3D Mohr circle analysis of varying tectonic mode for predicting dilation at Sunrise Dam

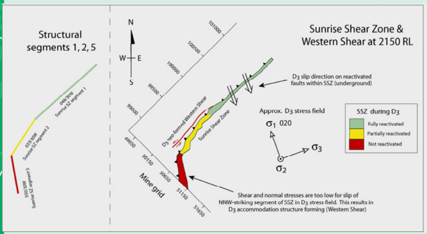
John Miller, Centre for Exploration Targeting, University of Western Australia

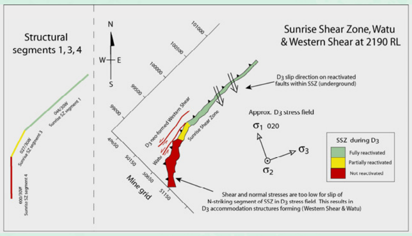
At the Sunrise Dam gold deposit steep W-dipping gold lodes have developed between lower angle W-dipping ductile shears (Sunrise Shear Zone and Cleo Upper Shear Zone). These steep dipping lodes propagate at a strike change on the early formed ductile shears. This has been interpreted to represent preferential reactivation of particular segments of the early formed Sunrise SZ during a late stage D_3 event .

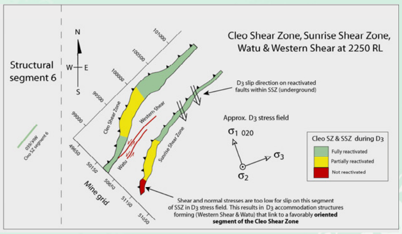
3-D Mohr circles where used to assess the proposed stress fields associated with this reactivation.

The work indicates for a NNW-SSE oriented σ_1 (D_3 of Nugus et al., 2005) that both compressional and strike slip stress fields could cause the observed reactivation with a low value of ϕ (i.e. σ_2 close to σ_3 in magnitude) . Such a stress field could easily cause switching between strike-slip and compressional behavior with relatively small changes in σ_2 or σ_3.

These results have implications for regional fault reactivation and targeting dilational structures. The results could also be utilised as input for future 3-D numerical models.







Within the Sunrise Dam gold deposit in the Eastern Gold Fields a series of steep-dipping gold lodes have developed between early formed lower angle W-dipping ductile shears. These early ductile shear zones are termed the Sunrise Shear Zone and the Cleo Shear Zone (Newton et al., 1998; Nugus et al., 2005). Two of these steep-dipping lodes, Watu and the Western Shear Zone, appear to propagate at a strike change in the Sunrise SZ to a more southerly trend (see top figure). The steep-dipping structures step over to a segment of the Cleo SZ that has a more NW trend. This has been interpreted to represent preferential reactivation of particular segments of the Sunrise SZ during the late stage D_3 deformation event, with subsequent development of linking structures between segments of the shear zones that failed. *This observation may be relevant for targeting gold deposits by assessing regional strike changes. This poster assesses the controls on reactivation of the early ductile shears in a D_3 stress field proposed by Nugus et al., (2005) (NNW-SSE oriented σ_1, other stresses unconstrained).*

