

Appendix 1 – HyLogger description, glossary of terms and TSG processing methods

HyLogger Specifications

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

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

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

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

HyLogger data collection and description of data files

Much of the information in the following sections have been updated from Smith and Huntington (2014). After each drill core tray is scanned by the HyLogger, the TSG-QC (Quality Control) software on the HyLogger imports the trays' worth of data to create an image of the scanned tray and provides information on HyLogger diagnostics (QC errors, described by an error code). This allows the HyLogger Operator to check that the data acquisition from the HyLogger contains no fatal errors, both from the HyLog Diagnostic codes and from the imagery. The current settings produce a down-sampled spectral dataset (from 256 spectra per tray row to 128 spectra), which is considered to improve the signal to noise ratio (SNR). When all the trays are imported into TSG for an entire drill hole, there are 2 TSG files with the prefix HOLENAME_TSG and HOLENAME_TIR_TSG (eg WRD0084_tsg.tsg and WRD0084_tsg_tir.tsg). A dataset which has undergone checking and interpretation by a processor will generally contain the following files (All examples here will reference drill hole 'WRD0084' for ease of reading):

- WRD0084_tsg.tsg; TSG master control file (shows the TSG logo in subdirectories) with VNIR/SWIR data as the primary datasets.
- WRD0084_tsg_tir.tsg; TSG master control file with TIR data as the primary dataset. It is linked within TSG to the VNIR/SWIR dataset so that components of both datasets can be shown together.
- WRD0084_tsg.bip; this is the main file containing VNIR / SWIR spectra and scalar data.
- WRD0084_tir.bip; main file containing TIR spectra and TIR related data.
- WRD0084_tsg_cras.bip; this is the line scan camera data file.
- WRD0084_tsg_cras.bip.bak; this is the backup linescan imagery (saved after trimming the imagery) and may be part of minimally processed datasets (but should be absent in this data package).
- WRD0084_tsg.cal; VNIR / SWIR calibration data file.
- WRD0084_tsg_tir.cal; TIR calibration data file.
- WRD0084_tsg_tsg.ini; TSG's initialisation file (for the VNIR / SWIR) that records all screen layouts and parameters. This is the file that loads the last layout view used in TSG by the processor.
- WRD0084_tsg_2.ini; these are processor-derived layouts that can be accessed from the top level | View | Plot Layouts menus. Up to 9 different scatter plot layouts (in the VNIR/SWIR dataset file) may be recorded here.
- WRD0084_tsg_tir.ini; TSG's initialisation file (for the TIR) that records all screen layouts and parameters. This is the file that loads the last layout view used in TSG by the processor.
- WRD0084_tsg_tir_2.ini; other layouts that can be accessed from the top level | View | Plot Layouts menus. Up to 9 different scatter plot layouts (in the TIR dataset file) may be recorded here. There may be a total of up to 18 different layouts preserved between the 2 dataset files.
- WRD0084_tsg.tdl; this is the depth logging backup file.
- WRD0084_hires.dat; laser profilometer data file.
- WRD0084_tsg_holeimg.jpg; this is the whole of hole linescan imagery comprising core tray images spliced together. This image is used on the HOLE screen in the TSG datasets.

- WRD0084_tsg_mosaic.jpg; this is an image generated by the dataset processor and shows the whole of hole imagery arranged in trays but is annotated (designed for publishing).
- WRD0084_0012.jpg; this is a core tray image generated by the dataset processor (designed for publishing). There is one jpeg image generated per core tray. The tray number is reflected in the filename (eg; in this example, the file is for Tray 12 from drillhole WRD0084).
- WRD0084_downsampled_1_m_TSG_data.xlsx – this is a processor-generated file designed to export out the TSG data to allow import into other drillhole analysis programs. The file has been generated in TSG using the File | Export | Downsample using ‘fixed span bins’ of 1 m (rounded to the nearest metre) and downsampling scalars and scalar sets. The downsampling is done using averages in each bin and expanded mixture levels. This is done on both the primary and associated TSG datasets, to return a mineral result and average scalar for VNIR, SWIR and TIR TSA mineral matches.

