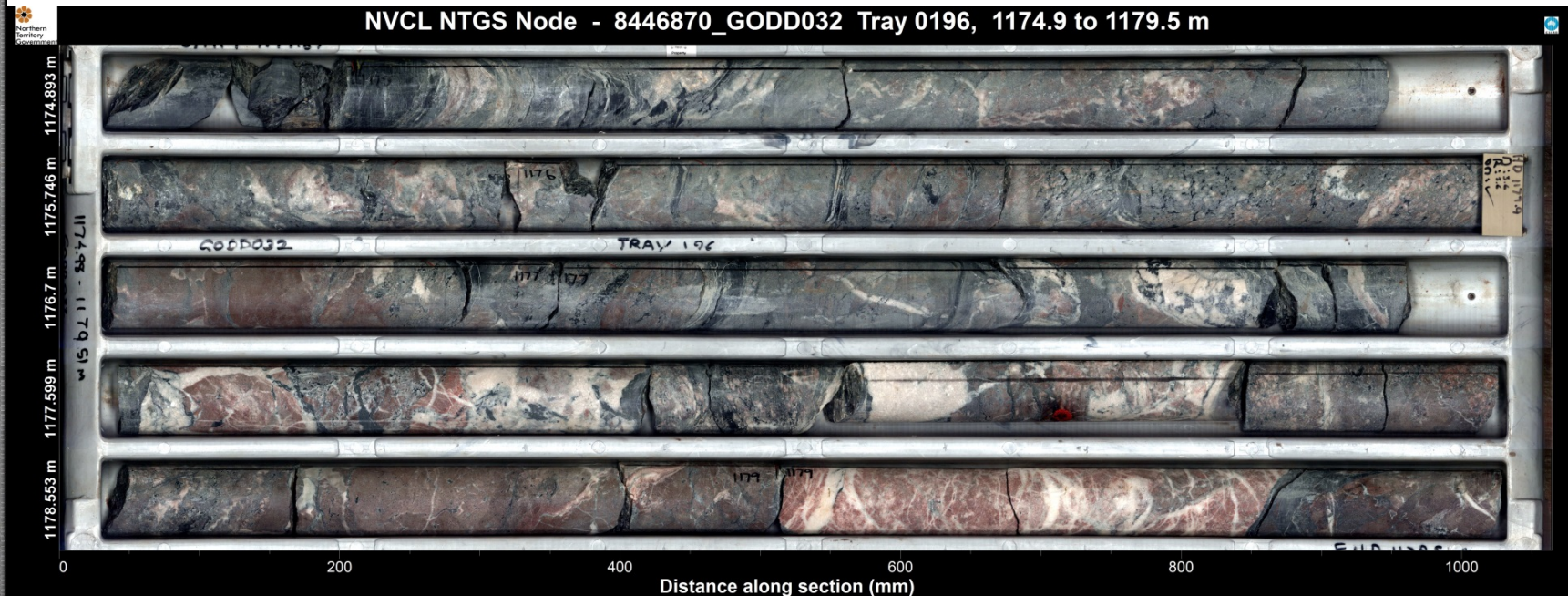
HyLogger Data Package 0060

HyLogger drillhole report for GODD032,
Warramunga Province, Tennant Region, Northern Territory.

Belinda Smith



DEPARTMENT OF PRIMARY INDUSTRY AND RESOURCES
MINISTER: Hon. Ken Vowles, MLA
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NORTHERN TERRITORY GEOLOGICAL SURVEY
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BR Smith
HyLogger drillhole report for GODD032, Warramunga Province, Tennant Region, Northern Territory.

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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) as a default 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. TSA abundances are relative abundances, only the two most prevalent minerals identified in the Short Wave Infrared (SWIR) and the three most prevalent minerals in the Thermal Infrared (TIR) wavelengths are reported. If there are more than two minerals actually present in the sample in the SWIR (or three 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 unlikely in that geological environment, introducing an 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 of that domain. Any results from the TIR should be used with caution as algorithms and TSA libraries are in a constant state of revision. These results were published using TSG Version 7.1.0.069 dated June 2016.

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

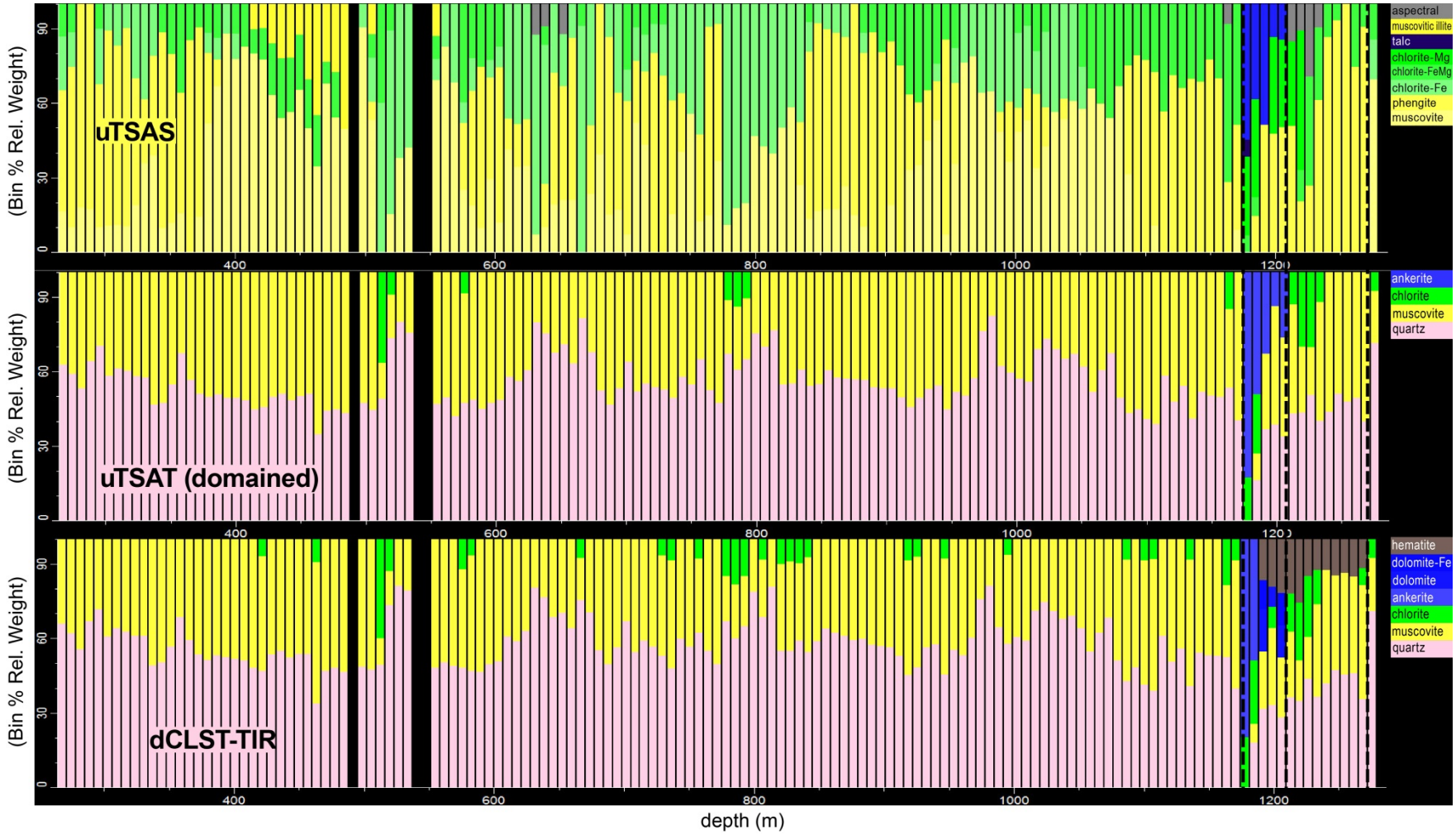
GODD032: Introduction

Hole ID	GODD032	**Unique identifier**	8446870
Geological terrane	Warramunga Province, Tennant Region	**Total depth**	1279.0 m
Latitude GDA94	-19.430667°	**Longitude GDA94**	134.06745°
Easting MGA94	402102.1 (Zone 53)	**Northing MGA94**	7851254.1 (Zone 53)
Dip	-85°	**Azimuth**	320°
Logged by	Emmerson Resources Ltd	**Logged report ref**	Garcia-Cuison (2015)
Start core depth	264.9 m	**End core depth**	1279.0 m
Date HyLogged	March 2016	**HyLogged by**	Nigel Saunders
Date of HyLogger report	October 2016	**HyLogger report author**	Belinda Smith
TSG version and build	HotCore Build 69 (June 2016)	**TSG product level**	3 (Huntington 2010)

