UNIVERSITY OF GOTHENBURG

’THE LIDAR REVOLUTION IN GLACIAL GEOMORPHOLOGY: ITS GIFTS AND CHALLENGES’

MARK D. JOHNSON EGU 2020

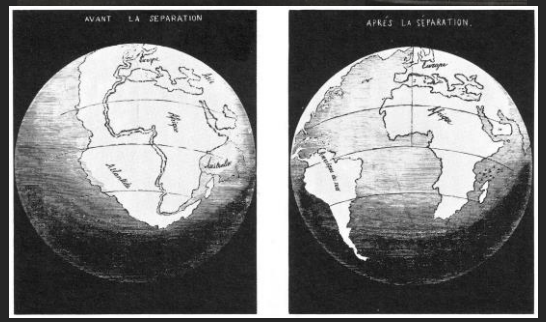
Abstract (with numbers that relate to the following slides)

1. Science progresses when we are afforded with a **‘better look’** at nature.
2. For geomorphology, the production over the last 100 years of an ever-increasingly resolved view of landscapes with topographic maps, DEMs, remote-sensing images, etc. has always been accompanied by new geomorphologic discoveries.
3. LiDAR images of formerly glaciated landscapes reveal glacial landforms in extraordinary detail, showing previously mapped landforms in exquisite new detail (for example, end moraines, drumlins, eskers, ice-walled-lake plains etc.).
4. Particularly important are a range of ‘mesoscale’ landforms that are better seen with LiDAR: De Geer moraines, crag-and-tail ridges, low-relief lineations, post-glacial faults, glacial hummocks, and raised shorelines to name a few. A spate of research has come out recently on such features.
5. LiDAR images also have the potential of revealing landforms new to glacier science, of which ‘murtoos’ are an example.
6. But LiDAR also raises the challenge of geomorphic classification. For example, glacial hummocks and glacial hummocky topography are a mesoscale landform that is known for its high variability. This variability, made more dramatic with new LiDAR images, along with the polygenetic origin of landforms called ‘hummocks’ reveals a weakness in our terminology that needs to be acknowledged and dealt with.

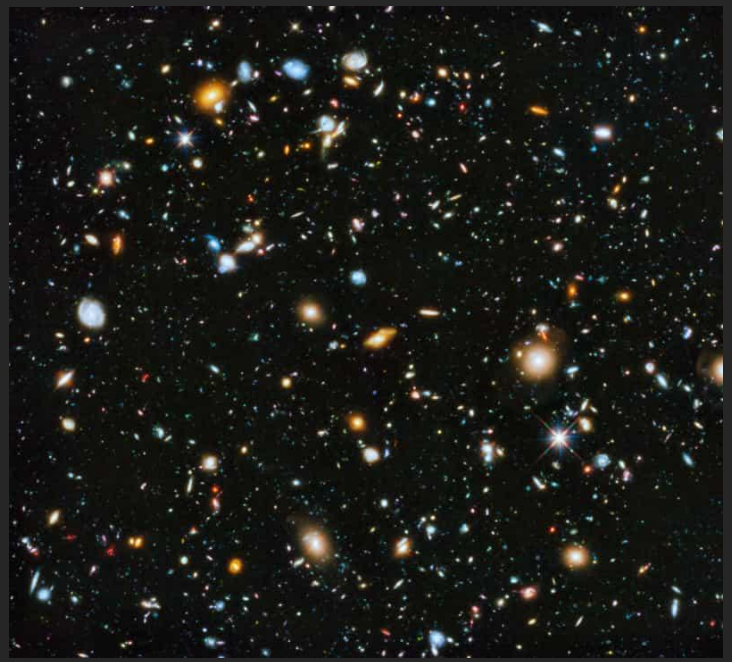
1 Science progresses when we are afforded with a ‘better look’ at nature.

