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Development and Field Testing of a Novel Technology for Evaluating Gravel Packs and Fracture Packs

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Outline

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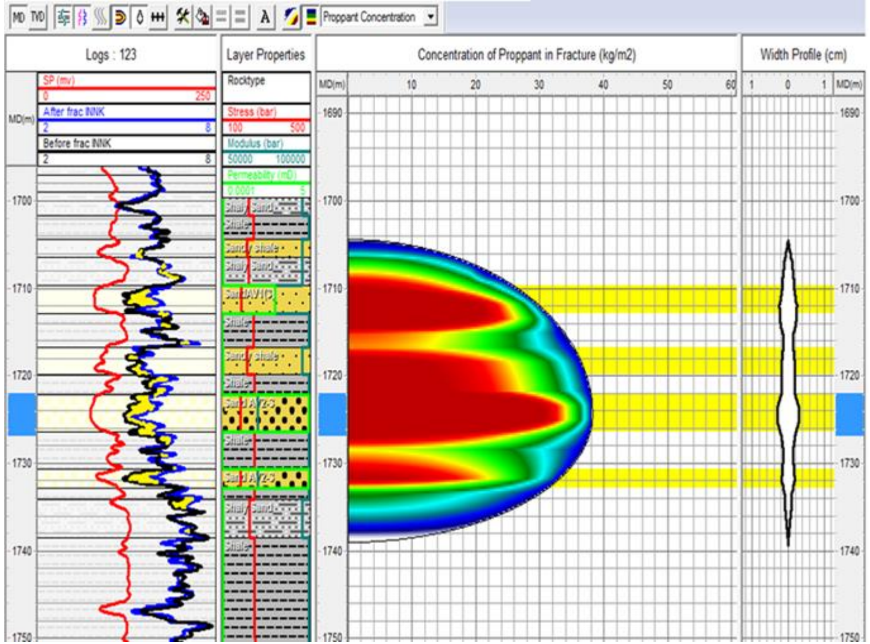
This technology allows us to evaluate gravel pack and frac pack at the same time

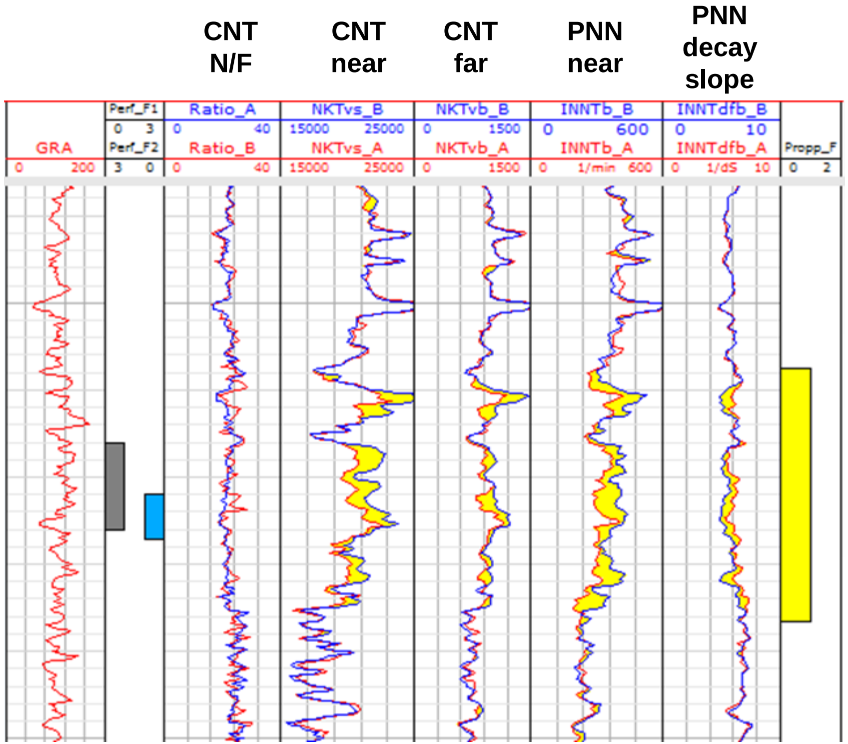
MCNP--Monte Carlo N-Particle code

1. Principles of Gravel Pack, Fracture Pack, and Conventional Induced Fracture Evaluation using Non-Radioactive Tracer (NRT) Tagged Proppant

