LiDAR Project

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Introduction

The Geological Survey Division (GSD) has recognized the importance of Digital Elevation Models (DEMs) as a tool for bedrock, surficial, and geohazard mapping for over 20 years. DEMs traditionally have been used to identify topographic features and drainage systems, but they can also help identify geological structures, lithological units, and surficial features. Stereo photogrammetry was the principal tool to create DEMs but has been replaced by Light Detection and Ranging (LiDAR) technology. LiDAR has advanced significantly over the past 15 years to create high resolution DEMs (1 m or less) with exceptionally clean bare-earth models. Table 1 summarizes some of the DEMs and geoscience products created by the GSD from DEMs over the past 20 years.

The Province of Nova Scotia now has full 1 m resolution LiDAR coverage, achieved by integrating individual surveys acquired over the past 15 years. (NS Data Locator - Elevation Explorer). The detail of the geological features that can be resolved between a 1 m LiDAR DEM and a 20 m DEM is quite remarkable (Figure 13). This positively impacts geological mapping and the next generation of bedrock and surficial maps.

Table 1. DEM and Shaded Relief Image products produced by the GSD over the years.

Product ID	Title	Resolution	Description
DP ME 55 2000 (v1)	Enhanced Digital Elevation Model of Nova Scotia	20 m, stereo photogrammetry plus other data	A 20 m hydrologically correct Digital Elevation Model for Nova Scotia.
DP ME 56 2003 (v1)	Shaded Relief Images of Nova Scotia	25 m from DP ME 55	Images generated with 8 Azimuths (000, 045, 090, 135, 180, 225, 270, 315) at 3 Altitudes (30°, 45°, 60°) and two Z-Factors (5 and 10).
DP ME 455 2010	Shaded Relief Image of the North Mountain Area, Nova Scotia	5 m LiDAR	Azimuth = 315 and Altitude = 45°
DP ME 447 2011	Surficial Geological Data of the Halifax Metropolitan Area	2 m LiDAR	Azimuth = 315°, Altitude = 45° and Z-Factor = 5
DP ME 479 2012	Shaded Relief Images of the Cobequid Highlands Area, Nova Scotia	1 m LiDAR	144 shaded relief images using 8 Azimuths (000, 045, 090, 135, 180, 225, 270, 315) and 3 Altitudes (30°, 45°, 60°) and two Z-Factors (5 and 10).

