NORTHERN TERRITORY GOVERNMENT

NORTHERN TERRITORY GEOLOGICAL SURVEY

HyLogger Data Package 0072

HyLogger drillhole report for CCD10, Coppermine Creek McArthur Basin, Northern Territory.

Belinda Smith

DEPARTMENT OF PRIMARY INDUSTRY AND RESOURCES
MINISTER (ACTING): Hon. Dale Wakefield, MLA
CHIEF EXECUTIVE: Alister Trier

NORTHERN TERRITORY GEOLOGICAL SURVEY
EXECUTIVE DIRECTOR: Ian Scrimgeour

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Northern Territory Geological Survey
3rd floor Paspalis Centrepoint Building
Smith Street Mall, Darwin
GPO Box 4550
Darwin NT 0801, Australia

Arid Zone Research Institute
South Stuart Highway, Alice Springs
PO Box 8760
Alice Springs NT 0871, Australia

For further information contact:
Minerals and Energy InfoCentre
Phone: +61 8 8999 6443
Website: **minerals.nt.gov.au/ntgs**
Email: geoscience.info@nt.gov.au

The Spectral Geologist Advisory

The results in this report were obtained using The Spectral Geologist (TSG) software. The software uses The Spectral Assistant (TSA) to identify minerals and their abundances for the Short Wave Infrared (SWIR) and Thermal Infrared (TIR) spectrum. TSA is a general unmixing algorithm and is trained on a relatively small subset of commonly-occurring minerals. It does not make the right identifications all of the time. The unmixing is an interpretation result of 'best fit'. TSA abundances are relative abundances, only the two (or three) most spectrally active minerals identified in the Short Wave Infrared (SWIR) and the three (sometimes four) most spectrally active minerals in the Thermal Infrared (TIR) wavelengths are reported. If there are more than two or three minerals actually present in the sample in the SWIR (or three to four minerals in the TIR) then this is not reflected AT ALL in the reported abundances. Minerals are reported as a fraction of the overall spectral fit rather than actual quantifiable concentrations (total minerals present add up to 1). The SWIR wavelength only identifies hydrous silicates and carbonates. It does not reflect the TOTAL mineralogy of the sample. NTGS processed datasets exclude some minerals in the TSA library if the mineral is a poor spectral fit or is unlikely in that geological environment, introducing a further element of interpretation.

Since April 2014, the TIR spectral responses have also been matched to minerals using Constrained Least Squares (CLS), which is an alternative unmixing classifier. CLS uses a Restricted Mineral Set (RMS) to minimise non-unique mineral modelling in the TIR spectrum. The RMS is determined by the processor who interprets 'domains' (hole intervals interpreted to have similar mineralogy) and then limits the set of possible mineral matches based on the geological understanding and spectral characteristics of that domain.

Since April 2017, the TIR spectral responses may also be matched to minerals using joint Constrained Least Squares (jCLST), which is an unmixing classifier that replaces the earlier system TSA (sTSAT) used in TSG versions 7 or earlier. In TSG8, jCLST is the default system unmixing algorithm, which interprets the TIR data using the results from the SWIR spectra, and using scalars focussing on selected features in the Visible Near Infrared (VNIR) and TIR wavelengths. TSG8 datasets may have TIR mineral results reported as domained TSA (dTSAT), user TSA (uTSAT) or domained CLS (TIR-CLS1).

Any results from the TIR should be used with caution as algorithms and TSA libraries are in a constant state of revision. More information about the samples in the TIR reference library can be found in Schodlok *et al* (2016a).

These results were published using TSG Version 8.0.3.2 dated September 2018.

Please note: the results in this report are an interpretation from the spectral response.

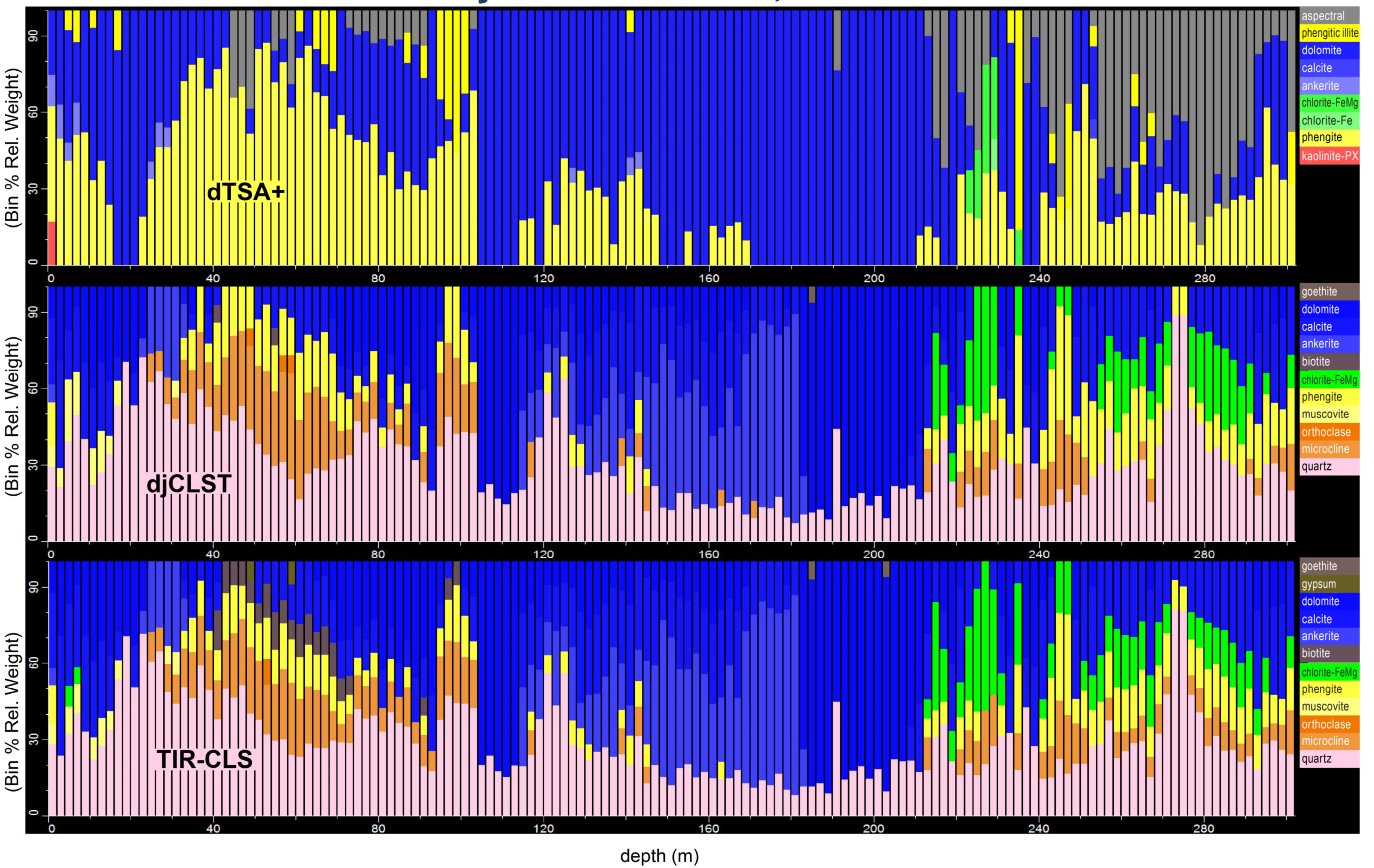
CCD10: Introduction

Hole ID	CCD10	**Unique identifier**	8471150
Geological terrane	McArthur Basin	**Total depth**	300.6 m
Latitude GDA94	-15.959786°	**Longitude GDA94**	135.528920°
Easting MGA94	556 602 (Zone 53)	**Northing MGA94**	8 235 441 (Zone 53)
Dip	-80°	**Azimuth**	360°
Logged by	Pacifico Minerals Ltd	**Logged report ref**	CR2017-0470
Start core depth	0 m	**End core depth**	300.6 m
Date HyLogged	February 2018	**HyLogged by**	Darren Bowbridge
Date of HyLogger report	November 2018	**HyLogger report author**	Belinda Smith
TSG version and build	8.0.3.2 (September 2018)	**TSG product level**	3 (Huntington 2010)

Summary of information from CR2017-0470 (Pacifico Minerals Ltd 2017).

