Making the Most out of Downhole Geophysics

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Agenda

1. Who are we?
2. Who am I?
3. Introduction to Downhole Geophysical Tools
4. Primary Uses
5. Unconventional Uses
6. Controlling Risk
7. Quality Control
8. Final Remarks

Who are we?

Listed on both

London Stock Exchange

New York Stock Exchange

40,000
people worldwide

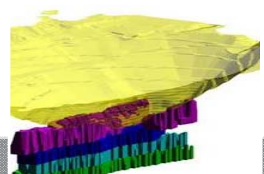
150+
year history
operating in over
50 countries

Market Cap

$6bn

Principal office locations

Environmental



Mining & Geology

Process development

Project delivery

Underground project delivery

Material handling systems

Mining and Metals

Who am I?

- Graduate of the University of Saskatchewan
- 2 years with Cameco Exploration
- Geologist at Grande Cache Coal 2009-2011
  - Exploration management
  - Open pit and underground support
  - Geological modelling and resource estimation
- Geologist at Amec Foster Wheeler (2012-present)
  - Involvement with greenfields and brownfields coal projects throughout BC, AB, and Colombia
  - NI 43-101 and JORC Technical Reports
  - Advance 3D modelling, resource estimation, and exploration management
  - Due Diligence, MRMR Audits, and Process Improvements

Go Riders!

Introduction to Downhole Geophysical Tools

The Big 7 and Small 2

The Big 7

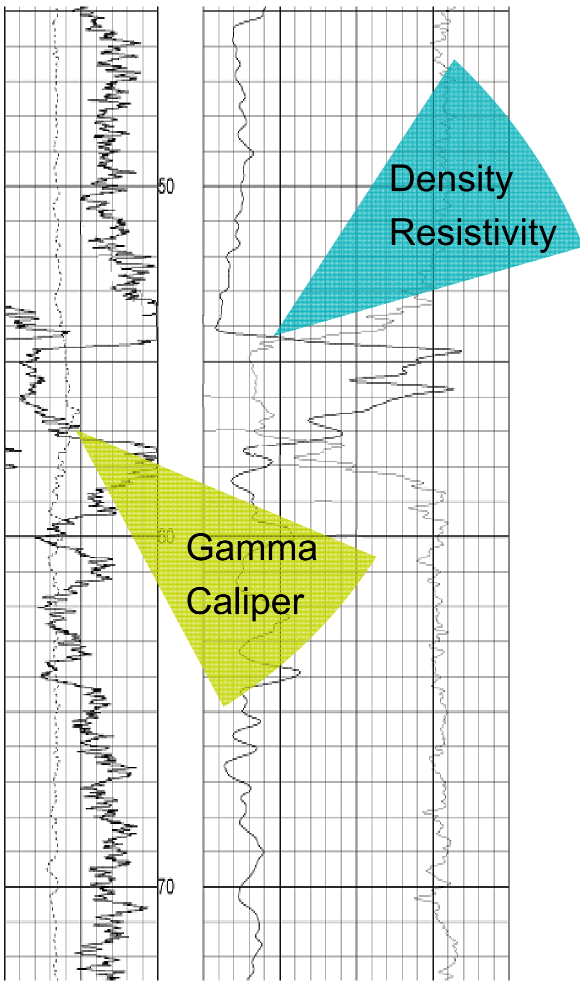
- Used in grassroots and brownfield operations.
  - Gamma Ray
  - Resistivity
  - Compensated Density
  - Dipmetre
  - Hole Deviation
  - Caliper
  - Neutron

The Small 2

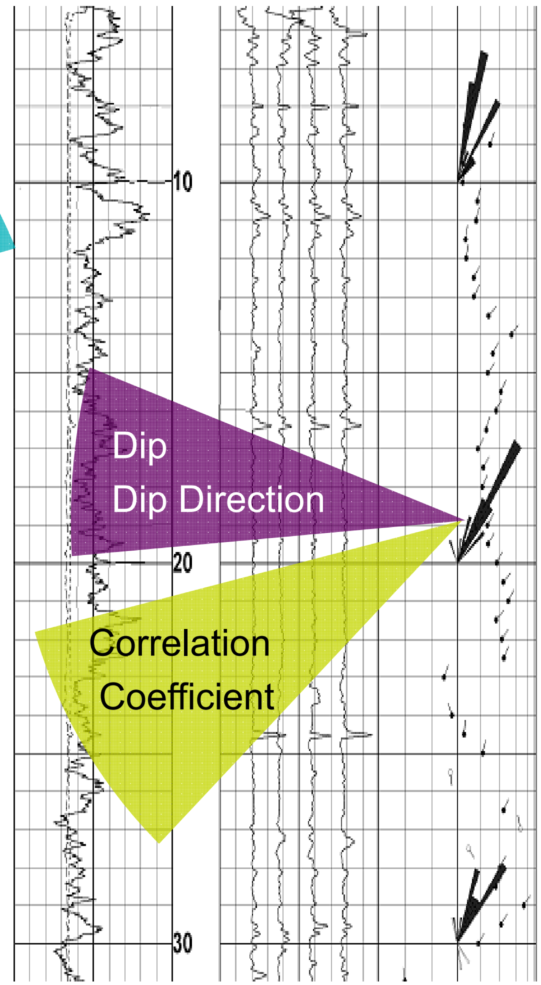
- Commonly used in advanced projects
  - Acoustic/Optical Televiewer
  - Sonic Tool

