# Bend Me, Shape Me, Molybdenite: Spokes on the Crustal Re-Os Wheel

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Re-Os first became a serious contender as a robust radiometric clock through molybdenite dating. In the last 20 years, we have put many new spokes on the Re-Os bicycle. Novel sampling strategies have been instrumental in recovery of the unifying fourth dimension, and our singular correlation tool in geoscience – TIME.

The first dating of molybdenite was soon followed by the discovery of parent-daughter decoupling[1,2], and the need for a double Os spike[3]. Molybdenite, the new zircon, holds its clock through high P-T conditions and deformation. This little-noticed metamorphic mineral, whose pliability reveals textural development, places precise time pins in complex tectonic histories. Arsenopyrite followed, a revolution for tracking timing of Au metallogenesis. Re-Os dating of pyrite gave us the first radiometric age for the timing of the rise of atmospheric oxygen[4]. And, Re-Os was the first to show that temperature, acidity, and anoxia – a choir of three unveiled by a single tool – conspired to kill in the marine environment at the end of the Permian[5].

From sulfides, organic matter – a gunky repository for metals – was the next target. Extraction of hydrogeneous organic matter from shales to acquire depositional ages opened Re-Os for work on the Geologic Time Scale[6,7]. Once it was shown that Re and Os are concentrated in the asphaltene fraction of hydrocarbons[8], meaningful ages for oil and bitumen, non-crystalline substances wandering the crust at low T, became possible. The challenge of dating oils, however, required some serious strategizing. The first Re-Os dating of a *single* crude oil was achieved by dismantling the oil into its asphaltene-maltene components with the crude oil holding center position on the isochron[9]. Oil-water mixing experiments confirmed integrity of the Re-Os clock and allowed recognition of a mixing history[10]. Reconstruction of entire petroleum systems in absolute time followed, as we date undermature and mature source rock, early (heavy) oil charges, oil-oil-water mixing and tar mat formation, arrival of later oil charges, and oil extracted from the well head[11].

[1]Stein et al 2001 [2]Stein et al 2003 [3]Markey et al 2003 [4]Hannah et al 2003 [5]Georgiev et al 2011 [6]Ravizza & Turekian 1989 [7]Creaser et al 2002 [8]Selby & Creaser 2004 [9]Georgiev et al 2016 [10]Hurtig et al 2019 [11]Georgiev et al 2019. *Supported by the Norwegian petroleum industry and the US-NSF. CSU provides no financial support for AIRIE's personnel or operations.*