

**Geostatistically-Constrained 3D Potential Field  
and Geology Modelling using Drillhole Data  
Case Studies from Hydrocarbons and Mineral  
Exploration**

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# Talk Outline

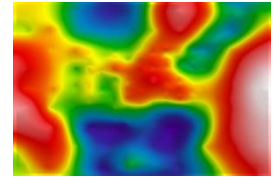
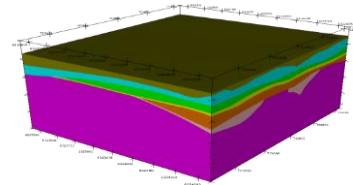
- Introduction – Purpose and Workflow
- Geological and Geostatistical Modelling
- East African Rift Case Study with FTG
- Uranium Case Study with Gravity
- Conclusions

# What's the Job??

- Build a 3D Geological Model from Drilling Data and additional data (Seismic Horizons, Mapping, Geophysical Interpretation)
- Analyse Formation Properties
- Geostatistically interpolate property data in Model
- Forward Model Geophysical Response
- Compare with Observed Geophysical Data
- Run Inversion
- Report on Outcomes

# Inversion Methods

- The purpose of any inversion is 3-fold:
  - Optimisation
  - Prediction
  - Validation
- We are dealing with sparse observations!!
- Outcome is highly dependent on initial conditions:
  - Known Geological Observations
  - Quality and Resolution of Observed Geophysical Response
  - Quality and Resolution of Terrain/Bathymetry
  - Source Location and Geometry
  - Physical Properties



# Geostatistics for Model Construction

- Creating a 3D property volume
- Drillhole log data are dense in information but may be sparse in distribution
- Physical and Chemical Properties, can be recorded and related to validate property and lithology models
- Think about Relationships
  - If data on one important logging parameter is limited, another parameter may help characterise its behaviour

# Model Constraints

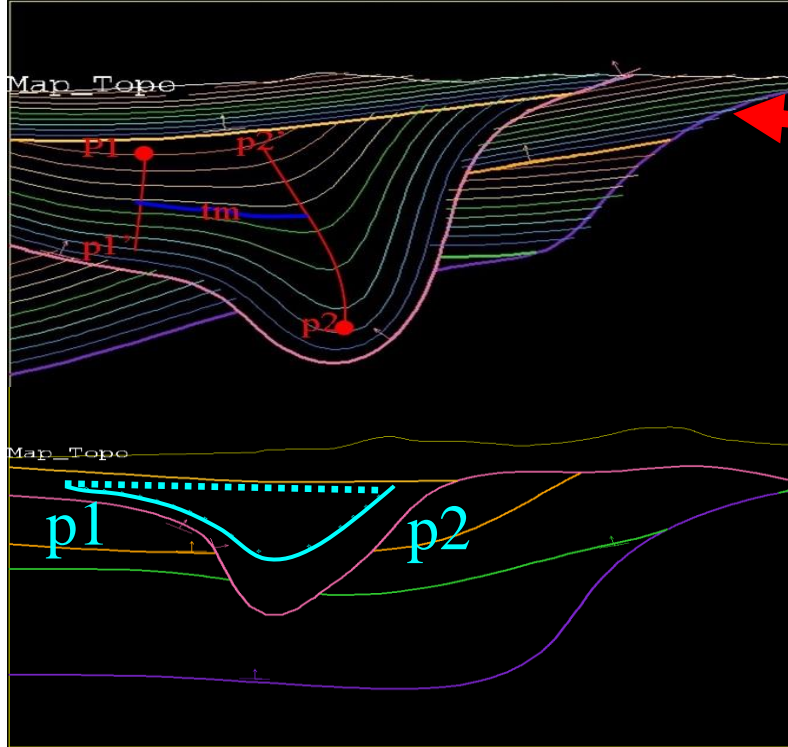
- 3D Lithology / Property model is desired
- Interpolation of downhole log properties to generate property voxel
- Solve Problems with properties and geometries
- Build Models using all sources – including proxies and property estimations
- *It can drive you a little crazy!!!*



# Geostatistical Methods

- Examine Logs and Property Distributions
- Compute Variograms
- Inverse Distance Weighting
- Kriging 1D and 2D
- Domain Kriging
  - Pot (t) Variogram of parameter correlates with 3D formation thickness
  - u, v, pot (t) (3D)
- Other techniques eg Gaussian Simulation

# Domaining



- GeoModeller interpolation follows isotopotential trend lines
- Uses Geodesic Distance
- Distance expressed in terms of potential function
- Generates more geologically plausible 3D property interpolations

# Case Study - Hydrocarbons

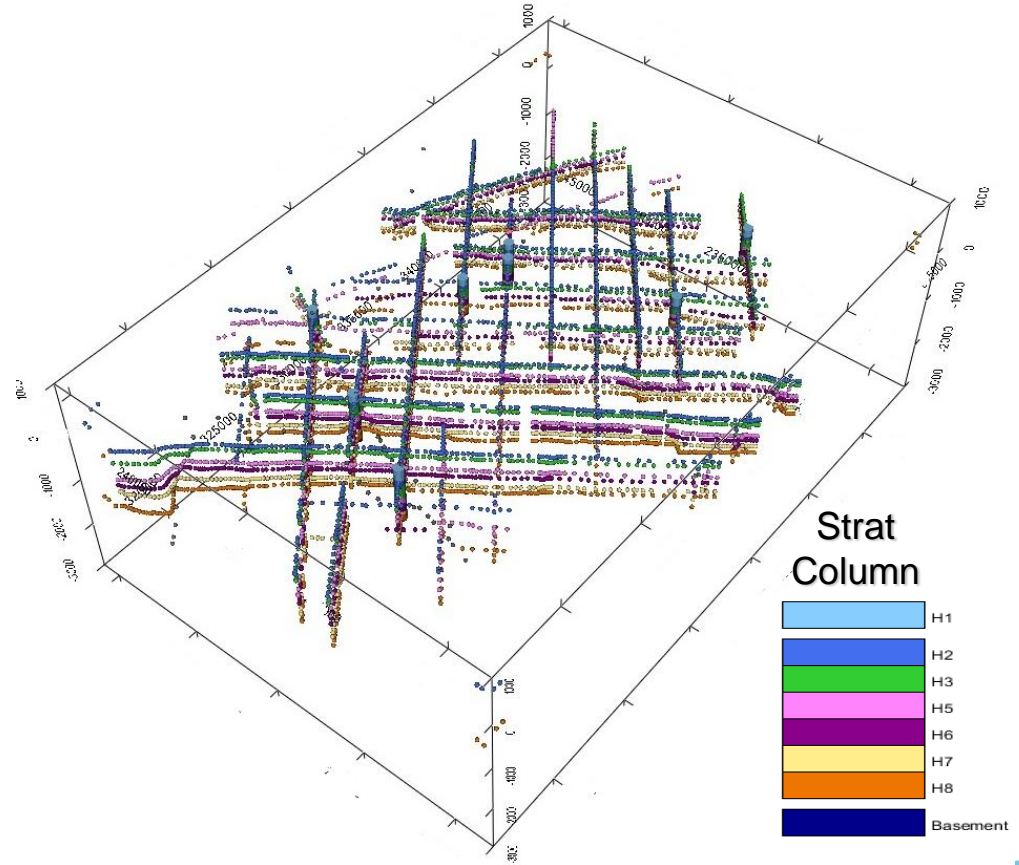
- Lake Albert, Uganda depth to basement inversion
- Performed with 2D seismic depth horizon picks, 8 well logs, digital terrain and Bell FTG data
- Originally done in 2010, refined in 2012 and 2014