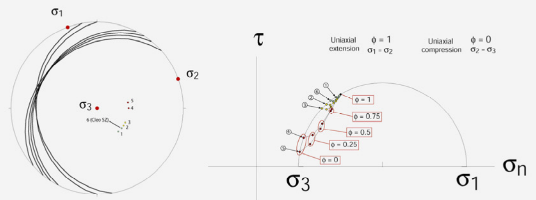
The Sunrise SZ and Cleo SZ have been subdivided into 6 different segments (see above figures) - segments 1 and 6 (colored green) appear to have been reactivated. The lower diagrams have used 3-D Mohr circle constructions to calculate the shear (τ) and normal stresses (σ_n) acting on the different fault segments (1 to 6) for both compressional and strike-slip stress fields for σ_1 oriented 0/ 340 (e.g., Nugus et al., 2005), with different stress shape ratios considered (ϕ = 0, 0.25, 0.5, 0.75, and 1.0; $\phi = (\sigma_2 - \sigma_3)/ (\sigma_1 - \sigma_3)$). This has been done to see what effect varying the stress field and stress shape ratio has on increasing (or decreasing) the probability of reactivating the different shear zone segments. Note that these diagrams do not include calculations of the direction of resolved shear stress (i.e. which way it slipped). The calculations shown below highlight that for a compressional stress field segments 1 and 6 will always be preferentially reactivated, with the greatest difference between the northern and southern segments of the Sunrise SZ occurring at low values of ϕ. In contrast for a strike-slip stress field segments 1 and 6 will only be preferentially reactivated if ϕ is below 0.25 - at higher values of ϕ the normal stress acting on the faults reduce the likelihood of reactivation. Furthermore at higher values of ϕ (in a strike-slip stress field), the southern segment of the Sunrise SZ would be more likely reactivated instead of the northern segment. The 3-D Mohr circle analysis highlights that ϕ was probably low (i.e. σ_2 close to σ_3 in magnitude) and such a stress field could easily have caused switching between strike-slip and compressional behavior with relatively small changes in σ_2 or σ_3.

Acknowledgments: Michael Nugus is thanked for extensive scientific and logistical input.

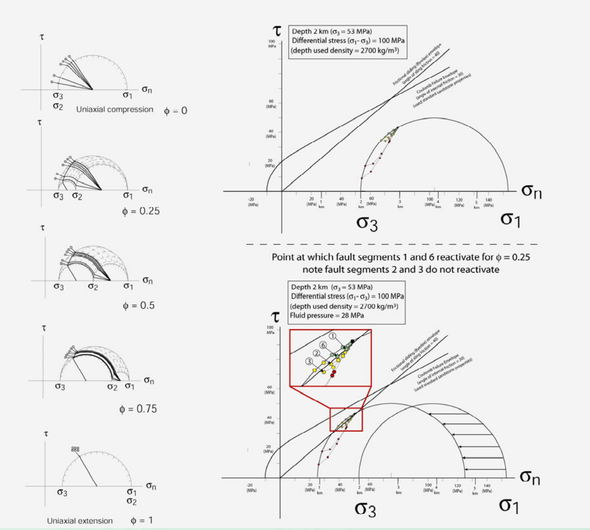
References: Newton P. G., Gibbs D., Grove A., Jones C. M. & Ryall A. W. 1998. The Sunrise–Cleo gold deposit. In: Berkman D. A. & McKenzie D. H. (eds.) Geology of Australian and Papua New Guinea Mineral Deposits, pp. 179–186. Australasian Institute of Mining and Metallurgy Monograph 22. Nugus, M., Blenkinsop, T., Biggam, J., Doyle, M., 2005. The role of early formed structures in lode gold mineralization: The Sunrise Dam Gold Mine, Yilgarn Craton, WA. In: Hancock et al., (eds), STOMP 2005, Structure, Tectonics and Ore Mineralisation Processes, Abstract Volume, p. 99.

Compressional stress field (σ_1 = 0/340)

Shear and normal stress calculations for different fault orientations and stress shape ratios (ϕ)

