Use of Geostatistically-constrained Potential Field Inversion and Downhole Drilling to Predict Distribution of Sulphide and Uranium Mineralisation

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Talk Outline

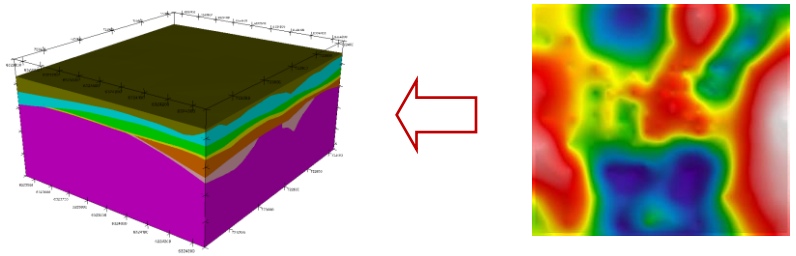
- Introduction – Purpose and Workflow
- Inversion Methodology
- Geological and Geostatistical Modelling
- Copper Case Study with Magnetics
- Uranium Case Study with Gravity
- Conclusions

What's the Job??

- Build a 3D Geological Model of a Deposit From Drilling Data
- Load in Assay Data for holes
- Analyse Formation Densities
- Geostatistically interpolate property data
- Forward Model Geophysical Response
- Compare with Observed Geophysical Data
- Run Stochastic Inversion
- Report

Inversion Methods

- The purpose of any inversion is 3-fold:
  - Optimisation
  - Prediction
  - Validation



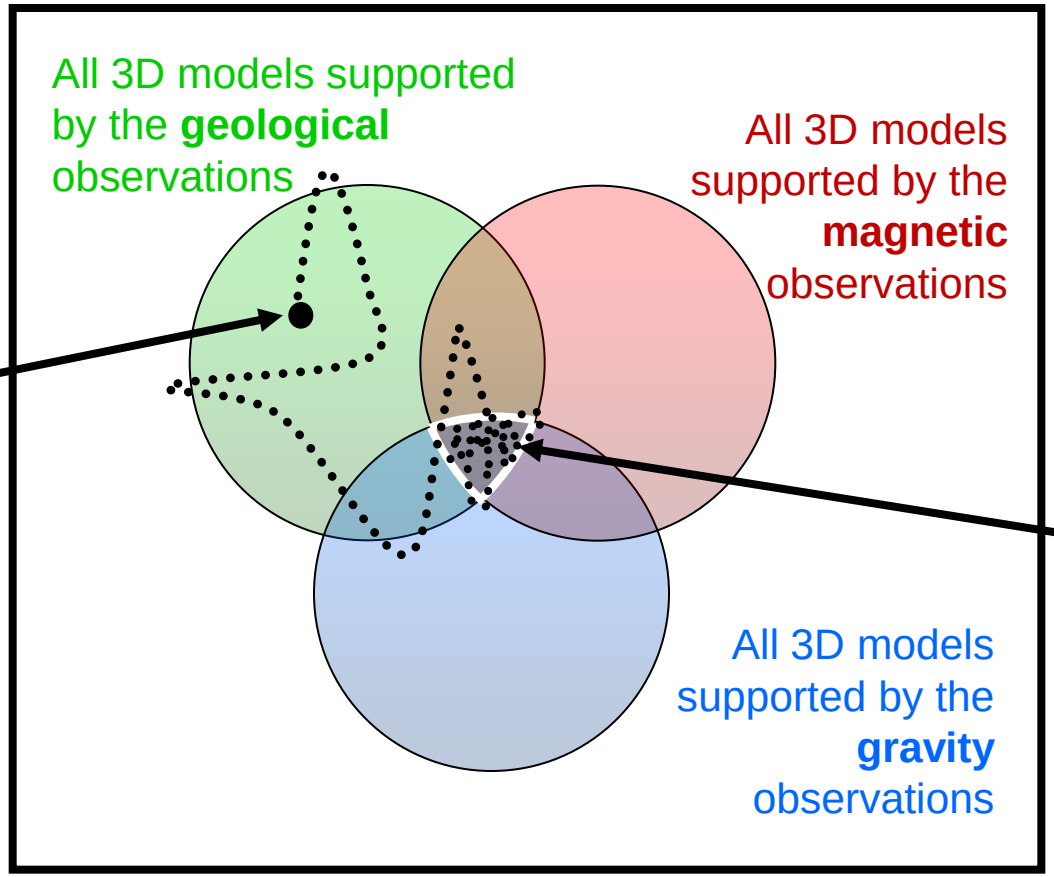
- We are dealing with sparse observations!!
- Outcome is highly dependent on initial conditions:
  - Known Geological Observations
  - Quality and Resolution of Observed Geophysical Response
  - Quality and Resolution of Terrain/Bathymetry
  - Source Location and Geometry
  - Physical Properties

Inversion Constraints

- 3D Lithology / Property model
- Inversion engine + constraints
- Problem with properties and geometries
- User or Software Problems?
- Build Models using all of sources – including proxies and property estimations
- *It can drive you a little crazy!!!*

Stochastic Inversion Pathways

BEGIN
An 'initial or reference' 3D geology model produced to honour the geological observations



END INVERSION
Gather all 3D geology models which are consistent with the observed geophysics to within a desired tolerance

[ready for likelihood stats]

"Stochastic exploration of alternate 3D geological models, guided by potential field data to quantify model uncertainty"

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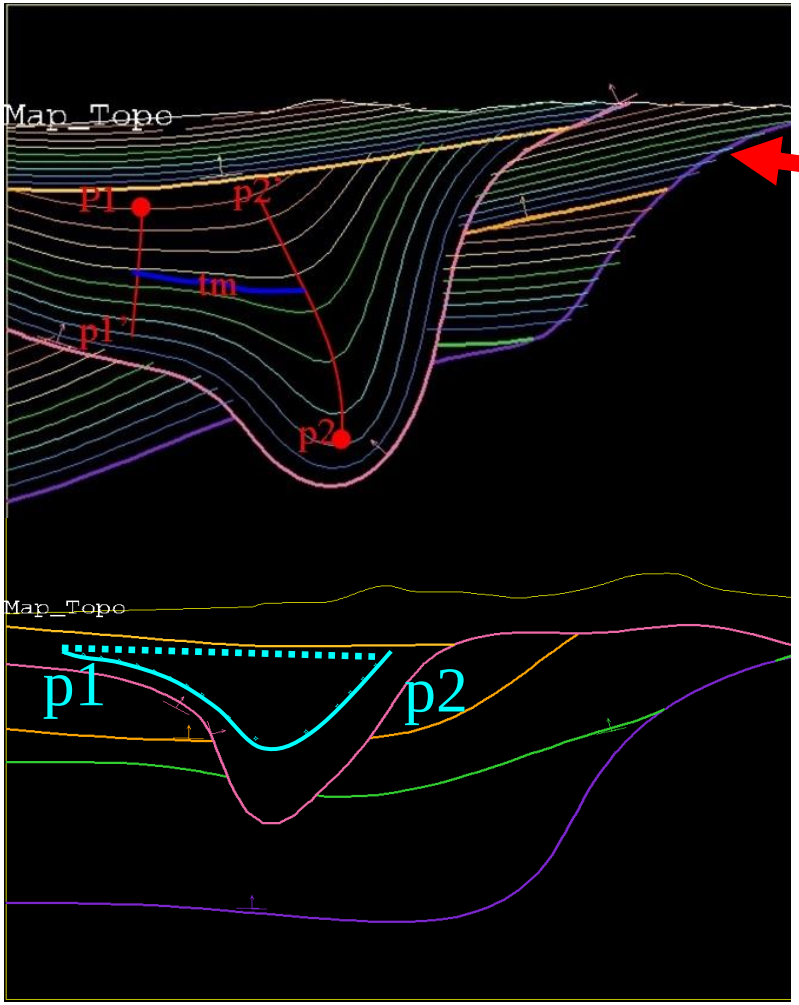
Geostatistics for Model Construction