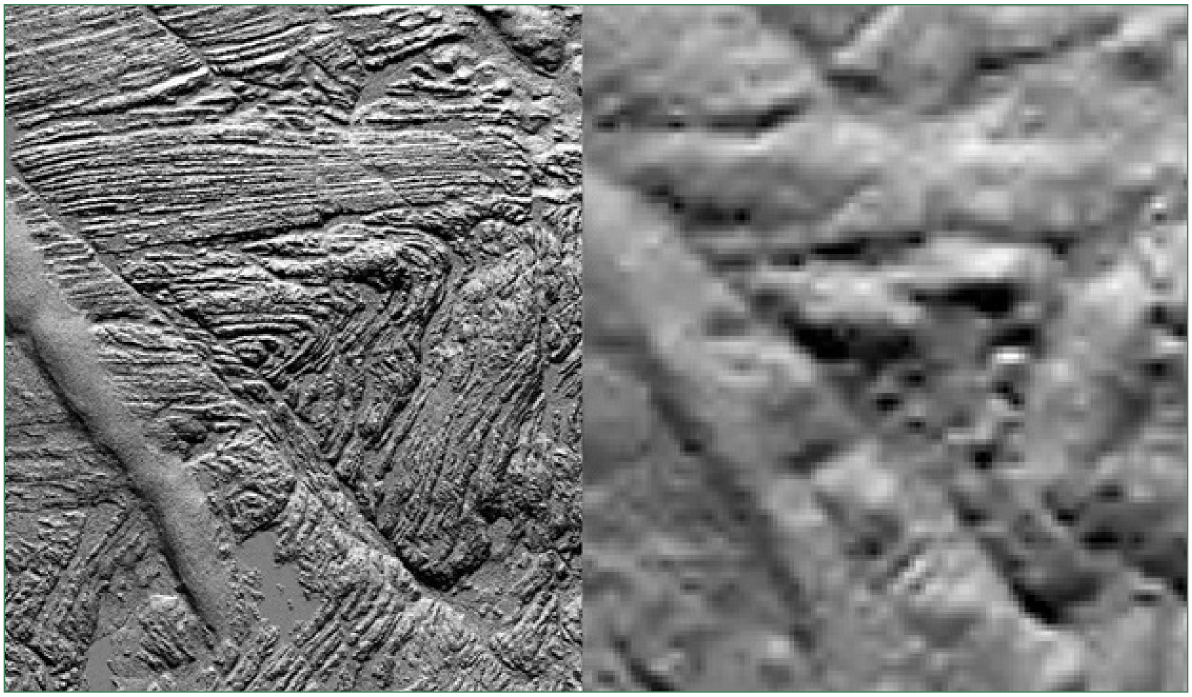

Figure 13. A comparison of a hillshade image derived from a 1 m resolution LiDAR dataset (left) and a 20 m DEM (right). The details of fold structures and faults are far easier to resolve in the left hillshade image derived from the 1 m DEM.

Purpose

The purpose of this project is to make LiDAR DEMs and/or products generated from the DEMs available to staff and clients. This will involve:

1. Reviewing and compiling all LiDAR data for the province, and determining a practical level of detail for regional or project area mapping – current resolutions: 1 m, 2 m, and 5 m.

2. Creating ArcGIS Pro hillshade projects from clipped LiDAR datasets to meet the project needs of staff. This will develop workflows that can be standardized in the future.

3. Applying other raster processing and machine learning tools to extract features from the LiDAR DEMs and create vector features (polygons). Examples include karst and other surficial geology features provincewide.

4. Updating or creating new hillshade image atlases using classic and multidirectional models for the province, and determining the best way to deliver this information, e.g. static downloadable products or web services.

Strategic Relevance

Bedrock and surficial geology maps are fundamental to what the GSD does. Improved maps help us make more informed decisions. For new projects, LiDAR provides staff with advance knowledge of field conditions, enabling more efficient use of time. Many of our legacy geologic maps were created using paper topographic maps. Using high resolution LiDAR, we can more precisely show the size, shape, and location of geological features, and define new features that were not recognized previously (Figure 14).