# Case Study – Hydrocarbons

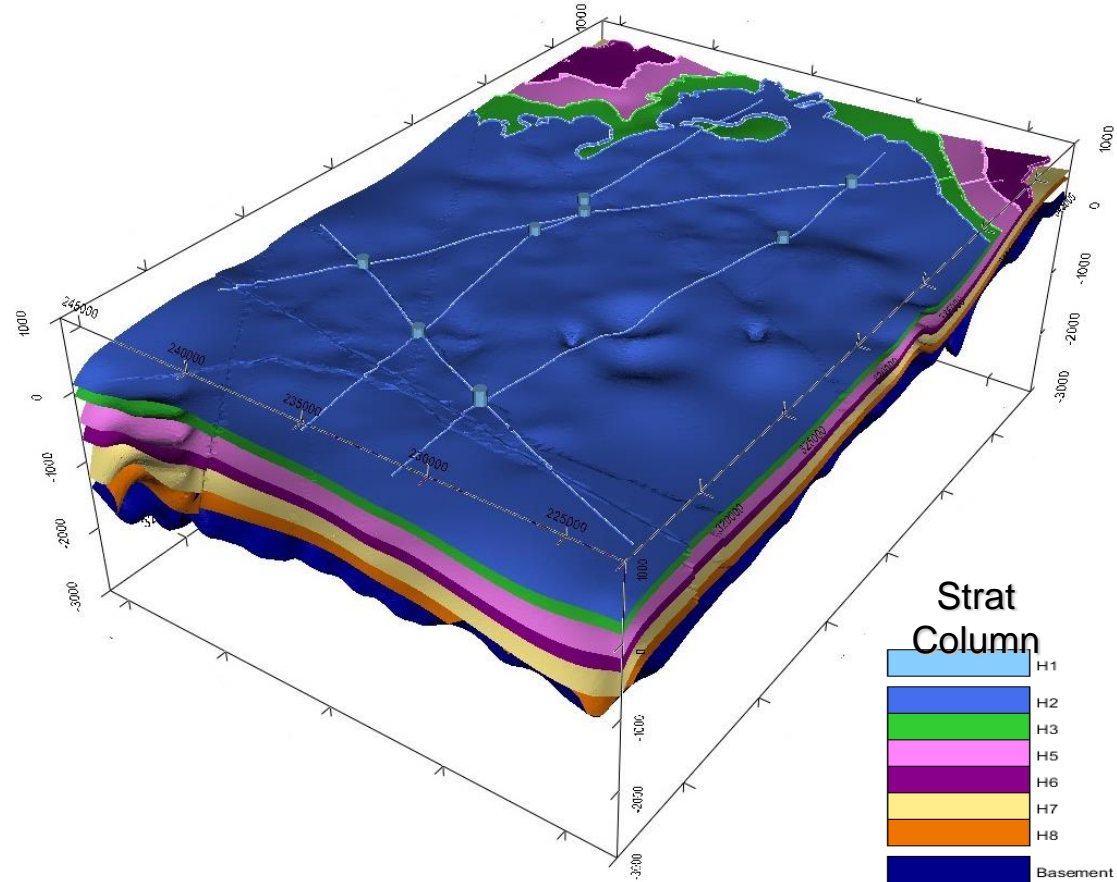
## Lithology

- Construction of initial 3D Lithology model from 2D seismic depth horizon picks and well formation boundaries
- Model dimensions are 33 x 23 km