- 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

Geostatistical Methods

- Inverse Distance Weighting
- Kriging 1D and 2D
- Domain Kriging
  - Pot (t) Variogram of parameter correlates with 3D formation thickness
  - u, v, pot (t) (3D)
- Gaussian Simulation

Domaining



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

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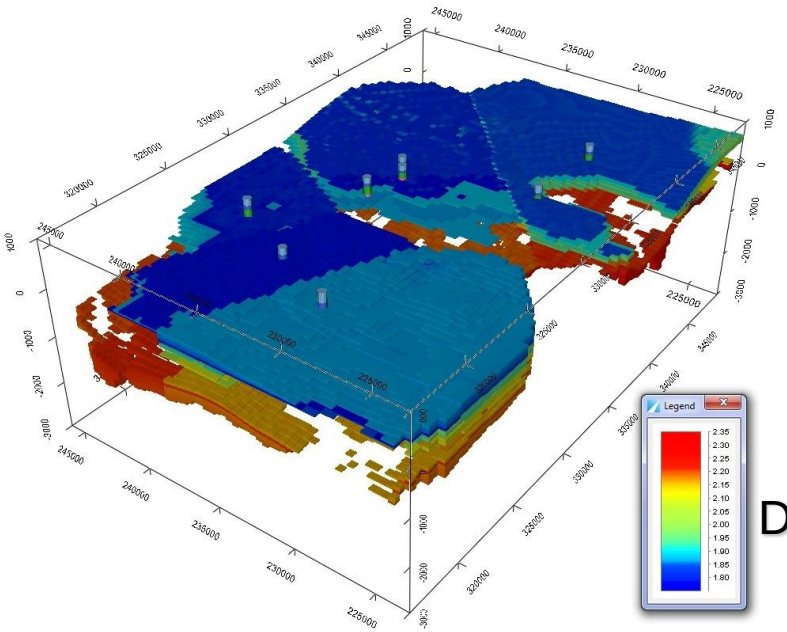
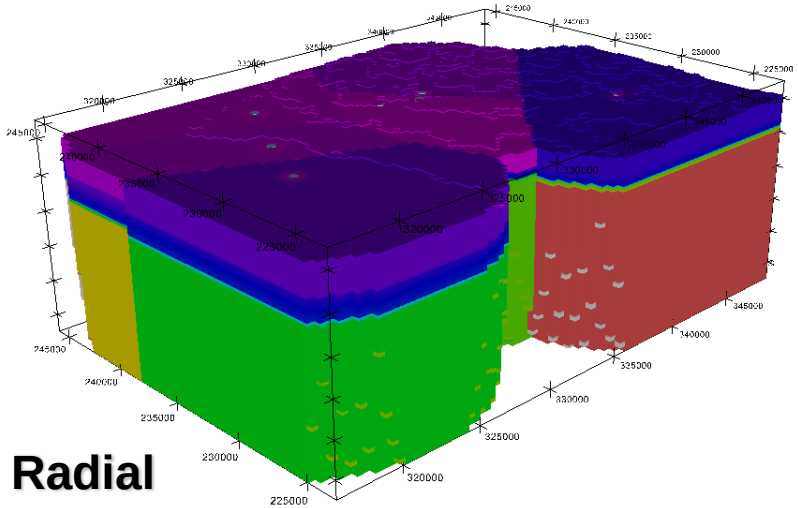
- Comparison of Interpolation Methods
- Domaining honours the Geology Model

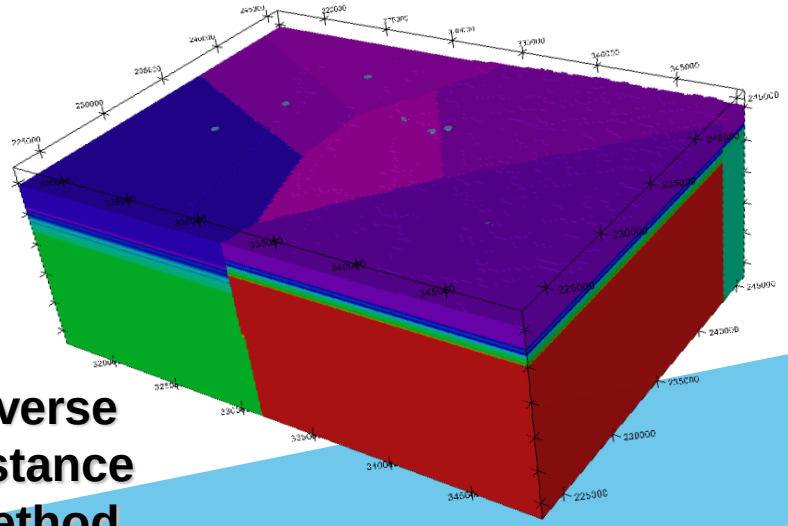


Domain Kriging

Kriged Densities



Radial Kriging



Inverse Distance Method

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Case Study – Cu/Co (Magnetics)

- Basil Cu/Co Deposit Irindina Province NT
- Metamorphosed VMS in Cambrian amphibolite
- Cu mineralisation association with magnetic Pyrrhotite
- Aim to predict extensions of mineralisation from Inversion

