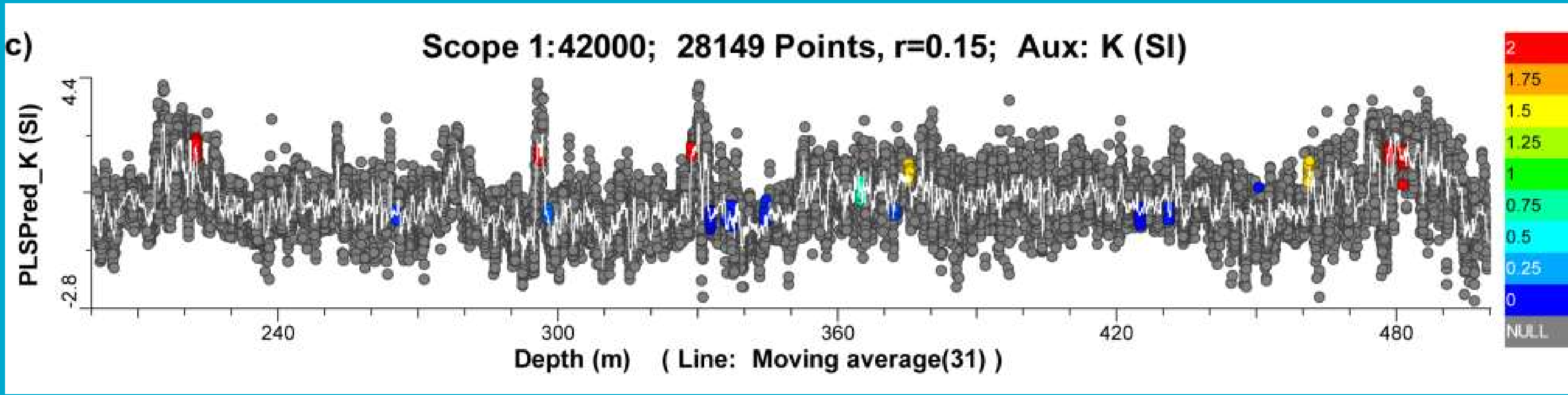

Modelling of petrophysical from hyperspectral drill core data collected from the Osborne Cu-Au deposit, Mount Isa Inlier, Queensland

Carsten Laukamp[1)], Neil Francis[1)], Suraj Gopalakrishnan[2)], Juerg Hauser[1)], Shane Mule[1)]

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12. February 2021 – Session 15.1: Applications of Spectral Geology

Introduction

- Certain proportions of magnetite, sulphide and hematite alteration can be indicative of IOCGs (Hanneson, 2003)
- Magnetic susceptibility and density of drill core samples from ore deposits in the Eastern Fold Belt (Mount Isa Inlier) were used by Gazley et al. (2016) to discriminate weathered, hem-rich iron stones and mgt-rich mineralised breccia from samples plotting along the mgt-enrichment trend
- Impact of hem, mgt and pyrrhotite on VNIR-SWIR-TIR reflectance spectra (e.g. diagnostic absorption features, thermal background) and absorptions of associated minerals (e.g. sheet silicates)
- Trial of a PLS-based modelling of magnetic susceptibility and density from hyperspectral drill core data.

