AIRBORNE HYPERSPECTRAL REMOTE SENSING

HyMap SURVEY AND PROCESSING REPORT

FRANCES CREEK

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EXPLORATION MANAGER

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REPORT DATE: 3RD January 2008

WRITTEN

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ISSUED

January 2008

Executive Summary

HyVista Corporation was contracted by Territory Iron (Contact: Bob Vivian) to acquire and process HyMap airborne hyperspectral scanner imagery from a site in Northern Territory. The data acquisition occurred on 15th of October 2007.

This report describes the processing that has been applied to the HyMap data to produce a number of image products including standard colour composites, a SWIR decorrelation colour composite, minimum noise fraction (MNF) colour composites and unmixed endmember mineral maps. To produce these products the data has had a series of processes applied that converts the raw data into reflectance imagery which is then geometrically corrected and radiometrically levelled so that seamless mosaic images can be produced.

Three (3) “Classes” of imagery have been produced:

1. Standard colour composites and MNF images can be used for photo-interpretation to delineate geological units and structural features. They do not provide information on the mineralogy of geological formations ie the same colour may map different rock types in these images.

2. The decorrelation stretch colour composite is derived from selected SWIR bands and produces an image that maps the overall distribution of Al-OH, Fe-OH, Mg-OH (and carbonate if present) bearing minerals within the area but not specific mineral species. Similarly, the Index Images which uses band depth ratio techniques to depict a specific absorption band; also does not map individual mineral species but may indicate the presence of a mineral “class” such as those minerals typical of advanced argillic alteration (ie pyrophyllite, alunite and / or dickite).

3. Specific species mineralogical information is extracted by applying end-member unmixing processing to the reflectance image mosaic. This requires several procedures that are carried out separately on the Short Wave InfraRed bands (SWIR: 2.00 microns to 2.43 microns) and the Visible Near InfraRed bands (VNIR: 0.488 microns to 1.12 microns). Processing of the SWIR bands maps the distribution of clay minerals, mica’s and carbonates and the VNIR bands the iron oxides.

    - The unmixing has located the 9 mineral:
      Illite-Kaolinite, Kaolinite, Chlorite-Carbonate, 3 Illites and 3 Hematites

All mineral identification is based on analysis of the spectra and since this is a subjective procedure it requires field confirmation. Some minerals, particularly those characterised by Mg-OH / carbonate absorption (~2.30 microns) have very similar spectra.

For each mineral the output products are grey scale and rainbow coloured images where the tone or colour depicts the abundance of the mineral mapped (i.e. increasing abundance from dark to light or from blue to red).

For the SWIR minerals a RGB colour composite image maps have been produced by assigning differing mineral abundance images to the red, green and blue image bands. Other combinations are possible.

The output images are written ENVI, ER Mapper and Jpeg formats. The geo-correction applied to the data results in image maps in the UTM/WGS-84 (Zone 52 South) map projection.

The final delivery of the output image products and intermediate products to the customer is on an external USB2 disk drive.

NOTE THE INTERMEDIATE PRODUCTS ARE NOT INTENDED TO BE USED BY THE CUSTOMER WITHOUT REFERRAL TO HYVISTA, THEY ARE PROVIDED FOR BACK UP PURPOSES AND POSSIBLE FUTURE REFERENCE BY HYVISTA STAFF.

INTRODUCTION

HyVista Corporation was contracted by Territory Iron (Contact: Bob Vivian) to acquire and process HyMap airborne hyperspectral scanner imagery from a site in Northern Territory. The data acquisition occurred on 15th of October 2007.

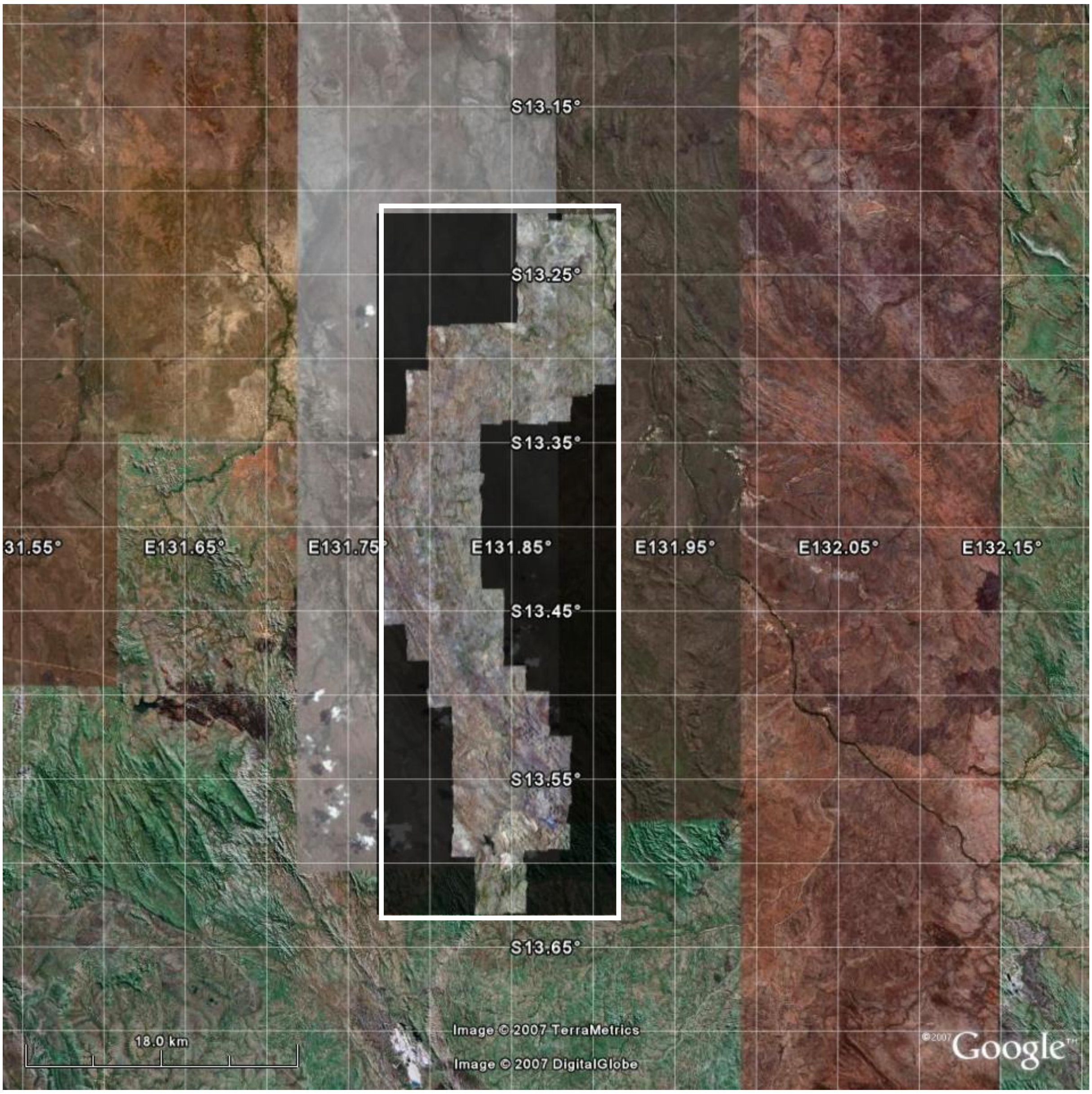


Figure 1: Frances_Creek, Northern Territory, surveys location map.

The HyMap is an airborne hyperspectral scanner delivering 126 bands (approx 18 nm width per band) of imagery over the 450nm to 2500nm spectral interval. The HyMap data pre-processing is carried out on a strip by strip basis, to produce radiance and apparent reflectance, and GLT files for later geometric rectification / mosaicing. The reflectance images are cross track and level corrected, (i.e. solar illumination corrected). These reflectance images are then geo-corrected to position each individual pixel in its accurate geo-location in the UTM/WGS-84 map projection. The corrected strips are them mosaiced to produce a seamless, homogeneous data (map) cube for the whole survey area. This data-cube is then processed to produce various band colour composite, minimum noise fraction (MNF), band ratio index images and image-maps that highlight mineralogical and geological / chemical variations.

Figures 2 and 3 are examples of images. produced from the cross-track illumination and level correction reflectance data; an RGB colour composite in which bands 109, 28, 03 are displayed in red, green, blue respectively. For colour composite images the order of band numbers, wavelengths or mineral names in the file name is always red, green and blue.