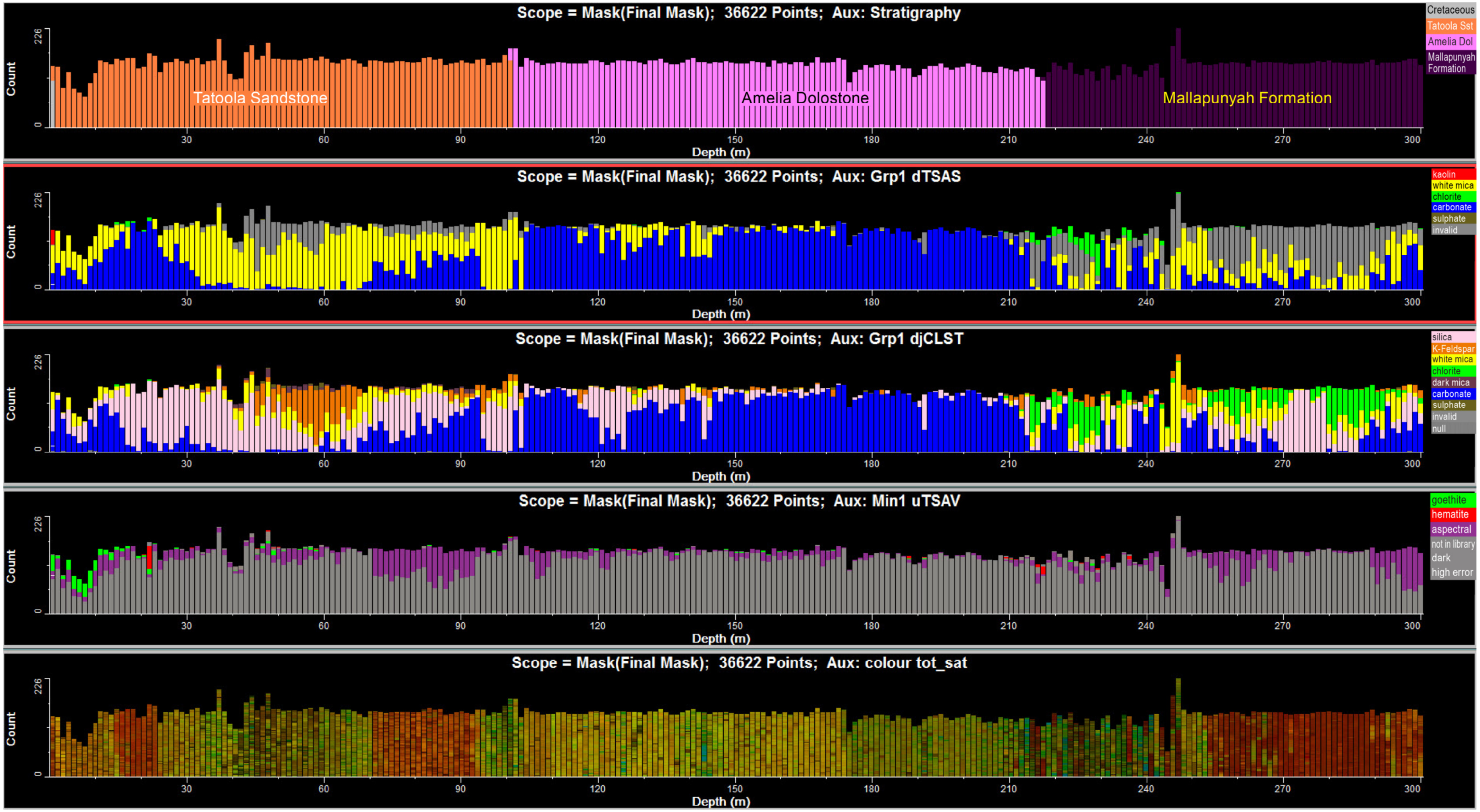
- Drilled 2 holes (CCD09 and CCD10) under the NTGS Geophysics and Drilling Collaborations program (Round 10: 2017/2018).
- Drilled to test for stratiform copper mineralisation within the Amelia Dolostone, south of Coppermine Creek Fault.
- Previous surface mapping and drilling gave indications of possible mineralisation, with brecciation, fracturing, dolomitisation and quartz-dolomite veining.
- Drilling intersected disseminated copper mineralisation (chalcopyrite and minor bornite) hosted by Amelia Dolostone, described as finely bedded dolomite with carbonaceous laminae. It is concentrated within the evaporite-rich (now dolomitised) part of the sequence. Reported textures include ex-anhydrite nodules and masses of ex-gypsum crystals.
- Best intercept of 18 m @ 0.2% Cu from 174 m (includes 2 m @ 0.4% Cu from 190 m) in CCD10. Shorter intervals of 3 m @ 0.4% Cu (which includes 1 m @ 0.7% Cu from 55 m) was reported in drillhole CCD09.
- Drilling confirmed that there is anomalous copper; copper mineralisation is stratigraphic and not confined to the Coppermine Creek Fault area.

CCD10: Mineral summary – all minerals, TSA and CLS



From Summary Screen: Row 1 is the domained SWIR results using TSA+. Row 2 is the TIR results derived from a domained joint CLS algorithm (see Guide to Scalars for a description of both TSA+ and djCLST). In this dataset, djCLST is used in preference over TIR-CLS1 and dTSAT (which was used in HDPs prior to HDP0067). Both TIR modelled results are shown here for comparison as the TIR spectra have non-unique results. There are no sharp contacts between mineralogy changes. The middle zone (~102-212 m) is carbonate-rich, with minor quartz and white mica. The TIR-CLS results plot sporadic biotite (brown colour, row 3) between 38 m and 100 m. This biotite is not noted in the dTSA+ results and is very minor in the djCLST results, so there is possibly less biotite than that indicated in the TIR-CLS plot. From 212 m to EOH, the dTSA+ have a lot of ‘aspectral’ matches. In the TIR, the corresponding depths have an increase in quartz and white mica. The aspectral results are discussed in more detail on page 15.

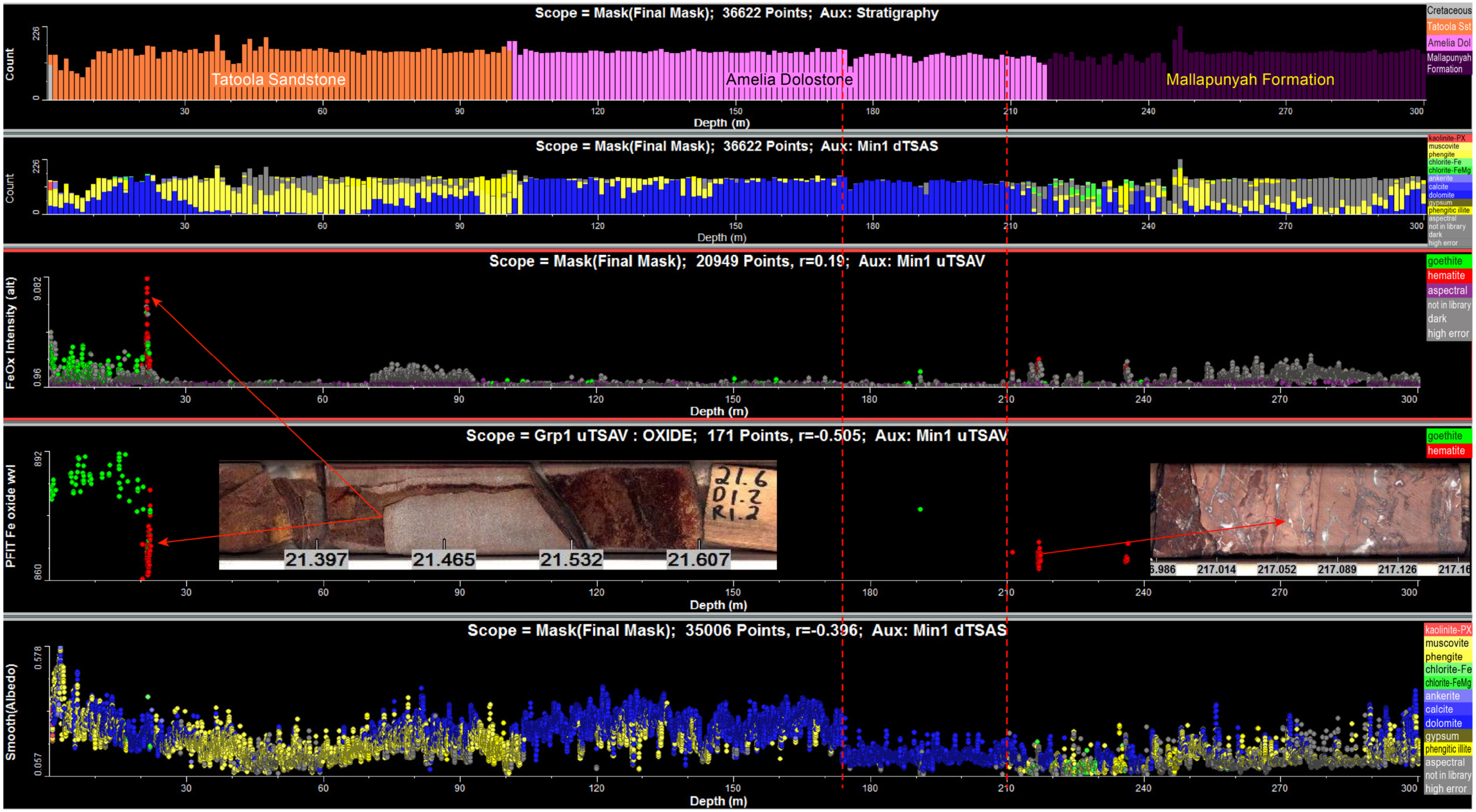
CCD10: Mineral summary (View | Plot Layouts Load file 1_VNIRSWIR: Mineral Summary)



Row 1 shows the logged stratigraphic intervals from the Company report. Ahmad *et al* (2013) describe these stratigraphic units as '*conformable with gradational upper and lower contacts*'. Rows 2 and 3 plot the SWIR and TIR spectra, coloured by the dominant mineral group match respectively. Row 4 plots the VNIR spectra, coloured to either goethite, hematite, aspectral, or Not In Library (VNIR has a limited TSA mineral library for matching). Row 5 is the core colour. The mineralogy and core colour change on the upper contact of the Amelia Dolostone, which is sharp and defined by carbonate abundance. The lower contact of the Amelia Dolostone is less distinct and appears gradational as indicated by both core colour and mineralogy changes. The gradational change between these conformable units is expected. The lower Tatoola Sandstone is dominantly sandstone at its base, which is also noted in Ahmad *et al* (2013).

