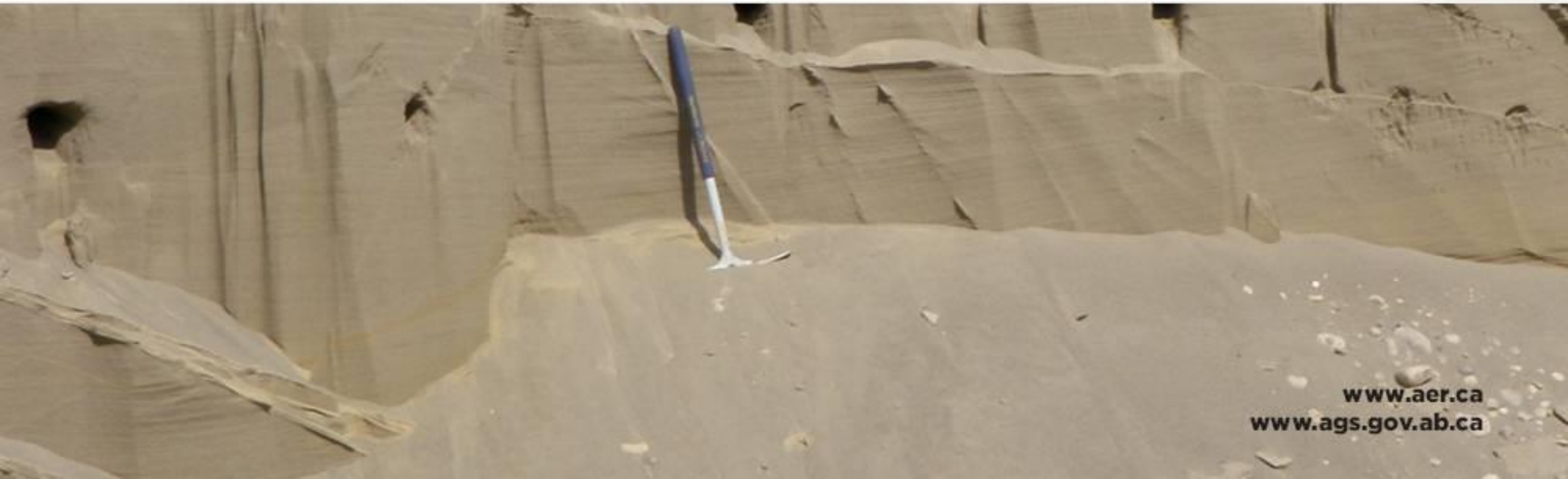
Applications of LiDAR and High-Resolution Earth Imaging for Quaternary Mapping: Opportunities and Challenges

Nigel Atkinson and Steven Pawley

Alberta Energy Regulator

AGS ALBERTA GEOLOGICAL SURVEY



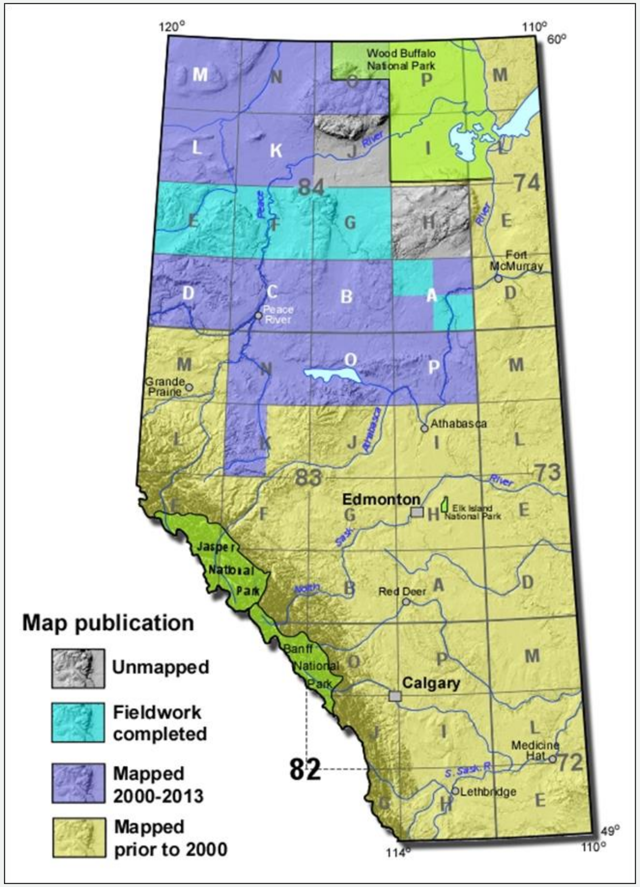
www.aer.ca
www.ags.gov.ab.ca

Outline

- Surficial mapping in northern Alberta
  - Traditional approach
  - Problems
- New approaches and benefits
  - LiDAR-based mapping
  - Mapping technology
  - New LiDAR-based maps
- Applications and future work

Surficial Mapping

- Initiated in 2000–2001
- Geological engineering
- Geohazard susceptibility (landslide, thermokarst distribution)
- Industrial mineral exploration
- Environmental assessment
- Depth to bedrock
- Hydrogeological modelling and groundwater protection

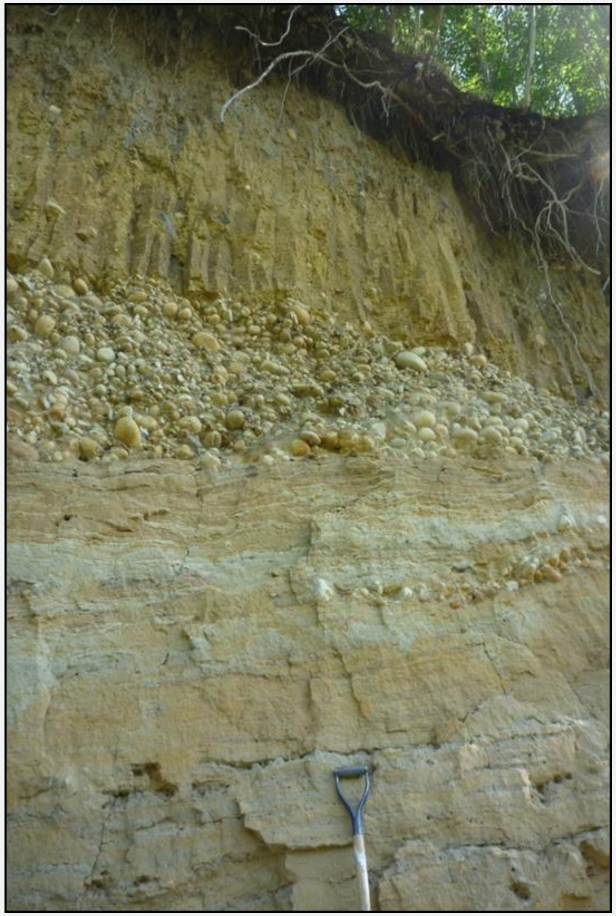


Previous Methodologies

- Ground survey/field mapping with topographic map data (>1970s)

Field Mapping

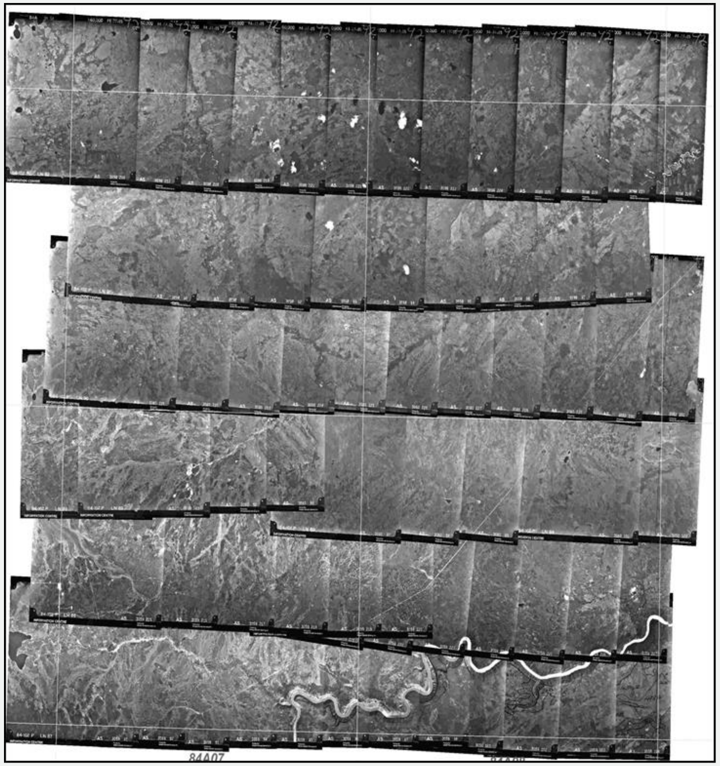
Locating Stratigraphic Sections

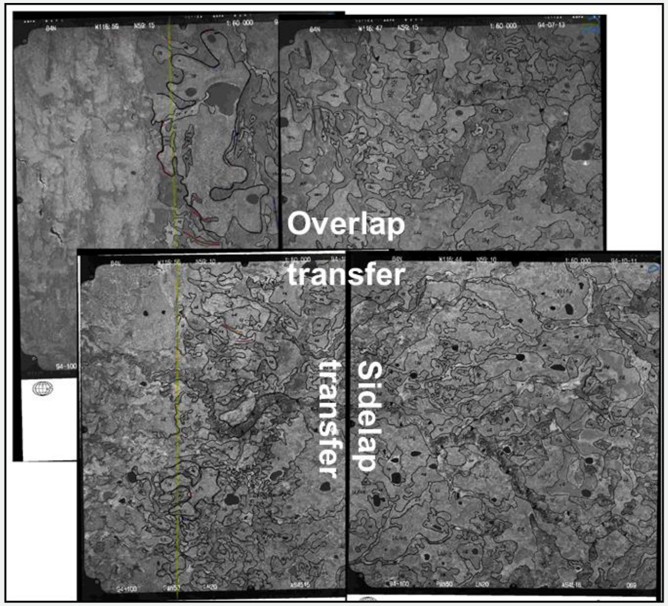


Previous Methodologies

- Ground survey/field mapping with topographic map data (>1970s)
- Stereoscopic airphoto interpretation (>1970s)

Airphoto Interpretation





- Inaccuracies
- Multiple editing stages
- Resources

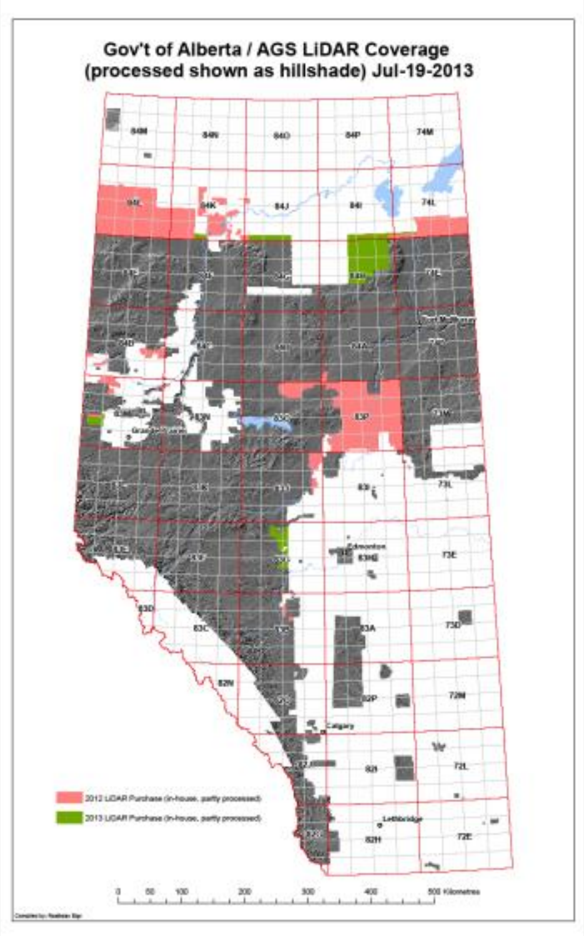
Previous Methodologies

- Ground survey/field mapping with topographic map data (>1970s)
- Stereoscopic airphoto interpretation (>1970s)
- DEMs and multi-layer GIS analysis (>2000)

Terrain Challenges

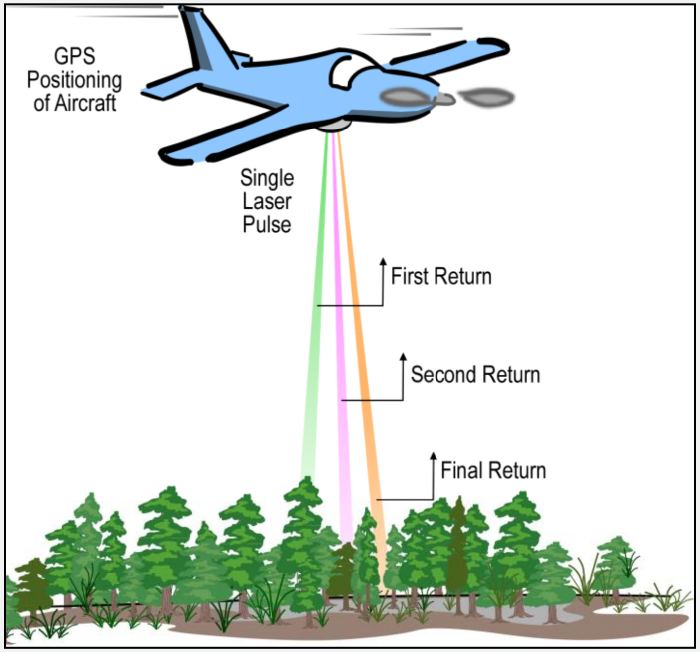
How can a geological map of the upper 1–2 metres be produced with reasonable accuracy in this terrain?

