical, sedimentological and paleontological observations. The Early Triassic carbon, sulfur, nitrogen and strontium isotope records show patterns that, in concert, are unprecedented in earth history. The Early Triassic carbon isotope record is marked by three positive excursions, all located at, or close to stage/substage boundaries—Dienerian-Smithian (Induan-Olenekian), Smithian-Spathian, and Spathian-Anisian (Olenekian-Anisian)—as reported previously from sites located in the Tethyan realm. Carbon isotope data from marine sequences on the western margin of the North American continent show an identical pattern, confirming the global nature of Lower Triassic carbon isotope fluctuations. All three excursions are present in the Ursula Creek section in Northeast British Columbia (Williston Lake), and fully or partially recorded in several sections within the Thaynes Formation outcrop in the Western United States (Utah, Nevada and SE Idaho). As in the Tethys, these carbon isotope excursions stand out, not only by their abruptness, but also by their extreme magnitude, comparable only with Precambrian and Early Cambrian counterparts.

The high abundance of organic matter throughout the Ursula Creek section allowed us to provide a continuous nitrogen isotope profile for the entire Early Triassic and part of the Anisian. The $\delta^{15}N$ values are relatively constant for most of the section, but display a negative excursion of 1.5‰ across the Olenekian-Anisian boundary, mirroring the carbon isotope excursion. It indicates increased nitrate availability, consistent with the onset of an upwelling system indicated by the presence of phosphate nodules. While the nitrogen isotope anomaly is likely to be local, confined to the North American upwelling zone, it suggests a sudden increase in ocean productivity, in agreement with a positive excursion in carbon isotopes. Another remarkable feature of the Early Triassic stable isotope record is represented by a large sulfur isotope shift, as recorded in sedimentary sulfates, though its timing and relationship to the carbon isotope record is not well defined. Sulfur isotope profiles in the Moenkopi Formation in SW Utah and N Arizona show a major increase in $\delta^{34}S$ values from approximately 11‰ in the Lower Red Member (Smithian) to values as high as 30‰ in the Shnabkaib Member (Spathian). $\delta^{34}S$ values from the younger (Lower Anisian?) Moqui Member are relatively low, around 10‰, indicating a return to initial values and thus defining a positive excursion within the Spathian, possibly spanning the Spathian-Anisian boundary. Tentative correlations with the carbon isotope record from the Thaynes Formation, due to interfingering relationships between the Thaynes and Moenkopi formations, indicate a decoupling of the carbon and sulfur isotope cycles during the Smithian and Spathian (Olenekian). Although it is difficult to reconstruct a scenario that would account for all geochemical anomalies described above, the stable isotope record is consistent with an Early Triassic stratified, stagnant ocean, low latitudinal temperature gradients, large carbon isotope gradients between deep, anoxic and surface waters, and increased sulfate reduction in the anoxic zone that would lead to large fractionation of sulfur isotopes and formation of residual brines enriched in ^{34}S. A reorganization of the ocean circulation system and onset of vigorous upwelling currents at the end of the Early Triassic would mark the return to normal conditions and final recovery after the end-Permian mass extinction.