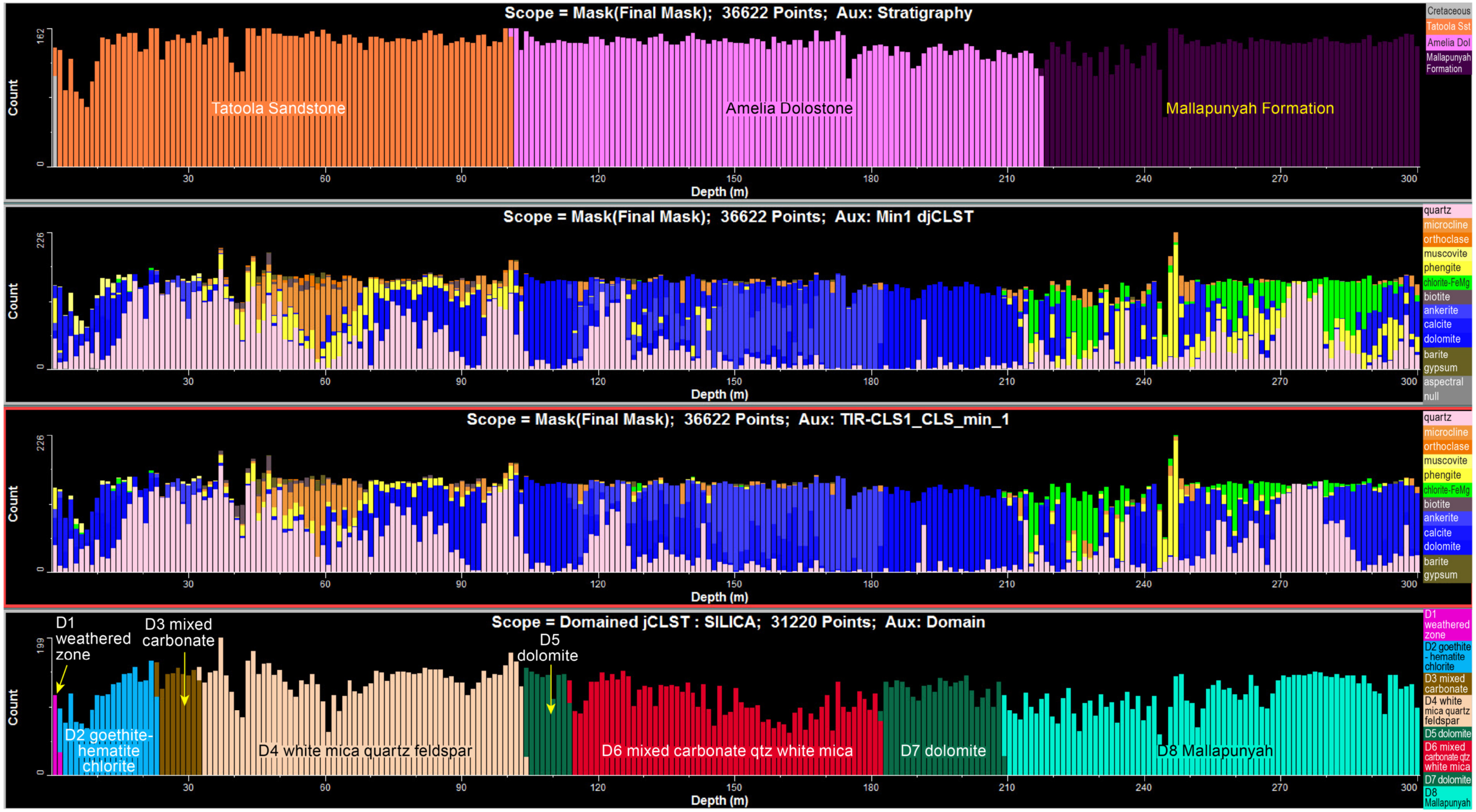
CCD10: SWIR and VNIR mineral summary

(View | Plot Layouts Load file 2_VNIRSWIR: SWIR VNIR Summary)



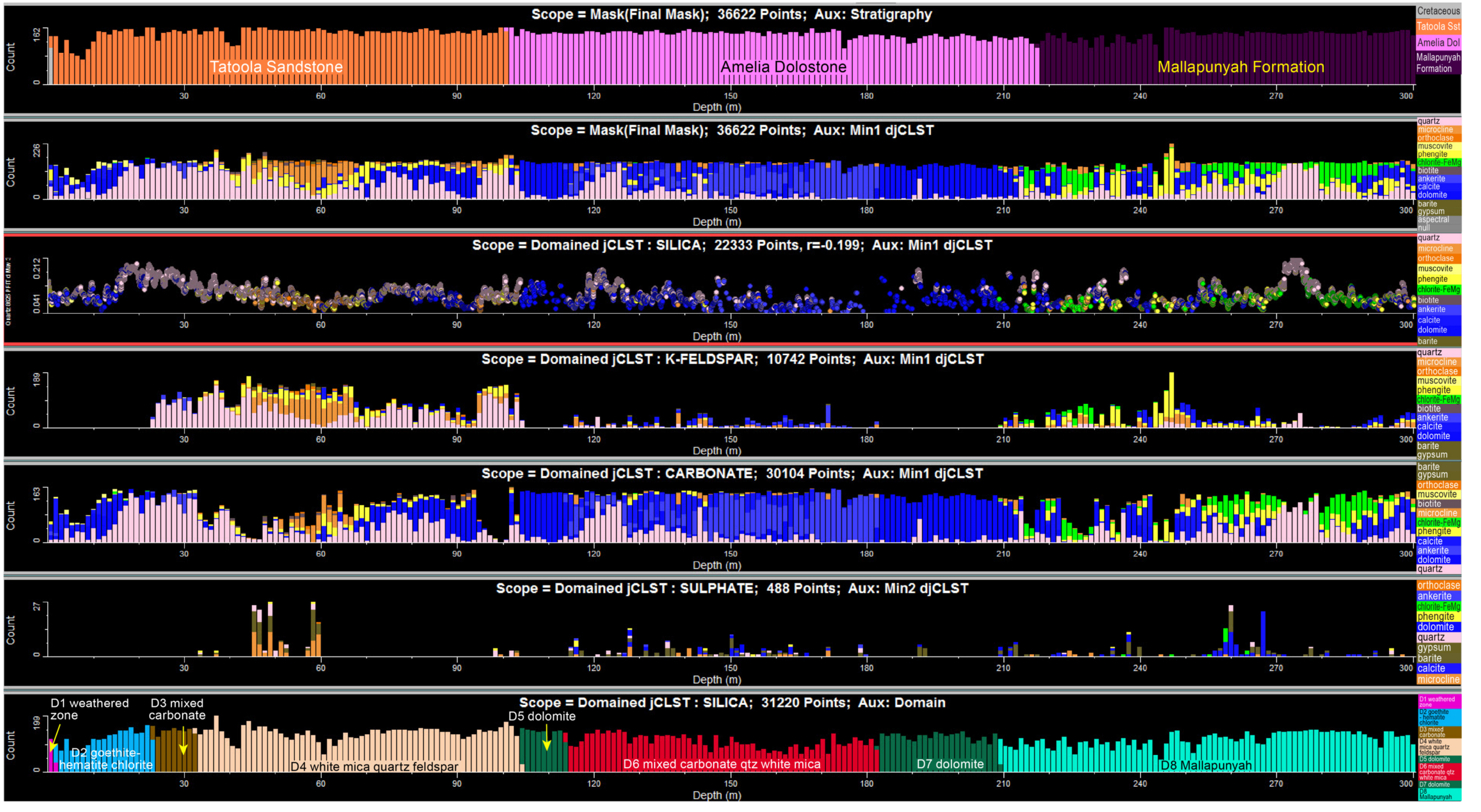
Row 1 shows the logged stratigraphic intervals from the Company report. Row 2 is the SWIR spectra coloured by the dominant mineral (may be in a mineral mixture). Row 3 is the VNIR spectra plotted against FeOx intensity batch scalar and coloured by the match to VNIR minerals. The high localised FeOx intensity results commonly map goethite or hematite on fracture surfaces close to the top of the hole (see inset left: 21.4 m). Row 4 are the VNIR spectra that match to either goethite or hematite, plotted by the wavelength of the Fe oxide feature. Hematite has a shorter wavelength feature compared with goethite. The hematite at 21.4 m has a distinctly different wavelength to the shallower goethite. There is also small hematite (with quartz) near the Amelia Dolostone/Wollogorang Formation contact (see inset right: 217 m). Row 5 plots the SWIR spectra by the smoothed albedo. Dotted lines show a zone of uniformly lower albedo. This zone corresponds to the reported mineralisation of 18 m @ 0.2% Cu from 174 m (includes 2 m @ 0.4% Cu from 190 m).

CCD10: TIR mineral summary - overview (View | Plot Layouts Load file 1_TIR: TIR Summary)



Row 1 is the logged stratigraphy from the Company report. Rows 2 and 3 plot the dominant TIR mineral (from a mineral mix) using a domained restricted mineral set (RMS). Row 2 uses the joint CLS algorithm that takes the results from a modified TSA and scalars operating on selected features in the VNIR and SWIR. Row 3 is the CLS algorithm that uses an RMS interpreted for each domain, allowing up to 6 mineral results per spectrum (dominant mineral shown here). Row 4 is the domains interpreted for this hole. For more information on domains in the TSG dataset, open the 'D' tool on the toolbar. The main differences between the 2 algorithms are: more biotite in the domained CLS (row 3) between 39 m and 100m; more chlorite in the djCLST results in the Mallapunyah Formation. Further analyses are recommended to clarify the mineral proportions at these depths.

CCD10: TIR mineral summary 2 (View | Plot Layouts Load file 2_TIR: TIR Mineral Summary 2)