The Big 7

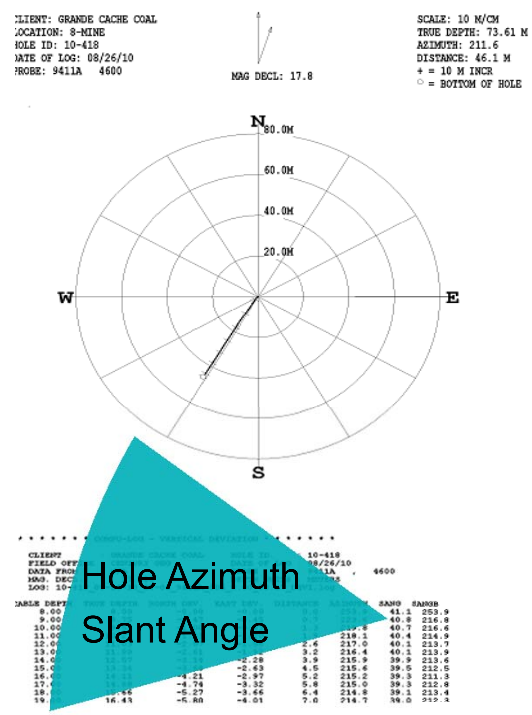
GRDC log



Dipmetre log

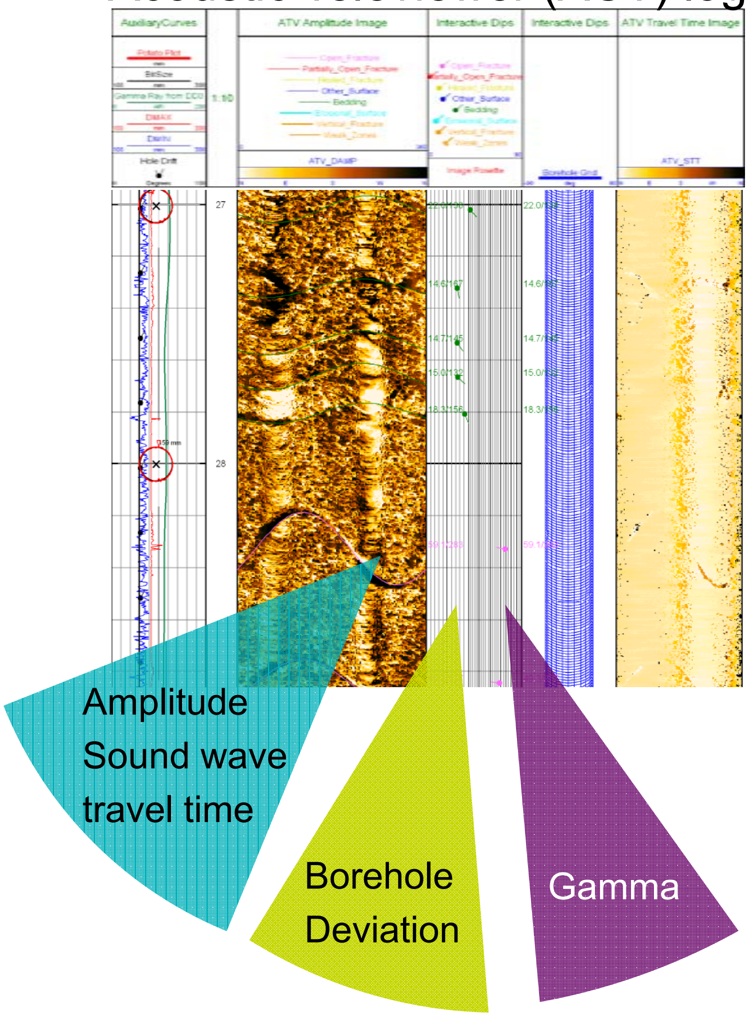


Deviation log

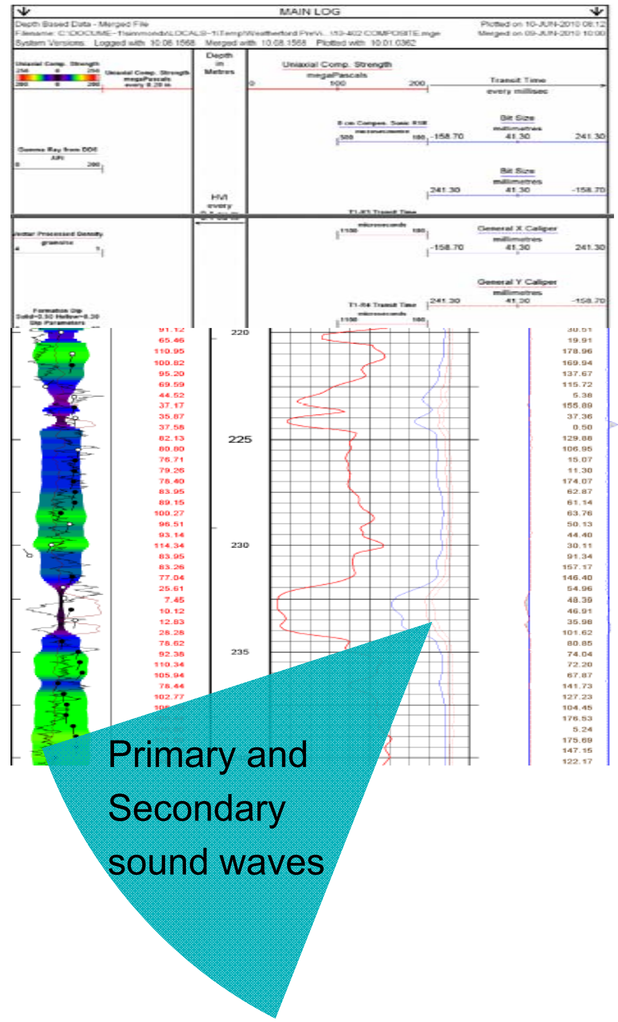


The Small 2

Acoustic Televiewer (ACT) log



Sonic log



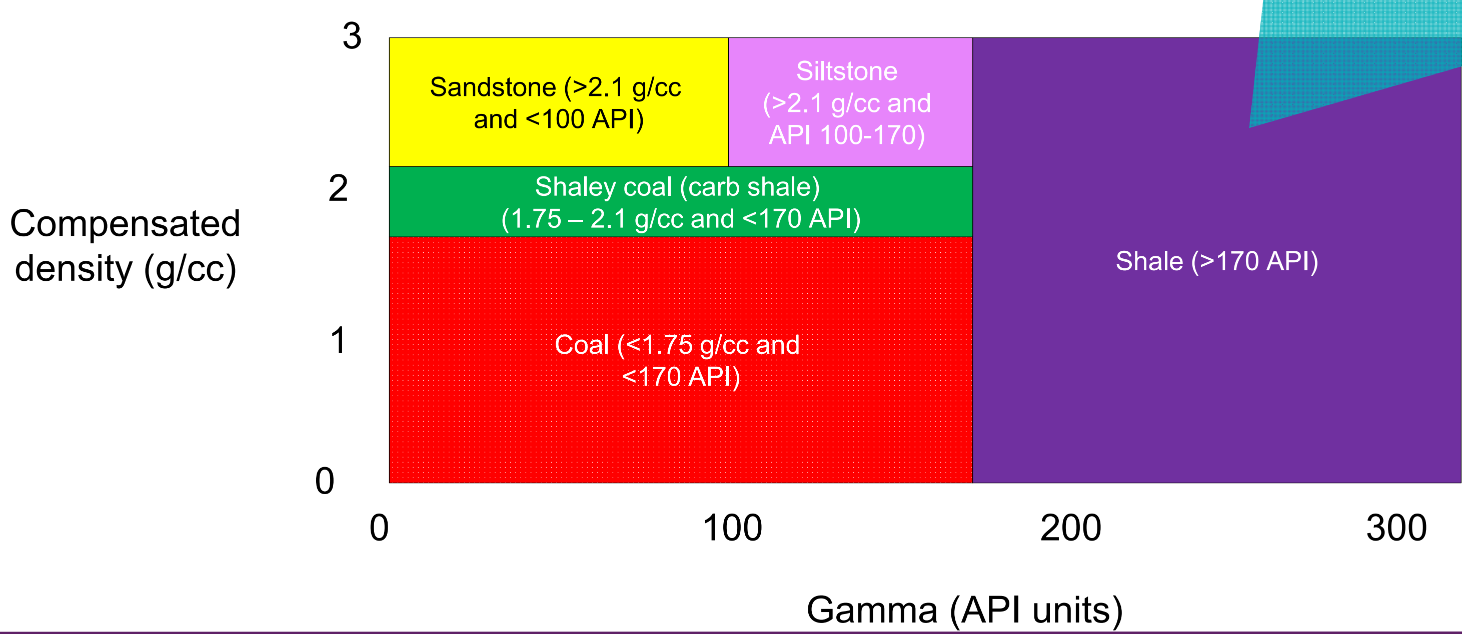
Primary Uses of Geophysical Data

Lithology Determination

GRDC log can be used for:

- Coal seam signatures and correlation
  - Thickness and position downhole
- Lithology type