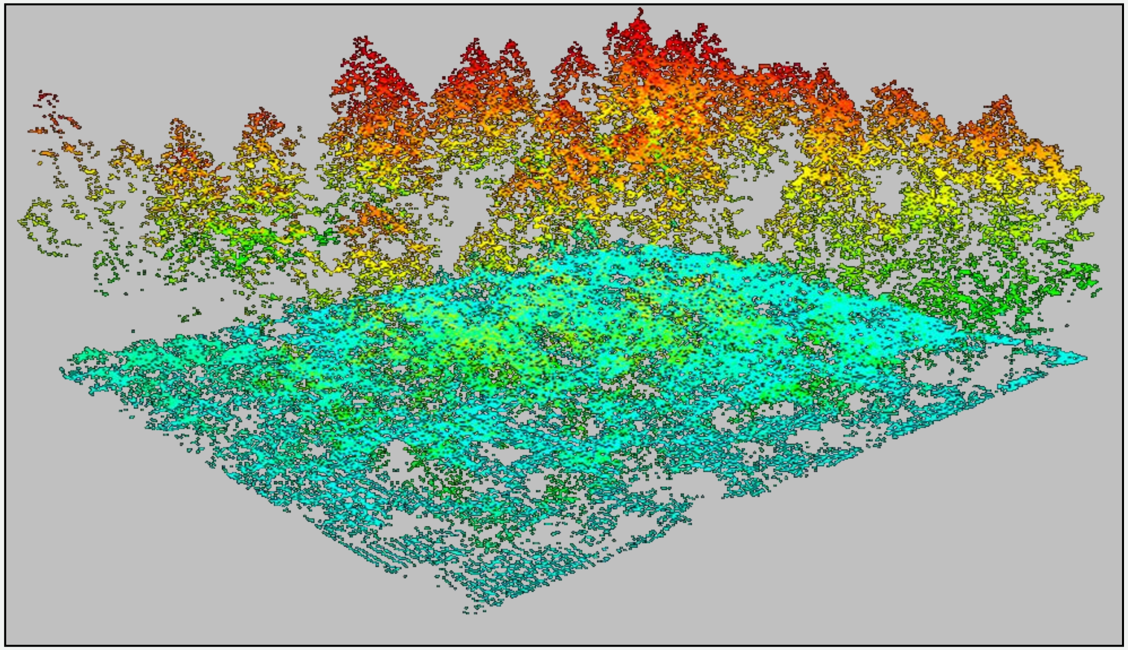
LiDAR Resources



- Highly accurate digital surface/elevation models
- Initially commissioned (ESRD) for forestry and pine beetle management
- Numerous subsequent applications with rapid expansion of coverage into northern regions

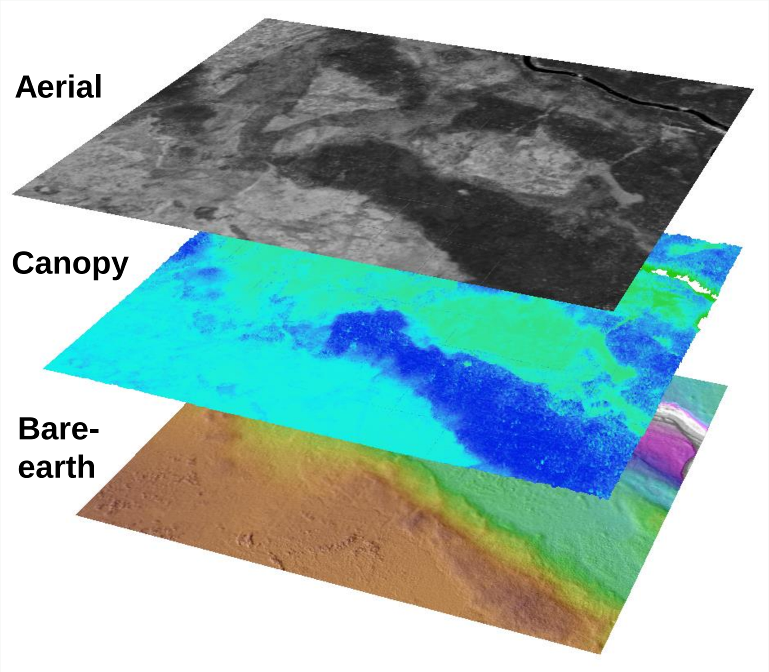
LiDAR Resources



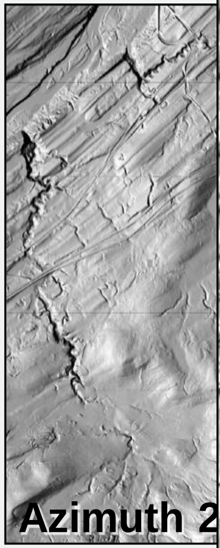


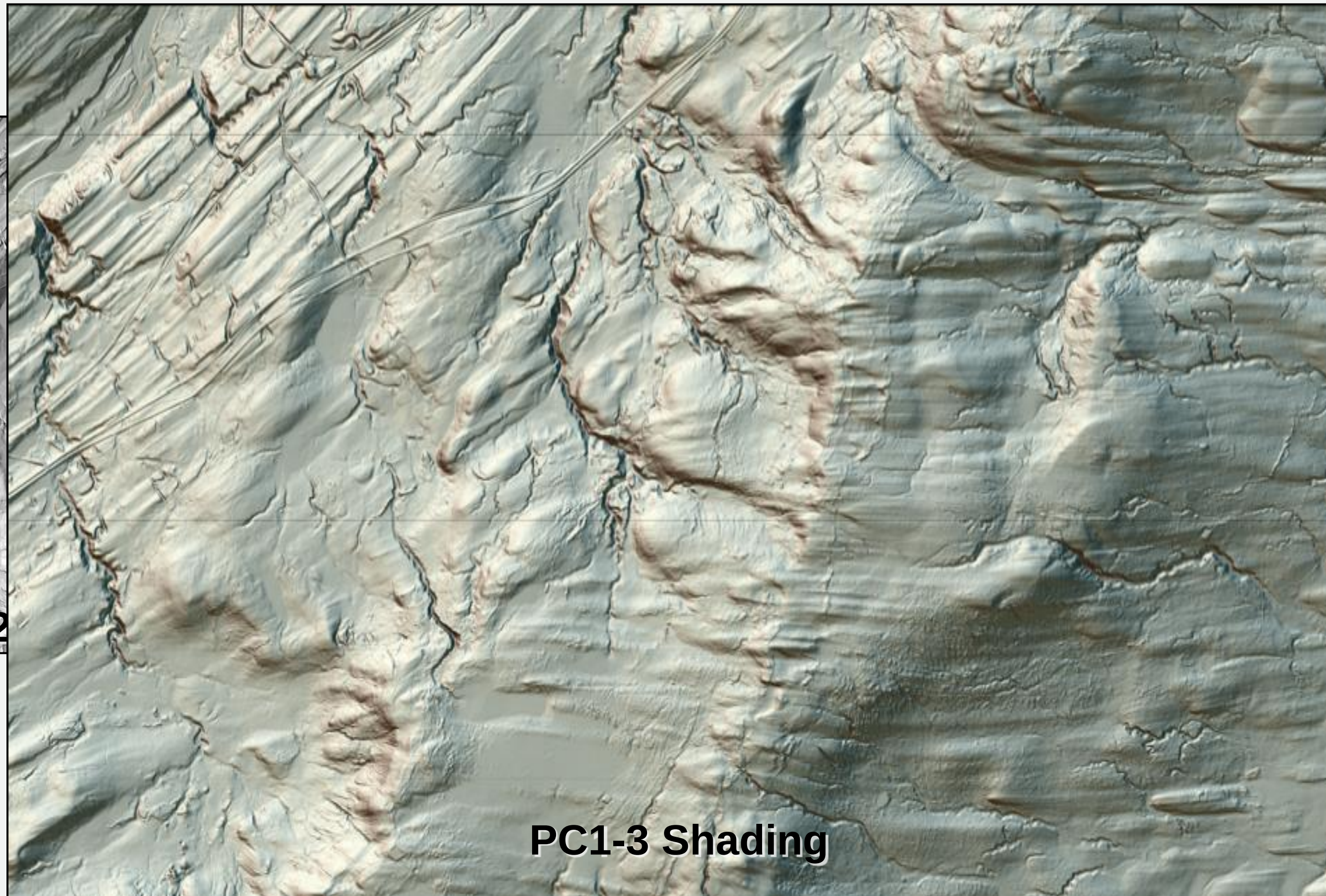
LiDAR Resources

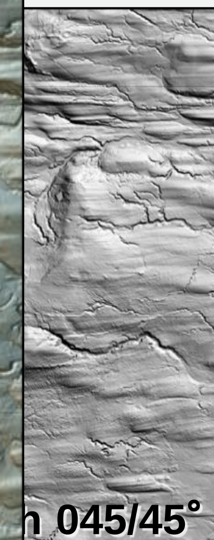
- Eliminates ‘vegetation problem’
- High-resolution imaging of landforms and terrain textures
- Conventional relief-shading and derivatives



Bare-Earth DEM – Relief-Shading



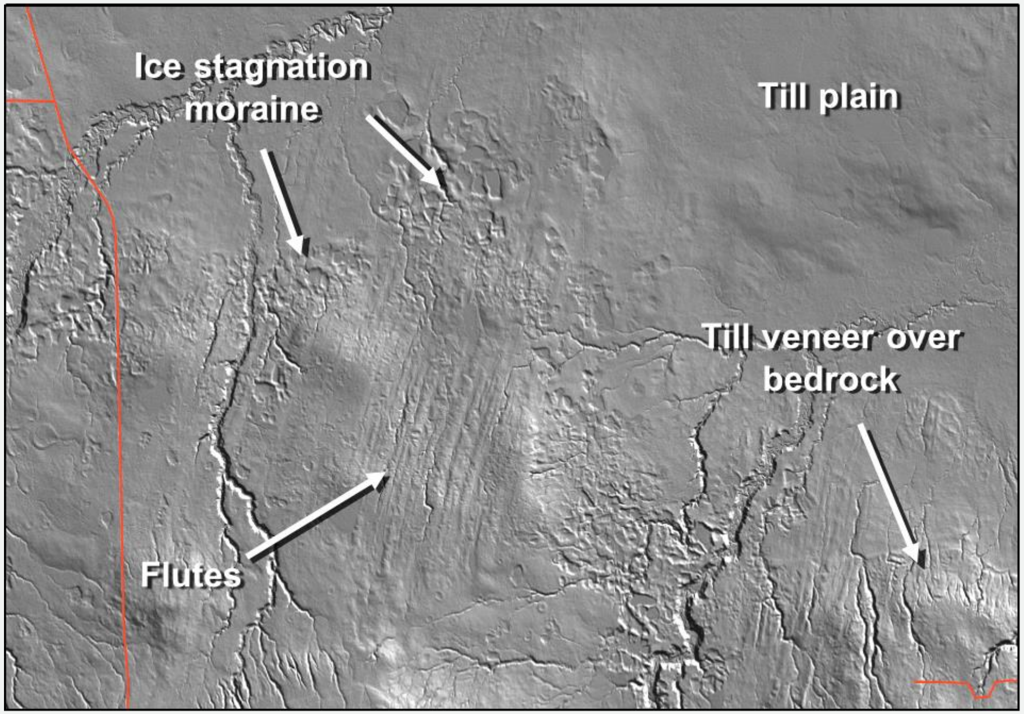




LiDAR-Based Regional Mapping

- High-resolution imagery reveals a detailed record of landforms that were previously unrecognizable

LiDAR-Based Regional Mapping

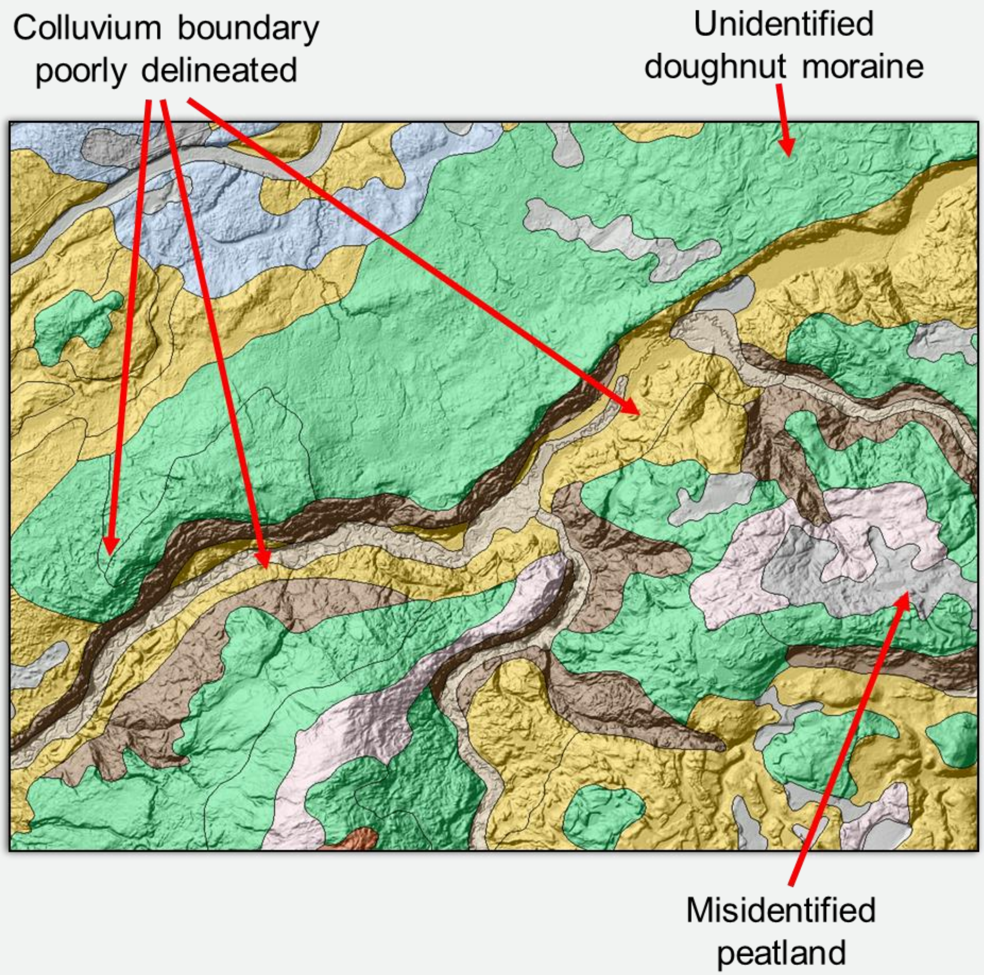


LiDAR-Based Regional Mapping

However…

- LiDAR reveals a number of mapping errors based on traditional methods

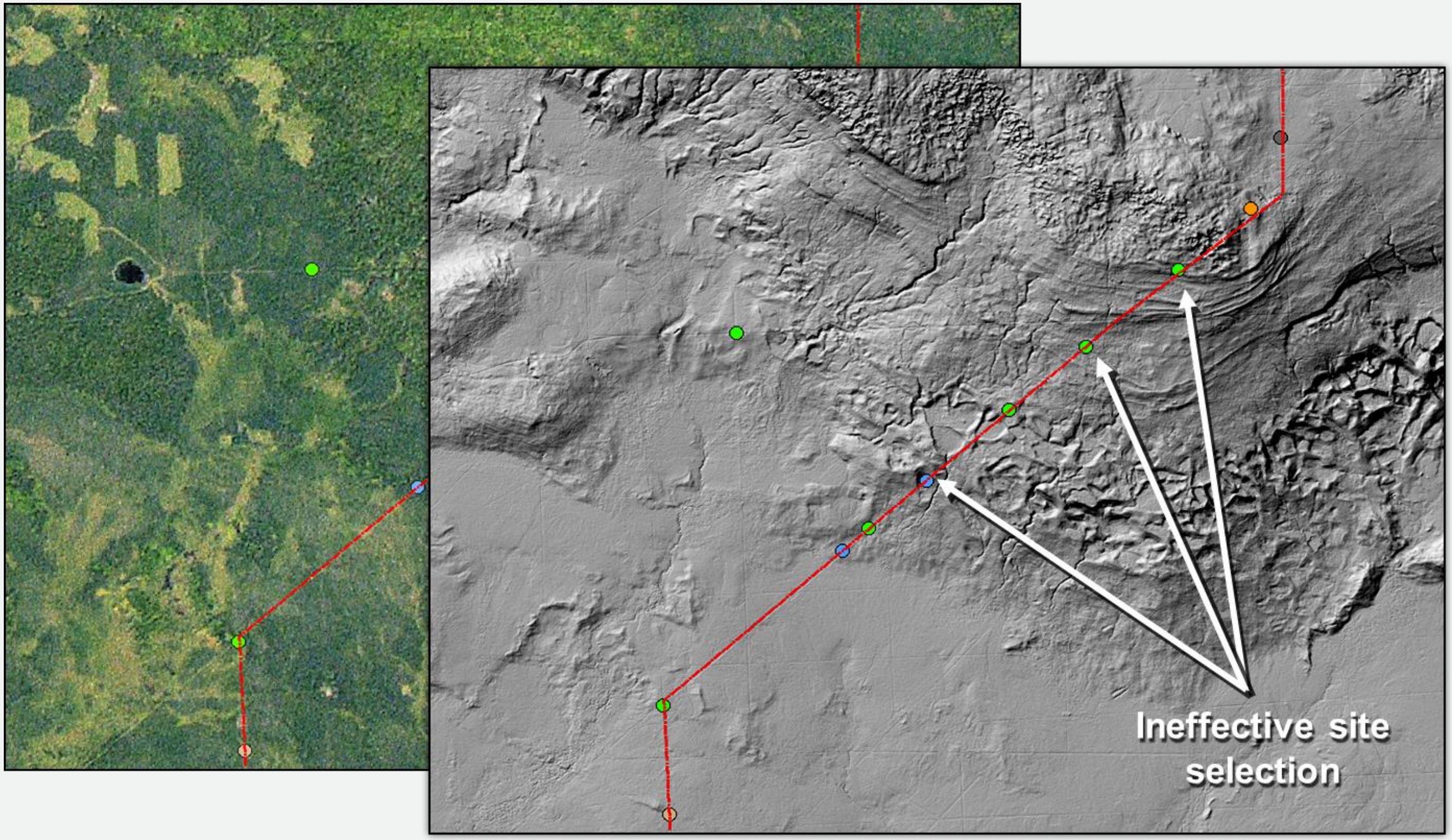
LiDAR-Based Regional Mapping



LiDAR-Based Regional Mapping

- Impacts on field site selection, time, and resources

LiDAR-Based Regional Mapping

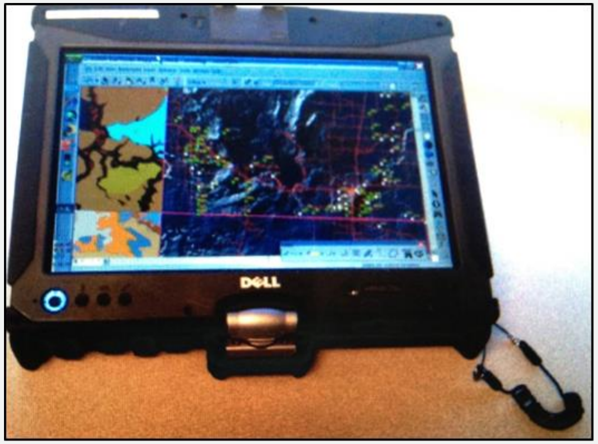


LiDAR-Based Regional Mapping

- Aim – improve the resolution and accuracy of surficial geology maps while maintaining or reducing the labour effort and production time