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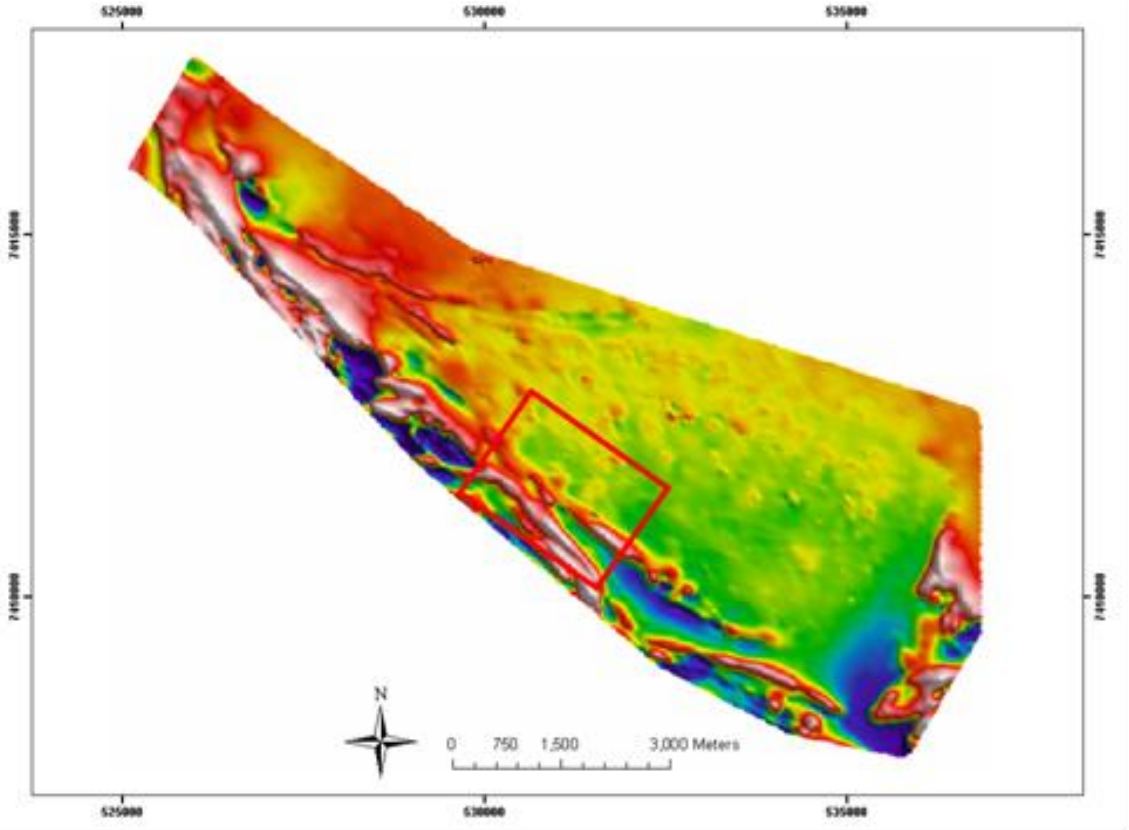
Basil Cu/Co Magnetics



- RTP Magnetics

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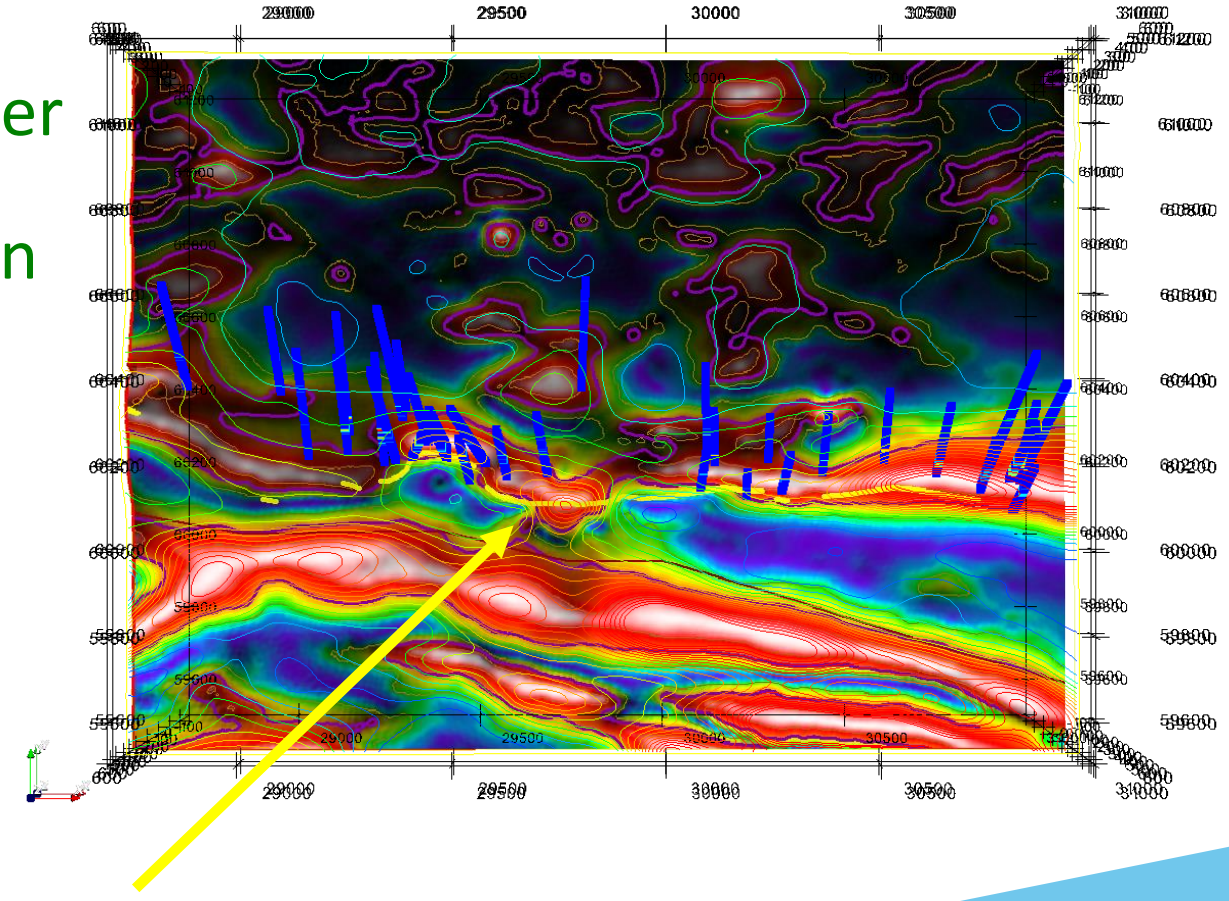
Basil Cu/Co Magnetics

- Tilt Angle Filter shows mineralisation trend
- Verified by drillhole intersections