Automatic lithology determination

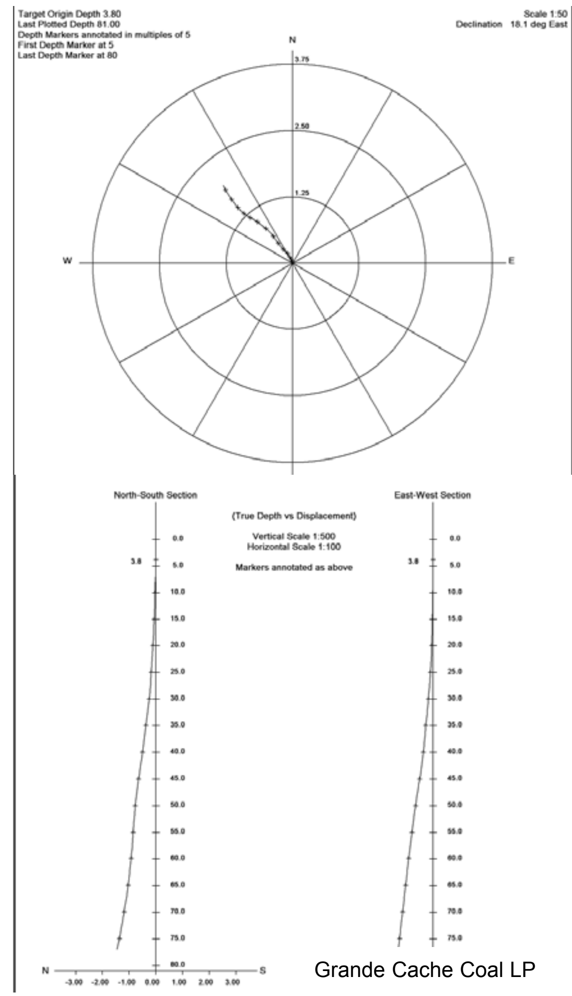


Drillhole Deviation

Determines borehole orientation

- ► Magnetic tools
  - ► Cost effective but less accurate
  - ► Open hole - magnetic declination
  - ► Recommended for open-pit applications

- ► Gyro tools
  - ► Costly but most accurate
  - ► Thru-pipe
  - ► Recommended for underground applications

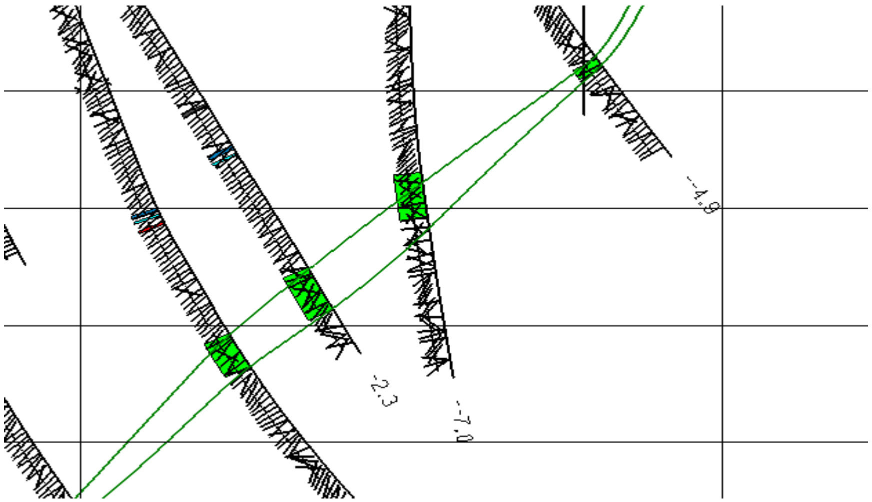


Grande Cache Coal LP

Dipmeter

Provides downhole structural measurements

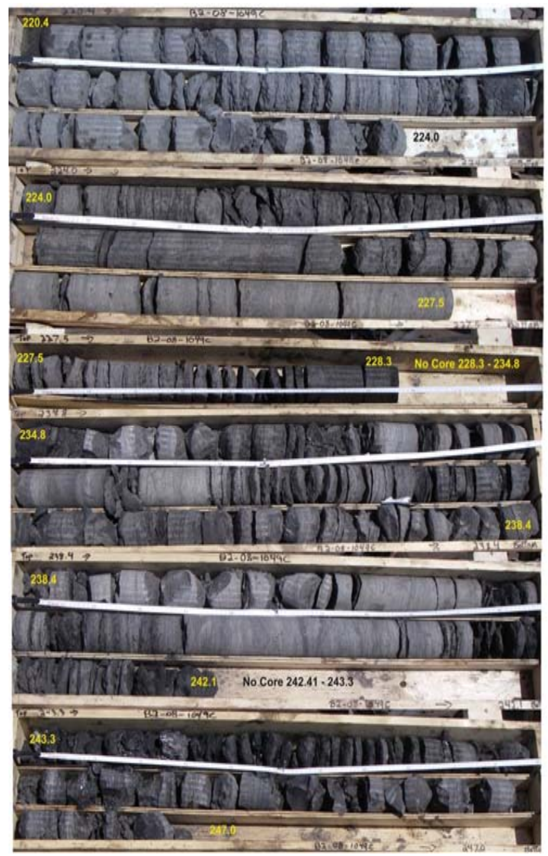
- ► Develop the geological model
- ► Interpreting data/tadpoles
  - ► Bedding
  - ► Anticline and synclinal structures
  - ► Faults

