Lidar Intensity as a Remote Sensor of Rock Properties*

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Search and Discovery Article #40618 (2010)
Posted October 22, 2010

*Adapted from oral presentation at AAPG Rocky Mountain Section 58th Annual Rocky Mountain Rendezvous, Durango, Colorado, June 13-16, 2010

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Abstract

Terrestrial lidar (light detection and ranging) has become a popular tool for outcrop investigation and modeling. Lidar units can collect a spatially accurate ‘cloud’ of points approximating the shape of the outcrops surface. In addition to providing detailed spatial data, lidar scanners record the intensity: the power of the backscattered signal relative to the power of the emitted signal. Intensity has been used as a remote sensing and surface classification tool in archeology, forestry, glaciology, volcanology, urban development, and other fields of study. However, lidar-based outcrop studies have largely ignored intensity data, focusing primarily on x, y, and z information. Experiments were conducted to test the relationship between lidar intensity and clastic lithology by scanning core of the Sego Sandstone from the Book Cliffs of Utah. Intensity shows a good log-linear correlation to shale (r= -.84) and sand (r= .88) weight percent. This relationship can be used on outcrop to estimate v-shale, net-to-gross, and even simulate gamma-ray logs in relatively unweathered outcrops.

Selected References

Hofle, B. and N. Pfeifer, 2007, Correction of laser scanning intensity data: Data and model-driven approaches: ISPRS Journal of Photogrammetry & Remote Sensing, v. 62, p. 415-433.

Lutz, E.R., in preparation, Investigations of Airborne Laser Scanning Signal Intensity on Glacial Surfaces – Utilizing Comprehensive Laser Geometry Modelling and Orthophoto Surface Modelling, A Case Study: Svartisheibreen, Norway: M.S. Thesis, Institute of Geography, University of Innsbruck, Austria.

Mazzarini, F., M.T. Pareschi, M. Favalli, I. Isola, S. Tarquini, and E. Boschi, 2007, Lava flow identification and aging by means of Lidar intensity: Mount Etna case, Journal of Geophysical Research, v. 112/B2, p. B02201, doi:10.1029/2005JB004166.

Pfeifer, N. and C. Briese, 2007, Geometrical Aspects of Airborne Laser Scanning and Terrestrial Laser Scanning, IAPRS Volume XXXVI, Part 3/ W52.

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Lidar intensity as a remote sensor of rock properties

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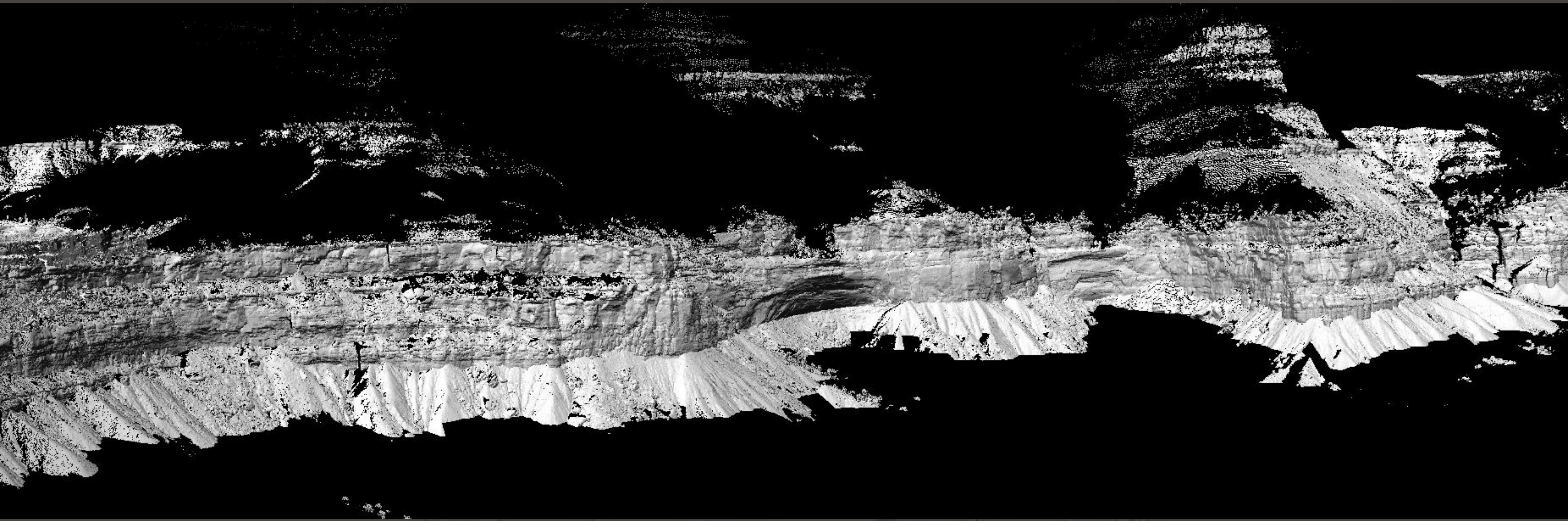
Digital outcrop models

QCLIA



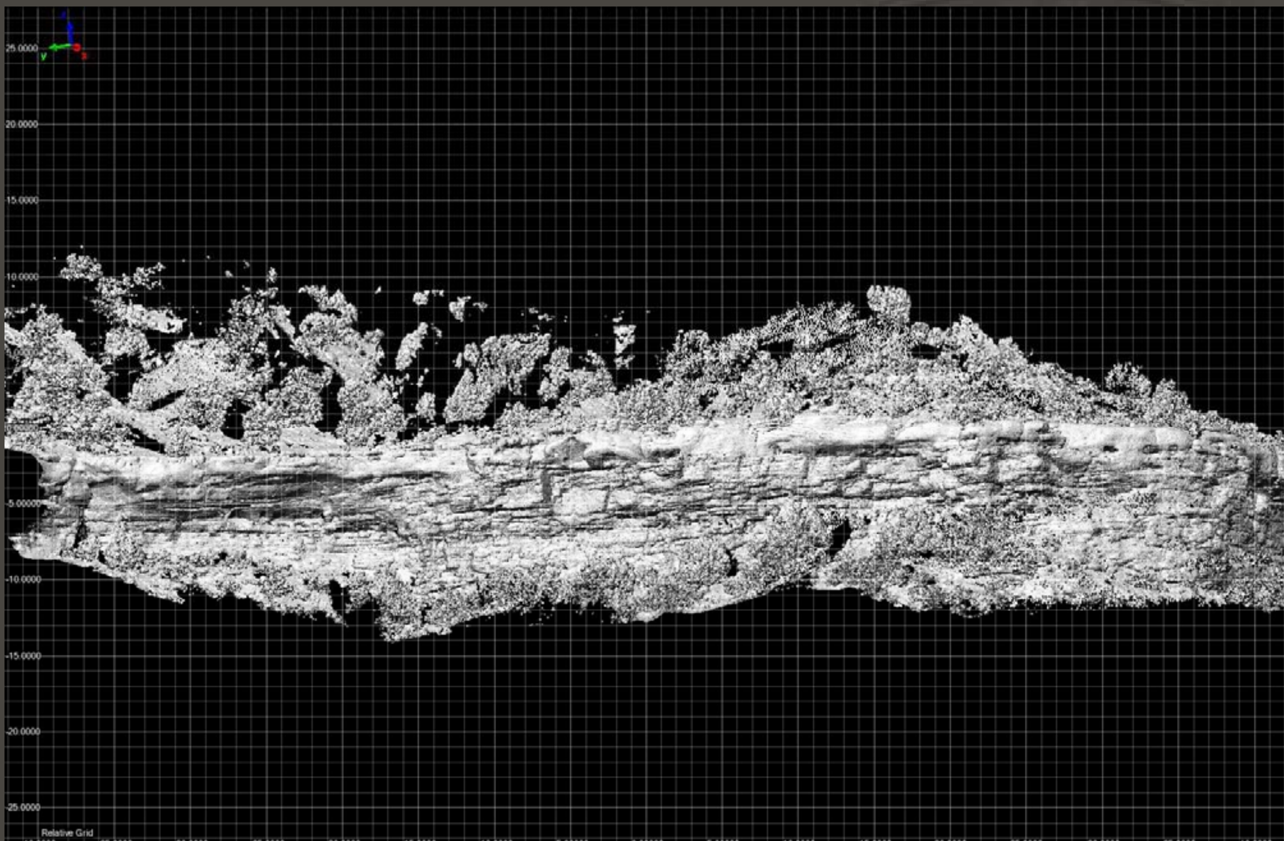
High resolution, 3D outcrop data.