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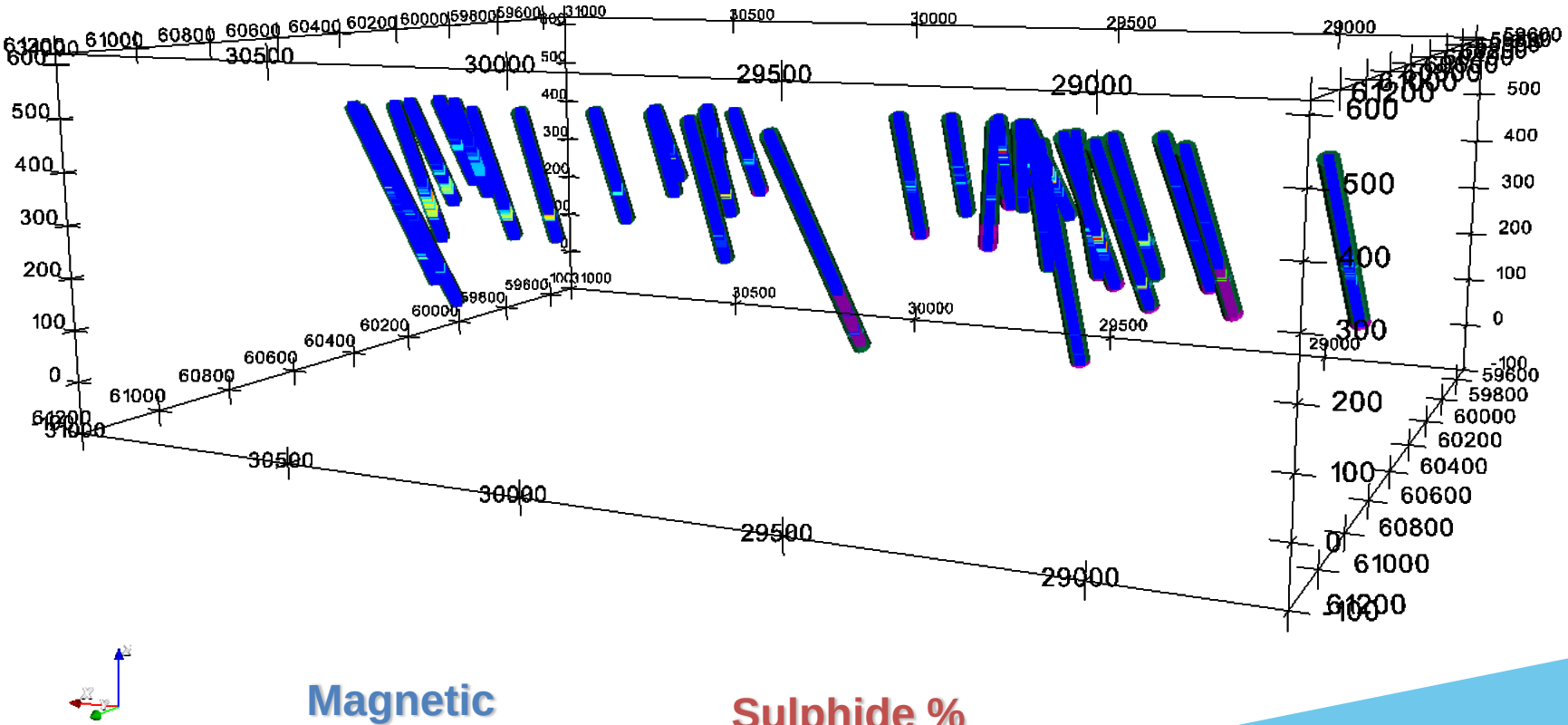
Basil Drillholes



Magnetic Susceptibility

Sulphide %

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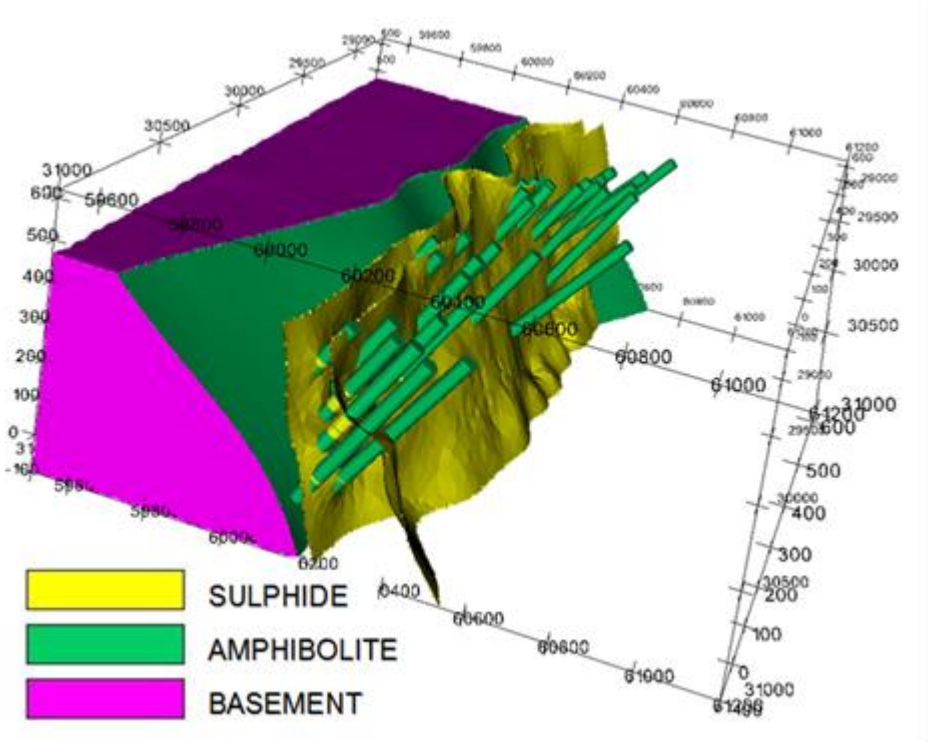
Basil Initial Geology Models

- Dyke/Sheet Model
- Similar to Inferred Resource Model
- **Bad for Inversion!!!!**
- Assumptions about continuity



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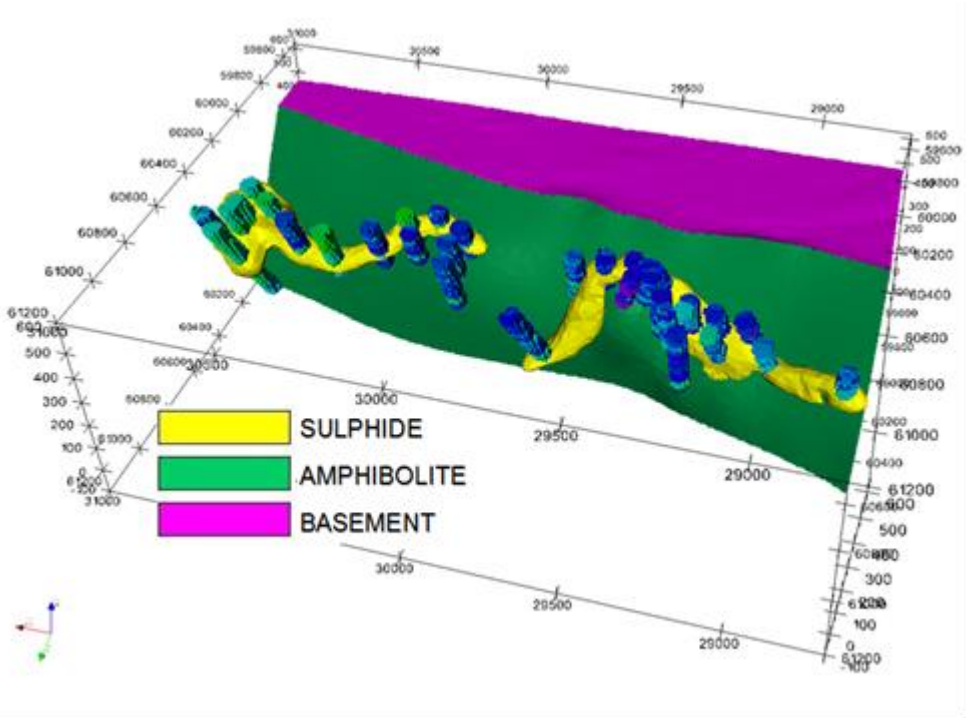
Basil Initial Geology Models

- Ribbon Model
- Defined by Kriging
- **Good for Inversion!!!!**
- Honours observations & locations
- Geometry suggests folding