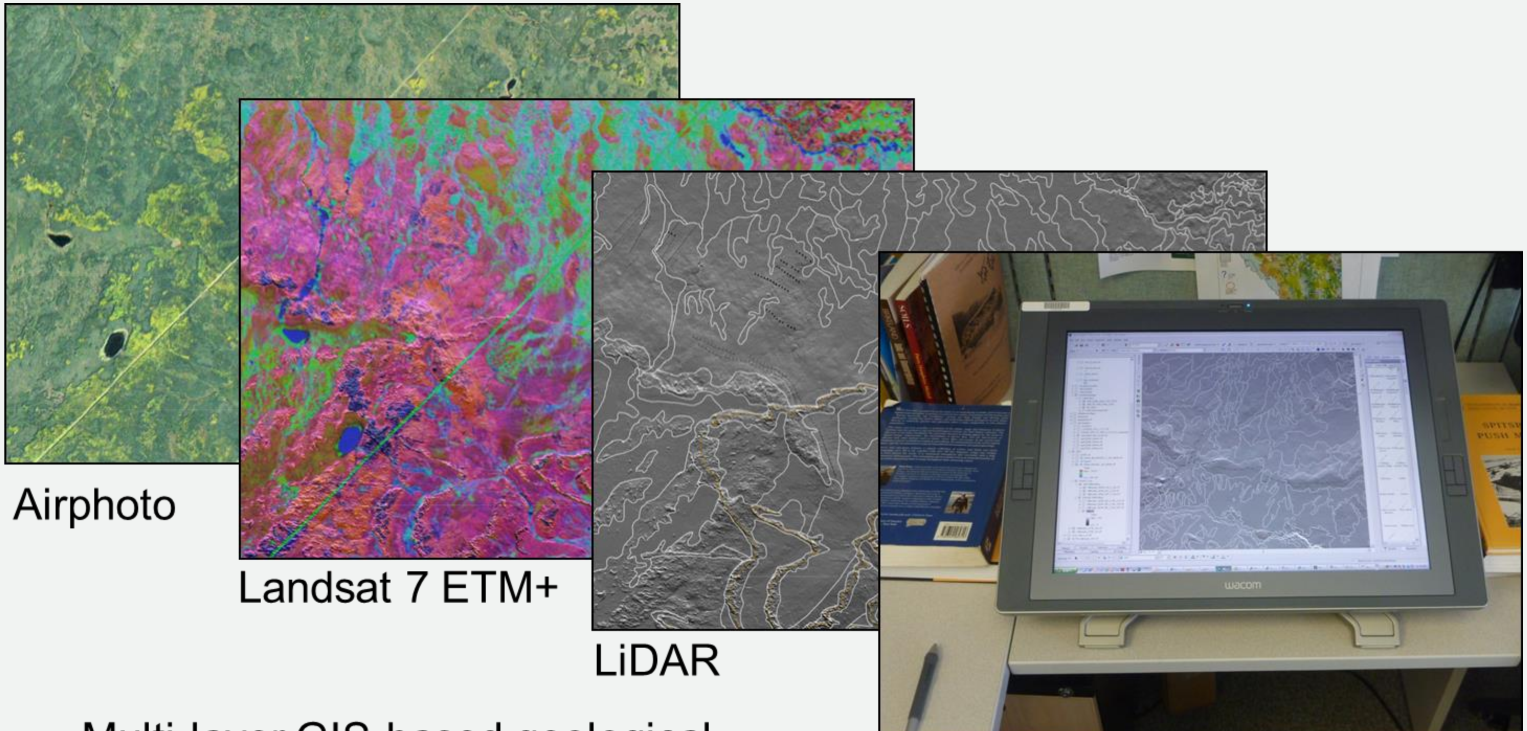
- Several potential approaches – imagery, technology, automation processes
  - Mobile GIS (2005 – now)
  - Predictive and quantitative characterization of remote sensing resources (2010 – now)

Mapping Technology



Targeted site selection and iterative map editing

Mapping Technology



Airphoto

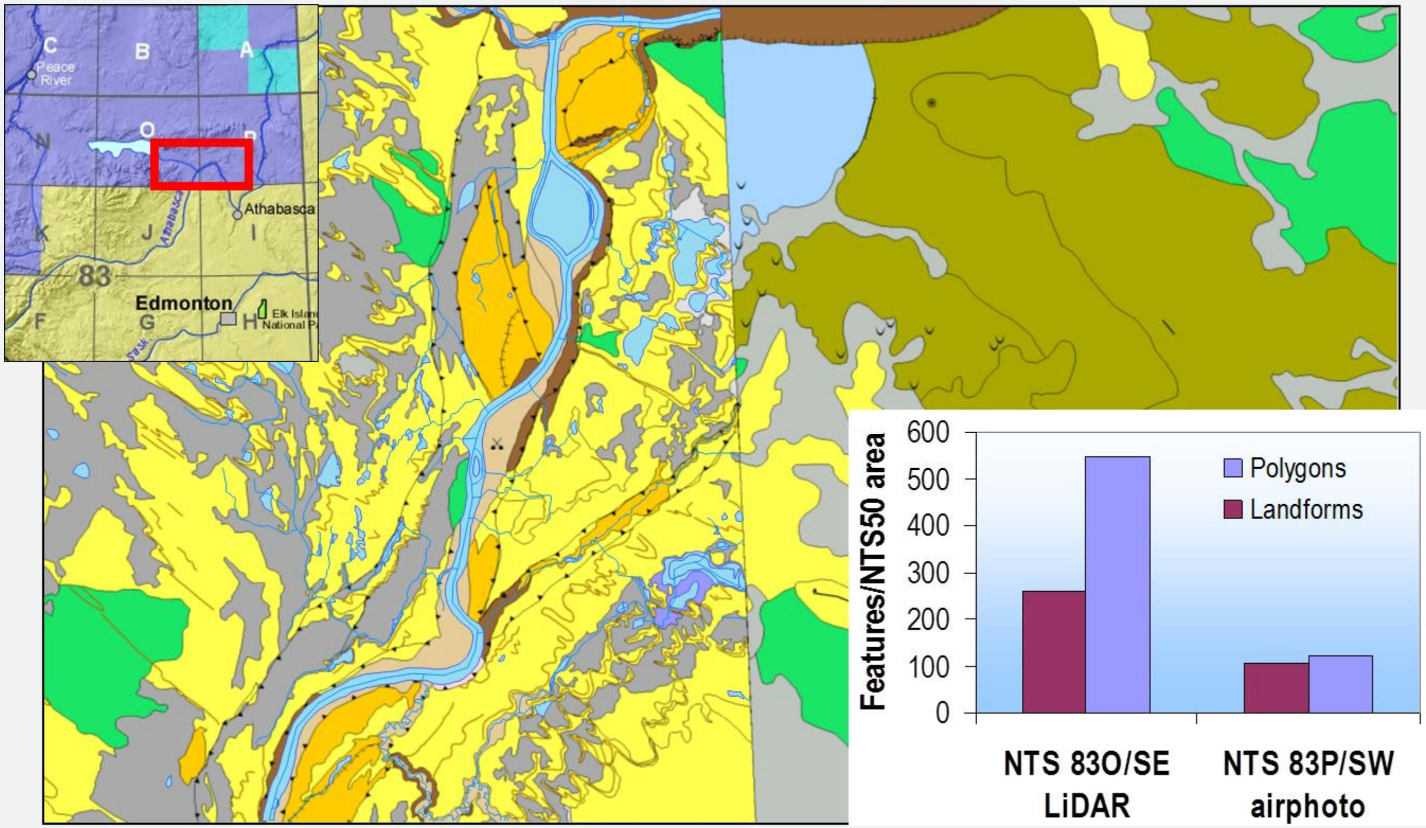
Landsat 7 ETM+

LiDAR

Onscreen digitization

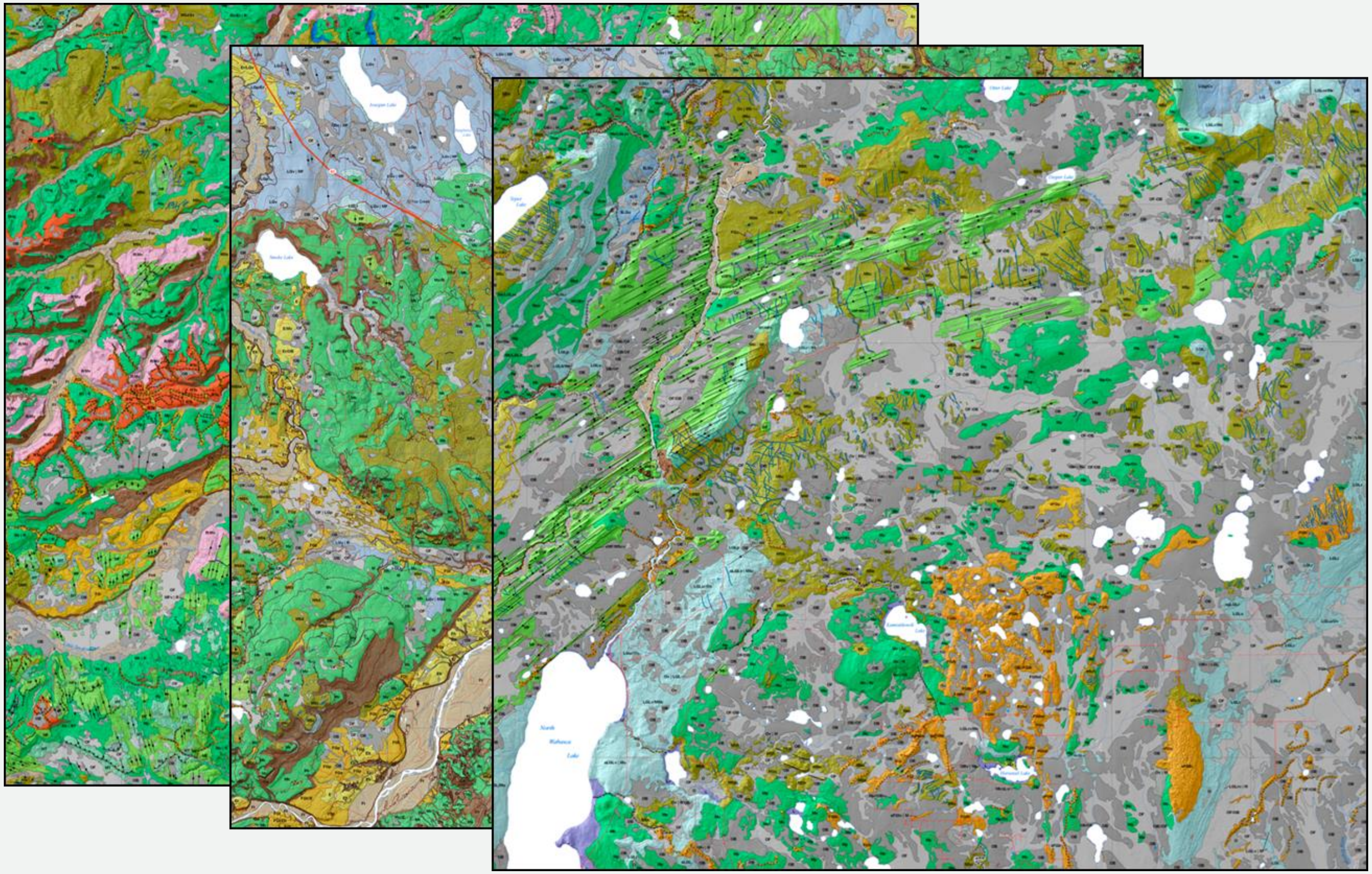
- Multi-layer GIS-based geological interpretation

LiDAR vs. Previous Mapping



Mapped with LiDAR (1:100 000)   Mapped without LiDAR (1:100 000)

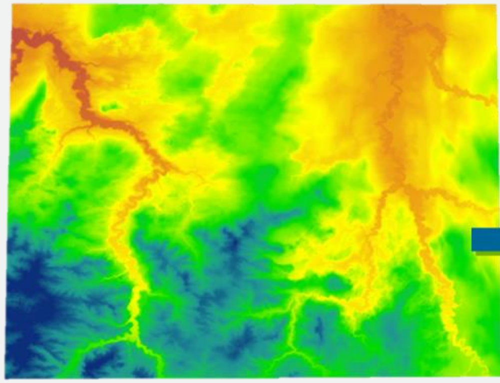
More Detailed Geological Maps



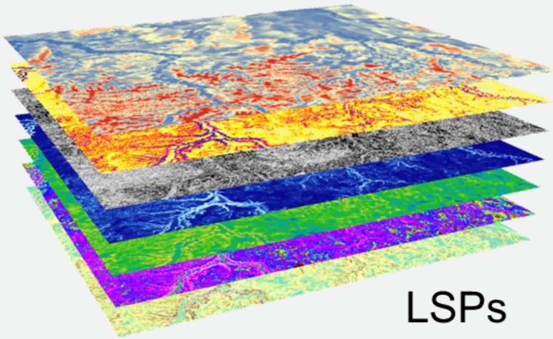
Future Work and Derivatives

- Thematic mapping
  - Predictive surface material and landform mapping
  - Slope stability
  - Permafrost distribution