- NRT taggant (Gd_2O_3) is incorporated into the proppant during manufacturing
- NRT taggant does not alter the physical properties of the proppant (crush, density, etc.)
- Since Gd_2O_3 is non-radioactive and stable, it's environmental friendly and there is no lifetime concern
- NRT proppant is pumped downhole into fractures and the gravel pack annulus
- PNC logs are obtained before and after the fracture treatment and compared
  - Gravel Packs: detector count rates decrease, Σ_{bh} increases, and Gd yield logs increase
  - Fracture Packs and conventional induced fractures: detector count rates decrease, Σ_{fm} increases, and Gd yield logs increase
  - In some situations, the before fracture log can be eliminated

2. A Field Example* Comparing NRT Signals with Predicted Fracture Geometry from Rock Properties Based Software





* From Paper AA, Trans. SPWLA 2017 Annual Symposium

3. Previous MCNP Modeling of Pre-pack, Gravel Pack(GP) and Frac-Pack (FP)*

Pre-pack

GP

FP

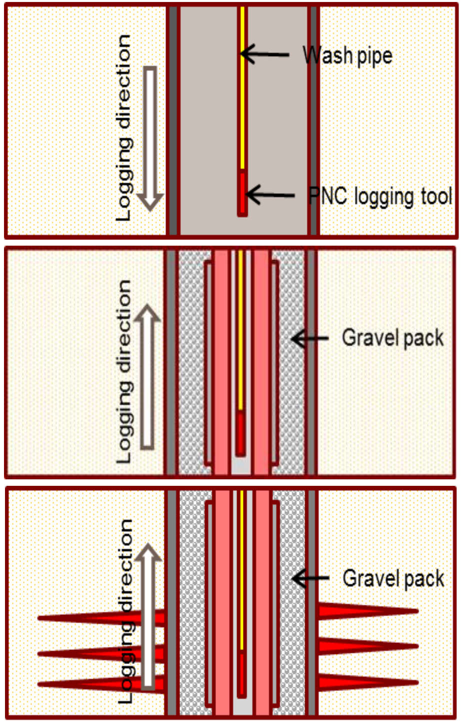


Fig. 1 MCNP Models

Table 1. PNC data for the pre-pack, gravel pack, and frac pack geometries for fresh water borehole fluid

Case	$\Delta\Sigma_{bh}$ (cu) %	Δ Borehole gamma ray counts (80-400μs) %	$\Delta\Sigma_{fm}$ (cu) %	Δ Formation gamma ray counts (400-1000μs) %	Δ Total gamma ray counts %
Pre-pack (case 1)	0.00%	0.00%	0.00%	0.00%	0.00%
Gravel pack (case2)	18.39%	-49.39%	1.60%	-44.75%	-49.10%
Frac-pack (case 3)	17.09%	-51.54%	8.70%	-59.05%	-52.01%

* From Xiaogang Han, OTC-25166-MS

4. New MCNP Modeling to Optimize Pulsed Neutron Measurements (Borehole Sigma, Count rates, Gd yield) and Tracer Concentrations

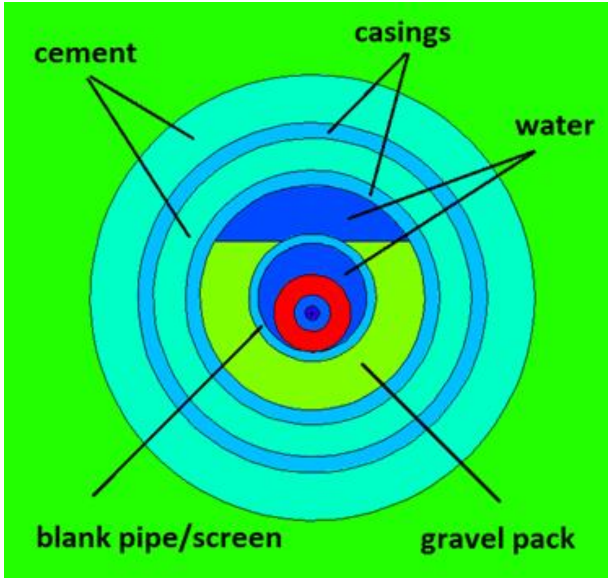


Fig. 2 Axial view of the geometry of MCNP model for layered voids (more realistic in the field)