Study outcrops at a variety of scales and viewing angles.

Quantify and spatially referenced geometries.

Improves reproducibility of results.

Digital outcrop models



In addition to spatial data, lidar units also collect intensity.

Intensity is rarely used in geologic investigations.

Outline

QCLIA

What is intensity?

What controls intensity?

Intensity & rock properties

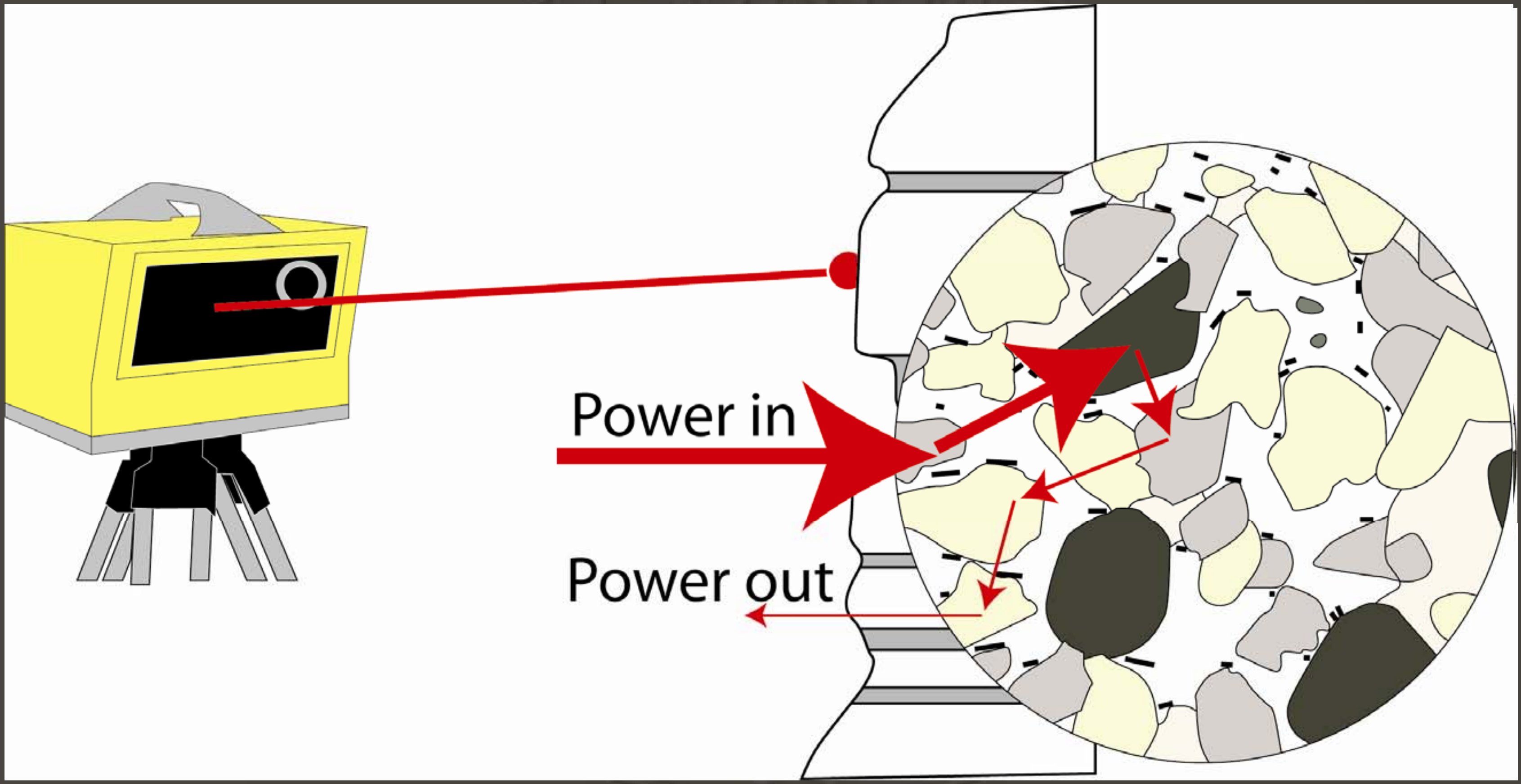
Limitations

Applications

Conclusions

What is intensity?

QCLIA



Intensity is the ratio of the power of reflected light to power of emitted light.

What controls intensity?

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Lidar equation:
(Pfeifer et al, 2007)