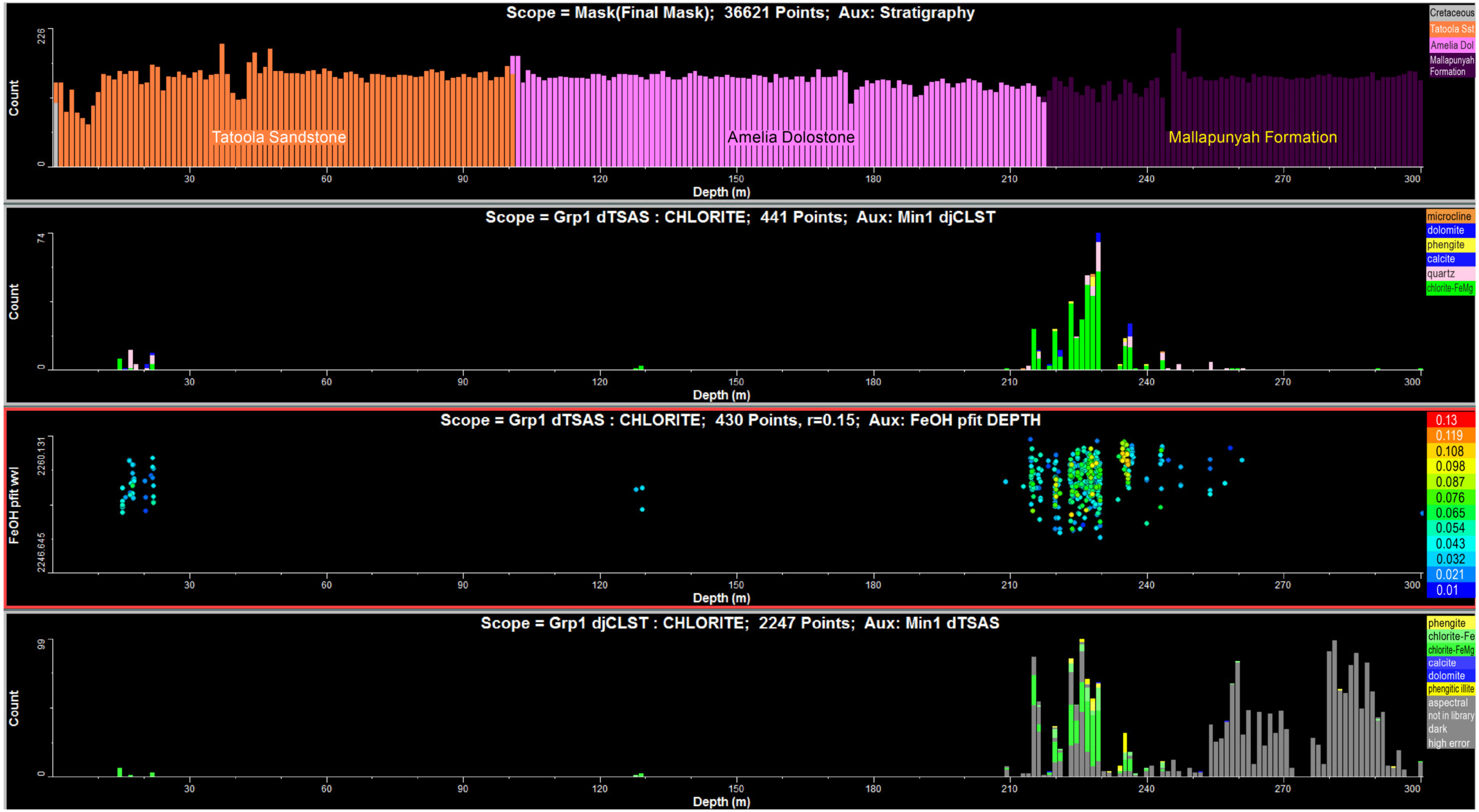


Row 1 shows the logged stratigraphic intervals from the Company report. Row 2 is the dominant TIR mineral from the domained joint CLS algorithm. Row 3 are the TIR spectra that contain a match to quartz, plotted by the depth of the quartz 8625 nm feature (analogous to abundance). Rows 4, 5 and 6 plot the TIR spectra that contain a match to kaolinite, apatite or gypsum respectively. Row 7 is the interpreted domains used for restricting the list of minerals for mineral matching in the TIR. The elevated quartz (row 3) in the Mallapunyah Formation corresponds with reddish puggy mudstones and hematitic breccias (eg about 217 m; see inset image on page 7). The elevated K-feldspar in the Mallapunyah Formation (row 3: about 245 m) corresponds with darker greenish grey (reduced) mudstones adjacent to (oxidised) reddish mudstones.

CCD10: White micas (View | Plot Layouts Load file 3_VNIRSWIR: White Micas)

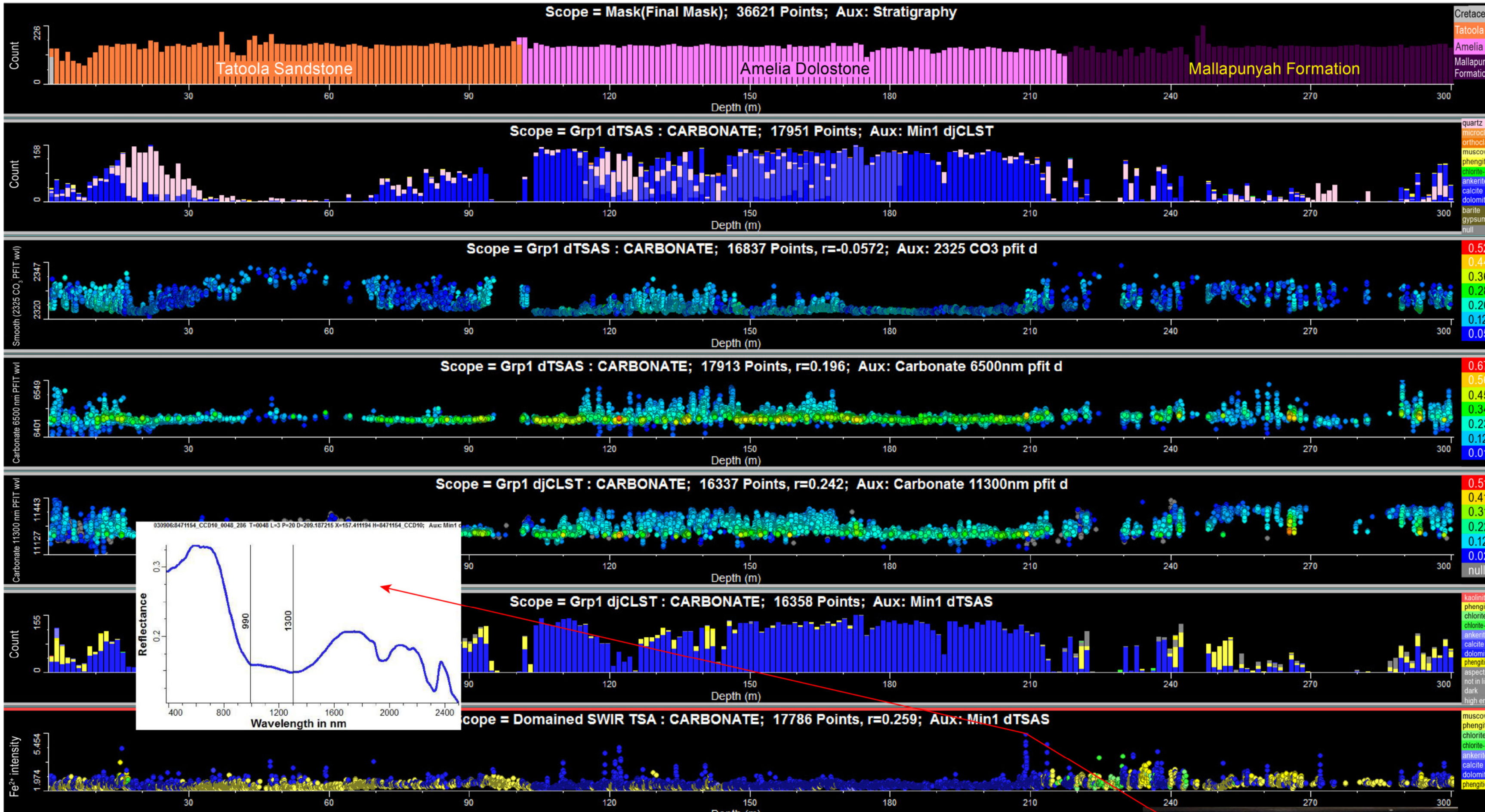
Row 1 shows the logged stratigraphic intervals from the Company report. Row 2 plots the SWIR spectra that match dominantly to white mica, coloured by the dominant TIR mineral. Most of the SWIR white mica are found with quartz. Row 3 are the SWIR white micas plotted by the wavelength of the white mica feature around 2200nm and coloured by the depth of that feature. Wavelength changes may show white mica composition changes. The depth of the white mica feature is a measure of the strength (abundance) of the white mica. The white micas in CCD10 are phengitic, with wavelengths ranging from 2213-2220 nm. There is an absence of white mica in the interval reported as containing anomalous copper (174–192 m). Row 4 plots the SWIR spectra that match dominantly to white mica (masking out any spectra with <85% weighting of white mica), plotted by the white mica wavelength and coloured by the white mica crystallinity. The white mica crystallinity is low throughout CCD10. Row 5 plots the TIR spectra that match dominantly to white mica, coloured by the dominant SWIR mineral. Most of the white mica is found with quartz or K-feldspar. Intervals with dominant TIR white mica tend to be fine-grained mudstones.

CCD10: Chlorite (View | Plot Layouts Load file 4_VNIRSWIR: Chlorite)



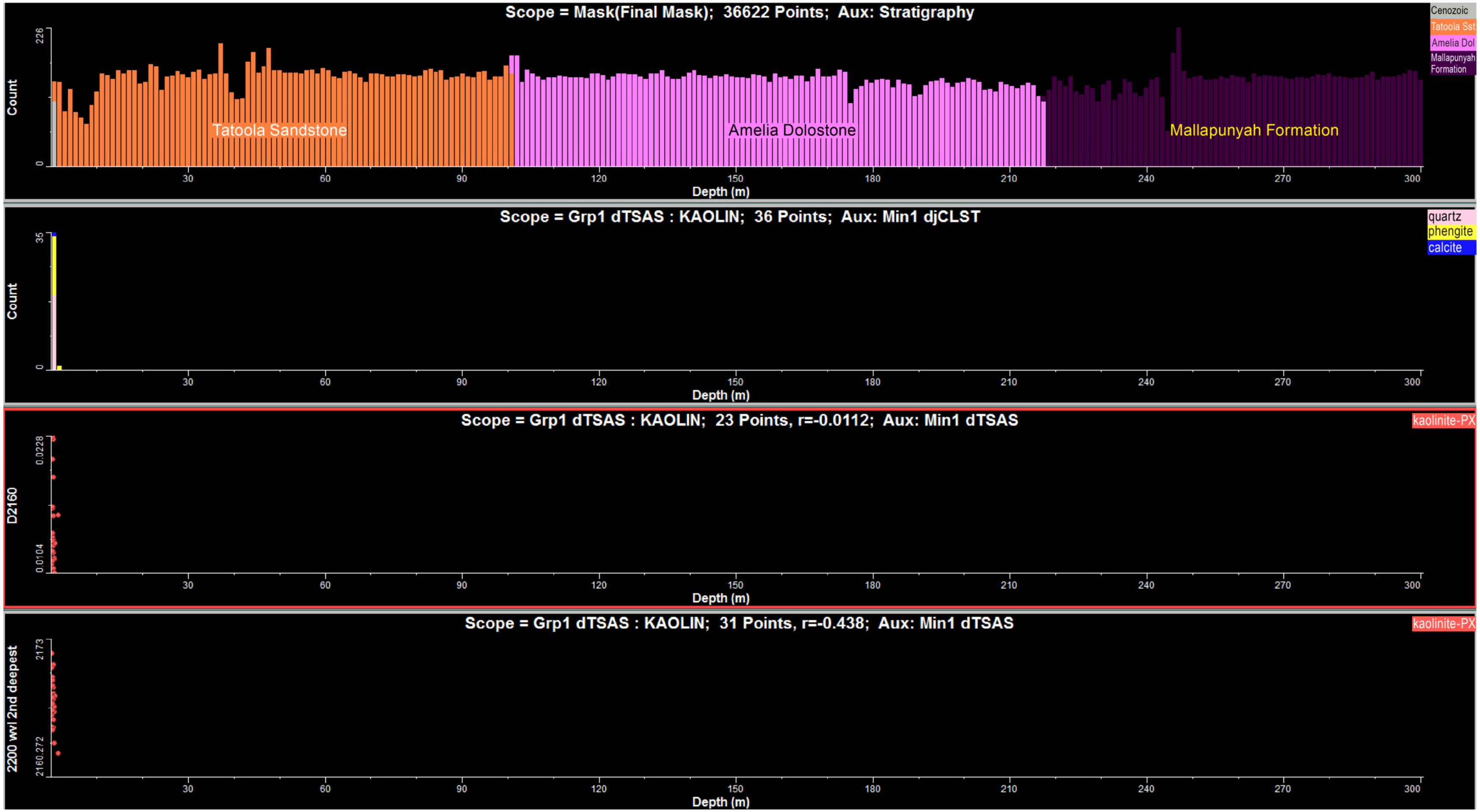
Row 1 is the logged stratigraphic intervals from the Company report. Row 2 plots the SWIR spectra that match dominantly to chlorite, coloured by the dominant TIR mineral. Row 3 plots the wavelength of the FeOH feature that varies with chlorite composition, coloured by the depth (abundance) of that feature. The most abundant chlorite is near the upper contact of the Mallapunyah Formation; the chlorite composition ranges from Mg-rich to MgFe-rich. Row 4 plots the TIR spectra that match dominantly to chlorite, coloured by the dominant SWIR mineral. Many of the TIR chlorite spectra have an 'aspectral' match in the SWIR, notably at depth in the Mallapunyah Formation. The imagery indicates that these aspectral SWIR / TIR chlorite spectra are puggy hematitic mudstones. The TIR spectra are not a close match to chlorite, and may also match to white mica. These chlorite matches should be treated with caution.

