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Micro-XRF Analysis of Mn and Cr Distribution in Seymchan and Esquel Pallasites: Insights into Formation and Cooling Histories

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The formation mechanisms of main-group pallasites, particularly the roles of collisional processes and thermal evolution, remain subjects of active debate. This study utilizes micro-X-ray fluorescence (micro-XRF) spectroscopy to investigate the spatial distribution of Mn and Cr in olivine aggregates and metal phases of Seymchan and Esquel pallasites, providing new insights into their genetic pathways.

In Esquel, Cr enrichment is associated with chromite formation and localized within olivine grains, while Mn exhibits homogeneous distribution across olivine crystals, consistent with slow cooling and prolonged annealing. In Seymchan, Cr shows distinct enrichment patterns: (1) within irregularly shaped, melt-modified olivines, and (2) at kamacite near interfaces between metal alloys and olivine domains, suggesting interactions between metal and silicate phases during cooling. Mn distribution in Seymchan is bimodal, occurring in both olivine and taenite within alloy regions, indicative of rapid thermal quenching that preserved compositional heterogeneity.

These contrasting Mn and Cr zoning patterns highlight divergent thermal histories. Esquel's slow cooling facilitated chromite crystallization and Mn equilibration, aligning with gradual mantle annealing. In Seymchan, rapid cooling likely arrested disequilibrium signatures, potentially linked to collisional events that influenced metal-silicate interactions. The localized Cr enrichment at kamacite-olivine boundaries may reflect dynamic processes during cooling, differing from those observed in Esquel.

By resolving sub-grain-scale chemical variations, micro-XRF provides critical evidence for correlating elemental redistribution with thermal and collisional processes. These findings advance our understanding of pallasite formation, emphasizing the role of variable cooling rates and potential impact-driven modifications in asteroidal mantle evolution.