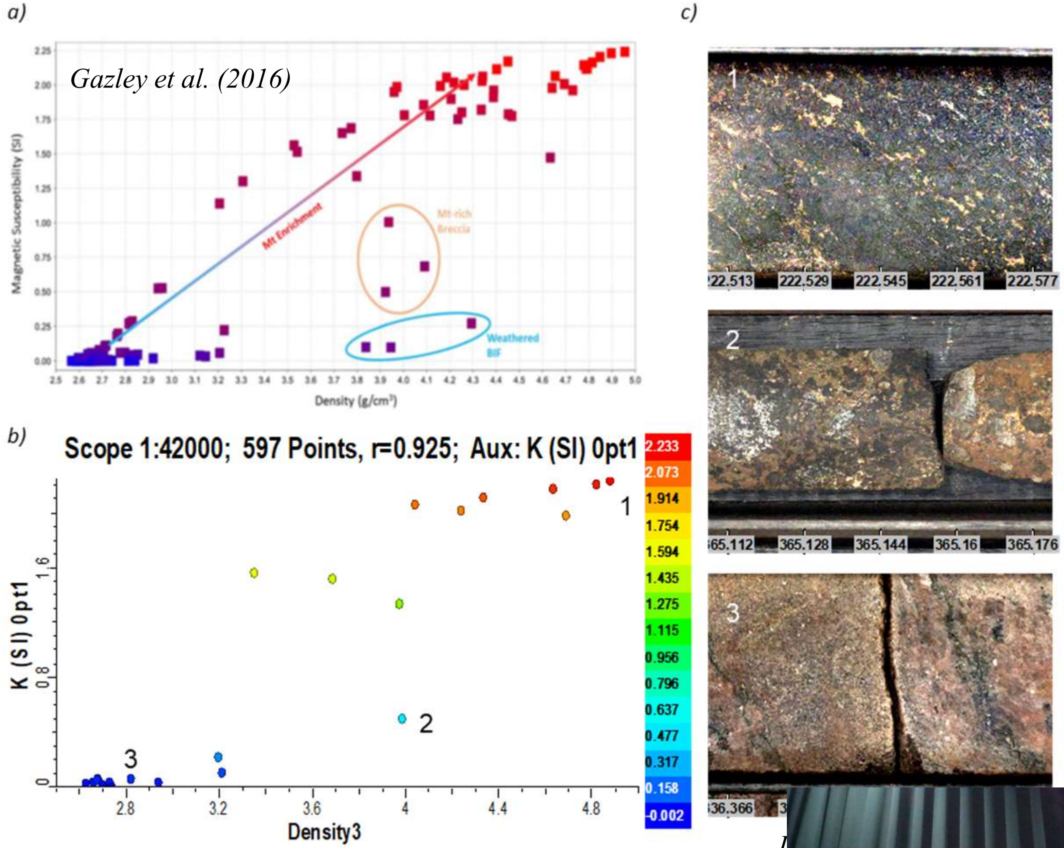

Figure 1: Magnetic susceptibility (K; y-axis) versus density (r; x-axis)
several drill cores from the Eastern Fold Belt, Mount Isa Inlier, Qld in
TTNQ0364 (Osborne, Qld, Gazley et al., 2016). In c), drill core images

Input data

- HyLogger3 (VNIR-SWIR-TIR reflectance spectra [n = 42,000]; high resolution RGB imagery)
- Petrophysical data (Gazley et al., 2016):
  - magnetic susceptibility [n = 23]
  - density [n = 23]

