Provenance analysis of gold and associated heavy minerals in the Black Reef Formation, South Africa, using geochemical fingerprints

Fuchs, S.[1,2*] & Gauert, C.D.K.[1]
[1]Dept. of Geology, University of the Free State, Bloemfontein, South Africa
[2]Institute of Mineralogy, Crystallography and Materials Science, University of Leipzig, Germany
([*]sfuchs@uni-leipzig.de)

The Black Reef Formation (BR), a thin, but laterally extensive unit of primarily conglomerates and quarzites at the base of the Transvaal Supergroup contains erratical gold at economic grade confined to regional areas. Highest gold grades are exploited in the West and East Rand area on top of underlying Witwatersrand Reefs. BR gold however occurs also outside of the Witwatersrand Basin in the eastern Mpumalanga and Limpopo Provinces, e.g. Kaapsehoop, in close contact to greenstone units. Platinum, Osmium and Iridium as well as Uranium-bearing minerals have been reported in association with gold in the BR mainly from BR exposures east of Klerksdorp [1]. Although most economic BR Au mineralization occurs at localities within the Witwatersrand Basin, a large number of Au occurrences are found in RR overlying Ventersdorp and Swaziland Supergroup strata; therefore, the reworking of Au placers of the prominent Wits Reefs such as the Ventersdorp Contact Reef the BR cannot be regarded as the only one source of gold within the BR.

Current geochemical fingerprinting attempts of BR Au and associated heavy minerals using Electron Microprobe, LA-ICP-MS, and NanoSims give an indication about a genetic relationship between the several Au deposits and their different underlying rocks. Constantinescu et. al [2] and McCandless et. al [3] successfully used indicator trace elements as such as Sb, Sn, As, Ru, Rh, Pd, Te, Ta, Os, Ir, (+Au, Ag, Cu) to characterize different gold deposits.

Average Ag contents in free gold from the East Rand determined by EMPA are high (14.8wt%, n=20), Hg contents low (on average 0.51 wt%); trace concentrations of S, Fe, Ni, Cu, As, Th, U and Cd in decreasing order were detected possibly because of micro-inclusions. The pyrite mineral chemistry shows minor As, Pb and traces of Ni and Cu, cobaltite contains minor Pb, gersdorffite Sb, and sphalerite shows minor Cu, Cd, and traces of Au and Pb. U-bearing phases such as Uraninite show minor Pb and Th and detectable trace amounts of S, Fe, Bi, As, Cd, Ag, Sb and In. The value of these trace elements for genetic and provenance interpretations still has to be assessed.

Investigation of detrital gold, gold in hydrocarbons and invisible gold in sulphides by LA-ICP-MS trace element of various BR sections is ongoing. In combination with NanoSims analyses for the visualization of invisible gold in pyrites, Ag-Au zoning in detrital gold grains the information could be relevant to determine possible gold sources, transport mechanisms, and depositional conditions. Finally it may allow to develop a holistic genetic model of the Au mineralization in the Black Reef Formation.

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Composition and stability of garnierites: Caribbean examples

Galí, S.[1*], Soler, J.M.[2], Proenza, J.A.[1], Lewis, J.F.[3], Cama, J.[2] & Tauler, E.[1]
[1]Dept. de Cristal·lografia, Mineralogia i Dipòsits Minerals, Universitat de Barcelona, Catalonia, Spain
([*]gali@ub.edu)
[2]Institute of Environmental Assessment and Water Research, IDAEA, CSIC, Barcelona, Catalonia, Spain
[3]Dept. of Earth and Environmental Sciences, The George Washington University, Washington, DC, USA

The chemical and structural characterization of garnierite minerals from several Caribbean lateritic mineralizations shows that this group of minerals is formed by intimate intermixings of three main Mg-Ni phyllosilicate solid solutions: serpentine-népouite, kerolite-pimelite and sepiolite-falcondoite [1-5]

The published experimental solubility constants for Mg end-members and the calculated constants for pure Ni end – members are used to calculate Lippmann diagrams for the three solid solutions, on the assumption that they are ideal. With the help of these diagrams, it is proposed that congruent dissolution of Ni-poor primary serpentine followed by equilibrium precipitation of Ni richer secondary phyllosilicates is an efficient mechanism of Ni supergene enrichment along the lateritic profile. The stability fields of the solid solutions are represented using [log $a_{SiO2(aq)}$, log $(a_{Mg2+} + a_{Ni2+})/a_{H+}^2$)] diagrams (Fig. 1). These, combined with Lippmann diagrams [6] give an almost complete chemical characterization of the solution and the precipitating phase(s) in equilibrium. The temporal and spatial succession of hydrous Mg-Ni phyllosilicates often encountered in Ni lateritic deposits is explained by the low mobility of silica [7] and the increase in its activity.
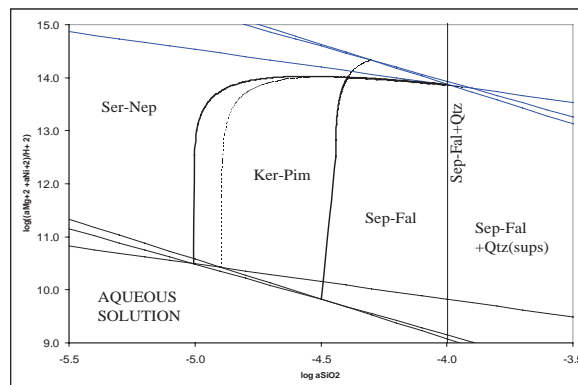

Fig. 1: Fields corresponding to the three solid solutions and boundaries: Ser-Nep+Ker-Pim; Ker-Pim+Sep-Fal and Ser-Nep+Sep-Fal. Dashed lines are metaestable extensions of these equilibria. Vertical line at log($a_{SiO2(aq)}$) = -4 gives equilibrium between quartz+Sep-Fal.

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