This document outlines the pre-processing (Level1) and details the Level2 and Level3 processing applied to HyMap data. Further information on the sensor specification, survey planning and data pre-processing is available upon request. A summary of the flight line planning supporting this survey is provided in Appendix 2.

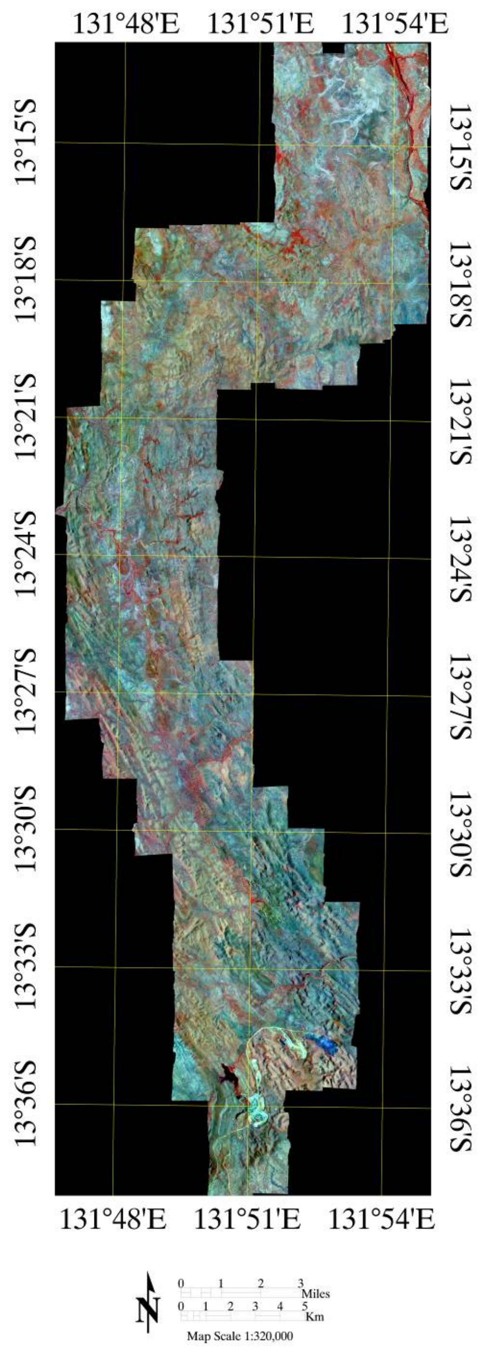


Figure 2: Frances_Creek ,Northern Territory - RGB colour composite of HyMap bands 2815-03 centred at 0.831 microns, 0.655 microns and 0.488 microns.

DATA PROCESSING

Three levels of process have been applied to the data for this project:

LEVEL 1 A&B
Raw and Pre-processed data

LEVEL 1C
Cross track corrected mosaiced reflectance image (Data-Cube)

LEVEL 2
Albedo Image
Colour composites, true and false colour
SWIR decorrelation stretch colour composite images
Mg-OH, Fe-OH and Mg-OH index images

LEVEL 3
SWIR MNF Image from which two 2 Colour Composites have been produced
SWIR and VNIR Endmember Unmixing Images:

- Spectral Library
- Unmixed Endmember Abundance
  - Mineral abundance images have been determined from unmixed images and are presented as:
    - Raw BW
    - Thresholded/Scaled BW
    - Rainbow coloured on threshold
    - Mineral Colour Composite
    - Wavelength Shift for White Mica Al-OH content Rainbow coloured.

MAP PRODUCTS

The delivered map products are precision geo-rectified mosaic images of products above written in ENVI and ER Mapper formats (UTM/WGS84 Zone 51S) formats.

LEVEL 1 / PRE-PROCESSING OF DATA

The HyMap scanner data is collected and stored on a DLT flight tape and converted to ENVI-compatible image files (16-bit integer, BIL data file with an ASCII header file) during pre-processing of the data, The HyMap stores the intensity of light reflected from the surface of the earth as digital numbers (DN). The intensity recorded is the net effect of the wavelength-dependent atmospheric absorption and scattering, solar irradiance, light scattered back from the earth surface, and background voltages from the scanner electronics. Pre-processing involves two corrections.

Dark Current Subtraction

This correction removes the "zero light" spectrum in all image pixels. The DN values for subtraction are obtained from the scanner while imaging a non-reflecting surface. It represents system voltages and electronic noise. It is additive and band-dependent.

Calibration – Radiometric, Spectral and Scaling

The scanner is calibrated using a standard light source so the response of each detector is known. Every pixel of each band has been scaled by this band constant and a multiplier has been applied so that the data is stored as a 16-bit integer.

Data Units

When the pre-processing corrections described above have been applied, the data are in radiance units of microwatts/cm^2/steradian/nm before the multiplier of 1000 is applied to convert it to a 16-bit integer.

Atmospheric Correction

Whilst the HyMap's radiance data is spectrally and radiometrically calibrated, the spectra are distorted by atmospheric absorption and scattering. The data has been processed using the HyCorr program that determines a model of a subset of atmospheric properties that are appropriate for the time (UTC), date, latitude/longitude and acquisition height (AGL) for HyMap data that has been radiance corrected. HyCorr uses radiative transfer calculations and the calibrated hyperspectral data (with artefact suppression) to remove and reduce atmospheric and solar illumination effects. The output of HyCorr is an apparent surface reflectance image from which spectra can be compared to relative reflectance library spectra, i.e. the atmospheric over-print has been removed and mineral absorption features are now recognisable HyCorr output is apparent surface reflectance. Reflectance imagery is unit-less.

Cross Track Correction and Strip Levelling

Prior to geometric correction each strip is processed to remove the effect of bi-directional reflectance that results from non uniform illumination across the image when the azimuth is to the side of the flight line. This results in the images being brighter on one side than the other. The levelling correction adjusts each data strip to the same data ranges. These corrections improve processing and ensure that the final mosaic images are seamless.

Geometric Correction

Variations in the aircraft orientation, speed and altitude during image acquisition result in spatial distortions of the images, even though the scanner is TalisonWed in a tri-axial, gyro-stabilised platform that compensates for some of these motion effects. An IMU/GPS unit is attached to the scanner and it provides data that can be used remove these distortions which would otherwise result in positional errors of several hundred metres. Using these data with the appropriate software permits geo-correction to be completed without the need for control point picking and, depending on terrain variation; this can reduce positional errors to below 20m.

Software developed by HyVista is used for to produce a ray traced image (.glt) file from combining the output from the IMU/GPS with a DEM (SRTM 90m image). The glt file is then used to georectify the image products produced to the UTM/WGS 84 map projection using proprietary HyVista software.

Level 1C Product

In this survey the cross track corrected and levelled reflectance data have been mosaiced into data cubes for the SWIR and VNIR bands and subsequent Level 2/3 processing has been carried out using these images. This image is a proprietary product and is not supplied to the customer. However, the HyMapView program is supplied which allows the customer to examine the images delivered, including the mineral maps, to check the spectra of any given pixel.

LEVEL 2 PROCESSING

Colour Composite Mosaics

Standard Colour Composites

Three colour composite images have been produced from the reflectance data consisting of:

Landsat TM 741 equivalent: RGB = 2.206um/0.851um/0.481um (HyMap bands 109, 28, 03 respectively)
True Colour: RGB=0.67um/0.58um/0.488um (HyMap bands 15, 09, 03 respectively)
False Colour: RGB =0.851um/0.665um/0.488um HyMap bands 28, 15, 03 respectively)

The contrast in these colour composites has been enhanced by applying the ENVI square root and then linear stretch to the images. Note all colour composite images (DCS, MNF and Mineral Map) have convention that band numbers or mineral names are given in order Red, Green Blue the same as they are displayed.

In addition the 109_28_03 image has been masked to remove vegetation and water showing which pixels have removed prior to processing.

