MODELLING OF DEFORMATION AROUND A GRANITE INTRUSION: USING CONTINUUM DAMAGE MECHANICS AT HIGH TEMPERATURE FOR SIMULATING AU-RELATED STRUCTURES IN THE YILGARN CRATON, WESTERN AUSTRALIA

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The Late Archaean Yilgarn Craton of Western Australia is one of the most important gold hosting terrains in the world. The main part of the Yilgarn crust consists of greenstone horizons overlying a predominantly granitic domain. Granitic rocks consist of high-Ca granites (more than 60% of total granites, ages from >3.0Ga to 2.655 Ga) intruded by low-Ca granite (>20% of the total, ~2.65-2.62 Ga).

Although gold deposits in the region are mainly hosted in greenstone rocks along shear zones, one of the major regional Au events closely coincides with the peak of low-Ca granite intrusions and the associated metamorphism, around 2.65 Ga. Recent structural and seismic studies conducted through the pmd*CRC at Geoscience Australia also suggest that the location of Au mineralization and the development of Au-bearing shear zones may be linked to the intrusion and geometry of low-Ca granites (granite domes). An improved understanding of rock deformation behaviour around low-Ca granite intrusions (domes) could enhance our understanding of Au mineralization in the Yilgarn Craton.

Here we present the results of a set of 2D generic numerical models focusing on deformation around pre-existing granite intrusions under both extension and compression. Our models employ an energy-based, temperature dependent, elastic-visco-plastic constitutive behaviour of crustal materials experiencing continuum damage which is formulated within a thermodynamic framework. Diffusion and dislocation creep mechanisms were combined to describe the rate-dependent aspect and to formulate the evolution of micro-cracks. These mechanisms, which are also characterized by their dependence on deviatoric stress, pressure, water content and temperature, act individually or jointly according to the loading conditions. The fact that the constitutive model is energy based allows for the coupling of deformation using this method to fluid and heat transport as well as geochemical reactions in the future.

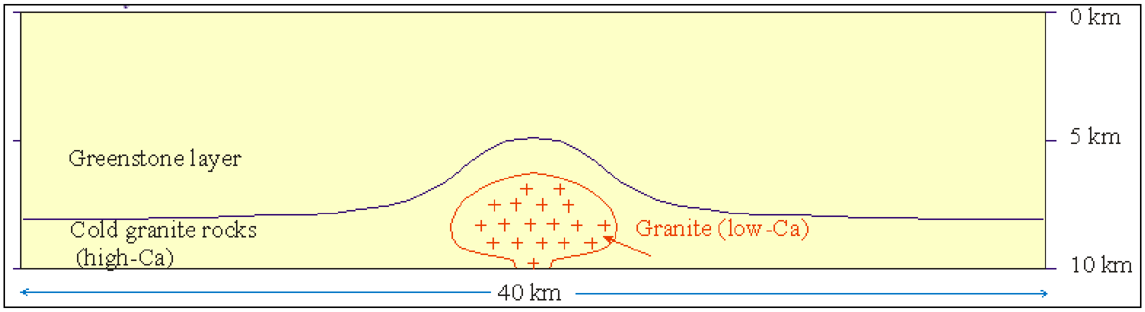

Figure 1. Initial geometry of 2D models.

The modelling results show that under tectonic loading, deformation and strain localization patterns in rocks and around intrusions are controlled by pre-existing architecture, strain rates and rock material property parameters.

In both extensional and contractional models, containing only a greenstone layer overlying a high-Ca cold granite unit, there is clear strain localization along the contacts between greenstone and granite (the flanks of cold granite dome, in particular). This leads to the development of a conjugate set of shear zones intersecting at the crest of the dome, followed by the development of more shear zones further away from the crest. For models with greenstone, cold granite (high-Ca) and a hot intrusion, strain localization initially occurred along the sides of the hot intrusion (or granite dome). This strain localization style seems to control the development of shear zones, which split out from the top sides of the intrusion/dome.

Strain rates have significant effects on the patterns of strain distribution. Smaller strain rates promote strain localization along the flanks and crest of cold high-Ca granite domes, which further facilitates the development of shear zones. Higher strain rates favour strain localization within and near hot intrusions. This is because the change of strain rate results in very different strain partitioning between elastic-plastic deformation and viscous creep deformation. Furthermore, the effects of intrusive temperatures has very different effects under different strain rate conditions (e.g. smaller effects under low strain rate conditions). The width of shear zones is dependent on strain rate and independent of mesh size.

These models also simulate the appearance of some larger scale structures due to the development of shear zones. This is expressed as the development of graben basins in response to bulk extension and the formation of thrusting “pop-up” structures as the result of horizontal compression. In models which incorporate a pre-existing shear zone and are deformed by contraction, both steeply and shallow dipping shear zones localise and splay from this major structure. Additionally, both extensional and contractional structures are developed in the hanging wall of the pre-existing shear zone at the top of the model. All of these features are recognised in seismic data of the Yilgarn as well as field observations but have been difficult to simulate using previous elastic-plastic (i.e. Mohr – Coulomb) simulations.

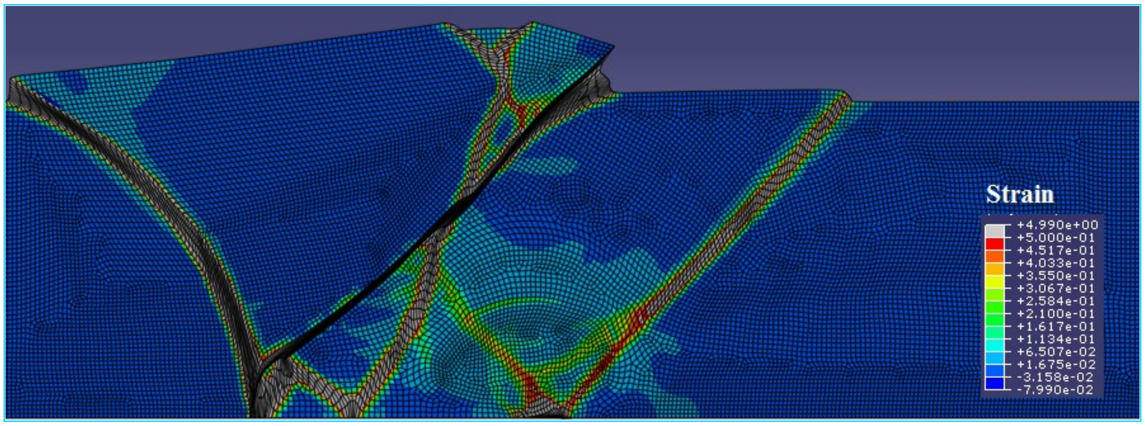

Figure 2. Total strain in contractional model with pre-existing fault.