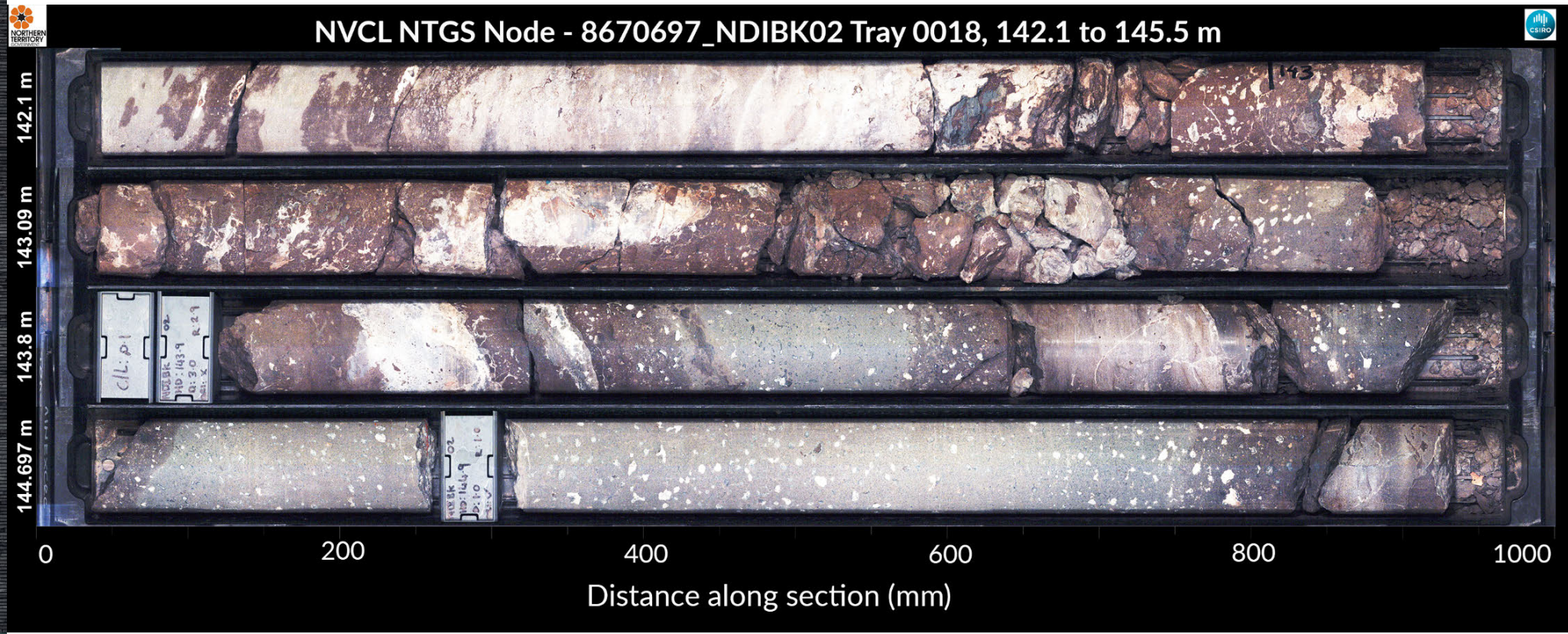
HyLogger Data Package 0110

HyLogger drillhole report for NDIBK02
MinEx CRC, National Drilling Initiative
Campaign 1 East Tennant, Northern Territory.

Belinda Smith



DEPARTMENT OF INDUSTRY, TOURISM AND TRADE
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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. 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. Northern Territory Geological Survey (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 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 8.1.0.5 dated May 2022.

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

NDIBK02: Introduction

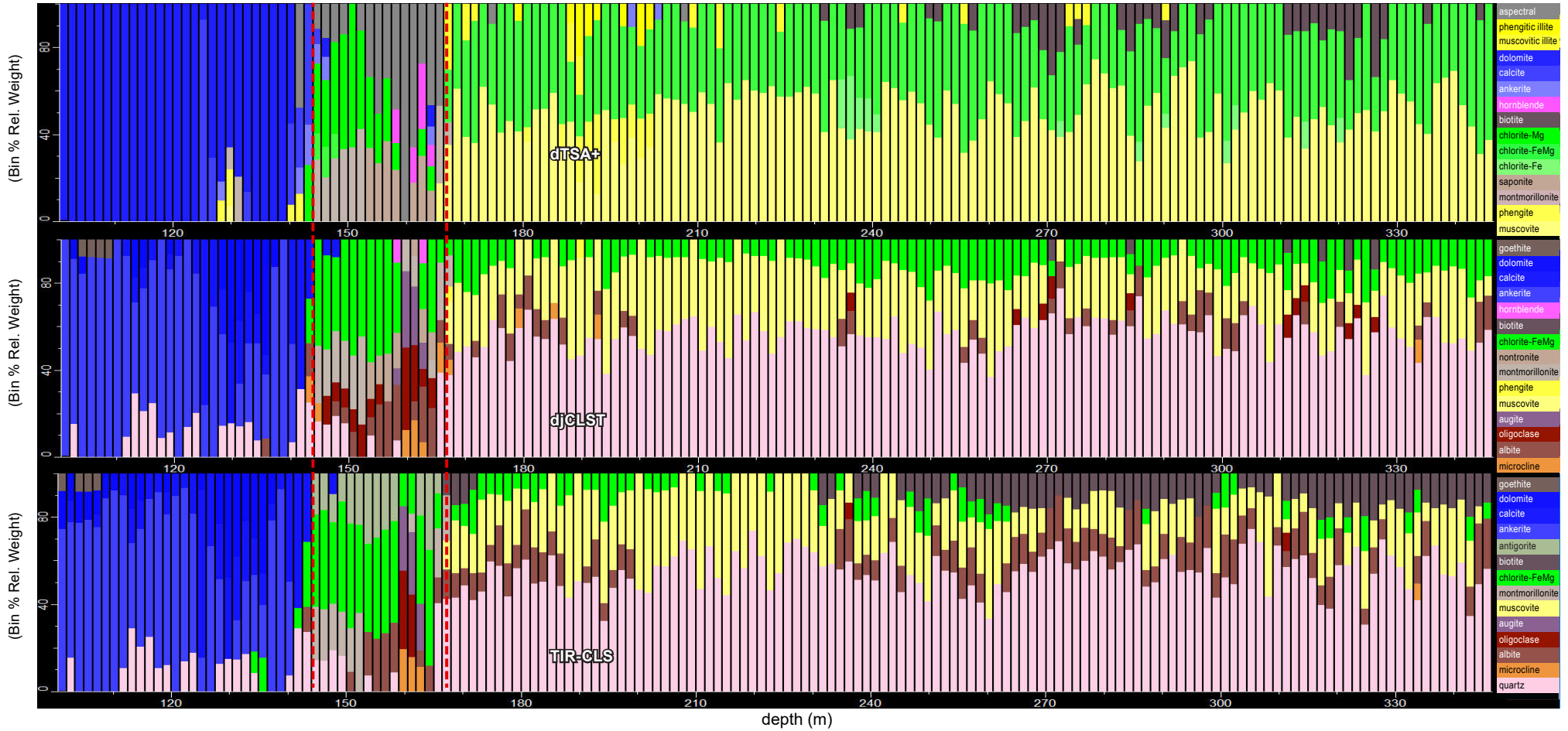
Hole ID	NDIBK02	**Unique identifier**	8670697 (NTGS); 648481 (MinEx CRC)
Geological terrane	To be confirmed	**Total depth**	347.04 m
Latitude GDA94	-19.5396941°	**Longitude GDA94**	136.0107313°
Easting MGA94	606037 (Zone 53)	**Northing MGA94**	7839144 (Zone 53)
Dip	-75.2°	**Azimuth**	330.2°
Logged by	MinEx CRC	**Logged report ref**	MinEx CRC 2022 https://portal.ga.gov.au/bhcr/minerals/648481?persona=minexcrc
Start core depth	100.6 m	**End core depth**	347.04 m
Date HyLogged	October 2020	**HyLogged by**	Darren Bowbridge
Date of HyLogger report	June 2022	**HyLogger report author**	Belinda Smith
TSG version and build	8.1.0.5 (May 2022)	**TSG product level**	3 (Huntington and Mason 2010)

NDIBK02 is one of 10 drillholes drilled in late 2020 as part of the National Drilling Initiative (NDI) Campaign 1: East Tennant project. The NDI vision is to drill multiple holes in a region to map the regional geology and architecture. This may define potential for mineral systems in 3D.

Information is from Schofield *et al* (2021); Schofield (2022) and the MinEx CRC Borehole Completion report (https://portal.ga.gov.au/bhcr/minerals/648481?persona=minexcrc) accessed May 2022. The Minalyze data was downloaded from https://minalogger.com/viewer/?project=NDI&hole=NDIBK02 and imported into the TSG dataset.

- NDIBK02 was drilled primarily as a stratigraphic hole, with a secondary target of testing the lithology of a striped magnetic feature interpreted as a possible banded iron formation. The target is coincident with a broadband magnetotelluric (BBMT) / audio magnetotelluric (AMT) conductor. A question is whether the magnetic pattern could be compared with nearby legacy hole DDH005. NDIBK02 was planned to constrain a package of rocks along a major fault.
- The cored interval of NDIBK02 intersected Thorntonia Limestone carbonates overlying logged basalt from the Helen Springs Volcanics. The basal unit comprises psammopelites and metasedimentary rocks of the Alroy Formation. The Alroy Formation consists of deformed pelitic, supracrustal metasedimentary rocks with maximum depositional ages between ca 1873 Ma and ca 1864 Ma (Schofield *et al* 2022). The age, structural and metamorphic characteristics are considered comparable to the Warramunga Formation of the Warramunga Province (Clark *et al* 2021) and the Murphy Metamorphics of the Murphy Province.
- Several external measurements are integrated with the HyLogger data. Field measurements (Schofield 2022) consisting of lithology logging, one metre-spaced handheld magnetic susceptibility, and portable XRF measurements are integrated with the HyLogger spectral data, along with wireline data (downhole natural gamma, magnetic susceptibility and formation density). A maximum magnetic susceptibility value of 113.44 SI units came from the basal cored portion of the Helen Springs Volcanics.
- MinEX CRC (2022) updated the logged field lithology ('LITHOLOGY_ORIGINAL') after further sampling ('lithology') with both logs integrated with the HyLogger data. A max copper value from pXRF is 1 m at 112 ppm Cu from 157 m within the cored section of NDIBK02 and within the Helen Springs Volcanics. A max copper value from the 10 cm Minalyze data is 10 cm at 349 ppm Cu, also in the Helen Springs Volcanics. Schofield (2022) assayed (ICP-MS) four samples from NDIBK02 with a max value of 1m at 16 ppm Cu from 269.49 m in the Alroy Formation.
- The International Geo Sample Numbers (IGSN) for pXRF and handheld mag susc measurements are also integrated with the HyLogger data. To enable multiple IGSN entries in depth intervals, the IGSN field is appended with the sample descriptor (eg IGSN_MagSus for magnetic susceptibility measurements assigned an IGSN). Refer to the web hyperlink in the 'sample identifier' field for information on individual IGSN.

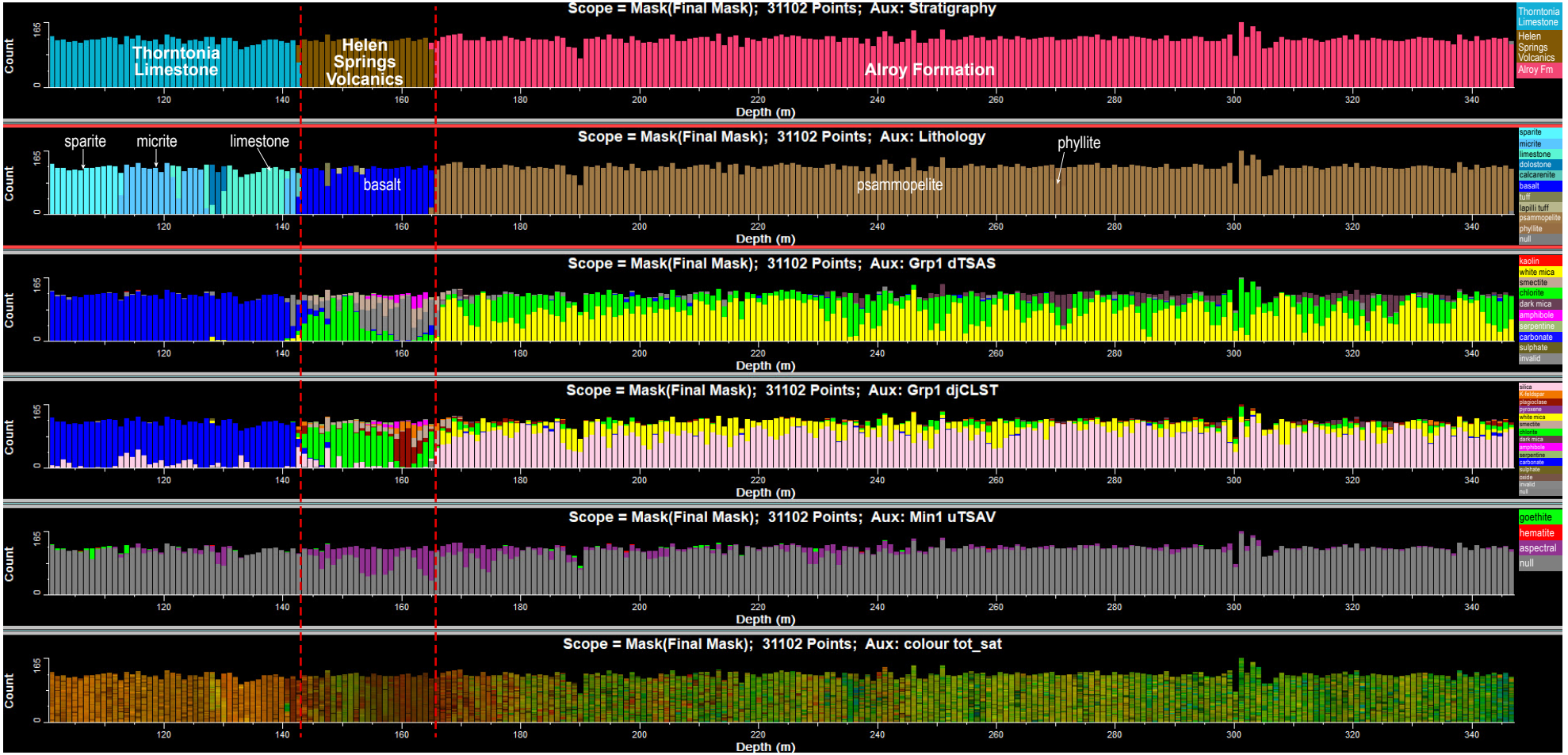
NDIBK02: Mineral summary – all minerals, TSA and CLS