SWIR Decorrelation Stretch (DCS) Colour Composite

The SWIR image bands: 2.211microns, 2.264microns and 2.332microns are selected as a RGB colour composite image and the ENVI decorrelation stretch function applied to this image. The resultant image maps the distribution of mineral classes that absorb at these wavelengths i.e. Al-OH, Fe-OH and Mg-OH/Carbonates respectively. However, since it is absorption being mapped the resultant colours are confusing, for example Mg-OH is mapped as not blue. However, by taking the negative of the bands (ie inverting the RGB colour image planes) an image results in which:

Red = Al-OH absorbing minerals (White mica, kaolinite, montmorillonite)
Green = Fe-OH absorbing minerals (Nontronite, Fe smectite, chlorite and epidote)
Blue = Mg-OH absorbing minerals (Amphibole, talc, Mg smectite and Mg carbonate etc)

Index Images

By calculating the depth of the absorption features at specific wavelengths it is possible to produce images that show the overall abundance of groups of minerals that have a primary absorption feature at the specified wavelength. In this case the band depths for 4 SWIR absorption features have been mapped to show the distribution of:

2.174microns – Advanced Argillic Minerals (Alunite, Pyrophyllite, Dickite, Ordered Kaolinite)
2.205micons – Al-OH minerals (Kaolinite, White Mica [Sericite-Muscovite-Illite], Montmorillonite)
2.26microns – FeOH minerals and Jarosite (Nontronite, Fe/Mg Smectite, Chlorite)
2.315microns – Mg-OH and Carbonate Minerals

These images are termed Index images and have been produced both as grey scale, rainbow coloured grey scale and colour composite images.

LEVEL 3 PROCESSING

MNF Transform

For the SWIR, MNF transforms have been applied to the reflectance data and from these images colour composites have been produced. The bands selected show the greatest variation is surface materials producing images that highlight geological and regolith variation within the area.

Mineral Mapping

Hyperspectral remote sensing is essentially a mineral mapping technology. Its fundamental principles are based on spectroscopy, so an understanding of the spectral signatures of surface materials is required for its application. Briefly, each pixel of a hyperspectral image contains a spectrum which forms the basis for determining the materials present in a scene. Surface mineralogy and other components are mapped using algorithms which either de-convolve a scene into component endmember signatures (unsupervised un-mixing) or specifically target spectral signatures of known materials (supervised match filtering). The former of these approaches has been applied in the project.

Spectral Endmember Un-mixing

Linear spectral un-mixing is the process of deriving the abundances of component materials in a scene from the individual pixel spectra, given the endmember spectral signatures. To give perfect un-mixing results, the signatures for all endmembers present in a scene would need to be known. However, in practice, un-mixing algorithms map the distribution of automatically scene-derived endmember materials. These are especially useful for analysis where signatures of the target(s) are not known and for general geological and regolith mapping.

Un-mixing methods output a set of endmember spectra with corresponding un-mixed images which are, in effect, mineral maps. There are several programs that can be used for this type of processing. HyVista has several proprietary un-mixing programs that can be applied to mosaiced reflectance imagery (as in this case) or allows for the selection of endmember data from multiple strips without the need to mosaic them. Thus, when they are un-mixed, the distribution of endmembers matches across images strip boundaries. This software produces mineral maps that can be used for geological and regolith interpretation where there is no a priori knowledge of the minerals present in the area.

Prior to applying the un-mixing algorithm, the data are processed to remove pixels that are of shadow, anomalously bright areas (such as active fires and metal roofs), and surface water, green and dry vegetation. These are effectively noise pixels and affect the image statistics. These pixels are masked out (i.e. set to zero).

Running the un-mixing algorithm produces two outputs; an endmember library that contains the spectra for each spectral endmember detected within the data, including minerals, and a series of abundance images (one for each flight line) each band of which maps the distribution of a spectral end member. The program is run several times, with differing parameters, to determine the optimum output in terms of minerals mapped and is run separately on the Visible Near Infra Red bands (VNIR 0.488 microns to 1.12 microns) for iron oxides and Short Wave Infrared bands (SWIR 1.95 microns to 2.43 microns) for phyllosilicates, carbonates and other minerals with cation OH bonds (e.g. amphiboles).

The spectral libraries are examined and endmembers recognised as minerals are determined and then mineral species identified. Non mineral spectra may include those from noisy spectra, residual vegetation, spectrally featureless areas and multiple mixed spectra that cannot be identified. The program uses a statistical technique to match each pixel to a spectral endmember and creates the abundance images such that each pixel has a value that is proportional to its closeness of fit to the spectra in question, the higher the value the better the match. In percentage terms, pixels with 0% have no match and the values of 100% have a perfect match and would be "pure" spectra but these will be quite rare within an image as most pixels will contain several different materials. Therefore, in probability terms pixels with percentage values of over 85% have a significant content of the spectral endmember (mineral). Those abundance image bands are then thresholded at ~85% with values below this being set to zero and those above scaled from 0 to 1 (i.e. real data).

Processing Sequence

In this case the following processing sequence was applied to the masked reflectance image:

SWIR

Unmixing

Unmixing set to detect up to 15 endmembers, examination of the spectral libraries and abundance images has identified meaningful mineral endmembers as follows:

- 5 mineral species: Illite(2229-Al-OH poor), Chlorite-Carbonate, Illite(2192-Al-OH rich), illite(2211-muscovite), kaolinite

These abundance images have been thresholded and the spectra examined to validate the mineral identification. Spectra from the highlighted regions of interest and the threshold values are provided in Table 1. Note the spectral identification of the Al-OH minerals that are not kaolinite or smectite is somewhat subjective as iIllite, muscovite, sericite and generic white mica are all spectrally similar. Hence, in this case these minerals have been referred to as white mica (abbreviated to WM) with the wavelength of the main absorption feature appended to the mineral name, e.g. TalisonW_ref_mos_plflr16_WM-2211, where 2211 means absorption at 2.21microns.

VNIR

Unmixing

Unmixing set to detect up to 9 endmembers, examination of the spectral library and abundance images has identified meaningful mineral iron oxide endmembers as follows:

- 3 spectrally slightly different hematite's. The threshold applied to the hematite images may be higher than required so that the extent is under represented in the image with the scaled, rainbow and cc suffix in the image name. The data will be adjusted to account for this and new images produced.

Output Products

After final thresholding the grey scale image then has a rainbow colour look up table applied to it (ENVI Rainbow) such that blue pixels indicate a less perfect match, possibly due to dilution effects, grading through green, yellow and red being the best match. This image is also saved in the formats mentioned above and has the identifier "rainbow" in the file name.

The endmember images can also be combined in RGB colour composites, that is, different endmember combined in red, green and blue, in the case of the SWIR for this project with eight (8) mineral end-members having been identified there are numerous combinations that can be produced. In this case one RGB colour composites has been produced. This combination has been selected on the basis of the mineral association; other combinations can be produced if required.

IMAGE PROCESSING PRODUCTS

Each delivery output product has been written in ENVI, ER Mapper, Jpeg and Geotiff formats; intermediate images are saved only in ENVI format, it is not intended that the customer use these files they are provided for future reference by HyVista staff.

Table 1 lists all of the files produced in the Level 2 and Level 3 processing. Examples of the images products are presented in Appendix I. The processed data are supplied an external disk with the following directory structure which is the same for both East and West Blocks:

Frances_Creek

Frances_Creek_01
- gs_geocorrection
- Radiance
- Reflectance
- Raw DN

To

Frances_Creek_14
- gs_geocorrection
- Radiance
- Reflectance
- Raw DN

Frances_Creek Intermediate_Products

Level 1c
- Reflectance Data Cube – retained by HyVista
- Frances_Creek Background Image

Level 2
- Standard_Colour_Composites
- Colour Composite Veg Off
- SWIR_Decorrelation_Composites
- Index_Images

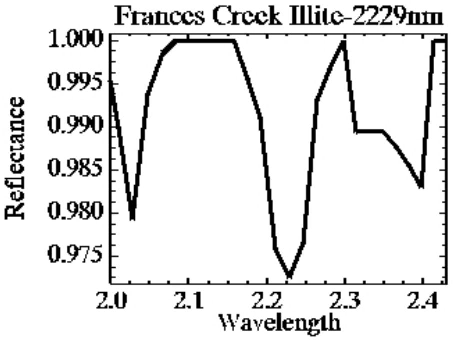
Level 3
- Endmember Abundance
  - SWIR_Mineral _Library
  - SWIR_Minerals
  - VNIR_Mineral_Library
  - VNIR_Minerals
- Wavelength Shifts
- Masks & Ratios
- MNF