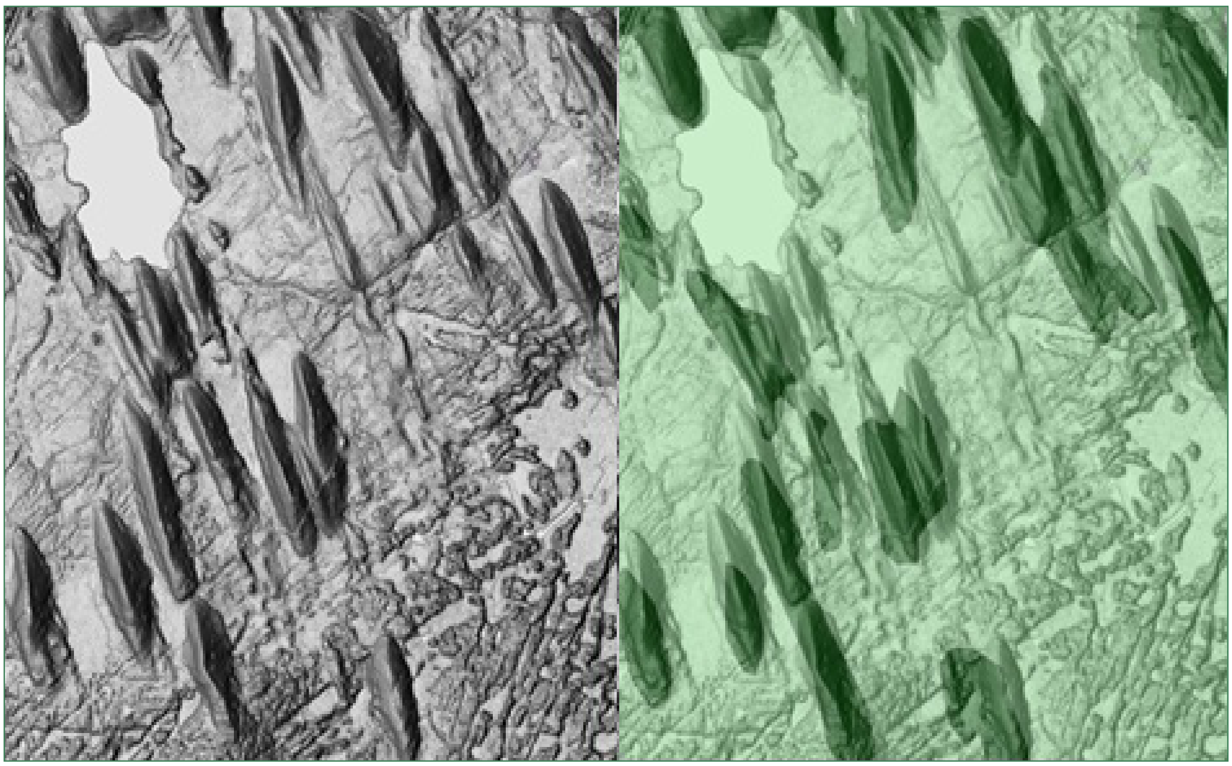

Figure 14. The left image shows a hillshade image of drumlins in southwest Nova Scotia. The right image shows the same area with an overlay of legacy mapped drumlin polygons created from old topographic maps. There is clearly an offset, size discrepancies and missing features. LiDAR can help "fine tune" the shape, size and location of these features.

Methodology and Preliminary Results

Practical case studies using staff geologists' project areas have been conducted by selecting LiDAR surveys and clipping the data to the designated project area. LiDAR survey data can be large and clipping it to smaller project areas can make processing and analysis more efficient. An initial assessment and application of hillshade parameters by GIS staff and one or two revisions in consultation with staff, can create useful results. The parameters that go into this modelling are demonstrated in OFM 2004-001.

Preliminary results indicate that there is a place for products derived from multidirectional hillshade models as well as one directional classical hillshade models depending on the topography and the geology in a study area. Multidirectional hillshade models provide a general unbiased overview of an area. Symmetrical depressed features (e.g. sinkholes) standout using a multidirectional hillshade model (Figure 15). When directional geologic features (e.g. bedding, folds, faults) are known, classical hillshade models oriented orthogonal or at high angles to these features are useful. If folds are suspected, hillshades aligned with fold axes can help highlight hinge zones. Depending on the topography in an area, varying the vertical exaggeration (Z-Factor) can also be useful and using Z-Factors up to 5 or 10 can be valuable. (Figure 16).