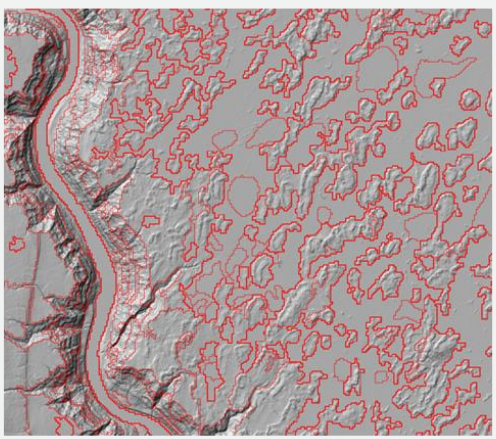
Object-Based, Predictive Mapping



Slope
MRVBF flatness
Topographic wetness
Topographic openness
Terrain texture
Ruggedness
Haralick Texture

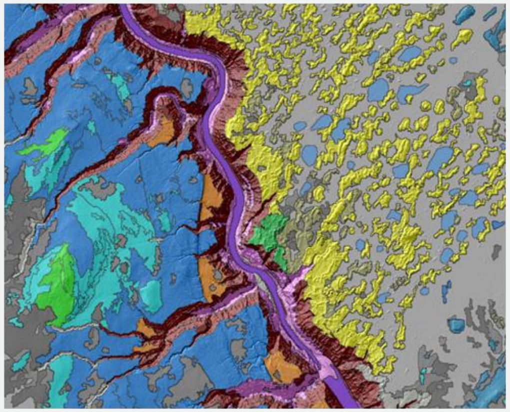


LSPs



Random Forest Classification

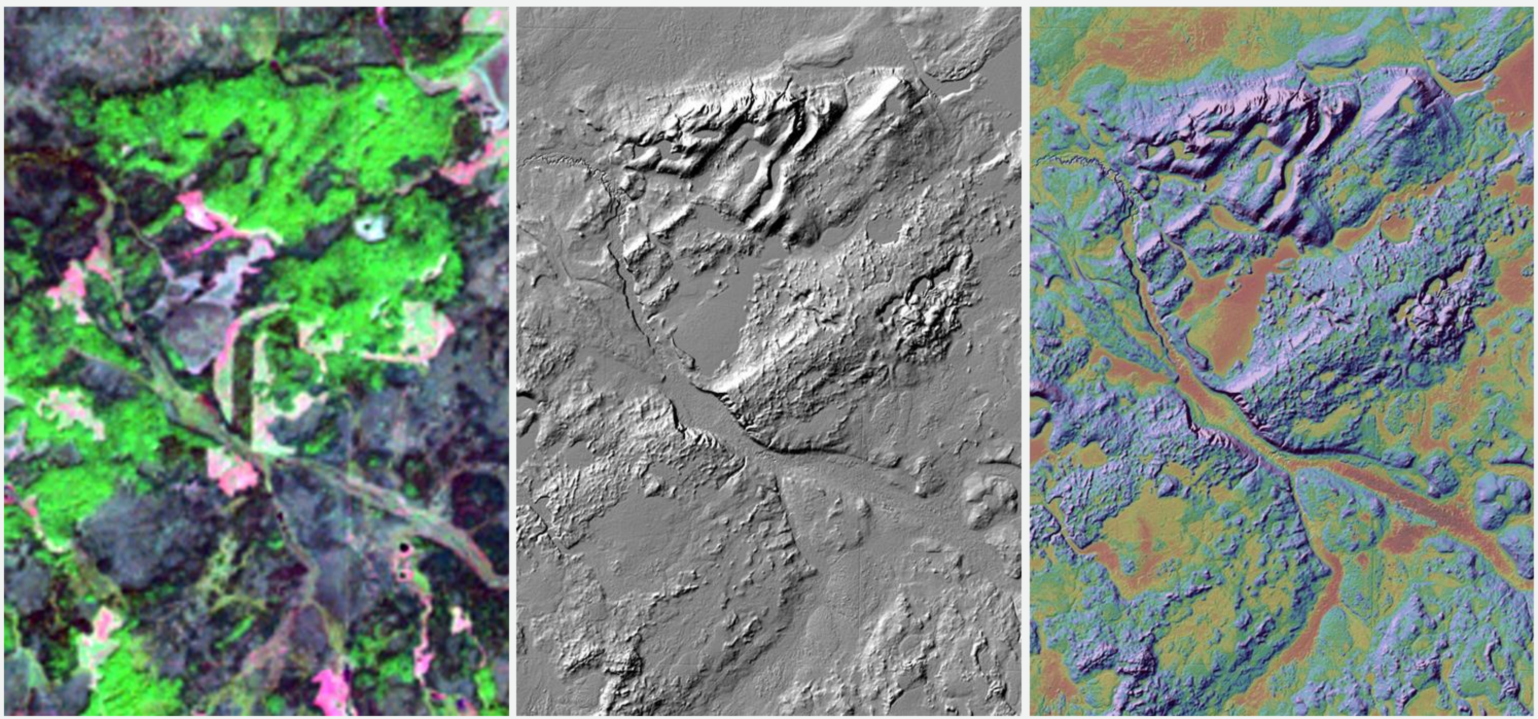
Mean, Std, Skewness, Kurtosis



Classified terrain

Peat Mapping

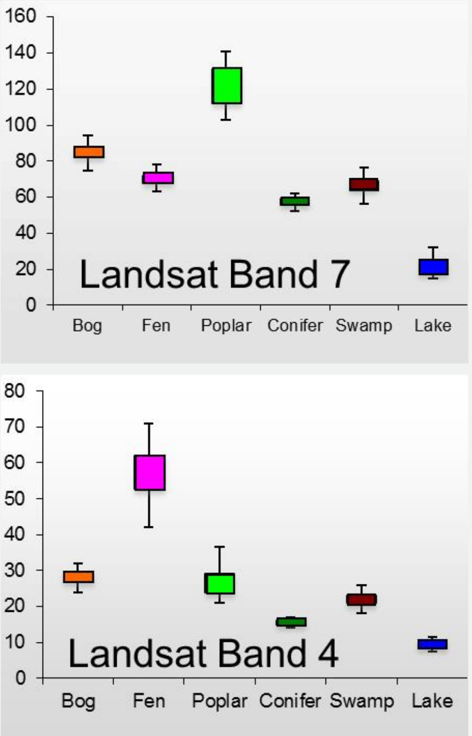
Landsat 7 ETM+ | LiDAR Bare-Earth | Multiresolution flatness index



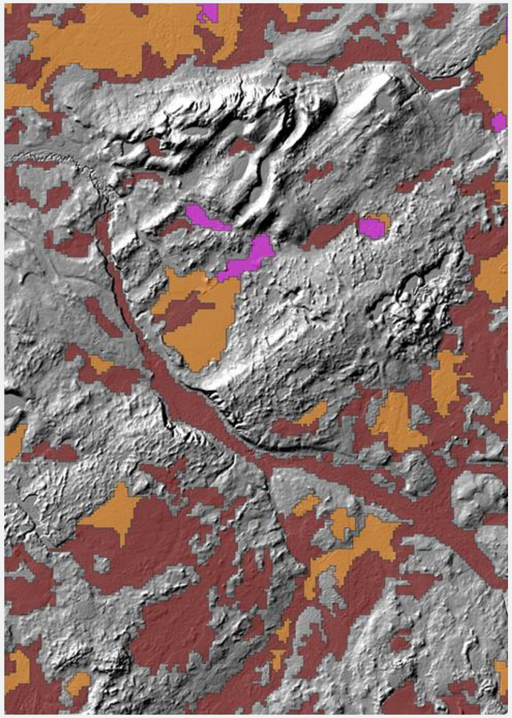
Peat Mapping

Landsat 7 ETM+

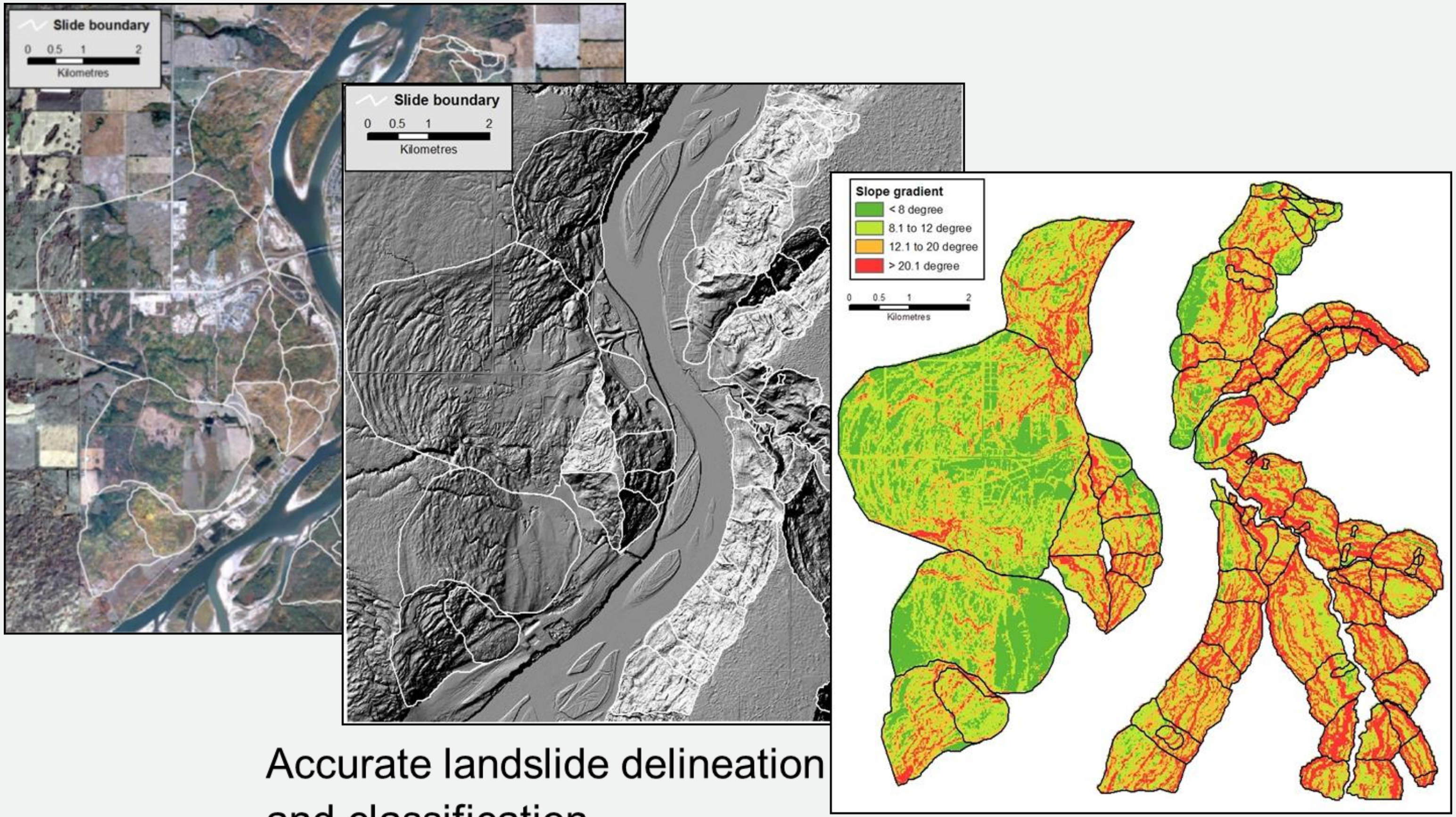
Vegetation Classes



Wetland Classification

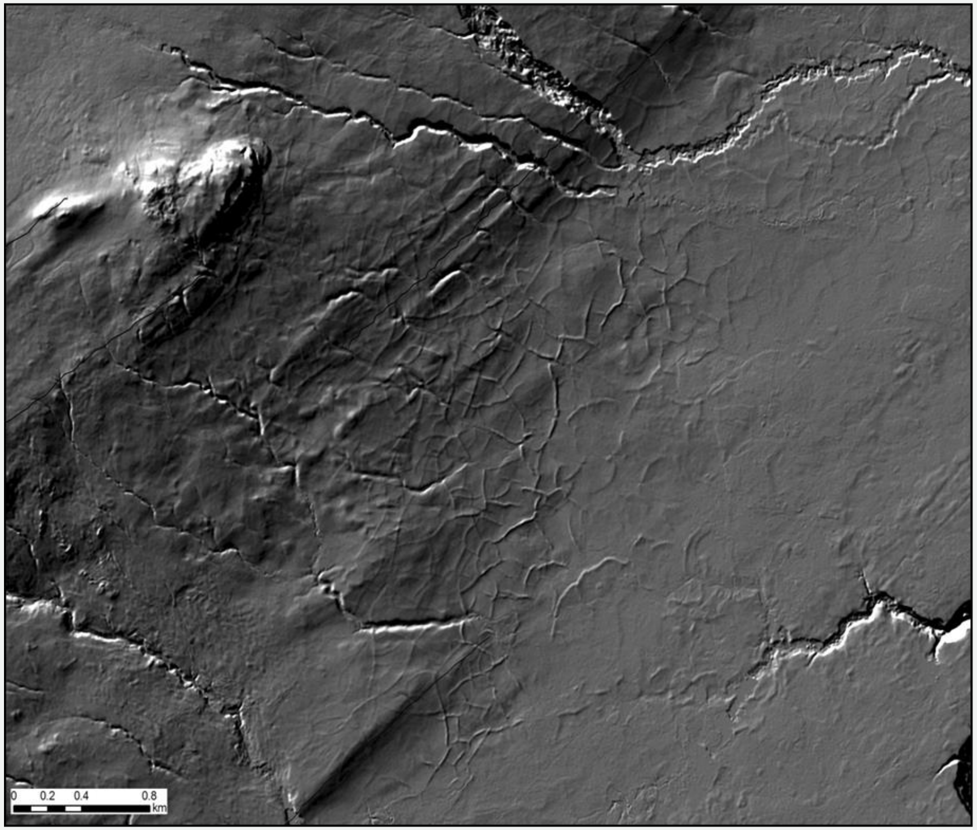


Slope Stability



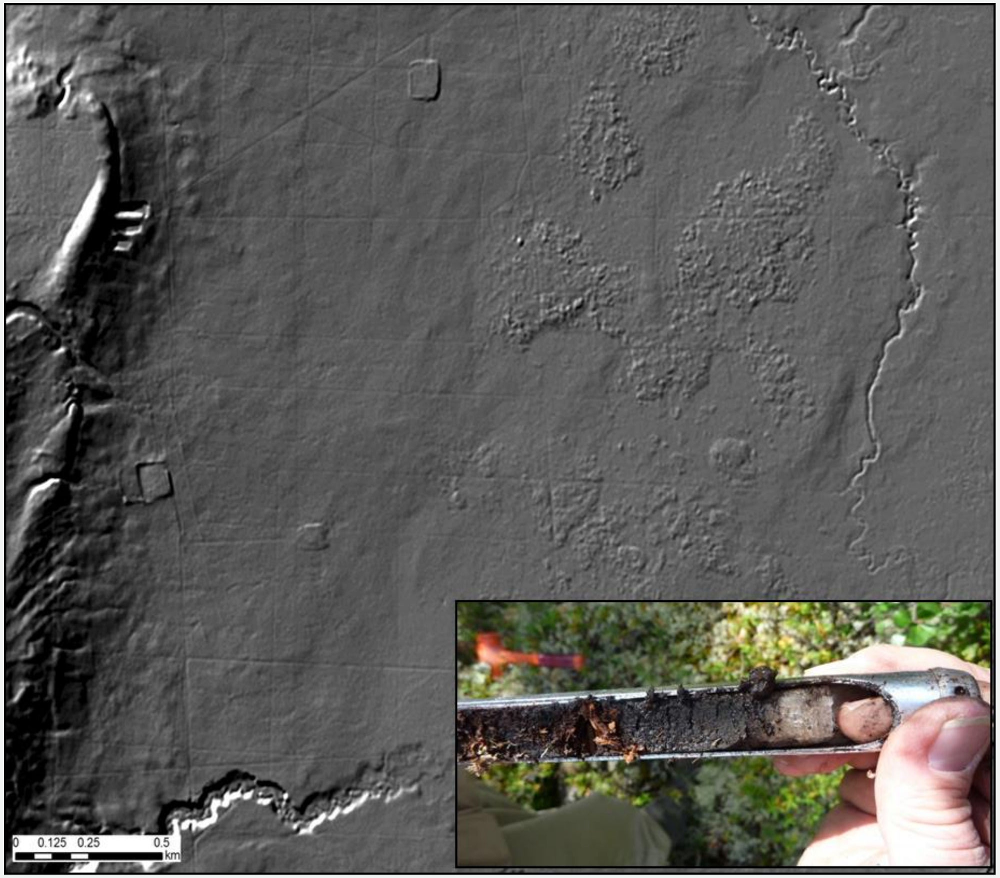
Accurate landslide delineation and classification