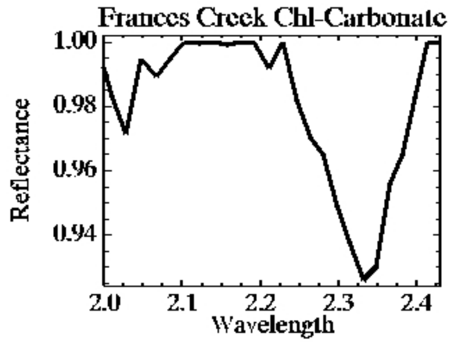
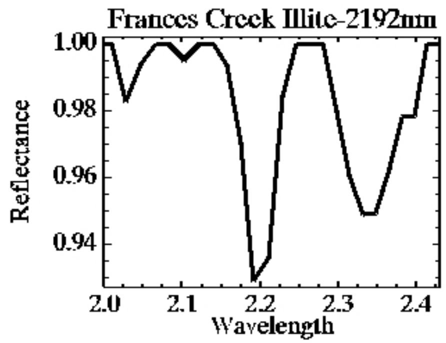
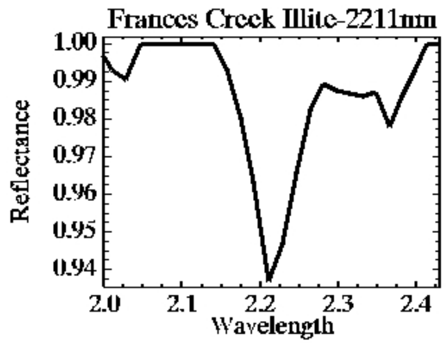
TalsionE Delivery_Products

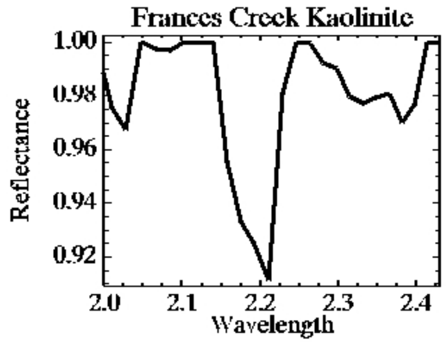
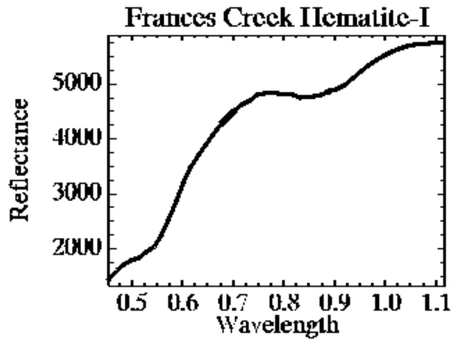
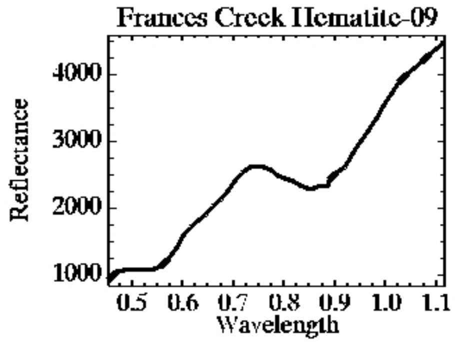
File Name Abbreviations

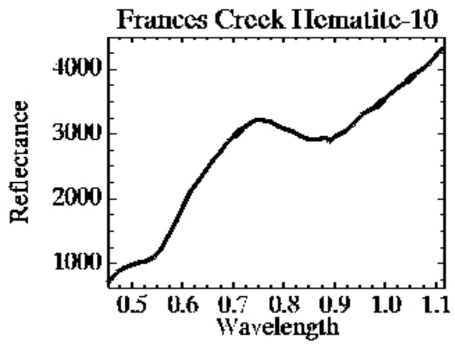
AB#	Abundance Band Number Of Unmixing Image
AMAP	Unmixing Technique That Maps Absorption Features
CC	Colour Composite
CUT	Selected Pixel Values Extract From Image Applied To Wavelength Shift Images
BD	Band Depth
DCS	Decorrelation Stretch
DV	Dry Vegetation
EQUALISE OR EQ	Histogram Equalise Contrast Stretch
FILT	Edge Sharpened Using Unsharp Mask Convolution Filter
GEO	Geo-Corrected Data Using A HyMap glt (Geometric Lookup Table) File
GUASS	Histogram Gaussian Contrast Stretch
GV	Green Vegetation
INDEX	Image That Has Been Thresholded To Highlight A Specific Mineral Group
INVERTED	Negative Image
MNF	Minimum Noise Fraction Transform Image
MOS	Mosaic Of All Survey Strips That Have Been Cross Track Corrected And Leveled
NO BG	Background Set To Black
PL	Unmixed Output
RAINBOW	ENVI Colour Look Up Table Applied To Image Such Grey Tones Are Coloured Dark To Light From Blue To Red.
REF	Reflectance Data – Atmospherically Corrected
SCALED	Linear Contrast Stretch
SGA	Unmixed Output
SR	Square Root Contrast Stretch
SWIR OR SW2	Derived From Processing 25 Selected Shortwave Infrared Bands
TH	Threshold Applied
VNIR	Derived From Processing 35 Selected Visible And Near Infrared Bands
WM	White Mica
WVL	Wavelength Shift Image
XAB	Mineral Abundance File Where *X* Is Number Of Endmembers Derived From Unmixing Software
XTR	X-Track (Brdf) Corrected Results (Removing Illumination Variations Common To One Survey Strip)

Table 1: Image Delivery Product

Folders	Image and Comment	Thresholds	Endmember Spectra
Frances_Creek			
Frances_Creek Delivery Products	*. Output files listed below are in ER Mapper (.ers) and ENVI formats (.img or bil)*	N/A	N/A
Standard_Colour Composite	frances_ck_ref_ cc_bds_109-28-03_rgb_scaled	N/A	N/A
	frances_ck_ref_ cc_bds_28-15-03_rgb_scaled	N/A	N/A
	frances_ck_ref_ cc_bds_15-09-03_rgb_scaled	N/A	N/A
	frances_ck_ref_ cc_bds_109-28-03_rgb_scaled_masked.img	N/A	N/A
Decorrelation Stretch	frances_ck_ref_dcs_cc_bds_2211-2264-2332_rgb_inverted_EQ	N/A	N/A
Index (Al_Fe_Mg+C03)	frances_ck_ref_AlOH_Index	1015-1051.4	N/A
	frances_ck_ref_FeOH_Index	1000.5-1009.0	N/A
	frances_ck_ref_MgOH_Index	1045.0-1071.0	N/A
	frances_ck_ref_Argillic_Aleration_Index	1021.6-1052.4	N/A
	frances_ck_ref_Al-Fe-MgOH_Index_rgb	As above	N/A
MNF (Colour Composite)	frances_ck_ref_swir_cc_mnf_234_rgb_scaled	N/A	N/A
	frances_ck_ref_swir_cc_mnf_456_rgb_scaled	N/A	N/A
	frances_ck_ref_vnir_cc_mnf_345_rgb_scaled	N/A	N/A
	frances_ck_ref_vnir_cc_mnf_234_rgb_scaled.bil	N/A	N/A
SWIR_Mineral_Maps	frances_ck_ref_swir_sga01_Illite-Kaolinite_bw This mineral has also been termed Illite_2229 which would be a very Al poor illite – Phengite. Author MCH does not consider this spectra shows kaolinite.	0.295-0.603	

	frances_ck_ref_swir_sga02_Chlorite-Carbonate_bw	0.097-0.360	
	frances_ck_ref_swir_sga10_Illite-2192_bw	0.207-0.323	
	frances_ck_ref_swir_sga11_Illite-2211_bw	0.219-0.425	

	frances_ck_ref_swir_sga13_Kaolinite_bw	0.064-0.233	
SWIR Mineral Maps CC	frances_ck_ref_swir_cc_sga011210_cc_Illite-2229-2211-2192_rgb_scaled	As above	As Above
FeOx_Mineral_Maps	frances_ck_ref_vnir_sga01_Hematite-01_bw	0.086-0.603	
	frances_ck_ref_vnir_sga09_Hematite-09_bw	0.115-0.281	

	frances_ck_ref_vnir_sga10_Hematite-10_bw	0.126-0.347	
FeOx_Mineral_Maps_cc	frances_ck_ref_vnir_cc_sga010910_Hematite_01-09-10_RGB_scaled	As above	As above
Wavlength_Shifts	frances_ck_ref_swir_cr_wvl_masked_rainbow_scaled	2.185-2.229	Sericite Wavelength Shift AlOH rich to AlOH poor