van Leeuwenhoek, 1670’s

Galileo, 1609



Snider-Pelligrini, 1858 map



Hubble deep-field, 1995

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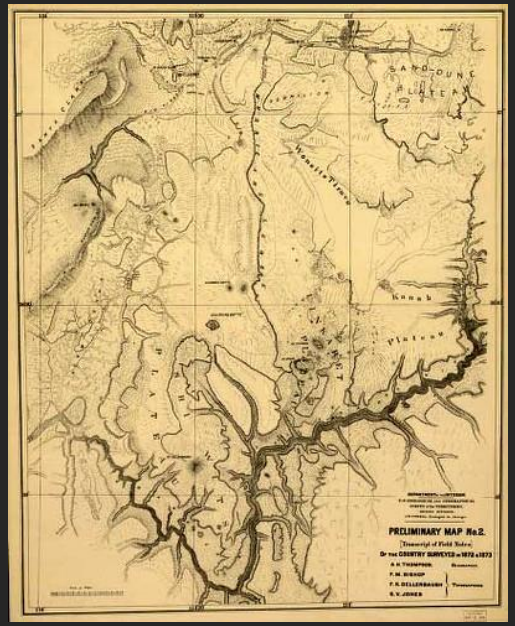
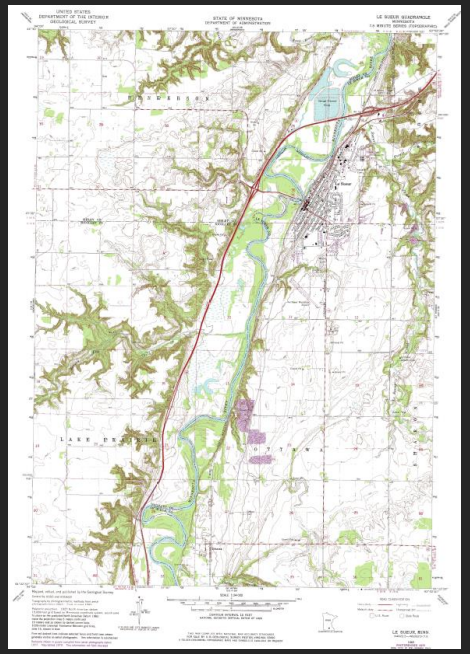
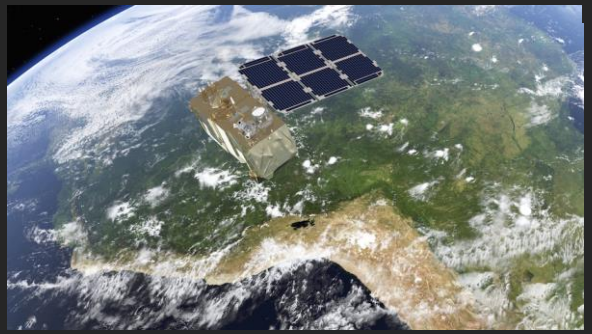


J.W. Powell, early physiographic map, Colorado Plateau, late 1800's



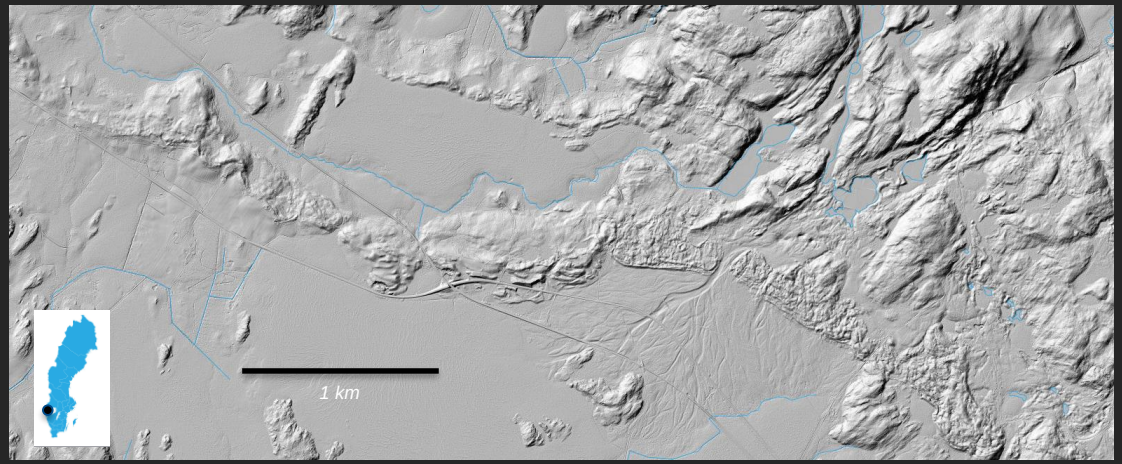
Modern topo maps (here, southern Minnesota)