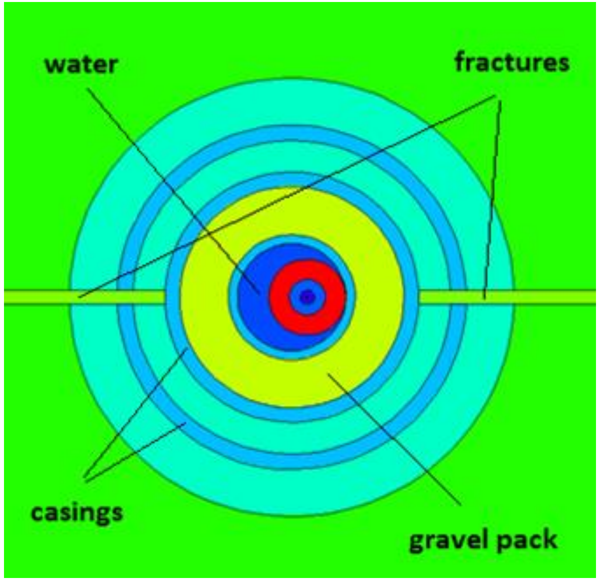


Fig. 3 Axial view of the geometry of MCNP model for uniformly distributed voids (the extreme case)

Layered Void Model

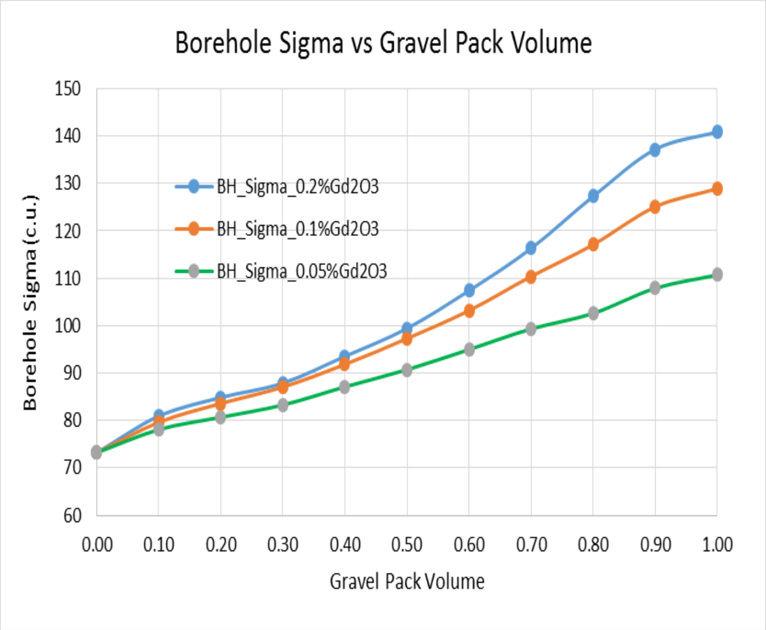


Fig. 4 shows that the response between Σ_{bh} and GP volume is roughly linear across the entire range of GP volume for all three Gd_2O_3 concentrations.