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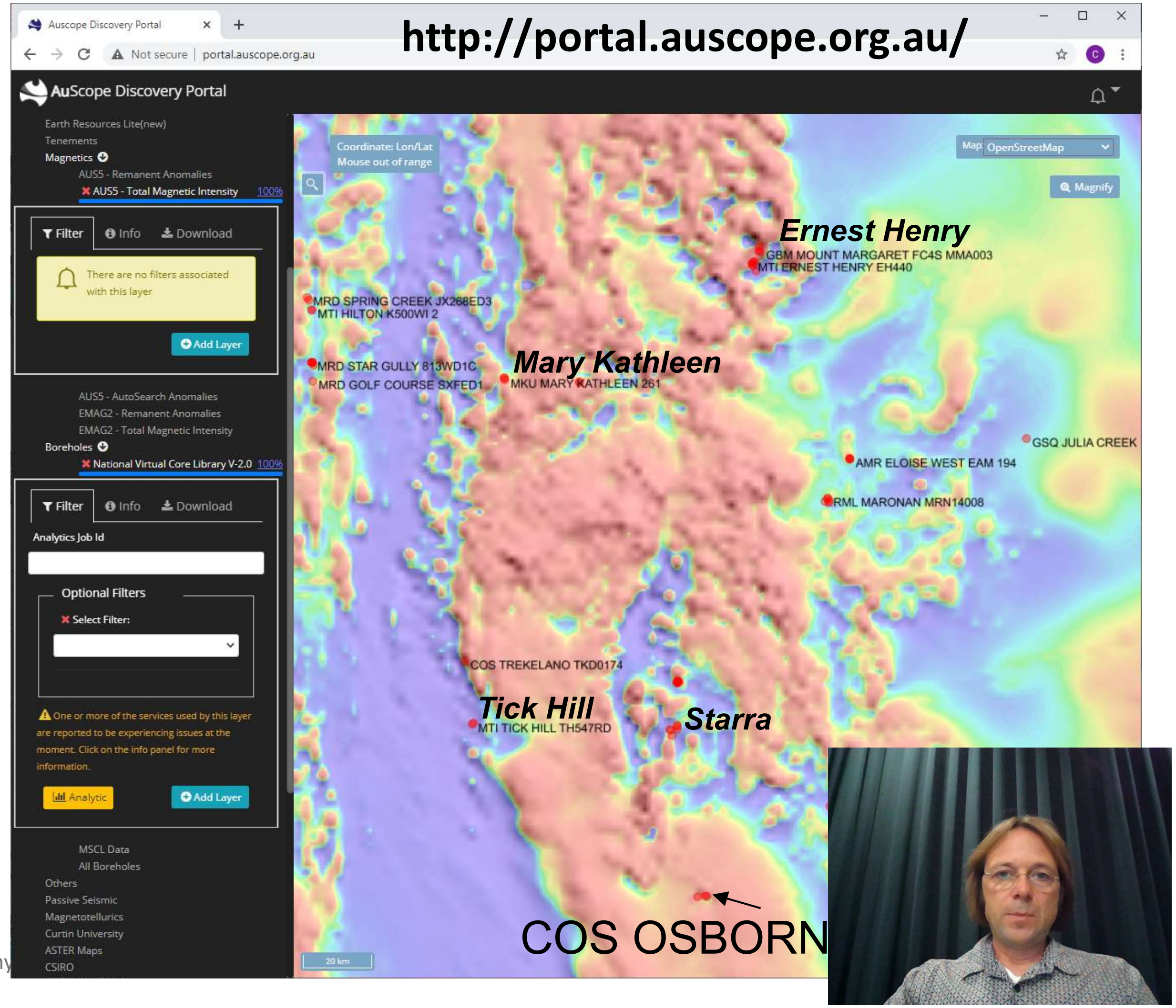


Figure 2

Partial least squares (PLS) modelling

1. Preparation stage: Investigation of data set and selection of calibration samples
2. Calibration stage:
   a. specification of input data (e.g. wavelength range, background removal, ...)
   b. cross-validation:
      – based on a leave-one-out method
      – comprises evaluation of the predicted residual error sum of squares (PRESS) and generation of the final regression coefficients (FRC) for each input (e.g. spectral band, spectral index),
      – iterative refining of steps a and b
3. Prediction stage:
   - application of FRC-based scalar to whole spectral data set and comparison of predicted with independent data
   - Accuracy of prediction depends largely on
     – independent measure (e.g. quality of QXRD in the case of modelling modal mineralogy)
     – calibration of the input multi-variate data, namely reflectance spectra