CCD10: Carbonates (View | Plot Layouts Load file 5_VNIRSWIR: Carbonates)



Row 1 shows the logged stratigraphic intervals from the Company report. Row 2 plots the SWIR spectra that match dominantly to carbonate, coloured by the dominant TIR mineral. Row 3 are the SWIR carbonate spectra plotted by the wavelength of the characteristic carbonate reflectance feature around 2325 nm and coloured by the depth of that feature. Changes in wavelength are analogous to carbonate composition. Rows 4 and 5 plot TIR spectra that match dominantly to carbonate, plotted by the wavelengths of characteristic carbonate features in the TIR around 6500 nm and 11300 nm. The results are coloured by the strength (height) of that feature. Row 6 plots the TIR spectra that match dominantly to carbonate, coloured by the dominant SWIR mineral. Row 7 plots the carbonate-bearing SWIR spectra, by the Fe^{2+} intensity. This highlights the zones of ferroan carbonates (with a distinctive broad feature between 990 – 1300 nm: inset left). These strongest ferroan carbonate responses appear to be from steep, subvertical veins that cross-cut bedding and may contain chalcopyrite. This observation is documented in Davidson *et al* (2017) and the high values in row 7 highlight this late-stage carbonate phase throughout CCD10. The Amelia Dolostone has the most carbonate and is dolomitic, with the strongest dolomite response coincident with the reported anomalous copper (approximately 182–208 m). The Tatoola Sandstone has carbonate throughout, although the middle section (32–70 m) has less carbonate.

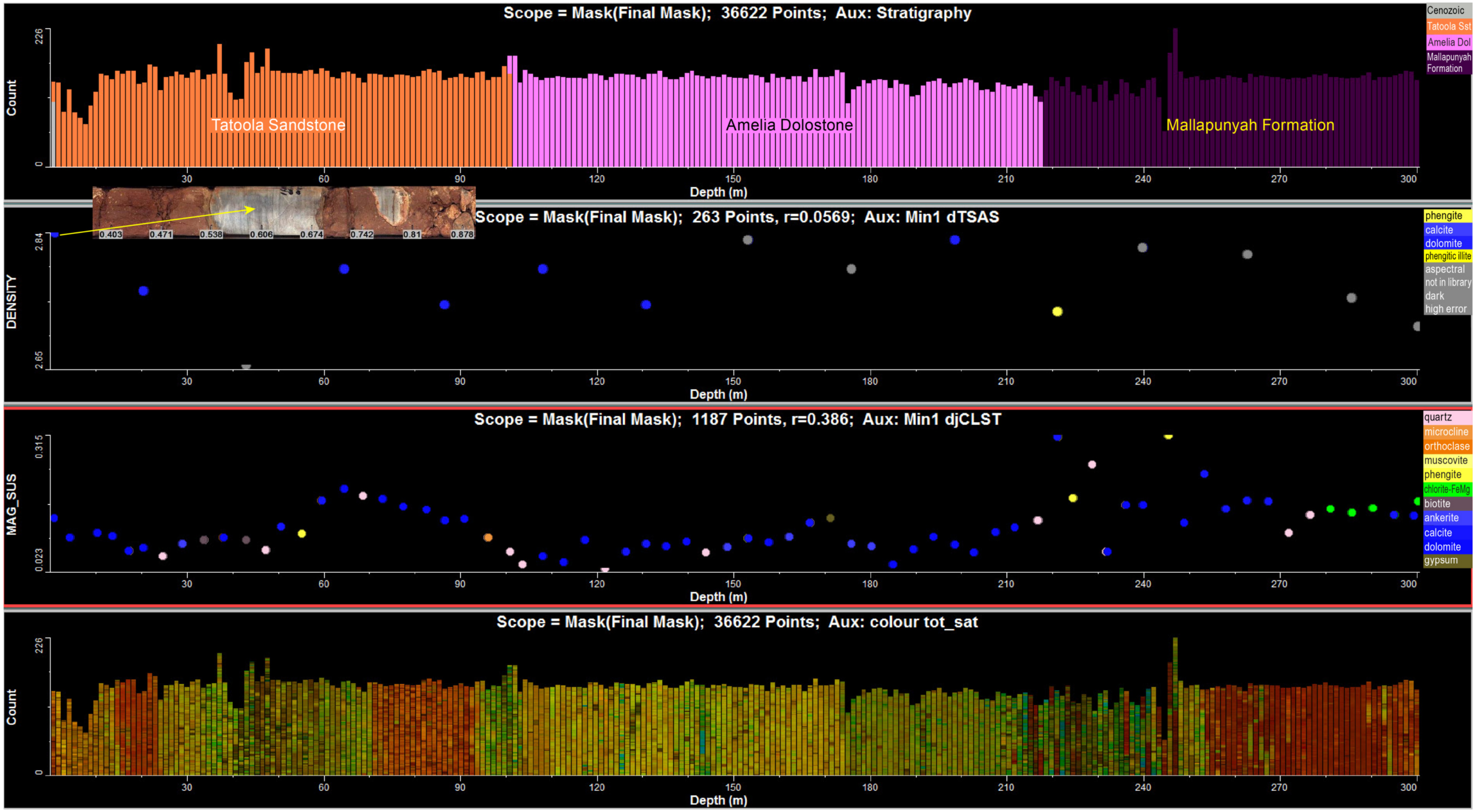
CCD10: Kaolins (View | Plot Layouts load file 6_VNIRSWIR: Kaolins)



Row 1 shows the logged stratigraphic intervals from the Company report. Row 2 are the SWIR kaolin spectra, coloured by the dominant TIR mineral. Row 3 are the SWIR kaolin spectra, plotted by the depth of the kaolin doublet feature (row 3: higher values indicate higher abundance of kaolinite). Row 4 plots the wavelength of the kaolin doublet feature. The shorter wavelengths indicate kaolinite (and not the kaolin polymorph, dickite) is present. There is only a small quantity of kaolinite associated with subsurface weathering at the top of the drillhole.

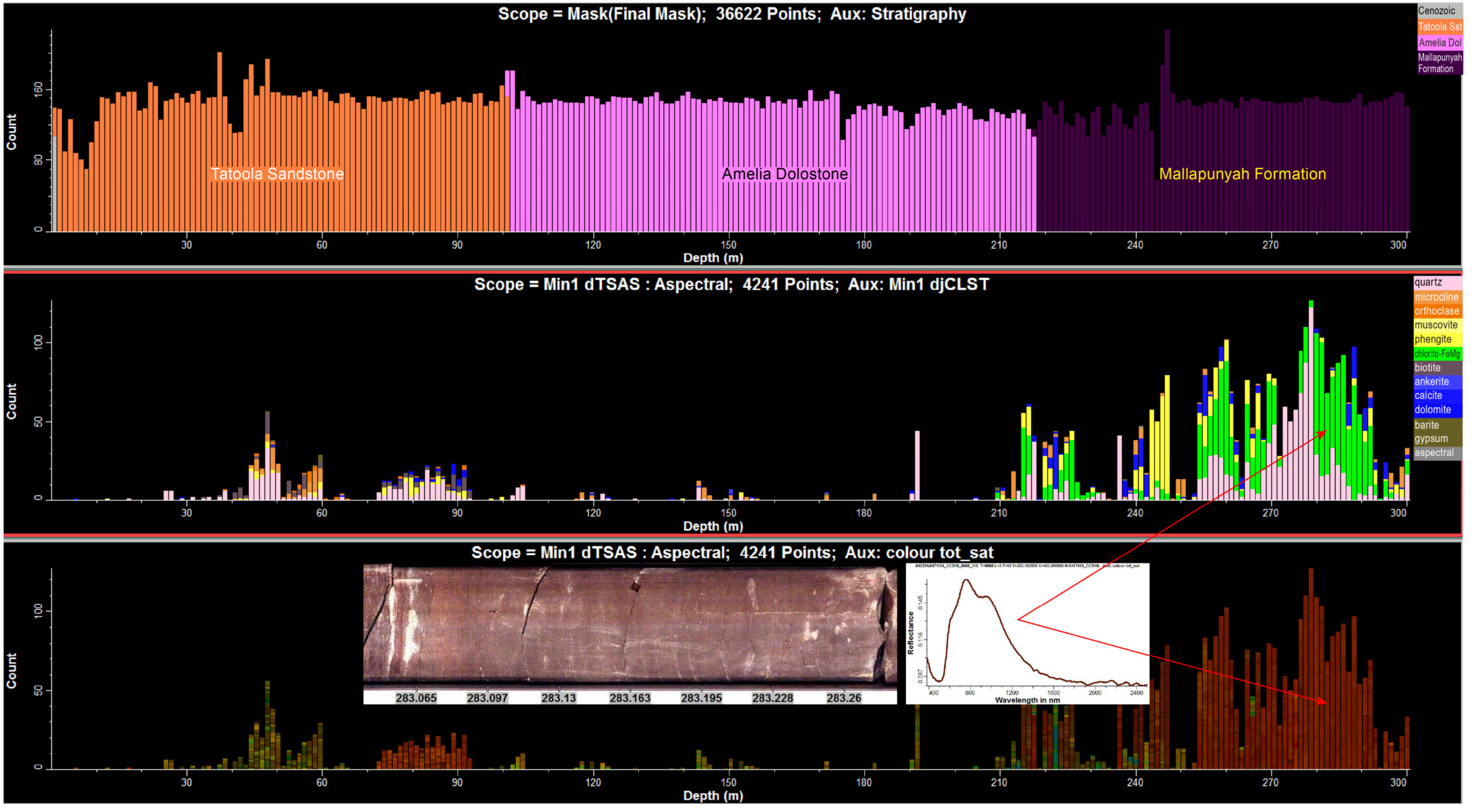
CCD10: Density and magnetic susceptibility