From Summary Screen: Row 1 is the domained SWIR results, using TSA+. Row 2 are the TIR results derived from a domained joint CLS algorithm (djCLST) and row 3 are the domained CLS results (TIR-CLS) (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). A comparison of djCLST and dTSAT results are on page 18, with an assessment of difference between the djCLST and TIR-CLS results on page 19. TIR modelled results in NDIBK02 are shown here for comparison as the TIR spectra have non-unique results. The dashed line at ~145 m marks a mineral change from dominantly carbonate (above 145 m; blue) to a mixture of smectites, chlorite, plagioclase and minor hornblende/pyroxene. The dashed line at ~167 m marks a change from this chlorite-smectite-plagioclase dominant rock to a quartz-white mica-chlorite-albite +/- biotite unit at depth.

NDIBK02: Mineral summary

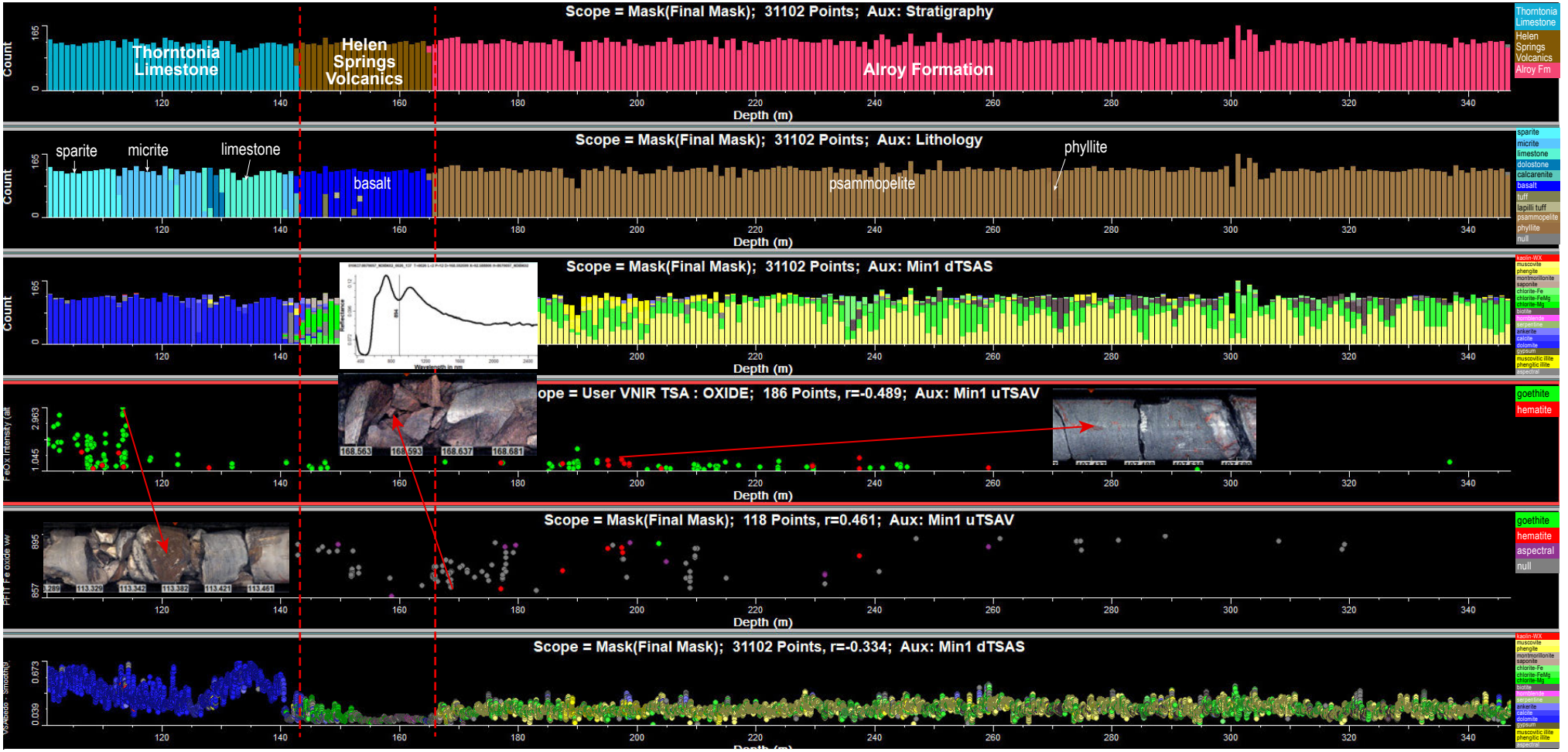
(View | Plot Layouts Load file 1_VNIRSWIR: Mineral Summary)



Row 1 shows the logged stratigraphic units; row 2, the logged lithological units from MinEx CRC (2022). Row 3 displays the dominant mineral group for spectral matches in the SWIR. Row 4 shows the dominant mineral group for spectral matches in the TIR (using djCLST results for the remainder of the HDP). Row 5 shows the VNIR matches; most of the matches are either 'null' or aspectral'. Row 6 is the core colour (derived from spectra RGB saturation). Dashed lines indicate changes in mineralogy. The dashed line at ~141 m marks a change from the carbonate-rich Thorntonia Limestone (above ~141 m) to the chlorite–smectite–plagioclase–quartz assemblage of the Helen Springs Volcanics basalt. The dashed line ~167 m marks the change from this assemblage in the basalt to a quartz–white mica–chlorite +/- biotite assemblage in the psammopelites and phyllites of the Alroy Formation. The dashed lines indicate diffuse changes in mineralogy and core colour; carbonates extend at depth into the basalt, and smectites extend at depth into the upper portion of the psammopelite. Row 5 shows few matches to either the VNIR hematite or goethite (further discussion on next page).

NDIBK02: SWIR and VNIR mineral summary

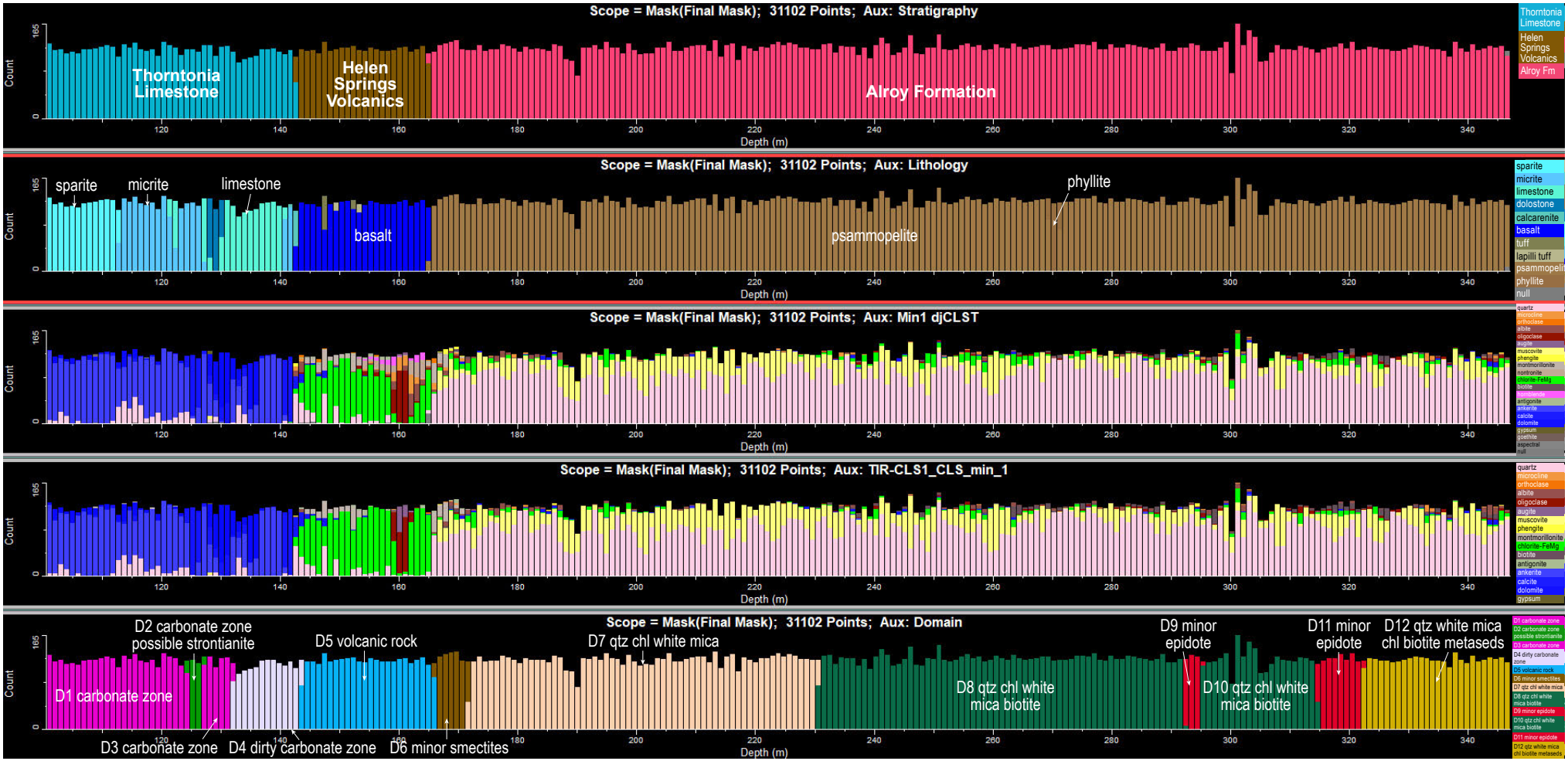
(View | Plot Layouts Load file 2_VNIRSWIR: SWIR VNIR Summary)



Row 1 shows the logged stratigraphic units; row 2, the logged lithological units from MinEx CRC (2022). Row 3 plots the dominant minerals from the SWIR spectrum. The dominant mineral may be in a mineral mix. Rows 4 and 5 are standard plots highlighting VNIR wavelength range results. The TSA algorithm can identify Fe oxides (hematite, red colour; goethite, green colour) in the VNIR wavelength range. Row 4 shows VNIR Fe oxide spectra, plotted by the FeOx intensity batch scalar (CSIRO, after Curtiss 1985) and coloured by the dominant VNIR Fe oxide mineral. The goethite matches in the carbonates at ~113 m are along open fractures (left inset image) and the hematite matches in the psammopelites are in hematite gash veins (right inset image). Row 5 plots all spectra that have an absorption feature between 857–895 nm. Hematite has a shorter wavelength feature than goethite, so this scalar can identify these Fe oxides that have an absorption in the range ~860–930 nm, but do not match as hematite or goethite using the TSA VNIR algorithm. Some spectra matched by TSA as 'null' or 'aspectral' in NDIBK02 have a feature indicating FeOx (eg centre inset spectrum and image) but do not match well to the inbuilt hematite and goethite library spectra. In this example, it appears that there is hematite present in a clay-rich metasedimentary rock. Row 6 shows all spectra, plotted by the smoothed albedo (using the VSAlbedo inbuilt CSIRO batch scalar) and coloured by the dominant SWIR mineral. The dashed line indicates changes in albedo and mineralogy. The logged basalt of the Helen Springs Volcanics has a lower albedo than the underlying sedimentary units, particularly towards the base of the unit.

