Lidar Intensity as a Remote Sensor of Rock Properties*

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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


Lidar intensity as a remote sensor of rock properties

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Digital outcrop models

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

What is intensity?

What controls intensity?

Intensity & rock properties

Limitations

Applications

Conclusions
What is intensity?

Intensity is the ratio of the power of reflected light to power of emitted light.
What controls intensity?

Lidar equation:  
(Pfeifer et al, 2007)

\[ i = \frac{\rho \cos(\alpha)}{r^2 \eta_{sys} C} \]

- \( i \) = intensity
- \( \rho \) = target reflectivity
- \( \alpha \) = angle of incidence
- \( r \) = range to target
- \( \eta_{sys} \) = transmission factor
- \( C \) = unknown constant

(Pfeifer et al, 2007)
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

(Mazzarini et al., 2006)

Glaciology

(Lutz et al., 2003)

Land use

(Hofle & Pfeifer, 2007)
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.
Intensity images of core confirm that sandstones are more reflective than mudstone.
### Results

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<th>Depth (ft)</th>
<th>Sego Cyn.</th>
<th>Gamma ray</th>
<th>Lidar Intensity from core</th>
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#### Clay [wt. %] vs. Log Intensity

- 

#### Qtz, Plag, Kspr [wt. %] vs. Log Intensity

- 

#### Graphs

- **Shale**
  - \( y = -0.0091x + 2.2394 \)
  - \( R^2 = 0.6974 \)

- **Sand**
  - \( y = 0.0095x + 1.4401 \)
  - \( R^2 = 0.7729 \)
**Sego Sandstone Outcrop**

**Lower Sego**

Relatively unweathered

Good correlation between lithology and intensity

**Upper Sego**

Highly weathered

Poor correlation between lithology and intensity
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

Intensity is also sensitive to variations in organic material.

Captures subtle stratigraphy in coal seams.
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

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.
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Special thanks to Reuben Reyes for programming intensity correction