Permafrost Distribution



Patterned ground

Permafrost Distribution

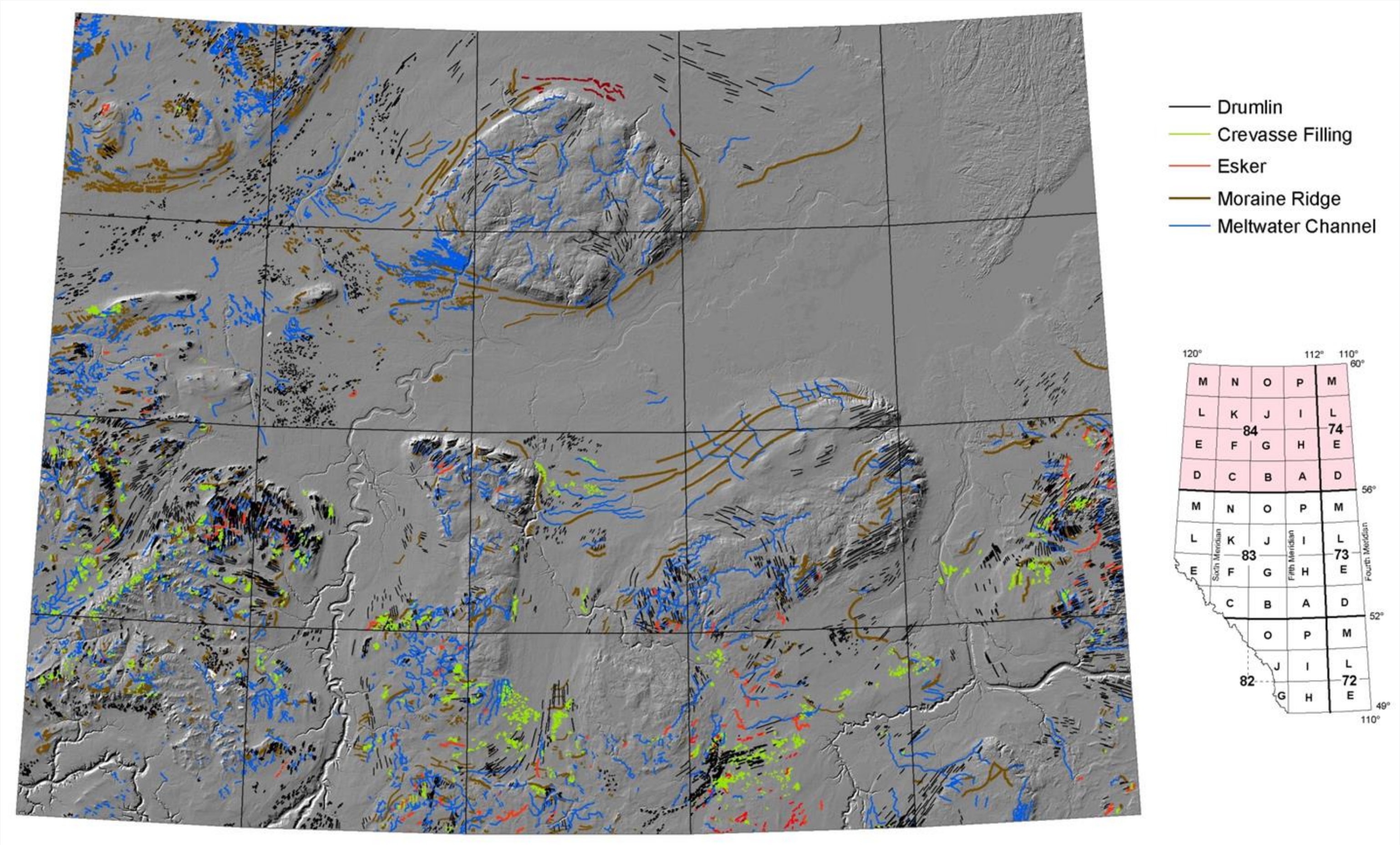


Cryoturbated peat

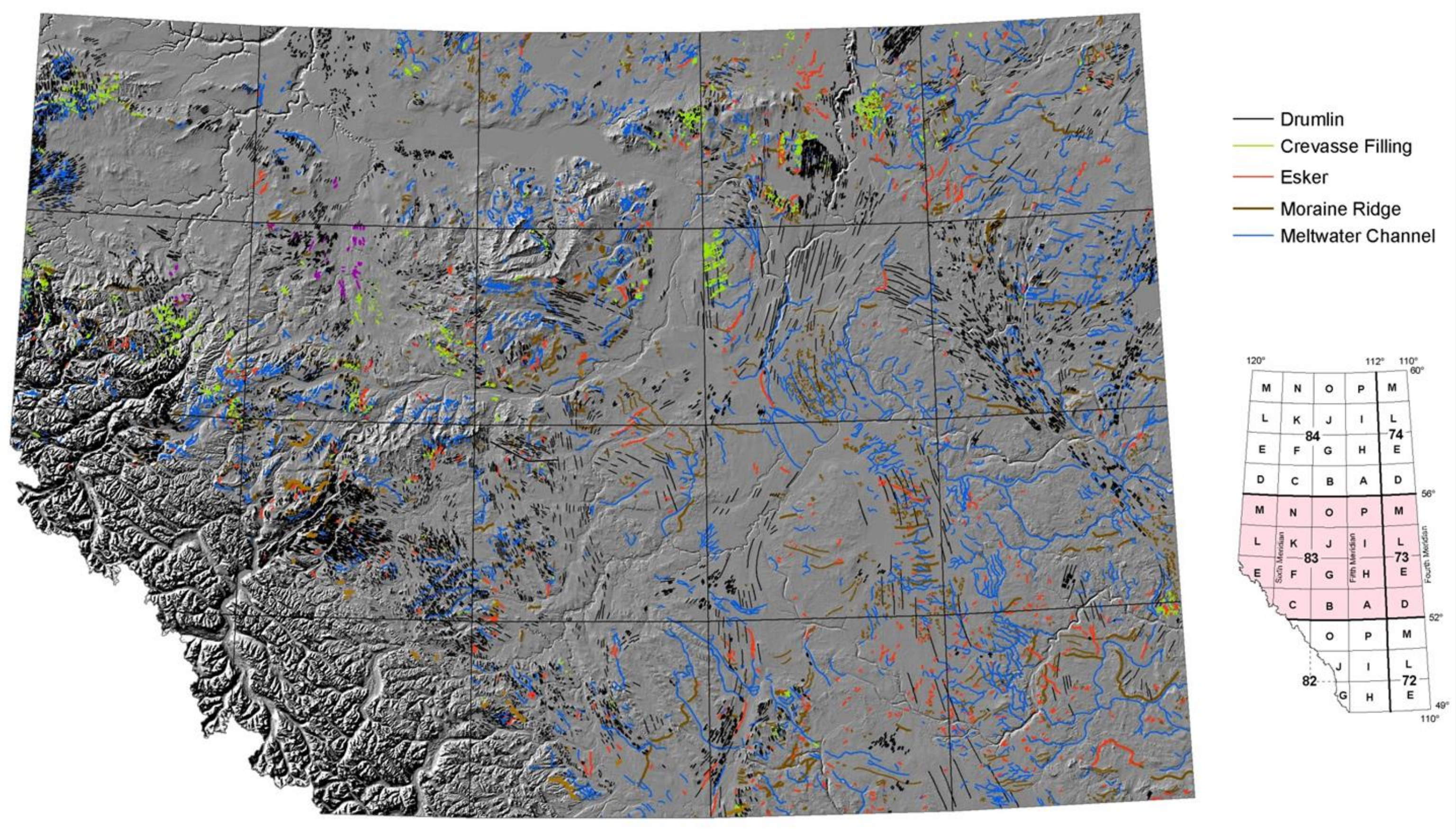
Future Work and Derivatives

- Geological data to constrain former ice sheet configuration and dynamics
  - Glacial Map of Alberta
  - Reconstructing complex ice flow trajectories (Laurentide, Cordilleran and local ice divides)
  - Morphometric analysis of streamlined landforms
  - Glacial landsystems

