BR Smith


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### Hole Specifications

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<td>400.4 m</td>
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<td>638203</td>
<td>94MGA_Northing</td>
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<td>Date HyLogged</td>
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<td>HyLogged By</td>
<td>Darren Bowbridge</td>
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<td>Date of HyLogger Report</td>
<td>25 August 2010</td>
<td>HyLogger Report Author</td>
<td>Belinda Smith</td>
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### INTRODUCTION

The National Virtual Core Library (NVCL) is a collaborative research infrastructure project funded by the Commonwealth Government’s ‘National Collaborative Research Infrastructure Strategy’ (NCRIS) within the Department of Innovation, Industry Science and Research. The project is one component of the earth sciences platform managed through AuScope Ltd and implemented by CSIRO and all State and Territory Geological Surveys.

The NVCL project has the goal of progressively building a high resolution hyperspectral and digital image of earth materials and properties for the upper one to two kilometres of the Australian continent, and facilitating world-class geoscience research. The HyLogger™ instrument rapidly measures reflectance spectra and also captures continuous high-resolution digital colour imagery of drill cores in their original trays. The HyLogger 2-7 is a ‘Version 2’ HyLogger instrument, and is the seventh machine built by CSIRO. Further information about the HyLogger (specifications and capabilities) is within Mason and Huntington (2010).

The Northern Territory Geological Survey (NTGS) is producing a record of HyLogger results for each drillhole that is scanned from the NTGS core facility collection. The HyLogger data is presented with reference to other known information, such as logged geology and assays (if available). If the hole was submitted to the government by a company, then the additional drillhole information provided in this report (coordinates, geological logs, assays, additional data) was sourced from the relevant company statutory reports. NTGS makes no assurances on the accuracy or quality of the lithological logs, assays, etc and further information should be sourced from the relevant company report. This report does not validate company-supplied data, but is referenced to give context to the HyLogger results.

For this report, the additional data (lithological logs, petrography, SEM data, assay data) was sourced from the Bondi Mining company report (Esser 2010).

### REGIONAL GEOLOGY

The following description is derived from Esser (2009).

The oldest rocks in the region are the Lower Proterozoic Murphy Metamorphics, which form the basal unit of the Murphy Inlier, and consist of isoclinally folded greenschist facies metasediments; typically quartz-feldspar-mica schists and gneiss with minor graphitic units. The Murphy Metamorphics form the core of the Murphy Tectonic Ridge and only outcrop in the Northern Territory portion of the inlier.

The northern margin of the Murphy Inlier is unconformably overlain by the Westmoreland Conglomerate, which is the oldest unit in the Middle Proterozoic Tawallah Group, and marks the base of the southern portion of the McArthur Basin.

The Seigal Volcanics lie conformably on top of the Westmoreland Conglomerate and consist of massive and amygdaloidal tholeiitic basaltic lavas with minor interbedded siltstones and sandstones. A thin shale bed is commonly found at the base of the Seigal Volcanics and marks the hiatus between deposition of the Westmoreland Conglomerate and the start of volcanism.

Structurally, the region is cut by a dominantly northwest-trending series of faults and joints paralleling the Calvert fault. Possible north-northwest-trending extensions of the Emu Fault also pass through the west side of the region under the Phanerzoic cover. A second set of northeast-trending faults can also be seen paralleling the structural trend of the Murphy Tectonic Ridge. Both sets of faults commonly consist of high angle normal and reverse faults whose intersection appears to form structural blocks displaying horizontal movement and/or tilting. Lateral movement is also common in the northwest-trending structures. Numerous mafic, commonly doleritic, dykes parallel the faulting and are thought to be cogenetic with the mid Proterozoic volcanics of the Tawallah Group.

### LOGGED GEOLOGY

The following description is derived from Esser (2010). MURD013 (**Figure 1**) was planned to test a target area along a major northwest-trending fault adjacent to a Proterozoic mafic intrusive and to also determine the depth of the Cambrian cover sequence. The hole intersected:

- 0–3 m; black soil
- 3–40 m; Cambrian limestone
- 40–93 m; Cambrian Antrim Plateau Basalt
- 93–218 m; Westmoreland Conglomerate (fine-grained hematitic laminated sandstone)
218–293 m; Westmoreland Conglomerate (coarse sandstone; pebble conglomerate, partly silicified and sericite altered – base of Westmoreland Conglomerate)

293–400.4 m; mafic intrusive; dark green chloritic dolerite with variable hematite-chlorite alteration to end of hole. Bondi hypothesises whether the mafic intrusive is a feeder dyke for the Cambrian mafic volcanics.