Uniform Void Model

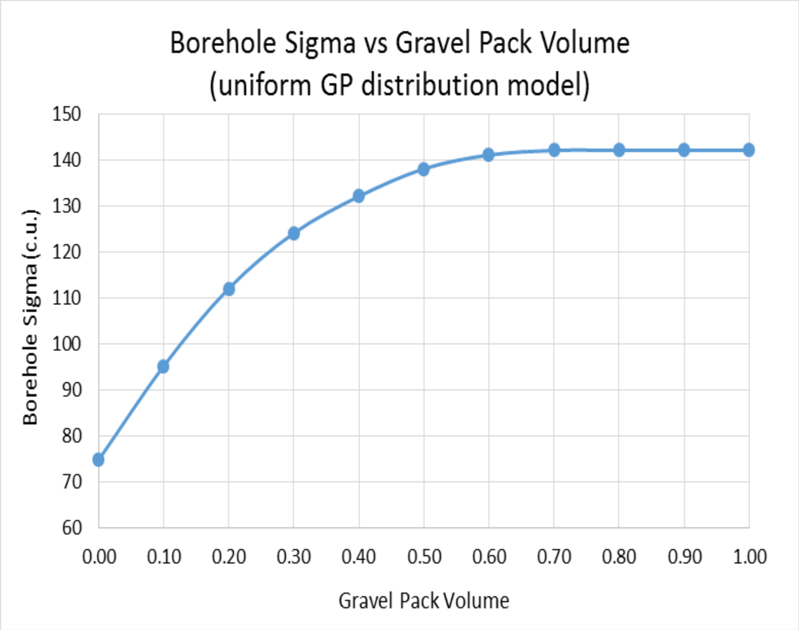
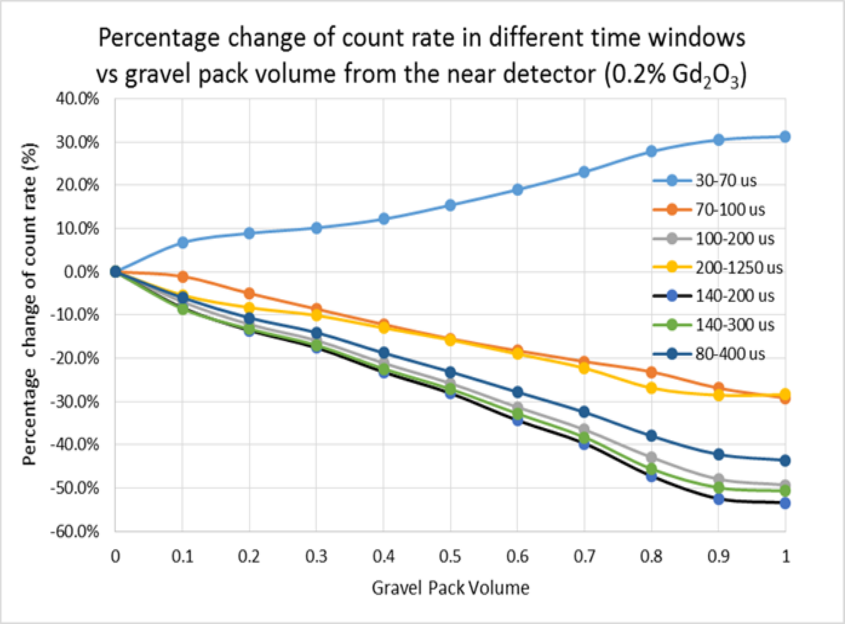


Fig. 5 shows that the response between Σ_{bh} and GP volume is highly non-linear, and for fractional GP volumes exceeding ~60%, there is no difference in Σ_{bh}.(containing 0.2%Gd_2O_3)

Layered Void Model



Uniform Void Model

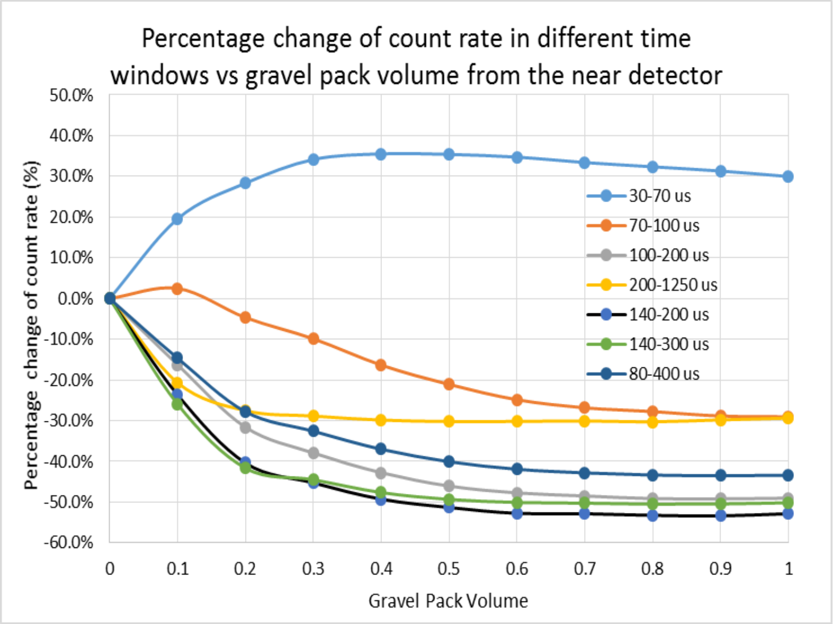
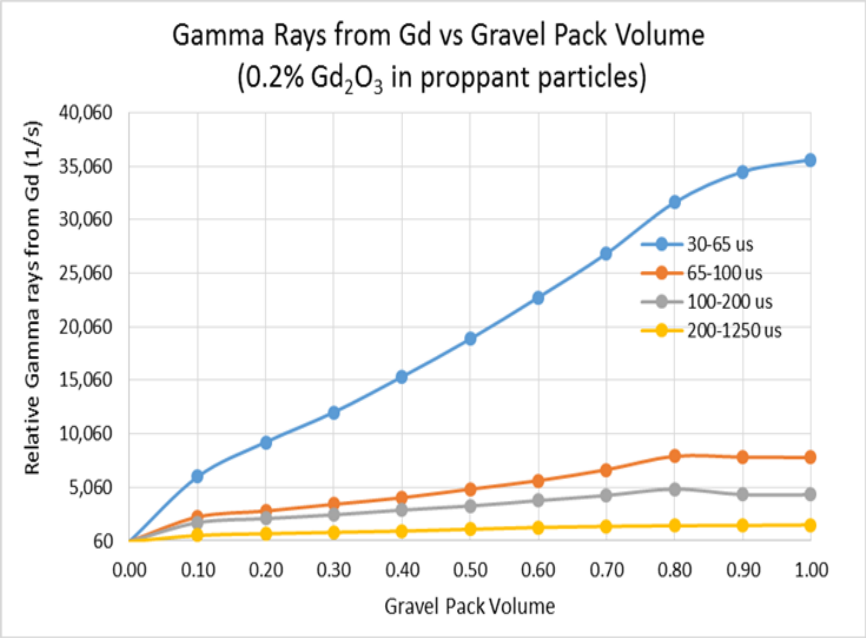


