# Investigating the Potential of Landsat 8 OLI Satellite Imagery for Geological Mapping in Namibia

Only two academic papers relating to geological remote sensing in Namibia have been published (Lord et al., 1996, Gomez et al., 2005) despite the complex and varied geology, cloud free atmospheres, and the almost ideal surface conditions of bedrock exposure. These two publications used moderate resolution sensors, Landsat MSS (1972-82, 4 - 8 spectral bands - VIS/VNIR, 80m pixels) – and ASTER ( 2000+ complex 14 spectral bands - VNIR/SWIR/TIR s 15-90m spatial resolution).

There has not been any published attempt to evaluate the potential of the more readily available Landsat TM, ETM and OLI imagery which has a longevity originating in 1978.

***This poster considers the potential, via display of processed imagery, of Landsat 5-7 (1999-2011) and Landsat 8 (2013 +) satellite imagery for the purpose of spectral mapping of Namibia's geology. It is important to note that spectral mapping is not equivalent to lithological discrimination mapping although it may be possible to draw valid lithological conclusions from the spectral patterns.***

The capacity to perform **spectral mapping or spectral stratigraphy** (Prost,1994) is enhanced by the application of standard image processing techniques and the utilisation of imagery captured under different atmospheric conditions and sun's illumination. The latter situation has been promoted by the advent of free, frequently updated imagery distributed through the internet. Spectral mapping can enhance photogeologic mapping by sensing and displaying signals beyond the human visible spectrum.

| Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) | | | Landsat 7 Enhanced Thematic Mapper Plus (ETM+) | | |
|---|---|---|---|---|---|
| **Bands** | **Wavelength (micrometres)** | **Resolution (metres)** | **Bands** | **Wavelength (micrometres)** | **Resolution (metres)** |
| Band 1 - Coastal aerosol | 0.43 - 0.45 | 30 | Band 1 - blue | 0.45-0.52 | 30 |
| Band 2 - Blue | 0.45 - 0.51 | 30 | Band 2 - green | 0.52-0.60 | 30 |
| Band 3 - Green | 0.53 - 0.59 | 30 | Band 3 - red | 0.63-0.69 | 30 |
| Band 4 - Red | 0.64 - 0.67 | 30 | Band 4 – near Infrared (NIR) | 0.77-0.90 | 30 |
| Band 5 - Near Infrared (NIR) | 0.85 - 0.88 | 30 | Band 5 - SWIR | 1.55-1.75 | 30 |
| Band 6 - SWIR 1 | 1.57 - 1.65 | 30 | Band 6 Thermal Infrared (TIRS) | 10.40-12.50 | 60 * (30) |
| Band 7 - SWIR 2 | 2.11 - 2.29 | 30 | Band 7 - SWIR | 2.09-2.35 | 30 |
| Band 8 - Panchromatic | 0.50 - 0.68 | 15 | Band 8 - Panchromatic | 0.52-.90 | 15 |
| Band 9 - Cirrus | 1.36 - 1.38 | 30 | | | |
| Band 10 - Thermal Infrared (TIRS) 1 | 10.60 - 11.19 | 100 | Tie lines show band equivalents | | |
| Band 11 - Thermal Infrared (TIRS) 2 | 11.50 - 12.51 | 100 | | | |
| *TIRS bands are acquired at 100 metre resolution, but are resampled to 30 meter in delivered data product* | | | *ETM+ Band 6 is acquired at 60-metere solution. Products processed after February 25, 2010 are resampled to 30-metre pixels* | | |