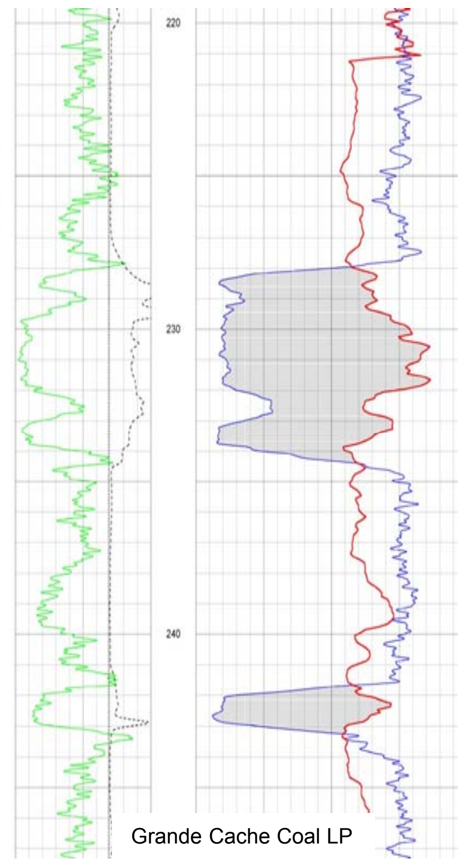


Coal Quality

Downhole geophysics and coal quality

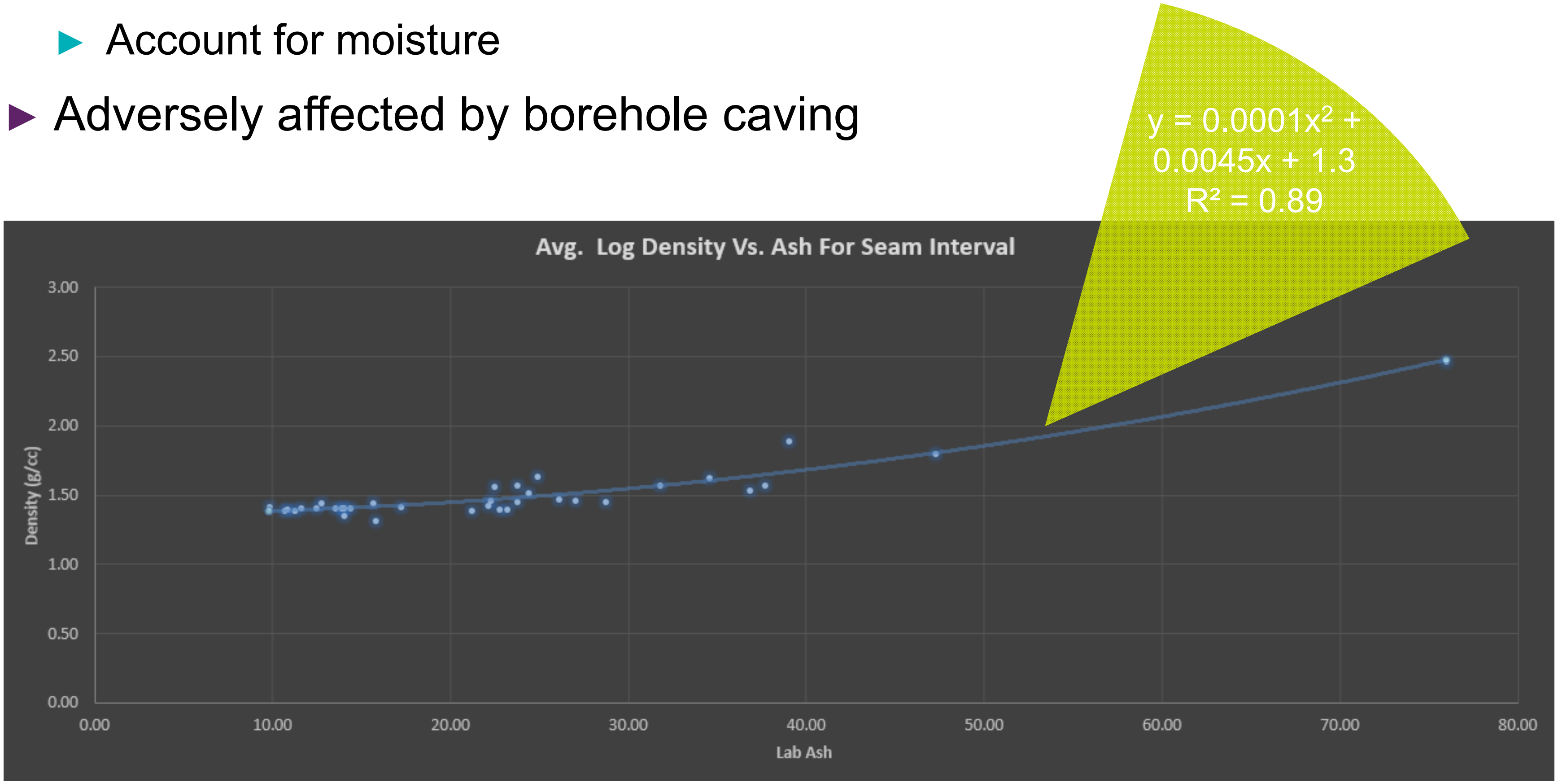
- Reconcile sampled intervals and position downhole
- Calculate core recovery
- Calculate predicted ash content from regression formula to validate samples





Coal Quality

- ▶ Calculating ash content using compensated density
  - ▶ Regression formula derived from site coal quality samples
  - ▶ Account for moisture
- ▶ Adversely affected by borehole caving



Unconventional Uses of Geophysical Data

Leading Edge Uses

Coal Fines – Case Study

- ► Increased fraction of coal delivered to the fines circuit
  - ► Mining method
  - ► Coal handling
  - ► Coal properties

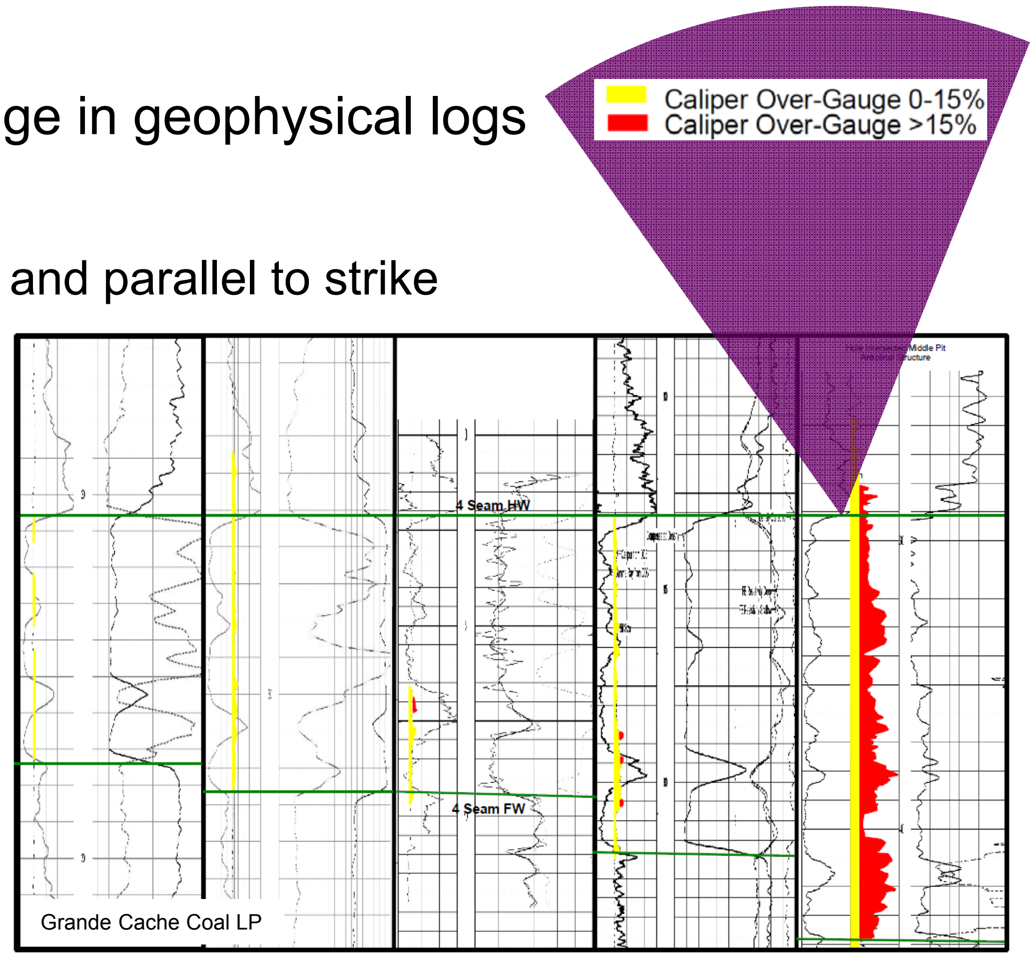
- ► Qualifying the issue
  - ► Fast turnaround
  - ► Use existing data