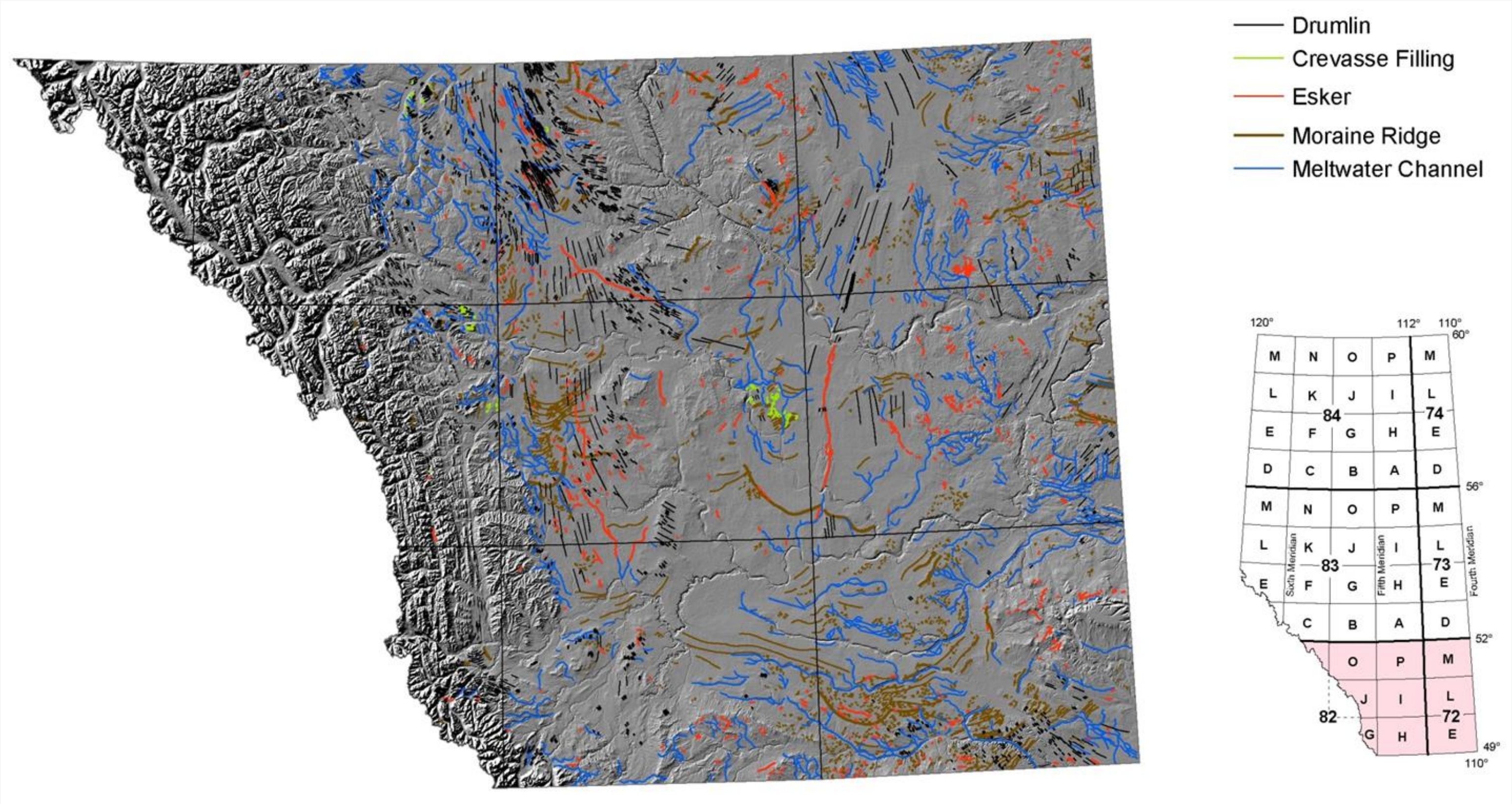
Glacial Map of Alberta



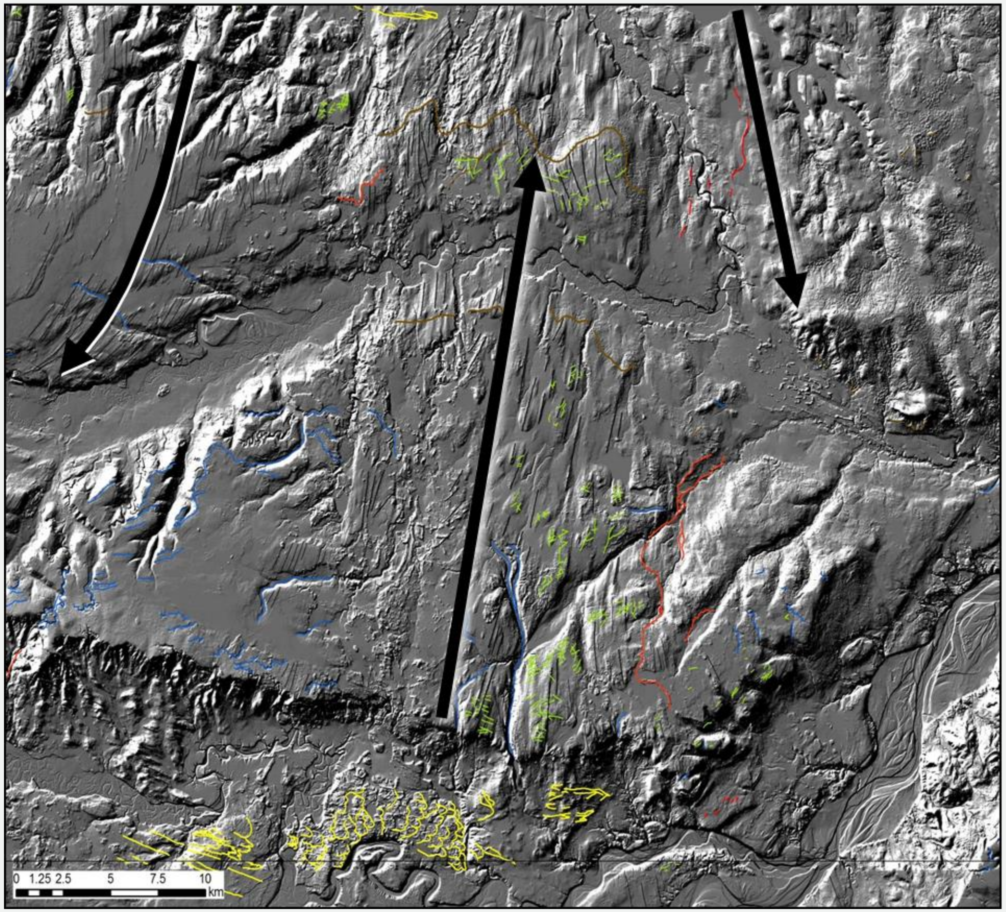
Glacial Map of Alberta



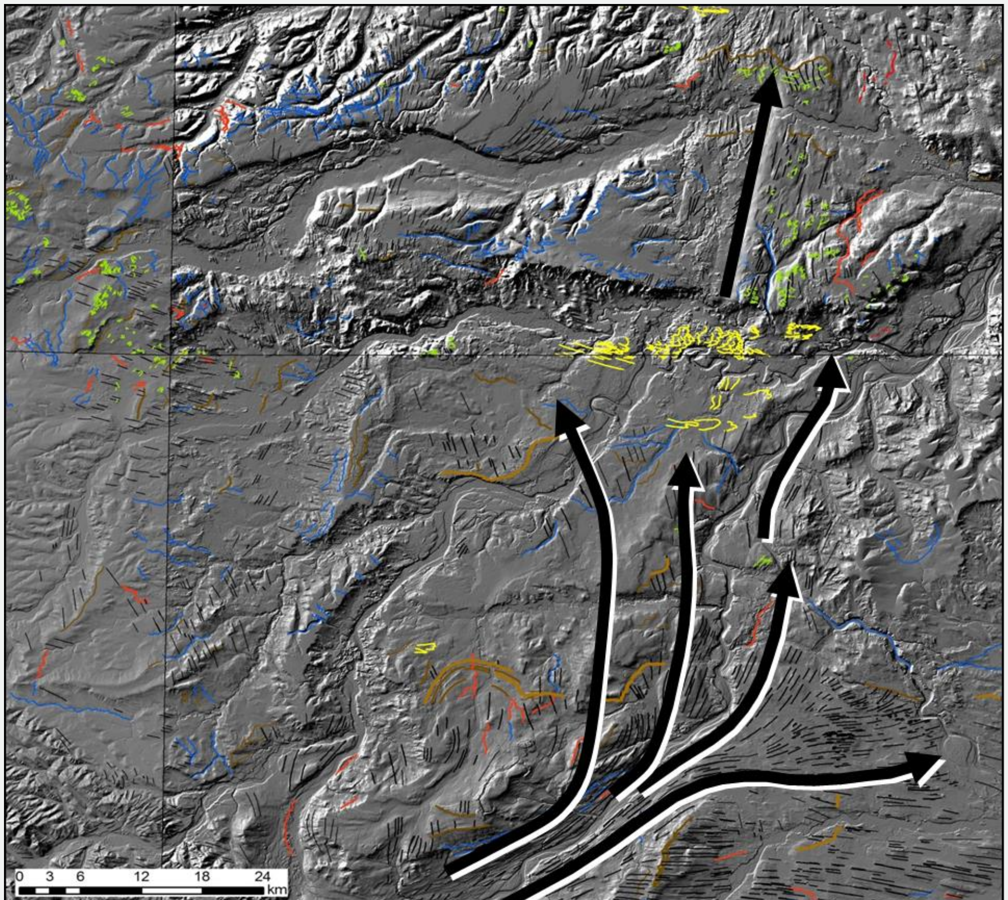
Glacial Map of Alberta



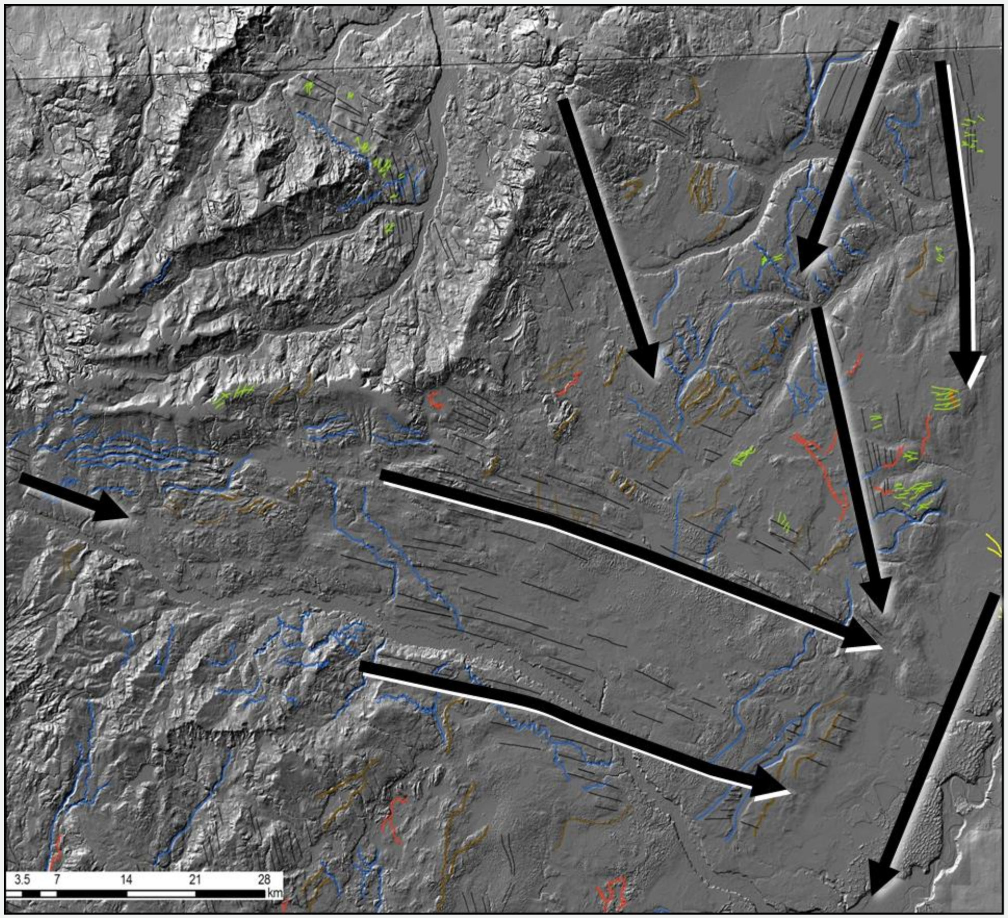
Ice Flow Trajectories



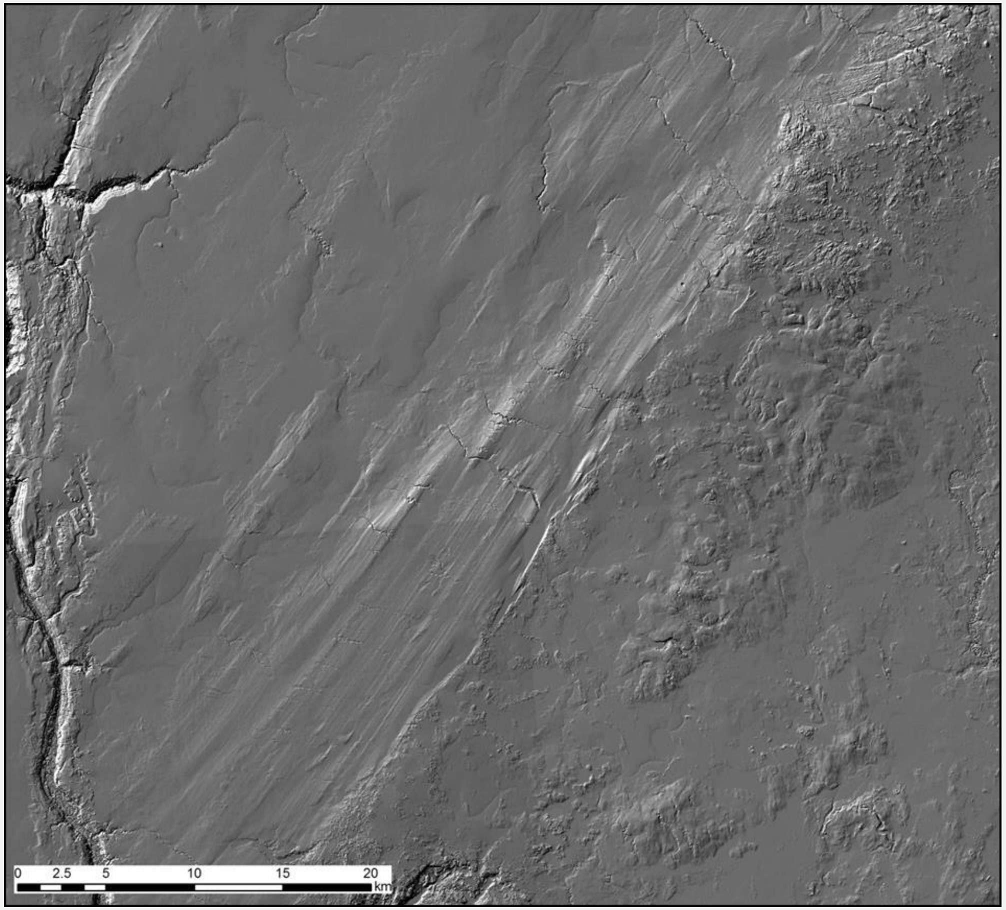
Ice Flow Trajectories



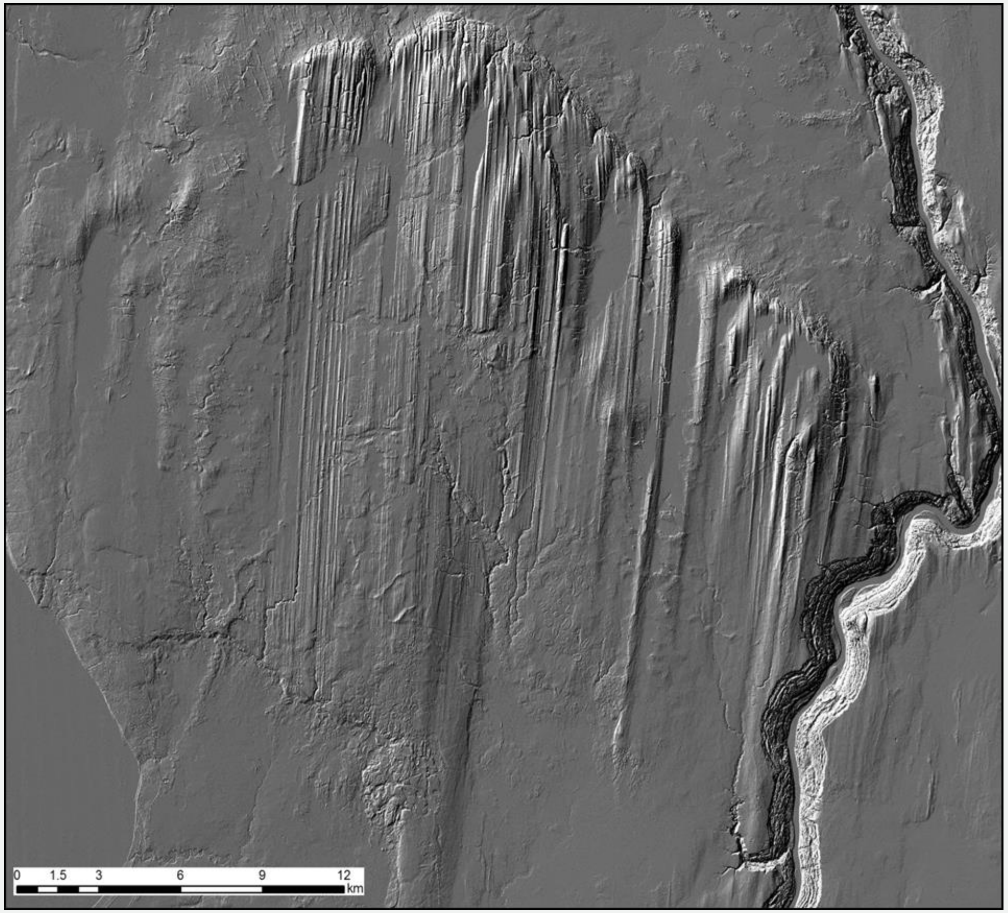
Ice Flow Trajectories



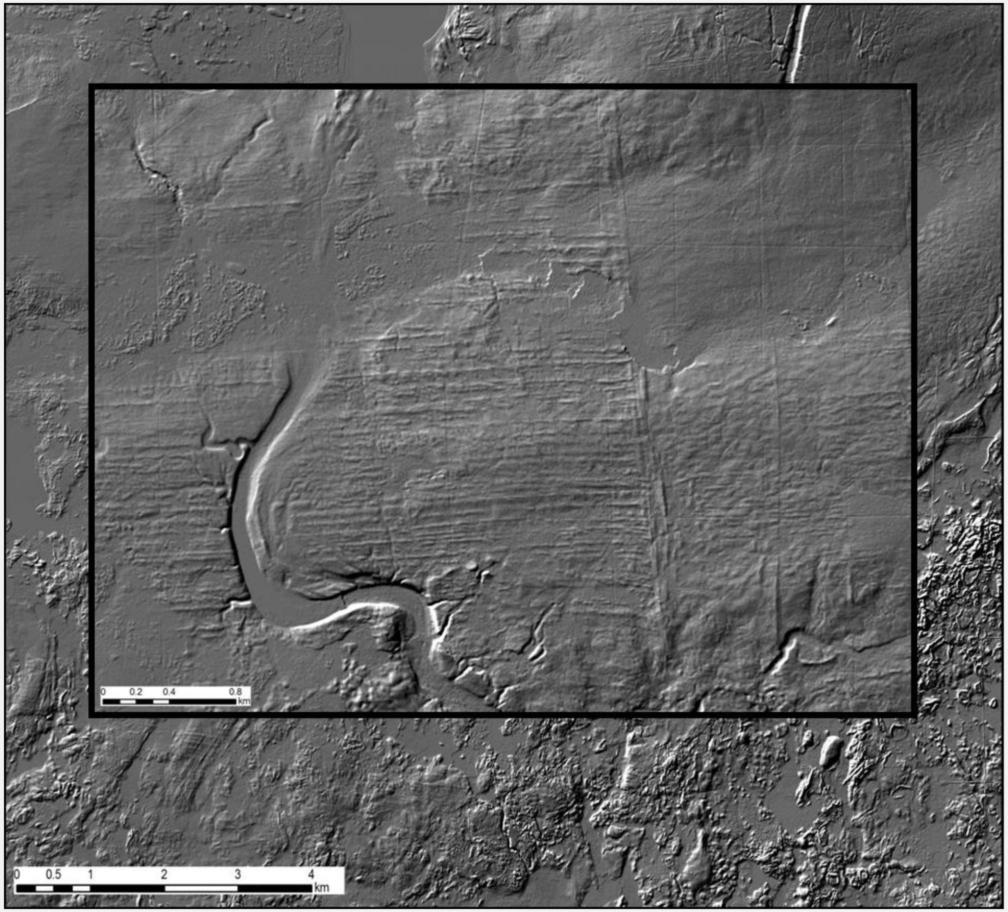
Streamlined Landform Morphology

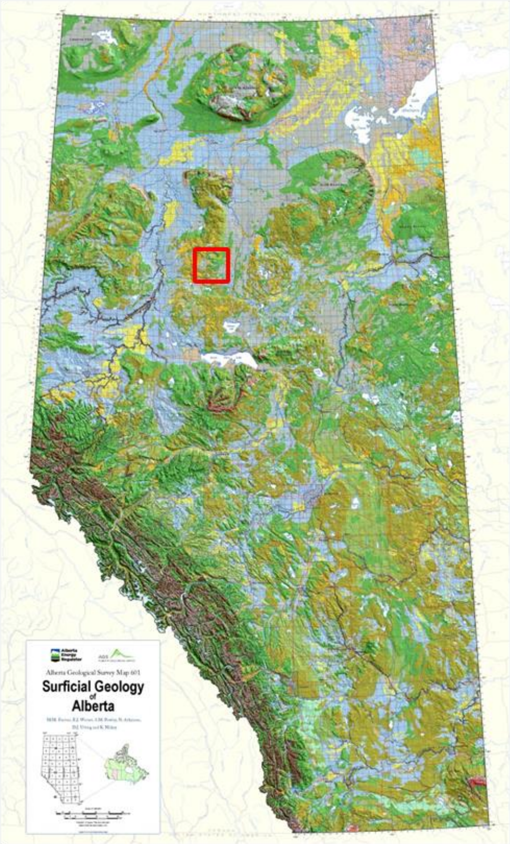