Summary of information from Garcia-Cuison (2015)

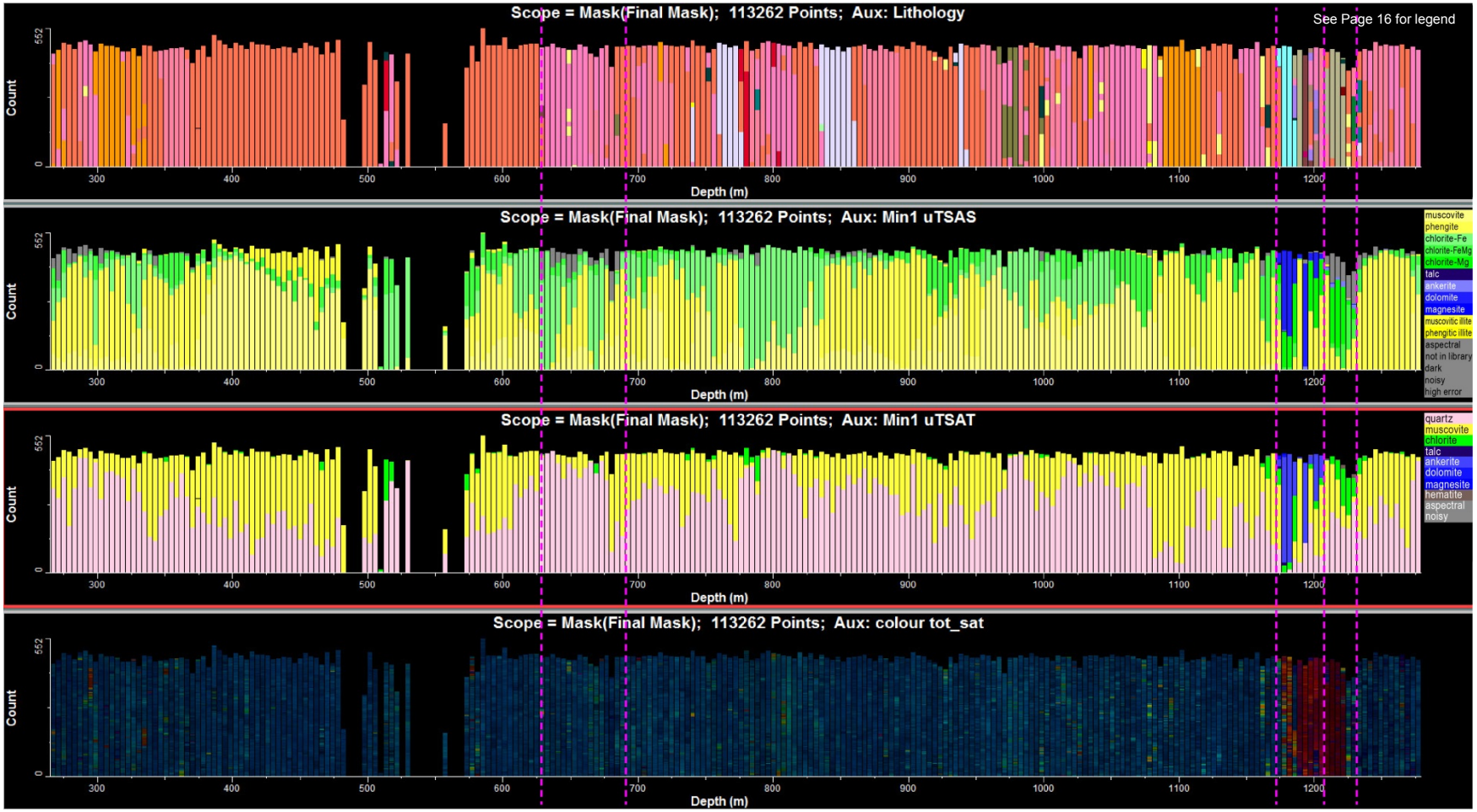
- Drilled under the NTGS Geophysics and Drilling Collaborations programme (Round 8; 2015/16).
- Drilled as a 'proof of concept' test of an interpretation from the 2D seismic reflection survey.
- GODD032 intersected Warramunga Formation sediments, a mineralised diorite from 968.2 m and an ironstone (with alteration) from 1191.5 m.
- The deep ironstone occurs in the footwall of a major fault. The ironstone is logged as hematite–quartz–jasper, with local colloform texture. Below this section is a 2 m zone of hematite–chlorite–quartz. The ironstones failed to return significant mineralised intercepts.
- Visually logged alteration noted quartz–hematite in siltstones and chlorite–sericite in the coarser unit. Pervasive quartz dolomite was intersected above the ironstone.
- GODD032 was drilled along a 2D seismic line, with results presented at AGES2016 (Osborne *et al* 2016).

GODD032: Mineral summary – all minerals, TSA and CLS



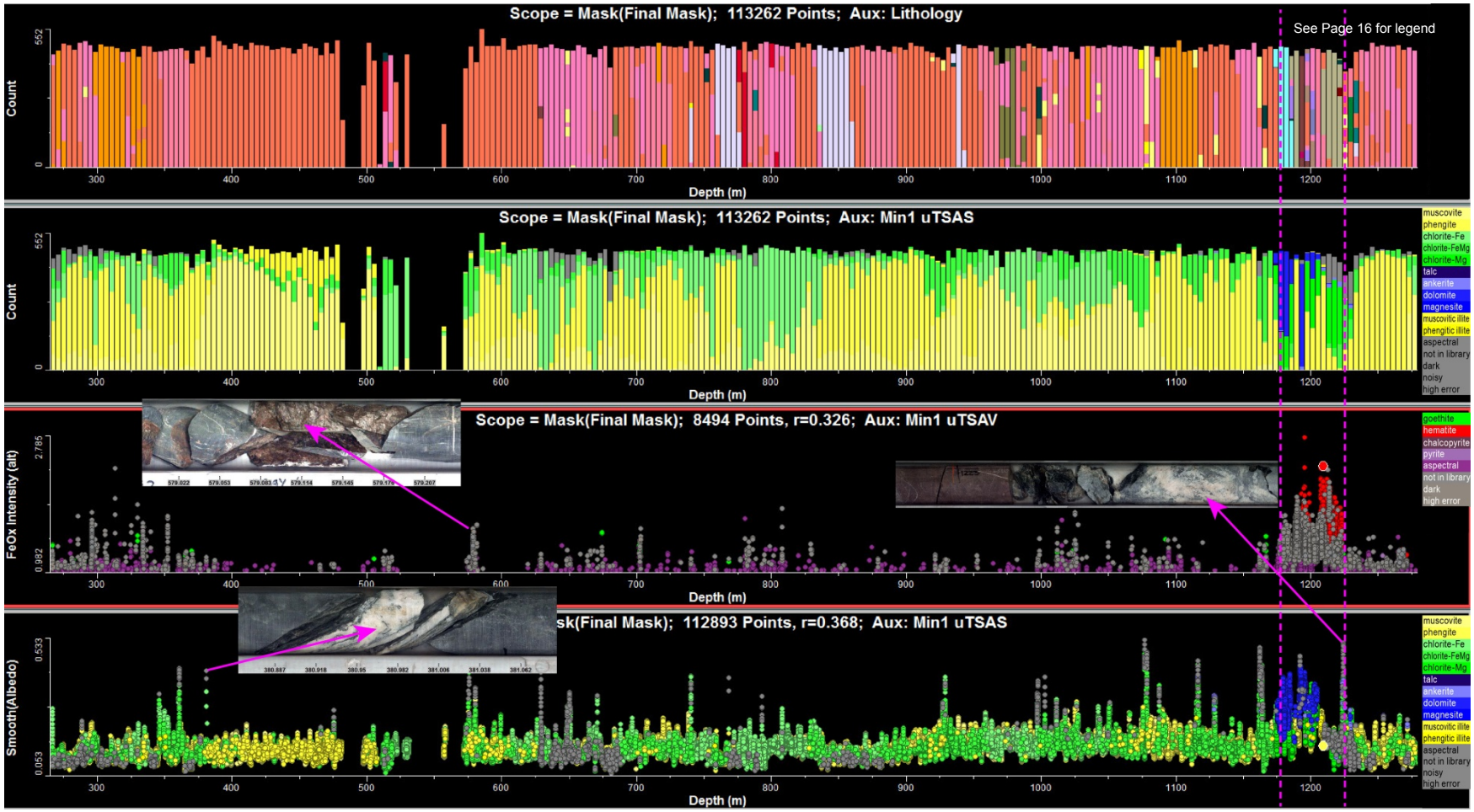
From Summary Screen: Row 1 shows SWIR mineral summary. Rows 2 and 3 show the TIR mineral summary. Row 2 is the TIR mineral summary using the TSA algorithm. Row 3 is the TIR mineral summary using the CLS algorithm. Rows 2 and 3 were domained into zones of similar mineralogy using a restricted mineral set. Dotted lines show mineralogy changes. Black zones from intervals of core loss (no spectra). Comparing the TIR mineral matches between the TSA (row 2) and CLS (row 3) shows that the CLS may be able to delineate individual carbonate minerals better than the TIR. The hematite in the CLS is probably over-represented and this mineral proportion from the CLS should be treated with caution.