  - ► Caliper measures borehole diameter, potential to use as a proxy

Leading Edge Uses

Coal Fines – Case Study

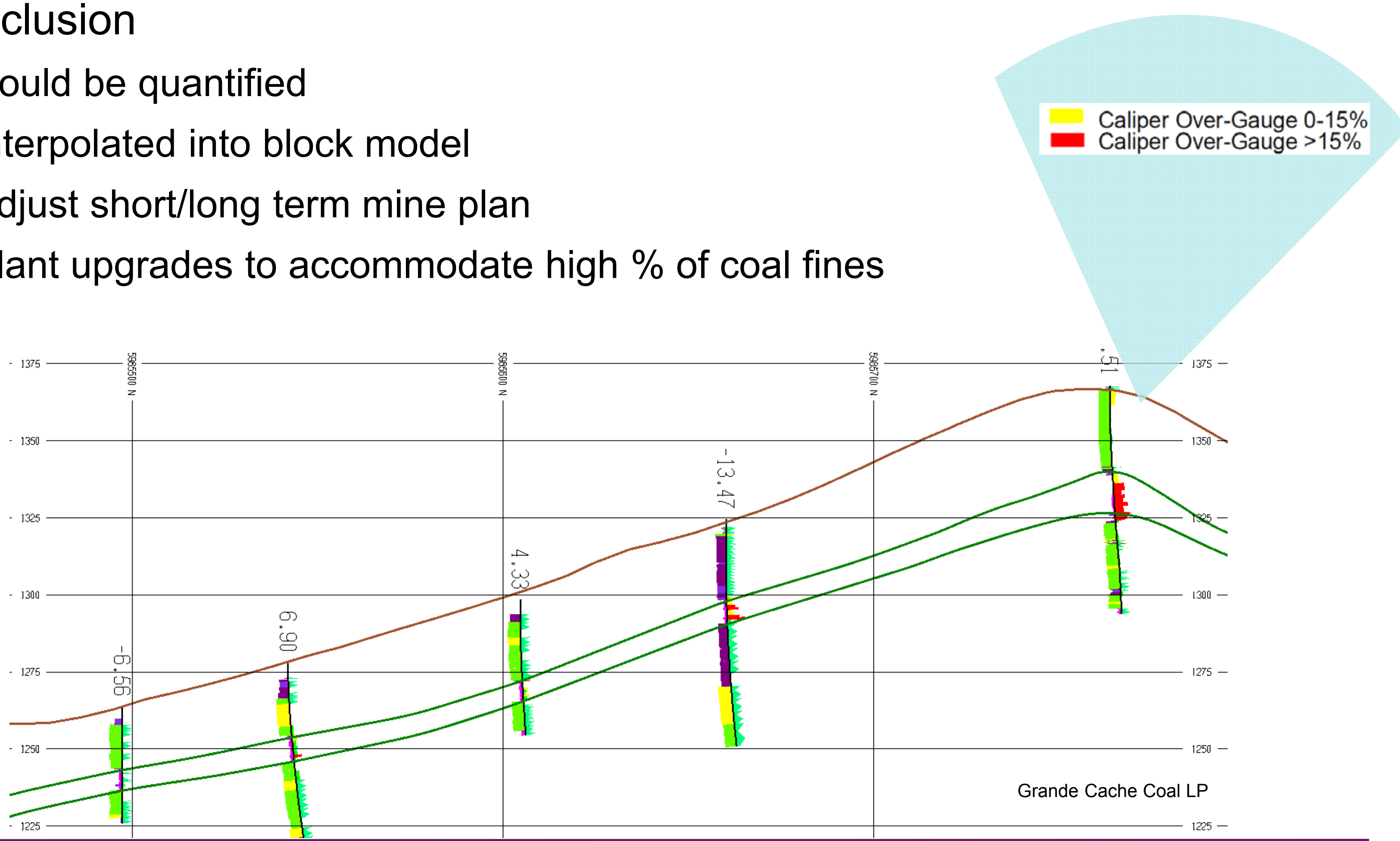
- Analyzed borehole over-gauge in geophysical logs
  - Segregated data by pit
  - Analyzed logs perpendicular and parallel to strike
- Limitations
  - Core hole vs RC hole
  - Depth and dip of coal seam
- Structurally controlled
  - Faulting
  - Flexural flow



Leading Edge Uses

Coal Fines – Case Study

- Conclusion
  - Could be quantified
  - Interpolated into block model
  - Adjust short/long term mine plan
  - Plant upgrades to accommodate high % of coal fines



Leading Edge Uses

Geotechnical Considerations – Case Study

- Augment geotechnical confidence in coal mine roof support design
  - Roof bolt length and frequency
  - Fill gaps between core samples

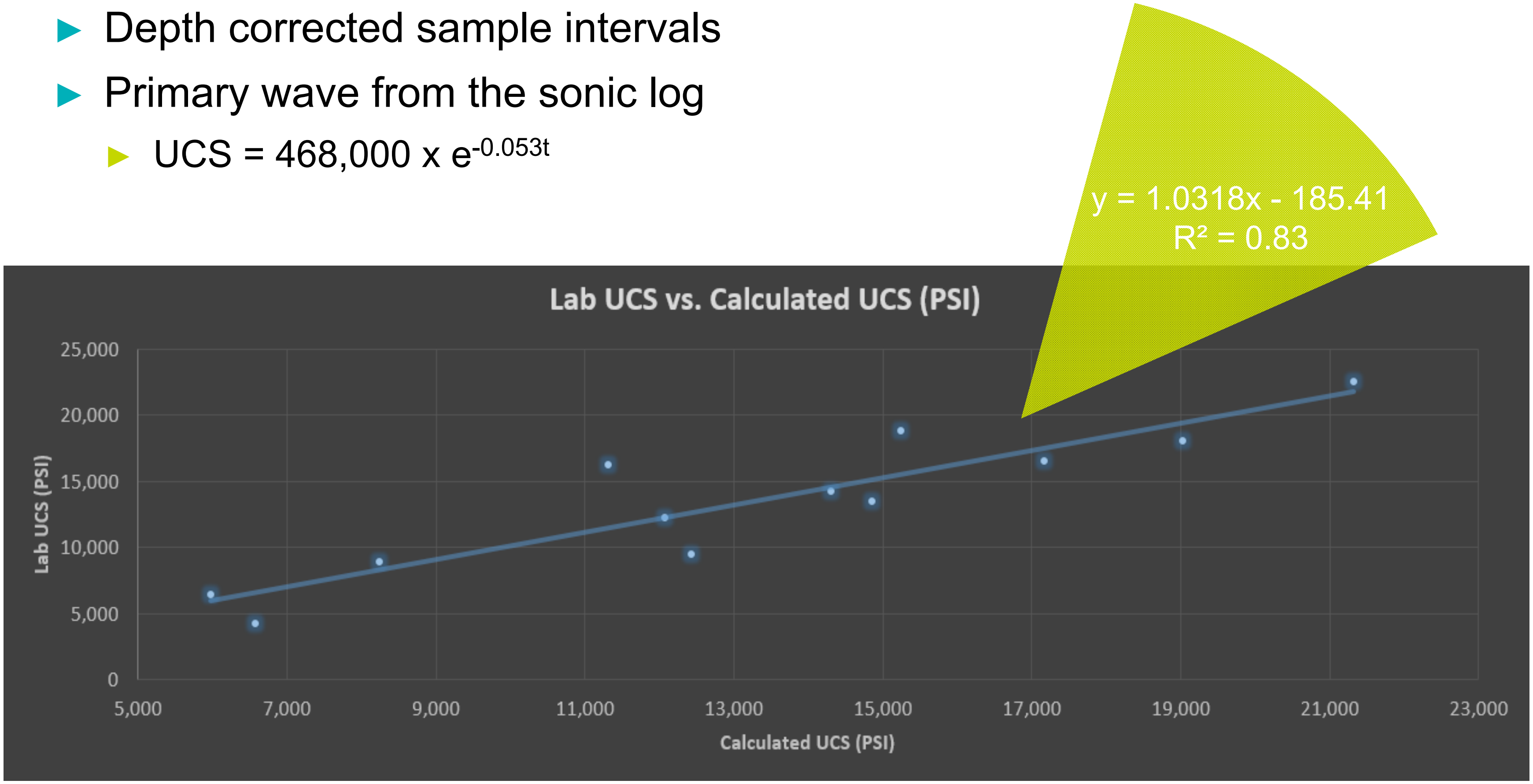
- Use downhole sonic measurements to calculate Uniaxial Compressive Strength (UCS)

