

However, uncertain inputs and calibration of the geomechanical model leaves ambiguity with respect to relative magnitudes of the principal stresses, and in turn, the stress regime. Both an extensional (low strain model) and a strike slip (high strain model) satisfy available observations that includes breakout and DFIT (in situ stress tests) orientations in horizontal wells e.g. DFIT at top of hole and break outs at the side of hole.

The resultant mechanical stratigraphy (YM & PR) and principal stress magnitude logs for both end member regimes were subsequently upscaled to grid resolution for implementation within the FracMan hydraulic fracture model, Fig 3.

4.0 Discrete Hydraulic Fracture Simulations

Discrete Hydraulic Fracture Simulations were carried in the FracMan code (Dershowitz et al 2010) that uses a unique geomechanical scheme to allow hydraulic fractures to grow and interact with natural structures in a highly efficient manner (Rogers et al 2010, Rogers et al 2014). The objective is to identify the optimum of injection layer that results in the greatest stimulated fracture area, comprising a combination of both hydraulic fracture and natural fracture area. As a simple sense check on the initial models, they were compared against reported stimulation from the Cardium where each frac was imaged with microseismic data, Duhault 2012, Fig 4. This showed that the frac lengths, complexities and general cloud shape of the actual and simulated fracs were very consistent

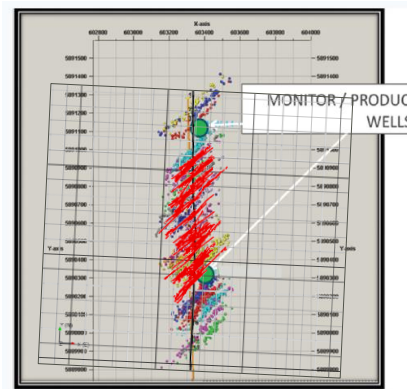


Fig 4: Comparison between simulated and actual (Duhault 2012) Cardium microseismicity

Having established the reasonableness of the simulation approach, a large number of simulations were conducted where the injection layer was varied through the modelling grid, stimulating different mechanical facies within different cycles and calculating the resultant stimulated area/volume.

This was carried for both the high and low stress conditions. Depending upon the combination stresses, elastic properties and the presence of natural fractures, the length, height and complexity of different stimulations was varied. One of the most effective ways of displaying the results was the injection-propagation matrix, which shows which layers will be stimulated depending upon which injection layer, Fig 5. The more vertical the array, the better the injection layer.

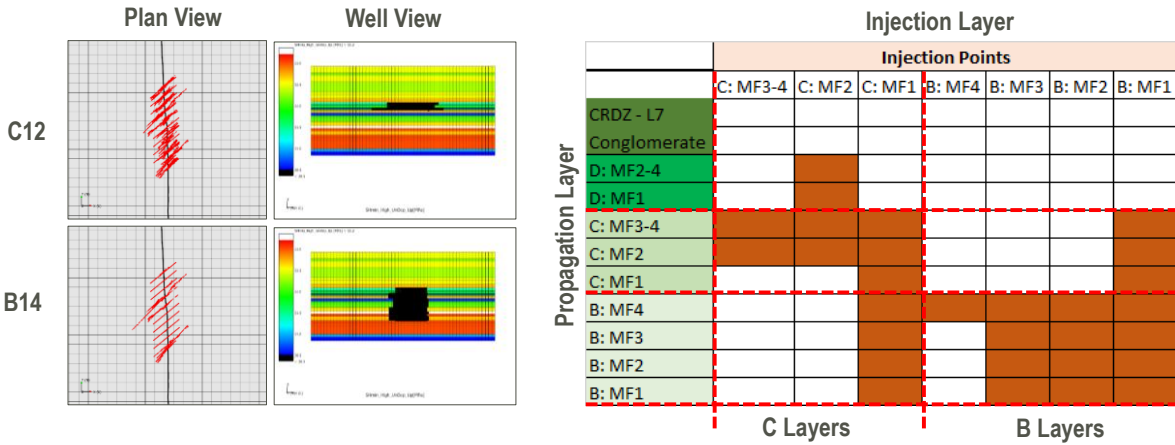


Fig. 5. Plan view and well section for 2 injection cases (C12 & B14 layers) injecting into different layers within the B and C sands, showing the likely length and height of the stimulations and also the injection-propagation matrix for one of the stress cases. The Injection & propagation layers are labelled by Cardium cycle and mechanical facies (MF), see Fig1

All of these simulations were carried out on the current N-S well trajectory. With future wells being planned, there was an opportunity to evaluate whether an alternative well orientation, might provide improved stimulation efficiency. To investigate this, models were run for a horizontal section of the well, placed into key layers, with their orientation rotating from SHMAX parallel (0 degs), incrementally around to SHMAX perpendicular (90 degs). For each of these scenarios, the SRV in both 2D (area) and 3D (volume) was calculated and plotted against the relative well direction, Fig 6.