# Case Study – Hydrocarbons *Lithology*

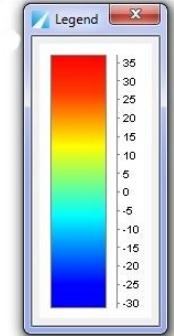
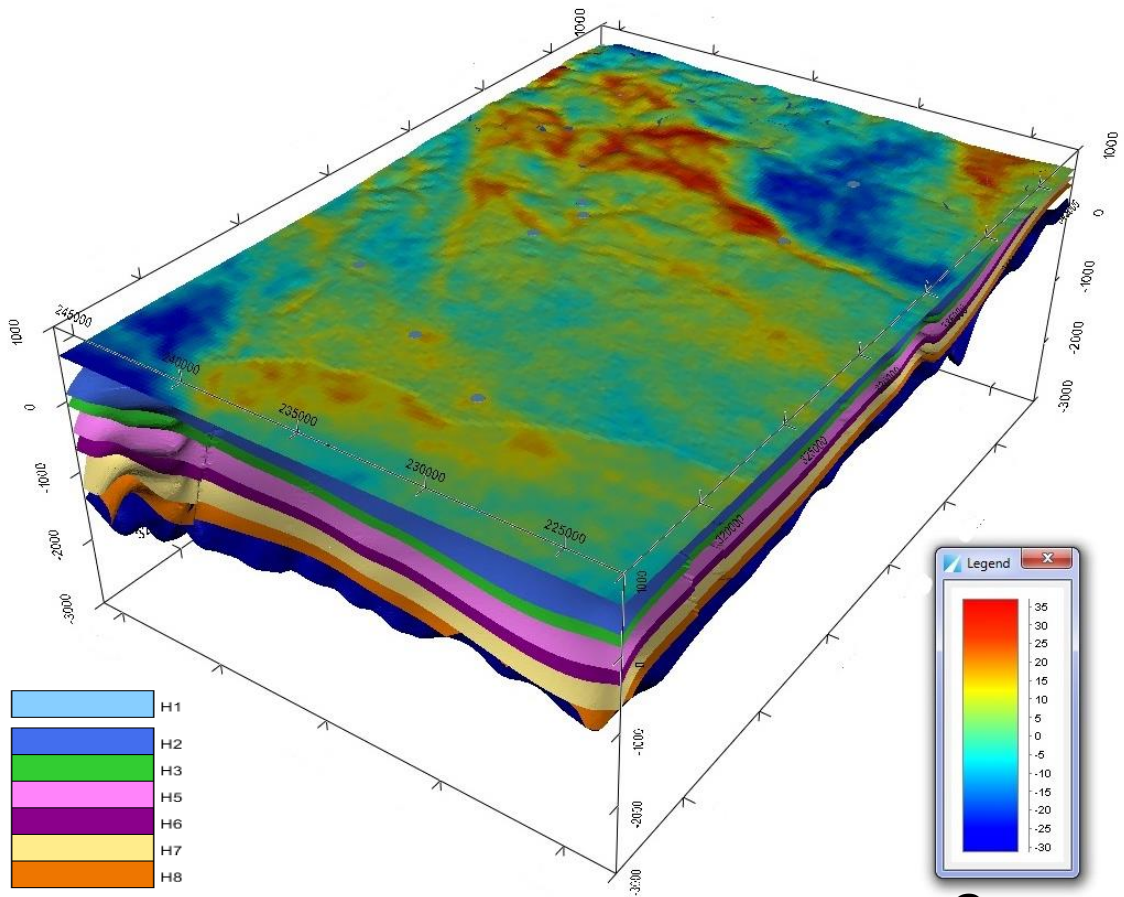
- Implicit Model is computed from seismic and drillhole interface contacts
- Orientations derived from intersections
- 3D implicit model rendered as horizon surfaces
- Note obvious faults and surface variations



# Case Study – Hydrocarbons *Lithology*

- 3D model showing horizon surfaces and vertical gravity gradient Gzz from FTG survey draped on topography

Strat  
Column

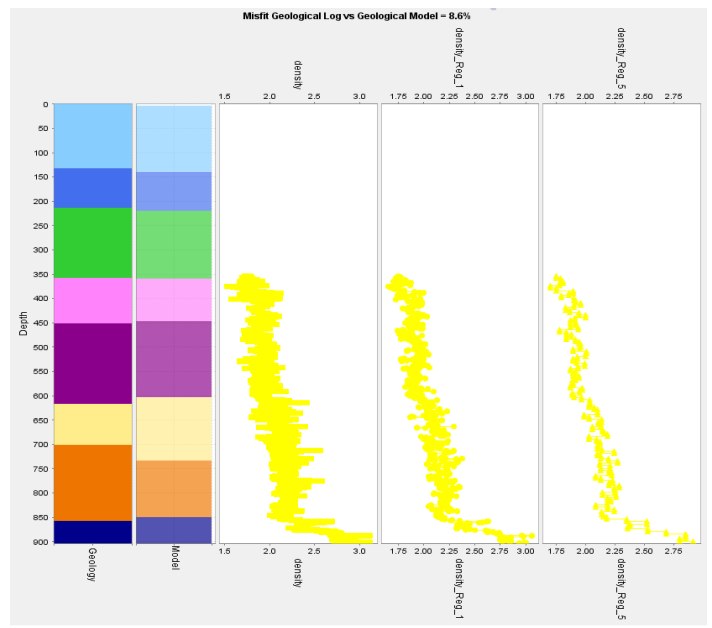


Gzz  
Eötvös

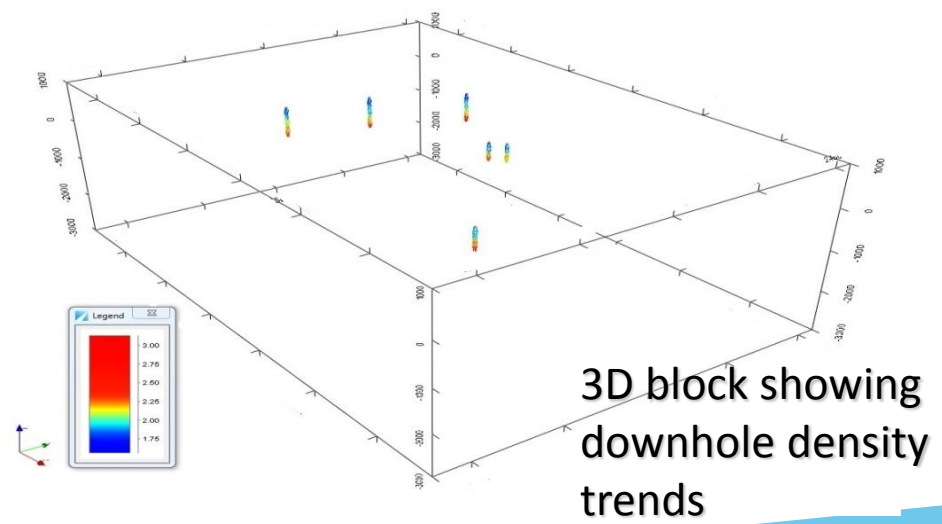
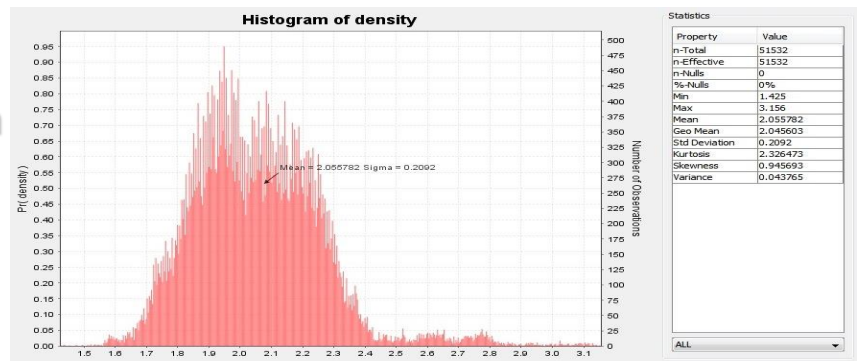
# Case Study – Hydrocarbons