PLS module in TSG™:
https://research.csiro.au
/thespectralgeologist/

Osborne (Qld) - TTNQ0364 – Calibration & Prediction

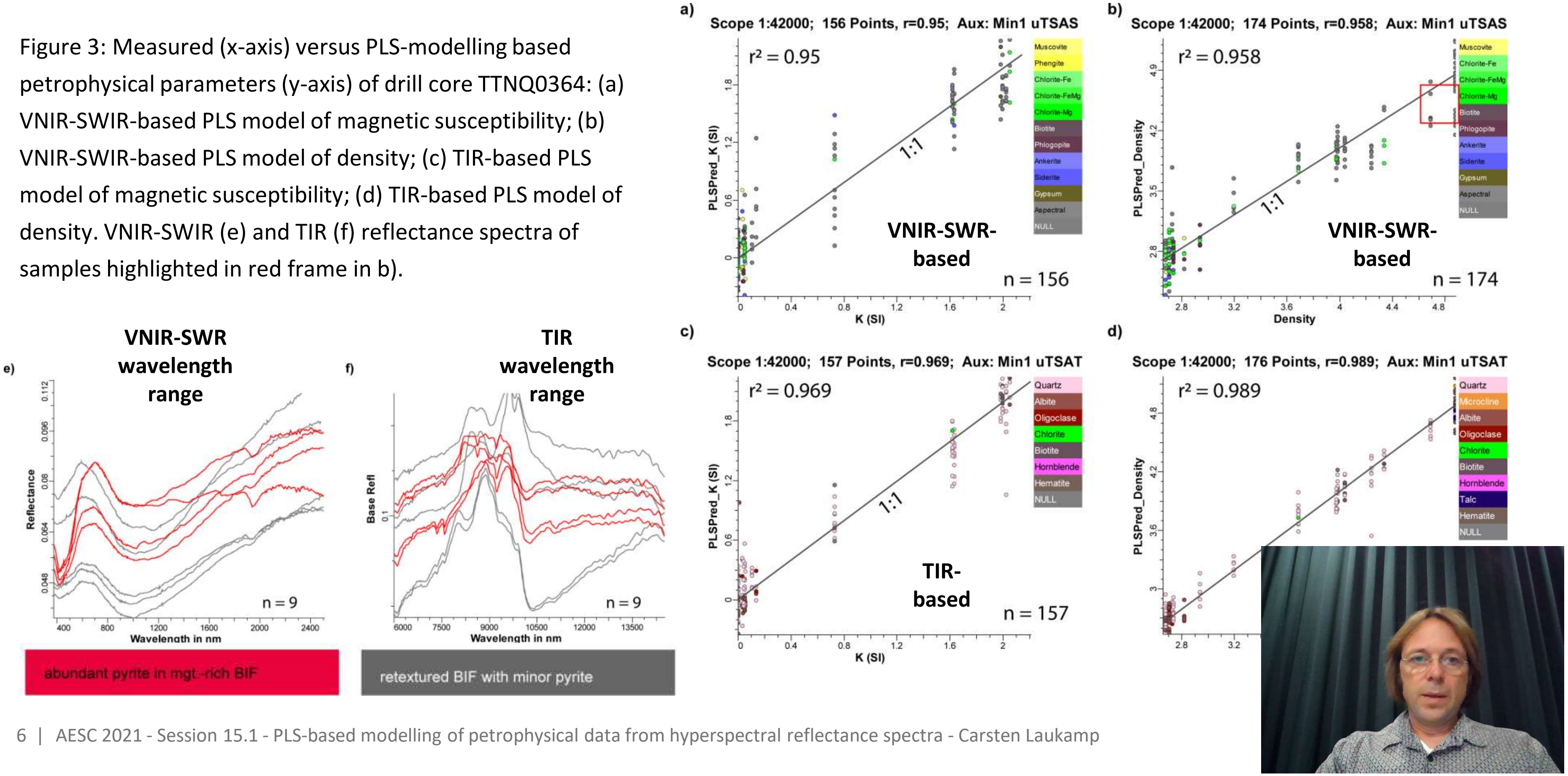
parameter	Wave-length range for cross-validation	value range	**SEP (standard error of prediction)**	Factor	Number of samples: petrophysical measurements/ hyperpectral	Notable FRC-features	**R^2 (PLS-script vs measured)**
magsus	380 to 2500 nm (full HyLogger3-VNIR-SWIR wvl range)	0 to 2.253 [Si]	**0.348 [Si]**	14	23/156	440 to 516 nm; 1148 to 1372 nm; 2040 to 2388 nm	**0.95**
magsus	6000 to 14500 nm (full HyLogger3-TIR wvl range)	0 to 2.253 [Si]	**0.321 [Si]**	21	23/157	6100 to 6575 nm; 8100 to 8775 nm; 9300 to 10300 nm; 11350 to 11775 nm	**0.969**
density	380 to 2500 nm	2.627 to 4.877 [g/m^3]	**0.276 [g/m^3]**	11	23/174	2108 to 2340 nm	**0.958**
density	6000 to 14500 nm	2.627 to 4.877 [g/m^3]	**0.219 [g/m^3]**	22	23/176	6425 to 6650 nm; 8125 to 8775 nm; 9300 to 9900 nm; 11375 to 12325 nm	**0.989**

Table 1: PLS-modelling input parameters and statistics for modelling magnetic susceptibility and density from VNIR-
hyperspectral data of drill core TTNQ0364. For details about PLS modelling routine in TSG™ see Mason (2(

