

Highly saline Palaeoproterozoic seawater inferred from fluid inclusions in 2.4 Ga Ongeluk Formation

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We present microthermometry of fluid inclusions in hydrothermally precipitated quartz in 2.4 Ga Ongeluk Formation, Kaapvaal Craton, South Africa. The studied lavas probably erupted during Palaeoproterozoic Snowball Earth event [1, 2], thus is prime target to obtain the information of seawater composition during the snowball period. The quartz crystals fill drainage cavities of pillowed basaltic lava and were probably precipitated soon after eruption under seawater [3]. The primary fluid inclusions show final melting temperatures from -31.4°C to -3.6°C for ice and from -48.3°C to -22.0°C for hydrohalite. Their homogenization temperatures range from 74.9°C to 160°C. These results indicate that the fluid composition can be assumed as a NaCl-CaCl₂-H₂O system. Thus, the salinity of fluid inclusion can be calculated from its melting point. We found that the fluids show various NaCl/CaCl₂ ratio (0.1 – 16.8 molar ratio). This variation is consistent with albitization of igneous plagioclase (Ca/Na exchange reaction), which commonly occur in seafloor alteration processes. Hence, the fluid may record altered 2.4 Ga seawater. Based on the extrapolation of this albitization trend, we conclude that the salinity of the 2.4 Ga seawater would have been at least two times higher than that of modern seawater. The estimated salinity is higher than previous estimate of the early seawater based on total amount of continental salt deposits [4], thus requires some sort of concentration process. The high salinity could be expected, if the Ongeluk ocean was quantitatively frozen. Thus our result is consistent with the “hard” snowball scenario.

[1] Evans *et al.* (1997) *Nature* **386** 262-266. [2] Kopp *et al.* (2005) *PNAS* **102** 11131-11136. [3] Gutzmer *et al.* (2003) *Chem. Geol.* **201** 37-53. [4] Knauth (1998) *Nature* **395** 554-555.

Distribution of trace metals in petroleums of different maturity levels

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A set of trace metals (V, Ni, Co, Fe, Zn, and Mo, As, Hg) in a suite of oil samples (studied and classified on the basis of biomarker data) from Hungary [1] was analysed by ICP-MS [2]. The carbon isotopic composition of the C₁₅₊ saturate and aromatic hydrocarbon fractions were also measured.

Discussion of Results

The stability of biomarkers and some metal complexes have shown similar thermal dependence. The median values of determined trace elements are displayed in Table Ia and Ib grouped in maturity ranked oils [1].

Table Ia: Maturity sensitive trace metals in maturity groups (ppb)

| | ranking of oils | Co | V | Ni | Mo |
|-----|-----------------|-----|-----|-------|------|
| LtM | least-mature | 111 | 425 | 11140 | 32,0 |
| LM | low-mature | 62 | 431 | 3229 | 13,0 |
| MM | moderate mature | 15 | 111 | 1236 | 1,6 |
| M | mature | 7 | 32 | 581 | 3,0 |
| VM | very-mature | 2 | 4 | 13 | 0,4 |

Table Ib: Trace metals in maturity groups (ppb)

| | Fe | Zn | As | Hg | ∑ of Ia+Ib |
|-----|-------|-----|-----|------|------------|
| LtM | 7145 | 116 | 222 | 845 | 27395 |
| LM | 6605 | 213 | 134 | 1150 | 15385 |
| MM | 13430 | 687 | 230 | 626 | 16833 |
| M | 2783 | 482 | 56 | 545 | 4548 |
| VM | 64 | 6 | 47 | 70 | 977 |

The metals (associated with the polar components and asphaltenes) in Table IA demonstrate direct maturity dependence [3]. The maturity dependence of metals in Table Ib are more complicated, partly governed by source facies and migration effects (picked up during migration) [4]. The evaluation of carbon isotopic data is also difficult because of the overlapping maturation and organic facies effects.

[1] Sajgo (2000) *Org. Geochem* **31**, 1301-1323. [2] Olsen *et al.* (1995) *Analyst* **120**, 1379-1390. [3] Lewan and Maynard (1982) *GCA* **46**, 2547-2560. [4] Punanova *et al.* (1988) *Geokhimiya* **No. 9**, 1360-1366.