Fig. 6 shows that the increase/decrease of count rate is almost linear for all time windows

Fig. 7 shows that the increase/decrease of count rate is non-linear for all time windows

Both figures show that there is a dramatic difference in the count rate response in the very early time window relative to the count rates in all later time windows. In the earliest time widow, the count rate increases as GP volume increases, whereas in later time windows, the count rates decrease as GP volume increases.

Layered Void Model



Uniform Void Model

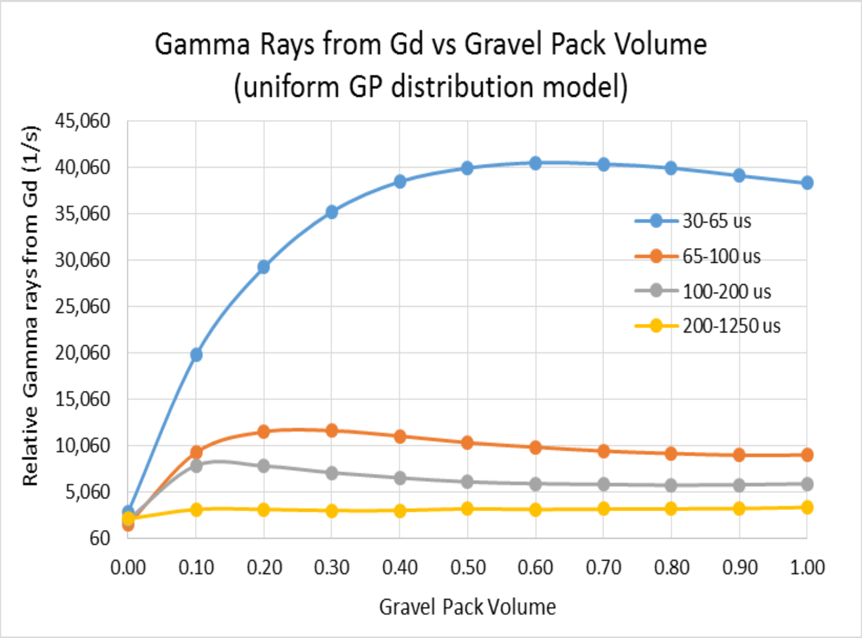


Fig. 8 shows the Gd yield is roughly linear for all time windows and the Gd_2O_3 concentration can be as high as 0.2%.

Fig. 9 shows the Gd yield is non-linear for all time windows and the Gd_2O_3 concentration should be lower than 0.12% (equiv. to 0.60 GP vol.)

Both figures show that the Gd yield in the early time window is the best indicator of the quality of the gravel pack.