NDIBK02: TIR mineral summary - overview

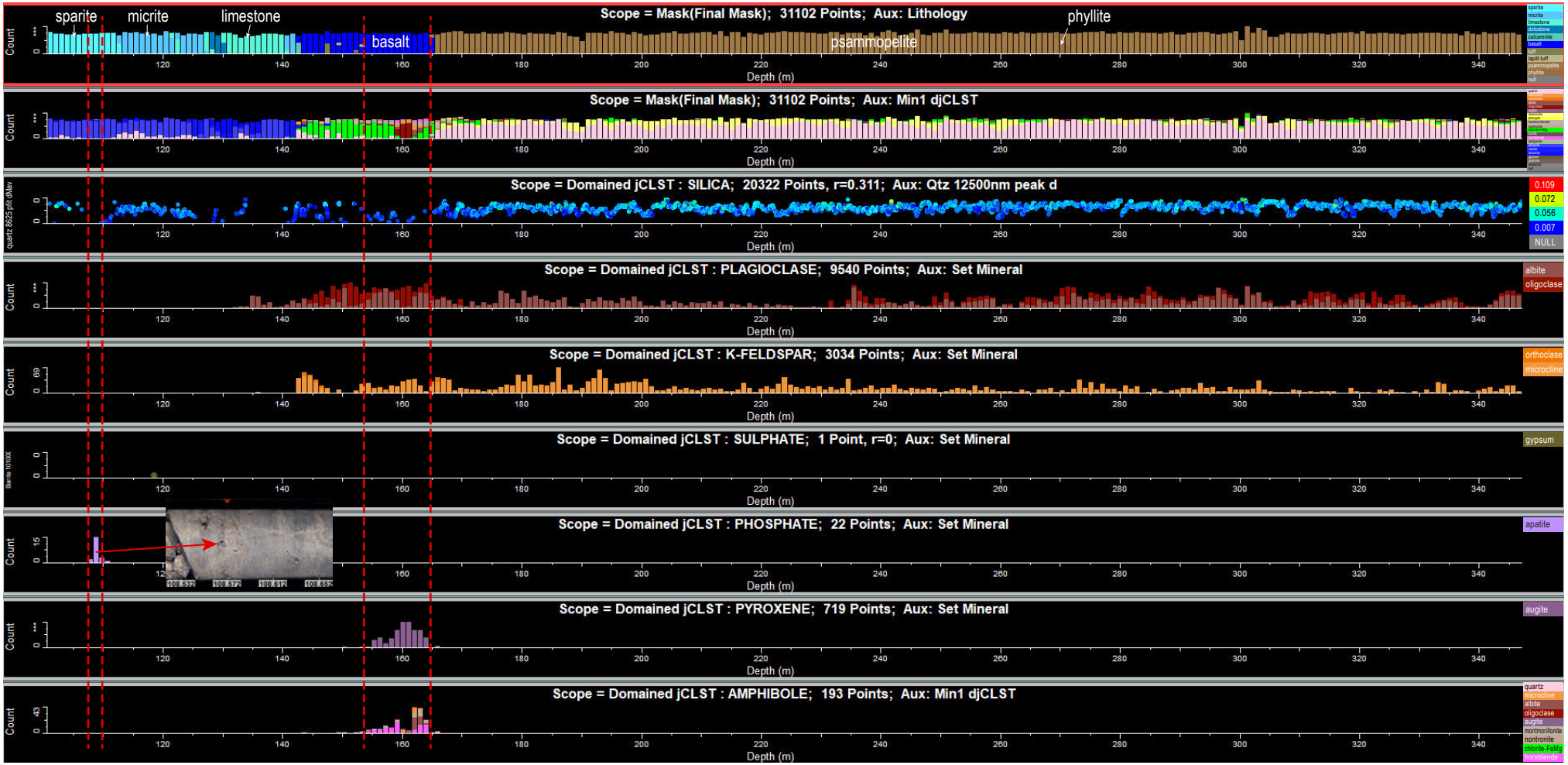
(View | Plot Layouts Load file 1_TIR: TIR Summary)



Row 1 shows the logged stratigraphic units; row 2, the logged lithological units from MinEx CRC (2022). Rows 3 and 4 plot the dominant TIR mineral (from a mineral mix) using a domained restricted mineral set (RMS). Row 3 uses the djCLST algorithm and row 4, the CLS algorithm. Both algorithms use a RMS interpreted for each domain, allowing up to 3 mineral results per spectrum in the djCLST results and up to 4 mineral results in the TIR-CLS1 results. However, these plots show only the dominant mineral in the mineral mix. Discussions on the main mineral differences between djCLST and dTSAT, and between djCLST and TIR-CLS1, are on page 18 and page 19 respectively. The TIR results are domained with row 5 showing the domains that control the restricted mineral set. For more information on domains in the TSG dataset, open the ‘D’ tool on the toolbar within the TSG software as each domain is described. At the dominant mineral level, there is very little difference in the TIR jCLST and TIR-CLS results. The carbonate–quartz results in the Thorntonia Limestone appear the same. The logged basalt of the Helen Springs Volcanics is dominated by chlorite, with minor smectites and plagioclases. The units below the basalt are quartz-dominant, with subdominant white micas, and minor biotite towards the base of NDIBK02.

NDIBK02: TIR mineral summary 2

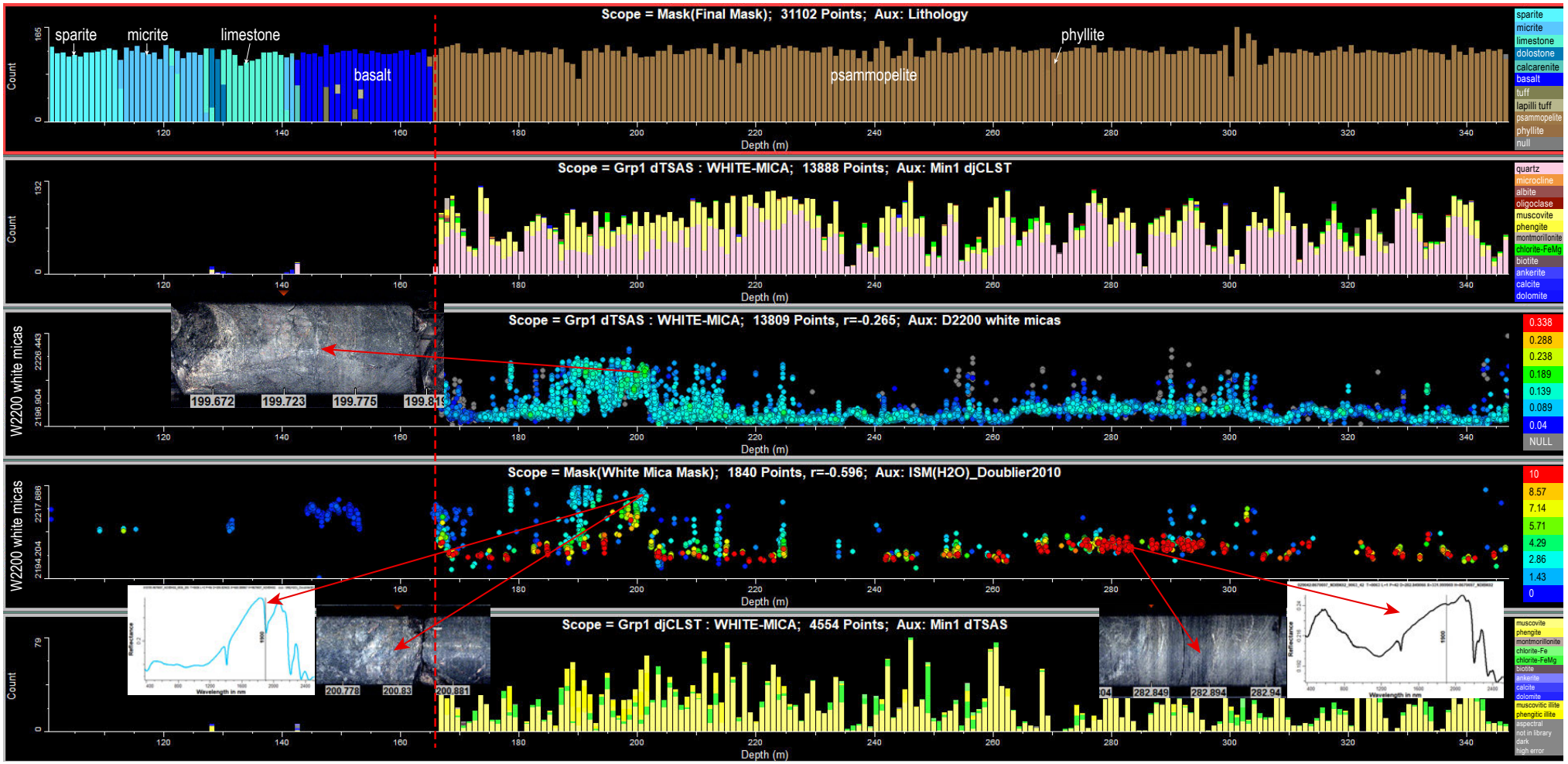
(View | Plot Layouts Load file 2_TIR: TIR Mineral Summary 2)



Row 1 is the logged lithological units from MinEx CRC (2022). Row 2 plots the dominant TIR mineral from the djCLST algorithm. Row 3 shows the TIR spectra that have a match to quartz, plotted by the depth of the quartz 8625 nm feature (analogous to abundance) and coloured by the peak of a longer wavelength quartz at ~12500 nm. Higher values and hotter colours indicate a higher quartz abundance. Small interval increases (eg hotter colour measurements around 242 m) highlight quartz veining. Quartz content is relatively consistent below ~165 m. Row 4 plots the TIR spectra that unmix with plagioclase (may be in a mineral mix), coloured by the plagioclase mineral. Oligoclase is found with albite in the logged basalt and at depth in the psammopelite. Row 5 shows the TIR spectra that unmix with K-feldspar (may be in a mineral mix), coloured by the K-feldspar mineral. Microcline is the dominant K-feldspar and is present in most depth intervals below the carbonates of the Thorntonia Limestone. Row 6 plots the TIR spectra that unmix with sulphate (gypsum) plotted by the SWIR gypsum feature at 1945 nm. Trace gypsum is within healed fractures in the Thorntonia Limestone carbonates. Row 7 plots apatite (dashed lines) in a zone with little or no quartz (row 3) lining vughs (left inset image). Rows 8 and 9 plot matches to pyroxene and amphiboles respectively. These are in the basal portion of the logged basalt.

NDIBK02: White micas

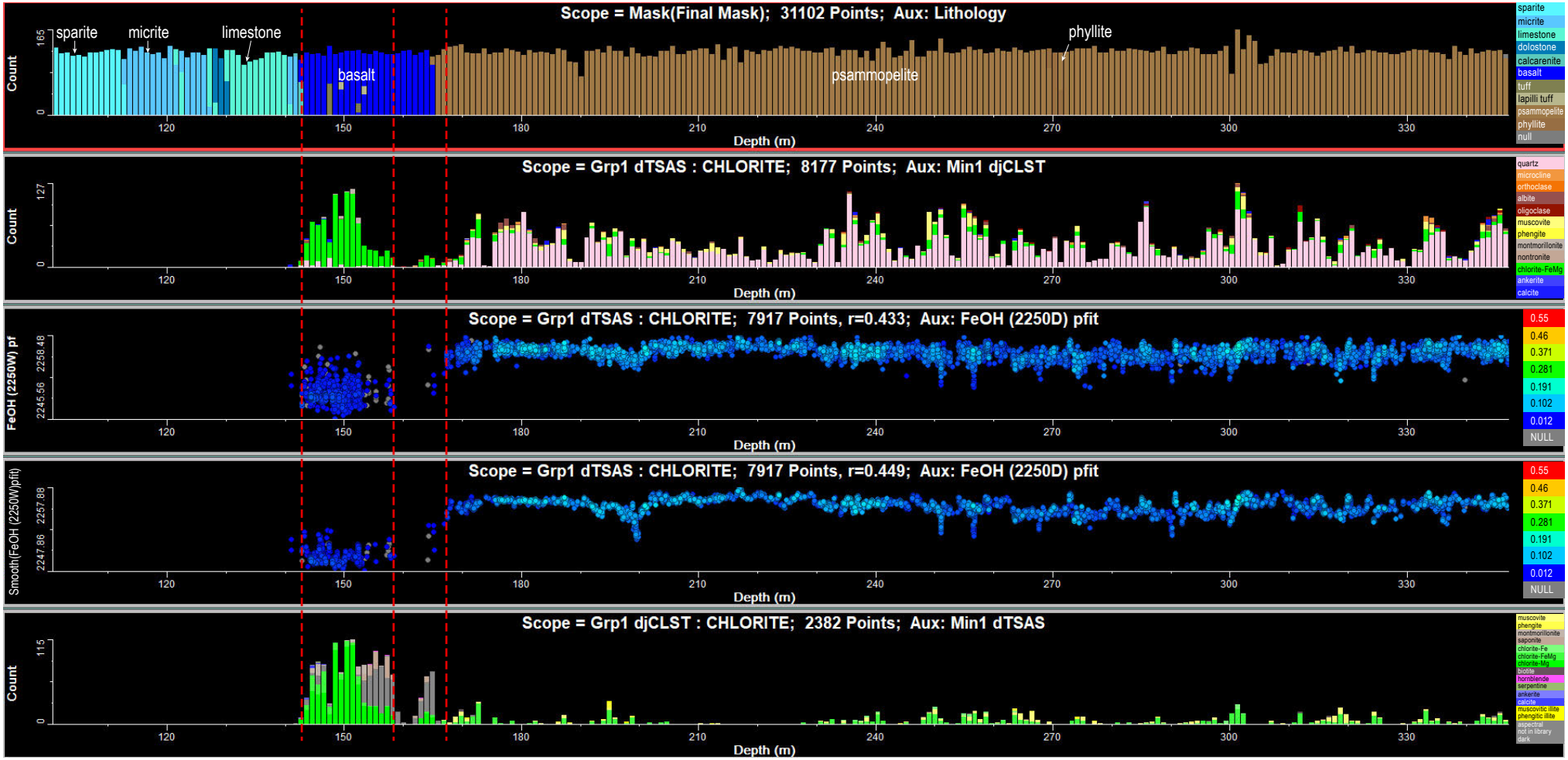
(View | Plot Layouts Load file 3_VNIRSWIR: White Micas)



Row 1 is the logged lithological units from MinEx CRC (2022). Row 2 plots the SWIR spectra that match dominantly to white mica, coloured by the dominant TIR mineral. Quartz is the dominant TIR mineral, with TIR white micas subdominant to quartz. Row 3 shows the SWIR white micas, plotted by the wavelength of the white mica feature ~2200 nm 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 dashed line at ~167 m is close to the upper contact of the logged psammopelite; this has persistent white mica with depth. Most of the white mica has shorter muscovitic wavelengths (around 2200 nm) with a more phengitic, longer wavelength white mica in logged foliated, folded psammopelite. Row 4 shows the SWIR spectra that match dominantly to white mica (masking out any spectra with <85% weighting of white mica using the TSA algorithm), plotted by the white mica wavelength and coloured by the 'illite spectral maturity' (ISM) scalar by Doublier *et al* (2010). The darker blue colours have a low ISM, with a more pronounced 1900 nm feature and a broader 2200 nm feature (left inset image and spectrum). The higher ISM (red colours; right inset image and spectrum) are most common in the shorter wavelength muscovitic white mica. Row 5 plots the TIR spectra that match dominantly to white mica, coloured by the dominant SWIR mineral. Most TIR white mica spectra match to SWIR white micas.

