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Geochemical compositions, chronology, and growth controls of cobalt-rich ferromanganese crusts on Magellan seamounts in the Western Pacific: Implications for resource potential

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Cobalt-rich ferromanganese crusts (CFCs) are an important deep-sea mineral resource, containing economically valuable metals such as cobalt, nickel, and rare earth elements (REEs). With the increasing demand for critical metals to support renewable and clean energy technologies, deep-sea mineral deposits are gaining attention as a potential alternative supply source to complement land-based resources. Understanding the spatiotemporal variations in metal enrichment and geochemical evolution of CFCs is essential for assessing their role in the global critical metal supply chain. This study investigates CFCs from seamounts within the Korean exploration license area in the Western Pacific, integrating geochemical and chronological data to evaluate their economic viability and the environmental factors influencing their growth. A multi-method geochronology approach, including U-Pb dating and Pb isotope composition analysis using LA-ICP-MS, was employed to determine crust formation ages and track metal enrichment processes over geological timescales. Elemental distributions and metal enrichment trends vary across different growth layers, reflecting layer-specific environmental conditions, including changes in seawater composition, redox environments, and the influence of seafloor topography and substrate lithology on seamounts. Growth rate analysis indicates significant spatial variations, with slower accretion rates corresponding to higher concentrations of cobalt and REEs, suggesting prolonged exposure to metal-enriched seawater. By linking growth environments to geochemical composition across individual layers and utilizing Pb isotopic signatures as a tracer for metal provenance, this study provides insights into the temporal and spatial dynamics of CFC formation. These findings highlight the potential of CFCs as a long-term repository of critical metals and their role in the evolving global resource supply network. Additionally, the integration of geochronology with metal enrichment studies allows for a more comprehensive understanding of how seafloor mineral deposits contribute to sustainable resource management and supply chain diversification. This study provides a scientific foundation for responsible sourcing of deep-sea minerals and their integration into the future critical metal supply chain.