GODD032: Mineral summary



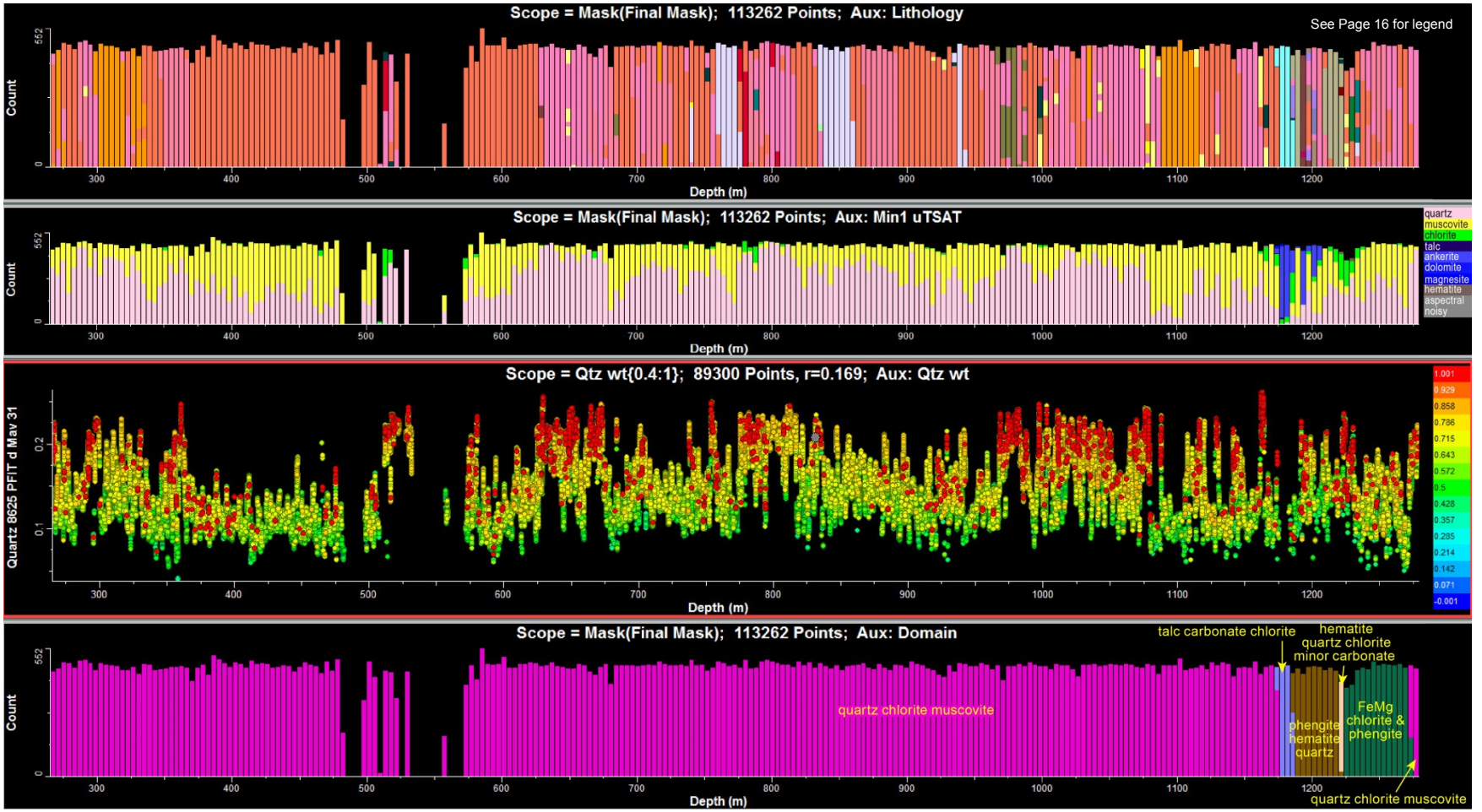
Row 1 shows logged lithology. A readable lithology log legend is on page 16. Row 2 shows SWIR mineralogy (Min1). Row 3 shows the dominant TIR mineralogy (using the TSA unmixing algorithm, which is used on all the following pages that discuss TIR mineral matches). Row 4 is a (total saturated enhanced) core colour. Dotted lines indicate changes in either mineralogy and/or core colour. The mineralogy of quartz, white mica and chlorite is quite consistent for most of the hole away from the logged ironstone and associated alteration, which consists of zones with talc, carbonate and hematite. The logged diorite has the same mineralogy as the surrounding metasedimentary rocks, which may indicate that the mineralogy reflects the effects of regional metamorphism, rather than the original lithology. The aspectral zone (minor grey colours in row 2 between 628 m and 684 m) is discussed on page 14.

GODD032: SWIR and VNIR mineral summary



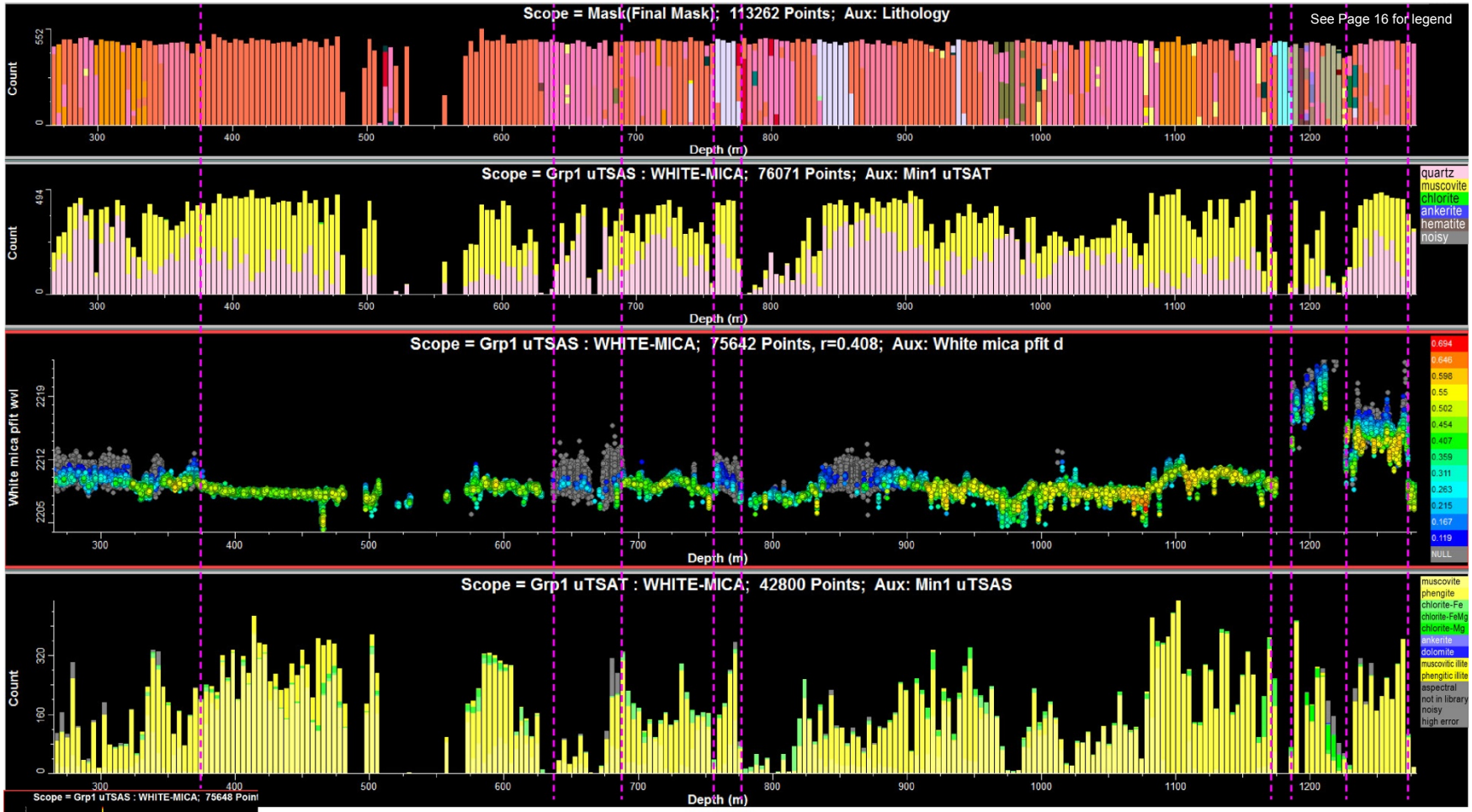
Row 1 is the logged stratigraphic sequence. Row 2 is the SWIR spectra matched to the dominant mineral (Min1 uTSAS). Row 3 is the FeOx intensity scalar coloured by the dominant VNIR mineral. Row 4 is the dominant SWIR mineral plotted by the (smoothed) albedo. Dotted lines show changes. As with the previous page, the main changes are in the area of the logged hematite rock and surrounding alteration. The core image (inset, right) shows the high albedo spike from white quartz vein; the zone with high hematite next to the quartz vein is the hematite shale. Sharp zones of high FeOx intensity show FeOx-lined fracture zones (see inset, upper left); the sharp spikes of high albedo show white quartz zones in darker grey metasedimentary rocks (see inset, lower left).