Streamlined Landform Morphology

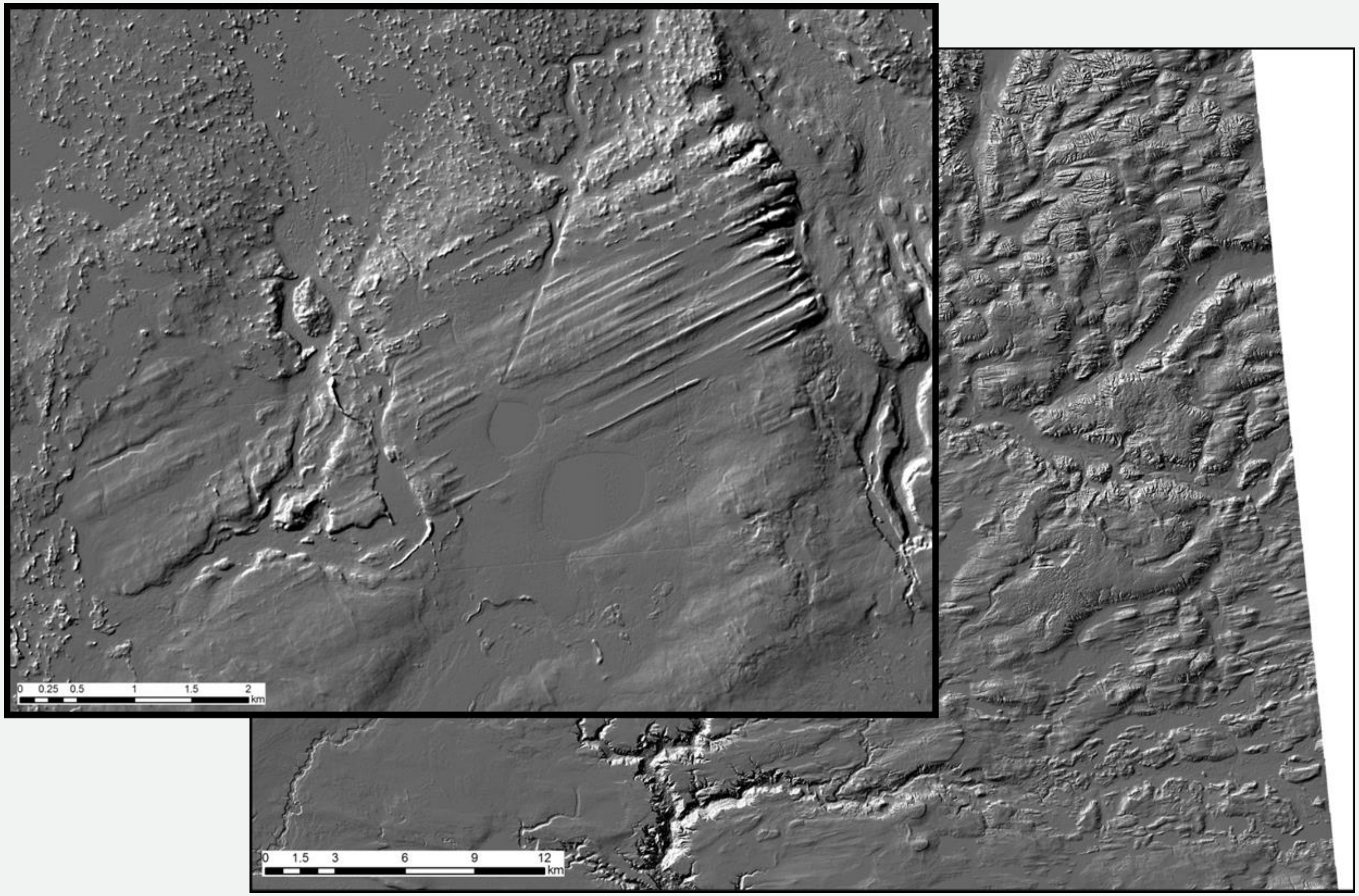


Streamlined Landform Morphology

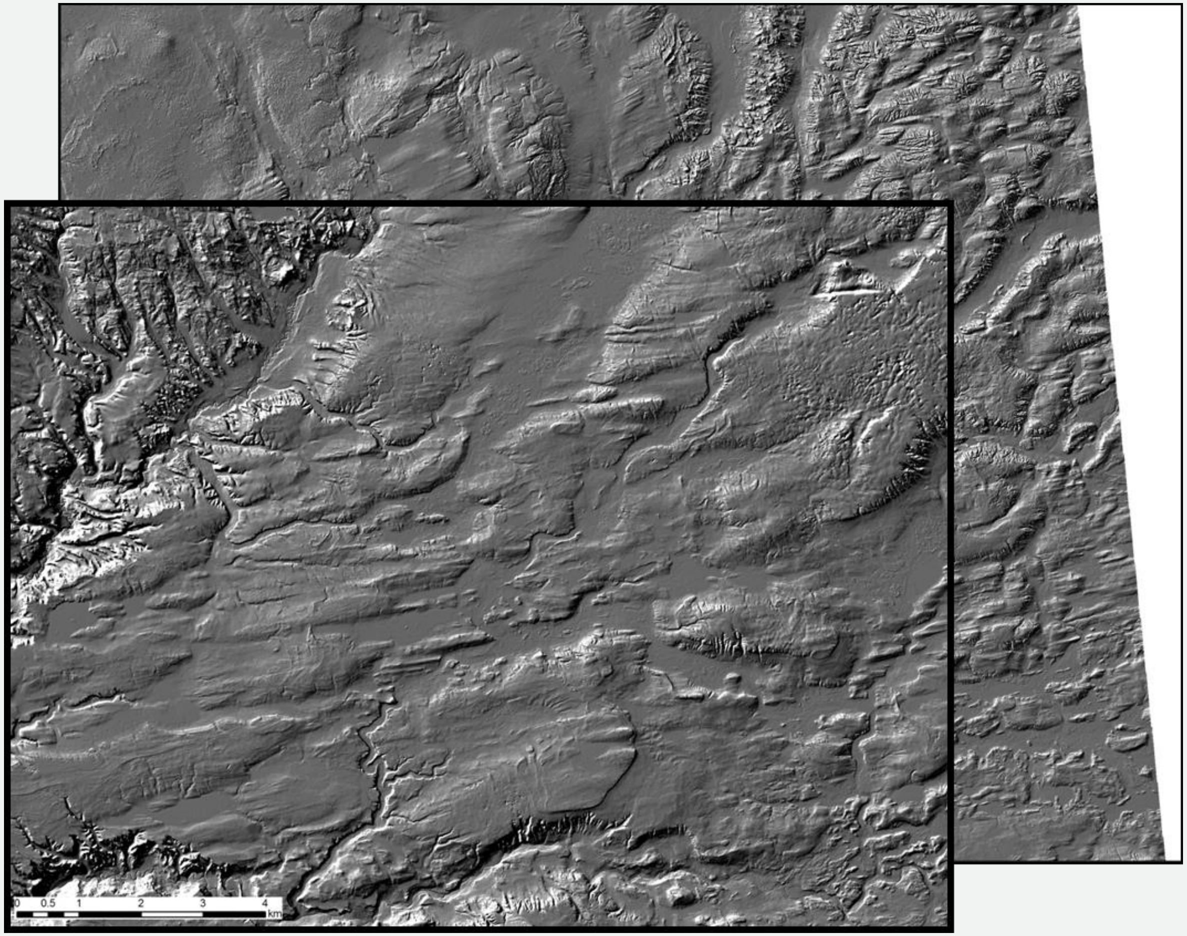




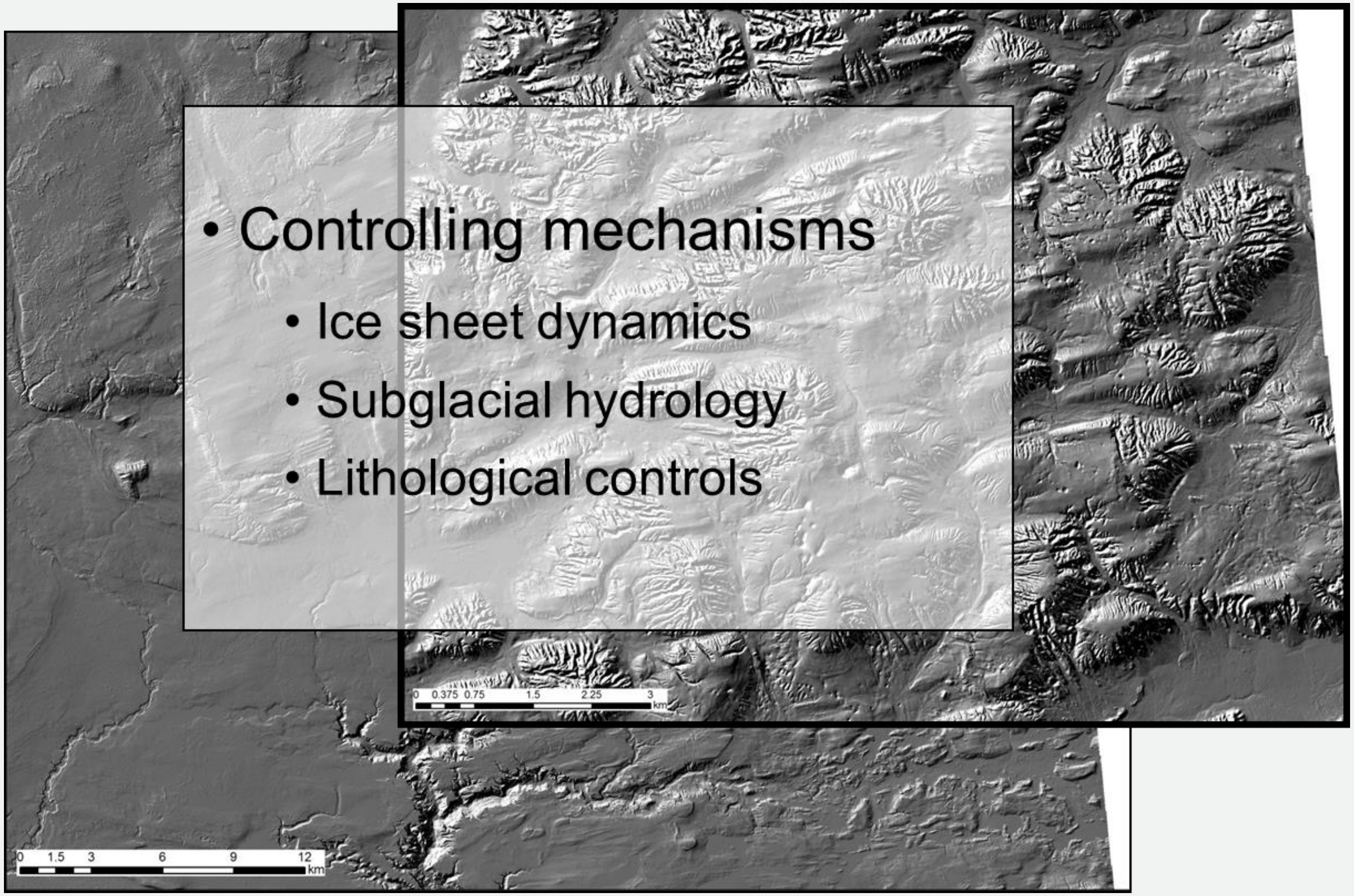
Streamlined Landform Morphology



Streamlined Landform Morphology

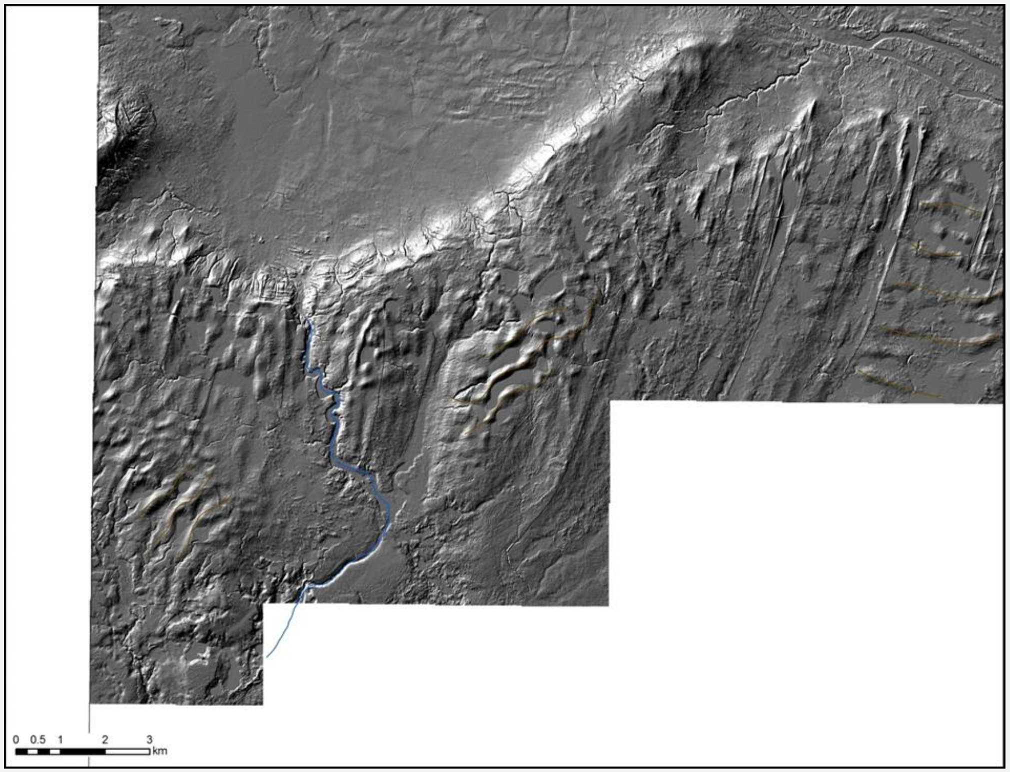


Streamlined Landform Morphology



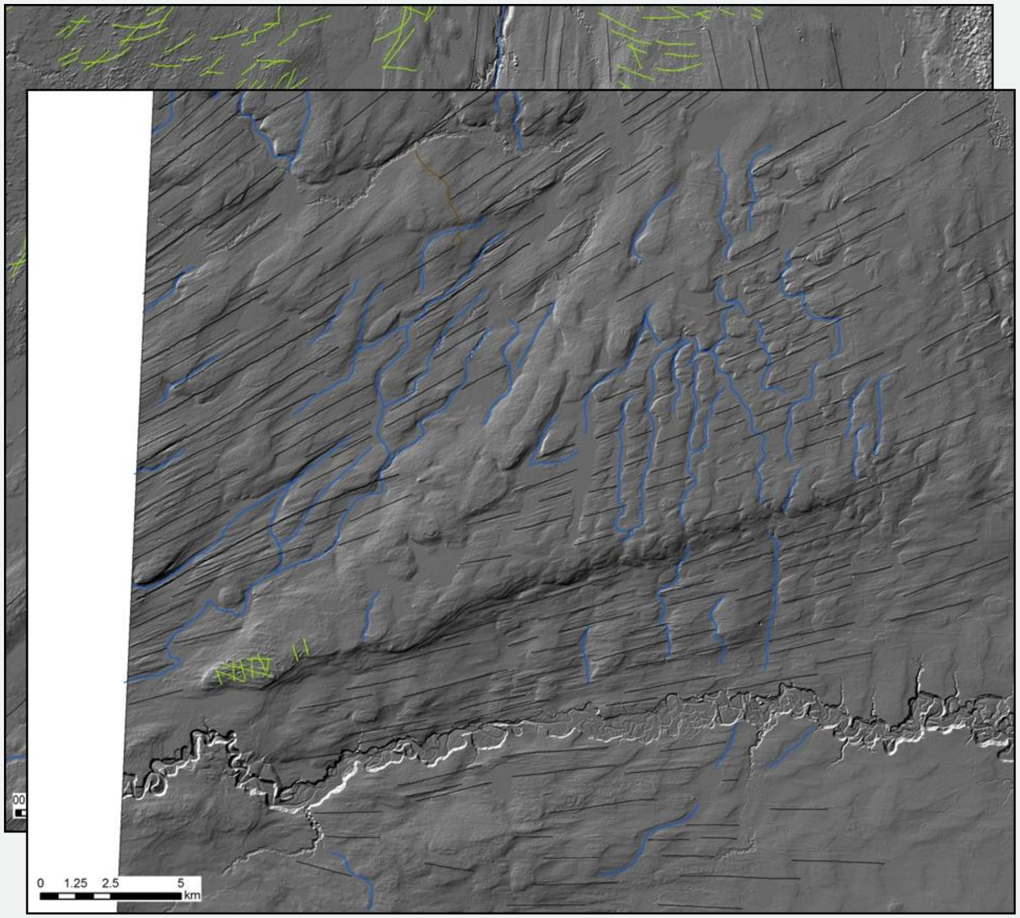
- Controlling mechanisms
  - Ice sheet dynamics
  - Subglacial hydrology
  - Lithological controls