NDIBK02: Chlorite

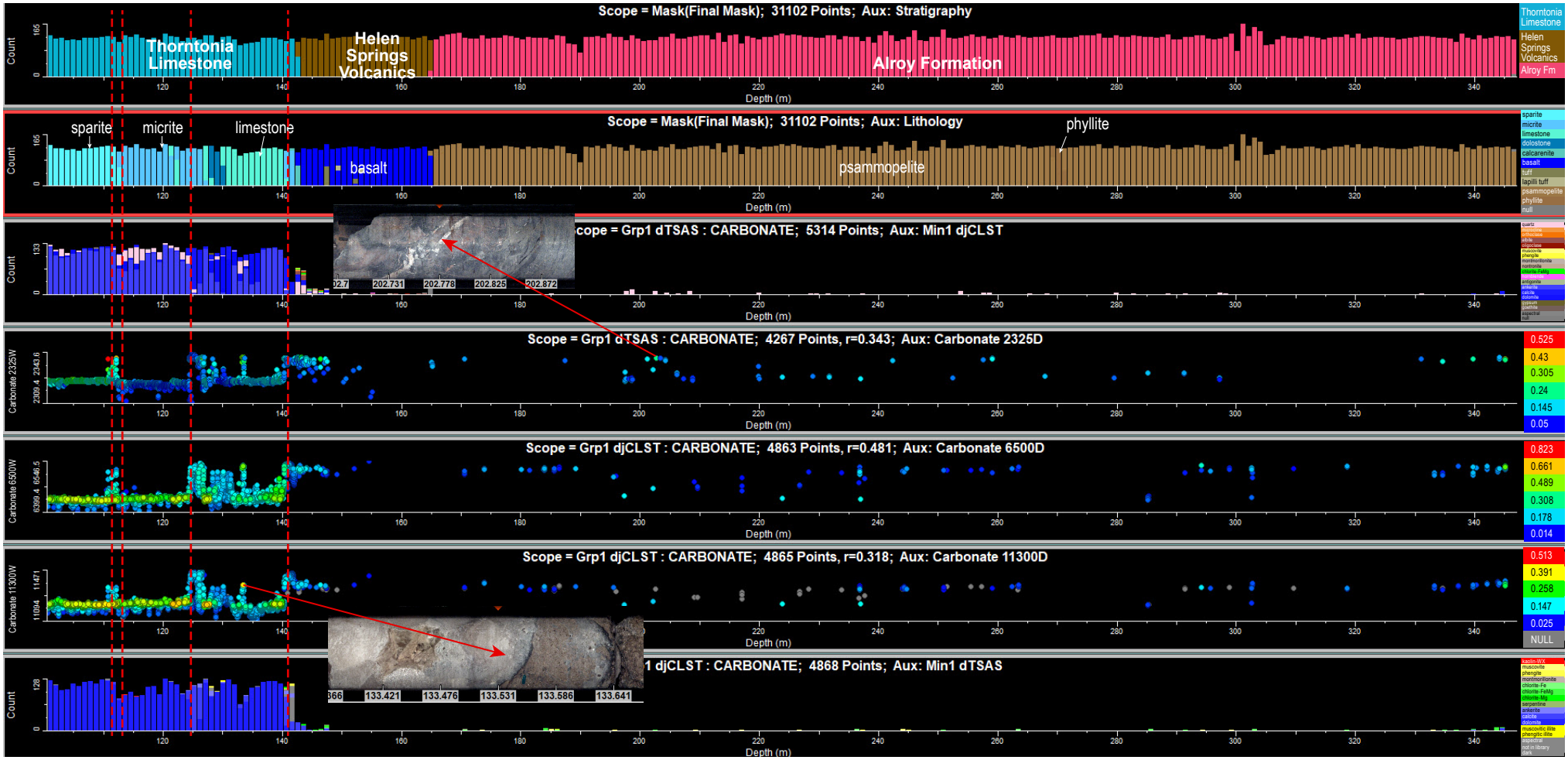
(View | Plot Layouts Load file 4_VNIRSWIR: Chlorite)



Row 1 is the logged lithological units from MinEx CRC (2022). Row 2 shows the SWIR spectra that match dominantly to chlorite, coloured by the dominant TIR mineral. In the upper logged basalt, the SWIR chlorites are also dominantly chlorite in the TIR. Quartz is the dominant TIR mineral for many SWIR chlorite spectra below ~167 m. Row 3 plots the SWIR chlorite spectra by the wavelength of the SWIR spectral feature at ~2255 nm (FeOH [2250W] pfit), coloured by the depth of that feature. The wavelength changes indicate chlorite composition changes; the depth of that feature is analogous to chlorite abundance. Row 4 is a similar plot to row 3, but the wavelength is smoothed (averaged) to highlight trends in wavelength and abundance variations with depth. Dashed lines show changes in either chlorite abundance and/or wavelength (composition). Chlorite is more abundant, with a higher wavelength (FeMg chlorite; 2255 nm) below the logged basalt from ~167 m (dashed line). The upper portion of logged basalt (between dashed lines) is notable for a shorter wavelength and more magnesian chlorite compared with the psammopelite chlorite. Row 5 plots the TIR spectra that unmix with chlorite as the dominant mineral, coloured by the dominant SWIR mineral. Most TIR chlorites are dominantly chlorite in the SWIR, although there are matches to SWIR smectites in the lower half of the logged basalt.

NDIBK02: Carbonates

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



Row 1 shows the logged stratigraphic units; row 2, the logged lithological units from MinEx CRC (2022). Rows 3–7 show the spectra that have carbonate as a dominant mineral in NDIBK02; it is sporadically distributed below the Thorntonia Limestone. Row 3 shows the SWIR spectra that match dominantly to carbonates, coloured by the dominant TIR mineral. SWIR carbonates mainly match to TIR carbonates, with some intervals also matching to quartz. Below the Thorntonia Limestone, SWIR carbonates commonly match with TIR quartz. Row 4 shows the SWIR carbonate spectra, plotted by the wavelength of the characteristic carbonate reflectance feature at ~2325 nm and coloured by the depth of this feature. Rows 5 and 6 plot TIR (djCLST) spectra that match dominantly to carbonate, plotted by the wavelengths of characteristic carbonate features in the TIR ~6500 nm and 11300 nm, coloured by the depth of the respective features. Wavelength changes (rows 4–6) are analogous to carbonate composition changes, with changes in the depth of the SWIR/TIR features analogous to abundance changes. Dashed lines in the Thorntonia Limestone show zones with wavelength changes: shorter wavelengths are most likely to be dolomitic; short zones of longer wavelength carbonates correspond with calcite–quartz infill/replacement (lower inset image). Sporadic longer wavelength carbonates in the Alroy Formation are calcite veins (upper inset image). Row 7 shows the TIR spectra that match dominantly to carbonates, coloured by the dominant SWIR mineral. Most TIR spectra (in the Thorntonia Limestone) match to SWIR carbonates.

NDIBK02: Minor minerals

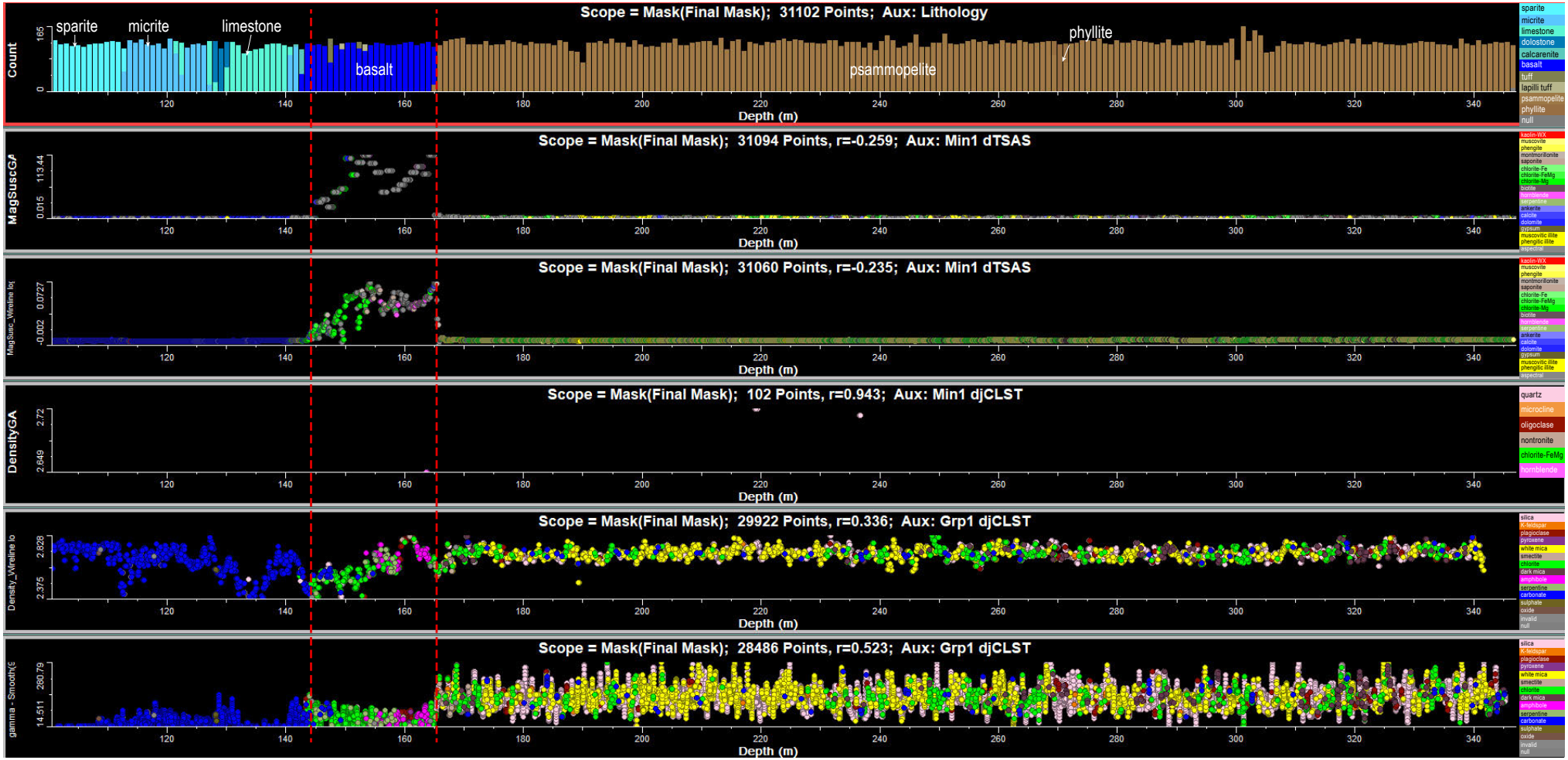
(View | Plot Layouts Load file 6_VNIRSWIR: minor minerals)



Row 1 shows the logged lithology from the borehole completion report (MinEx CRC 2022). Row 2 shows the SWIR spectra that contain a match to kaolin, plotted by the depth of the 2160 nm diagnostic kaolin doublet. There are few sporadic kaolinite spectra in the Thorntonia Limestone on open fractures (upper left inset image). Rows 3 and 4 are SWIR smectite matches to montmorillonite and saponite respectively. Montmorillonite spectra are plotted by an Al smectite abundance batch scalar, and saponite is plotted by the depth of a diagnostic saponite feature at 2309 nm. Saponite is found in the upper basalt. Montmorillonite found within the upper basalt and in at the upper contact of the psammopelite. Row 5 shows the SWIR spectra that have a match to serpentine, plotted by the depth of a diagnostic feature at 2218 nm. There are sporadic serpentine matches to ~158 m within the basalt. Row 6 are the SWIR spectra that have a match to biotite, plotted by the depth of a biotite feature at 2355 nm. Biotite is noted in the lithology logs, and is common in the TIR-CLS unmixing results. SWIR biotite is less common and the results from row 6 indicate biotite is present below ~232 m. Row 7 shows sporadic matches to epidote, associated with veining (lower right inset image). Row 8 are SWIR spectra that match to hornblende, plotted by the depth of the 2390 nm feature. These SWIR hornblende also show matches to TIR hornblende (see page 9, row 9).