## Property

Downhole drilling log from Project Area showing density variation with depth and regularisation over intervals

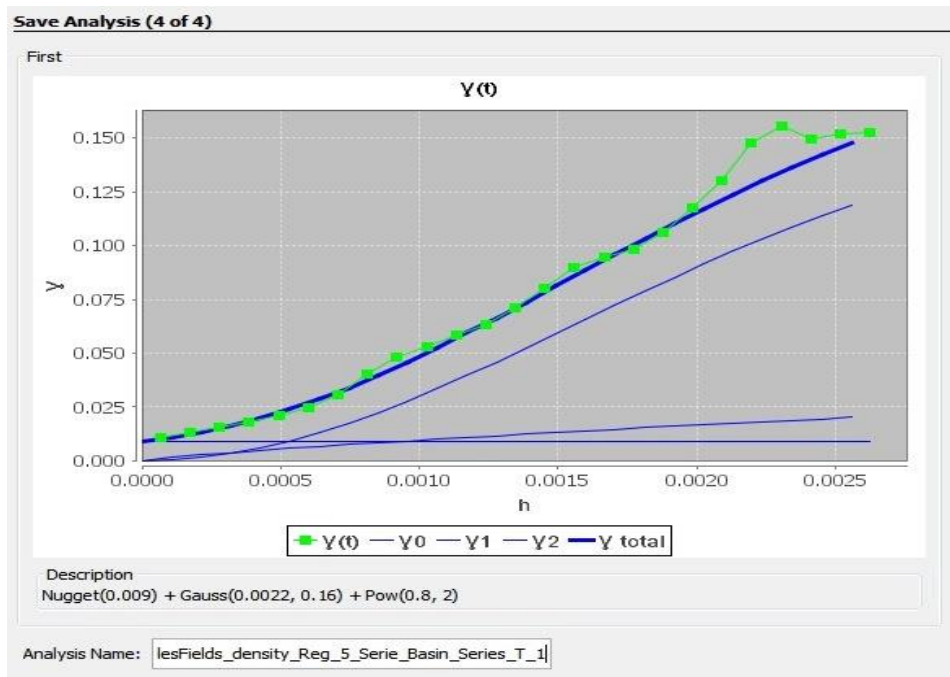


Full Histogram of all hole densities



# Case Study – Hydrocarbons

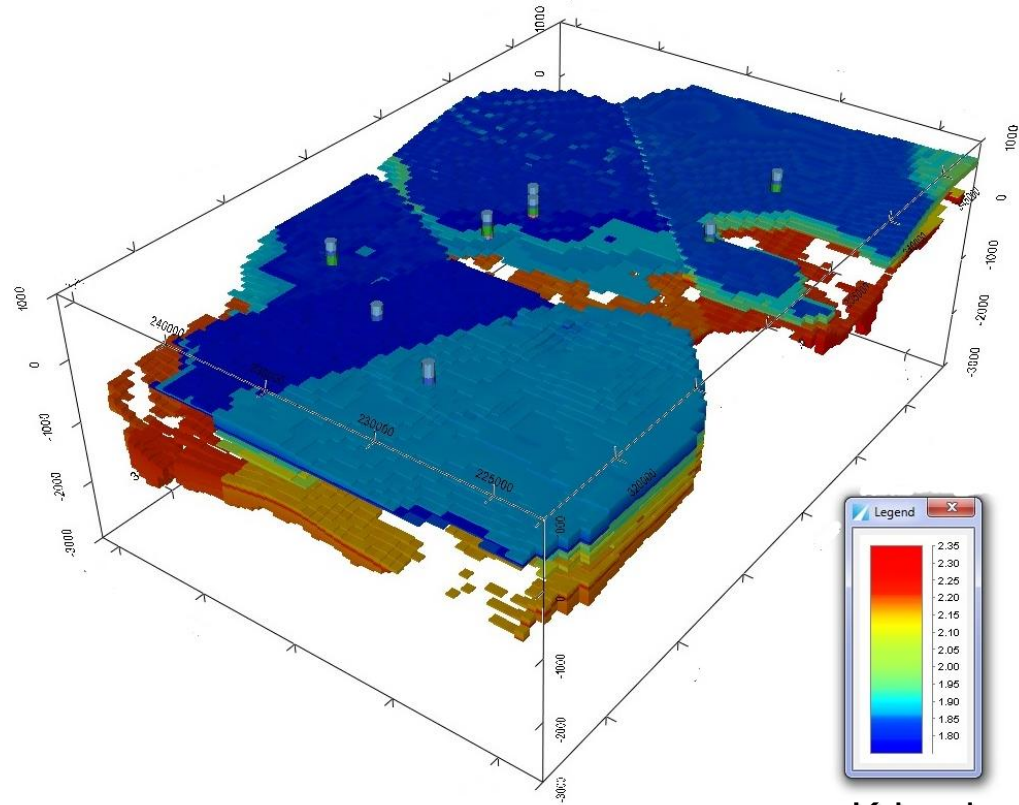
## Property



- Computation of domain experimental variogram based on geological potentials from model, using sedimentary series
- A Gaussian model for variogram fits in this instance

# Case Study – Hydrocarbons Property

- Interpolation of downhole densities using domain kriging, based on pot variogram
- Used as basis for pre-inversion density voxel
- Remaining areas replaced by random values defined by Physical Property Laws for each Formation