Laukamp

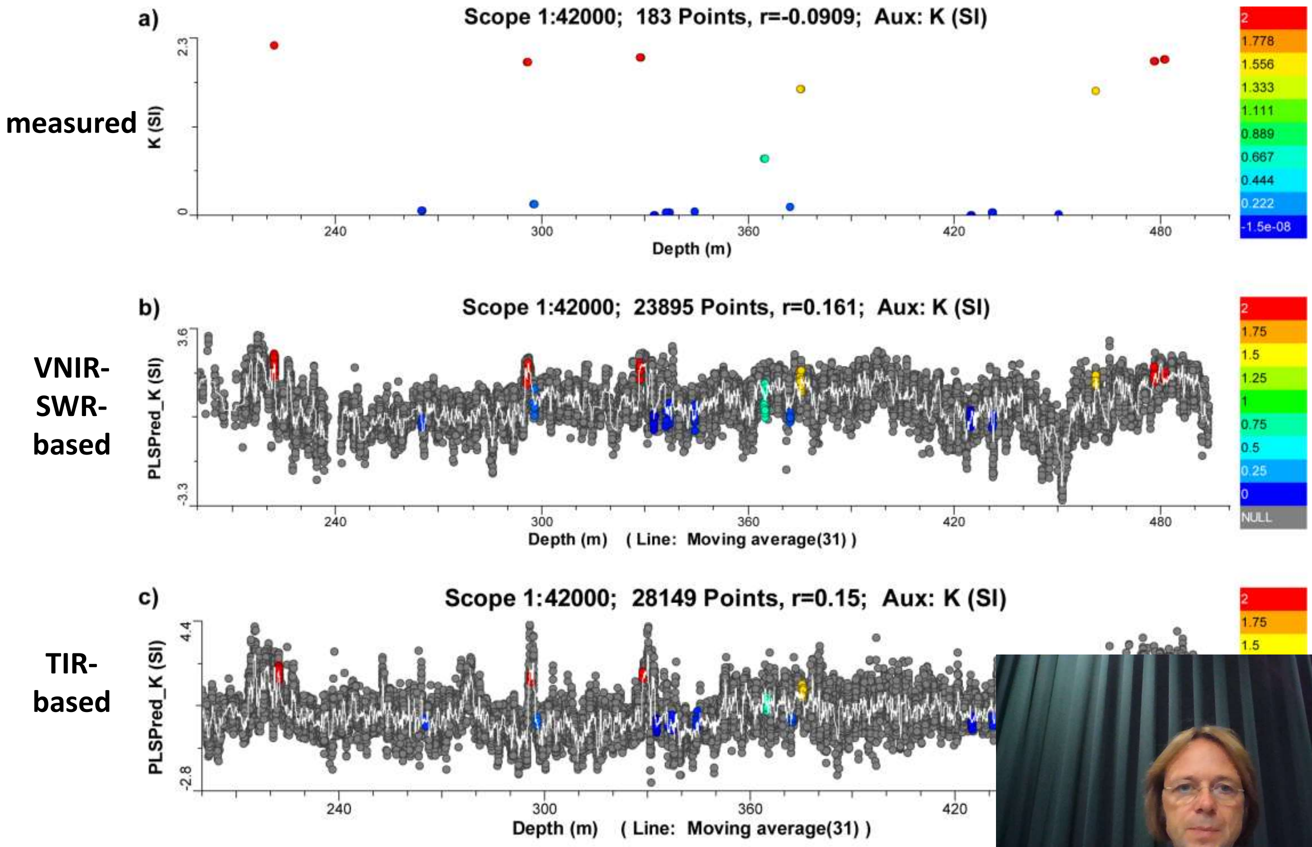
Osborne (Qld) - TTNQ0364 – Prediction stage I

Figure 3: Measured (x-axis) versus PLS-modelling based petrophysical parameters (y-axis) of drill core TTNQ0364: (a) VNIR-SWIR-based PLS model of magnetic susceptibility; (b) VNIR-SWIR-based PLS model of density; (c) TIR-based PLS model of magnetic susceptibility; (d) TIR-based PLS model of density. VNIR-SWIR (e) and TIR (f) reflectance spectra of samples highlighted in red frame in b).