$$i = \rho \cos(\alpha) \; / \; r^2 \eta_{sys} C$$

i=intensity

ρ=target reflectivity

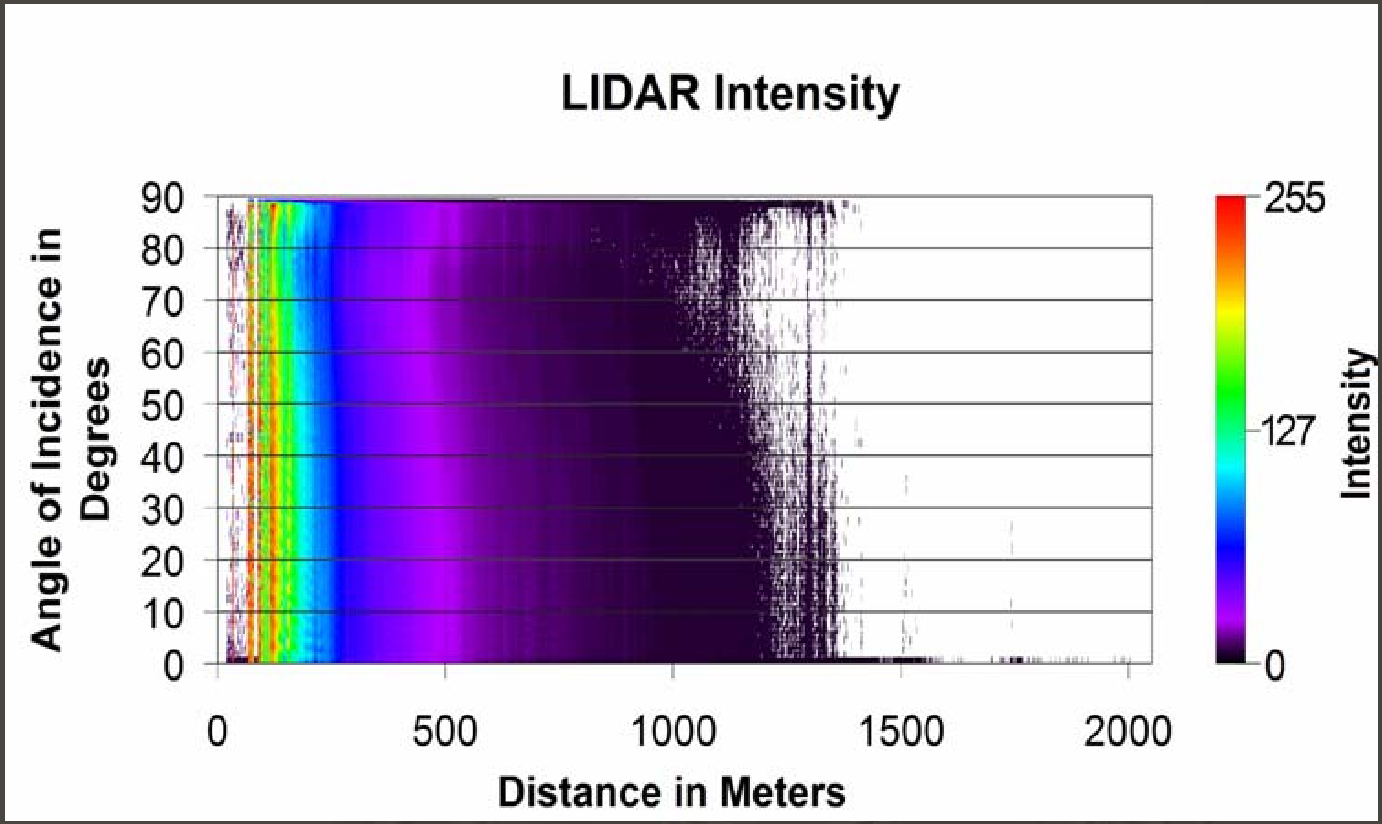
α=angle of incidence

r=range to target

η_{sys}=transmission factor

C=unknown constant

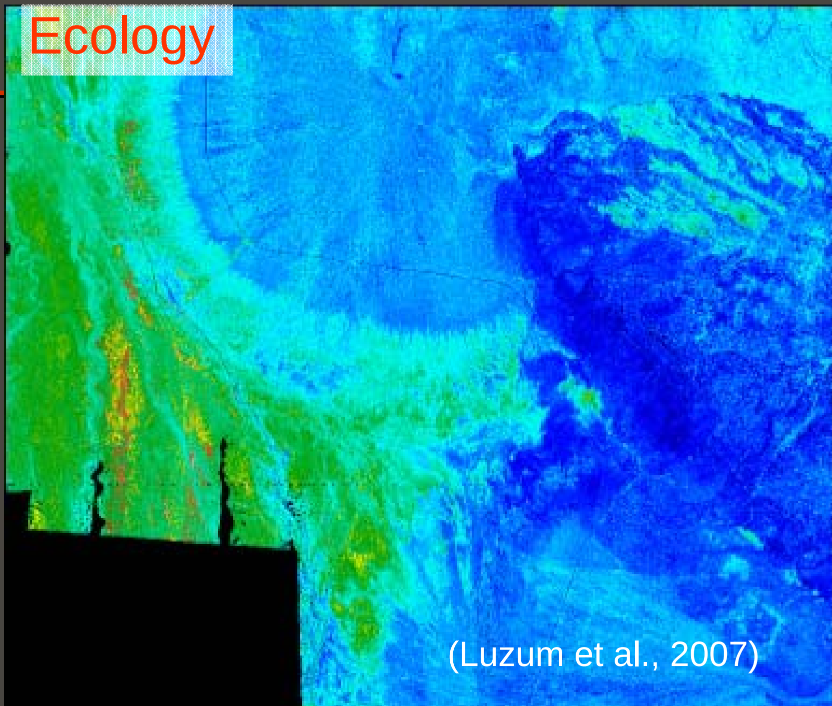
Principal controls

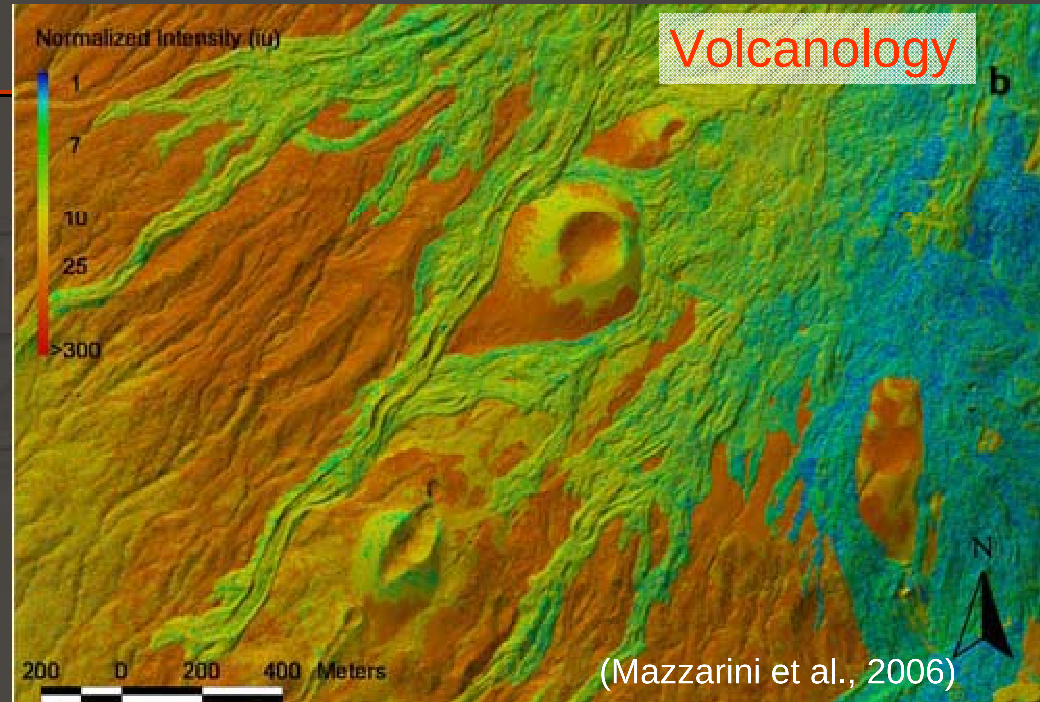


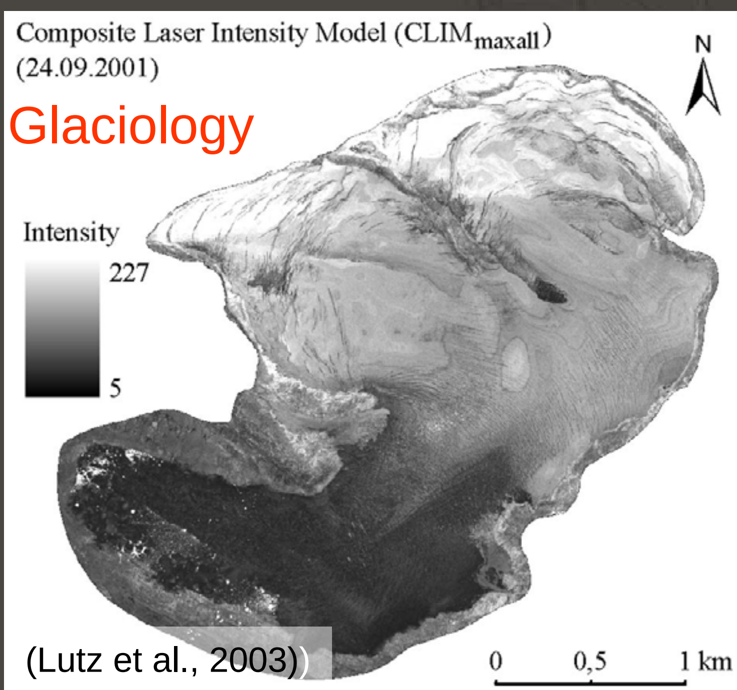
Distance has the biggest impact on intensity and correction can be made for it.