First DEM's. late 1970's

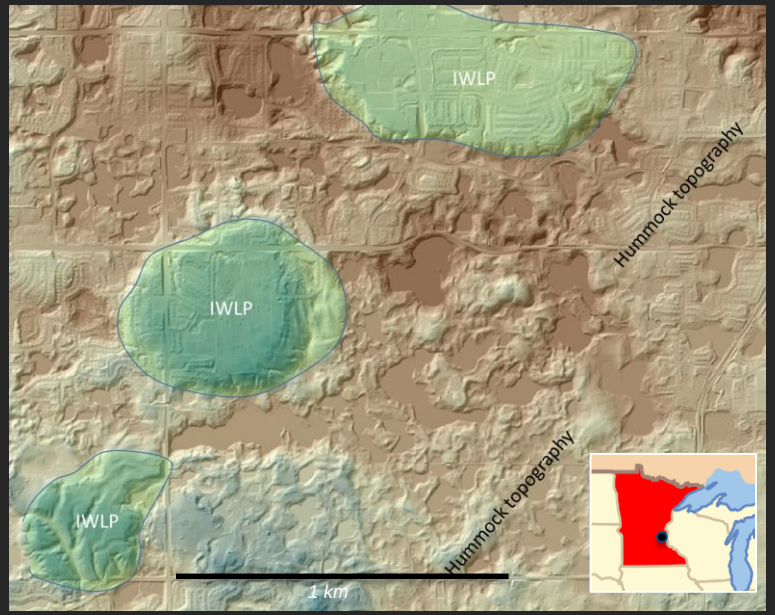


Satelitte imagery

3a. LiDAR images of formerly glaciated landscapes reveal glacial landforms in extraordinary detail, showing previously mapped landforms in exquisite new detail (for example, end moraines, drumlins, eskers, ice-walled-lake plains etc.).

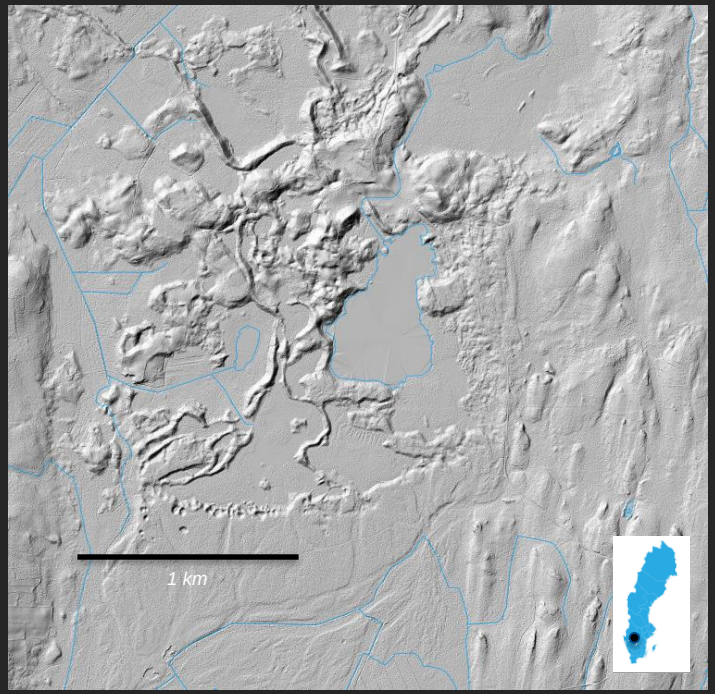


Double Younger Dryas end moraines with outwash fan, SE of Dals Ed, Sweden (Swedish Lantmäteriet)