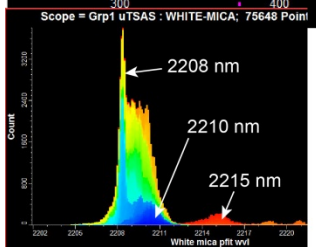
GODD032: TIR mineral summary



Row 1 shows logged lithology. Row 2 is the dominant TIR mineral (using the domained TSA algorithm). Row 3 is silica plotted by the depth of the reflectance feature (deeper feature may indicate more abundant quartz in sample) coloured by the quartz proportion in the TSAT mineral match. Row 4 shows the domains used to restrict the minerals allowed for matching the TIR spectra (see page 16 for further information). The more abundant quartz zones may highlight quartz veins or zones of silica alteration. There is no discernible correlation between quartz content and logged lithology for the Warramunga metasedimentary rocks (sandstone, siltstone and interbedded sandstones/siltstones/greywacke). There is higher quartz for ‘quartz rock’ and ‘quartz chlorite rock’.

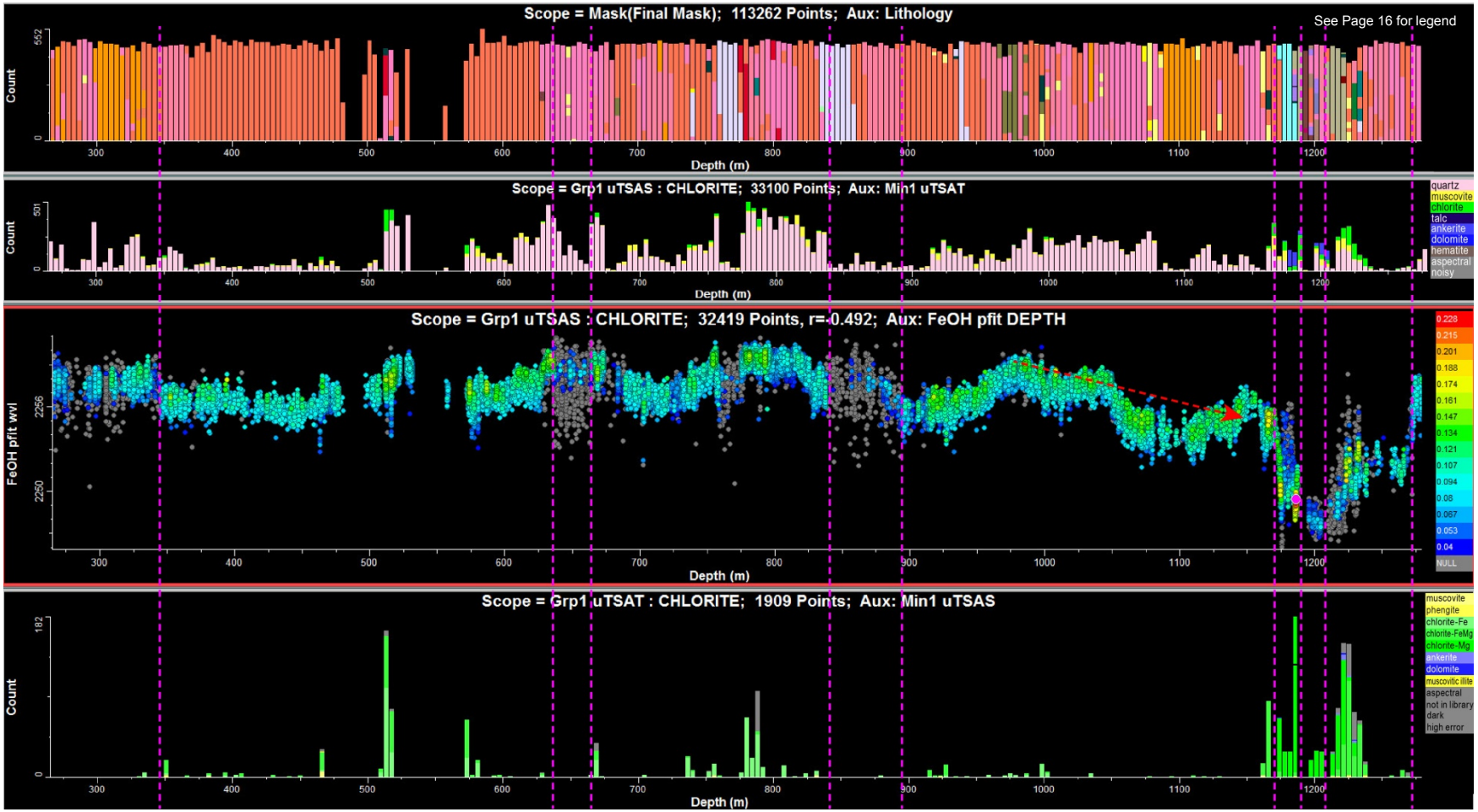
GODD032: White micas





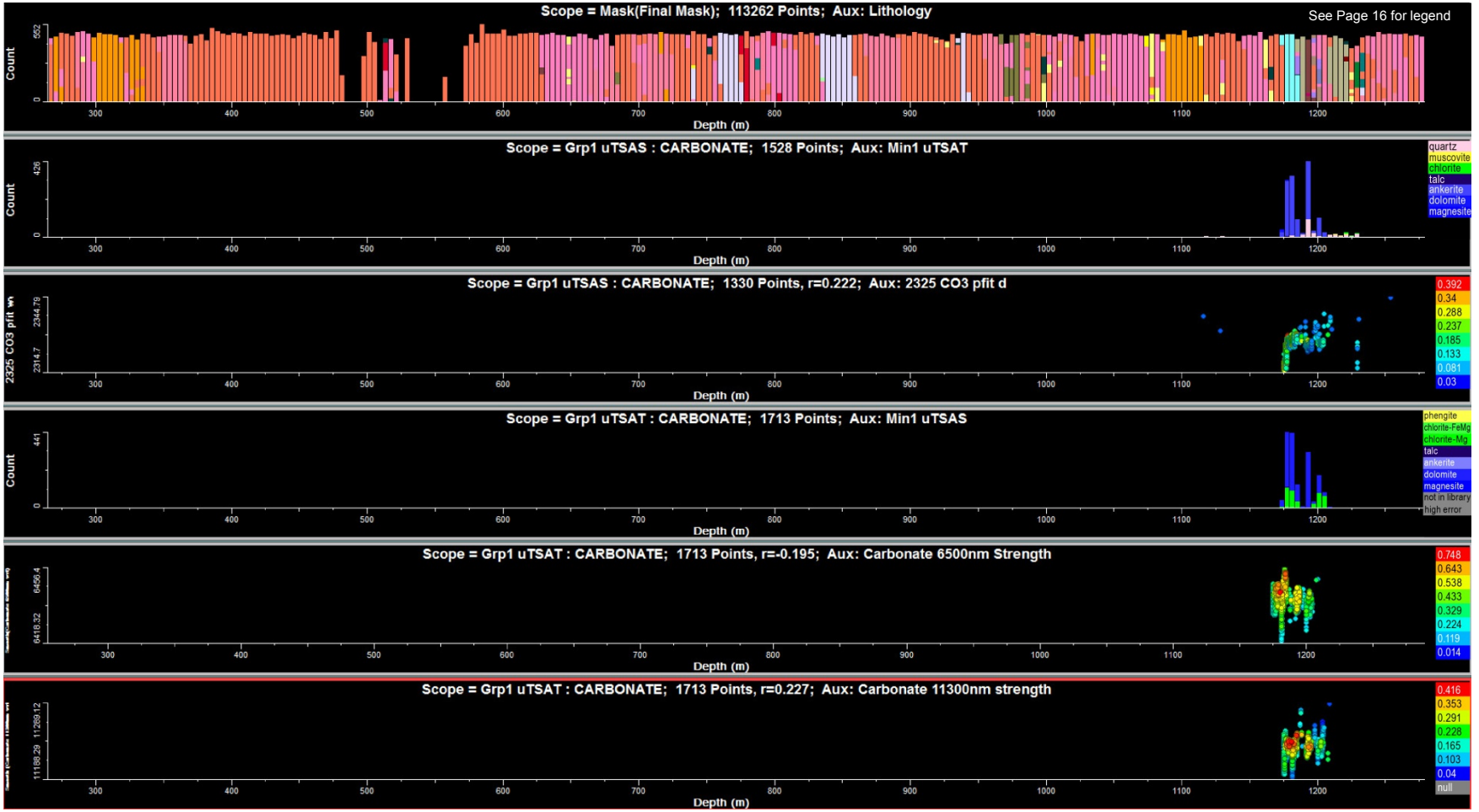
Row 1 shows logged lithology. Row 2 is the distribution of the SWIR spectra that match dominantly to white mica, coloured by the dominant TIR mineral. Row 3 is white micas plotted against the wavelength of the characteristic white mica absorption feature (which changes with white mica composition changes), and coloured by the depth (strength) of the white mica feature. Row 4 is TIR-assigned white micas coloured by SWIR mineralogy. The dotted lines show breaks in white mica occurrences, or in white mica composition. Dotted lines at 377 m, 636 m, 689 m, 758 m, and 777 m mark the breaks between zones of strong white mica with consistent composition (~ 2208 nm muscovitic composition; see inset left) and