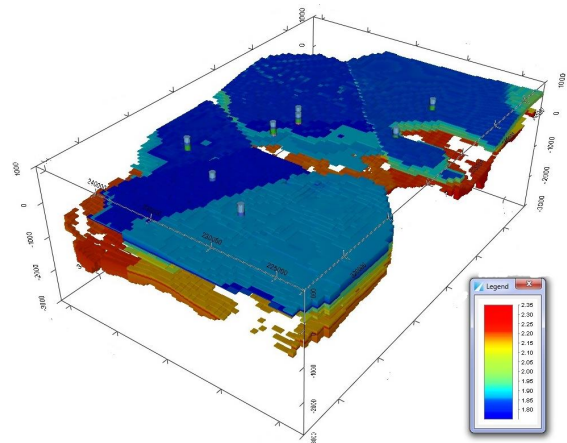


Kriged  
Densities

# Case Study – Hydrocarbons

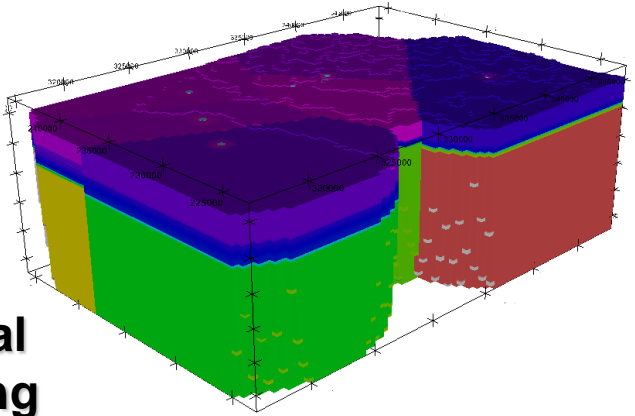
## Property

- Comparison of Interpolation Methods
- Domaining honours the Geology Model



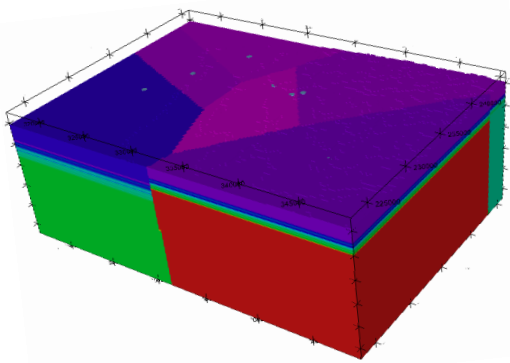
Domain Kriging

Kriged Densities



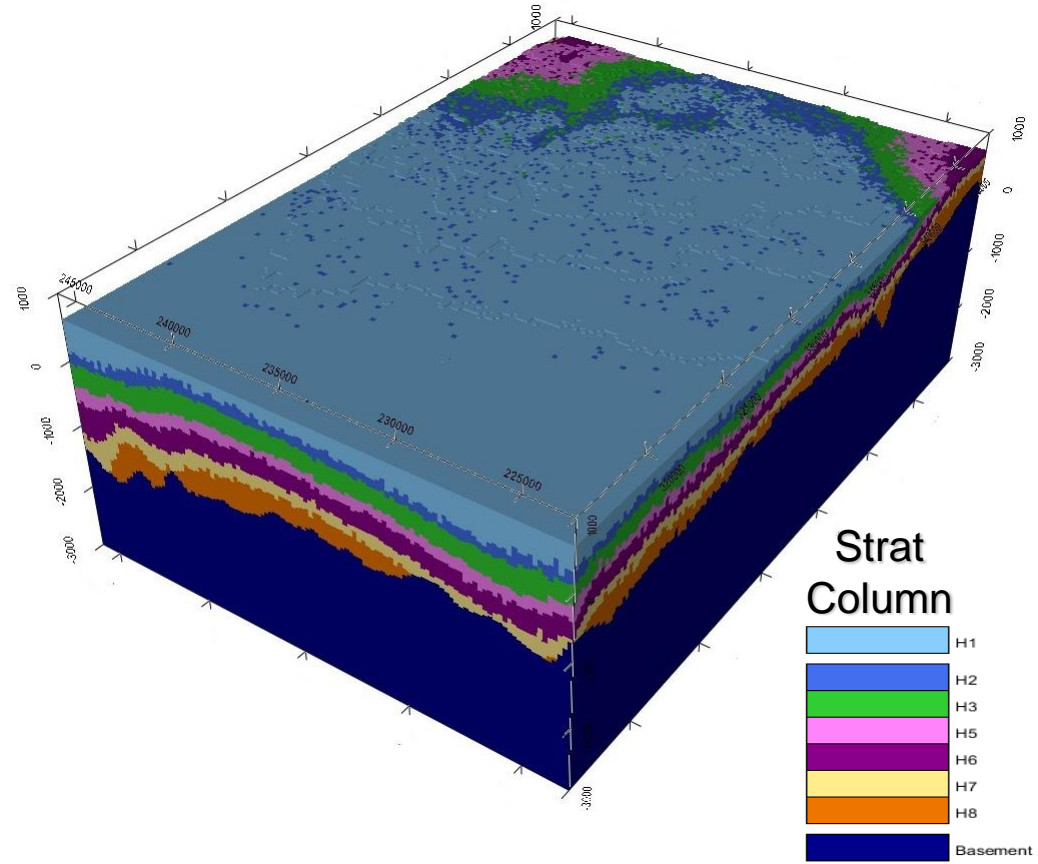
Radial Kriging

Inverse Distance Method



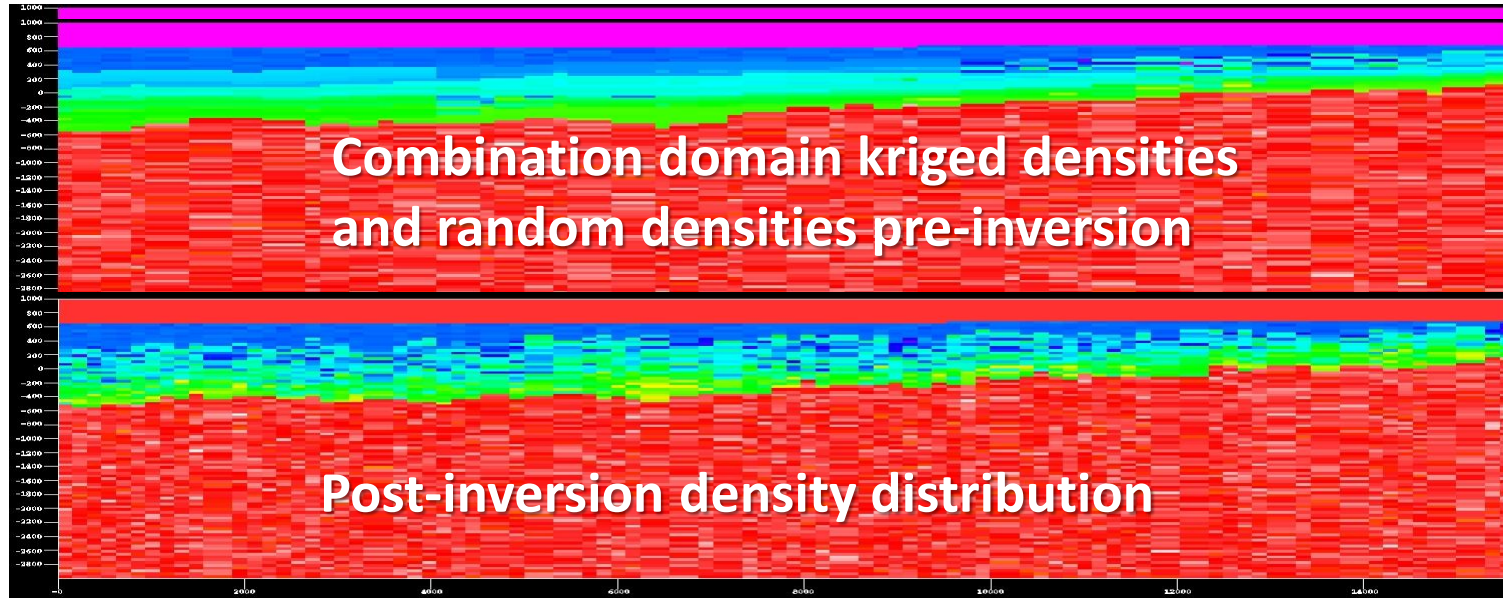
# Case Study - Hydrocarbons

- 3D Lithology Model Post-Inversion
- GeoModeller stochastic 3D Inversion changes either Property or Lithology
- Geometrical conditions are imposed by Stratigraphy, Similarity, Shape and Volume
- Property follows Distribution
- Note most apparent changes are short-wavelength due to high sample resolution