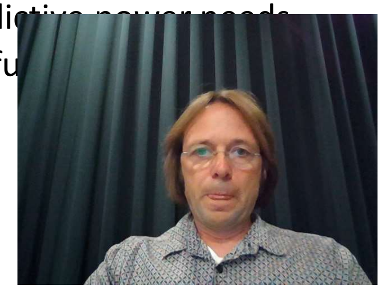
Osborne (Qld) - TTNQ0364 – Prediction stage II

Figure 4: Measured and PLS-modelling based petrophysical parameters of drill core TTNQ0364: a), b), c) Measured, VNIR-SWIR-based, and TIR-based magnetic susceptibility (y-axis) downhole (x-axis), coloured by measured magnetic susceptibility.



Summary

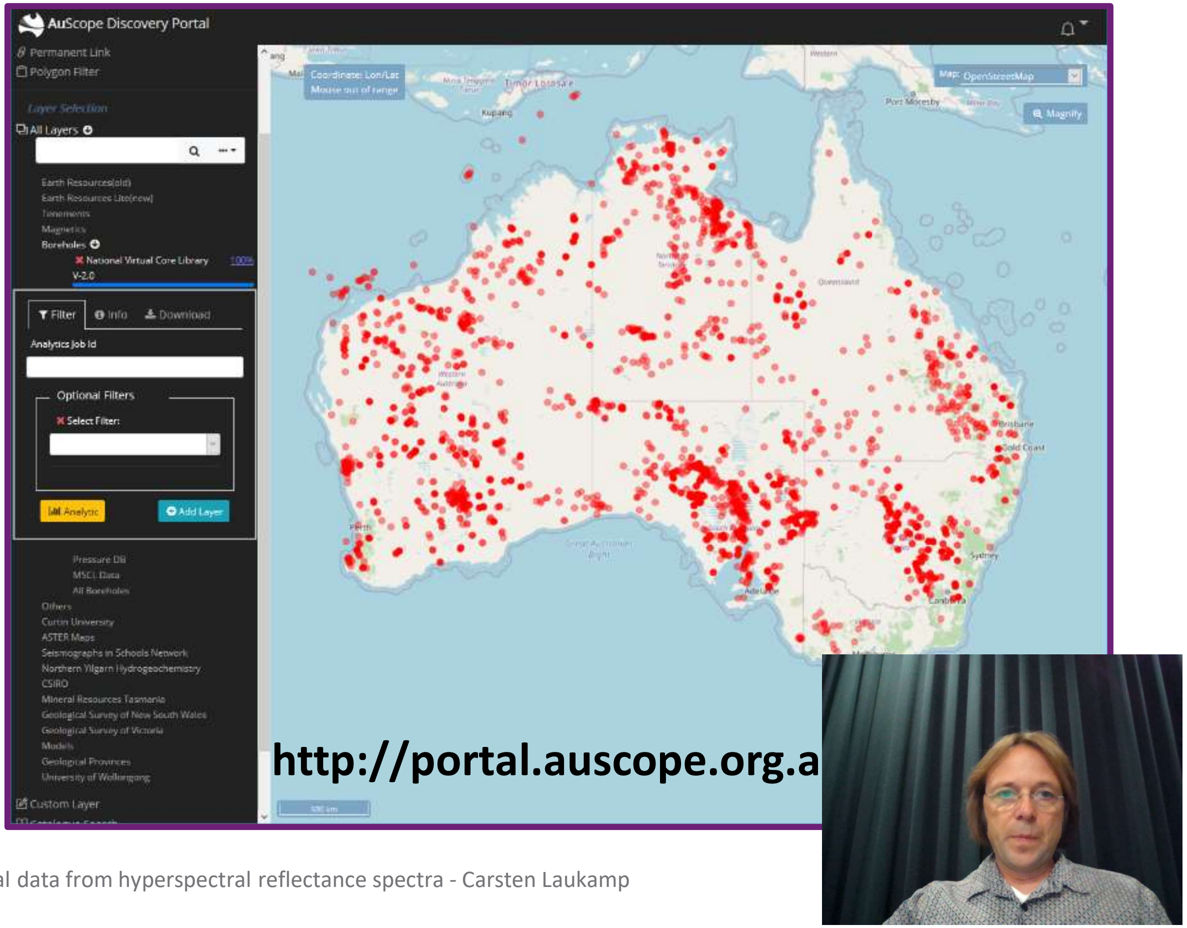
- HyLogger3 high-resolution RGB imagery confirmed that the predicted value ranges were sufficiently different to discriminate drill core intervals dominated by magnetite-rich rocks, from magnetite-rich breccia and least-altered (non-mineralised) rocks.
- PLS models based on the VNIR-SWIR wavelength ranges were mainly driven by depth changes of electronic transition absorption features related to Fe and Cu in the VNIR, which are most intense in the highly altered, magnetite- and/or sulphide rich rocks.
- PLS models based on the TIR wavelength ranges were highly influenced by the thermal background typically associated with iron oxides and sulphides.
- Density values modelled from VNIR-SWIR compared to those modelled from TIR showed a good correlation ($r2$ = 0.729), whereas the correlation between magnetic susceptibility modelled from VNIR-SWIR and TIR was comparably low ($r2$ = 0.518).
- While the small amount of data used to infer the models discussed here means that their predi
to be assessed comprehensively, our results nevertheless indicate a high potential for successfu
petrophysical from hyperspectral data and cost-effective mapping of IOCG-related alteration.