white micas that are less abundant and with variable composition (scattered grey / blue dots in row 3). If the uniform abundant white mica composition zones reflect regional metamorphism, then these variable composition and low abundance zones (which don't always correlate with logged lithology) may reflect zones of alteration from later movement of hydrothermal fluids (?). Note the lack of white mica in zones around the ironstone.

GODD032: Chlorites



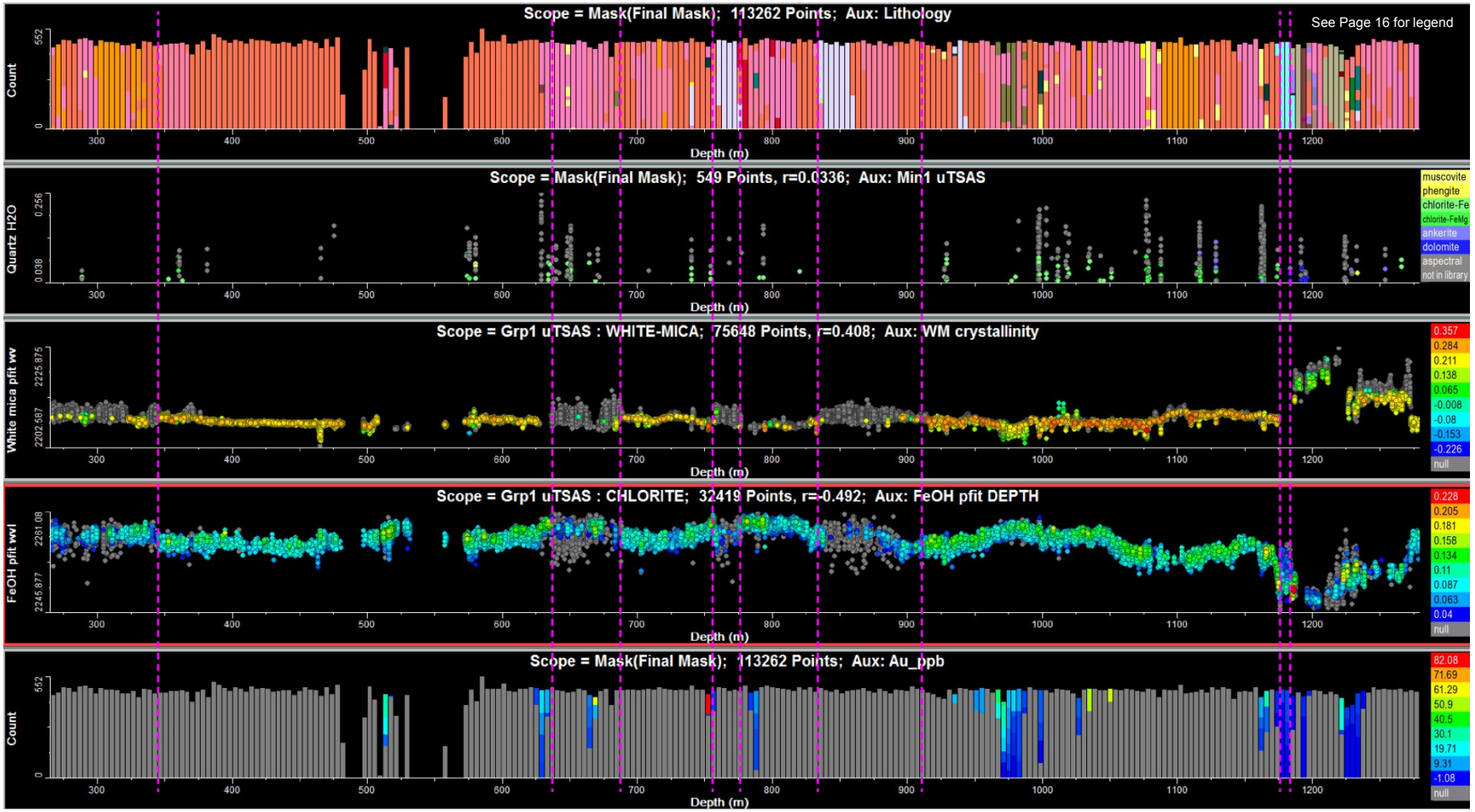
Row 1 is the logged lithology. Row 2 is SWIR chlorites coloured by TIR mineralogy (most SWIR-assigned chlorites match to quartz). Row 3 are spectra that match dominantly to chlorite in the SWIR, plotted by the wavelength of the diagnostic SWIR chlorite FeOH absorption feature. The wavelength changes with chlorite composition changes. Each point is coloured by the depth (strength) of the FeOH feature, which is analogous to chlorite abundance. Row 4 is the TIR chlorite coloured by SWIR mineralogy. The TIR chlorites are not usually dominant, as most matches are in rocks where quartz is the primary TIR mineral, so chlorite is a secondary TIR mineral. In GODD032, most of the TIR chlorite matches are from the Mg chlorite alteration associated with the deep ironstone. Most of the chlorite is Fe to FeMg chlorite (FeOH wavelength around 2256 nm) with some zones of disturbance (637–677 m, 839–892 m). There is a slight overall increase in Mg (decreased Fe) going downhole from around 988 m (see dotted arrow, row 3) approaching the ironstone alteration zone. As with the white micas, the zone from 1272 m reverts to similar composition as higher in the hole.