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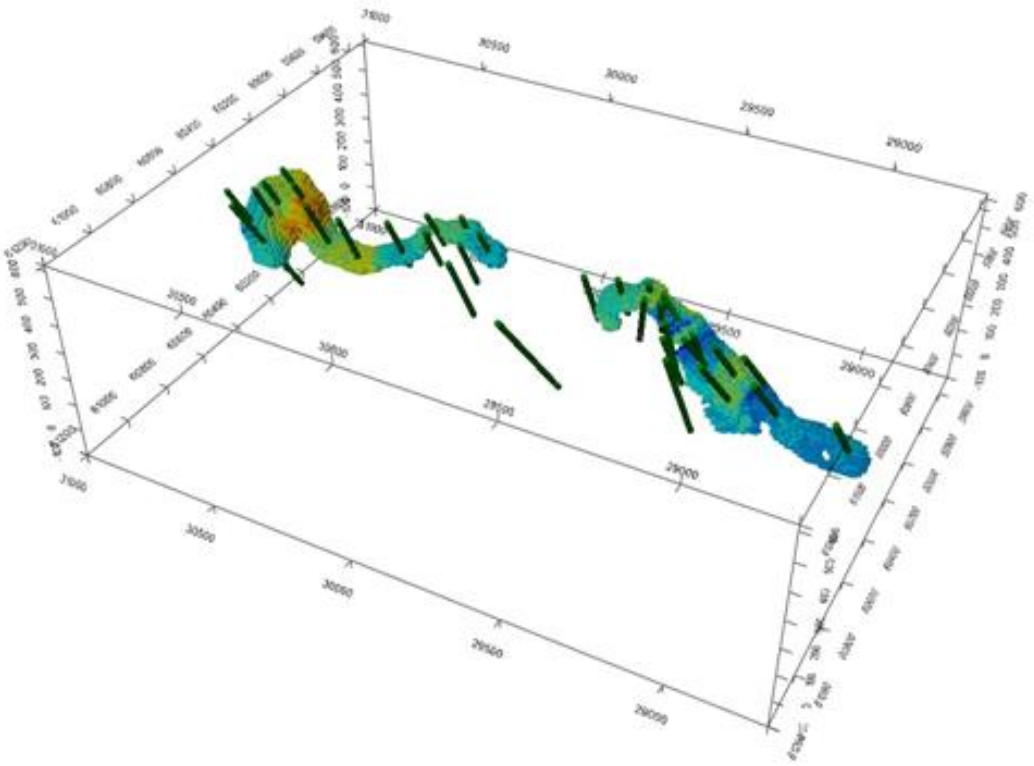
Basil Initial Property Model

- Defined by Domain Kriging along “Ribbon” Trends
- Better Estimate of Initial Susceptibilities



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Pre-Inversion Checklist

- Build models preferably in 3D
- Use available Geological Observations, Geophysical Inferences and Drillhole log interfaces to build Lithology Model
- Rank your input data
- Statistically characterise your formation data, regularise downhole measurements
- Use Geostatistical Interpolation of log data to generate 3D Property models
- Pre-condition geophysical and elevation data. This may include:
  - Terrain corrections for gravity or gravity gradiometry
  - Regional-Residual separation at model scale
  - Smoothing, resampling or upward continuation
- Scenario Testing
- Targeting of short and long wavelength-features to be resolved
- Don’t expect it to work the first time!!!

Press Go!!!

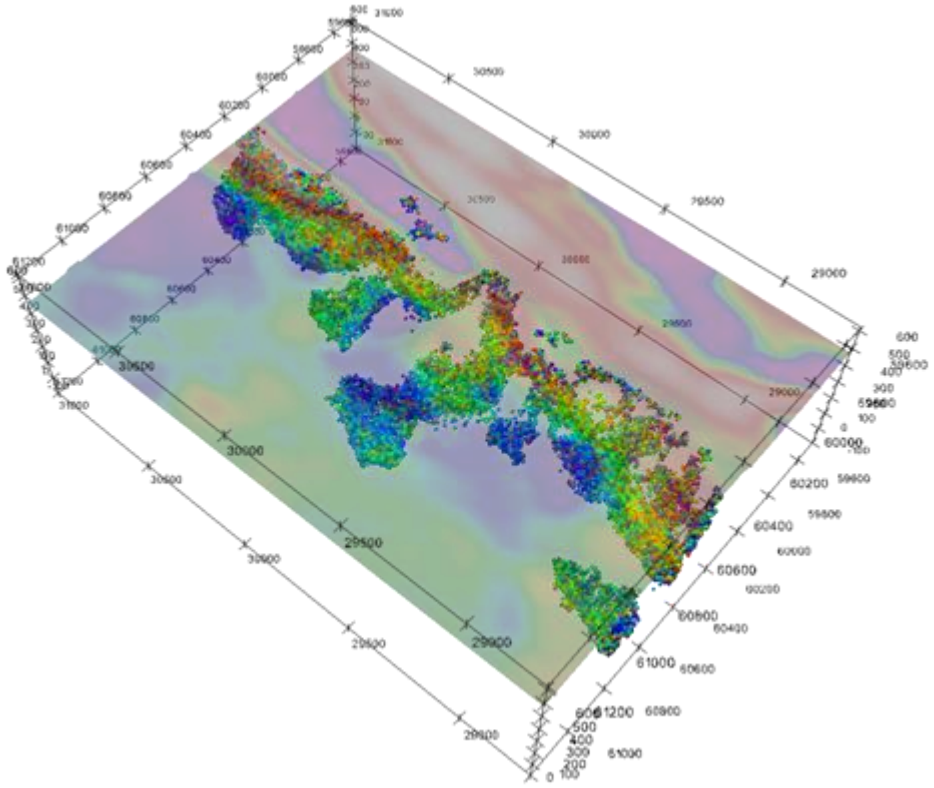
- GeoModeller stochastic 3D Inversion uses optimised prediction processes based on PropertyLaws
- At each iteration, changes made to either Lithology or Property
- Geometrical conditions are imposed by a priori grid/model parameters
- Also user defined geometrical parameters

Press Go!!!

- The model will optimise the Misfit between Observed and Computed Field for each voxel and sums the effects for all iterations
- After the Misfit reaches a critical threshold above the data error, iterations continue in a steady state fashion
- A statistical distillation is then made of the best solutions
- In this case, Reduced-To-Pole magnetics was used due to local coordinate conventions
- 2,185,000 cells at 10x10x10m
- 10,000,000 iterations of run in ~4 hours

Basil Inversion Model

- Inversion performed in successive runs
- Property Only
- Lithology + Property
- Final reflects magnetics and sheet geometry
- Not without flaws - untested



Basil_propmovie2.wmv

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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

