Geological Outcrop Modelling and Interpretation Using Ground Based Hyperspectral and Laser Scanning Data Fusion

Tobias H. Kurz[1], Simon J. Buckley[1], John A. Howell[1], Danilo Schneider[2]

[1]Centre for Integrated Petroleum Research, University of Bergen, Norway
[2]Institute of Photogrammetry and Remote Sensing, Technische Universität Dresden, Germany

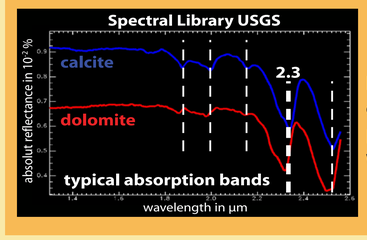
tobias.kurz@cipr.uib.no

Ground based lidar has become a widely used method for the capture of geological data and the creation of 3D virtual outcrops, useful for understanding hydrocarbon reservoirs and aquifers. Many lidar systems are equipped with a digital camera and afford the creation of photo-realistic 3D models. However, the mapping of geology is restricted to the visible light spectrum and is limited in its ability to detect variations in lithology and geophysical properties. The semi-automatic extraction of geological features from the lidar data and the digital images remains a major challenge.

This research uses a new ground based hyperspectral sensor (1.3-2.5 µm) and lidar to improve and automate the generation of 3D outcrop models of nearly vertical cliff sections. To carry out the integration, a cylindrical panoramic camera model was used. The method has been tested on carboniferous limestone in the Peak District (UK) to map and quantify dolomitization.

Limestone - Dolomite

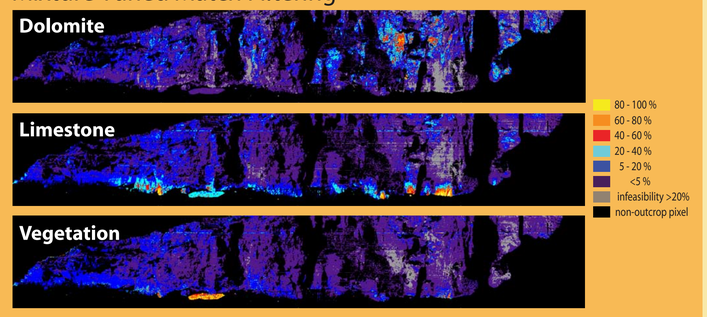
Dolomitization increasing the porosity of limestone and can improve the flow properties in reservoirs and aquifers significantly.



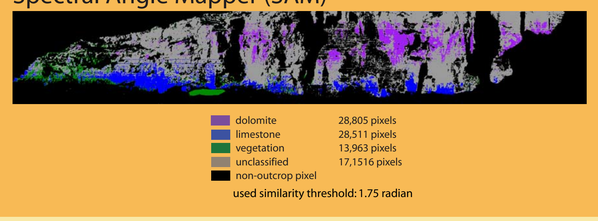
Higher amounts of magnesium cause a slight shifting of the 2.3 µm absorption band to lower wavelegths.

Spectral Mapping

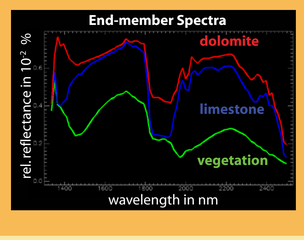
Mixture Tuned Match Filtering



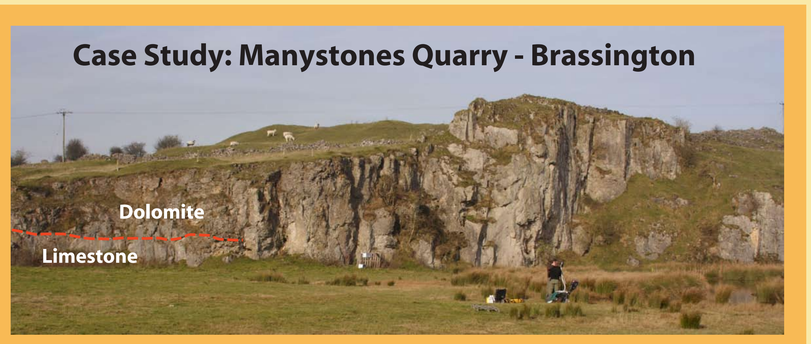
Spectral Angle Mapper (SAM)



End-member collection based on pure pixel indices

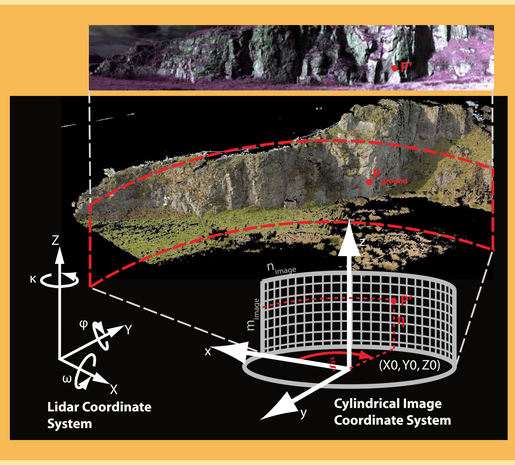


Case Study: Manystones Quarry - Brassington



- Dolomitization of Dinantian carbonates at late Carboniferous or Permian time.
- Two stages of dolomitization, second stage with significant Fe and Mn.
- No pure dolomite.