OTHER WORK (PETROGRAPHY, GEOCHEMISTRY)

Esser (2010) also reported results from downhole gamma probing, magnetic susceptibility readings and assay data. Composite samples (two metre spear samples) were collected every ten metres in the precollar of MURD013. In the core, one half of the core was sampled and assayed every ten metres as well as along the unconformity contact of the Westmoreland Conglomerate and the Antrim Plateau Basalt. Within the diamond core of MURD013, seventeen samples were assayed for multi-element analysis using a four acid digest / ICPAES for thirty-three elements. Highest uranium values for MURD013 were recorded in the Antrim Plateau Basalt (within the precollar) with a max value of 1.5 ppm U and 169 ppm Cu from 48–50 m.

HYLOGGER RESULTS

The core was scanned by the HyLogger 2–7 in Darwin. HyLogger specifications and raw data specifications are in Mason and Huntington (2010). Level-1 processed TSG data can also be requested (available for viewing using TSG Viewer [http://www.thespectralgeologist.com] and is also be available via the NVCL Database [http://portal.auscope.org/portal/gmap.html]). TSG dataset files are included in a separate folder on the DVD product, or can be requested from NTGS using the Unique Identifier plus Hole ID (ie; 7963228_MURD013).

General mineralogy

Figure 2 shows the hole summary with core image mosaic, logged lithology (by Bondi Mining) and dominant mineralogy. The overall distribution of white micas and chlorites follow logged lithology; the overlying Westmoreland Conglomerate sediments are dominantly white mica–rich and chlorites are most common within the mafic intrusive (Figure 3). There is a small zone around 275.5–293 m where the chlorites increase and the white micas decrease. Examining the core imagery indicates that there is a lithology change and it may be a mafic intrusive (but it is recommended that the core be physically checked

![Figure 1](https://example.com/figure1.png)

**Figure 1.** Location map of MURD013.
Figure 2. MURD013 from the TSG ‘Hole’ Screen; this summary screen is available as a pdf file from TSG. Column 1 is the hole image mosaic; Column 2 is the logged lithology; Column 3 shows the main mineralogy group down the hole while Column 4 shows the dominant mineral downhole. The key is for the minerals in Column 4 (‘Min1’). White micas and chlorites are the dominant mineral groups, with the white micas dominant in the Westmoreland Conglomerate and chlorites dominant in the mafic intrusive.
Figure 3. Distribution of chlorites, white micas and FeOx minerals in MURD013. A change in chlorite / white mica distribution around 275.5 – 279 m may highlight a lithology change (possibly a small mafic intrusive).
to confirm this). There are zones of hematite and goethite throughout the hole, which was noted in logging by Bondi Mining.

**Spatial patterns in mineral distribution**

**White micas**

The white micas are concentrated within the sedimentary sequences of the Westmoreland Conglomerate (Figure 3). However, there appears to be more than one mica population, with a composition ranging from paragonite (Na–rich muscovitic white mica) through muscovite (Al–rich muscovite) to phengite (Fe/Mg–rich white mica, with the Fe +/- Mg substituting for octahedral Al). **Figure 4** shows the distribution of white micas according to AlOH wavelength (white mica composition) which indicates possibly two white mica populations; one around 2201 nm and one around 2208 nm. Separating the mica groups into TSA-assigned mineralogy indicates that the two populations are dominantly muscovitic (Figure 5).

Further examination of the muscovite in MURD013 shows that there is a trend within the Westmoreland Conglomerate of increasing aluminium with depth in the logged coarse sandstone / pebble conglomerate (Figure 6). There are some sharp changes in the AlOH wavelength of the muscovite, coinciding with the logged mafic intrusives (275.5–279 m; and from 293 m to end of hole).

![Figure 4](image1.png)

**Figure 4.** White mica population distribution in MURD013. There appears to be two overlapping populations of white mica centred around 2201 nm and 2209 nm.

![Figure 5](image2.png)

**Figure 5.** Muscovite population distribution in MURD013, which mirrors the white mica distribution (Figure 4) with overlapping populations of muscovite centred around 2201 nm and 2208 nm.
Paragonite

Paragonite (and illitic paragonite) is confined to an interval of logged conglomeritic sandstone (approximately 279–293 m; Figure 7). On further examination, the paragonite is within an interval of rock that is bounded by a mafic intrusive; the logged contact at around 293 m, plus the previously unidentified interval of ?mafic intrusive from 275.5 to 279 m. From the HyLogger imagery, the conglomeritic sandstone appears to be quite altered with some recrystallisation (Figure 8). The TSA-assigned muscovite in this interval has a similar AlOH wavelength (around 2200 nm) to paragonite that is distinctly different from the phengite/chlorite mineral mix present in the surrounding mafic intrusive (Figure 7).