Subglacial Landsystems



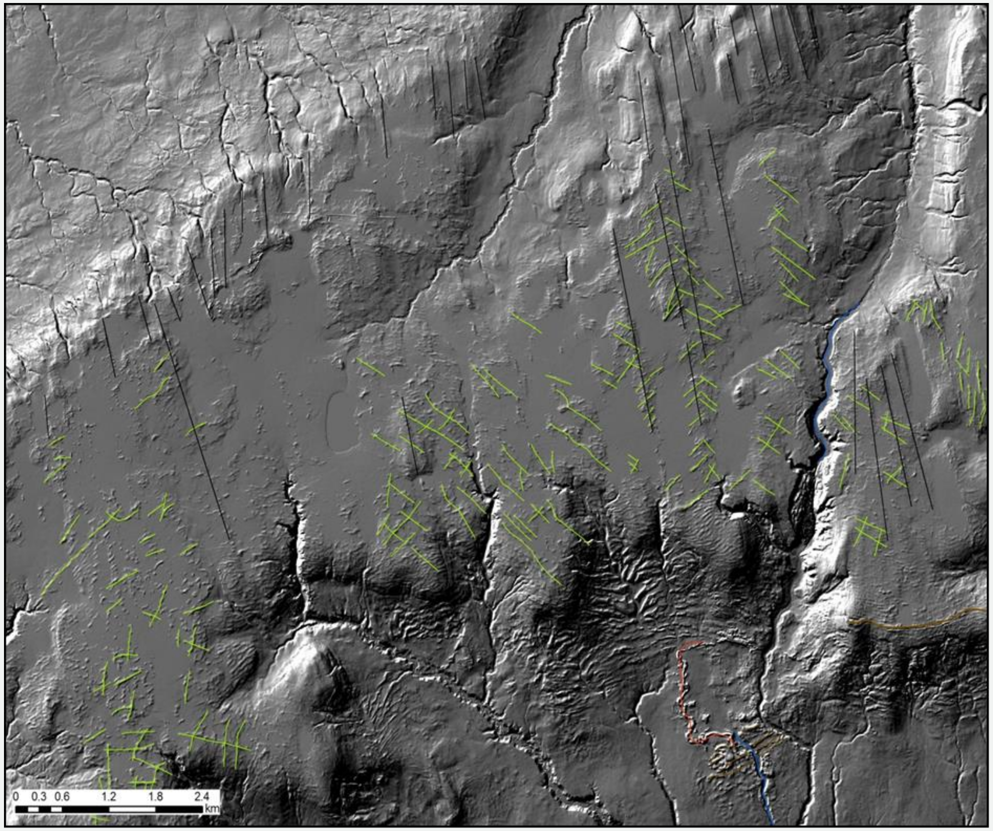
Superimposed Ribbed Moraine

Subglacial Landsystems

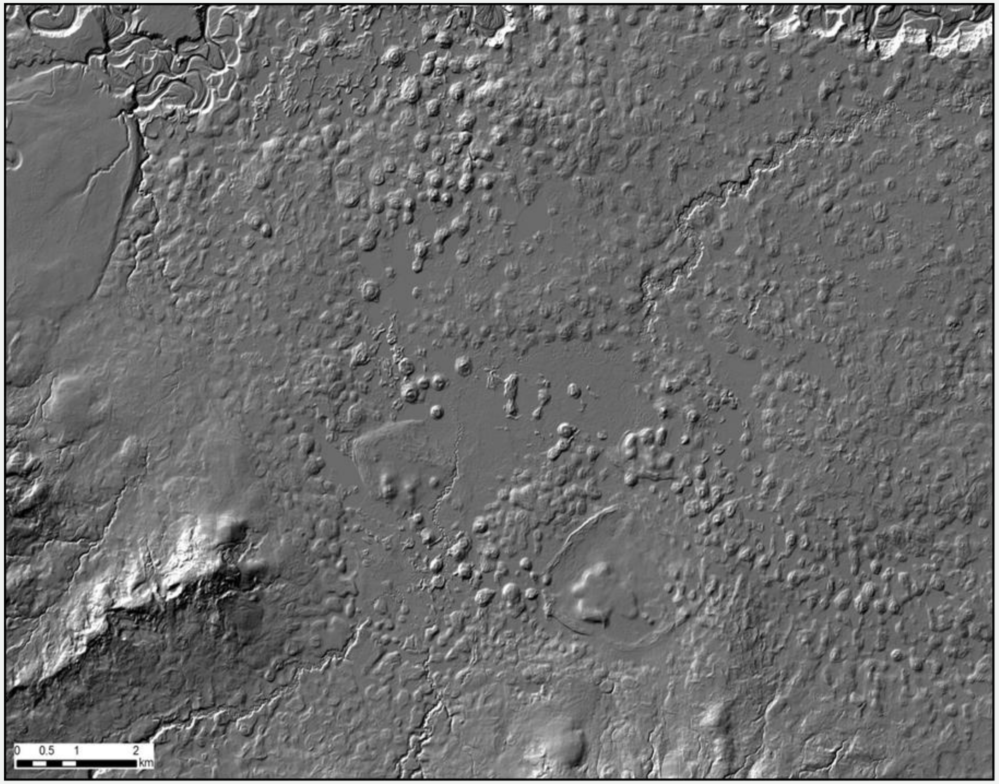


Subglacial conduits

Surging Glacier Landsystems

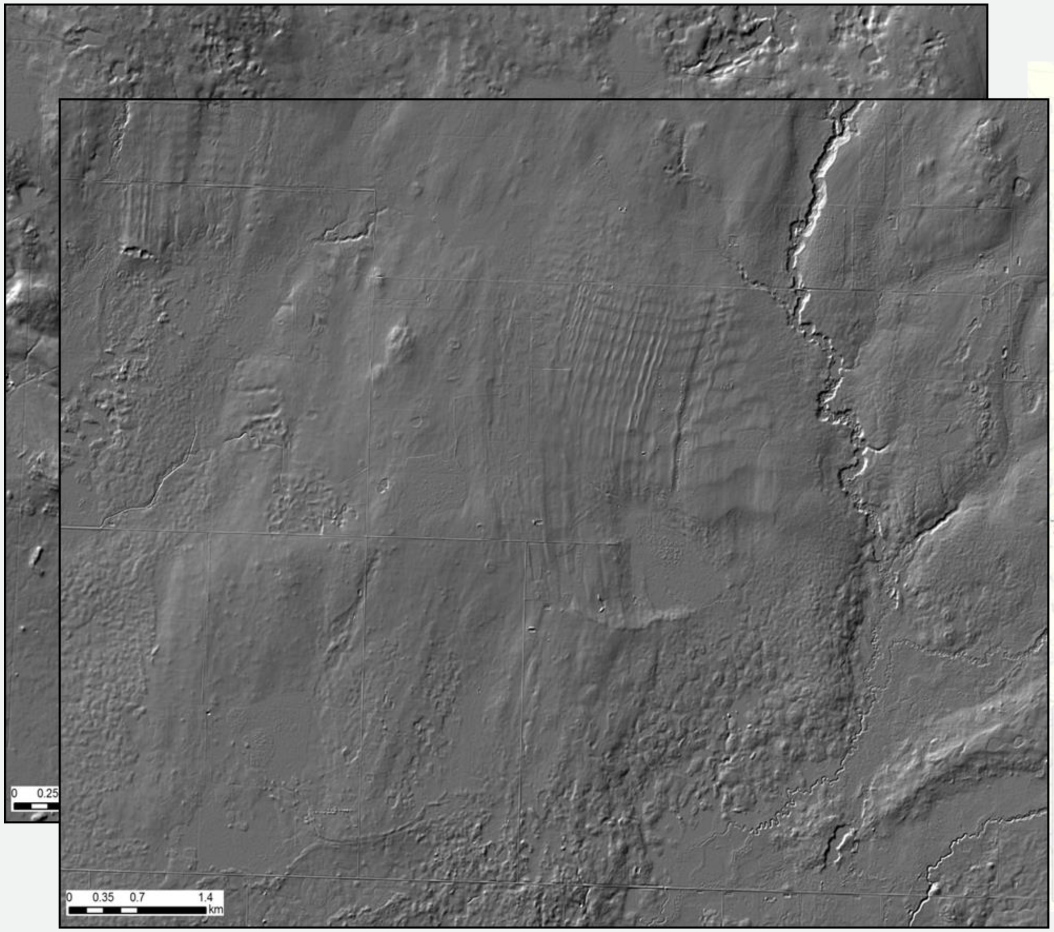


Supraglacial Landsystems



Ice-walled lake plains

Subaquatic Landsystems



Summary

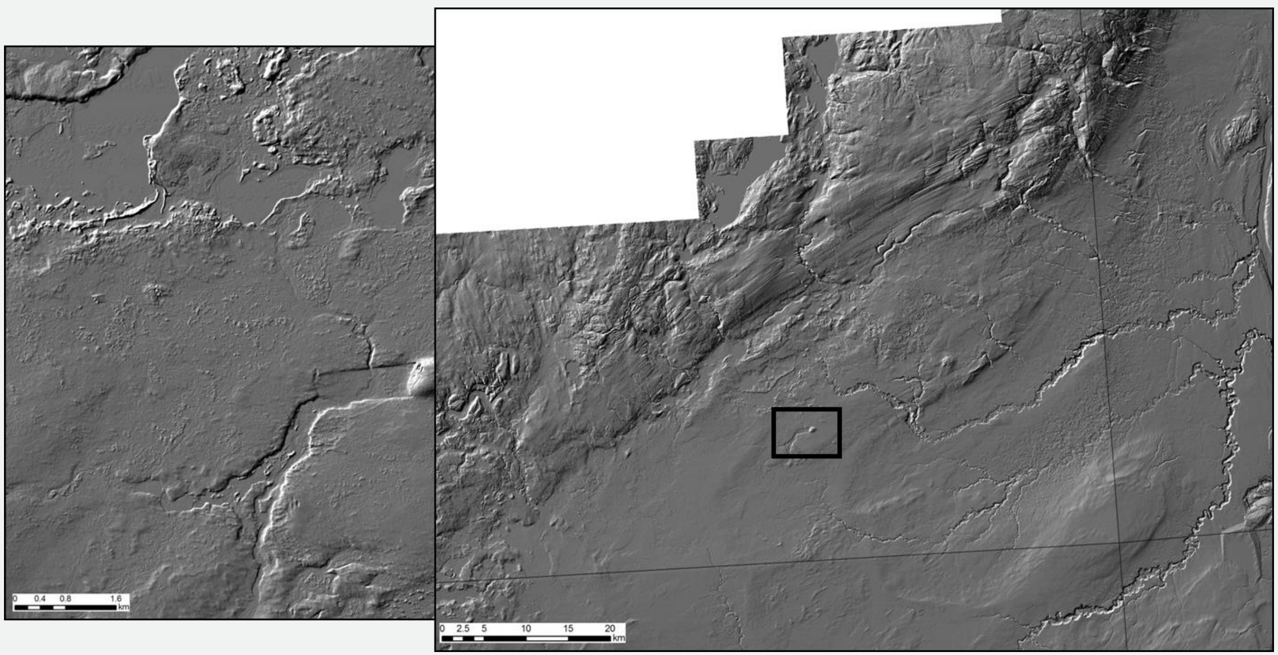
- LiDAR benefits
  - Significant increase in detail and map accuracy
- Scientific insights
  - Detection of new landform/lithological packages
  - Significant underestimation of slope instability using previous methods
- Scope and efficiency
  - Suitable for high-resolution geological mapping
  - Essential for future for detailed/thematic surface geological mapping needs

Summary

- Challenges remain
  - Although LiDAR enables the mapping of previously unidentifiable landforms, dense vegetation hinders access to many sites

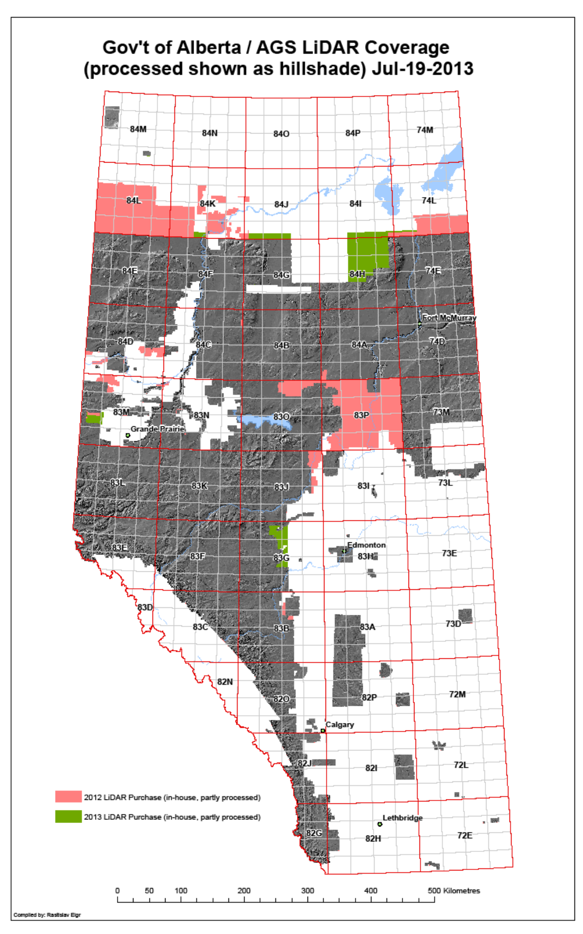
Summary

- Challenges remain
  - Interpreting the origin and significance of enigmatic landforms



Summary

- Challenges remain
  - Scope of future work
    - From the interpreted areas of current LiDAR coverage, northern Alberta contains at least:
      - 13 500 streamlined bedforms
      - 900 eskers
      - 2300 moraines



? Questions