Figure 1
Comparison and equivalence of Landsat 5, 7 and 8 spectral bands

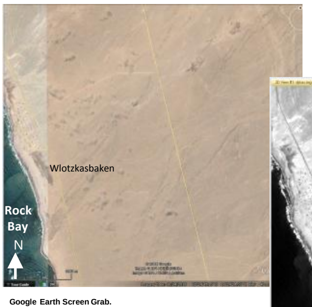

Figure 2. Landsat 8 OLI is freely available from GLOVIS

Gerry Lucas
Geosciences
Edge Hill University
Ormskirk, UK
Lucasg@edgehill.ac.uk

Landsat 5-7(1999-2011) and especially Landsat 8 (2013+) offer new potential for spectral mapping of lithologies and structures. Reference spectral graphs for individual minerals have been available for decades (Hunt and Salisbury 1970) but the spectral discrimination of rocks with variable types and quantities of mineral, variable weathering, surface crusts, hybrids of rock types (shaly limestones) and frequently altering atmospheres is problematical for lithological discrimination. The capacity to perform spectral mapping or spectral stratigraphy(Prost,1994) can assist field mapping by using a mixture of spectral reflectance (colour), brightness and erosional texture associated with lithologies. Many systems, e.g. the industry standard ERDAS Imagine image processing software enable the user to link the satellite image view to Google Earth which is beginning to offer true colour Earth views at 2.5 - 0.65cm pixels. Thus the use of dual PC monitors offers a formidable opportunity for reconnaissance mapping. Landsat 8 bandwidths are similar to the earlier Landsat 5 and 7 with just a few exceptions (Band 1 – coastal aerosols, Band 9- Cirrus). This has resulted in some possible confusion as Landsat 7 ETM Band 1 is now Landsat 8 OLI Band 2 etc. A comparison and equivalence of Landsat 5, 7 and 8 bands is shown in Figure 1. The images below have made use of techniques developed for Landsat 5 and 7 Imagery.

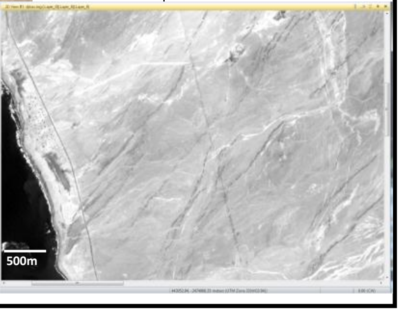
Landsat 8 is radiometrically more sensitive than earlier platforms. The spectral signal is measured and presented across a much greater range. Earlier imagery were 8 bit giving 256 distinct values from the ground. Landsat 8 data are quantised to 12-bits before transmission and are mapped to 16-bits for Level 1T data products giving 65,536 distinct values. Theoretically, subtle variations in geological spectra might be detected. This remains to be tested in practice and the gain in sensitivity maybe offset by the spatial resolution which remains at 30 metres. Additionally, the web accessibility of the data, regular database updates (for Namibia most scenes are added on a monthly basis), and the overall quality of the data (radiometric sensitivity, cloud cover etc.) offers great potential. Landsat 7 ETM data suffered a data devaluation (May 31, 2003) when the onboard Scan Line Corrector (SLC) in the ETM instrument failed. The net effect is that 22% of the data in a Landsat 7 scene is missing when acquired without an operational SLC. Gap masks are available to correct some SLC-off images.

**Thus for explorationists wanting to use Landsat satellite imagery they should be pointed to the use of Landsat 7ETM SLC on ( 1999-2003) and Landsat 8 OLI.**




**Google Earth Screen Grab.**
***Image date 24/10/2013***
**True colour view from altitude of 8.53Km.**

**Landsat 8 OLI**
***Path/Row 180/075 2014086 (March 27 2014)***
**Independent Component 6 Correlation: Skewness: Kurtosis**

