Re-Os fractionation on instantaneous maturation at the Siljan meteorite impact site, central Sweden

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Key inputs for modelling hydrocarbon systems are source rock and time(s) of maturation and migration. Typically, biomarkers are used to link migrated hydrocarbons to source rocks, but these may be compromised by biodegradation of oils. Time of maturation is generally estimated from burial history and is dependent on biostratigraphic ages, sediment thickness and compaction history, and subsidence rates. Re-Os geochemistry can overcome some of these inherent assumptions, serving as a tracer with a clear time component.

To test the effectiveness of the Re-Os system for defining source rocks and time of maturation, we turn to a system in which key variables are constrained. At 377 Ma, a large meteorite impacted the Siljan area in central Sweden, heating still immature Ordovician source rocks at the impact site. Oil seeps and asphaltene coatings in sandstones and carbonates just outside the Siljan impact crater attest to hydrocarbon maturation at the time of impact. This unique setting offers source rocks and migrated hydrocarbons in immediately adjacent units, with maturation pinned to a geologic instant.

We analyzed four aliquots of an oil sample from a quarry seep in the Boda Limestone at Solberga, on the east flank of the impact crater. The results are, at first glance, surprising. The apparent Re-Os age of 812 ± 48 Ma is difficult to explain, as host and source rocks are Ordovician. Similarly, the initial $^{187}Os/^{188}Os$ implied by the intercept is within uncertainty of the ratio for chondrite (0.1245) at the time of the Siljan impact (377 Ma). In contrast, $^{187}Os/^{188}Os$ in Ordovician seawater was probably within the range 0.6 to 0.8. Thus, more likely, our data points define a mixing line.

Our simple mixing model yields two important conclusions. First, the oil contains debris of chondritic composition, supporting its origin by heating of source rocks by a meteorite impact. Second, an oil of appropriate composition for the mixing model must have a $^{187}Re/^{188}Os$ ratio much greater than that of the source rocks. This implies significant fractionation of Re and Os during maturation, at least under conditions for which heating is brief. This preliminary measure of fractionation between source rocks and hydrocarbons provides critical information for interpreting Re-Os systematics in hydrocarbon systems.

The last termination at the Dead Sea basin: Catastrophic aridities, salt deposition and human culture development

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During the late Quaternary the Dead Sea basin (DSB) accommodated a series of terminal lakes whose limnological and geochemical properties (e.g. lake level and salinity) reflect the regional climatic conditions at the Levant. Detailed studies (exposures and boreholes) of the sedimentary sequences that were deposited at the DSB during the last termination (~17.4-10 ka cal BP) discovered several catastrophic lake level drops that were accompanied by massive deposition of gypsum and salt (at 17.4; ~14 -13.5; and ~11-10 ka cal BP). The lake drop at the 14th millennium BP brought the Dead Sea to a minimum level of less than 450 m below mean sea level, possibly the lowest late Pleistocene stand, reflecting catastrophic regional aridity that was accompanied by the collapse of the Natufian culture. The regional hydrological conditions improved during the Younger Dryas (higher lake level). Then, between 11-10 ka cal BP the lake dropped again depositing a thick sequence of salts. The transition to the milder early Holocene at ~ 10 ka cal BP was accompanied by the rise of the Pre-Pottery Neolithic culture (PPNB) and the establishment of early agriculture settlements in the Jordan Valley (e.g. Jericho, Gilgal). The abrupt lake drops at ~17.4, ~ 14 and ~11 ka coincided with times of ice and melt-water discharges into the North Atlantic (NA) during Heinrich event (H1), Melt Water Pulse (MWP)-1a and upon the transition to the Holocene, respectively. Similar, but milder drops in lake level occurred during the last glacial indicating persistent and rapid transfer of the climatic signal from the NA to the east Mediterranean – Levant, but also pointing to the highly instable nature of the last termination period.