Angle of incidence plays a minor role when imaging natural surfaces.

Corrected intensity is proportional to target reflectivity.

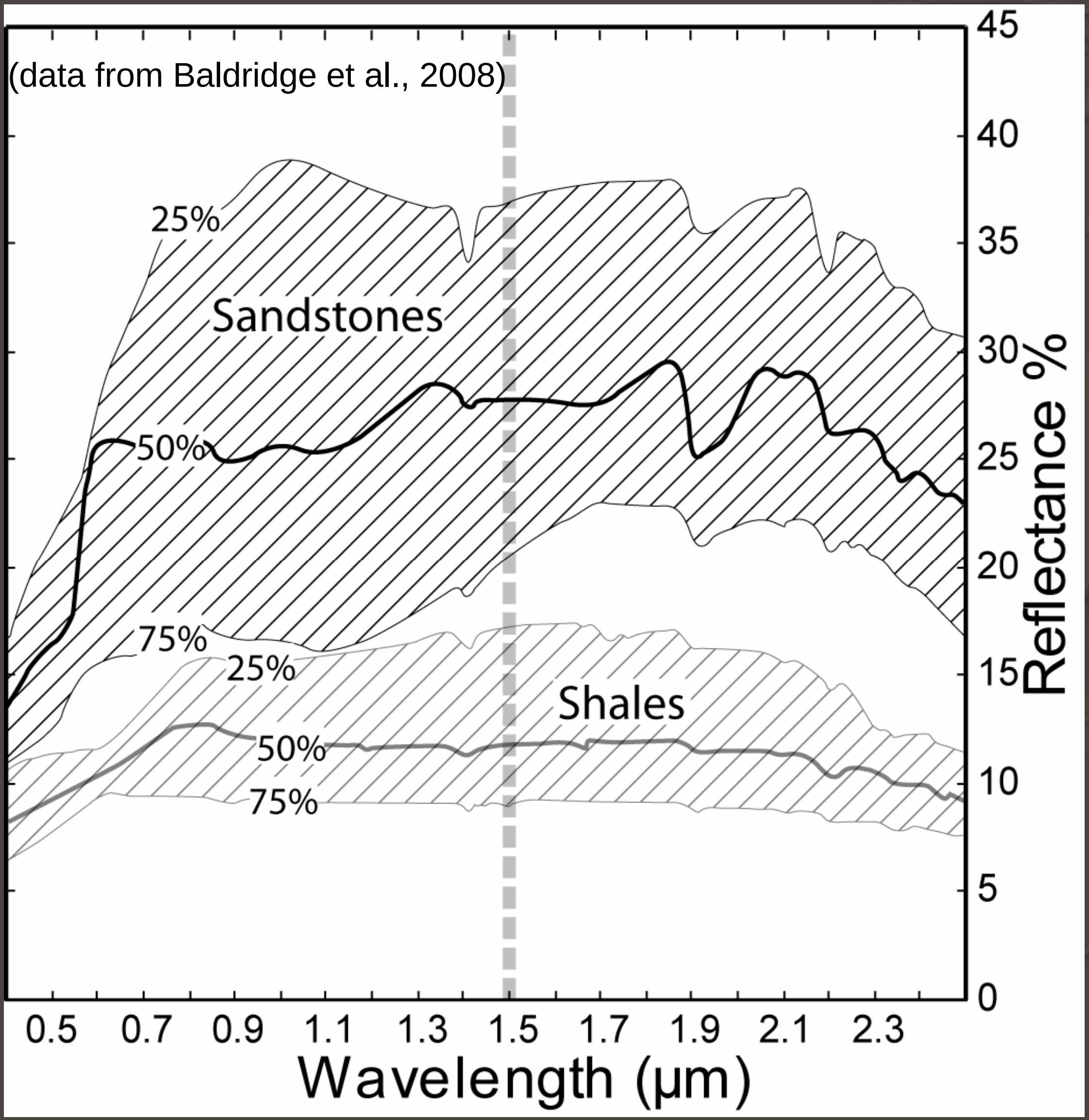

Ecology
(Luzum et al., 2007)


Volcanology
Normalized Intensity (iu)
1
7
10
25
>300
b
N
200 0 200 400 Meters
(Mazzarini et al., 2006)


Composite Laser Intensity Model (CLIMmaxall)
(24.09.2001)
N
Glaciology
Intensity
227
5
0 0,5 1 km
(Lutz et al., 2003)


(b)
Land use
(Hofle & Pfeifer, 2007)

Spectral properties of clastic rocks



Hypotheses

- **The intensity quantity is strictly related to the reflective properties of rocks.**

- **Lithologies with different reflective properties can be differentiated and mapped using intensity.**