NDIBK02: Rock properties and petrophysics

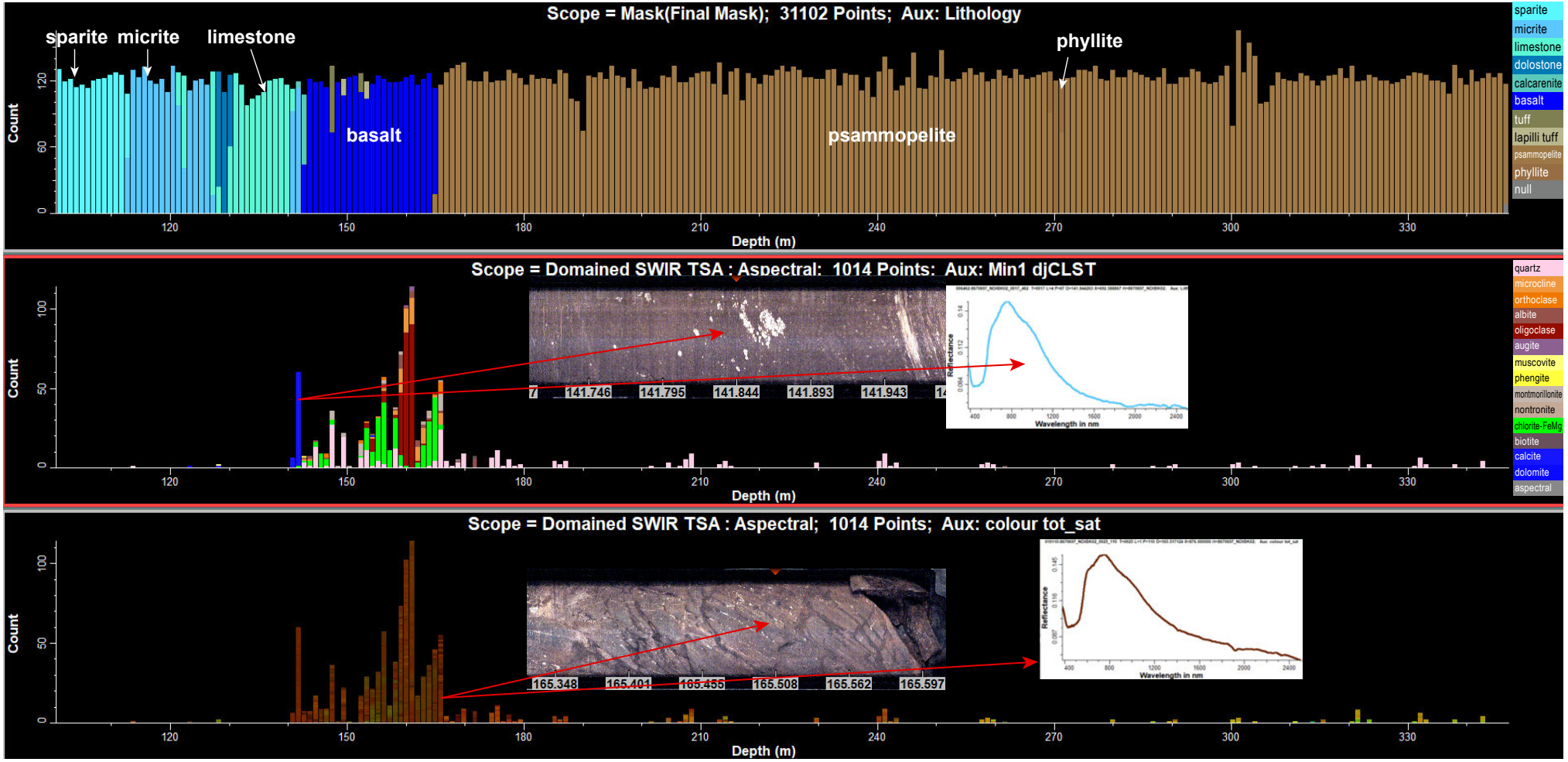
(View | Plot Layouts Load file
7_VNIRSWIR: Rock properties and petrophysics)



Row 1 are the logged lithological units from MinEx CRC (2022). Row 2 are magnetic susceptibility readings (10^{-3} SI units measured using a KT-10SC instrument in the field: data from the borehole completion report) with one sample measured every metre. The IGSN numbers and labels for the magnetic susceptibility readings are imported into the TSG dataset ('IGSN_MagSus' and 'label with IGSN_MagSus' for numbers related to magnetic susceptibility) from the borehole completion report. The magnetic susceptibility readings are coloured by the dominant SWIR mineral. Rows 3, 5 and 6 are imported from the wireline logs supplied in the borehole completion report. Row 3 are the magnetic susceptibility measurements recorded from wireline logging in SI units. The highest magnetic susceptibility reading is within the logged basalt. Within the basalt, there are trends in the magnetic susceptibility that can be noted in both the handheld measurements and the wireline measurements. Row 4 plots density measurements (n=3) taken by GA during geochemical sampling after field measurements. Row 5 plots the short spaced density measurements from the wireline logs, using a 24cm length of measurement, coloured by the dominant TIR mineral group and reported as gram/cc. Row 6 plots the natural gamma (in API units) from the wireline logs, smoothed (averaged) over 9 readings of the 1 cm measured intervals. Dashed lines show changes in both density and gamma measurements; these correspond with geological log and mineralogy changes.

NDIBK02: Aspectral response in SWIR

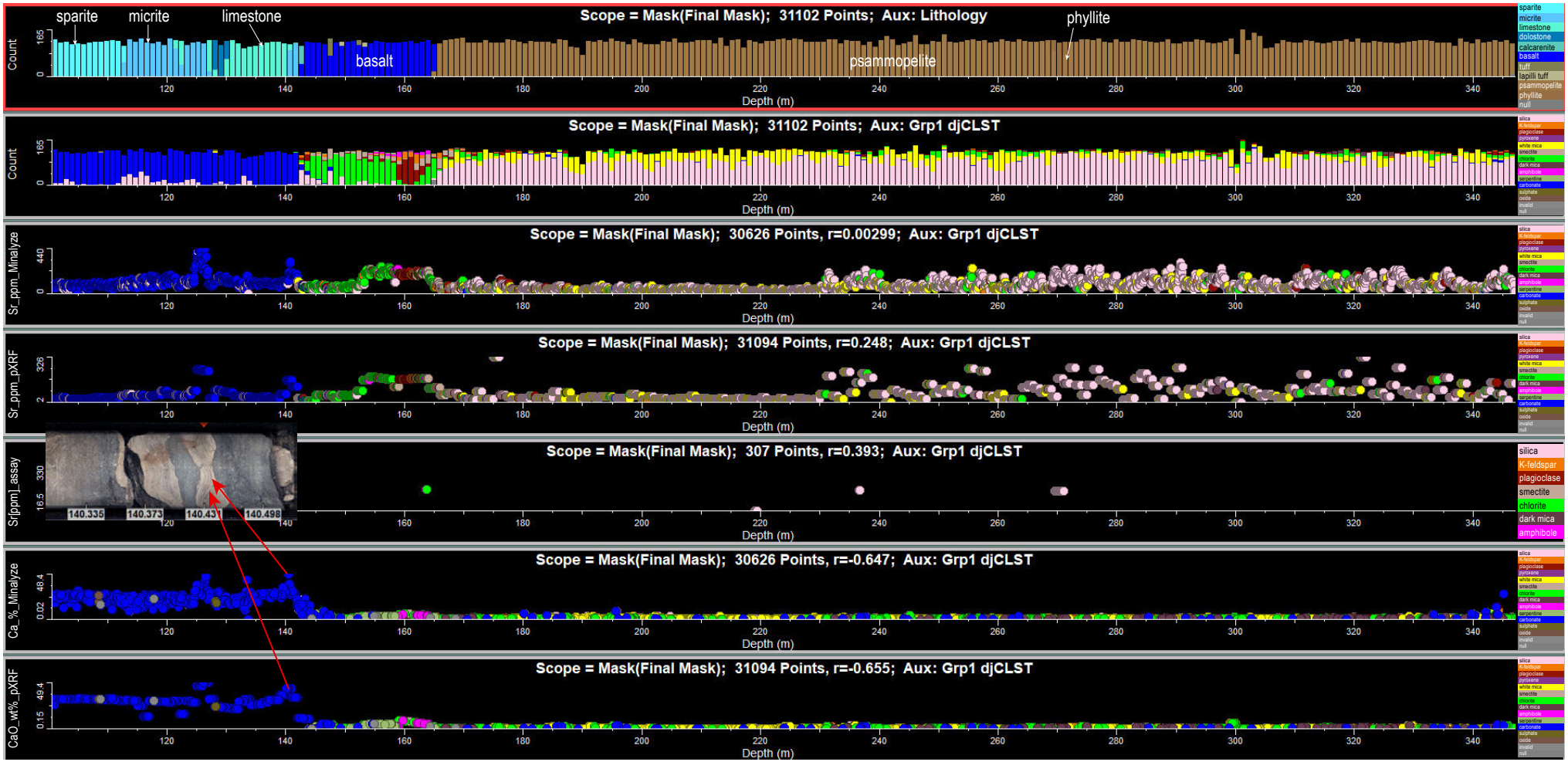
(View | Plot Layouts Load file 8_VNIRSWIR: SWIR Aspectral)



A SWIR aspectral response is when the SWIR spectra cannot match to the library mineral spectra. This may be due to noisy spectra from measurements on dark core or due to measurements from core containing minerals not in the TSA SWIR library. Some minerals do not have any diagnostic SWIR reflectance features, for example silicates such as quartz. Fine disseminations of sulfides or magnetite can affect the SWIR reflectance and result in a lack of features. Row 1 displays the logged lithological units from the MinEx CRC borehole completion report (MinEx CRC 2022). Row 2 plots the SWIR spectra that are classed as aspectral and coloured by the dominant TIR mineral. Most of the SWIR aspectral measurements are within the logged basalt of the Helen Springs Volcanics. These match to chlorites, plagioclases and quartz. The basalt has low albedo (see page 7 row 6) resulting in noisy SWIR spectra for some of the TIR chlorite intervals. The TIR carbonate in the logged micrite has a ‘quenched’ SWIR spectrum from a puggy reddish fine-grained carbonate interval (upper inset image and spectrum). Row 3 plots the SWIR spectra that are classed as aspectral and coloured by the core colour. Core colour can sometimes highlight quartz vein zones, black shales or ‘puggy’ reddish sediments that may contain finely disseminated iron oxides. In NDIBK02, the reddish brown aspectral core colour is from puggy reddish sediments (lower inset image and spectrum).

NDIBK02: Geochemistry

(View | Plot Layouts Load file 9_VNIRSWIR: pXRF, Minalyze, Assays)



Row 1 displays the logged lithological units from the MinEx CRC borehole completion reports (see page 4). Row 2 displays the dominant TIR mineral group. Rows 3 and 6 plot the 10 cm averaged Minalyze data downloaded from https://minalogger.com/viewer/?project=NDI&hole=NDIBK02. Rows 4 and 7 are point value XRF field measurements from the borehole completion report, taken every metre using Geochem (3-Beam) method from instrument SN 800044. The IGSN numbers and labels for the pXRF readings are imported into the TSG dataset ('IGSN_pXRF') from the borehole completion report. Row 5 plots the assay values (ICP–MS) from Schofield (2022). There are only 4 samples assayed in NDIBK02. The element values for rows 3–7 are coloured by the dominant TIR mineral group. In NDIBK02, rows 3–5 compare the Sr values obtained by pXRF with Minalyze XRF in ppm. Note the trends in Sr changes are similar for both the pXRF and the Minalyze values. The Sr values between 163.55–163.74 m (assayed interval) are 163 ppm (ICP–MS lab assay), 173–214 ppm (pXRF), and 173 ppm (Minalyze). Rows 6 and 7 compare CaO values: row 6 has CaO wt% values from the Minalyze and row 7 has CaO wt% from pXRF. The Thorntonia Limestone has notably higher CaO, with calcite-rich intervals (eg at ~127 m, 140.5 m; inset image).

