Interpretation of Downhole Physical Property Logs

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Workshop 8: "Improving Exploration with Petrophysics: The Application of Magnetic Remanence and Other Rock Physical Properties to Geophysical Targeting"
Density Prediction from Multi-element Geochemistry data

Case Study

Denison Mines Wheeler River
Project Objective

- Build a density model for input to a constrained gravity inversion.
  - 35 boreholes with downhole density measurements
  - 716 boreholes with multielement geochemistry data
  - Can we successfully apply a predictive analytics (ML) to leverage / extract value from existing data?
  - Accurate predictive models would significantly improve the understanding of density distribution across the deposit, without the requirement or cost of acquiring additional density data.
Project Location

- Wheeler River property is located along the eastern edge of the Athabasca Basin in northern Saskatchewan
- 35 km north-northeast of the Key Lake mill
- 35 km southwest of the McArthur River uranium mine
- The Wheeler River property is host to the Phoenix uranium deposit and the Gryphon uranium deposit, discovered in 2008 and 2014, respectively.
Dataset Overview

- **Boreholes**
  - 716

- **Datasets**
  - Multielement Geochemistry
    - 251 Boreholes | Old Lab Method (3A_ICP)
    - 465 Boreholes | New Lab Method (3A_ICP,3AMS)
  - Downhole Density (DGI Geoscience)
    - 35 Boreholes
Dataset Overview

- 716 Boreholes
Dataset Overview

- **Boreholes**
  - 716

- **Datasets**
  - Multielement Geochemistry
    - 251 Boreholes | Old Lab Method (3A_ICP) (64 element)
    - 465 Boreholes | New Lab Method (3A_ICP,3AMS) (64 element)
  - Downhole Density (DGI Geoscience)
    - 35 Boreholes
Dataset Overview

- Multielement Geochemistry
  - 251 Boreholes | Old Lab Method (3A_ICP)
  - 465 Boreholes | New Lab Method (3A_ICP, 3AMS)
Dataset Overview

- Multielement Geochemistry
  - 251 Boreholes | Old Lab Method (3A_ICP)
Dataset Overview

- Multielement Geochemistry
  - 251 Boreholes | Old Lab Method (3A_ICP)
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Dataset Overview

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  - 251 Boreholes | Old Lab Method (3A_ICP)
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Dataset Overview

- **Boreholes**
  - 716

- **Datasets**
  - Multielement Geochemistry
    - 251 Boreholes | Old Lab Method (3A_ICP)
    - 465 Boreholes | New Lab Method (3A_ICP,3AMS)
  - **Downhole Density (DGI Geoscience)**
    - 35 Boreholes (15 – Old Geochem, 18 New Geochem, 2 – No Geochem)
Dataset Overview

- 716 Boreholes
Dataset Overview

- Downhole Density (DGI Geoscience)
  - 35 Boreholes
Dataset Overview

- Downhole Density (DGI Geoscience)
  - 35 Boreholes (smoothed using a robust locally weighted regression method)
Dataset Overview

- Downhole Density (DGI Geoscience)
  - 35 Boreholes (15 – Old Geochem, 18 New Geochem, 2 – No Geochem)
Merge Datasets

- All data sets QA/QC’d, with problem data omitted or corrected
- Collocated density and geochemistry data was merged together for use with machine learning.
- Median smoothed density value was calculated for each geochemistry interval.
Machine Learning Strategy

- Train two sets of machine learning models:
  - 251 Boreholes | Old Lab Method (3A_ICP)
  - 465 Boreholes | New Lab Method (3A_ICP,3AMS)

Geochemistry + Lithology Domain

ML Model Training
Machine Learning Strategy

- Machine Learning Algorithms
  - Linear
  - Bayesian Ridge
  - K Nearest Neighbors
  - Support Vector Machine
  - Random Forest
  - Xtreme Gradient Boosting
Model Evaluation

The diagram shows the cross-validation scores for various model types: Linear, Bayesian Ridge, K Nearest Neighbour, Support Vector Machine, Random Forest, and Xtreme Gradient Boosting. The scores are compared between an 'Old Dataset' and a 'New Dataset'. The models are evaluated based on their mean squared error.
Model Evaluation
Model Evaluation
Model Evaluation

Old Geochemistry

New Geochemistry

Predicted Density, gcc

Measured Density, gcc

Predicted Density, gcc

Measured Density, gcc
Density Prediction

- Predict density on all boreholes where only geochemistry data exists
Density Prediction
Density Prediction

New Geochemistry
Hole ID: WR-681A

Depth m

Prediction Target

Cu ppm    Dy ppm    Er ppm    Eu ppm    Fe2O3 ppm    Ga ppm    Gd ppm    Hf ppm    Ho ppm    K2O ppm    La ppm    Li ppm

Density, g/cm³
Density Prediction

- Downhole Density (DGI Geoscience)
  - 35 Boreholes
Density Prediction

- Density Prediction
  - 251 Boreholes (Old)
Density Prediction

- Density Prediction
  - 465 Boreholes (New)
Density Prediction

- Density Prediction
  - 465 Boreholes (New)
Density Prediction

- Density Prediction
- 716 Boreholes
Density Prediction

- Downhole Density (DGI Geoscience)
  - 35 Boreholes
Density Prediction

- Density Prediction
  - 716 Boreholes
Comparison with Inversion Results

- WR-193 inversion attempts to place a large density layer near surface
- Compensated for by a lower density unit immediately beneath (possible gibb’s effect)
- High density unit placed at or near surface can be attributed to an artifact in the gravity data.
- WR-219, (same area) similar near surface artifact, but no predicted response.
- Provides a means of QA/QC processing to identify what holes may need to be logged for density.
Conclusions

- The density predictions from both new and old geochemistry data correlated well with measured density (hold out data)
- Test results indicate that the predictive models were effective in predicting density from multielement geochemistry
- The predictive models cost effectively improve our understanding of the density distribution across the deposit by leveraging the existing and abundant geochemistry data
- Augmented 35 boreholes of measured downhole density with 681 boreholes of predicted density totaling 716 boreholes of measured + predicted (20x increase) without the requirement or cost to acquire any new data.
- QA/QC work completed by Denison on the geochemistry data has had a very noticeable impact and lead to improved results.
Recommendations

- Conduct a comparative study of gravity inversion results - unconstrained vs constrained with 35 boreholes (measured) vs 716 (measured + predicted).
- Consider evaluating a similar approach with different prediction targets such as resistivity.
- Use prediction results to QA/QC measured density – potentially identify instrument calibration issues.
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