- Sonic log is commonly used in Australia and in the Appalachian Mountains
  - “Correlation of Sonic Travel Time to the Uniaxial Compressive Strength of US Coal Measure Rocks”, David Oyster et al.

Leading Edge Uses

Geotechnical Considerations – Case Study

- Modified regression formula using site samples
  - Depth corrected sample intervals
  - Primary wave from the sonic log
    - UCS = 468,000 x $e^{-0.053t}$

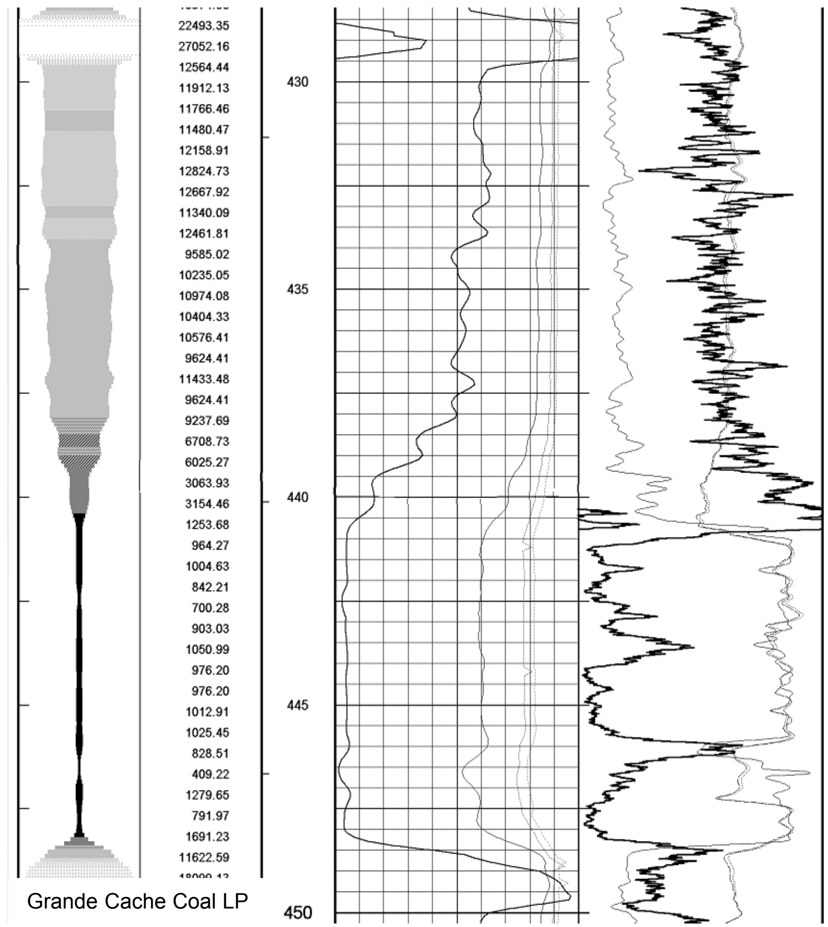


Leading Edge Uses

Geotechnical Considerations – Case Study

- ► Conclusion
  - ► Produced good correlation coefficient
  - ► Improved confidence in roof bolt lengths (1.8 m and 2.4m)
  - ► Incorporated formula within geophysical log prints
  - ► Interpolated into block model

- ► Applicable for pit wall stability analysis
- ► Adversely affected by borehole caving



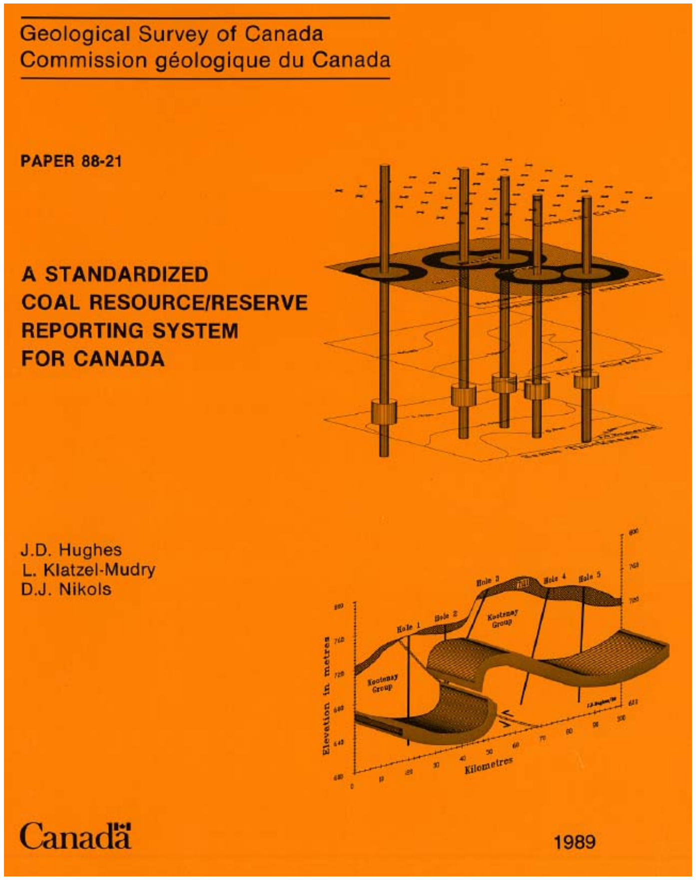
Grande Cache Coal LP

Leading Edge Uses

Resource Classification

- "Assurance of existence categories are intended to reflect the level of certainty with which the quantities are known"
  - Downhole geophysical data is extensively used in reconciling sample intervals