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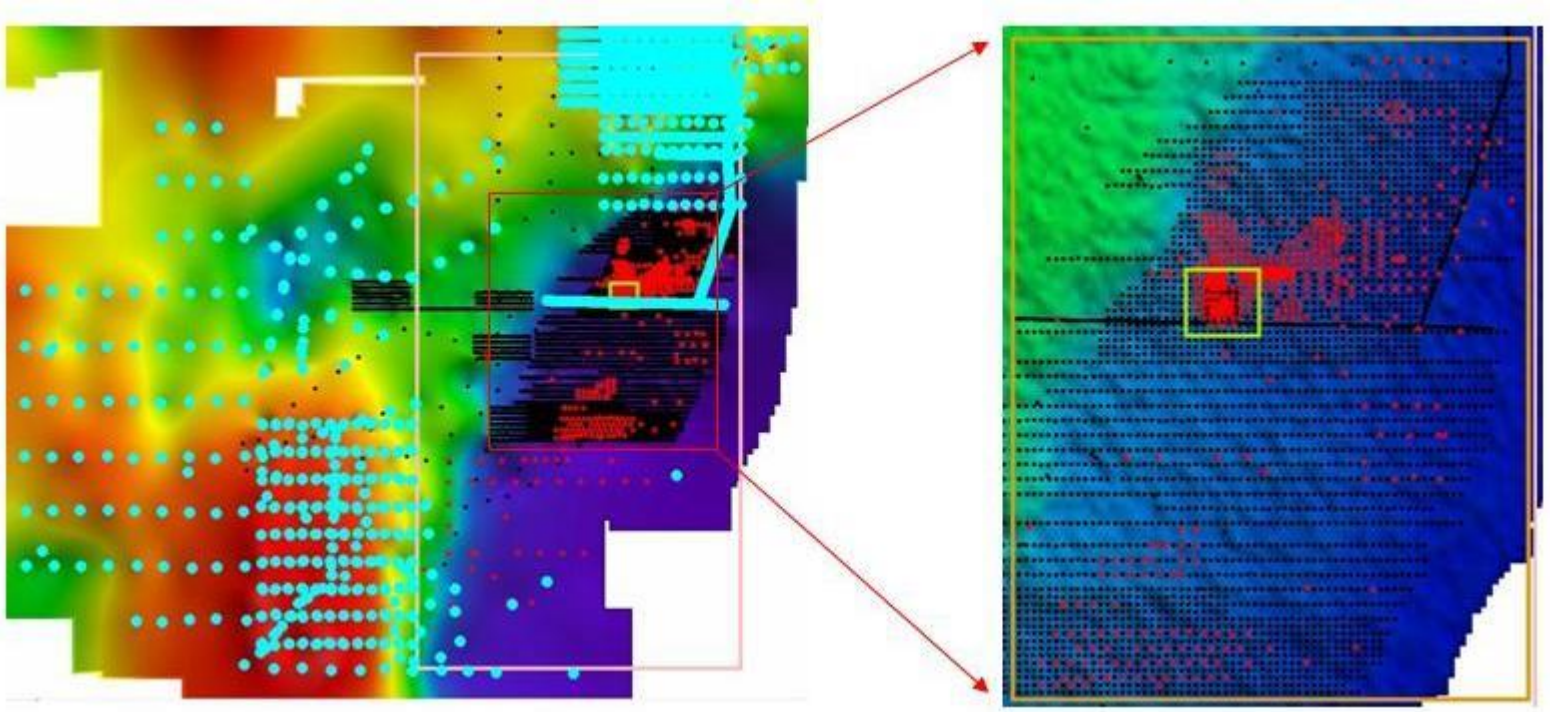
Bouguer Gravity Anomaly Map



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

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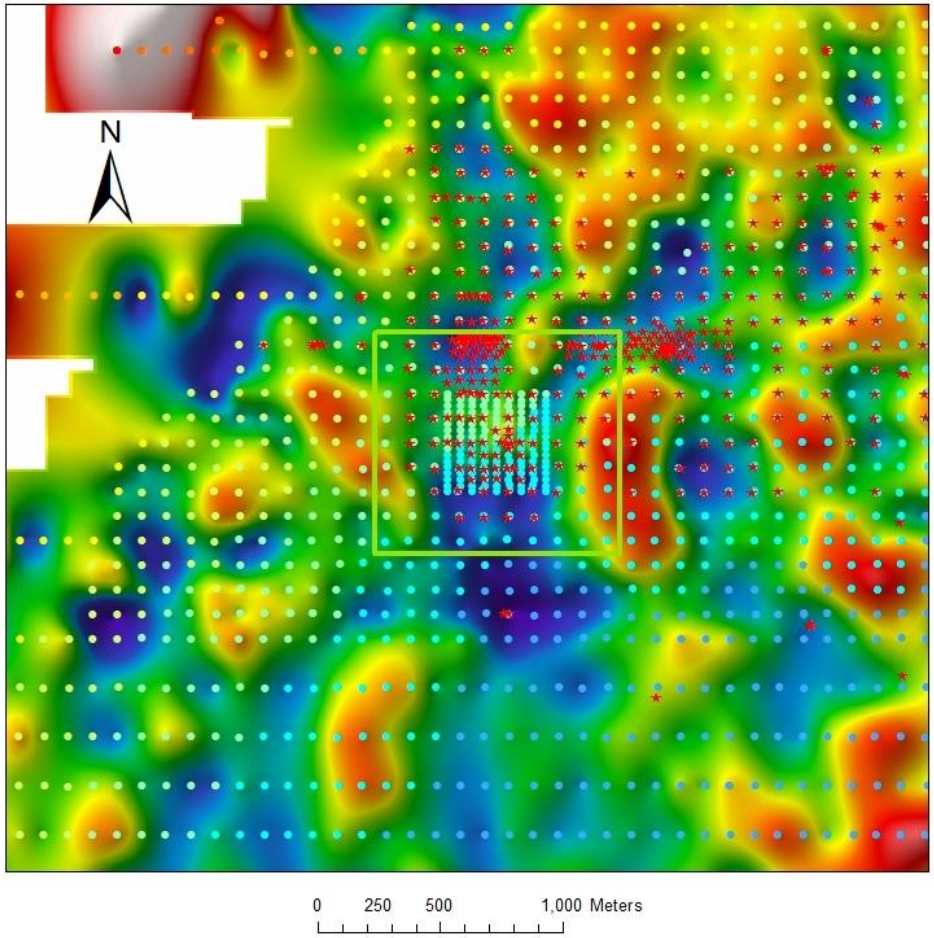
Residual Gravity Anomaly Map