Appendix I
Example Image Gallery

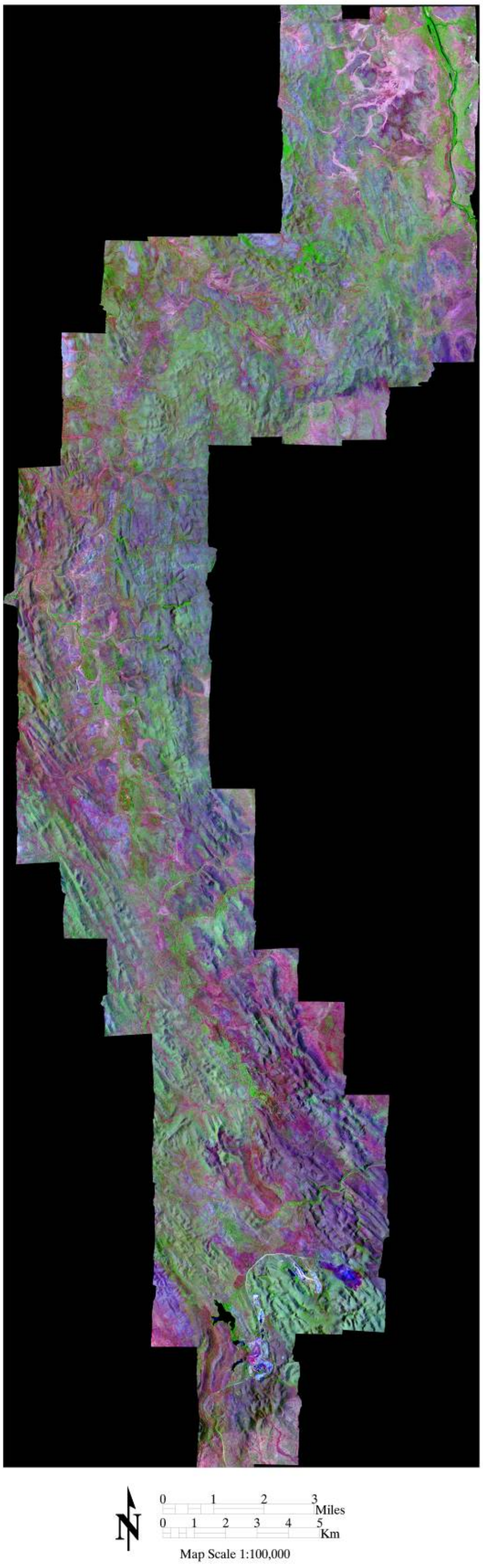


Plate 1: ***RGB colour composite of HyMap bands 109, 28, 03, centred at 2.205 microns, 0.851 microns and 0.488 (Image: frances_ck_ref_cc_bds109-28-03_rgb_scaled)***

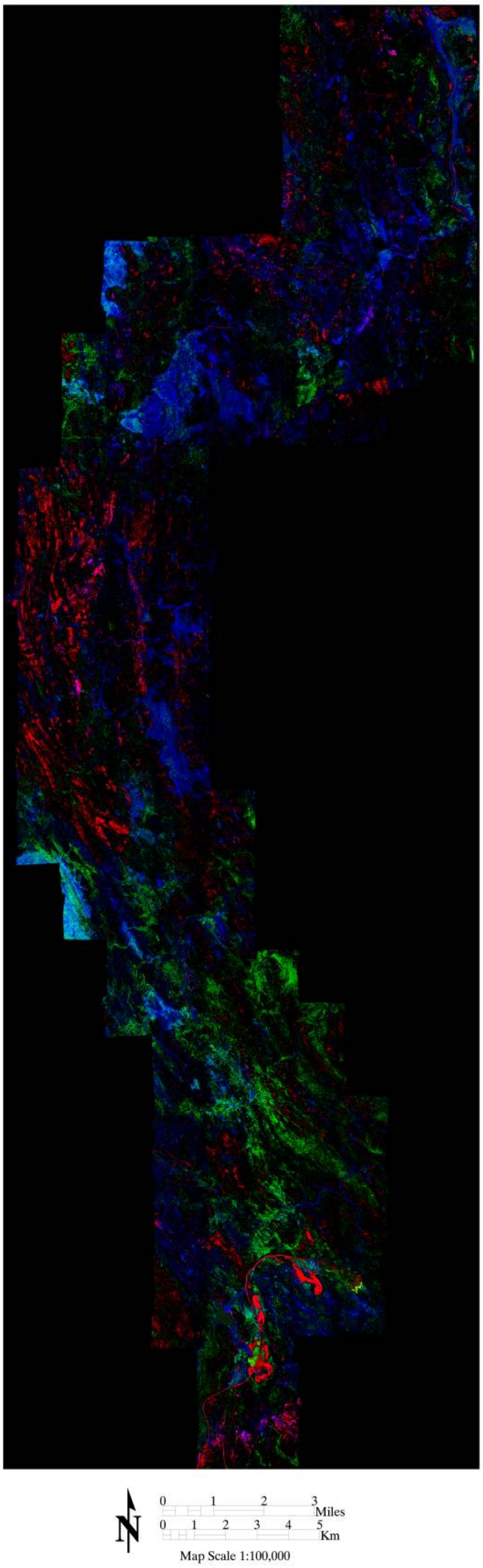


Plate 2: SWIR Decorrelation Stretched Colour Composite (Image frances_ck_ref_dcs_cc_bds2211-2264-2332_rgb_inverted_threshold)