Opening a TSG dataset

All TSG datasets in this Record have been created and edited using TSG Version 8. Earlier versions of TSG software will NOT open these datasets, as TSG is not backwards compatible. A (free) TSG Viewer licence is available from <http://www.thespectralgeologist.com/>.

Opening a dataset through the TSG software will give two dataset file options:

HOLENAME_tsg.tsg

HOLENAME_tsg_tir_tsg.tsg

(eg WRD0084_tsg.tsg and WRD0084_tir_tsg.tsg).

The first dataset is the VNIR / SWIR dataset and the second (or associated) one is the TIR dataset. Until June 2011, HyLogger datasets consisted of only the VNIR / SWIR dataset. The addition of the TIR spectrometer (containing spectra from anhydrous silicates and carbonates) led to the creation of the second (TIR) dataset, to hold the TIR data. Both datasets are paired. If you open one in TSG the other is opened too. The dataset you open is called the ‘primary’ dataset and the other is the ‘associated’ dataset. TSG’s screens can show spectra or scalars from either dataset.

Each dataset will open at the Summary screen when first opened. However, if the TSG software has edit capabilities (any version of TSG except TSG Viewer) then the dataset will open at the last screen viewed. For example, if a dataset is closed at the Log screen, it will open at the Log Screen when it is next opened, not the Summary screen.

Most of the interpretation and results in this Record are shown in the VNIR/SWIR dataset (eg HOLENAME_tsg.tsg) so this should be the primary TSG dataset that is opened for further viewing and interrogation.

Scalars – definition and description

A TSG scalar (it is sometimes also called a spectral parameter or index) is an imported or calculated value in TSG designed to describe the spectroscopic data in some way. A scalar can be numeric (eg the wavelength of an absorption feature or a mineral proportion) or a text class (eg the name of a mineral or a stratigraphic name). Schodlok et al (2016) describes scalars as a procedure to measure the characteristics of a spectral features within the TSG software. Table 1 lists the scalars used in the TSG datasets for this Record.

Some scalars are ‘System’ scalars, which are produced by the TSG software for particular purposes (such as core recovery index, minimum height from profilometer measurements etc). The most significant System scalar results come from the automated mineral matching of the TSG data upon data import (Protected System Scalars). TSG offers 2 automated unmixing methods: The Spectral Assistant (TSA™) and Constrained Least Squares (CLS), both which are described in Schodlok *et al* (2016).

TSA runs automatically in the background when creating a new TSG dataset, with the results shown as ‘system TSA results’. In earlier versions of TSG, this would show as sTSAV (system The Spectral Assistant VNIR) for VNIR; sTSAS for SWIR; and sTSAT for TIR mineral results. In TSG8, this has been refined (to give better automated results to TIR spectra) by using a joint unmixing CLS algorithm (jCLST) System result for the TIR data and TSA+ for the SWIR data).

‘User’ TSA or CLS results are created after an analyst notes poor spectral fit to the mineral matches (eg due to noisy spectra in dark rocks, or distortions from surface conditions or cracks) and applies geological context to

the dataset. This results in turning off some of the minerals in the TSA training library (such as those which are geologically unlikely in a particular environment) or were erroneously matching, and then re-running the algorithm (in this Record, the TSA algorithm is preferentially used).

As a drillhole may intersect different geological terrains (for example, basin sediments overlying crystalline basement), the range of geologically likely minerals will change within the one dataset. The analyst can create an interpreted Restricted Mineral Set (RMS) to restrict the assemblage of minerals on an interval by interval basis, before running the (TSA or CLS) algorithm to model the mineral matches throughout the drillhole. When TSA is run with this user-selected RMS in domains, the end result is a domain-TSA (dTSA).

Schodlok et al (2016) summarises the differences and uses of the TSA and the CLS algorithms in TSG. In this Record, domained TSA (dTSAV for VNIR; dTSA+ for the SWIR (which uses rules to give a better result in reporting chlorite) and dTSAT is used for the TIR. Domained CLST (domained CLS algorithm in the TIR) is calculated for comparison and is shown on the LOG screens (TIR-CLS1_CLS_min) and also in the TIR associated dataset.

