



How Two Unassuming Elements, Re and Os, Assumed Acclaim in the Geosciences

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Re and Os (rhenium and osmium) are chalcophile-siderophile elements (transition metals) with a unique position in isotope geochemistry. Unlike other commonly used decay schemes for radiometric dating, these metals take residency in resource-related media, for example, sulfide minerals, the organic component in black shales, coals, and bitumens and oils. In sum, the reducing environment is their haven whereas under oxidizing conditions, Re and Os become unmoored and the radiometric clock becomes compromised. The clock is not temperature sensitive, and its applicability spans Early Archean to Pleistocene.

This Bunsen Medal lecture will explore and review the challenges in bringing Re-Os from the meteorite-mantle community into the crustal environment. At the center of it all is our ability to turn geologic observation into a thoughtful sampling strategy. The potential to date ore deposits was an obvious application and molybdenite [Mo(Re)S₂], rarely with significant common Os and rarely with overgrowths, became an overnight superstar, yielding highly precise, accurate, and reproducible ages. Yet, molybdenite presented our first sampling challenge with recognition of a puzzling parent-daughter (¹⁸⁷Re-¹⁸⁷Os) decoupling in certain occurrences. A strategic sampling procedure was employed. From there, the diversity of applications spread, as molybdenite is also an accessory mineral in many granitoids, and can be a common trace sulfide in metamorphic rocks. Whether conformable with and/or crosscutting foliation, molybdenite ages define the timing of deformational events. Pyrite and arsenopyrite can also be readily dated.

Applications jumped from sulfides to organic matter. The hydrogenous component from organic matter in black shales gives us Re-Os ages in the sedimentary record for the Geologic Time Scale. This led to construction of an Os isotope seawater curve – an ongoing process. Unlike the well-known Sr seawater curve, the short residence time of Os in the oceans creates a high-definition time record with unambiguous high-amplitude swings in ¹⁸⁷Os/¹⁸⁸Os. Re-Os puts time pins into the biostratigraphic record, and we have even directly dated fossils. Re-Os opened the door for a new generation of paleoclimate studies to evaluate seawater conditions at the time of organic blooms and organic sequestration in bottom mud. Uplift and continental erosion can be balanced with hydrothermal input into oceans based on changes in the Os isotope composition of seawater. The timing and connectivity of opening seaways can be determined, and the timing of glaciation and deglaciation events can be globally correlated. The timing and instigators of mass

extinctions are carried in the Re-Os record. A major meteorite impact places an enormous scar in the Os isotope record as seawater drops toward mantle values but recovers in just a few thousand years. Most recently, Re-Os has transformed our understanding of the events and fluids involved in construction of whole petroleum systems.

Looking to the future, what kinds of data sets will be explored and what are the interdisciplinary skill sets needed to interpret those data? Re-Os will continue to provide us with new ways to dismantle geologic media for new scientific understanding of processes that have shaped our lithosphere, biosphere and hydrosphere, recording their intersection and exchange.