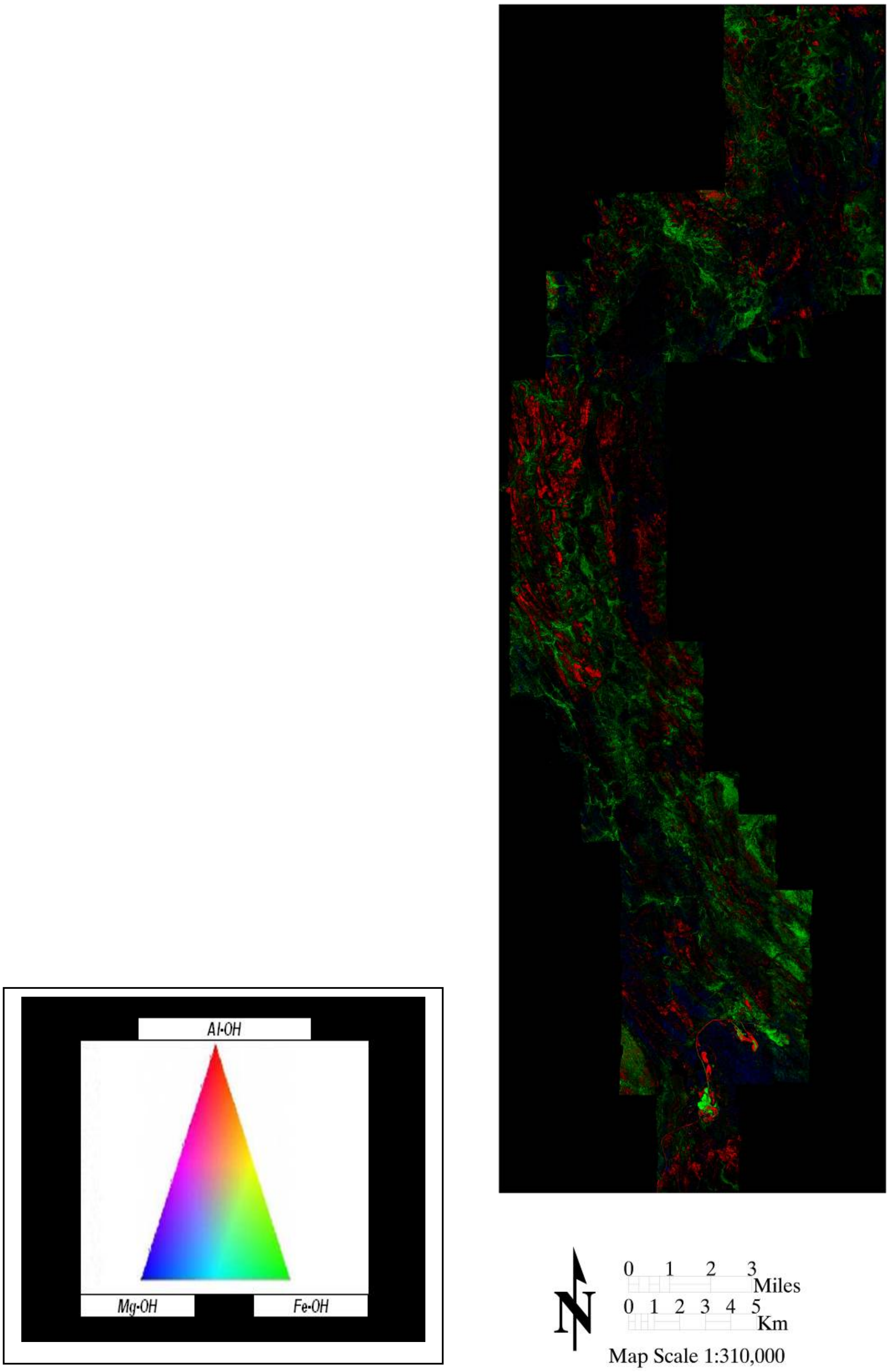


Plate 3: Index Image – Band Depth Colour Composite Al-OH 2.202 microns, Fe-OH 2.265 microns, Mg-OH-Carbonate 2.32 microns (Image: frances_ck_ref_Index_CC_Al-Fe-Mg)

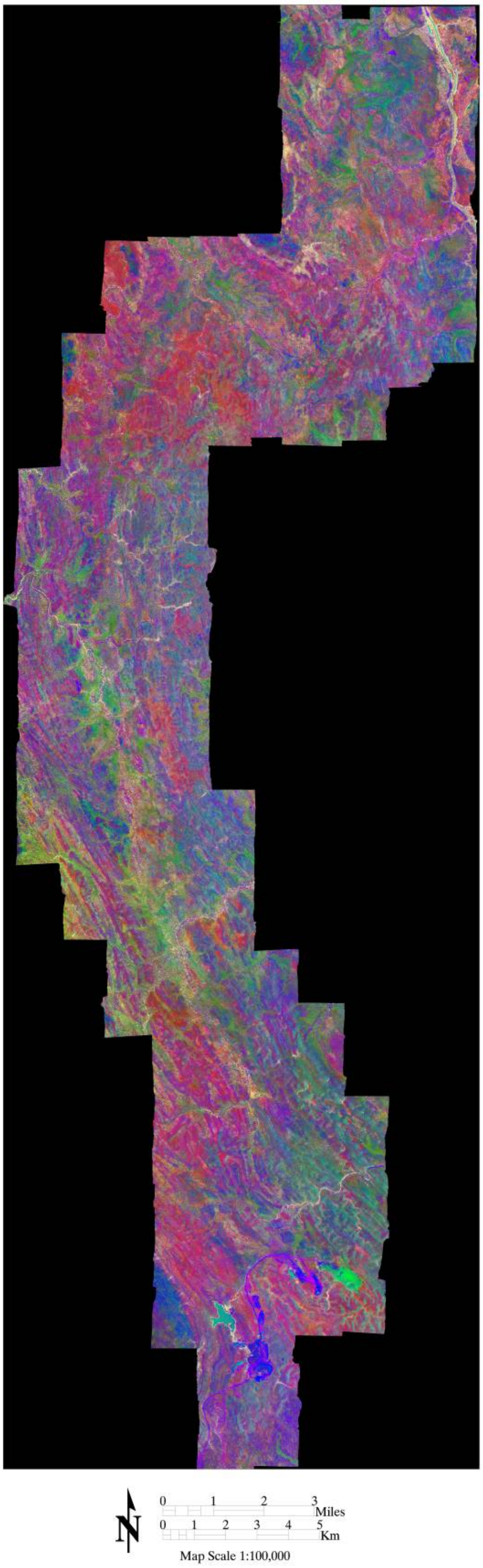


Plate 4: MNF VNIR Colour Composite (Image: frances_ck_ref_vnir_cc_mnf_234_rgb_scaled)

Plate 5: Mineral Map Image Hematite (Image: frances_ck_ref_vnir_sga09_Hematite-09_bw_scaled+SB)

Plate 6: Mineral Map Image of Hematite rainbow coloured (Image: frances_ck_ref_vnir_sga09_Hematite-09_rainbow+SB)

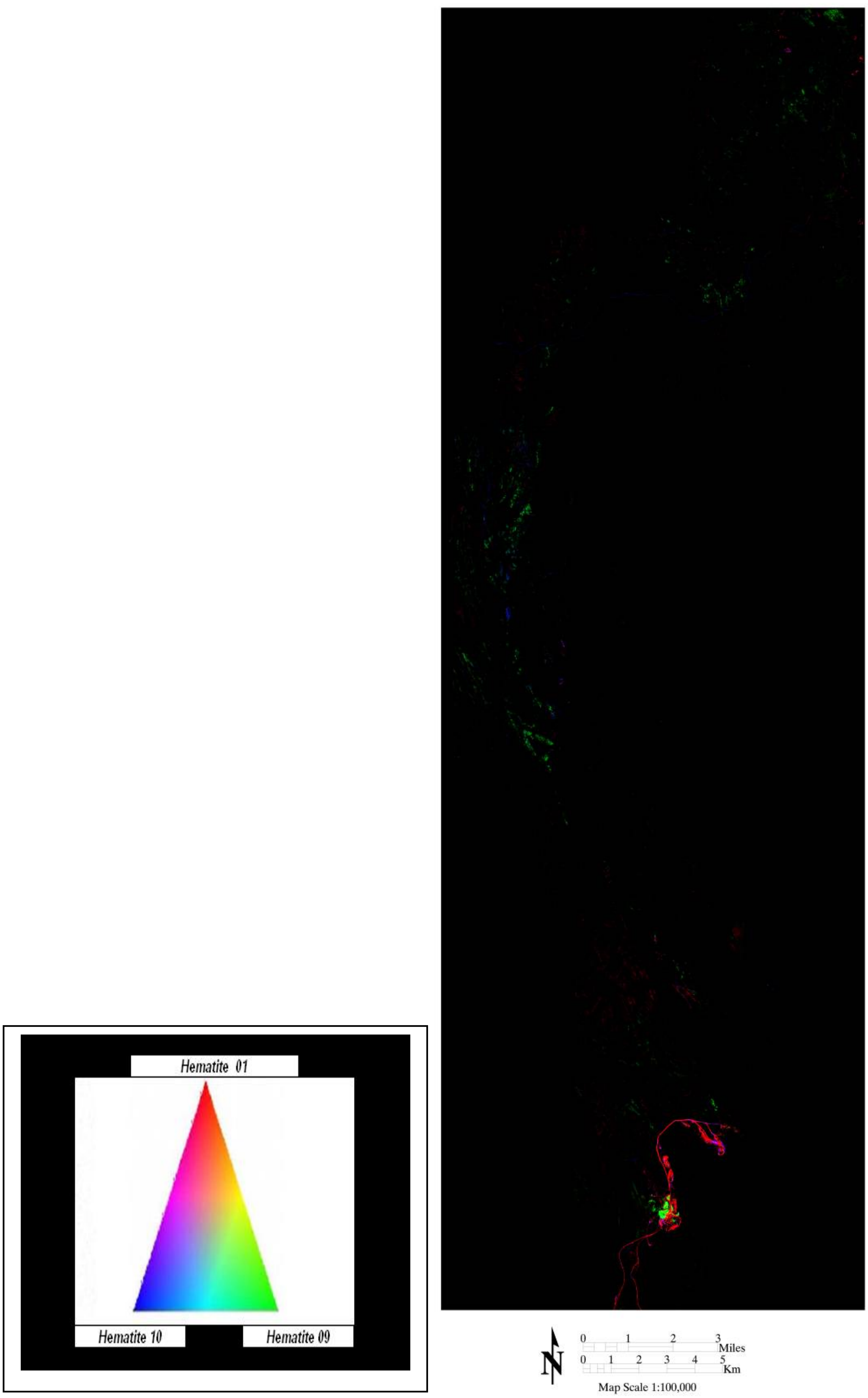


Plate 7: Colour Composite Mineral Map Hematite (Image: frances_ck_ref_vnir_cc_sga010910_Hematite_01-09-10_RGB_scaled)