(View | Plot Layouts Load file 7_VNIRSWIR: Petrophysics)



Row 1 shows the logged stratigraphic intervals from the Company report. Row 2 plots the density measurements (coloured by the dominant SWIR mineral). Row 3 plots the magnetic susceptibility (10^{-3}) collected by NTGS and reported in Hallett (2018). Row 3 mag susc measurements are coloured by the dominant TIR mineral. The dry bulk density measurements are derived using the vacuum bagging method (Hallett 2018). Row 4 is core colour. The sample at the top of the hole (0.6 m: see inset image) is not representative of this interval as this is a dolomite clast amongst kaolinitic clays.

CCD10: Aspectral response in SWIR (View | Plot Layouts Load file 8_VNIRSWIR: SWIR Aspectral)



A SWIR aspectral response is when the SWIR spectra cannot match to the library mineral spectra. This may be due to noisy spectra (which may result from measurements on dark core), or measurements from core that contain minerals that are not in the TSA SWIR library. Some minerals do not have any diagnostic SWIR reflectance features, for example silicates such as quartz. Row 1 shows the logged stratigraphic intervals from the Company report. Rows 2 and 3 plot the SWIR spectra that are classed as aspectral and coloured by the dominant TIR mineral (row 2) and the core colour (row 3). The aspectral SWIR matches to TIR chlorite are a puggy ferruginous mudstone, with a 'quenched' response in the SWIR from around 1400 – 2400 nm. This has been previously observed in these fine-grained ferruginous sediments.

CCD10: Summary of HyLogger data interpretation

- CCD10 was drilled to test for copper mineralisation in the Amelia Dolostone. The reported anomalous copper interval (18 m @ 0.2% Cu from 174 m, with 2 m @ 0.4% Cu from 190 m) is characterised by:
    - strongly dolomitic (SWIR and TIR) with minor quartz
    - no white mica
    - finely disseminated chalcopyrite (noted in the imagery)
    - lower albedo than surrounding zone
    - different core colour as observed from the *colour tot_sat* scalar.
- Cross-cutting (late-stage) carbonate is characterised by a strong ferroan dolomite response (broad 990–1300nm spectral response). These carbonates also form steep, subvertical veins that cross-cut bedding and may contain chalcopyrite. This observation is documented in Davidson *et al* (2017).
- The Tatoola Sandstone has variable proportions of carbonate, quartz, white mica and feldspar, with subsurface goethite and hematite along fractures.
- The Amelia Dolostone is dominantly dolomitic, with minor mixed carbonates, quartz, and white mica.
- The Mallapunyah Formation has variable mineralogy, with increasing reddish (oxidised?) ferruginous mudstone at depth. This ferruginous mudstone has variable matches to quartz, white mica, chlorite and carbonate (and may match to aspectral in the SWIR due to the featureless spectrum).
- The elevated K-feldspar in the Mallapunyah Formation corresponds with darker greenish grey (reduced) mudstones adjacent to (oxidised) reddish mudstones.

Logged contact between the Amelia Dolostone (left) and Mallapunyah Formation (right). Note the hematitic breccia within the dolomite unit.

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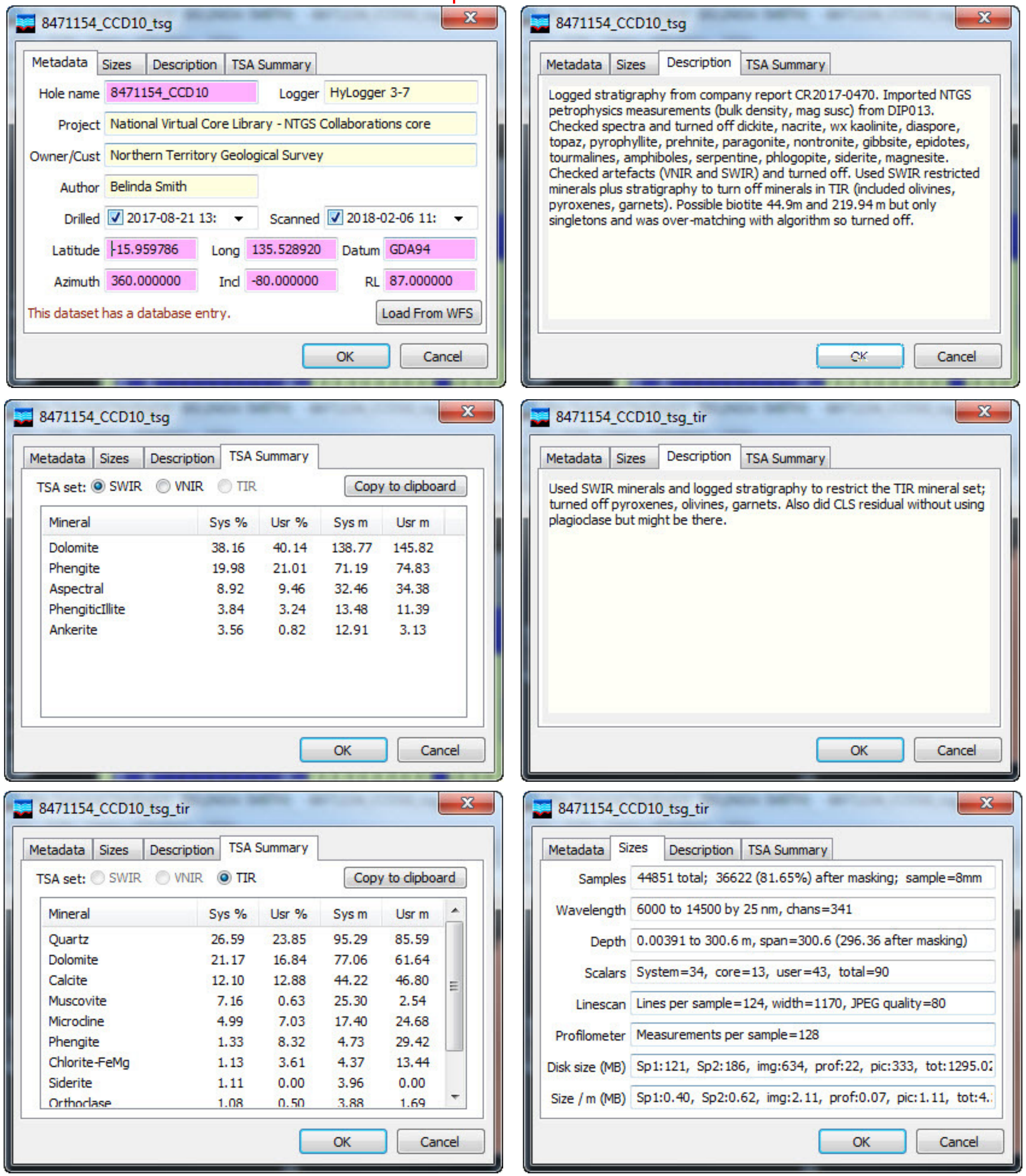
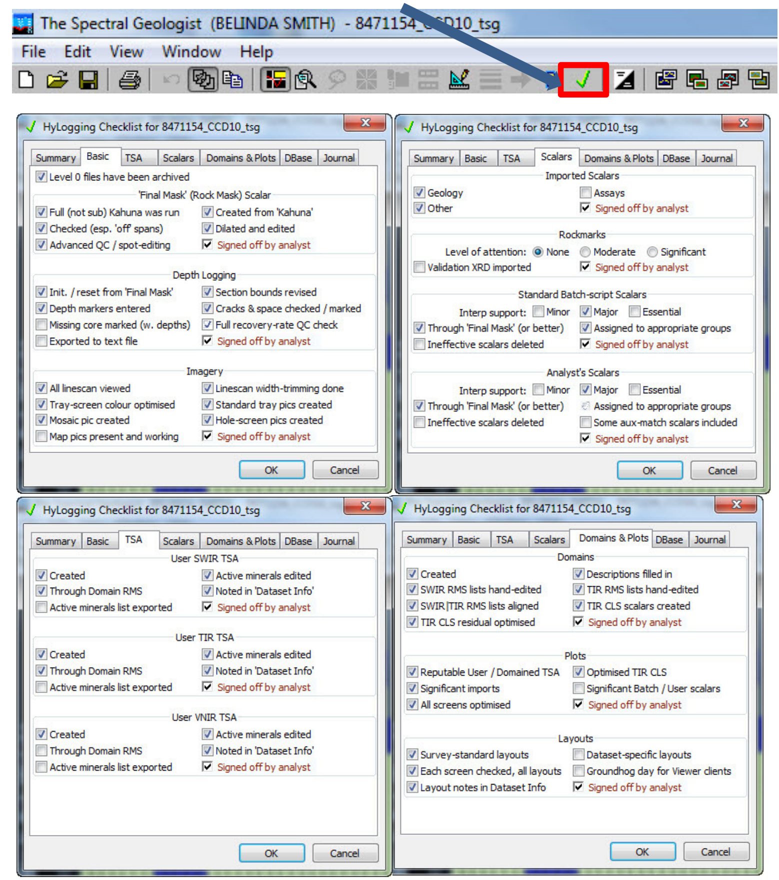
CCD10: TSG metadata

File | Dataset Info



From HyLogger Checklist icon



HyLogger specifications

The TSG dataset originated from HyLogger™3–7. The HyLogger instrument rapidly measures reflectance spectra and also captures continuous high-resolution digital colour imagery of drill cores in their original trays.