5. Frac-Pack Field Log Example (only using after frac logs)

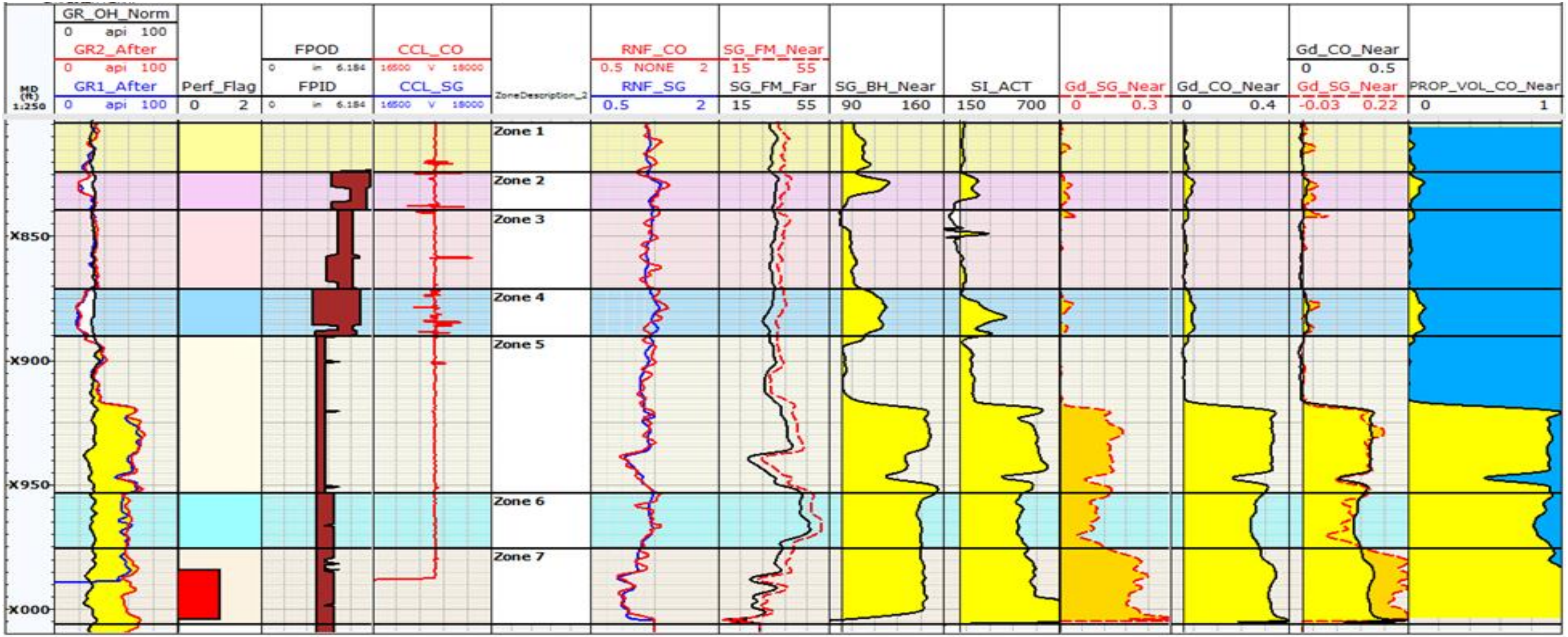


Fig. 10 shows the Gd yield log from the near detector in CO mode is one of the best PNC logs for gravel pack evaluation. Furthermore, the overlay of Gd yield logs in C/O and Sigma modes provides another feasible way for fracture pack evaluation. However, it would be the best practice to use before and after-fracture formation sigma logs for fracture pack (height) evaluation.

6. Summary / Conclusions

- It is feasible to evaluate gravel packs and fracture packs using NRT tagged proppant and a PNC tool
- Simulation data were utilized to optimize NRT tracer concentrations and obtain most effective time windows for analyzing count rates and Gd yield
- Three most effective PNC measurements for GP evaluation: borehole sigma, detector count rate, and Gd yield
- Layered model: changes in all three PNC measurements are linearly to GP volume, tracer concentrations up to ~0.2% (or possibly higher) can be effectively used
- Uniform void model: the changes are non-linear and tracer concentrations would need to be ≤0.12% to detect small or isolated voids
- Actual void distribution in the GP regions is unknown but is generally believed more closely associated with the layered void model

6. Summary / Conclusions (continued)

- Uniform void model is not realistic, but does provide valuable information to detect small voids
- Best practice: use formation sigma logs (before and after fracture) for fracture height evaluation

  --Note: without the before-fracture log, it was also possible to get fracture height by comparing after-fracture Gd yield logs from C/O mode and sigma mode
- New non-radioactive technology allows us to evaluate gravel pack and frac pack at the same time, more field tests are undergoing at present.

Acknowledgements / Thank You / Questions

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