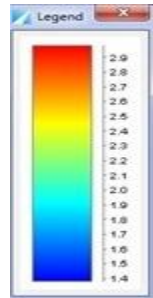


# Case Study - Hydrocarbons

- Example section view of Densities pre and post-inversion
- Population of optimised densities can be isolated by Lithology



Density

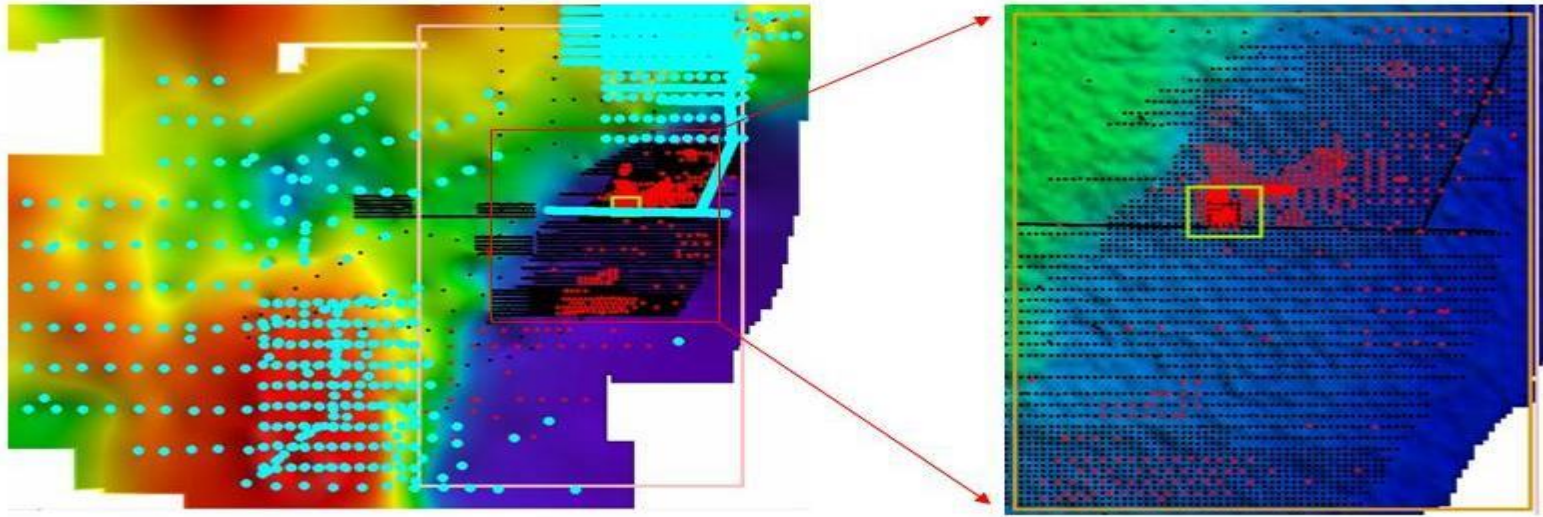


# Case Study – Uranium (Gravity)

- Blackbush Uranium Deposit, Tertiary Pirie Basin SA
- Unconformity deposit lying over radiogenic Proterozoic Granite
- 115 drillholes over 1x1km
- Aim to establish if relationship exists between gravity and mineralisation



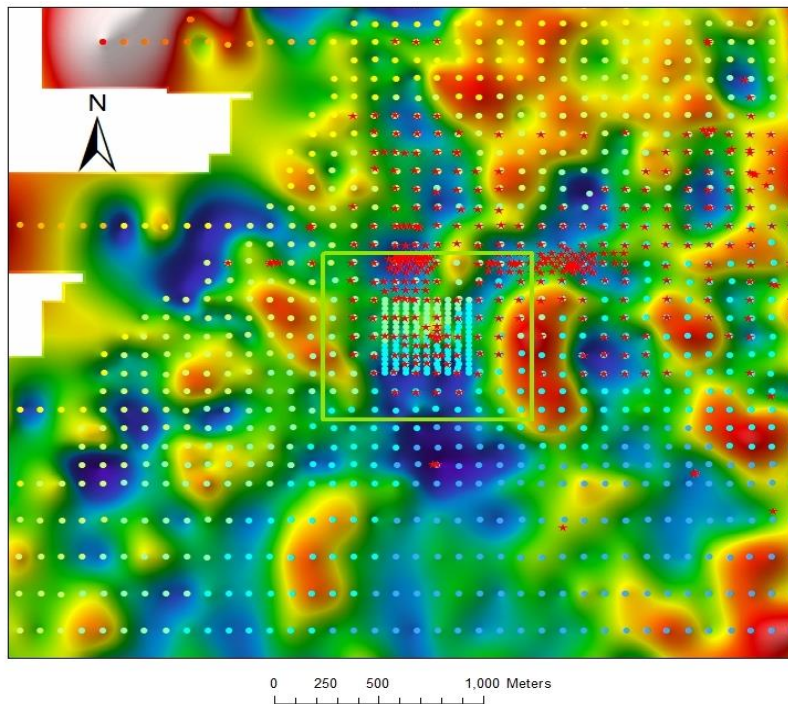
# Bouguer Gravity Anomaly Map



- Variable regional and high density station coverage
- Pattern drilled and logged for U308
- Samphire Granite well-defined low