GODD032: Carbonates



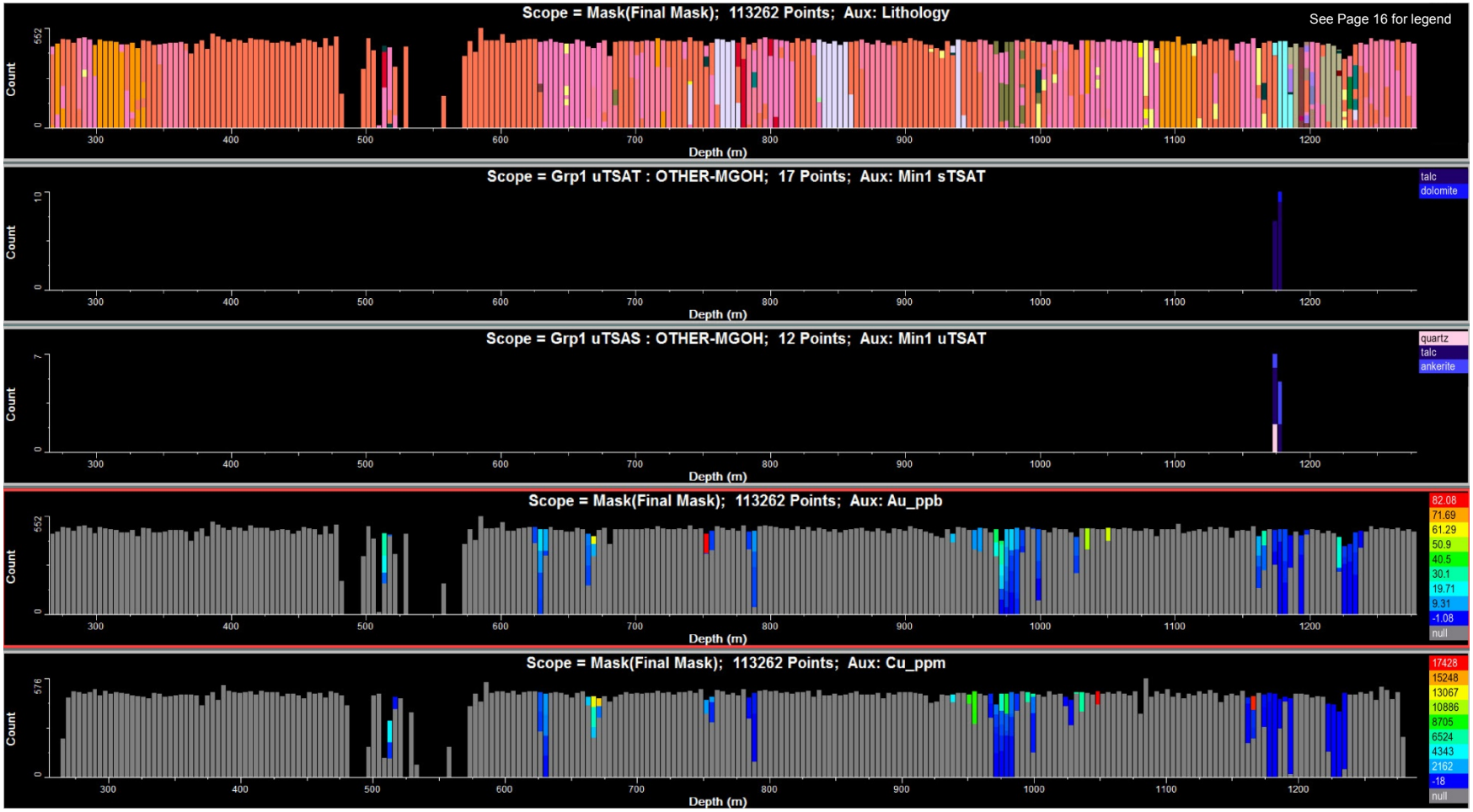
Row 1 is logged lithology. Row 2 is the SWIR carbonates coloured by TIR mineralogy. Row 3 is the SWIR carbonates plotted by the wavelength of the carbonate feature, coloured by the depth (abundance) of that feature. There is a range of wavelengths at 1176 m that suggests a mixture of dolomite with some magnesite and possible ankerite. Row 3 plots the TIR carbonates coloured by the SWIR mineral. Rows 5 and 6 plot the TIR carbonates by the wavelength of characteristic reflectance features in the TIR at 6500 nm and 11300 nm respectively. The carbonates are limited to the carbonate alteration on the hangingwall of the ironstone. It seems to be dominantly dolomite but with minor magnesite and possibly ankerite. With depth, the carbonate is more uniformly dolomitic but occurs with hematite and quartz (logged quartz–hematite rock). Of note is the logged sandstone interval at 1203–1204 m is dolomitic.

GODD032: Quartz veins and possible hydrothermal fluid zones



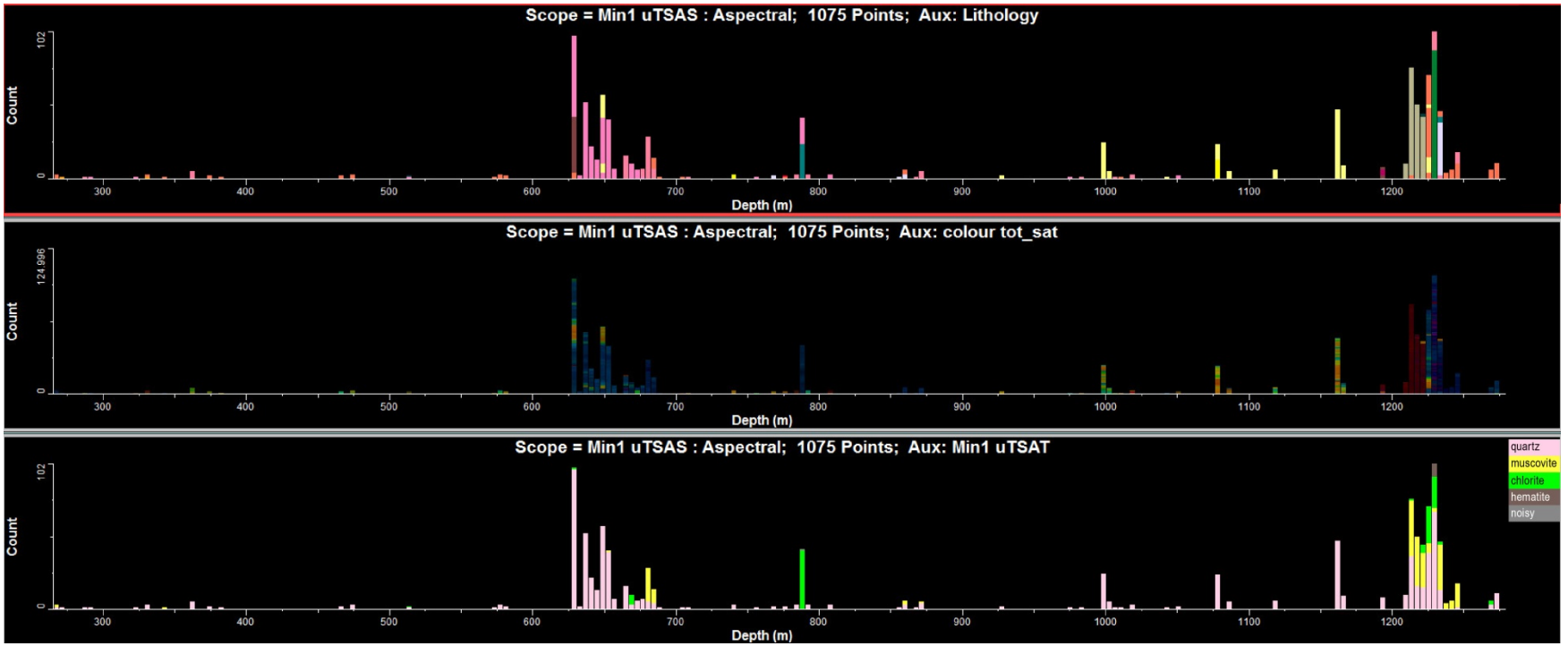
As mentioned on pages 9 and 10, it is possible to interpret zones that may have hydrothermal overprinting, as evidenced by a lack of uniformity in the wavelength of the white mica and chlorite wavelengths. This slide shows where these sections are located with reference to quartz veining (row 2; which uses the CSIRO 'quartz H_2O' scalar to map spectra that have a 1900 nm water feature from fluid inclusions in quartz). Row 1 is logged lithology. Row 2 plots the quartz veins from the quartz H_2O scalar. Row 3 plots the SWIR white mica spectra by the characteristic white mica reflectance feature wavelength, coloured by white mica crystallinity. Low crystallinity (grey or blue colours) are expected in zones that have a high bound water content within the mineral (see page 17 for white mica crystallinity explanation). Row 4 plots the SWIR chlorites by the characteristic chlorite reflectance feature wavelength, coloured by the depth (strength) of that feature. Row 5 plots the Au (ppb) assays for the sampled intervals (samples were collected only in the intervals coloured above). The highest Au value (at 753 m of 82 ppb) appears to be associated with quartz veining on the edge of a hydrothermal fluid zone (fault?).

GODD032: Talc and Au, Cu assays



Row 1 is logged lithology. Rows 2 and 3 plot the few spectra that are dominantly talc in both the SWIR and TIR. The talc is above the dolomite associated with the hematite rock logged from 1191.5 m. Rows 3 and 4 plot the available assay results (from Garcia-Cuison, 2015) for Au and Cu. Grey coloured intervals were not sampled.