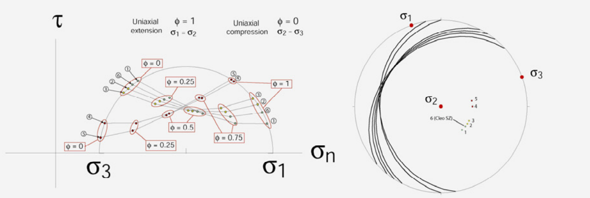


For ϕ = 0 segments 1, 2, 3 and 6 are more likely to reactivate instead of intact rock failing.
For ϕ = 0.25 segments only 1 and 6 reactivate (Northern part of Sunrise SZ and Cleo SZ) at fluid pressure = 28 MPa, differential stress = 100 MPa at depth of 2 km (using standard frictional sliding failure envelope).
At higher fluid pressures more segments (i.e. segments 4 and 5 = southern Sunrise SZ) will reactivate.
At high values of ϕ (0.75 and greater) no major difference exists for which particular structural segments (1, 2, 3, 4, 5, or 6) will be preferentially reactivated.
REACTIVATION OF SEGMENTS 1 AND 6 PREFERENTIALLY OCCURS AT ALL ϕ VALUES (EXCEPT 1.0) WITH A MARKED DIFFERENCE IN SHEAR STRESS ACTING ON THE SEGMENTS 1 AND 5 FOR ϕ VALUES OF 0.5 AND LESS. COMPARED TO A STRIKE-SLIP STRESS FIELD THIS OCCURS OVER A GREATER RANGE OF FLUID PRESSURES AND DIFFERENTIAL STRESSES



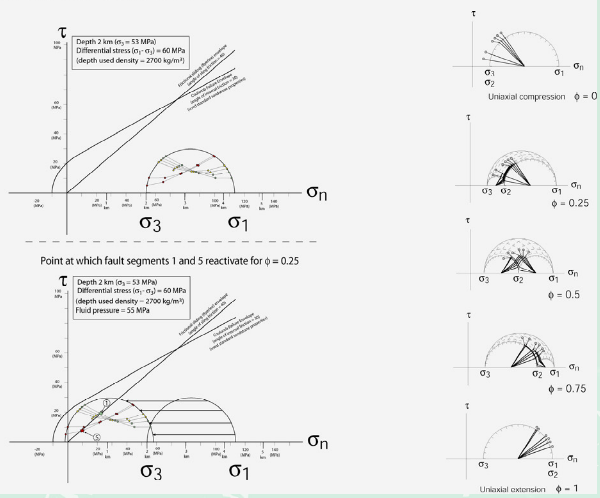
Strike-slip stress field (σ_1 = 0/340)

Shear and normal stress calculations for different fault orientations (fault segments 1 to 6) and stress shape ratios (ϕ)



A major difference between this stress field and the compressional field is that as ϕ increases (i.e. σ_2 increases) the normal stress increases making reactivation less likely to occur.
It also means higher fluid pressures are required, combined with lower differential stresses, to cause reactivation (otherwise intact rock will fail instead of reactivation occurring).
Unlike the compressional stress field for ϕ values of 0.5, 0.75 and 1.0 segments 4 and 5 (i.e. the southern section of the Sunrise SZ) will reactivate first - note the cross over on the diagram).

In summary,
For ϕ = 0 segments 1, 2, 3 and 6 are more likely to reactivate instead of either intact rock failing or segments 4 and 5 reactivating.
For ϕ = 0.25 segments 1 and 6 reactivate about the same conditions BUT this requires supralithostatic fluid pressures (fluid pressure = 55 MPa compared to σ_3 of 53 MPa).
and differential stress less than 75 MPa otherwise the fluid over pressure will cause intact rock to fail (in the example shown the differential stress is 60 MPa).
For ϕ = 0.5 and above even higher fluid pressures and lower differential stresses are required to cause reactivation. Also for these higher values segments 4 and 5 will reactivate first.
TO REACTIVATE SEGMENTS 1 AND 6 PREFERENTIALLY REQUIRES LOW ϕ VALUES (LESS THAN 0.25) AND, COMPARED TO A COMPRESSIONAL STRESS FIELD, IT ALSO NEEDS LOWER DIFFERENTIAL STRESSES BUT HIGHER FLUID PRESSURE



predictive mineral discovery

Cooperative Research Centre

John Miller
Centre for Exploration Targeting
University of Western Australia
Phone: 61 (0)8 6488 5803
Email: jmmiller@cyllene.uwa.edu.au
www.pmdcrc.com.au