Tourmaline

There is a grouping of tourmaline within the conglomeritic sandstone unit of the Westmoreland Conglomerate (approximately 253–268 m; Figure 9). A possible secondary zone of tourmaline is suggested (as part of a mineral mix) from around 330 m (Figure 9). Drill logs by Bondi Mining indicate the conglomerate has strong to moderate silicification and sericite alteration along sub-vertical joint sets. Tourmaline was not detected in core logging. Orth et al (2010) noted that a halo of possible tourmaline occurs at the fringes of the orebody within CHDDH49 (Coronation Hill Au + PGE + U). A comparison of the tourmaline spectral response from CHDDH49 and MURD013 is shown in Figure 10. The significance of possible tourmaline within holes such as MURD013 and CHDDH49 remains unknown.

A sample of the tourmaline was sent for XRD and petrographic analysis (Bottrill and Woolley 2011) for validation of the TSA tourmaline response. XRD confirmed tourmaline ‘albeit only in small amounts’ which gave a weak pattern making full compositional interpretation difficult. The XRD showed peaks suggestive of calcic tourmaline, but complex substitutions in tourmaline make these identifications tenuous. Petrographic analysis indicated that the tourmaline is Fe-poor, Mg-rich with fibrous aggregates that suggest a relatively moderate temperature, post-depositional hydrothermal origin.

Gypsum

The diagnostic absorptions for gypsum (at 1750 nm plus the three diagnostic water features between 1450–1535 nm) are present in most of the spectra TSA has assigned as gypsum (Figure 11). The gypsum appears almost as surficial smears on the core and within fractures. The gypsum may well be a surface artefact of the drillcore rather than an interstitial mineral in the rock. Further examination of the drillcore (with perhaps follow-up petrographic / x-ray diffraction work) is recommended if the presence (or absence) of gypsum is important in geological interpretations.

Kaolin group

There is a grouping of kaolin group minerals between around 223 and 234 m (mainly along fracturing planes within the conglomerate sandstone; Figure 12). The diagnostic double OH absorption (1400 nm, 1412 nm) and double AlOH absorption (2162 nm, 2206 nm) is visible in most spectra assigned as either dickite or well-crystalline kaolinite (Figure 13). The TSA-assigned poorly crystalline kaolinite is less definitive; the diagnostic kandite doublets are usually not present due to a poor spectral response. Caution is suggested when using any of the poorly crystalline kaolinite spectra in interpretations.
Figure 7. Distribution of paragonite and phengite in MURD013. Note that the paragonite distribution is limited to the interval above the unconformity.
Carbonates

Dolomite response in the mafic intrusive is generally due to dolomite veins at a low angle to the core axis (Figure 14). Ankerite / siderite are also present as mixtures with chlorites and phengite within the mafic intrusive.

Imaging results

Core tray images (Figure 15) and a hole mosaic image (Appendix 1) are available as jpeg files. The jpeg resolution of the core tray images is set at 4000 pixels per metre (approximately 5.4 Mb file sizes). The hole mosaic image has a resolution of 1000 pixels per metre (20.5 Mb file size).

CONCLUSIONS AND / OR FURTHER WORK

Analysis of the hyperspectral data suggests that:

- Dominant mineralogy follows lithology, with white micas in the Westmoreland Conglomerate and chlorites in the mafic intrusive.
- There is a mineralogy change between 275.5–279 m in the Westmoreland Conglomerate; this may be a mafic intrusive, but the core should be checked to determine whether there is a lithology change in this interval.
- There are possibly two white mica populations; the coarse sandstone / pebbly conglomerate interval of the Westmoreland Conglomerate tends to have more Na-rich muscovite (paragonite) while the white mica within the mafic intrusive is a mineral mix of Fe/Mg–rich white mica (phengite) with chlorite.
- Tourmaline is grouped around 253–268 m within the Westmoreland Conglomerate and has a similar spectral signature to tourmaline found in a Coronation Hill drillhole (CHDDH49).
- Petrographic analysis of tourmaline indicates that it is Fe-poor, Mg-rich with fibrous aggregates that suggest a relatively moderate temperature, post-depositional hydrothermal origin.
- Well crystalline kaolinite and dickite appear along fracture planes in the conglomeritic coarser sandstones of the Westmoreland Conglomerate.
- Gypsum is also present along fracture planes and on the core surface. The surface expression of gypsum may be the result of handling the drill core, rather than being an interstitial mineral of the rock. Further examination of the drillcore is advised.

Figure 8. Conglomeritic sandstone (Westmoreland Conglomerate) in the area of white paragonitic mica. The conglomerate appears to have some recrystallisation.
Figure 9. Distribution of tourmaline in MURD013. Middle plot shows that tourmaline-dominant mineralogy is grouped around 253 – 268 m, while the bottom plot shows the distribution of tourmaline as a secondary mineral in a mineral mix. The bottom plot also shows a grouping around 253 – 268 m.
Figure 10. Shows a comparison of the tourmaline spectrum from Coronation Hill (CHDDH49; top plot) and MURD013 (bottom spectrum). The diagnostic absorptions are present in the MURD013 hole, with XRD results confirming the presence of tourmaline.