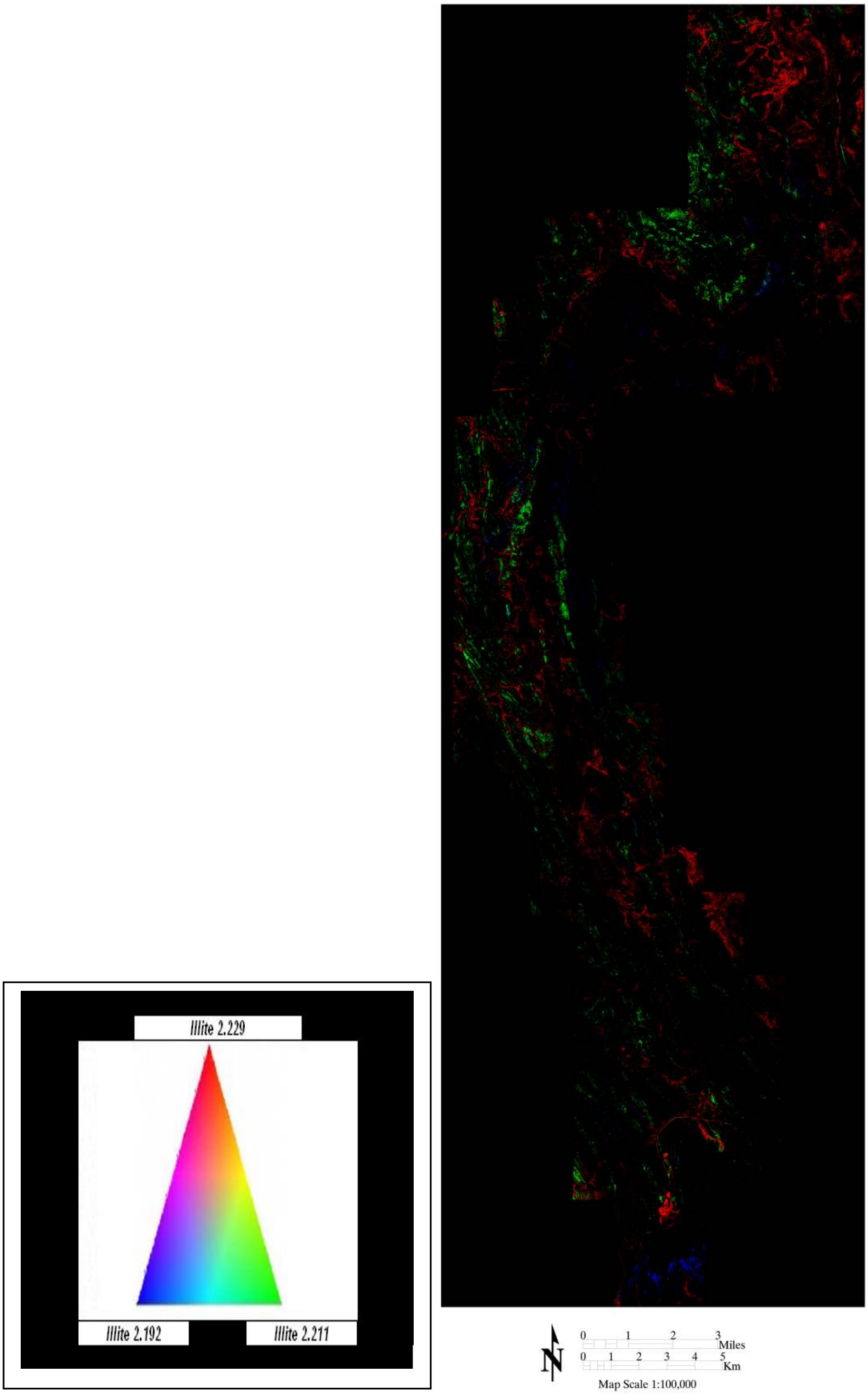


Plate 8: Colour Composite Mineral Map Image 3 White Micas (Image: frances_ck_ref_swir_cc_sga011210_cc_Illite-2229-2211-2192_rgb_scaled)

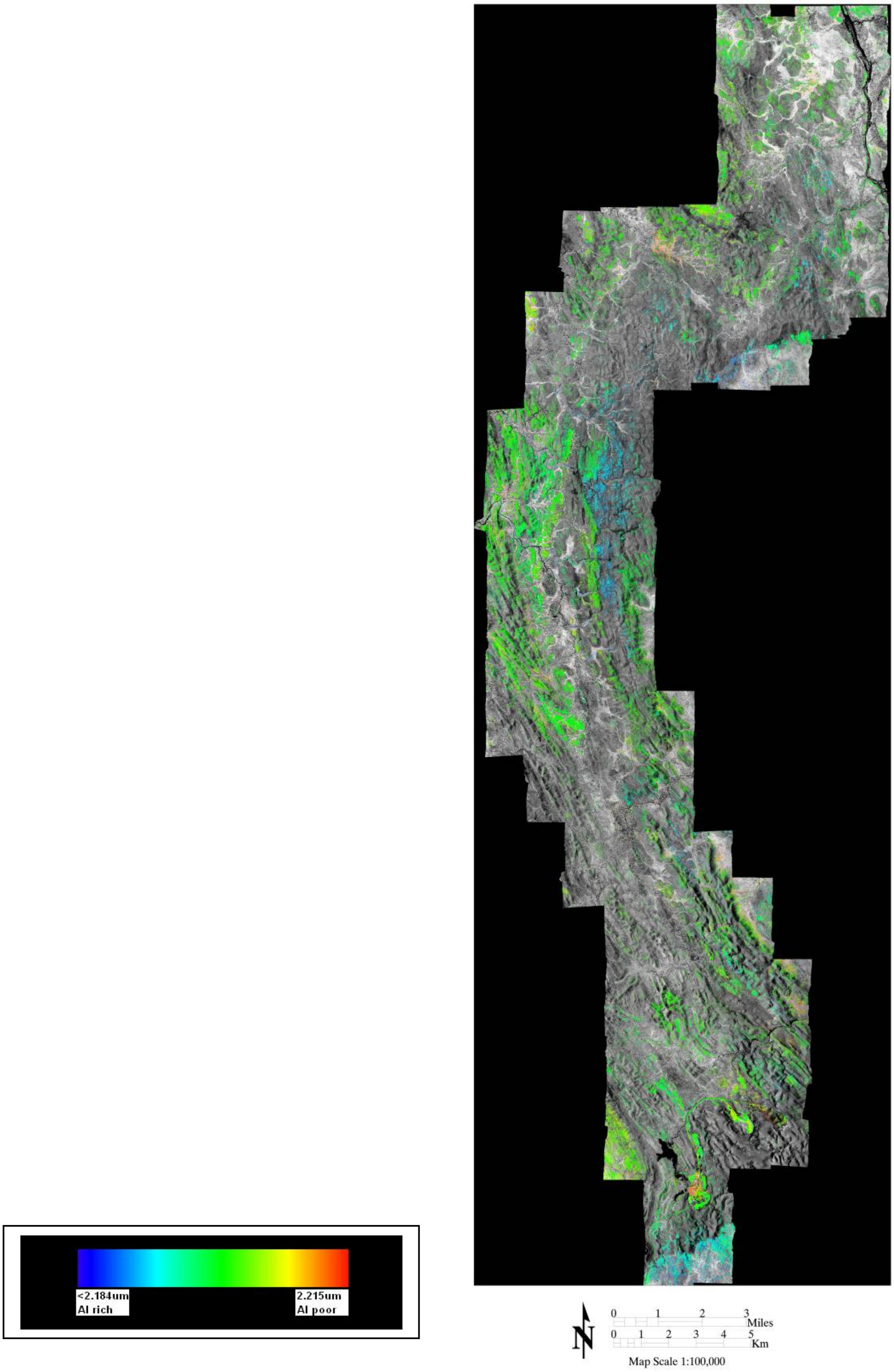


Plate 10: Illite Wavelength Shift Image 2.185 microns to 2.215 microns RAINBOW coloured and overlain on greyscale background (Image*: *frances_ck_ref_swir_cr_wvl_masked_rainbow_scaled_bg:)

Appendix 2

Survey Planning and Specifications

For survey operations and flight logistics and planning, HyVista utilises two integrated software and hardware packages.

