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Reconstructing Latitudinal Surface Temperature Gradients During the Ordovician Warming

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Earth's surface habitability is governed by latitudinal thermal gradients caused by solar insolation, while the continent-ocean distribution modulates the heat redistribution through atmospheric and oceanic circulation over geologic time. During the late-Ordovician, this climate shifted from warm-tropical waters to a cooling trend culminating in Hirnantian glaciation [1]. We investigated a fossiliferous, stratigraphically-constrained Late-Ordovician succession from Spiti, Himachal Pradesh [2]-an obducted sedimentary package deposited in the low to intermediate southern paleolatitudes (~15° to ~30°S) [3].

We integrated the lithostratigraphy with carbonate and organic carbon isotopes ($\delta^{13}C_{carb}$, $\delta^{13}C_{org}$) and oxygen isotopes ($\delta^{18}O$) across transgressive–regressive cycles expressed by a sandstone→platform-carbonate→shale-transition. $\delta^{13}C_{carb}$ values range from −0.88‰ to +1.95‰ and $\delta^{13}C_{org}$ values from −26.7‰ to −19.7‰. The maximum positive $\delta^{13}C$ excursion (+1.95‰) is noticed within the fossiliferous limestone, closely matching the nearby Parahio record (+2.03‰) [4] supporting regional chemostratigraphic correlation. Using a simple carbon-mass-balance approach, we estimated organic carbon burial fractions of ~2% to 14.8%, exhibiting an increase as reconstructed paleotemperature decreases. $\delta^{18}O$-derived sea-surface paleotemperatures yield an average apparent temperature of ~47 °C, motivating verification via clumped-isotope thermometry.

Comparison with the Anticosti-Island succession [5] highlights that the Spiti $\delta^{13}C$ excursion is notably smaller than the Hirnantian signal (~+4.8‰; 442.6–442.18 Ma), yet the overall isotopic profile aligns with sections deposited at ~0°–30°S. Together, these data indicate that late-Ordovician cooling in Spiti was accompanied by enhanced organic-carbon burial, implying strong coupling between temperature, productivity, and carbon-cycle perturbations during climate deterioration towards glaciation.

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