HYDROTHERMAL ALTERATION AND GOLD MINERALISATION IN THE WITWATERSRAND – WHEN, WHERE AND WHY? V. J. Wall[1], R. A. Mason[2] and G. C. Hall[3], [1]Taylor Wall & Associates, P.O. Box 921, Spring Hill, Australia, 4004; [2]Tectonic Enterprises Pty Ltd; mason@kampong.cc; [3]Golden Phoenix International, P.O. Box 591, West Perth, Western Australia, 6872; greghall06@bigpond.com.

Introduction: The vast goldfields of the Witwatersrand are enveloped by even larger hydrothermal alteration systems to which gold mineralisation has been related [1, 2, 3, 10]. However, the timing of hydrothermal alteration and mineralisation remains controversial and the localisation of more than 90% of gold in conglomeratic packages requires explanation. We utilise detailed studies in the West Rand (South Deep and Randfontein) and observations elsewhere to address these questions and account for the scale and other key aspects of Witwatersrand auriferous systems.

When?: Aluminous (eg pyrophyllite-bearing) hydrothermal alteration is widespread in the West Rand and elsewhere [3] in and around the conglomeratic packages. Pyrophyllitic alteration also overprints auriferous Black Reef metasediments that underlie other members of the (~ 2.6Ga) Lower Transvaal Group in the Randfontein district and in the East Rand. The pyrophyllitic assemblages define shallowly dipping, bedding-subparallel foliations, phyllonites, small displacement thrusts and locally pyritic styloveins. These features are kinematically related to low bulk strain N- to NW-shortening of both the Central Rand Group and Transvaal Group that share the same fabrics (eg Lindum Reefs pits). High variance mineral assemblages and stylo-vein fabrics are consistent with aluminous alteration synchronous with this deformation and greenschist facies metamorphism, post Lower Transvaal Group c.f. [3, 5]. Indeed the attendant 300-350ºC temperatures and pressures up to 3kbar [4] require the 6-8kms of (Transvaal Group) cover. Aluminous alteration is not observed above the Black Reef and thus the dolomitic section of the Transvaal Group apparently acted as a regional seal [Figure 1] over the regional metamorphic/ hydrothermal system. Thermal metamorphic overprints related to Bushveld-age intrusions (e.g. Evander Goldfield, [6]), constrain the operation of the metamorphic-hydrothermal system between 2.6 and 2.1Ga, compatible with ages of hydrothermal zircons [7] and basement fluid infiltration of the basement [8].

Observations on drill core and underground mapping provide a relative chronological and kinematic framework for the structural and fabric evolution of part of the South Deep mine area: i) uncommon, healed, dip slip (?normal, ? Platberg age) faults overprinted and cut by; ii) shallowly dipping foliations, phyllonite zones, rare E- to W-verging small displacement thrusts and duplex fracture arrays, shallowly (and less commonly steeply) dipping stylo-veins all of which exhibit aluminous and pyritic alteration; iii) late (post Transvaal), mainly steeply-dipping fault arrays which truncate and displace all above features and; iv) pseudotachylite-bearing zones, which cross cut these faults. The South Deep Mine thus has a similar structural and alteration history to that outlined above for the Randfontein district. Hydrothermal gold mineralisation is constrained to post Black Reef ages.

Where?: At South Deep Mine economic to subeconomic gold mineralisation occurs in shallowly dipping Ventersdorp Contact Reef (VCR) conglomerate phases which are overlain by massive Ventersdorp lavas and also in the Upper Elsberg conglomeratic packages below low angle unconformity contacts with the VCR. 3D modelling of gold grade distributions integrated with lithostratigraphic and lithological architectures indicates i) the intensity of gold mineralisation is highest where the proportion of conglomerates close to the VCR unconformity is highest; ii) the main trend of gold mineralisation coincides with the (NNE) intersection of the VCR unconformity with underlying conglomerates (Elsberg 'subcrop'); iii) other grade trends relate to WNW zones of thickening and higher proportions of conglomerates (?channels). Similar relationships are observed in Black Reef and Kimberley reef packages around Randfontein.

Detailed multiparametic logging of South Deep drillcore shows higher concentrations of gold mineralisation and sulphide (mainly euhedral and some round pyrite) occurring in clast-supported and generally coarser quartz conglomerates that exhibit strongly stylolitic clast boundaries. Lower concentrations of gold and pyrite occur through quartzites and matrix-supported conglomerates in mineralised zones. Fractures, styloveins and phyllonites are far more abundant in psammites and matrix supported conglomerates and these are commonly foliated, highlighting their different deformation mechanisms compared to the clast supported conglomerates. At low strains clast-supported conglomerates deformed by clast boundary adjustments, the stylolitic clast boundary network providing permeability (and facilitating fluid flow) as well as being inherently dilatant, facilitating fluid mixing in the conglomerates. We infer that the mixing of relatively oxidised fluids (transporting Au, U, etc) and a reduced (CH_4-bearing) fluid was a major contributor to mineralisation in dilatant zones [1, 3, 10]. Some fluid components may have derived from interaction with Transvaal Group sediments.