Experiment- Sego Canyon 2 core

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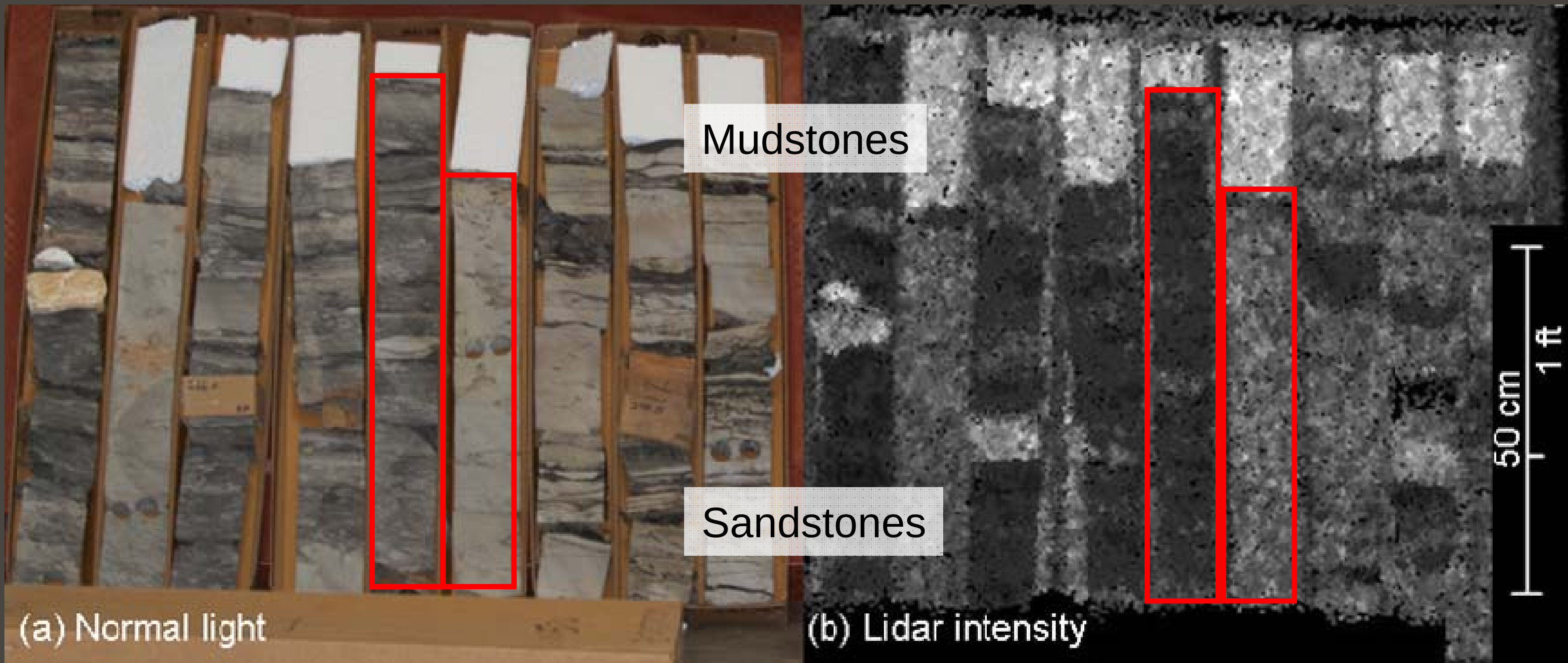
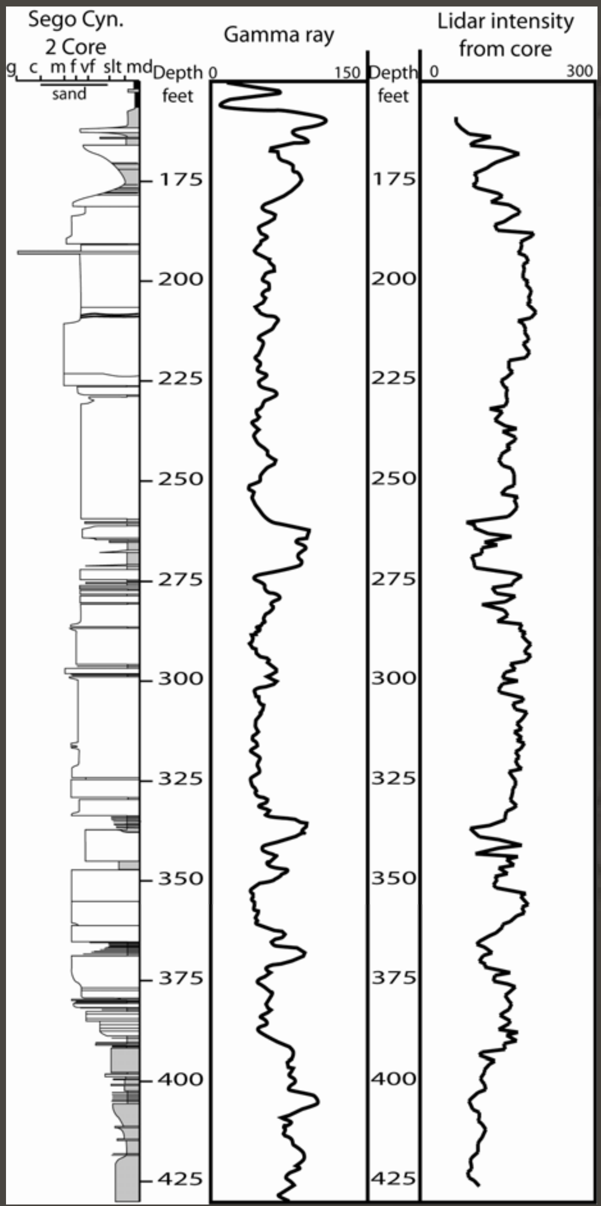
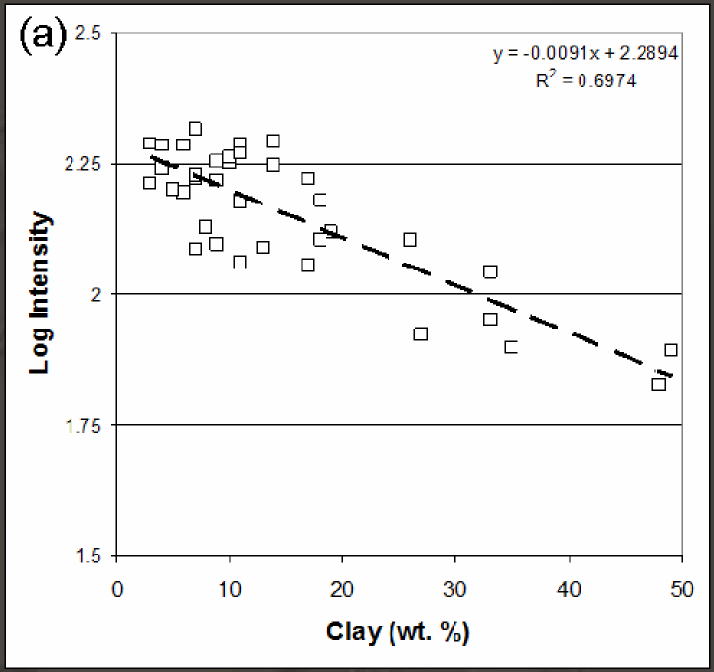


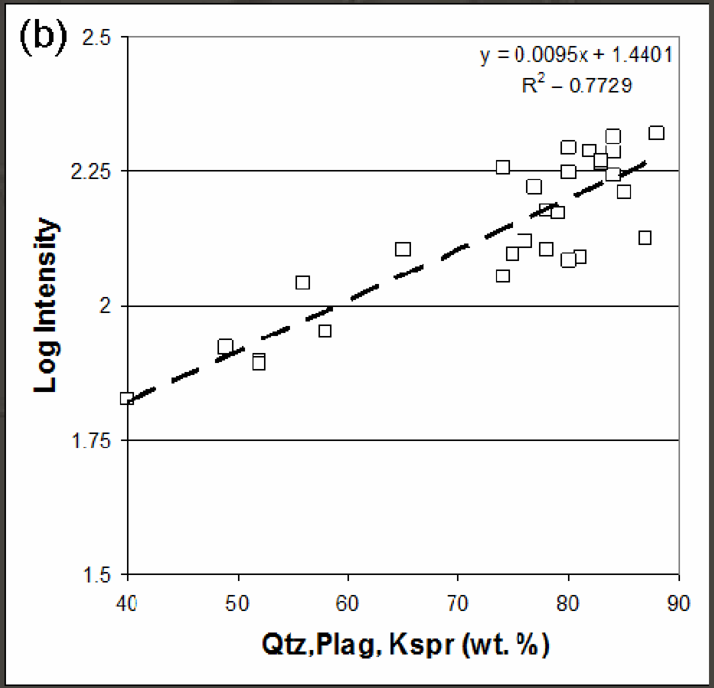
Intensity images of core confirm that sandstones are more reflective than mudstone.