Opportunities

PLS-based modelling of geoscience parameters from hyperspectral data is a powerful tool for:

- Obtaining quantitative mineralogy
- Predicting non-mineralogical geoscience parameters
  - Petrophysical indices
  - Geochemical indices
  - Grain size, lump-fine ratio, fracture indices, …
- Understanding the relationship between mineralogy and geochemistry and petrophysics
- Applicable across scales!



Thank you

Mineral Resources
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abstract

Modelling of petrophysical from hyperspectral drill core data collected from the Osborne Cu-Au deposit, Mount Isa Inlier, Queensland

Carsten Laukamp[1)], Neil Francis[1)], Suraj Gopalakrishnan[2)], Juerg Hauser[1)], Shane Mule[1)]

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The combination of magnetic susceptibility and density allows identification of iron oxide copper-gold (IOCG) mineralisation by estimating proportions of magnetite, sulphide and hematite alteration which can be indicative of IOCGs. In the frame of the National Virtual Core Library project, hyperspectral reflectance spectra acquired from drill core of the Osborne Cu-Au deposit, Mount Isa Inlier, Queensland using a HyLogger3 at GSQ's Exploration Data Centre were compared with magnetic susceptibility and density measurements. In this study we explore the feasibility of inferring the petrophysical data from the 1) visible-near (VNIR), shortwave (SWIR) and 2) thermal (TIR) infrared wavelength regions. Specifically, we seek to predict magnetic susceptibility and density values in drill core sections where petrophysical data are not available and potentially extrapolate these to other hyperspectral data sets, such as those acquired by field or Earth Observation instruments.

Using The Spectral Geologist (TSG^{TM}) software, partial least squares (PLS) was employed to derive predictive models using 23 unique magnetic susceptibility and density measurements, that were assigned to all nearby spectral measurements (+/- ~10cm). The values of the input magnetic sustainability and density values ranged from 0 to 2.3 K (Si) and 2.7 to 4.9 g/cm^3, respectively. The hyperspectral data were not spatially re-sampled to fit with the drill core interval measured for petrophysical data. Instead, the original 1 cm spatial resolution was used to evaluate the variability of hyperspectral data within the petrophysical sample intervals. The correlation between the 23 measured and corresponding modelled magnetic susceptibility (n = 157) for the same 23 depth intervals was high for the VNIR-SWIR (r^2 = 0.95) and the TIR (r^2 = 0.969), but the PLS-modelled magnetic susceptibility values showed a large variance (± 0.8 and ± 0.5, respectively). Similarly, the correlation between the measured and modelled density was high for the VNIR-SWIR (r^2 = 0.958) and the TIR (r^2 = 0.989), with the PLS-modelled density values showing a large variance (± 0.4 g/cm^3 for both wavelength ranges). However, HyLogger3 high-resolution RGB imagery showed that the predicted value ranges were sufficiently different to discriminate drill core intervals dominated by magnetite-rich rocks, from magnetite-rich breccia and least-altered (non-mineralised) rocks. PLS models based on the VNIR-SWIR wavelength ranges were mainly driven by depth changes of electronic transition absorption features related to iron and copper in the VNIR, which are most intense in the highly altered, magnetite- and/or sulphide rich rocks. PLS models based on the TIR wavelength ranges were highly influenced by the thermal background typically associated with iron oxides and sulphides. Density values modelled from VNIR-SWIR compared to those modelled from TIR showed a good correlation (r^2 = 0.729), whereas the correlation between magnetic susceptibility modelled from VNIR-SWIR and TIR was comparably low (r^2 = 0.518). While the small amount of data used to infer the models discussed here means that their predictive power needs to be assessed comprehensively, our results nevertheless indicate a high potential for successfully inferring petrophysical from hyperspectral data and cost-effective mapping of IOCG-related alteration.