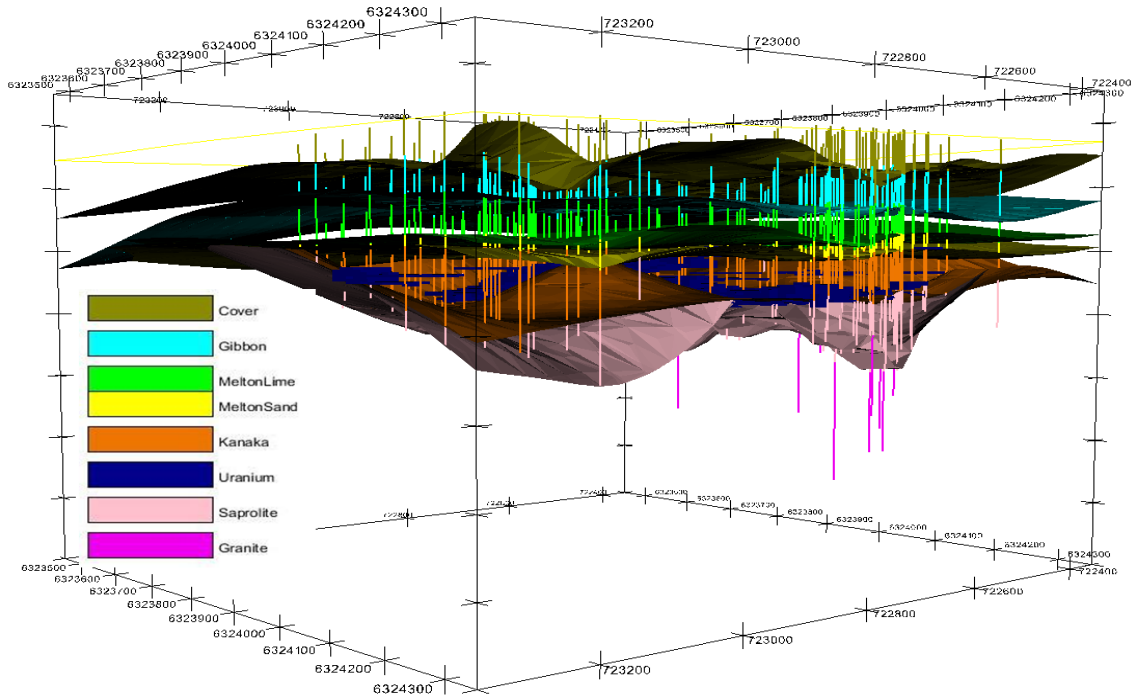
# Residual Gravity Anomaly Map

- Residual Gravity Map generated by **Spectral Filtering**
- Shows wavelengths < 250m
- **Unconformity Deposit** located in **Paleochannel**
- Gravity Station Density and Drilling Locations shown



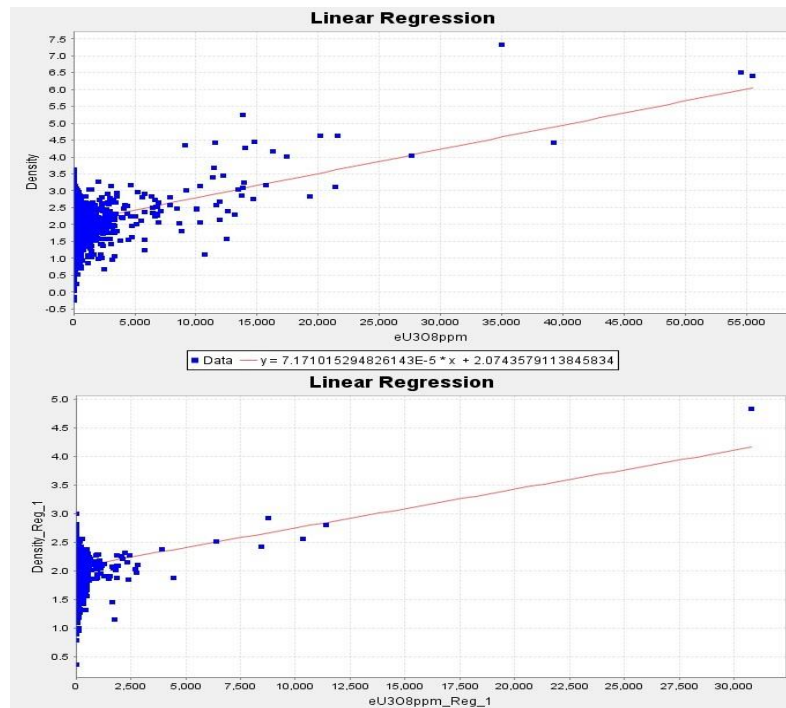
# 3D Geological Model from Drilling

- Geological Model established using abundant drilling
- Low Density Tertiary Sediments
- Granite Basement
- Uranium occurs in Kanaka Beds
- Flanks Basement High

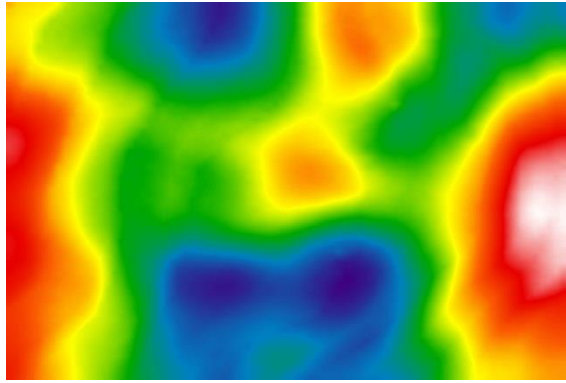


# Downhole Density and Uranium Logs

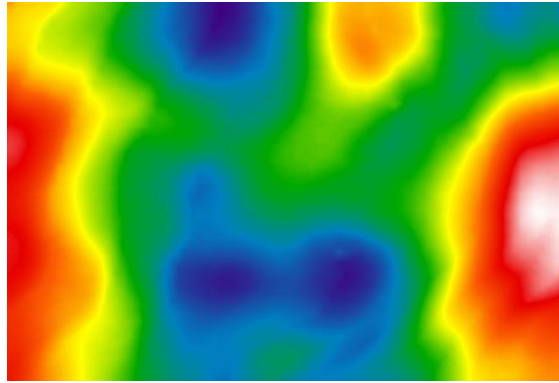
- Strong correlation between Density and U3O8 above 1000ppm
- Strong possibility of anomalous response in gravity
- if U-accumulations are thick enough!
- Exploits low density contrasts