Results





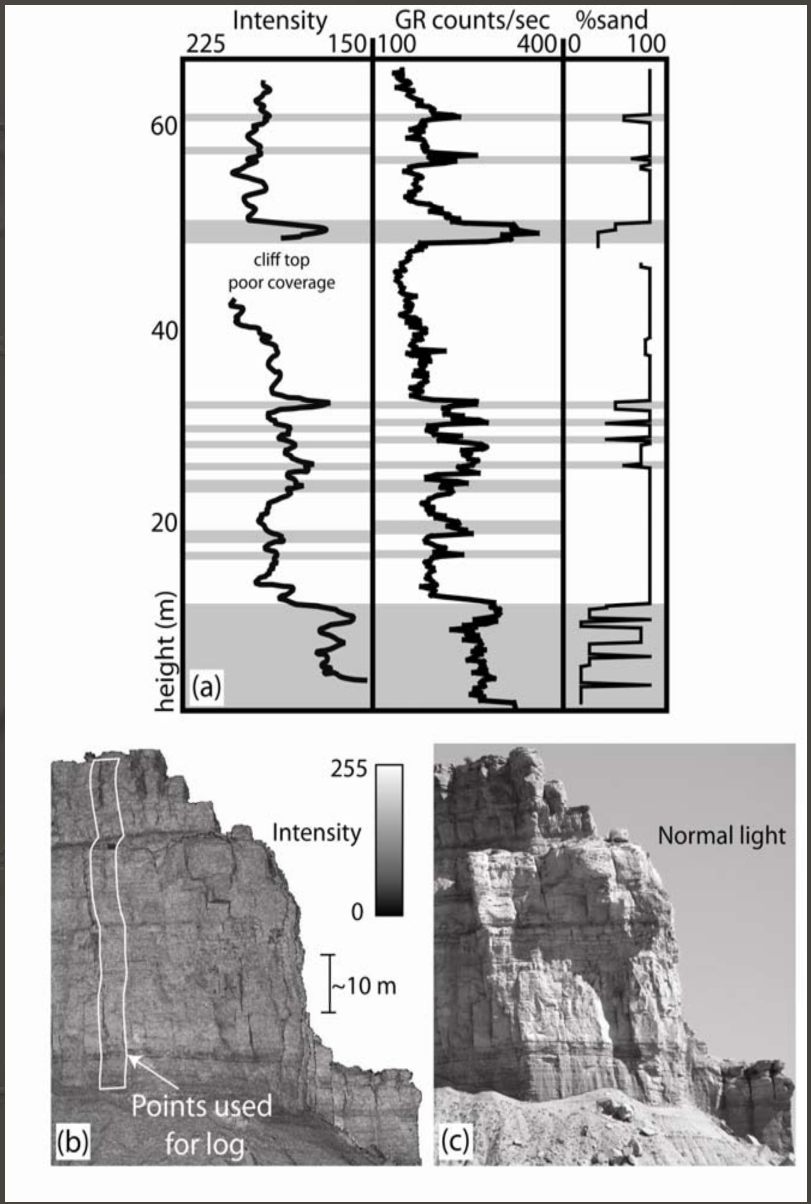
Shale



Sand

Sego Sandstone Outcrop

QCLIA



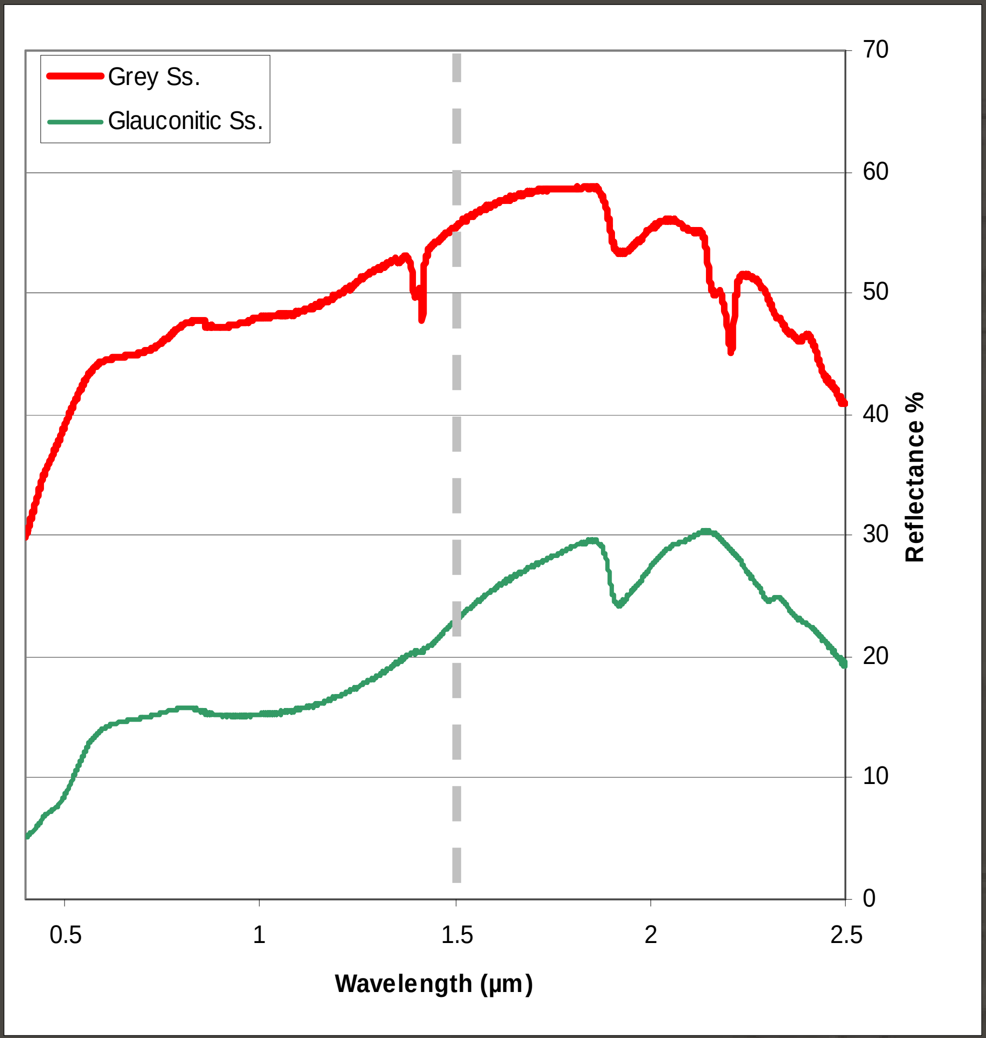
Lower Sego

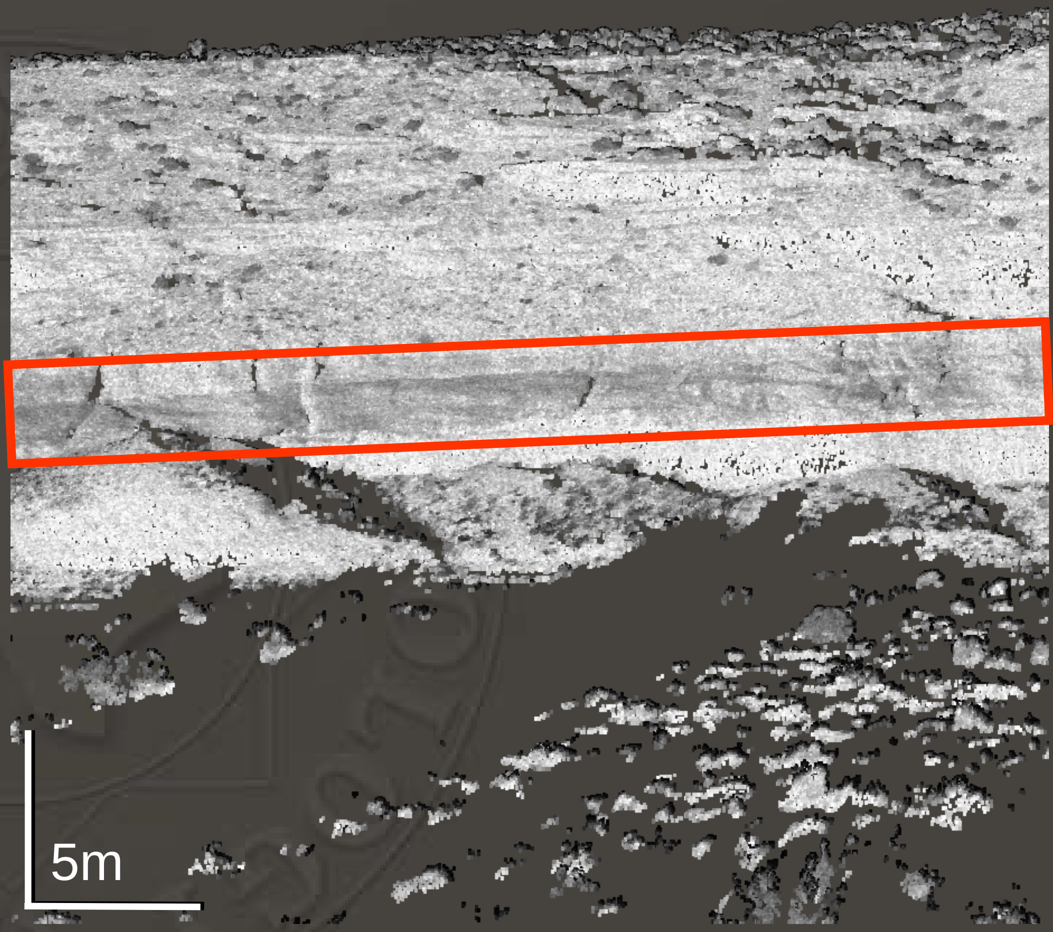
- Relatively unweathered
- Good correlation between lithology and intensity