Figure 1 summarises our model for West Rand hydrothermal alteration and mineralisation. Key aspects of this model are i) the Transvaal Group forming a regional but episodically breached seal on the hydrothermal system, the Ventersdorp Lavas constituting a district scale cap which also contrasts mechanically with the underlying Central Rand metasediments; ii) unconformities overlain and underlain by conglomeratic packages forming planar to linear competent zones which, where appropriately oriented and subject to weak compression, exhibit zones of deformation controlled permeability and dilation at low bulk strains; iii) syn-deformational hydrothermal fluid flow under greenschist facies conditions focussed in conglomeratic packages and dilatancy of clast–supported conglomerates, reflecting the contrasted deformation mechanisms of these conglomerates with enveloping lithologies; iv) fluid mixing and fluid rock interaction resulting in sulphide, Au, U and C deposition in conglomerates in the planar-linear dilation zones. This model is similar to that developed for unconformity-related U, Au, PGE systems [11].

Why?: Key factors contributing to the broad scale and huge gold endowment of the Witwatersrand reflect its cratonic setting – "the mother of all cratons" (Keith Kenyon) and are i) its tectonostratigraphic evolution which resulted in the extensive development of stacked packages containing quartz-rich conglomerates and unconformities which overly rift structures and were draped by a thick, effective seal – the Transvaal Group; ii) the regionally extensive preservation of this mainly shallow dipping assemblage in a broad antiformal zone around the margin of the Wits basin; iii) uncommonly low strain regional deformation under (post Transvaal Group) greenschist facies conditions, the consistent layering orientations and lithological architectures facilitating similar responses to regional stresses over broad areas; iv) lithology partitioned fluid flow focussed in and around the conglomeratic packages; v) sources of relatively oxidised, acidic and also reduced (CH_4-bearing) metamorphic-hydrothermal fluids in the rock mass; vi) fluid mixing and fluid rock interaction in dilatant zones which developed in appropriately oriented lithological architectures and structural settings around unconformities.

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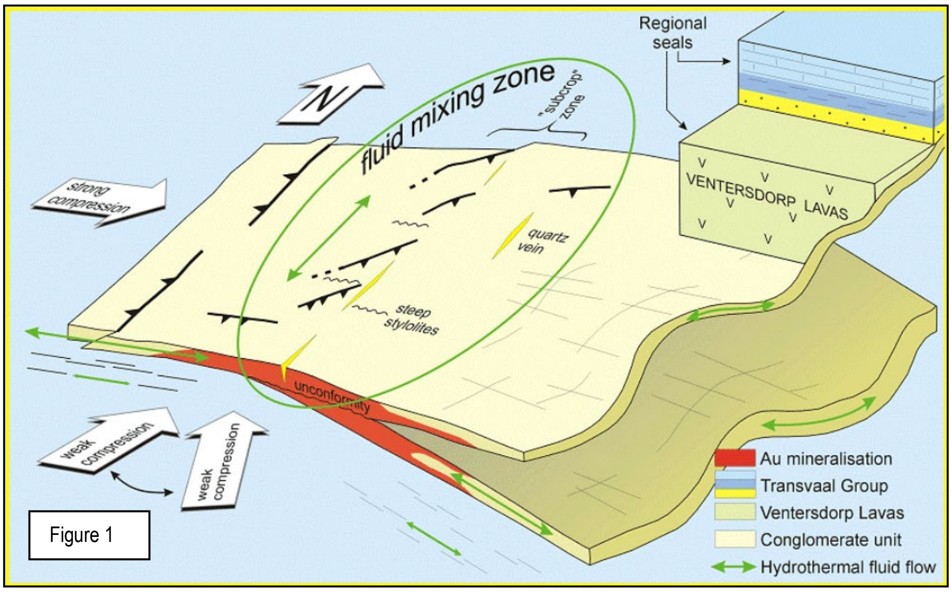

Figure 1

SPEAKER BIOGRAPHY - GREG HALL

Greg Hall is a geological consultant of Golden Phoenix International Pty Ltd. Greg was Chief Geologist for Placer Dome Group from 2000 to 2006. He managed exploration in Western Australia for CSR Limited until 1988 and Placer Dome from 1988 to 2000. The discovery of Rio Tinto's Yandi iron ore mine and Gold Fields's Granny Smith gold mine in WA are highlights in his career.

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5 KEYWORDS FOR USE IN INDEXING

Witwatersrand
hydrothermal
gold
age
model