Out of this world crude oil – Separating meteoritic and hydrocarbon Re-Os components

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Recent application of Re-Os geochronology and $^{187}Os/^{188}Os$ tracer studies to hydrocarbons affords petroleum geologists access to techniques successfully utilized by the mineral industry for the past decade. The ability to determine directly the age of a black shale and/or resultant maturation product sheds light on the absolute timing of hydrocarbon production and migration. The $^{187}Os/^{188}Os$ ratio serves as a tracer to the hydrocarbon source. Much experimentation is on-going to apply the methodology to petroleum exploration. Here we report analyses of four aliquots from a single sample of impact-derived crude oil from the Solberga Quarry, Siljan, Sweden. Rhenium concentrations were notably consistent at ~1.5 ppb, whereas osmium concentrations ranged from 40 to 300 ppt. The expected age, if the crude oil was generated upon bolide impact, is ~377 Ma based on Ar-Ar analyses of melt breccias. The initially determined Re-Os isochron "age" of ~810 Ma with an $^{187}Os/^{188}Os$ initial value of ~0.2 presents an impossible result, given that both host and source rocks for the oil are Ordovician. We are constructing analytical tests to remove the Re-Os impact signature from the crude oil mixture. These tests will determine if dissolved components (vaporized meteorite) within the crude oil or solid meteorite detritus suspended in the crude oil produced the mixing line with Neoproterozoic "age" and low $^{187}Os/^{188}Os$ ratio. By passing the sample through various filter media, the liquid crude may be separated from any detritus and the resultant components individually analyzed to define relative contributions. Subsequent modifications to published procedures will depend on where the Re- and Os-rich components reside. Additionally, further refinement of analytical procedures and, equally important, sampling protocols may lead to higher precision, improved sample throughput, and an overall increase in the robustness of the methodology in complex systems. Successful separation and isolation of Re-Os components within a crude oil sample attest to the future of Re-Os tracer studies in migrated hydrocarbons, including those in unusual geologic settings.

Unroofing the Kalahari craton: Provenance data from Neoproterozoic to Paleozoic successions

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The formation of the Kalahari craton ended with massive Mesoproterozoic tectonic processes, but hosts the history of the craton evolution since the Paleoarchean. We sampled more than 50 Neoproterozoic to Devonian sedimentary formations from the western and southern margin of the craton to decipher a typical Kalahari/Kaapvaal provenance. Major peaks for detrital zircons revealed an overwhelming abundance of Mesoproterozoic zircons (1.4 – 1.0 Ga) reflecting the Natal and Namaqua orogenies with multiple collisional phases. Zircons older than 1.8 Ga were not found in the samples. Other major peaks reflect tectonic processes during the Ediacara and Cambrian. The mostly immature Neoproterozoic rocks host partly an active margin provenance but no definite arc signature. Detrital zircon data, whole rock Pb and Nd isotope analyses resemble the existent data from Patagonia, and Antarctica fragments. We propose therefore, that an exotic block (Patagonia) represented the actual Neoproterozoic arc terrane and rifted away during the Paleozoic. The immature Devonian Bokkeveld Group hosts surprisingly Silurian to Lower Devonian zircons related to magmatic activity at the western and southwestern margin of the Kalahari craton, so far understood to be a passive margin. Massive pyroclastic activity is recorded only in Eastern Argentina, associated with a formerly Neoproterozoic Hirnantian glacial diamictite (now dated as 485 Ma) and quartz-arenites. The origin of this magmatic event is unknown. Our study demonstrates that detrital zircon data should be treated carefully if used for "understanding a cratonic fingerprint" as characterising magmatic events might not be reflected at the margins of a craton.