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Hydrocarbon-mediated gold and uranium concentration in the Witwatersrand Basin, South Africa

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The Witwatersrand deposits in South Africa represent the largest repository of gold in the World and a major resource of uranium. The genesis of the gold and uranium ores in the quartz-pebble conglomerates (reefs), however, is still a matter of considerable discussion. Opinion has been divided over whether they represent paleo-placers that have been partly remobilised by hydrothermal fluids or if the mineralisation is entirely hydrothermal in origin. In addition, recently published models have proposed a syngenetic origin for the gold involving bacterially-mediated precipitation from meteoric water and shallow seawater.

An important feature of the gold and uranium mineralisation in the reefs is the strong spatial association with organic matter. In some reefs, up to 70% of the gold and almost the entire uranium resource is spatially associated with pyrobitumen seams, suggesting a genetic relationship of the gold-uranium mineralisation with hydrocarbons. Here we report results of a study of the Carbon Leader Reef, using high-resolution scanning and transmission electron microscopy (SEM / TEM) and LA-ICP-MS that provide new insights into the role of hydrocarbons in the concentration of the gold and uranium.

A detailed examination revealed gold monocrystals containing numerous rounded or elliptical inclusions filled with pyrobitumen. We interpret these inclusions to record the crystallisation of the gold around droplets of a hydrocarbon liquid that migrated through the Witwatersrand basin, and was converted to pyrobitumen by being heated. We propose that the gold was transported in a hydrothermal fluid as a bisulphide complex and that this fluid mixed with the hydrocarbon liquid to form a water-oil emulsion. The interaction between the two fluids caused a sharp reduction in fO_2 at the water-oil interface, which destabilised the gold-bisulphide complexes, causing gold monocrystals to precipitate around the oil droplets.

In contrast to the gold, uraninite, the principal uranium mineral, occurs as complex-shaped grains that represent aggregates containing billions of uraninite nanocrystals (5 – 7 nm in diameter), which grew in situ in the pyrobitumen matrix or more likely its liquid precursor (Fuchs et al., 2015). This in situ growth of isolated nanocrystalline aggregates shows that uranium was mobilised and concentrated by liquid hydrocarbons, and that uraninite nanocrystals were released from the oils during the conversion of oil to pyrobitumen.

Our study provides new insights into the complex mechanisms of ore formation in the Witwatersrand Supergroup and compelling evidence that hydrocarbons played a major role in the concentration of the gold and uranium. It does not rule out the possibility that gold and uranium were introduced into the Witwatersrand Basin as detrital grains but shows that mobilisation of gold and uranium by hydrothermal fluids and hydrocarbon liquids, respectively, and the mixing of these fluids, were essential to ore formation.

Fuchs, S., Schumann, D., Williams-Jones, A.E., Vali, H., 2015. The growth and concentration of uranium and titanium minerals in hydrocarbons of the Carbon Leader Reef, Witwatersrand Supergroup, South Africa. Chemical Geology 393–394, 55-66.