HyLogger 3–7 was built by CSIRO (CSERE, North Ryde, NSW) and delivered to NTGS in February 2010 as part of the AuScope National Virtual Core Library (NVCL) project, which was a collaboration between Federal Government's Department of Innovation, Industry Science and Research, CSIRO and state and territory Geological Surveys.

The HyLogger has a continuous motion table that moves at 48 mm/second, three spectrometers (a silicon-detector grating spectrometer for the [380, 1072] nm VNIR interval, an InSB-detector FTIR (fourier transform infrared) spectrometer for the [1072, 2500] nm SWIR interval and a further FTIR spectrometer with a HgCdTe photoconductive detector for the [6000, 14500] nm TIR interval. The spectrometers measure 12 spectra per second, or one spectrum for each 4 mm at the standard table speed of 48 mm/second. The camera is a Basler piA1900-32gc camera, taking 12 frames per second (or one for every 4 mm).

Full details of the HyLogger specifications can be found in Schodlok *et al* (2016b).

Glossary

Glossary of acronyms and technical terms commonly used in HyLogging spectroscopy.

albedo	Normally applied to the mean broadband brightness of a spectrum over a specified wavelength range. A white or altered sample will commonly have a high albedo, whereas a graphitic rock will have a very low albedo.
aspectral	An aspectral response is a spectrum that does not match a TSA library spectrum within the SRSS error cut-off. An aspectral response may be due to many different factors including: dark/noisy spectrum; a mineral not in the TSA library; a silicate mineral without any absorptions in the SWIR (such as olivines, pyroxenes, feldspars, quartz without fluid inclusions).
AlOH	Aluminium hydroxide.
AusGIN	Australian Geoscience Information Network (Geoscience portal): http://portal.geoscience.gov.au/gmap.html is a web portal that hosts NVCL data.
AuScope	The national provider of integrated research infrastructure, of which the NVCL is an infrastructure programme. The AuScope portal (http://portal.auscope.org/portal/gmap.html) hosts NVCL data.
CLS	Constrained Least Squares – an alternative unmixing classifier that uses a RMS to minimise non-unique mineral modelling. Used mainly to model TIR spectra that can have several mixed mineral matches.
Corstruth	A webpage that plots the results (as a pdf summary) from an automated analysis of HyLogger data in the NVCL; www.corstruth.com.au
domain	A zone within a drillhole interpreted to contain a restricted set of minerals that are different to adjacent zones. Unmixing algorithms applied to domained datasets use a RMS that has been defined for each domain by the processing geologist.
FTIR	Fourier transform infrared spectrometer.
HgCdTe	Mercury cadmium telluride used in infrared detectors.
HQ	Hull quotient – a type of background corrected spectrum.
InSb	Indium antimonide – used in infrared detectors.
MCT	Mercury cadmium telluride used in infrared detectors.
MgOH	Magnesium hydroxide.
nm	Nanometre, being one billionth of a metre. A HyLogger 3 operates between 380 and 14 500 nm, with no measurements between 2500 to 6000 nm.
NVCL	National Virtual Core Library; the library of nationally available TSG datasets
scalar	Any set of imported or calculated values associated with spectral data loaded in TSG.
RMS	Restricted mineral set. The processor limits the set of possible mineral matches based on the geological understanding and spectral characteristics of the domain.
SEM	Scanning Electron Microscopy is a type of electron microscope that images the sample surface by scanning it with a high energy beam of electrons, giving information on sample composition and other properties. SEM results may be used to validate mineral identification by the HyLogger.
SNR	Signal-to-noise ratio.
SRSS	Standardised residual sum of squares (TSA's measure of mineral identification error). Low SRSS values are more reliable than high ones. The current 'bad' threshold is 1000.
SWIR	Shortwave infrared (light). In HyLogging applications it nominally covers the range 1000–2500 nm.
TSA	'The Spectral Assistant' – CSIRO trademarked algorithm that uses training libraries of pure spectra to match an unknown spectrum to a single mineral or to identify mixtures of two or more minerals. Part of the TSG software package.
TSG	'The Spectral Geologist' – CSIRO-developed specialist processing software, designed for analysis of field or laboratory spectrometer data. http://thespectralgeologist.com/
TIR	Thermal infrared (light). In HyLogging applications it nominally covers the range 6000–14000 nm.
VIS	Visible (light). The human eye is nominally sensitive between 390 and 750 nm.
VNIR	Visible near infrared (light). In HyLogging applications it nominally covers the range 380–1000 nm.
volume scattering	Radiation that is reflected after some absorption into the rock and changes the spectral shape and features. TIR spectral interpretation assumes that there is only surface scattering in a spectrum. Volume scattering leads to errors in TSA and CLS modelling.
wvl	Wavelength - used in TSG scalar names.
XRD	X-ray diffraction - an analytical technique that reveals information about the crystallographic structure, physical properties and chemical composition of a sample. It is based on observing the scattered intensity of an X-ray beam hitting a sample and measuring the scattered angle and wavelength or energy.

Guide to scalars in figures produced using TSG software

The terms used in the titles, x and y-axis for figures produced from TSG are described in the table below:

2200 wvl 2nd deepest	FEATEX scalar that measures the wavelength of the second deepest absorption feature from 2200nm +/- 50nm. Designed to measure the wavelength of the kandite doublet, which has a variable wavelength depending on whether it is kaolinite or dickite.
2325 CO3 PFIT wvl	PFIT scalar to measure the wavelength of a trough minima between 2290–2370 nm with a depth >0.05; polynomial order 8; hull envelope divided by reflectance reported as wavelength at minimum in nm. Used mainly to analyse carbonate composition changes by observing wavelength changes in the dominant absorption feature for carbonate in the SWIR.
Al smectite abundance	Developed by CSIRO in 2011 as multiple feature extraction method (MFEM) batch script, this (unvalidated) scalar maps montmorillonite and beidellite abundance by measuring the continuum removed depth of a fitted 4th order polynomial between 2120 and 2245 nm.
Apatite 9200 PFIT d	PFIT scalar created by J Huntington to confirm the TSA apatite response. Measures the wavelength of the minimum trough between 9192 nm and 9270 nm with a depth of >0.0006; polynomial order 6; hull envelope subtract base reflectance to give a relative depth.
Aux	Aux in a plot indicates the parameter that is colouring the points (bars in bar plot, points in scatter plot) in a figure. For example, Aux: stratigraphy indicates that the colours relate to stratigraphy. The key to the Aux colours are on the right side of each plot.
Aux match scalar	Aux matching involves simple curve matching between spectra in a main dataset and spectra in a Aux (Auxiliary or Custom) dataset. The Aux dataset is usually a custom library containing special hand-chosen spectra that have been interpreted in detail.
Carbonate 6500 nm PFIT wvl	Experimental batch scalar created by CSIRO derived from the reflectance of the 6500 nm wavelength peak. Used to determine differences in the wavelength of the peak around 6500 nm, which shifts with different carbonate compositions.
Carbonate 11300 nm PFIT wvl	PFIT scalar to measure the wavelength of the peak maxima between 11000–11580 nm with a height of >0.04; polynomial order 9; hull envelope subtract base reflectance to give wavelength at maximum.
Christiansen Minimum	Experimental batch scalar created by CSIRO that plots the Christiansen Minimum wavelength. The Christiansen Minimum occurs when the refractive index of the sample approaches the refractive index of the (medium) air surrounding the mineral grains, resulting in minimal scattering and minimal reflectance (Conel 1969). The Christiansen Minimum wavelength varies according to composition, so measuring the Christiansen Minimum wavelength can differentiate igneous rock compositions in the TIR.
Colour tot_sat	TSG standard scalar; it calculates the colour (separately per band) from the visible interval of the reflectance spectra and it is enhanced by a ‘total saturation’ (the S band is ‘wired to 1’; no pastels’). Refer to TSG Help Manual for more explanation.
Count	The feature frequency plots are bar plots with y-axis = count. The count is cumulative number of features within a bin. The bin size will vary according to the x-axis, which might be depth, wavelength in nanometres etc.
FEATEX scalar	FEATEX scalars use a feature extraction algorithm in TSG to calculate the depth, width and/or wavelength position of a spectrum’s absorption features. It uses pre-calculated feature extraction information from TSG’s default algorithm.
Felsic-Mafic Index wvl	Experimental batch scalar created by CSIRO that maps the peak wavelength between 7500 and 12000 nm from a 4th order polynomial. Shorter wavelengths are more felsic than longer mafic ones. Most carbonate-bearing samples are excluded.
Fe^{2+} intensity	A CSIRO batch scalar that is a measure of the depth of the Fe2+ reflectance absorption (a double ratio - either side of the expected absorption)
FeOH PFIT depth	PFIT scalar to measure the depth of a trough minima between 2240–2270 nm with a depth >0.04; polynomial order 10; hull envelope divided by reflectance reported as relative depth.
FeOH PFIT wvl	PFIT scalar to measure the wavelength of a trough minima between 2245–2260 nm with a depth >0.04; polynomial order 10; hull envelope divided by reflectance reported as wavelength at minimum in nm. Used mainly to analyse chlorite composition changes.
FeOx intensity (alt)	TSG standard scalar (batch scalar) that ratios the reflectance at 742 nm / reflectance at 500 nm to give the Fe slope.
Garnet 11400 comp wvl	PFIT scalar to measure the wavelength of the trough minima focussed between 10550 to 11600nm with a depth >0.2; polynomial order 6; hull envelope divided by base reflectance reported as wavelength at minimum in nm. Used to validate garnet species; almandine has shorter wvl; andradite has longer wvl.