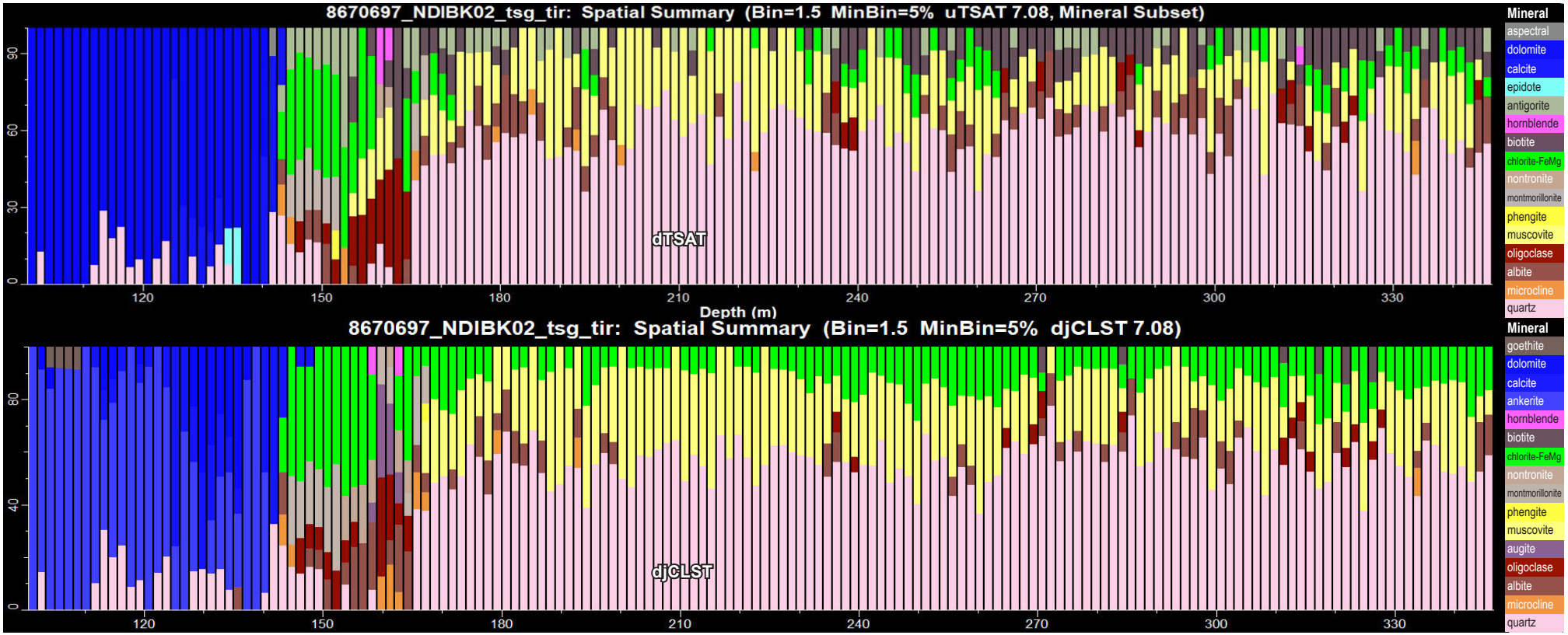
NDIBK02: Summary of HyLogger data interpretation

- NDIBK02 is one of 10 drillholes completed in late 2020 as part of the National Drilling Initiative (NDI) Campaign 1: East Tennant project. Stratigraphic information was the main rationale for drilling NDIBK02, with a secondary target being to investigate a striped magnetic feature that may be a banded iron formation. The stratigraphic, lithologic, petrophysical and XRF/assay data imported into the TSG dataset are from the borehole completion report and other reports referenced on page 4 as of May 2022.
- The upper cored Thorntonia Limestone comprises carbonates, dominantly dolomite. Most of the Thorntonia Limestone is logged as limestone, sparite and micrite, although the spectral data indicate that dolomite > calcite for most of these intervals.
- The mineralogy within the logged basalt from the Helen Springs Volcanics varies with depth. The upper portion is chlorite-rich, with variable smectites, feldspars, quartz, and carbonates (in vesicles). The lower portion is finer-grained, with a higher proportion of plagioclases, with minor amphiboles, pyroxenes, smectites, and chlorite. The chlorite is a shorter wavelength, magnesian chlorite.
- The Alroy Formation is uniformly logged as psammopelite, with a short interval of phyllite from 269.5–271.1 m. The psammopelite consists of quartz, white mica (dominantly muscovite), with lesser chlorite, K-feldspar, and plagioclase (dominantly albite). The lower interval of psammopelite has more biotite than the upper portion. The phyllite interval is mineralogically similar to the psammopelite. although it may have a higher proportion of biotite. Carbonate is present in sporadic, rare veins. Chlorite is FeMg (intermediate) and is pervasive but minor in most depth intervals.
- White micas are most common in the Alroy Formation and have a high illite spectral maturity (ISM); this may indicate a more crystalline muscovite. Lower ISM phengitic white micas appear from ~189–201 m; this may indicate a zone of mixed origin white micas (?).
- The secondary drill target of a possible banded iron formation (interpreted from the striped magnetic feature) is not evident in the spectral data. The highest magnetic susceptibility is from the logged basalt. Minor hematite in the psammopelites is noted in gash veins (see page 7).



Contact between the quartz–carbonate calcarenites at the base of the Thorntonia Limestone with carbonate-infilled vesicles chloritic basalt at the top of the Helen Springs Volcanics.

NDIBK02: Comparison of TIR results using dTSAT and djCLST

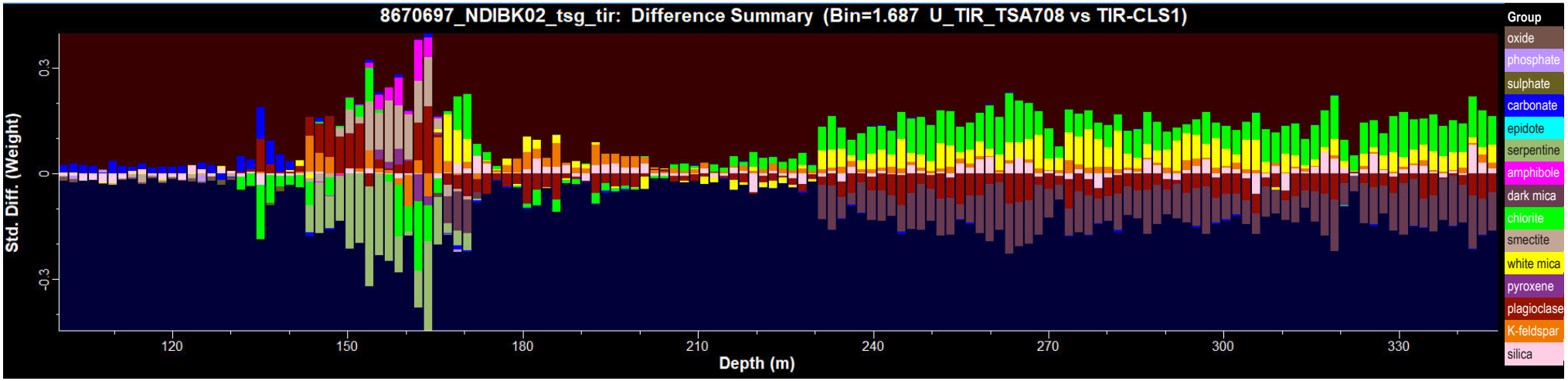


TIR spectra can have non-unique unmixing results, so different mineral assemblages could be modelled to fit the measured spectrum. As noted on page 3, TSG has a number of unmixing algorithms that can be used to produce a mineral result. During spectral interpretation and processing, the TIR spectra are assessed by spectral features, VNIRSWIR results, geological context, and available external data such as assays and petrophysics. Spectral data are domained (as previously described). A final step is producing the mineral summary using TIR-CLS (as outlined on page 5) and also comparing the domained joint CLS algorithm (djCLST) with the older TSA algorithm (dTSAT). In HDP0068–0080, and most HDPs from HDP0084, the djCLST algorithm is used. Above is a comparison of the domained TSAT results with the domained jCLST results in NDIBK02. Summary results from both algorithms are similar and either could be used confidently. The main differences are:

a) Biotite abundance and distribution: dTSAT has a greater proportion of biotite within more depth intervals compared with djCLST, particularly with depth. TIR biotite spectra do not have distinct features that distinguish biotite from other minerals, particularly in a mineral mix with muscovite. Looking at the external imported data, biotite is commonly visually logged from ~243 m to EOH, in a mineral mixture with quartz, muscovite and K-feldspar. The logged intervals of biotite may indicate that the SWIR results (page 5 row 1) and the djCLST results under-report biotite, whereas the dTSAT results over-report biotite. No thin sections or XRD results were available at the time of report writing to enable comparison.
b) Hornblende is reported between ~156–164 m in the djCLST results but not in the dTSAT results. The SWIR results indicate minor hornblende present (page 13 row 8) and is not shown in the dTSAT result.

The djCLST result is used in preference over the dTSAT result for NDIBK02. However, it is not clear as to which algorithm works better; there are minor variations in the distribution of sporadic hornblende and minor biotite.

NDIBK02: Differences in TIR results using dTSAT and TIR-CLS



A feature introduced to the Summary Screen in TSG from TSG Build 8.0.4.2 is the 'Summary screen difference plot'. This is described in Mason (2019) and is designed to highlight the differences in unmixing results between the TIR-CLS result, and either the dTSAT or djCLST result. In NDIBK02, it is the djCLST result with the TIR-CLS result. A comparison of the djCLST and dTSAT is on the previous page.

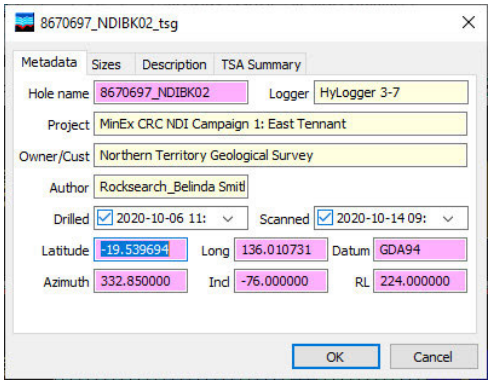
The x-axis is the scanned depth, plotted with an arbitrary 1.68 m bin size. The y-axis shows the difference between the compared results (at mineral group level); a line at 0 would indicate no difference between the unmixing results. The results above the 0 show minerals that match with a higher proportion in the djCLST result. The results below the 0 show mineral groups that match with a higher proportion in the TIR-CLS results. The carbonates (from start of cored interval to ~132 m) are quite similar. There main differences in mineral group matches between the 2 algorithms in NDIBK02 are:

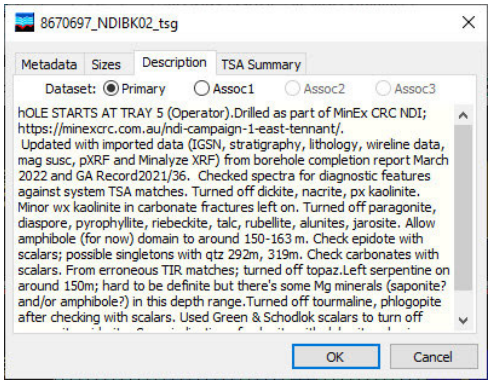
a) The interval ~142–165 m shows serpentine (antigorite) minerals in the TIR-CLS result. Minor serpentine may be present in this portion (page 13 row 5); however, it is a minor sporadic mineral component.
b) The TIR-CLS results consistently match to biotite, whereas the djCLST result matches consistently to chlorite. This is also a similar result for the djCLST / dTSAT mineral unmixing results, as outlined on the previous page. Biotite is likely present in fewer depth intervals than indicated in the TIR-CLS result but in more depth intervals than indicated in the djCLST result.

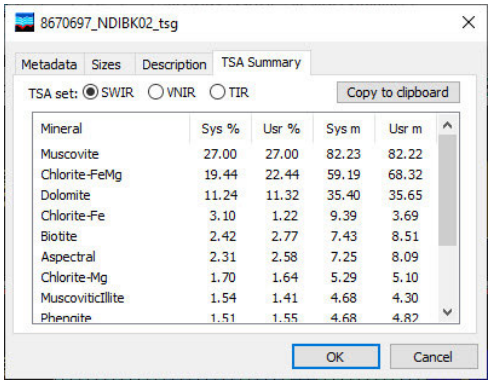
NDIBK02: TSG metadata

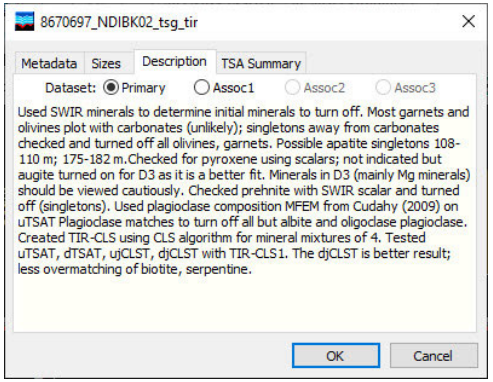
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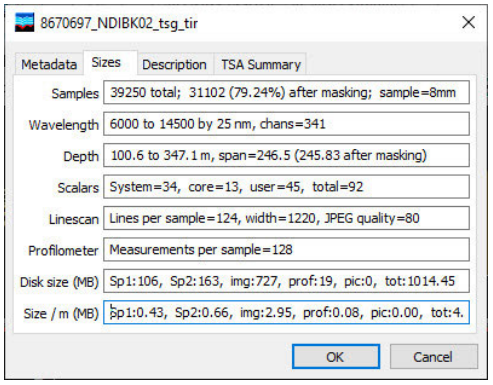
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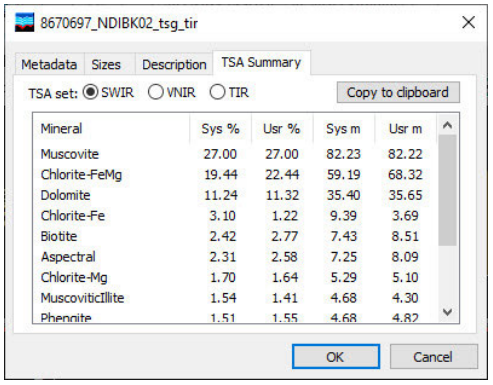