Data Fusion



- Linear array based cylindrical panoramic camera model.
- Bundle adjustment using GCPs to calculate the sensor orientation and position and additional camera parameters for camera self-calibration.
- Coloring and texturing of the lidar point cloud using collinearity condition for cylindric projection

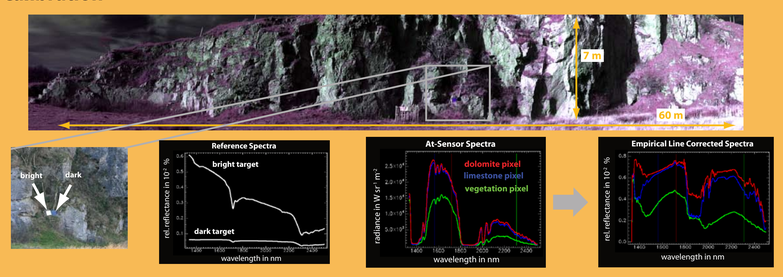
Parameters of HySpex^{R} SWIR-320

(Norsk Elektro Optikk AS)

• Detector	MCT (HgCdTe)
• Spectral range:	1.3 - 2.5 µm
• Spectral sampling:	5 nm
• Spectral bands:	240
• Spatial pixels:	320
• FOV across track:	14°
• Pixel field of view	0.75 mrad
• Digitisation:	14 bit

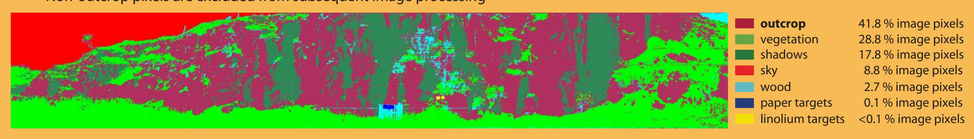
Spectral Data Processing

1. Image calibration



2. Maximum Likelihood Classification (accuracy 98.98 %)

- Non-outcrop pixels are excluded from subsequent image processing



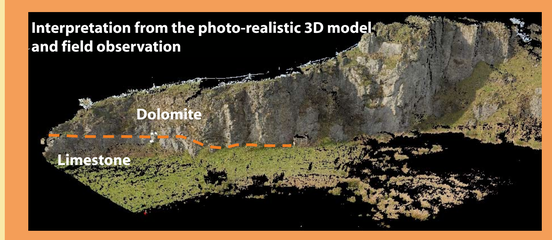
outcrop	41.8 % image pixels
vegetation	28.8 % image pixels
shadows	17.8 % image pixels
sky	8.8 % image pixels
wood	2.7 % image pixels
paper targets	0.1 % image pixels
linolium targets	<0.1 % image pixels

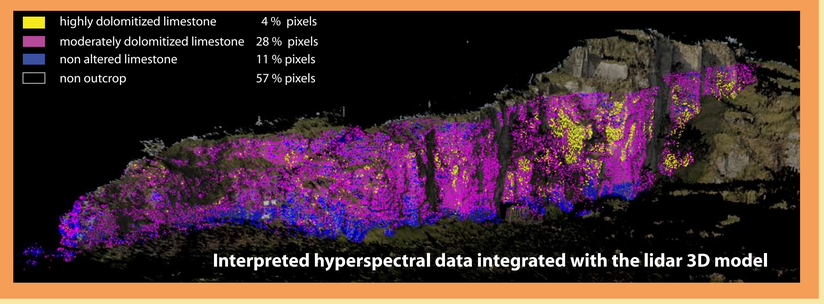
3. Main Noise Fraction Transform (MNF)

- First 10 components have noise removed

Result

As the spectral data show, the alteration of the upper portion to dolomite is not uniform and is incomplete. Residual patches of limestone prevail and the degree of dolomitization varies. The spectral images allow quantification of the spatial distribution of dolomitization. Variations in dolomitization are interpreted to result from differences in diagenetic fluid pathways.





Conclusions

This paper has demonstrated the application of a ground based hyperspectral sensor for the study of geological outcrops. Integration of the hyperspectral imagery with detailed lidar geometry, using the panoramic camera model, allows the classification results to be projected into 3D space to make more quantitative analysis.

Further development and testing of the system will follow. This will include:

i. **Calibration of the Manystones Quarry case study results with spot sampling and XRF.**
ii. **Further testing on a second limestone-dolomite outcrop.**
iii. **Testing the system on outcrops with different mineralogical characteristics, i.e. moving beyond carbonates.**

• This project is funded by the Norwegian Research Council and StatoilHydro through the Petromaks program.
• Thanks to Ivar Baarstad and Trond Løke from Norsk Elektro Optikk AS for technical support and instruction in scanner handling.
• Thanks to Peter Gutteridge for acting as a field guide for the dolomite outcrops in the Peak District.