GODD032: Aspectral in SWIR

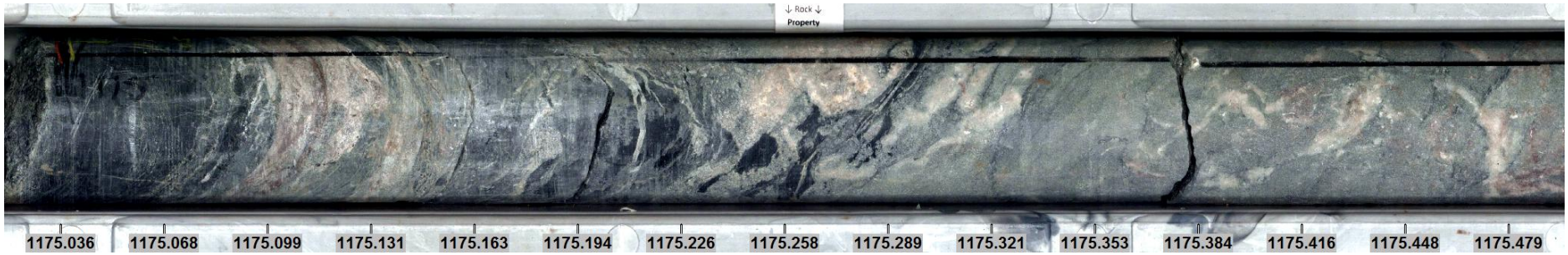


A SWIR aspectral response is when the spectra can't match to the library mineral spectra. This can be due to the spectra not being in the library, being noisy or dark spectra, or because the minerals present have no SWIR reflectance features (eg quartz). The SWIR aspectral response in GODD032 is plotted here coloured by the logged lithology (row 1). Row 2 plots the aspectral response is coloured by the (total saturation) colour. In row 3, the aspectral response is coloured by the dominant TIR mineral. From row 1, the aspectral response can be found in a number of logged lithologies. Within the sandstone, it may show as an aspectral response due to the quartz-rich sandstone or quartz veins (628–682 m). The quartz-rich lithologies around below the ironstone (1210–1243 m) may have an alteration overprint of Fe oxides and silica, which have no features in the SWIR. The aspectral response around 788 m that plots as TIR chlorite is in logged 'chlorite–hematite rock'. The SWIR response is featureless, possibly due to very fine-grained disseminated Fe oxides 'quenching' the SWIR spectra so that it has a relatively low reflectance and is featureless in the SWIR.

In GODD032, the aspectral response may highlight zones with Fe oxide or silica alteration.

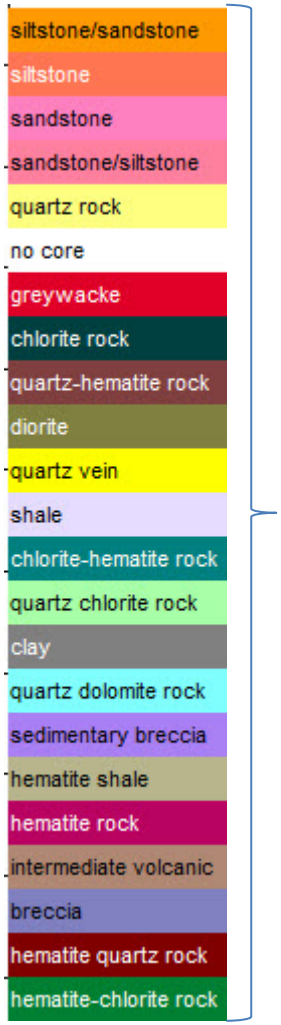
GODD032: Summary of HyLogger data interpretation

- The dominant mineralogy is white mica, quartz and chlorite.
- White mica distal to the ironstone is mainly highly crystalline muscovite with a 2208 nm wavelength feature.
- The chlorite that is distal to the ironstone is mainly FeMg to Fe chlorite with a 2256 nm feature.
- The white mica and chlorite composition away from the ironstone are fairly consistent regardless of logged lithology. This is particularly notable with the logged diorite (which comprises Fe chlorite, muscovite and quartz). This is not the expected mineralogy of an intermediate igneous rock. The textures suggest that this is likely to be a precursor igneous rock, although there are no other analyses at the time of this report that confirm the lithology. The uniformity of mineralogy and consistent high white mica crystallinity may reflect alteration from regional metamorphism, or may reflect alteration within the Gecko corridor. To confirm this, the mineralogy from other holes distal to ironstone emplacement and known mineralisation should be compared with the GODD032 mineralogy.
- Zones of low crystallinity white mica and variable white mica / chlorite composition (distal to the ironstone alteration) may highlight fault zones, or zones of hydrothermal fluid pathways. Quartz veining can also be identified from the spectral response.



Alteration above the ironstone; talc chlorite on LHS grading to ferroan carbonate and minor magnesite on RHS

GODD032: Legend for lithology (left) and domain (right)



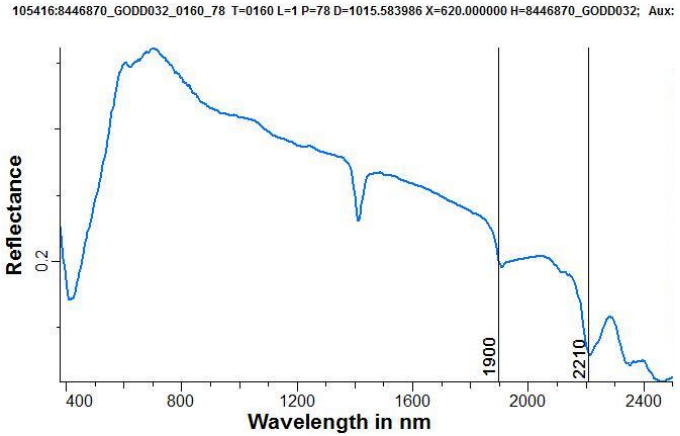
Logged lithology from Garcia-Cuison (2015)

Quartz chlorite muscovite domain for zone distal to ironstone (including a zone below the ironstone, from 1272.42 m). Chlorite is FeMg chlorite and/or Fe chlorite but NOT Mg chlorite.
Talc carbonate chlorite domain for zone above ironstone. Mainly dolomite but some indications of magnesite and possibly ankerite. NO white mica at all in this zone.
Phengite hematite quartz domain has longer wvl white mica (phengite), Fe oxides (possibly magnetite, goethite but matches best with hematite in TIR), some Mg to MgFe chlorite
Hematite quartz chlorite, minor carbonate domain: small zone with carbonate (compared with no carbonate in previous domain).

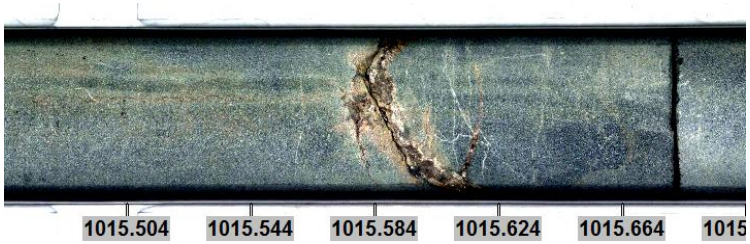
Domains are created by the processor to simplify the minerals (create a 'restricted mineral set' or RMS) for each interval of the drillhole that is mineralogically distinct. Domains are used to deal with non-uniqueness issues from modelling the TIR spectra. In GODD032, most of the hole is within the quartz chlorite muscovite domain (see above) as there is very little mineralogical variation away from the ironstone and surrounding alteration.

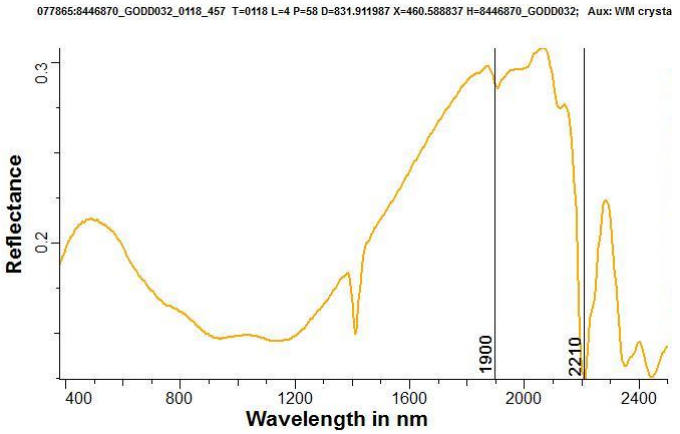
GODD032: White mica crystallinity

White mica crystallinity is measured by the increasing sharpness of the AlOH absorption (at around 2200 nm); increasing depth of the AlOH absorption feature relative to the water absorption and a weakening water feature with increased crystallinity (AusSpec 2008). Other AlOH minerals (such as smectites, kaolinites) can interfere with the white mica crystallinity scalar. Highly crystalline white micas are usually muscovite or phengite. The illitic white micas show some compositional substitution and have lower crystallinity.