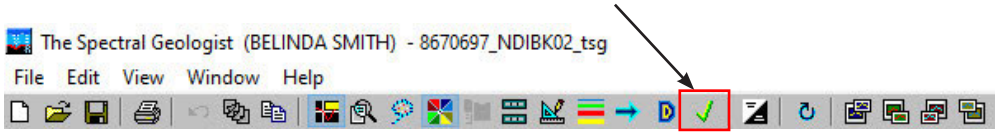


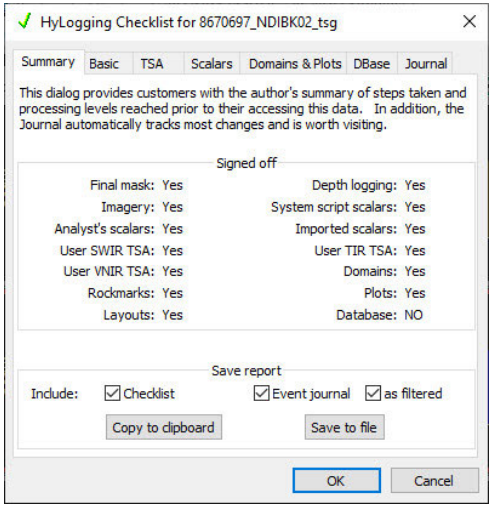


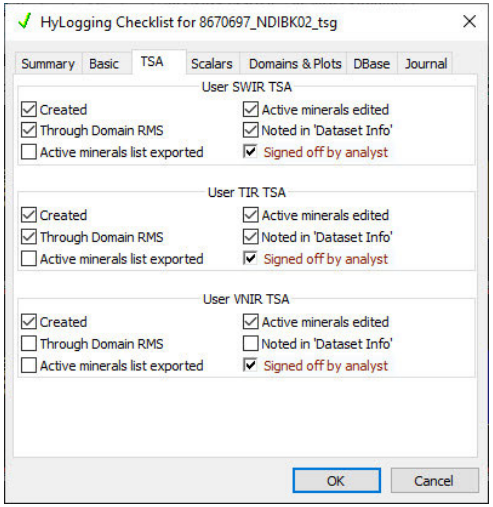


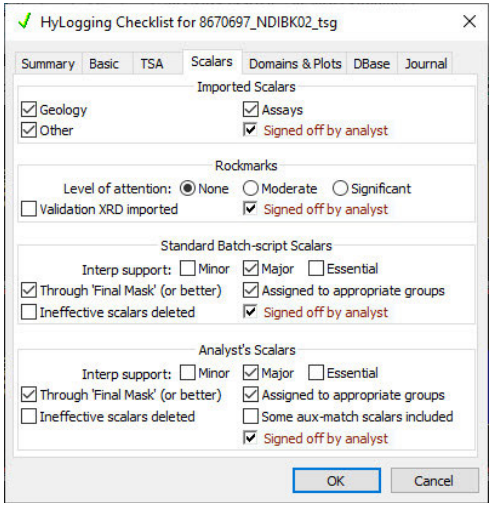


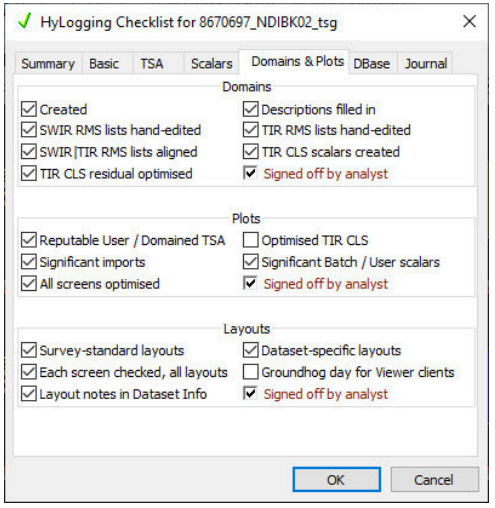












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HyLogger specifications

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 and 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, 1450) 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	Refers to Al-O-H hydroxyl bonds present in some minerals (eg; white micas, kaolins, montmorillonite). In terms of spectra; this relates to the Al-O-H stretching vibrations that produce absorption (reflectance) feature around 2190–2220 nm. May be used interchangeably in literature with '2200 nm feature'.
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 Restricted Mineral Set (RMS) to minimise non-unique mineral modelling. Used mainly to model TIR spectra that can have several mixed mineral matches. Developed by A.Green of OTBC Pty Ltd for CSIRO. More information and references can be found at www.corstruth.com.au
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.
EOH	'End Of Hole' – the end depth of the scanned (or drilled) core
FeOH	Refers to Fe-O-H hydroxyl bonds present in some minerals (chlorites, epidotes, biotite). In terms of spectra; this relates to the reflectance feature around 2245–2260 nm.
FTIR	Fourier Transform InfraRed (spectroscopy). An FTIR spectrometer simultaneously collects high resolution spectral data over a wide spectral range.
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	Refers to Mg-O-H hydroxyl bonds present in some minerals (eg chlorites). In terms of spectra; this relates to the reflectance feature around 2350 nm that characterises chlorites. This overlaps the wavelength range for carbonates (2300–2340 nm).
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. A measurement of the signal-derived variance with the noise-derived variance. Details on how this is calculated in TSG can be found in the Help document.
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. Other technologies may refer to part of this wavelength range as 'LWIR'.
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 Plot Layouts in TSG and for figures produced from TSG are described in the table below. This list is comprehensive; not all terms are used in every dataset. Some terms have changed over time in an attempt at standardisation. Thresholds used in scalar creation may vary between datasets, as the data varies according to geological environment. Please check the scalar creation parameters under 'modify scalar' in LOG screen using Edit toolbar.

2200 wvl 2nd deepest	FEATEX scalar that measures the wavelength of the second deepest absorption feature from 2200 nm +/- 50 nm. Designed to measure the wavelength of the kandite doublet, which has a variable wavelength depending on whether it is kaolinite or dickite.
2390 pfit d	PFIT scalar to measure the depth of a trough minima between 2365–2434 nm with a depth >0.02; polynomial order 10; hull envelope divided by reflectance reported as a relative depth. It is commonly used to confirm the presence of amphiboles, and other minerals with a 2390 nm feature. The 2390 pfit wvl uses the above parameters but reports the result as a wavelength at minimum (composition change).
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. Generally superseded by the White mica_Al smectite abundance (wmAlsmai.txt) batch scalar >HDP0100.
Apatite 9200D *(previously called Apatite 9200 PFIT d)*	PFIT scalar created by J Huntington (of Huntington Hyperspectral) 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.
Biotite 2355D *(previously called Biotite 2355nm PFIT depth)*	PFIT scalar to measure the depth of the MgOH trough minima between 2345–2370 nm with a depth >0.009; polynomial order 6; RMSE <=0.1; hull envelope divided by reflectance reported as wavelength at minimum in nm. Used in conjunction with the Biotite 2355nm PFIT wvl scalar and the TSAS results to characterise the presence of biotite, which may be difficult to distinguish from chlorite.
Biotite 2355W *(previously called Biotite 2355nm PFIT wvl)*	PFIT scalar to measure the wavelength of the MgOH trough minima between 2345–2370 nm with a depth >0.009; polynomial order 6; RMSE <=0.1; hull envelope divided by reflectance reported as wavelength at minimum in nm. Used as a measure for the presence of biotite but has some overlap with chlorite.
Carbonate 2140W (2nd feature)	PFIT scalar to measure the wavelength of a trough minima between 2120–2170 nm with a depth >0.003; polynomial order 6; hull envelope divided by reflectance reported as wavelength at minimum in nm. The scalar 2140D CO3 (2nd feature) is the same scalar but the reported result is relative depth. This scalar can be used to examine a secondary SWIR carbonate reflectance feature that is around 2140nm (dolomite) to 2156nm (calcite); Ausspec (2008). Note that other minerals (alunite, pyrophyllite) have features around this wavelength range. This is a secondary carbonate feature and may not always be diagnostic.
Carbonate 2325W *(previously called 2325 CO3 pfit wvl)*	PFIT scalar to measure the wavelength of a trough minima between 2285–2400 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. The Carbonate 2325D (previously 2325 CO3 pfit d) measures the relative depth using the same parameters (above). The depth scalar is used to measure abundance (strength of feature).
Carbonate 6500W *(previously called Carbonate 6500nm pfit wvl)*	PFIT scalar that replaces an earlier CSIRO batch scalar of a similar name. The PFIT scalar fits the feature between 6300–6800 nm; focus 6400–6700 nm, height >0.015; polynomial order 6; hull envelope subtract base reflectance for a wavelength at maximum result. Used to determine differences in the wavelength of the peak around 6500 nm, which shifts with different carbonate compositions. The Carbonate 6500D (previously called Carbonate 6500nm pfit d) uses the same parameters but returns a result of relative height.
Carbonate 13900D *(previously Cb13900d)*	PFIT scalar created by Green and Schodlok (2016) and renamed here for consistency with other PFIT carbonate scalars. The Carbonate 13900D scalar maps the depth of the trough minima focus 13380–14100 nm; polynomial order 10; local maximum subtract base reflectance to give a relative depth. Must be used cautiously when albite is present, or with spectra that show noise or attenuation at longer wavelengths.
Carbonate 11300W *(previously called Carbonate 11300nm pfit wvl*	PFIT scalar to measure the wavelength of the peak maxima between 11000–11580 nm with a height of >0.005; polynomial order 9; hull envelope subtract base reflectance to give wavelength at maximum. The Carbonate 11300D (previously called Carbonate 11300nm pfit d) scalar uses the same parameters to return a relative height result. Usually used in conjunction with the 6500 nm feature. Recent work by Green and Schodlok (2016) suggests also analyzing features at 14 000 nm.

Guide to scalars in figures produced using TSG software (continued)

Carbonate 13900W max *(previously Cb 13900 max w)*	PFIT scalar created by Green and Schodlok (2016) and renamed here for consistency with other PFIT carbonate scalars. The Carbonate 13900W max scalar maps the peak maxima focus 13400–14200 nm; height >0.005; polynomial order 12; local minimum subtract base reflectance to give a wavelength at maximum result.
Carbonate 13900W max-min *(previously Cb 13900 max-min)*	Arithmetic scalar created by Green and Schodlok (2016) and renamed here for consistency with other carbonate scalars. The Carbonate 13900W max-min scalar determines the separation of the peak and trough of the carbonate feature around 14000 nm.
Carbonate 13900W min *(previously Cb 13900 min w)*	PFIT scalar created by Green and Schodlok (2016) and renamed here for consistency with other PFIT carbonate scalars. The Carbonate 13900W min scalar maps the wavelength of a trough associated with a carbonate feature around 14000 nm.
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. It is designed for unaltered igneous rocks (Walter and Salisbury 1989) and is impacted by alteration (especially silicification).
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.
D1900	Measures the depth of the 'water feature' (O-H bond vibration) between 1860–1970 nm (focus 1880–1950 nm); depth >0.03; polynomial order 4; hull envelope divide reflectance reported as relative depth. This scalar is also an intermediate scalar in the 'WM crystallinity' scalar.
D2200 white micas *(previously called White mica PFIT d)*	PFIT scalar to measure the depth of a trough minima between 2180–2230 nm, focus 2190–2225 nm with a depth of >0.01; polynomial order 4; hull envelope divided by reflectance reported as a relative depth. This could be used for other minerals with a 2200 nm feature (kaolins, Al smectites) but the focus interval may change.
Epidote 473D *(previously called Epidote 473nm PFIT d)*	Measuring the depth of a trough minima between 440–490 nm with a depth >0.013; polynomial order 8; hull envelope divided by reflectance reported as a relative depth. Used as one of 3 scalars to confirm the presence of epidote within the SWIR wavelength range. Other epidote scalars may include those searching for features at 1555 nm and/or 1830 nm
Epidote 1555D *(previously called Epidote 1555nm PFIT d)*	PFIT scalar to measure the depth of a trough minima between 1500–1610 nm; polynomial order 10; hull envelope divided by reflectance reported as a relative depth. Measures the presence of epidote in a wavelength range which other minerals (such as chlorite) does not have features. The scalar 'Epidote 1555 W' uses the same parameters but reports the result as 'wavelength at minimum'. The 1555 scalars are best used in conjunction with the Epidote 1830D and/or Epidote 473D
Epidote 1830D *(previously called Epidote 1830nm PFIT d)*	PFIT scalar to measure the depth of a trough minima between 1805–1850 nm (focus 1824–1835 nm); polynomial order 8; depth >0.0159; hull envelope divided by reflectance reported as a relative depth. Measures the presence of epidote in a wavelength range which other minerals (such as chlorite) does not have features. The scalar 'Epidote 1830W' uses the same parameters but reports the result as 'wavelength at minimum'. The 1830 scalars are best used in conjunction with the Epidote 1555D and/or Epidote 473D.
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.
FeOH (2250D) pfit *(previously called FeOH PFIT depth)*	PFIT scalar to measure the depth of a trough minima between 2235–2282 nm, focus 2240–2260 nm with a depth >0.012; polynomial order 6; hull envelope divided by reflectance reported as a relative depth. Measures the relative abundance of chlorite.
FeOH (2250W) pfit *(previously called FeOH PFIT wvl)*	PFIT scalar to measure the wavelength of a trough minima between 2235–2285 nm, focus 2245–2260 nm with a depth >0.01; area>0.0009; polynomial order 6; hull envelope divided by reflectance reported as a wavelength at minimum. Designed to track wavelength differences with a chlorite feature between around 2245–2260 nm. Shorter wavelength chlorites are magnesian; longer wavelength are Fe-rich. The scalar Smooth(FeOH(2250W))pfit applies averaging to the FeOH (2250W) pfit scalar over a window of 21, to smooth outliers and display overall trends in wavelength changes.