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



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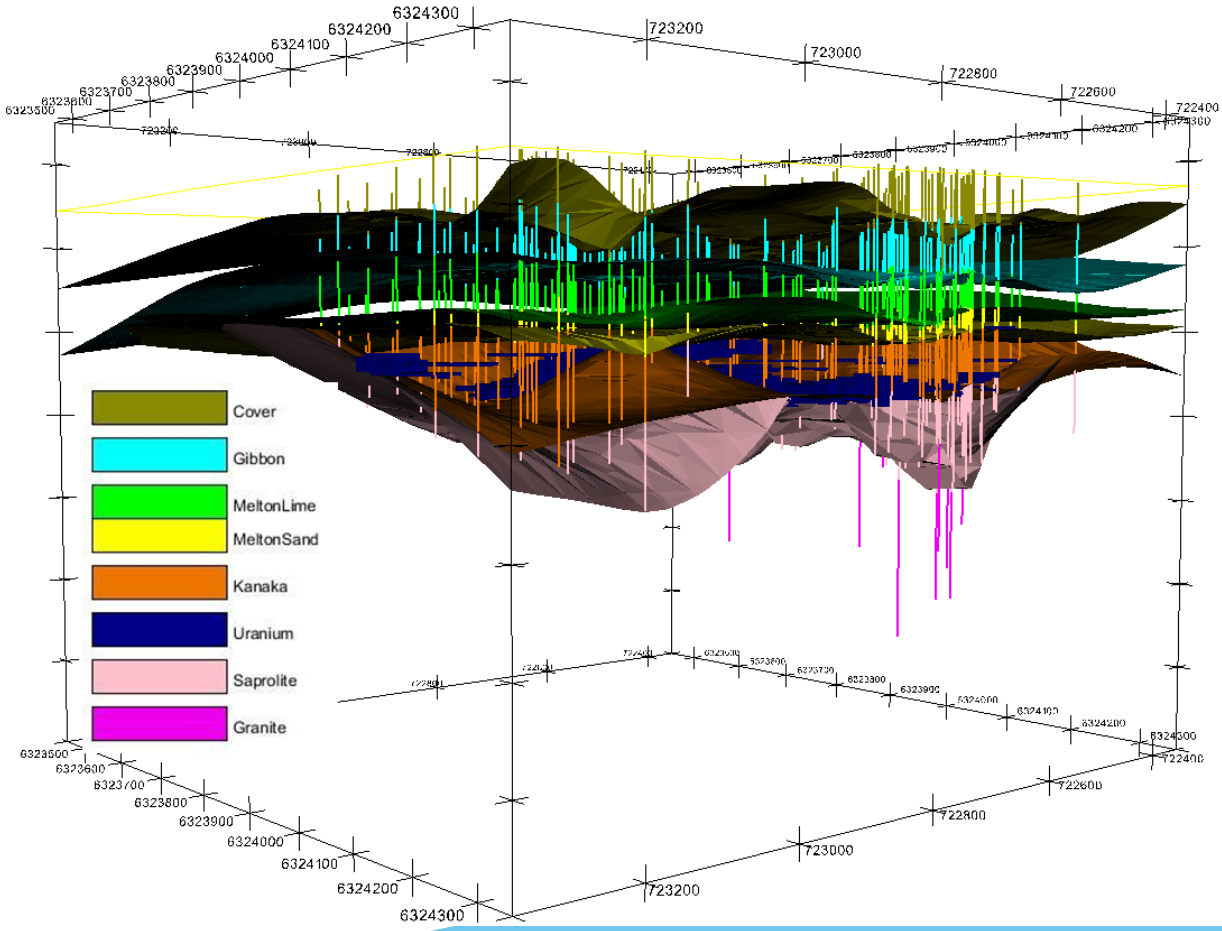
3D Geological Model from Drilling

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



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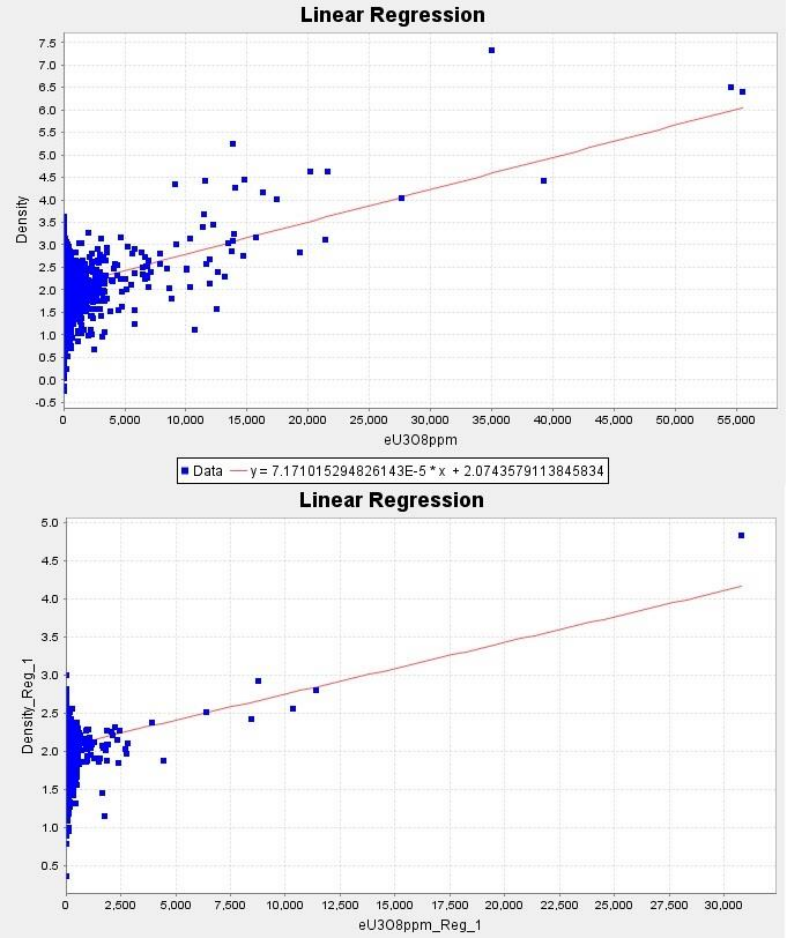
Downhole Density and Uranium Logs

- 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



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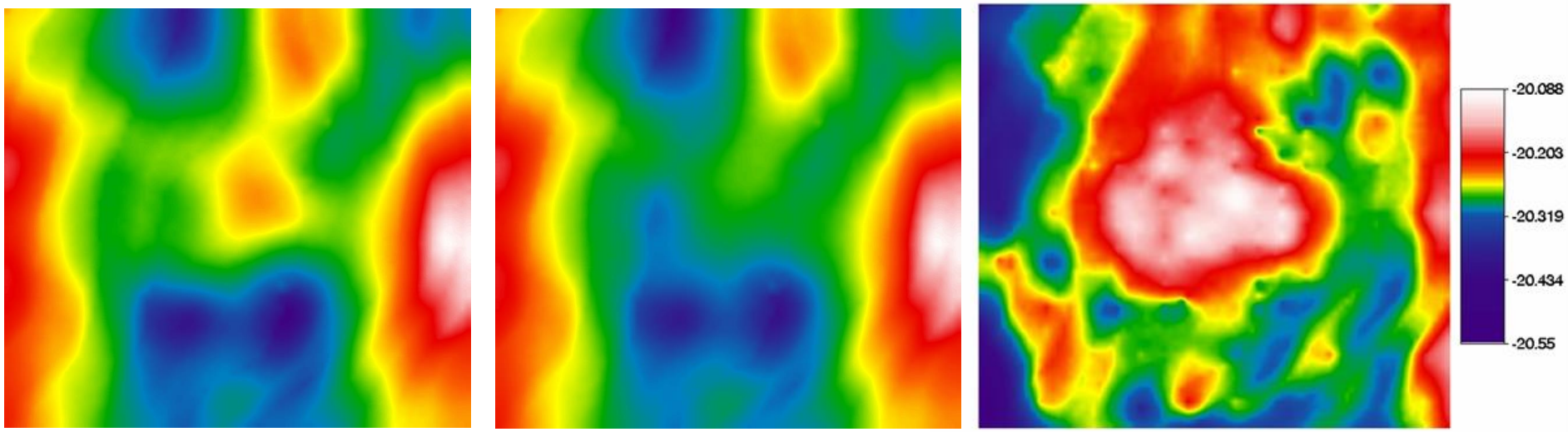
Bouguer Gravity Response Grids