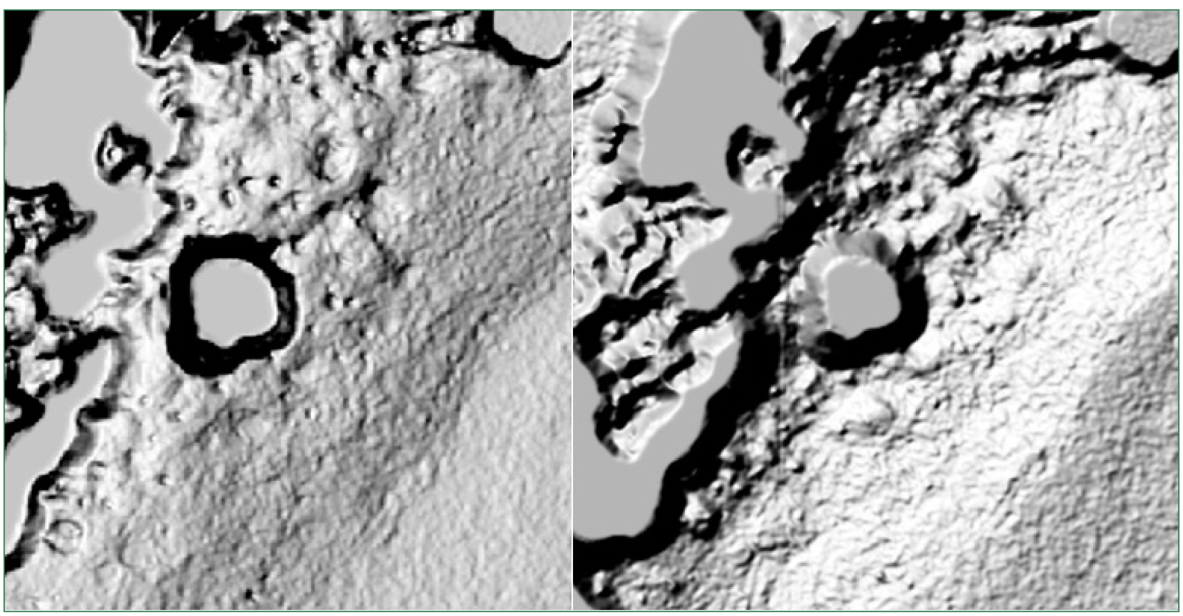

Figure 15. The left image shows a multidirectional hillshade image of sinkholes east of Black Lake in the Oxford area of Nova Scotia. The right image shows the same area with a classical single direction hillshade image (Az 135, Angle 45, Z-Factor 10). The left multidirectional hillshade image results in shadows that follow the inner slope of the sinkhole depression and make it stand out more than the right single directional hillshade image where a shadow is only partially visible in the sinkholes.

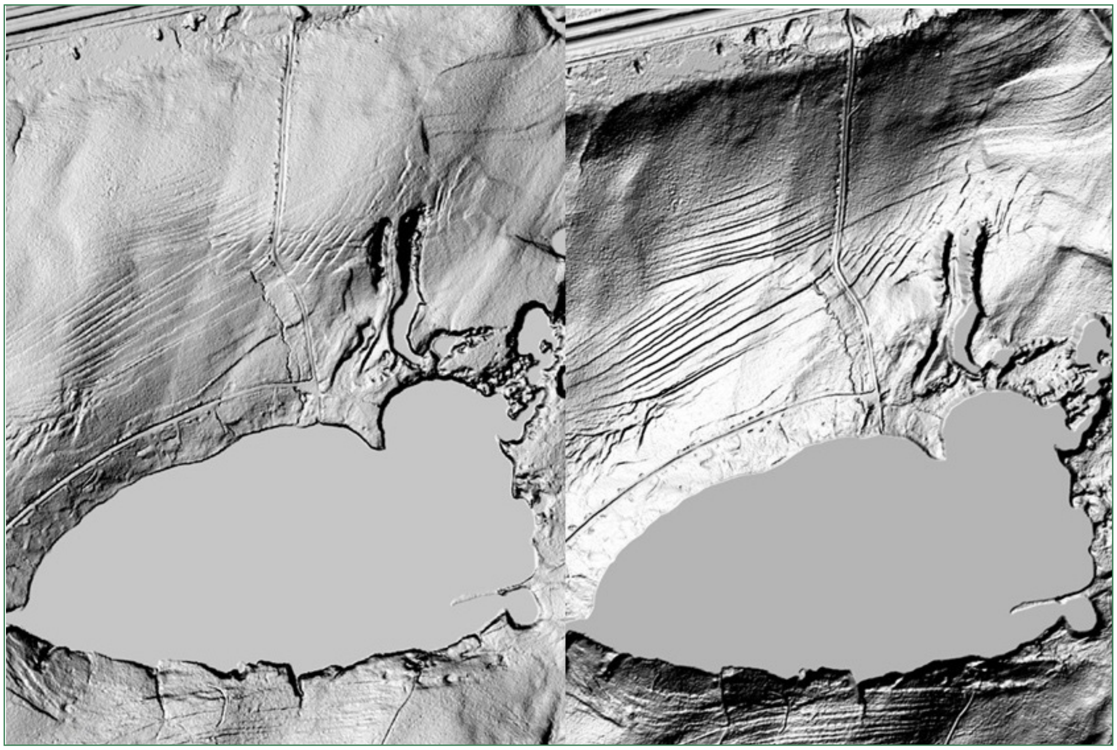

Figure 16. The left image shows a multidirectional hillshade image of the geology north of Black Lake in the Oxford area of Nova Scotia. The right image shows the same area with a single direction classical hillshade image (Az 135, Angle45, Z -Factor 10). The NE- SW trending stratigraphy stands out in the right image with an unconformity clearly visible north of the lake. The stepped nature of the beds is only ~1 m.

Next Steps

The next steps in this project will be to investigate raster processing and machine learning tools to extract features from the LiDAR DEMs and create vector features (polygons). An example would be creating filters and models to automate finding karst topography and sinkholes.

Opportunities will also be explored to make general products from this work available to staff and clients. This includes updating or creating new hillshade image atlases for the province using both classical and multidirectional algorithms. The optimal delivery method (e.g. static downloadable products or web services) will need to be determined, as the large file sizes of high resolution 1 m LiDAR products, compared to older 25 m products, present a significant challenge.

References

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