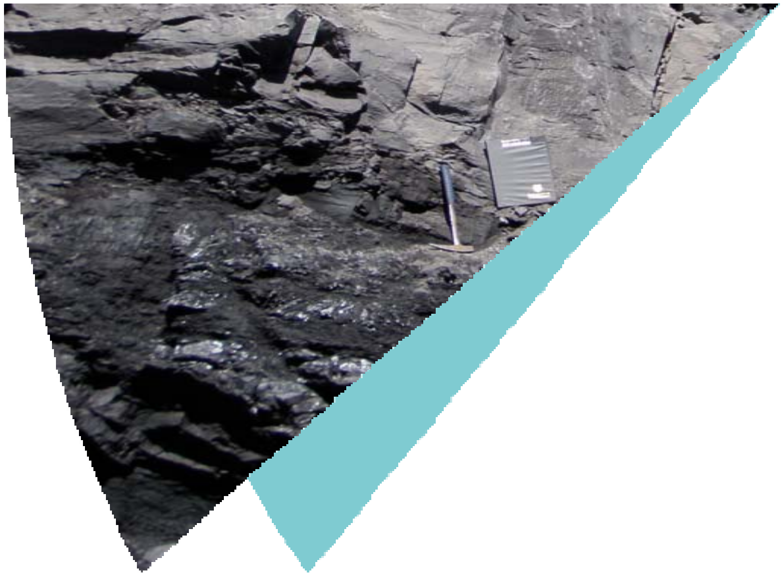
  Should drillholes without geophysics be considered to have the same level of certainty?



Leading Edge Uses

Other Uses

- ► Automatic lithology determination – Blast Optimization
- ► Hydrogen Index Log – Rock quality indices
- ► Density vs Sonic – Coal Rank
- ► Borehole Temp – Artesian zones
- ► Resistivity – Static water depth
- ► Caliper – Oxidation

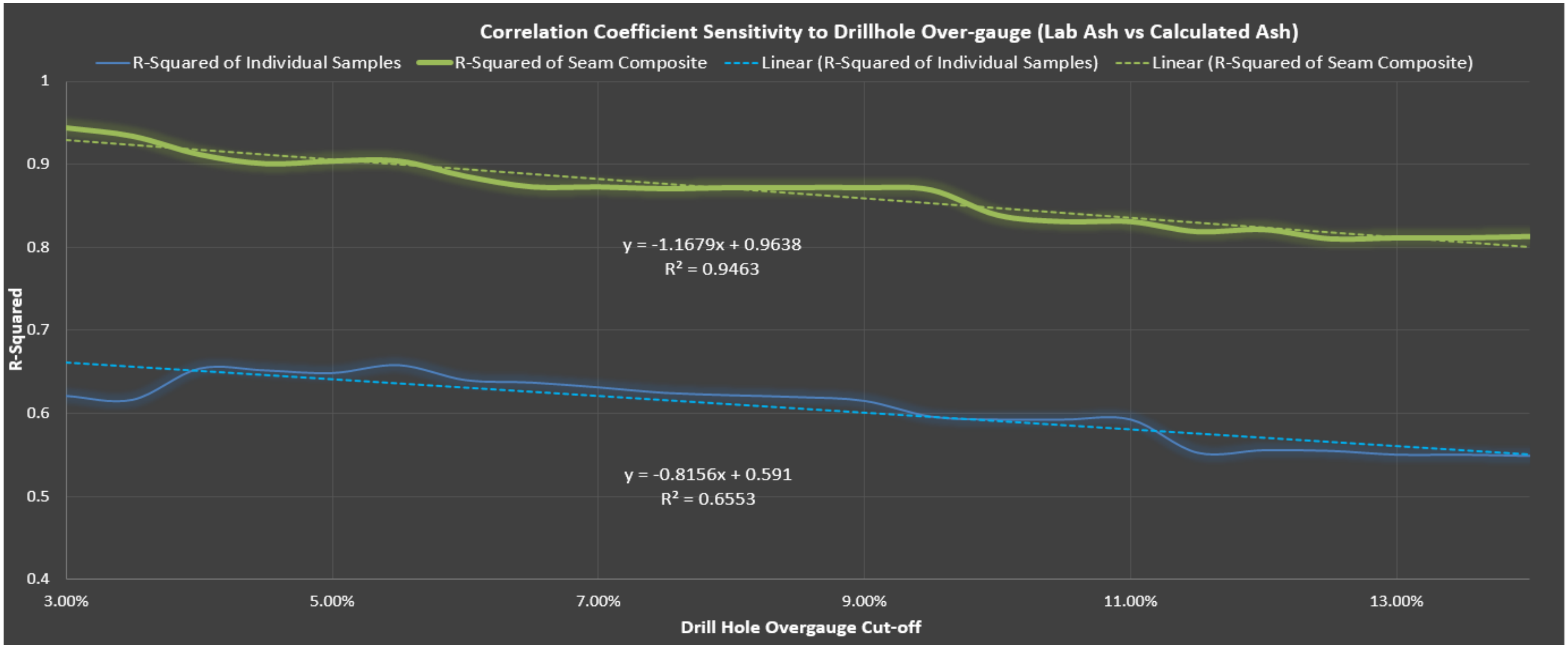


Controlling Risk

Controlling Risk

Importance of considering borehole over-gauge

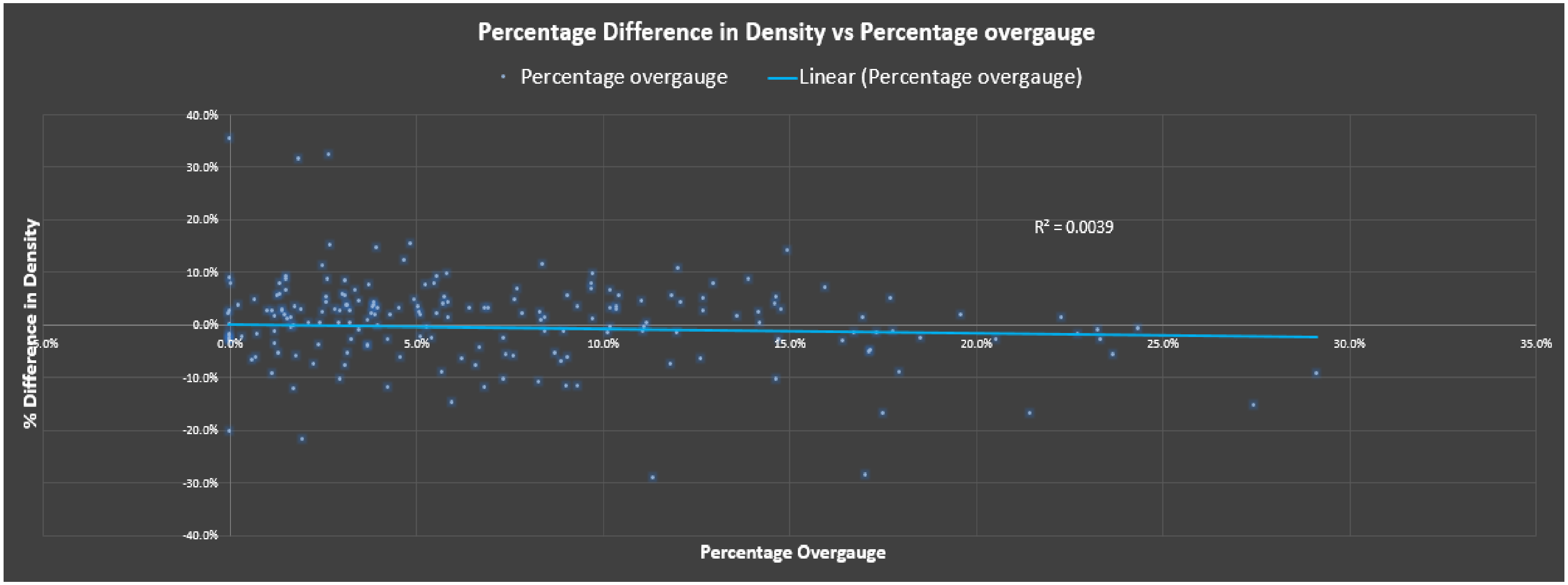
- Recognized as reducing reliability of density readings
  - Can we make a qualified decision?
- Compare calculated ash vs lab ash



Controlling Risk

Importance of considering borehole over-gauge

► Could difference be Improved?