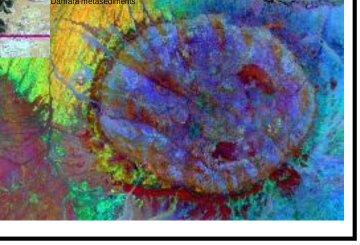


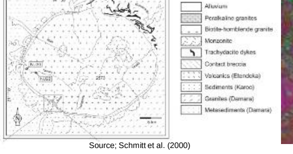

The earliest remote sensing of Namibia geology by Lord et al., (1996) used Landsat MSS to map the Lower Cretaceous regional dyke swarm across the central zone of the Damara orogen north east of Walvis Bay. Despite the relatively low spatial resolution (80m pixel) they were able to map 414 linear dykes. Landsat 8 OLI multispectral imagery is better resolution (30m pixel) with the Pan band (15m pixel). In this arid environment crossed by anastomosing fluvial splays the dark dolerite dykes should stand out on most imagery. The Google Earth (GE) screen grab (SPOT 2.5m pixel) does not pick out the dykes as well as the Landsat 8 image which has been processed* to enhance the prominent scene feature of the dykes. ERDAS Imagine allows users to link GE views to the processed layer under analysis. In this case zooming into GE pyramids shows a DigitalGlobe image at 1.84m pixel where the dykes appear more visible

**The ERDAS image shows a greyscale of Independent Component Analysis (ICA) Band 6. This is a feature extraction process ideal for this type of scene. ICA performs a linear transformation of the spectral bands such that the resulting components are decorrelated and independent. Each independent component (IC) will contain information corresponding to a specific feature in the original image. In this case the asymmetry and peakedness of the reflectance histogram has been emphasised to pick out the black lines (dykes).*


**Landsat 8 OLI**
***Path/Row 180/075 2014086 (March 27 2014)***
**True Colour Composite 432**

**Landsat 8 OLI**
***Path/Row 180/075 2014086 ( March 27 2014)***
**Band Ratio Colour Composite 7/6 6/5 4/2**
**- Gad and Kusky 2006**

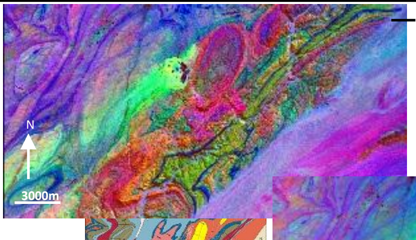



Source; Schmitt et al. (2000)

The Brandberg Massif is a Cretaceous igneous complex (one of c.20) emplaced into a late Precambrian basement. The complex outcrops with a nearly circular body of granite 23km in diameter, which forms a prominent mountain some 2000m above the peneplain. It is surrounded by a ring of low hills formed by Damaran granites and metasediments covered by Karoo group volcanic rocks. Numerous sill and dykes of peralkaline granite cut the massif and adjacent country rocks. The desert landscape combined with highly defined structure and distinctive lithologies make for an ideal Spectral Mapping target. The upper image is a true colour composite and displays the topography and structure very well. Some spectral discrimination of the lithology is possible.

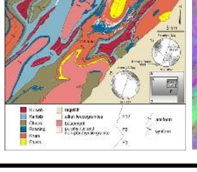
The lower band ratio colour composite based on Gad and Kusky (2006) provides a spectacular image. Numerous lithologies can be discerned and are an almost perfect fit to Schmitt et al (2000) map. The image and georeferenced Schmitt's map was examined in ArcMap with the Effect slider to make the comparison. The comparison is stark when examined on screen. The band ratio composite 7/5, 5/4, 3/1 of Gad and Kusky (2006) was converted to the equivalent Landsat 8 7/6,6/5,4/2 for this image.



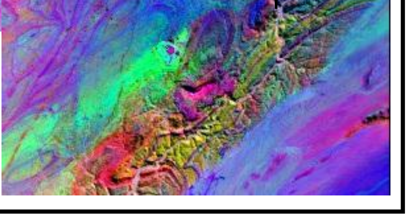

**Landsat 7 ETM**
***Path/Row 179/076 2002 166 (June 15 2002)***

**Principal Component Analysis 432**

**Landsat 8 OLI**
***Path/Row 179/076 2014 175***
***(June 24 2014)***
**Principal Component Analysis 432**



Geological map source : http://www.mining-technology.com/contractors/project/tect-geological/tect-geological4.html

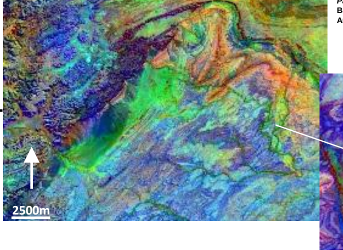


Both images are Principal Components 432.