Guide to scalars in figures produced using TSG software (continued)

FeOx intensity (alt)	Fe slope: straight ratio of reflectance (742 nm) / reflectance (500 nm) to map the depth of the Fe^{3+} charge transfer absorption band (Curtiss 1985). Developed by J. Huntington and P. Mason (CSIRO) to map the Fe^{3+} charge transfer band between 400–500 nm and the red peak near 740–760 nm characteristic of oxidised iron oxides used in Landsat satellite applications. Does not work as well for steel grey hematites in BIFs and IOCG deposits
Garnet 11400W *(previously Garnet 11400 comp wvl)*	PFIT scalar to measure the wavelength of the trough minima focussed between 10550 to 11600 nm 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. The depth scalar (Garnet 11400 comp d) uses the same parameters but reports a relative depth and can measure strength (abundance) of the feature. The Garnet 11400D (previously called Garnet 11400 comp d) scalar has the same parameters but returns a relative depth. This can be used to indicate the presence of garnet.
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.
Gypsum 1945D (previously Gypsum 1945 nm)	PFIT scalar to measure the depth of a trough minima between 1900–1960 nm (focus 1935–1960 nm); polynomial order 5; hull envelope divided by reflectance reported as a relative depth. Developed to separate out poorly crystalline gypsum from quartz with a 1900 nm water feature in SWIR only drillholes. maps the characteristic 1945 nm H2O feature found in gypsum (longer wavelength H2O feature than found in most other minerals).
Hydrocarbon presence	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 2310 nm PFIT scalar. Using both scalars together can identify oil bleeds when the spectral response is preserved (it can deteriorate over time). Use with caution as it produces 'false positives'.
ISM(H2O)_Doublier2010	Batch script scalar designed to measure 'illite spectral maturity' (ISM) published in Doublier *et al* (2010). Measures the depth ratio of the 2000 nm and 1900 nm features obtained using a Profile scalar in preference to a PFIT scalar. Similar to WM crystallinity scalar. Low ISM indicate poorly formed white micas with a high molecular water content.
jCLST, ujCLST, djCLST	The jCLST algorithm has been developed by Andy Green (OTBC Pty Ltd; www.corstruth.com.au) as a replacement for sTSAT. The older sTSAT unmixes the TIR spectra on a sample by sample basis without reference to the results in the VNIR or SWIR, commonly returning 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.
Kaolin composition	CSIRO MFEM batch scalar that measures the composition and crystallinity of kaolin group minerals ranging from well-ordered kaolinite to halloysite to dickite and nacrite (after Sonntag *et al* 2012). Also referred to as 'Kaolin crystallinity index' and 'Kaolin_comp_2011v2.txt'.
Kaolinite 2380D *(previously called PFIT kaolinite 2380nm)*	PFIT scalar to measure the depth of a trough minima between 2375–2400 nm (focus 2378–2392 nm) with a depth >0.0016; polynomial order 5; hull envelope divided by reflectance reported as a relative depth. Used to assist in identifying kaolinite in mineral mixtures, particularly if white micas are present.
Kaolinite PFIT 2160 doublet d or D2160	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.
MFEM	Multiple Feature Extraction Method: a CSIRO-derived method to describe the position and depths of absorption features described in Haest *et al* (2012). The resultant script scalars may be referred to as "MFEM Scripts'.
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.
New Hem/Go Ratio	Batch scalar validated by Jake Moltzen (NVCL (unpubl) 2017) based on work done by Erick Ramanaidou (CSIRO) after Haest *et al* (2012).
Nontronite 2290D *(previously called 2290D nontronite)*	PFIT scalar fitting 2270–2325 nm; focus 2270–2305 nm; hull envelope divide reflectance; polynomial order 4 to return a relative depth. This scalar is used to confirm the TSA SWIR nontronite matches by identifying the depth (strength) of the characteristic 2290 nm feature.
PFIT Fe oxide wvl	PFIT scalar to measure the VNIR feature fitting 750–950 nm (focus 830–910 nm); depth 0.026; area >0.0046; polynomial order 3; hull envelope divided by reflectance to report wavelength at minimum. Used to test the wavelength of hematite and goethite matches, and perhaps identify hematite and goethite in zones that would return a uTSAV 'Not In Library' or 'aspectral' response. PFIT Fe oxide d has the same parameters but returns a relative depth of the absorption feature.

Guide to scalars in figures produced using TSG software (continued)

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.
Phlogopite 2325W *(previously Phlogopite PFIT 2325nm)*	PFIT scalar to measure the wavelength of the MgOH trough minima between 2300–2350 nm (focus 2320–2330 nm) with a depth >0.005; area >= 0.005; polynomial order 5; hull envelope divided by reflectance reported as wavelength at minimum in nm. Phlogopite has a characteristic MgOH feature around 2325–2326 nm. Care should be taken with spectra that may contain dolomite as this feature will overlap.
Phlogopite 2378W *(previously Phlogopite PIFT 2378nm)*	PFIT scalar to measure the wavelength of the secondary MgOH trough minima between 2365–2390 nm (focus 2370–2385 nm) with area >= 0.005; polynomial order 5; hull envelope divided by reflectance reported as wavelength at minimum in nm. Phlogopite has a characteristic feature around 2377–2378 nm (at a longer wavelength than biotite and shorter wavelength than amphiboles).
Plagioclase composition index (plagioclase_ composition.txt)	Batch script scalar calculating the ratio of (1) the relative height of the 9660 nm peak using a fitted fourth-order polynomial with the endpoints located at 9400 nm and 9780 nm (9660D) divided by (2) the relative height of the 9920 nm peak using a fitted fourth-order polynomial with the endpoints located at 9800 nm and 10150 nm (9920D). Developed by Cudahy *et al* (2009) and used to estimate the Na-Ca plagioclase composition with high values (>1.08) equating to Na plagioclase (albite) and <0.97 (anorthite). Used as an intermediate tool to restrict the plagioclase minerals allowed in domains prior to calculating the domained TIR mineral result.
Prehnite 1475D *(previously 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.
Pyrophyllite 2078D *(previously Pyrophyllite 2078nm D)*	PFIT scalar to measure the depth of a trough minima between 2060–2090 nm (focus 2070–2083 nm) with a depth >0.002; polynomial order 4; hull envelope divided by reflectance reported as a relative depth and masked. Used to measure presence of pyrophyllite (along with Pyrophyllite 2319 nm D) which is useful in mineral mixtures which also contain overlapping features around 2200 nm (such as kaolins and white micas).
Pyrophyllite 2166D *(previously Pyrophyllite 2166nm D)*	PFIT scalar to measure the depth of a trough minima between 2156–2172 nm (focus 2160–2172 nm) with a depth >0.0507; polynomial order 4; hull envelope divided by reflectance reported as a relative depth. Used to measure presence of pyrophyllite but has limited use in mineral mixtures with kaolin group minerals (as there are overlapping features at this wavelength range).
Pyrophyllite 2319D *(previously Pyrophyllite 2319nm D)*	PFIT scalar to measure the depth of a trough minima between 2297–2335 nm (focus 2310–2323 nm) with a depth >0.024; polynomial order 6; hull envelope divided by reflectance reported as a relative depth. Used to measure presence of pyrophyllite (along with Pyrophyllite 2078 nm D) which is useful in mineral mixtures which also contain overlapping features around 2200 nm (such as kaolins and white micas).
Pyroxene 9300W *(previously Px 9300 wvl)*	PFIT scalar developed by David Green (Mineral Resources Tasmania 2017 unpubl) to measure the wavelength of the 9300 nm peak feature between 8700 and 9800 nm (focus 8900–9550 nm); polynomial order 7; local minimum subtract base reflectance reported as a wavelength at maximum. This is used as one of 2 scalars (the other is Px 11000 wvl) to confirm pyroxene presence in mixtures and can be used for pyroxene composition.
Pyroxene 11000W *(previously Px 11000 wvl)*	PFIT scalar developed by David Green (Mineral Resources Tasmania 2017 unpubl) to measure the wavelength of the broad 11000 nm peak feature between 9700 and 1200 nm (focus 9700–12000 nm); polynomial order 2; local minimum subtract base reflectance reported as a wavelength at maximum. This is used as one of 2 scalars (the other is Px 9300 wvl) to confirm pyroxene presence in mixtures and can be used for pyroxene composition.
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 12500nm peak d	Measuring a characteristic quartz peak between 12430–12600 nm, polynomial order 3; hull envelope subtract base reflectance reported as a relative height. Used as a secondary feature for determining quartz presence. The quartz 12500 nm peak wvl uses the same parameters but returns a wavelength at maximum result.
Quartz 12800nm peak d	Experimental PFIT scalar to identify a secondary quartz feature at around 12800 nm by fitting 12650–12950 nm; (focus 12700–12900 nm); polynomial order 4; hull envelope subtract normalised TC reflectance. This is an experimental scalar (so parameters may slightly change between datasets) and results can overlap with plagioclase and K-feldspar features. Use with care if these minerals are present.
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_H_2O	Batch scalar created by CSIRO; may also be known as '1900W50'. Described as 'normalised ratio that maps samples with appreciable (1950 nm) water absorption in fluid inclusions, found mostly in quartz (and some carbonates)'.

Guide to scalars in figures produced using TSG software (continued)

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.
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, uTSA+, dTSA+	Mineral result from matching to the short wave infrared (SWIR) spectra against the TSA library. In TSG versions 7 and earlier; 'sTSAS' is the default system match, replaced by sjCLST in TSG8. 'uTSAS' is the author-derived result from manually excluding some minerals and artefacts (eg; wooden core blocks, plastic chip tray spectra) using the TSA algorithm. 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'.
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	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 sulfides or artefacts (such as metal tray edges, metal depth marker tabs or instrument issues).
Tourmaline 2247D *(previously Tourmaline PFIT 2247nm d)*	PFIT scalar to measure the depth of a trough minima between 2230–2270 nm; focus 2235-2259nm); depth >0.02; polynomial order 4; hull envelope divided by reflectance reported as a relative depth. Used in conjunction with the Tourmaline 2366D scalar to determine if tourmaline is present, and as a check of the SWIR TSA+ unmixing results that include (Fe) tourmaline in the result.
Tourmaline 2366D *(previously Tourmaline PFIT 2366 d)*	PFIT scalar to measure the depth of a trough minima between 2358–2385 nm; polynomial order 5; 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).
U_SWIR_TSA705 Groups{item=WHITE-MICA]-> Set Weight	Class Extraction scalar that extracts all the SWIR spectra that contain white mica and returns the weighting of the white mica within the uTSAS result (as a number between 0.15 and 1). Used as an intermediate scalar for the White Mica Mask. Created by New Scalar | CLASSEX Search in: Domained SWIR TSA Groups and Match this item WHITE MICA and extract U_SWIR_TSA705 Weight (masked through Final Mask).
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	Scalar created and used mainly in TSG7 datasets 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.
VSAlbedo – Smooth(9)	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) the albedo using a window of 9 spectra. May also be called Albedo Rmean Smooth or Smoothed Albedo. Batch scalar updated by CSIRO in 2020.
W2200 white micas *(previously called White mica PFIT wvl)*	PFIT scalar to measure the wavelength of a trough minima between 2180–2230 nm, focus 2190–2225 nm with a depth of >0.01; polynomial order 4; hull envelope divided by reflectance reported as a wavelength at minimum. Used mainly to analyse white mica composition changes by observing wavelength changes in the 2200 nm feature. This could be used for other minerals with a 2200 nm feature (kaolins, Al smectites) but the focus interval may be more restricted.
White Mica 2342D	PFIT scalar to measure the depth of a trough minima between 2320–2370nm (focus 2330–2355 nm); polynomial order 4; hull envelope divided by reflectance reported as a relative depth. This is one of 2 longer wavelength SWIR features that can be used to try confirming white mica in the presence of other minerals that have a 2200 nm feature.
White Mica 2430D	PFIT scalar to measure the depth of a trough minima between 2420–2450nm (focus 2425–2450 nm); polynomial order 4; hull envelope divided by reflectance reported as a relative depth. This is one of 2 longer wavelength SWIR features that can be used to try confirming white mica in the presence of other minerals that have a 2200 nm feature.

Guide to scalars in figures produced using TSG software (continued)

White mica and Al-smectite abundance (wmAlsmai.txt)	CSIRO MFEM batch script scalar, using the relative absorption depth of the 2200 nm absorption for which the continuum is removed between 2120 and 2245 nm, determined using a 3 band polynomial fit around the band with the lowest reflectance. Further developed on the basis of Sonntag *et al* (2012). In NTGS TSG datasets, it is applied to results filtered to SWIR TSA smectites.
White Mica Mask	Mask of the TSA results so that dTSAS (or uTSAS) results match only to white mica. Results from scalars such as WM crystallinity and White mica PFIT wvl (white mica composition) are affected by the presence of other minerals with an AlOH feature (such as smectites, kaolin group minerals, pyrophyllite). Using the White Mica Mask gives a better result for WM crystallinity. The White Mica Mask is developed from the U_SWIR_TSA705 Groups{item=WHITE-MICA]-> Set Weight by Edit | New Scalar | Method = UCLASS; Initialise as a mask from U_SWIR_TSA705 Groups{item=WHITE-MICA]-> Set Weight. Within the White MIca Mask then select Class/Rock Mark Edit and Select U_SWIR_TSA705 Groups{item=WHITE-MICA]-> Set Weight LE (less than or equal to) 0.85 and select IN for Class OFF.
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).

Guide to scalars references

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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.