Upper Sego

- Highly weathered
- Poor correlation between lithology and intensity

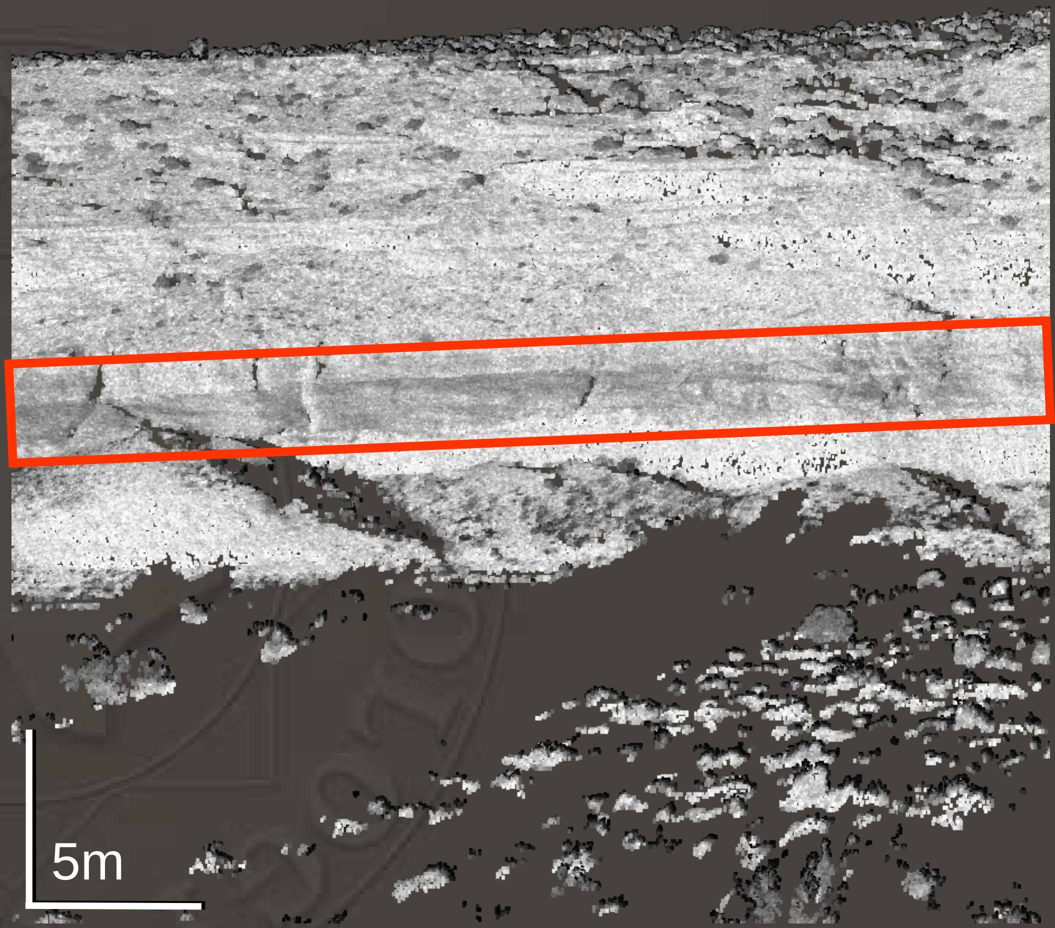
Glauconitic Sandstone





Glauconitic sandstones reflect less light than typical quartz-rich sandstones

Glauconitic Sandstone



Intensity is capable of imaging significant variation in sandstone composition. Example-Lower Tocito Sandstone

Coaly Stratigraphy

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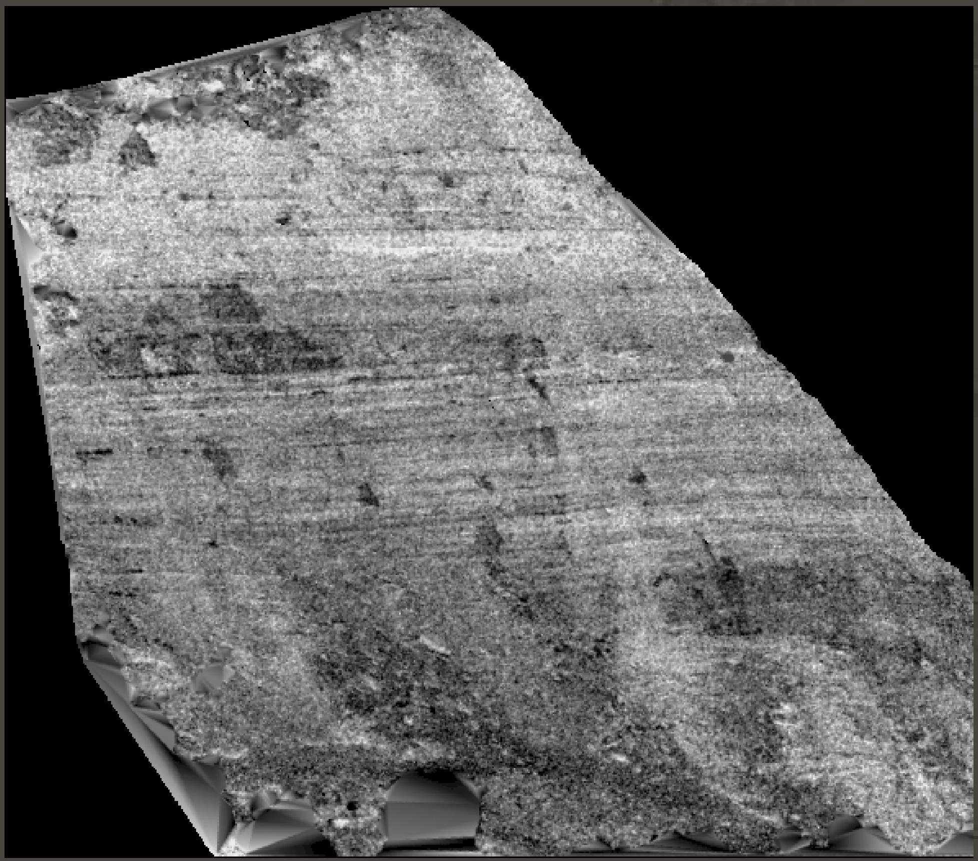
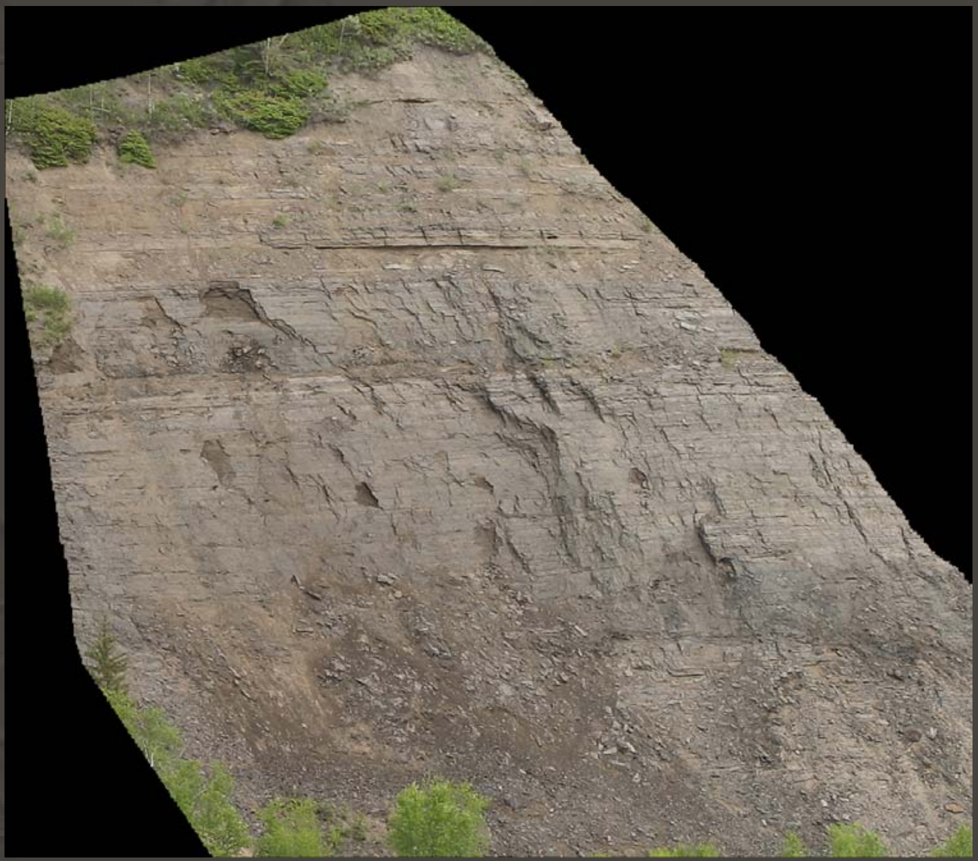
Intensity is also sensitive to variations in organic material.