Principal components analysis – (PCA) is often used as a method of data compression. It allows redundant data to be compacted into fewer bands - that is, the dimensionality of the data is reduced. The bands of PCA data are non-correlated and independent, and are often more interpretable than the source data (Jensen 1986).

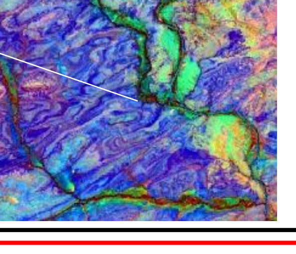
In this example one might expect the Landsat 8 OLI – the newer dataset to be better. In reality the same processing on a Landsat 7 ETM image reveals more and better spectral mapping potential. This demonstrates the scene dependent nature of image processing. The availability of large, easily accessed datasets enable spectral mappers to derive images of value from a substantial pool. Newer is not always better!
An assessment of lithological discrimination using this imagery remains to be completed using ground truthing and existing maps. On visual inspection identification of differing lithologies appears possible. The structural detail is impressive.

Gomez, et al., (2005) used ASTER data for geological mapping on the southern margin of the Damara orogen south of Rehoboth. ASTER data is often preferred by geologists for mineral prospecting because of the 14 available bands (VNIR , SWIR, TIR) . Some of the ASTER bands were designed to enhance separation of lithologies (Bands 10-14 - quantised to 12 bits). Gomez et al., (2005) performed a Principal Component Analysis and Supervised Classification of VNIR and SWIR data. They reported that this afforded a powerful tool for geological mapping and allowed the validation and revision of lithological boundaries on published geological maps as well as providing new information on previously unrecognised surficial formations. Some ASTER data is free for educational purposes but subject to restrictions otherwise (https://lpdaac.usgs.gov/products/aster_policies) and SWIR is not available post 2008.Using Landsat OLI data and the band ratios published in Amer, et al., (2010) exceptional results have been produced in the area of Gomez's study area. The image is a band ratio colour composite that is typically used by geologists for lithological mapping. In this case the composite is derived from an ASTER recipe (4/7, 4/1, 2/3*4/3) quoted by Abdeen et al., (2001) for mapping a complex of ophiolites, metasediment, volcaniclastics and granitoids in Egypt. Here the recipe appears to spectrally separate clastics, carbonates and surficial sands, gravels and calcretes as well as highlighting some spectacular structures in the Mulden Group in the south eastern portion of the image.




**Landsat 8 OLI**
***Path/Row 178/077 2014168 ( June 17 2014)***
**Band Ratio Colour Composite 6/7, 6/3, 4/5*6/5**
**Area is 70Km SW of Rehoboth.**

Enlargement



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## Conclusions.

1. Landsat 8 OLI data is freely available without restrictions on use. The easy to use portal (GLOVIS- http://glovis.usgs.gov/) is providing Level 1 T – Terrain corrected GeoTiff. WGS 84 datum. 1 Gb. compressed size. Figure 2.
2. New design pushbroom sensors and higher bit quantisation on Landsat 8 produces images of quality and high radiometric sensitivity which may help resolve geology with additional processing.
3. Band ratios, Principal and Independent Component analyses can deliver high quality spectrally discriminating images that can be used to validate existing maps or utilised for exploration.
4. Preliminary work here, without recourse to comparative geological data, suggests from visual inspection that Landsat 8 OLI data deserves more research investment for geological mapping and exploration in Namibia.
5. Currently available software (e.g. ERDAS Imagine) allows users to dynamically link screen imagery with Google Earth promoting additional interpretation advantages. For band ratios/PCA processing the industry standard software is required. Free software for viewing processed images is available e.g. ERDAS Viewfinder 2.1