TSG Advisory on automated mineral matching

The TSG software uses the TSA (and CLS) 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, and can report up to three of the most spectrally active minerals identified in the Short Wave Infrared (SWIR) and commonly three (but up to six when using CLS) of the most spectrally active minerals in the Thermal Infrared (TIR) wavelengths. In the VNIR, the common matches are for hematite, goethite and possibly jarosite. Sulphides (pyrite, chalcopyrite, sphalerite) are difficult to accurately match. Rare earths are not in the VNIR spectral library so will not be identified if present. If there are more minerals actually present in the sample than the software can identify, 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 a further element of interpretation.

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* (2016b) or by visiting <http://mineralspectrallibraries.csiro.au>

Generated user Scalars

Other user scalars include scalars that have been either created or imported by the user (analyst). This includes importing external datasets (such as lithology, assays or petrophysics data) as well as building a scalar to filter the spectral results (such as a white mica wavelength scalar (ie, 'white mica pfit wvl' is used to map white mica compositional variations). This type of scalar can highlight changes in the composition of a mineral group by plotting changes in wavelengths of characteristic reflectance features. User calculated scalars can also be used to check uTSA results, by looking for diagnostic spectral features for a particular mineral. For example, pyrophyllite, white mica and kaolin group minerals all have close-spaced or overlapping features between 2160-2210 nm. The 2166nm feature in pyrophyllite is also overlapping with the kaolinite doublet (2162 / 2206nm) but less so with dickite (2178 / 2206nm). However, pyrophyllite has other minor features at 2078 nm and 2319nm that persist in mineral mixtures. The 2319nm feature would overlap with some carbonates (if carbonates were present) although this is not an issue with the Angularli datasets. For these datasets, to check whether pyrophyllite is present, the scalars 'Pyrophyllite 2078D' and 'Pyrophyllite 2319nm D' were created to cross-check against the TSA results.

TSG also has some in-built user scalars, which use a batch script to build the scalar within the dataset. Batch scripts may be 'base' scripts (such as the 'kahuna' junk mask) or may be specialist scripts that are being internally validated (such as CSIRO's inbuilt 'kaolinite crystallinity' batch scalar). All user scalars are routinely filtered through the Final Mask scalar, which masks out spurious spectra from tray edges, core blocks and other non-mineral sources.

A list of scalars used is in List of Scalars.xlsx (in this Appendix).

Data Processing Methodology

Processing steps are recorded in the HyLogging Checklist (✓ found on the menu bar of TSG), which records items ticked on a checklist by the analyst, as well as automatically recording version updates, edits of Final Mask; date and time of creation of new scalars etc.

Standard processing steps used by the HyLogging community and recorded in the HyLogging Checklist for these datasets include:

Basic Processing tab

1. depth logging (ie, matching core block or marked metre depths with the HyLogger depth - this is important for sampled areas and for recognising zones of core loss)
2. trimming linescan imagery (decreasing file size and creating a better image for viewing by removing excess imagery of the tray rows)
3. applying image colour stretch to core tray images in TSG
4. creating tray image and hole image outputs
5. masking off spurious spectra (core blocks, tray base and edges) to create a Final Mask. All scalars are filtered through the Final Mask.

TSA tab

6. creating a common list of minerals to turn off in File | Settings | TSG | Active Minerals in VNIR, SWIR and TIR
7. noting minerals turned off in Dataset Info.

Scalars tab

8. importing list of standardised scalars using TSG's copy processing function
9. importing lithology, assays, (supplied by the Rio Tinto/Cameco JV)
10. importing petrology data (using rock marks) with data supplied by Rio Tinto / Cameco JV

Domains and Plots tab

11. domaining of drillholes by mineralogy
12. editing of restricted mineral sets in VNIR, SWIR and TIR in the domain editor, with notes
13. reapplying formatting to show only uTSA (or domained TSA) screens
14. formatting layout manager to highlight different scalars, with 8 to 9 layouts showing in the VNIR SWIR dataset (HOLENAME_tsg.tsg).