The first is Flitemap (Jeppesen - www.jeppesen.com) which is a high resolution moving map and flight planning application. Using HyVista propriety software, flight line information is plotted as user waypoints and entered to the FliteMap database. This information then can be used to plan day to day flight logistics and flight logging and reporting. Another important feature of Flitemap is the ability to log the GPS signal from the HyMap system while in flight. A GPS signal is transmitted from the HyMap system via the Omnistar 3000LR DGPS as RTCM. This signal is recorded every second and plotted on the Flitemap display and can also be saved for archiving and reporting purposes to easily and quickly show terrain coverage and target acquisition completion.

The second and most important survey operation software/hardware package is Eztrack Aerial Survey System (TRACK'AIR – www.trackair.com). The system is a combination of specially developed software and hardware tools integrated to streamline airborne survey operations. The system consists of an equipment kit and the TRACKER planning and reporting software. This includes the TECI (Tracker External Camera Interface), snapSHOT software running on a laptop, a panel display for pilot viewing and a complementary cross track indicator (CTI) for the pilot. The Eztrack is a complete Aerial Survey System which starts at the planning stages of a survey mission. Utilising snapXYZ and snapPLAN a survey area consisting of flight lines can be planned in minutes from any waypoint or polygon coordinates. Flight lines are stored in a database system making it easy to archive and report survey missions. Tracker also accepts many different projections and datums making it easy to use with different client needs. Actual flight operation utilises the Eztrack hardware and snapSHOT software. The Eztrack receives a GPS signal transmitted from the HyMap system via the Omnistar 3000LR DGPS as RTCM. This increases the accuracy of flight line operations.

Appendix 3

Survey Flight Line Specifications

Project name: AUS2007B

Date: 24/07/2007 10:48:16 AM
Flying height agl: 1400 m
Field of view: 61

TOTAL QUANTITIES
Totals for runs + strips
Total lines: 14
Total length (km): 191 km
Total length (nm): 103 nm

Coordinate system: UTM coordinate system
Projection: Transverse Mercator
Ellipsoid: wgs-84

Strips

Strip number: 1
Terrain height = 0m / 0ft
Course: 180°/360°
Length: 8.8 km
Swath width: 1649 m
Geo Start: -13 13.207 131 54.175
Geo End: -13 17.960 131 54.243
WGS84 Start: -13 13.207 / 131 54.175
WGS84 End: -13 17.960 / 131 54.243
UTM WGS84 Start: [52] 814637 / 8536699
UTM WGS84 End: [52] 814658 / 8527926

Strip number: 2
Terrain height = 0m / 0ft
Course: 180°/360°
Length: 11.0 km
Swath width: 1649 m
Geo Start: -13 13.219 131 53.399
Geo End: -13 19.192 131 53.485
WGS84 Start: -13 13.219 / 131 53.399

WGS84 End: -13 19.192 / 131 53.485

UTM WGS84 Start: [52] 813234 / 8536692

UTM WGS84 End: [52] 813262 / 8525668

Strip number: 3

Terrain height = 0m / 0ft

Course: 180°/360°

Length: 12.3 km

Swath width: 1649 m

Geo Start: -13 13.228 131 52.624

Geo End: -13 19.885 131 52.722

WGS84 Start: -13 13.228 / 131 52.624

WGS84 End: -13 19.885 / 131 52.722

UTM WGS84 Start: [52] 811832 / 8536692

UTM WGS84 End: [52] 811867 / 8524406

Strip number: 4

Terrain height = 0m / 0ft

Course: 180°/360°

Length: 12.3 km

Swath width: 1649 m

Geo Start: -13 13.218 131 51.848

Geo End: -13 19.875 131 51.945

WGS84 Start: -13 13.218 / 131 51.848

WGS84 End: -13 19.875 / 131 51.945

UTM WGS84 Start: [52] 810429 / 8536727

UTM WGS84 End: [52] 810464 / 8524441

Strip number: 5

Terrain height = 0m / 0ft

Course: 180°/360°

Length: 5.0 km

Swath width: 1649 m

Geo Start: -13 17.155 131 51.130

Geo End: -13 19.872 131 51.169

WGS84 Start: -13 17.155 / 131 51.130

WGS84 End: -13 19.872 / 131 51.169

UTM WGS84 Start: [52] 809048 / 8529476

UTM WGS84 End: [52] 809062 / 8524462

Strip number: 6

Terrain height = 0m / 0ft

Course: 180°/360°

Length: 5.0 km

Swath width: 1649 m

Geo Start: -13 17.168 131 50.357

Geo End: -13 19.885 131 50.393

WGS84 Start: -13 17.168 / 131 50.357

WGS84 End: -13 19.885 / 131 50.393

UTM WGS84 Start: [52] 807652 / 8529469

UTM WGS84 End: [52] 807659 / 8524455

Strip number: 7

Terrain height = 0m / 0ft

Course: 180°/360°

Length: 33.8 km

Swath width: 1649 m

Geo Start: -13 17.245 131 49.582

Geo End: -13 35.587 131 49.840

WGS84 Start: -13 17.245 / 131 49.582

WGS84 End: -13 35.587 / 131 49.840

UTM WGS84 Start: [52] 806250 / 8529343

UTM WGS84 End: [52] 806327 / 8495493

Strip number: 8

Terrain height = 0m / 0ft

Course: 180°/360°

Length: 23.5 km

Swath width: 1649 m

Geo Start: -13 17.287 131 48.810

Geo End: -13 30.055 131 48.986

WGS84 Start: -13 17.287 / 131 48.810

WGS84 End: -13 30.055 / 131 48.986

UTM WGS84 Start: [52] 804854 / 8529280

UTM WGS84 End: [52] 804903 / 8505718

Strip number: 9

Terrain height = 0m / 0ft

Course: 180°/360°

Length: 17.8 km

Swath width: 1649 m

Geo Start: -13 18.900 131 48.049

Geo End: -13 28.544 131 48.184

WGS84 Start: -13 18.900 / 131 48.049

WGS84 End: -13 28.544 / 131 48.184

UTM WGS84 Start: [52] 803445 / 8526320

UTM WGS84 End: [52] 803487 / 8508523

Strip number: 10

Terrain height = 0m / 0ft

Course: 180°/360°

Length: 11.0 km

Swath width: 1649 m

Geo Start: -13 21.147 131 47.310

Geo End: -13 27.128 131 47.387

WGS84 Start: -13 21.147 / 131 47.310

WGS84 End: -13 27.128 / 131 47.387

UTM WGS84 Start: [52] 802063 / 8522190

UTM WGS84 End: [52] 802077 / 8511152

Strip number: 11

Terrain height = 0m / 0ft

Course: 180°/360°

Length: 20.0 km

Swath width: 1649 m

Geo Start: -13 26.686 131 50.488

Geo End: -13 37.554 131 50.637

WGS84 Start: -13 26.686 / 131 50.488

WGS84 End: -13 37.554 / 131 50.637

UTM WGS84 Start: [52] 807687 / 8511903

UTM WGS84 End: [52] 807722 / 8491847

Strip number: 12

Terrain height = 0m / 0ft

Course: 180°/360°

Length: 14.8 km

Swath width: 1649 m

Geo Start: -13 29.463 131 51.298

Geo End: -13 37.484 131 51.409

WGS84 Start: -13 29.463 / 131 51.298

WGS84 End: -13 37.484 / 131 51.409

UTM WGS84 Start: [52] 809090 / 8506763

UTM WGS84 End: [52] 809118 / 8491959

Strip number: 13

Terrain height = 0m / 0ft

Course: 180°/360°

Length: 9.0 km

Swath width: 1649 m

Geo Start: -13 30.393 131 52.089

Geo End: -13 35.283 131 52.152

WGS84 Start: -13 30.393 / 131 52.089

WGS84 End: -13 35.283 / 131 52.152

UTM WGS84 Start: [52] 810499 / 8505030

UTM WGS84 End: [52] 810506 / 8496005

Strip number: 14

Terrain height = 0m / 0ft

Course: 180°/360°

Length: 6.3 km

Swath width: 1649 m

Geo Start: -13 31.888 131 52.884

Geo End: -13 35.289 131 52.933

WGS84 Start: -13 31.888 / 131 52.884

WGS84 End: -13 35.289 / 131 52.933

UTM WGS84 Start: [52] 811902 / 8502254

UTM WGS84 End: [52] 811916 / 8495977