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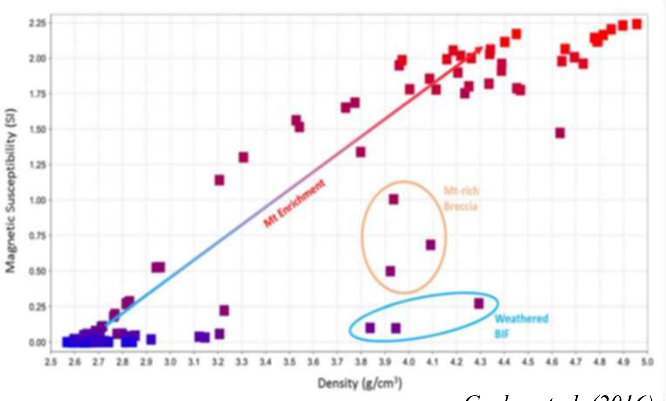
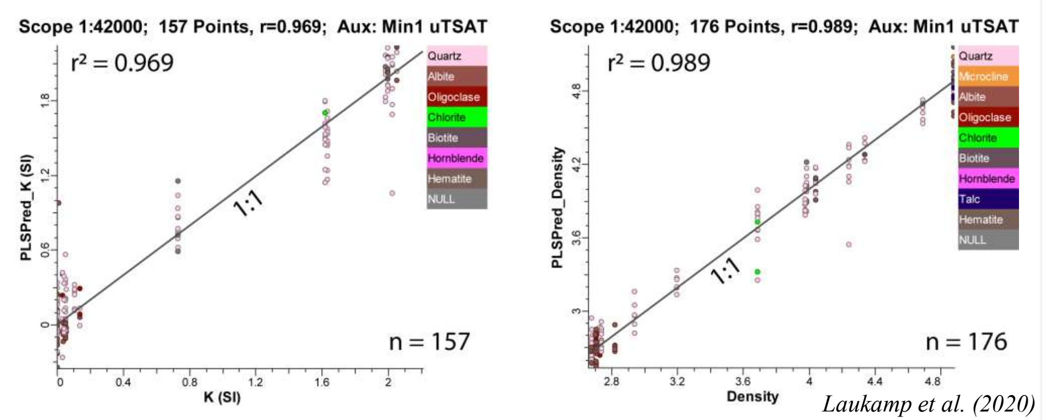


Gazley et al. (2016)



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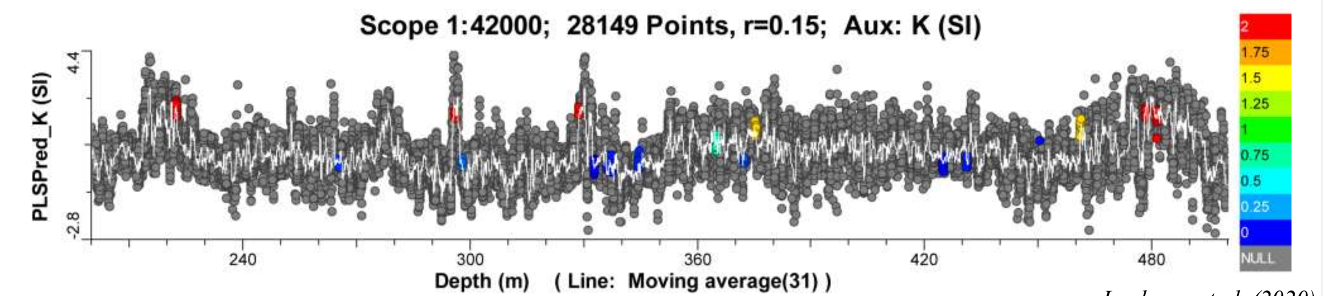

Laukamp et al. (2020)