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Cool and volatile-rich reservoir revealed in the early Inner Solar System

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The origin of volatile elements in the inner Solar System remains poorly constrained, despite their fundamental importance for terrestrial planet differentiation and habitability. The proto inner Solar System is traditionally assumed to have been too hot for volatile condensation, requiring later delivery from the outer Solar System. Here we present geochemical, isotopic, and disk-evolution modeling evidence that challenges this view. Our results indicate that the ureilite parent body possessed CI-like (Ivuna-type carbonaceous chondrite) abundances of volatile elements. The oldest known andesitic achondrite, Erg Chech 002, exhibits similarly CI-like volatile signatures, suggesting that such enrichment was not unique to ureilites. Combined with non-carbonaceous zinc isotopic anomaly characteristics, indicate an inner Solar System origin for these volatiles. Thermal modeling further shows that the inner proto-nebular disk could have cooled sufficiently within the first million years after the formation of calcium-aluminum-rich inclusions (CAIs) to permit volatile condensation, supporting the existence of a transient, volatile-rich CI-like reservoir in the early inner Solar System.