Observed Bouguer Gravity

3D Forward Bouguer Gravity

Misfit or Residual Bouguer Gravity

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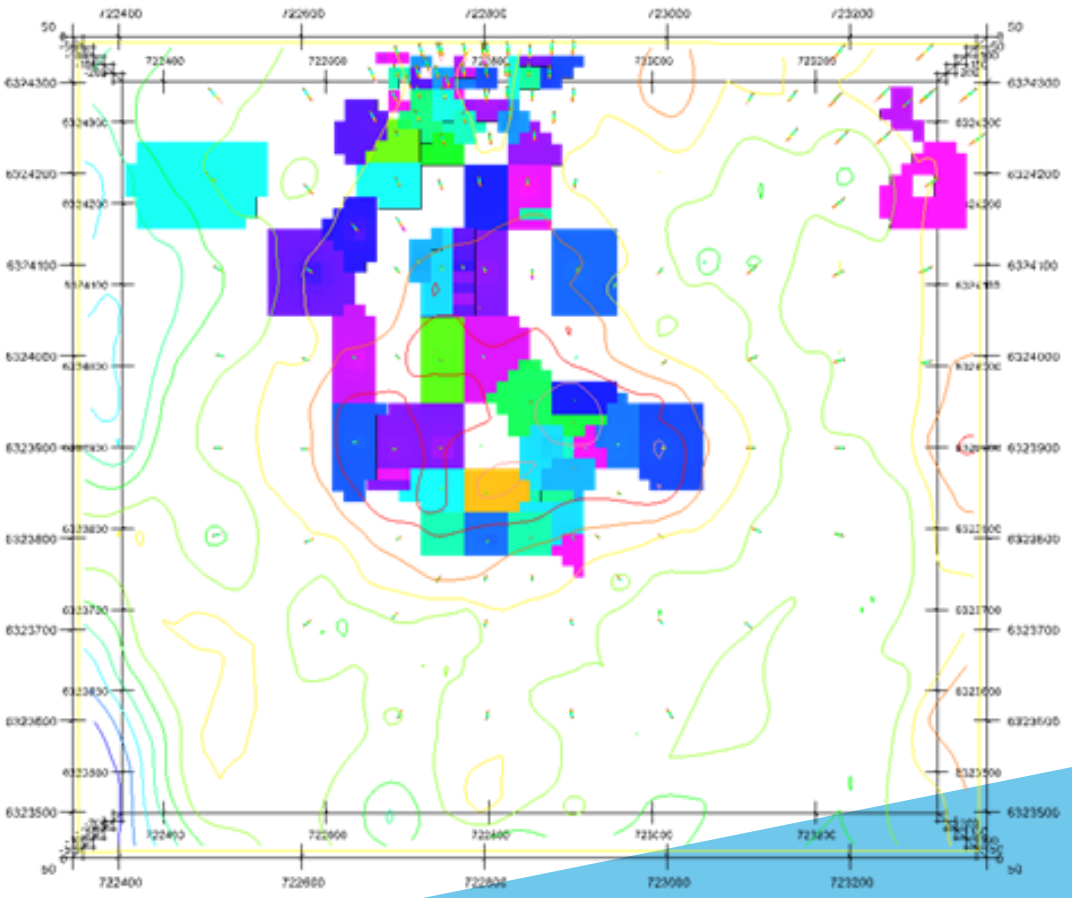
Kriging of Uranium Logs Pre-Inversion

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



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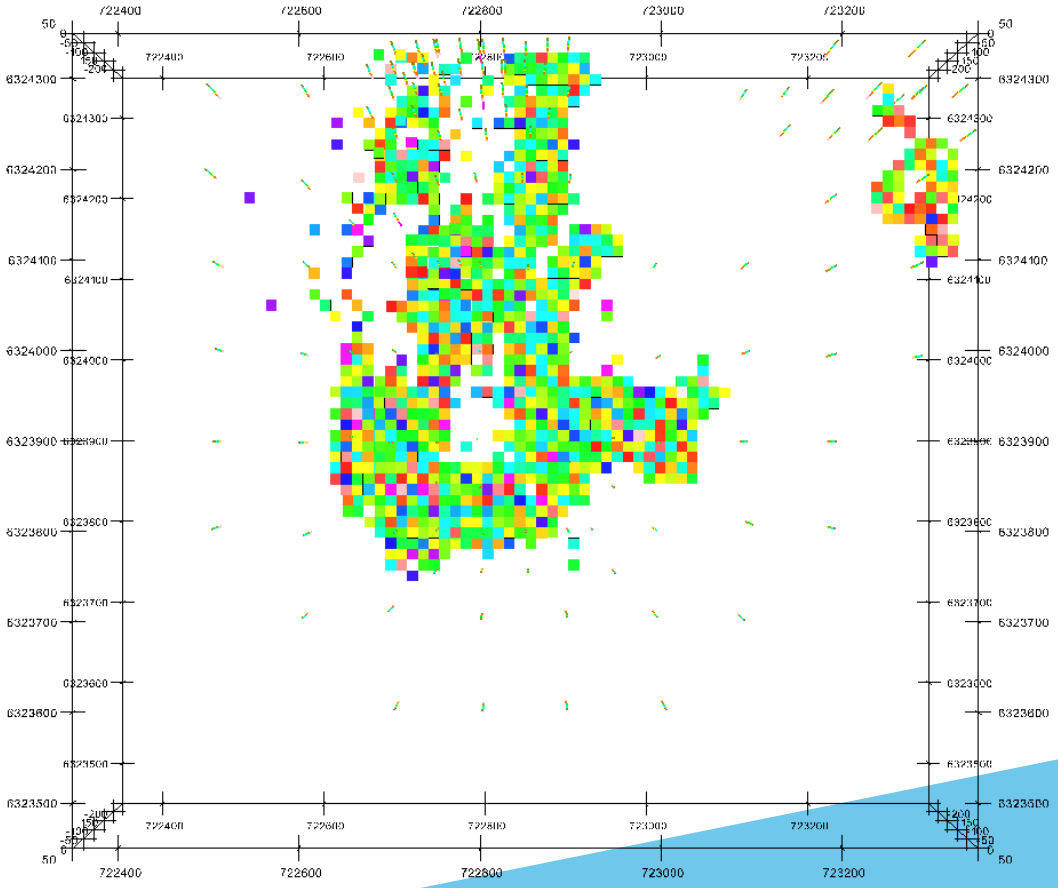
Uranium Distribution following Inversion

- Inversion run on 12.5x12.5x1m grid
- 1,440,000 cells
- Redistributed Uranium constrained by both drilling and gravity response



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Conclusions and Recommendations

- Using Geostatistical Interpolation 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!!!!
- USE your drilling logs!!!

Conclusions and Recommendations

- Initial Model is Driving Constraint
- Physical property model may imply the lithology
- Result from Blackbush has illuminated a potential exploration technique using gravity and pattern drilling together
- Final 3D model for Blackbush Deposit after inversion is being explored for structural behaviour to aid further drilling
- These inversion techniques will lead to more robust constrained pathways.

Acknowledgments

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- Thanks to Mithril Resources, Uranium SA and Intrepid Geophysics for permission to publish these studies
- Thankyou for your attention!!!

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