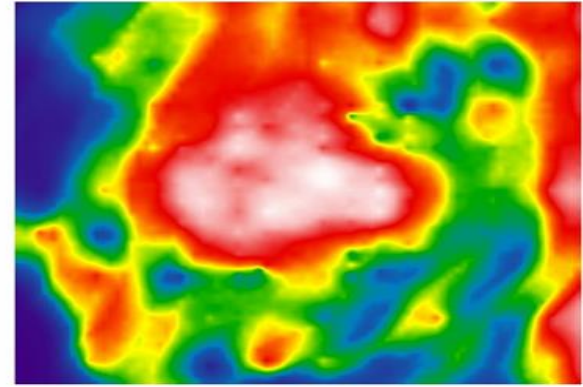
# Bouguer Gravity Response Grids



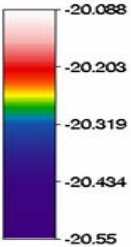
Observed  
Bouguer Gravity



3D Forward  
Bouguer Gravity

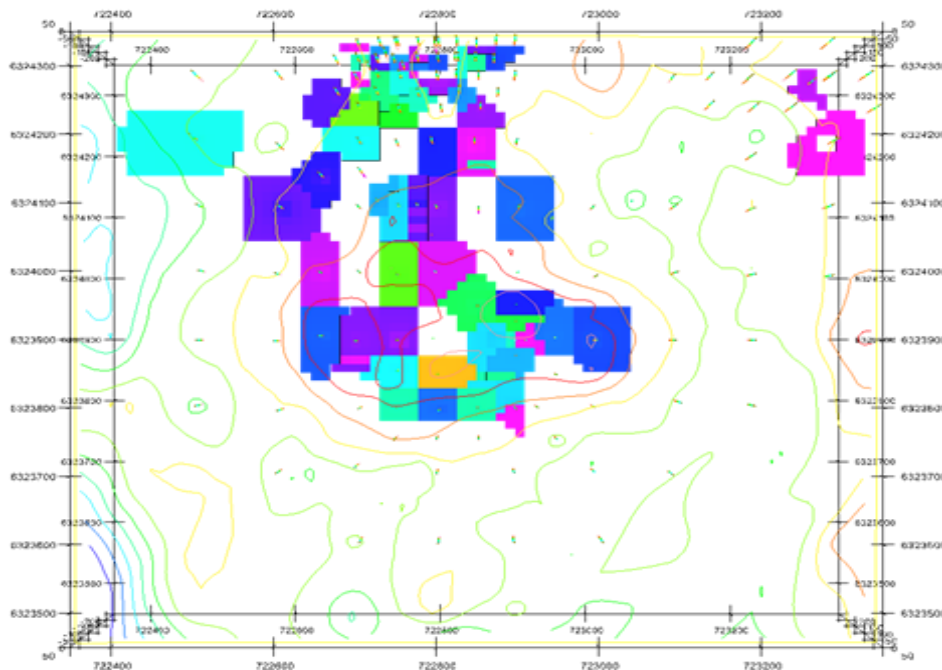


Misfit or Residual  
Bouguer Gravity



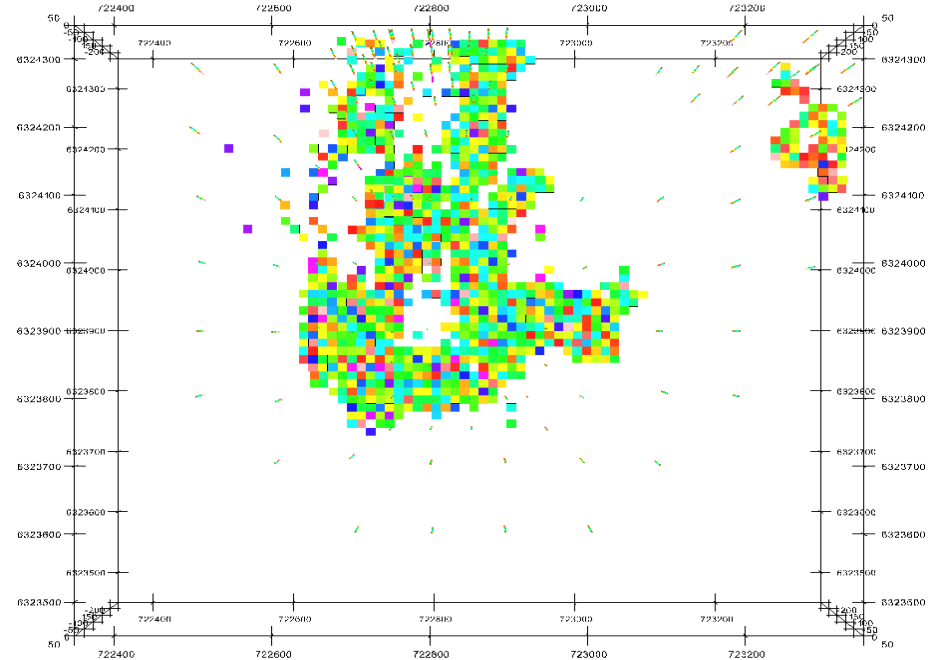
# Kriging of Uranium Logs Pre-Inversion

- Kriged eU3O8 values clipped above 1000ppm
- Distribution compared to Forward Modelling of Bouguer Gravity
- Strong match discovered
- Anomaly < 0.4 mGal!!!



# Uranium Distribution following Inversion

- Inversion run on 12.5x12.5x1m grid
- 1,440,000 cells
- Redistributed Uranium constrained by both drilling and gravity response
- New inferred U-resource can be computed from voxel



# Conclusions and Recommendations

- Using Geostatistical Interpolation from Drilling logs to construct 3D property models is a powerful aid to constrained inversion
- Relations of measured physical properties and geochemistry need to be routinely logged and compared!!!!
- Initial Model is Driving Constraint
- Physical property model may imply the lithology
- USE your drilling logs!!!

# Acknowledgments

- Thanks to Tullow Oil, Uranium SA and Intrepid Geophysics for permission to publish these studies
- Thankyou for your attention!!!
- [www.intrepid-geophysics.com](http://www.intrepid-geophysics.com)