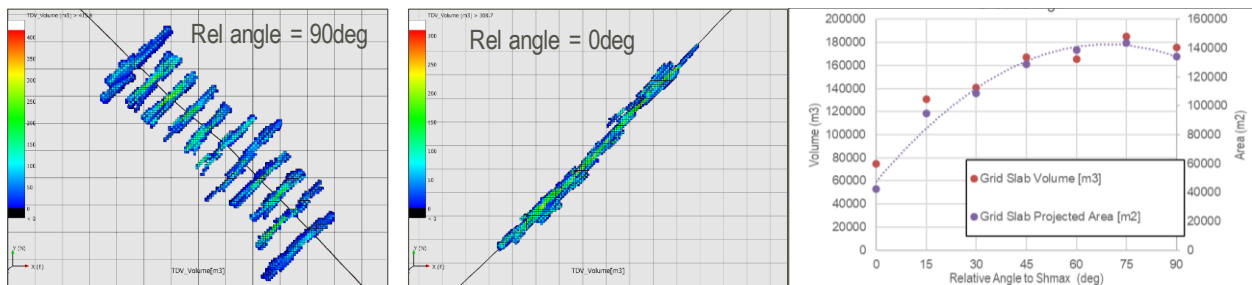


Fig. 6. Plan view of SRV results for 2 end member cases of well orientation expressed as well orientation relative to SHmax and graph showing 2D and 3D SRV results as a function of relative well angle.

What these results showed was that SRV could be optimized for either water flood or primary production by adjusting well orientation within the constraint of the well layouts. As Fig 6 shows small modifications of direction, can result in relatively large increases in connected area. Wells drilled following this study used this information to improve completion efficiency, plan interwell spacing, and plan future secondary recovery design. Many of these wells, showed a marked increase in production.

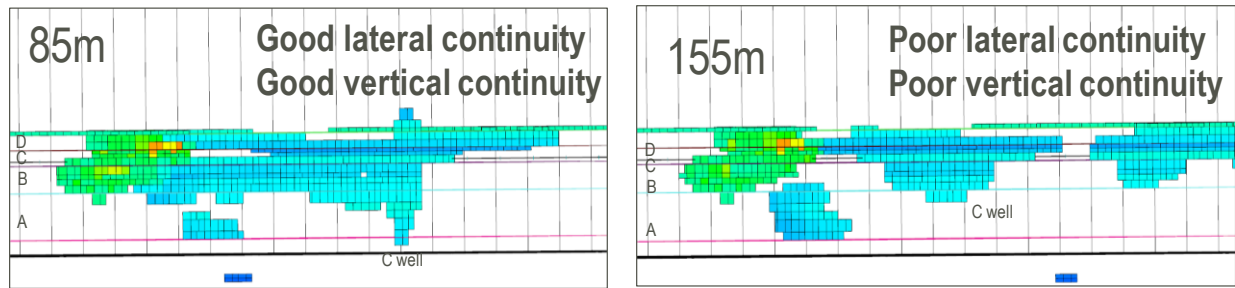


Fig. 7. Plan view and well section for 2 cases injecting into different layers within the B and C sands and the injection-propagation matrix for one of the stress cases

A further investigation of stimulation efficiency was an evaluation of the stage spacing on SHMAX parallel drilled wells. Simulations were carried out for a range of different stage spacings, and the interaction between each stimulation evaluated, by establishing the volume of reservoir where S3 was impacted. At closer spacings (85 m) the impacted S3 volume was shown to have good vertical and lateral continuity, particularly in the B and C sand layers. However, as the spacing increased, the resultant stimulation efficiency drops, with poor continuity, Fig 7.

5.0 Summary

Both the geomechanical and hydraulic fracture modelling showed that the Cardium system is complex with resultant stimulation effectiveness, highly sensitive to the injection layer due to stress and elastic property heterogeneity and natural fracture influences. Based directly on some of the findings of this study, implemented drilling pattern changes, resulted in all subsequent drilling programs having improved production rates. Importantly, the results of the study remained useful when the decision was made to change to primary production wells, where SRV rather than drain effectiveness is most important.

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