Captures subtle stratigraphy in coal seams.

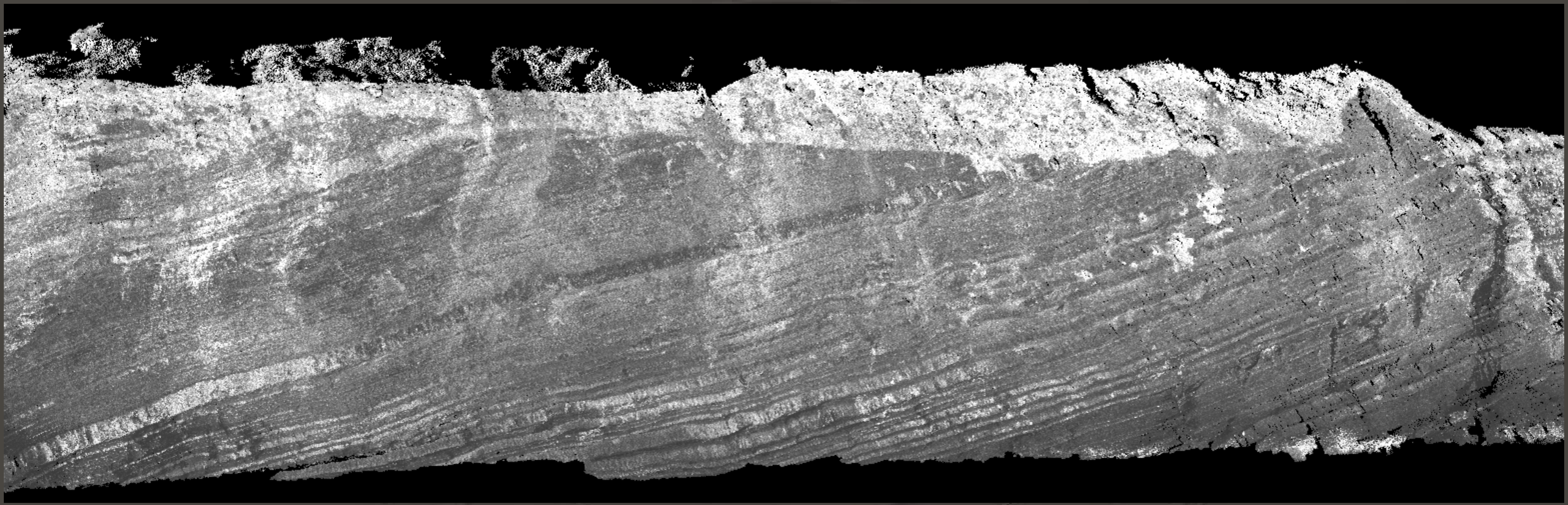
Tar Sand Stratigraphy

Variations in stratigraphy are more apparent in intensity image than in photos.





Limitations



Weathering
Moisture
Vegetation

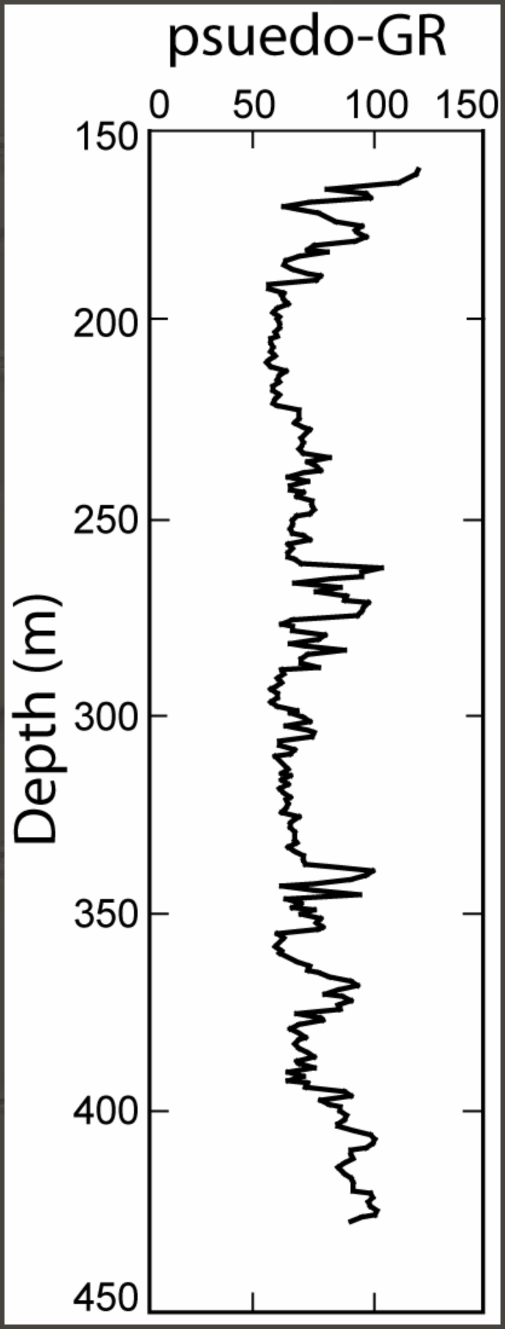
Intensity data is most likely to be useful where *physical weathering* dominates.

Applications

Pseudo-GR from outcrop

Map stratigraphy in inaccessible outcrop (shale, coal, bitumen)

Quantitative estimates of sand / shale volumes



Conclusions

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Lidar quickly collects accurate spatial and spectral data.

Corrected intensities are proportional to target reflectivity at the laser wavelength.

In unweathered outcrops, intensity is an effective remote sensor of rock properties.

Intensity images can be used to map lithology in inaccessible outcrops.

Acknowledgements

This work is supported by the member companies of the Quantitative Clastics Laboratory Industrial Associates.

Special thanks to Reuben Reyes for programming intensity correction