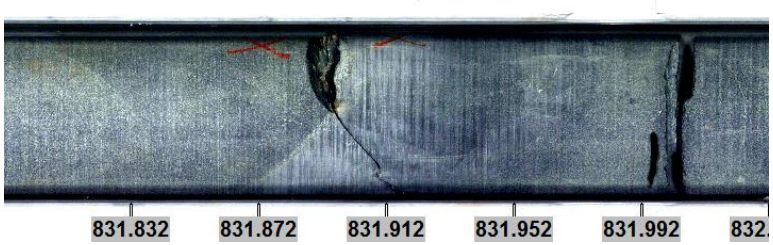


Low crystallinity white mica: the depth of the 1900 nm is quite deep compared with the 2200 nm feature. This may indicate hydrothermal fluids (deeper 1900 nm feature). This spectrum (core image below) is from a zone adjacent to a bleached fracture zone.





High crystallinity white mica: the depth of the 1900 nm is quite shallow compared with the sharp and deep 2200 nm feature. This spectrum (core image below) is taken from a logged siltstone zone.



GODD032: References

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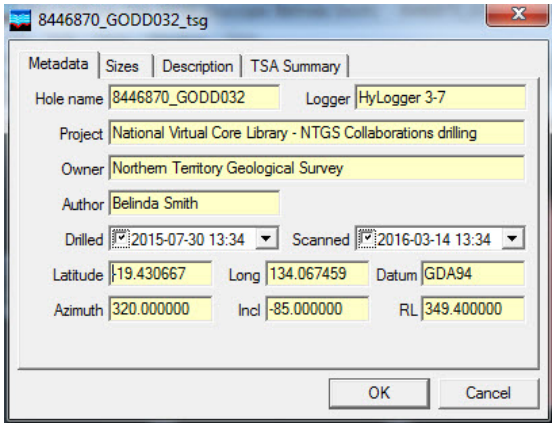
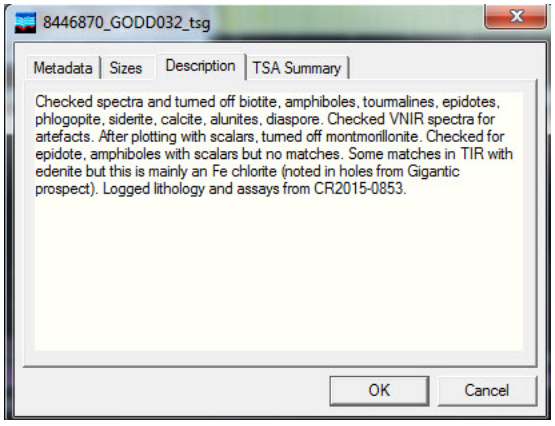
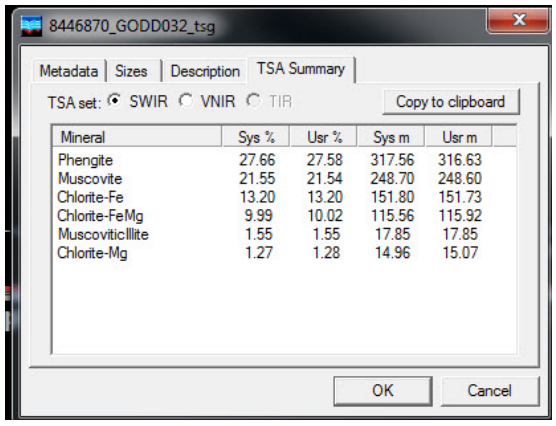
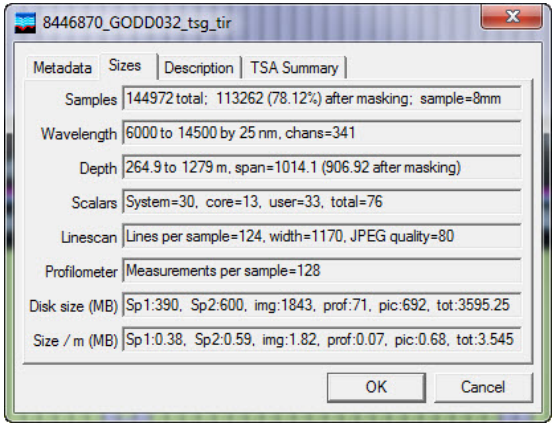
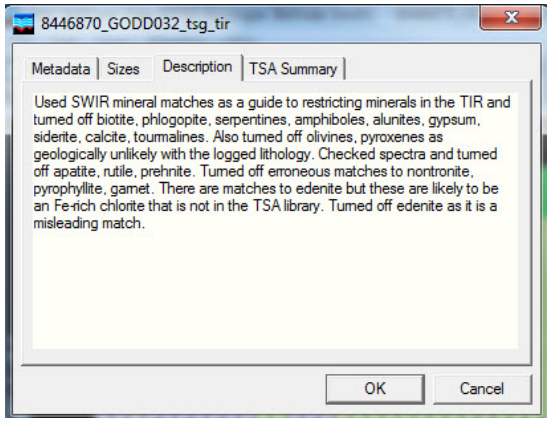
GODD032: TSG metadata

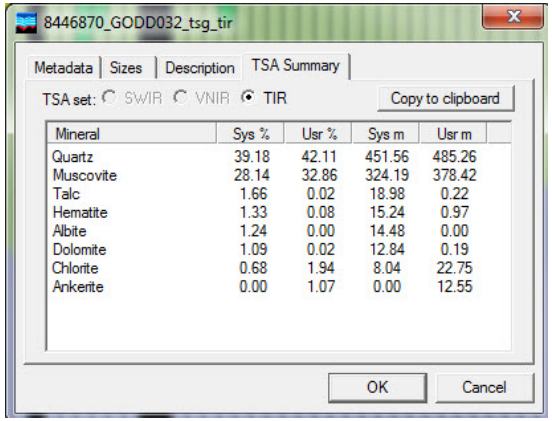












HyLogger specifications

The TSG dataset originated from HyLogger^{TM}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 Mason and Huntington (2012).

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 cutoff. 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.
CLS	Constrained Least Squares – an alternative unmixing classifier that uses a Restricted Mineral Set to minimise non-unique mineral modelling. Used mainly to model TIR spectra, which can have several mixed mineral matches.
domain	A zone within a drillhole interpreted to contain a restricted set of minerals that are different to adjacent zones.
FTIR	Fourier transform infrared spectrometer.
HgCdTe	Mercury Cadmium Telluride used in infrared detectors.
HQ	Shorthand for 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 2,500 to 6,000 nm.
scalar	Any set of imported or calculated values associated with spectral data loaded in TSG.
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). Nominally covering 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 a mixture of two 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.
TIR	Thermal infrared (light). Nominally covering the range 6000–14000 nm.
VIS	Visible (light). The human eye is nominally sensitive between 390 and 750 nm.
VNIR	Visible near infrared (light). Nominally covering the range 380–1000 nm.
volume scattering	Radiation that is reflected after some absorption into the rock, which 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	Abbreviation for wavelength, found 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. Eg; 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 6500nm 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 11300nm 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 linescan raster 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 uses a Feature Extraction algorithm in TSG to calculate the depth, width and/or wavelength position of a spectrum's absorption features. The FEATEX scalar uses pre-calculated feature extraction information using 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.
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.
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.

Continued on next page

Guide to scalars in figures produced using TSG software

Continued from previous page

Hydrocarbon Presence	A PFIT scalar designed to measure the presence of an absorption feature at 1730nm, which is often found associated with oil bleeds. Another scalar designed to identify hydrocarbons is the 23140nm 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) using the algorithm [(R2138+R2173)/(R2156) [(R2156+R2190)/R2173]] KC.
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 – 2180nm to determine the relative depth usinga >0.01 cutoff, 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.
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 smoothing 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 designed 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 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.
sTSAS, uTSAS	Mineral result from matching to the Short Wave Infra Red (SWIR) spectra against the TSA library. ‘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.
sTSAV, uTSAT	Mineral results from matching to the Thermal Infra Red (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.

Continued on next page

Guide to scalars in figures produced using TSG software

Continued from previous page

sTSAV, uTSAV	Mineral result from matching to the Visible Near Infra Red (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	Combined Least Squares (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 (Restricted Mineral Set or 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).
uTSA*	The result from TSA (The Spectral Assistant, which is the algorithm used for unmixing and classifying spectral responses relative to the included TSG reference library of minerals). 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, which 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.

Excerpt from Huntington and 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.