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Guide to scalars in figures produced using TSG software

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Grp 1 Min	Group (coarse level) index of the primary mineral group component in a TSA result. Mineral groups include carbonates, white micas, pyroxenes etc. Grp2 Min would be the secondary/minor mineral group component in a mineral mix.
Hydrocarbon presence	A PFIT scalar designed to measure the presence of an absorption feature at 1730 nm, which is often found associated with oil bleeds. Another scalar designed to identify hydrocarbons is the 23140 nm PFIT scalar. Using both scalars together can identify oil bleeds when the spectral response is preserved (it can deteriorate over time).
Kaolin composition	A CSIRO-built batch scalar in TSG that measures the composition and crystallinity of kaolin group minerals ranging from well-ordered kaolinite to halloysite to dickite (and nacrite).
Kaolinite PFIT 2160 doublet d	A PFIT scalar measuring the relative depth of the kandite doublet absorption feature, as an analogue for crystallinity / abundance of kaolinite. Used to confirm that TSAS-assigned well-crystalline and poorly-crystalline kaolinite are present. PFIT used hull envelope divided by reflectance; focussed on 2155–2180 nm to determine the relative depth using a >0.01 cut-off, polynomial order 3, masked through Final Mask.
Mask (Final Mask)	Mask scalars are used to filter out unwanted spectra caused by scanning tray edges, core blocks etc. TSG uses the Final Mask as the default mask for both SWIR and TIR datasets and will synchronise the mask for both datasets. Many in-built TSG scalars are calculated after being filtered through the Final Mask.
Min 1	Mineral index of the primary mineral for a TSA singleton match or primary mixture component. Min 2 is the subordinate/minor mineral in a TSA mineral mix.
PFIT scalar	PFIT scalars take a section of the spectrum specified by the user, optionally does a local continuum removal, fits a polynomial and calculates a result directly from the polynomial's coefficients. PFIT scalars are used to define the wavelength of noted spectral features.
Prehnite 1475 nm PFIT	PFIT scalar to measure the wavelength of a trough minima between 1460–1485 nm with a depth >0.009; polynomial order 6; hull envelope divided by reflectance reported as a relative depth. Used to confirm prehnite, with the depth of the 1475 nm feature indicative of abundance.
Quartz 8625 PFIT d abundance	Experimental PFIT scalar to measure the 'abundance' of quartz in a sample by measuring the depth of reflectance minima at 8625 nm, which is characteristic of the presence of quartz. Scalar measure returns relative depth in nm, by subtracting the low side of the minima from normalised TC reflectance using a depth >0.02 between 8580–8700 nm.
Quartz 8625 PFIT d MAV	Smooths the 8625 PFIT d abundance scalar (above) by using the mean through a moving window. The output smooths out the effect of outliers to display gross changes in the quartz abundance in plots.
Quartz absorption depth	Experimental batch scalar created by CSIRO to measure the depth of the characteristic quartz reflectance feature at 8625 nm. Similar to the Quartz 8625 PFIT d abundance scalar, but can be more effective in masking out spurious matches to some sulphates that formed from the core decomposition after drilling (refer Sever No.1 drillhole).
Quartz_H2O	An inbuilt batch scalar found in HotCore. Described as 'normalised ratio that maps samples with appreciable (1950 nm) water absorption in fluid inclusions, found mostly in quartz (and some carbonates)'.
Scope	The Scope option allows users to filter their data to visualise the behaviour of selected classes (eg; stratigraphy, mineral groups) and samples in different XY plots. The Scope indicates how many samples out of the total samples in the dataset are currently displayed in this plot window.
Smooth (Albedo)	TSG standard scalar (batch scalar) that first calculates the reflectance albedo over 450–2450 nm with basic channel outlier masking, then averages the numeric response (smooths) of the albedo. May also be called Albedo Rmean Smooth or Smoothed Albedo.
Smoothed scalar	Created by 'smooth an existing scalar using a moving window'. Generally uses averaging of the numeric response to create a smoothed scalar.

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sTSAS, uTSAS, uTSA+, dTSA+	Mineral result from matching to the short wave iInfrared (SWIR) spectra against the TSA library. In TSG versions 7 and earlier; 'sTSAS' is the default system match. 'uTSAS' is the author-derived result from manually excluding some minerals and artefacts (eg; wooden core blocks, plastic chip tray spectra) during processing. In TSG versions 8 and later, TSA+ uses some information derived from selected features in both the SWIR and TIR to make a more informed choice about mineral mixtures. The 'd' indicates the results are 'domained'.
sTSAT, uTSAT, dTSAT	Mineral results from matching to the thermal infrared (TIR) spectra against the TSA library. 'sTSAT' is the default system match. 'uTSAT' is the author-derived result from manually excluding some minerals and artefacts during processing. 'dTSAT' indicates the results are 'domained'.
jCLST, ujCLST, djCLST	The jCLST algorithm has been developed by Andy Green (OTBC Pty Ltd; www.corstruth.com.au) as a replacement for sTSAT, which unmixes the TIR spectra on a sample by sample basis without reference to the results in the VNIR or SWIR (which can commonly return spurious mineral matches). In comparison, jCLST interprets TIR data using the results from a modified TSAT, TSA+ and from scalars using selected features in the VNIR and TIR. 'ujCLST' is the author-derived results from manually excluding some minerals during processing. 'djCLST' is author-derived results from manually domaining the drillhole into zones of similar mineralogy and restricting the minerals available for the jCLST algorithm in each domain.
sTSAV, uTSAV	Mineral result from matching to the visible near infrared (VNIR) spectra against the TSA library. 'sTSAV' is the default system match. 'uTSAV' is the author-derived result from manually excluding some minerals and artefacts (eg; galvanised tray spectral matches) during processing.
TIR-CLS1_CLS_min_1	CLS scalar showing the dominant modelled mineral (using the CLS unmixing algorithm) from the TIR wavelength range. For this scalar, the number of minerals allowed in the CLS mineral output is 3 (shows the 3 most dominant) although the scalar can allow for up to 6 minerals. The minerals available for modelling in the domain (RMS) is selected during the interpretation / processing stage.
TIRDeltaTemp	An inbuilt TSG scalar that measures the change in temperature between the instrument response measured from the rock and the background response. Plotting this scalar can highlight sulphides or arterfacts (such as metal tray edges, metal depth marker tabs or instrument issues).
Tourmaline PFIT 2366 nm	PFIT scalar to measure the wavelength of a trough minima between 2360–2375 nm with a depth >0.015; polynomial order 5; root mean square error (RMSE)<=0.06; hull envelope divided by reflectance reported as a relative depth. Used to search for tourmaline in mixtures with chlorite and white micas (which may have overlapping features at around 2206 nm and 2244 nm).
uTSA*	The result from TSA. The prefix 'u' is for 'user' and refers to the fact that TSA is trained on a reference library of minerals that have been limited by the author from the system set of minerals called sTSA* during the processing of the dataset. The minerals that are excluded from being matched to the TSA library are those that are considered to be unlikely in that geological environment and do not visually match the spectra well.
uTSAT invalid	A scalar created to mask out both Final Mask and 'aspectral', 'noisy' or 'null' for uTSAT Min 1 minerals. Plots that use uTSAT plot only spectra that were successfully matched in the TSA library, so noisy spectra (which may be noisy due to rubbly core, volume scattering etc) don't detract from displaying the dominant mineral or mineral group in the TIR. If a hole has a lot of 'invalid' spectra due to rubbly core, it may over-emphasise minor minerals in the TIR that are perhaps within unbroken core and may not reflect accurate mineral proportions.
White mica PFIT wvl	PFIT scalar to measure the wavelength of a trough minima between 2190–2229 nm with a depth >0.04; polynomial order 10; hull envelope divided by reflectance reported as wavelength at minimum in nm. Used mainly to analyse white mica composition changes by observing wavelength changes in the dominant absorption feature for white mica in the SWIR.
White mica PFIT d	PFIT scalar to measure the depth of a trough minima between 2190–2229 nm with a depth >0.12; polynomial order 10; hull envelope divided by reflectance reported as relative depth.
WM crystallinity	Arithmetic scalar measuring D2200 white mica divided by D1900 masked by the Final Mask. White mica crystallinity measures the depth of the AlOH absorption feature relative to the depth of the water feature. A deeper water feature indicates lower crystallinity and may indicate an illitic white mica (which may also have some compositional substitution).

Excerpt from Huntington & Mason 2010

1.1 Basic HyLogging Product Levels

0. **Machine Data** package (QCed & archived by collecting team / agency: i.e. all repeats taken care of and data checked).
1. **TSG Data** package - TSG imported and formatted data (see note about TSG-QC outputs)
   - 1A. TSG imported imagery, spectra and supporting data (nothing else done). Raw system TSA run on import but no checking. Depths only based on tray starts & ends.
   - 1B. Final masked, basic depth-logged data, imagery enhanced, new tray imagery & mosaics created.. Further updates possible.
   - 1C. All standard "system" scalars (includes basic masked and reviewed TSA mineralogy) created & checked.
   - 1D. User TSA results included (i.e. retrained TSA) and all Scatter screens changed to uTSAS. Minimum database entry point.
   - 1E. Non-standard mineralogical (manually-generated) "user" scalars added, thresholded and checked. Might include an Aux match library or stats (PC) analysis.
   - 1F. All metadata tables updated. Optimum database loadable level. Further updates possible.
2. **Integrated Data** package - Imported numeric or class scalars added into TSG and depths adjusted if required to fit assay intervals.
3. **Published Data** package - Signed-off for public (NVCL) database publication. Default set of products (for web discovery) identified and tagged.
4. **Down-sampled Data** package - Optional down-sampled version of all of above.
5. **Project data** package. Abstracted data from many holes integrated in some way.

The HyLogger Product level refers to the level of processing of a dataset. This dataset is at 'Level 3' as it has imported stratigraphic information.