Figure 11. Gypsum in MURD013. a) shows the spectral response for TSA-assigned gypsum, which has diagnostic absorptions at 1449 nm, 1490 nm, 1545 nm and 1750 nm. b) shows the core which has the gypsum response; it is difficult to identify the gypsum (surficial or interstitial?) without further examination of the core. Hole depth in metres along base.
Figure 12. Kaolin group minerals (comprising poorly crystalline kaolinite in blue; well crystalline kaolinite in red and dickite in green) in MURD013. There is a grouping of kaolinite minerals around 223–234 m.
Figure 13. Dickite in MURD013; a) shows the spectral response which is indicative of dickite (with doublet absorption features at 1400 nm and 2200 nm). b) Shows the core image which gives the dickite response; dickite / well-crystalline kaolinite is mainly present as fracture fill between 223–234 m. Hole depth in metres along base.
Figure 14. a) Carbonate distribution and mineral type within MURD013. b) Dolomite veins within mafic intrusive.
REFERENCES


**GLOSSARY**

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

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
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<tr>
<td>Albedo</td>
<td>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.</td>
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<tr>
<td>AIOH</td>
<td>Aluminium hydroxide.</td>
</tr>
<tr>
<td>CCD</td>
<td>Charge coupled device.</td>
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<tr>
<td>FTIR</td>
<td>Fourier transform infrared spectrometer.</td>
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<tr>
<td>HgCdTe</td>
<td>Mercury Cadmium Telluride used in infrared detectors.</td>
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<tr>
<td>HQ</td>
<td>Shorthand for hull quotient (a type of background corrected spectrum).</td>
</tr>
<tr>
<td>IFOV</td>
<td>Instantaneous field of view (of an instrument).</td>
</tr>
<tr>
<td>InSb</td>
<td>Indium antimonide – used in infrared detectors.</td>
</tr>
<tr>
<td>LN₂</td>
<td>Liquid nitrogen.</td>
</tr>
<tr>
<td>MCT</td>
<td>Mercury Cadmium Telluride used in infrared detectors.</td>
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<tr>
<td>MgOH</td>
<td>Magnesium hydroxide.</td>
</tr>
<tr>
<td>MIR</td>
<td>Mid infrared.</td>
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<tr>
<td>NH₄</td>
<td>Ammonium cation. An NH₄ mineral is a mineral that contains the ammonium cation. In terms of spectral response, the NH₄ cation has characteristic absorptions at 1912 nm, 2013 nm, and 2112 nm. Other absorptions features can diagnose the type of ammonium mineral.</td>
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<tr>
<td>nm</td>
<td>Nanometre, being one billionth of a metre. A HyLogger 2 operates between 380 and 2500 nm.</td>
</tr>
<tr>
<td>Ref</td>
<td>Abbreviation for reflectance.</td>
</tr>
<tr>
<td>Scalar</td>
<td>Any set of imported or calculated values associated with spectral data loaded in TSG</td>
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<tr>
<td>SEM</td>
<td>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.</td>
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<tr>
<td>SNR</td>
<td>Signal-to-noise ratio.</td>
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<tr>
<td>SRSS</td>
<td>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 in the SWIR.</td>
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<tr>
<td>SWIR</td>
<td>Shortwave infrared (wavelength). Nominally covering the range 1000–2500 nm.</td>
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<td>TSA</td>
<td>‘The Spectral Assistant’ – CSIRO trademarked algorithm that uses training libraries of pure spectra to match an unknown spectrum to a single mineral or to identify a mixture of two minerals. Part of the TSG software package.</td>
</tr>
<tr>
<td>TSG</td>
<td>‘The Spectral Geologist’ – CSIRO-developed specialist processing software, designed for analysis of field or laboratory spectrometer data.</td>
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<tr>
<td>TIR</td>
<td>Thermal infrared (wavelength). Nominally covering the range 6000–14000 nm.</td>
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<tr>
<td>um or µm</td>
<td>Micrometre (formerly micron), being one millionth of a metre. A HyLogger 2 operates between 0.38 and 2.5 micrometres.</td>
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<tr>
<td>VIS</td>
<td>Visible (wavelength). The human eye is nominally sensitive between 390 and 750 nm.</td>
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<tr>
<td>VNIR</td>
<td>Visible near infrared (wavelength). Nominally covering the range 380–1000 nm.</td>
</tr>
<tr>
<td>wvl</td>
<td>Abbreviation for wavelength, found in TSG scalar names.</td>
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<td>XRD</td>
<td>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.</td>
</tr>
<tr>
<td>λ</td>
<td>Lambda – Often used as a symbol for wavelength of light.</td>
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Appendix 1. Hole Mosaic of MURD013, with Trays 1–3 on top row; Trays 3–6 on second row etc until end of hole.