Controlling Risk

Considerations in running downhole geophysics

- Proper sequencing of tools
- Risk and stratigraphy
- Special Considerations
  - Density/Neutron thru drill rods
  - Block bottom of drill string

Quality Control

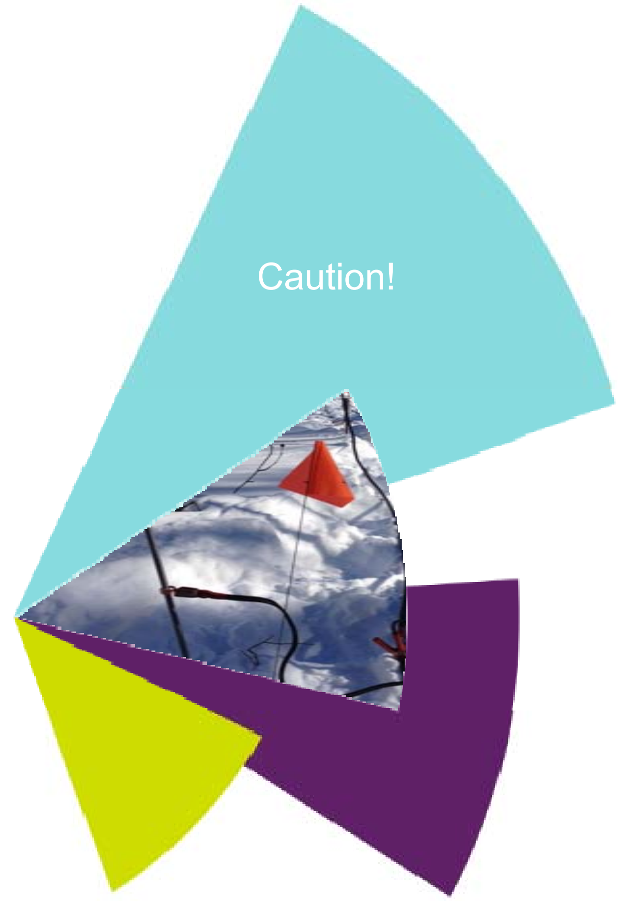
Quality Control

Dealing with large datasets

- Implementing appropriate drillhole database.
  - Aligning to CIM Best Practice Guidelines

Must be supported by laboratory testing

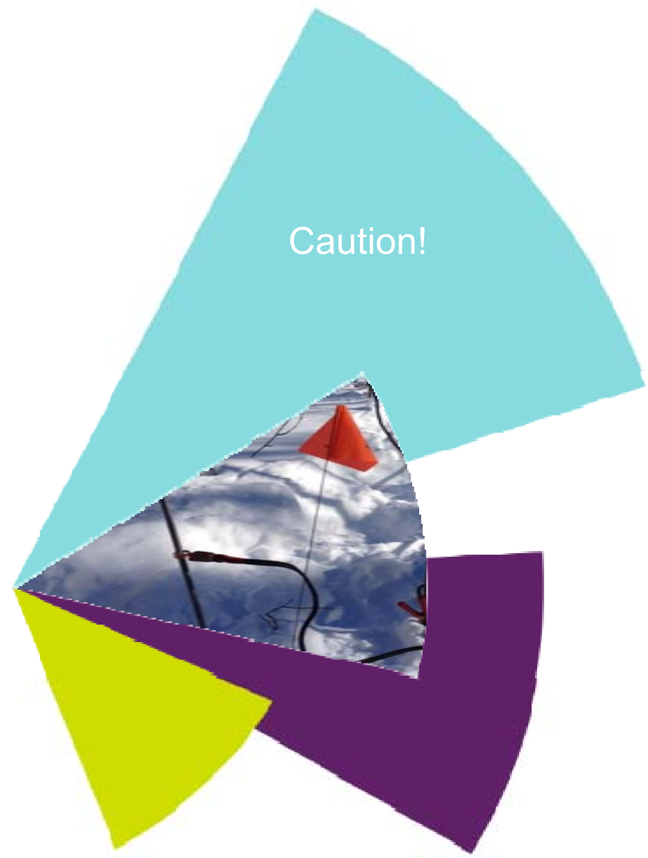
- Sufficient effort undertaken to ensure both the samples and the geophysical data are of high quality and free of errors



Quality Control

Implementing strict quality control procedures

- ► Ensure proper geophysical tool calibration conducted prior to site mobilization
- ► Site calibrations for prolonged exploration programs



Final Remarks

- Downhole geophysics are an integral component in the geological model and resulting mine design
- Strive to obtain the highest quality of data
- Understanding the variables that affect the resource

Thank you

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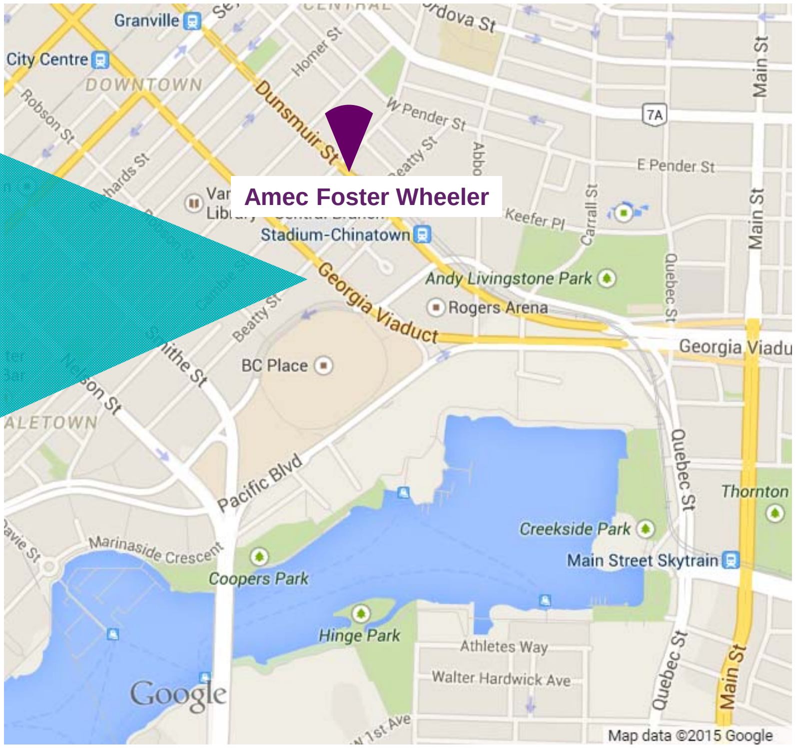

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