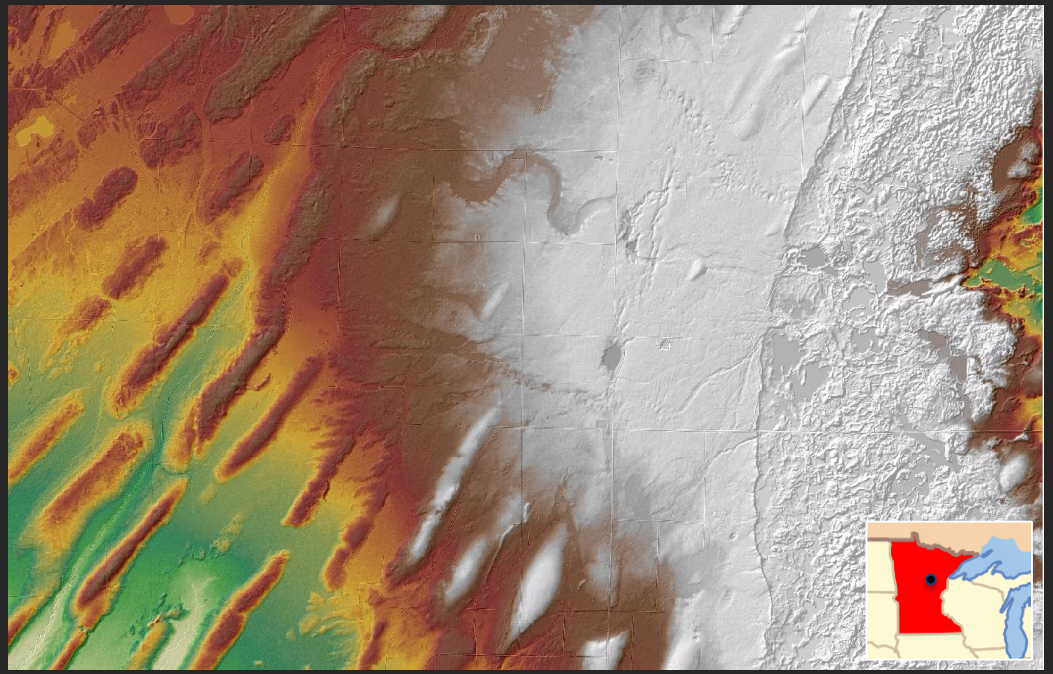


Ice-walled-lake plains (IWLP) surrounded by collapse hummocks, in the St. Croix moraine, Lebannon Hills, Twin Cities, Minnesdota (mngeo.state.mn.usl)

3b. LiDAR images of formerly glaciated landscapes reveal glacial landforms in extraordinary detail, showing previously mapped landforms in exquisite new detail (for example, end moraines, drumlins, eskers, ice-walled-lake plains etc.).

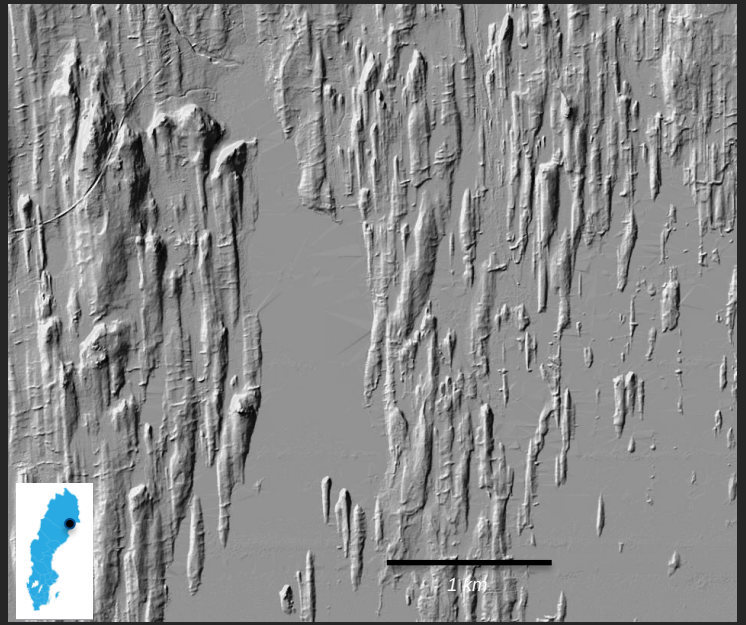


Late Allerød (?) esker net, outwash fan (with ice-contact slope), pits, crag-and-tails, SE of Tibro, Sweden (Swedish Lantmäteriet)

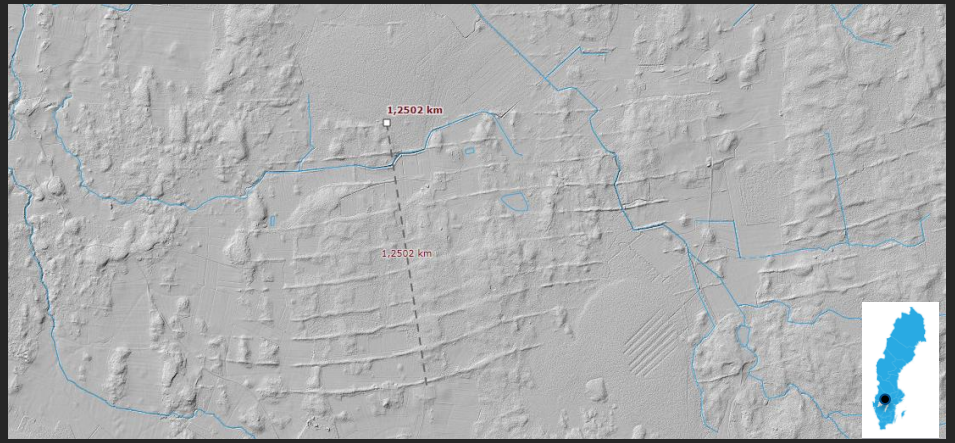


Northeast corner of the Wadena drumlin field, central Minnesota, St. Croix moraine (with hummocks and a dump ridge) on the east edge of image (mngeo.state.mn.usl)

4a. Particularly important are a range of ‘mesoscale’ landforms that are better seen with LiDAR: De Geer moraines, crag-and-tail ridges, low-relief lineations, post-glacial faults, glacial hummocks, and raised shorelines to name a few. A spate of research has come out recently on such features.

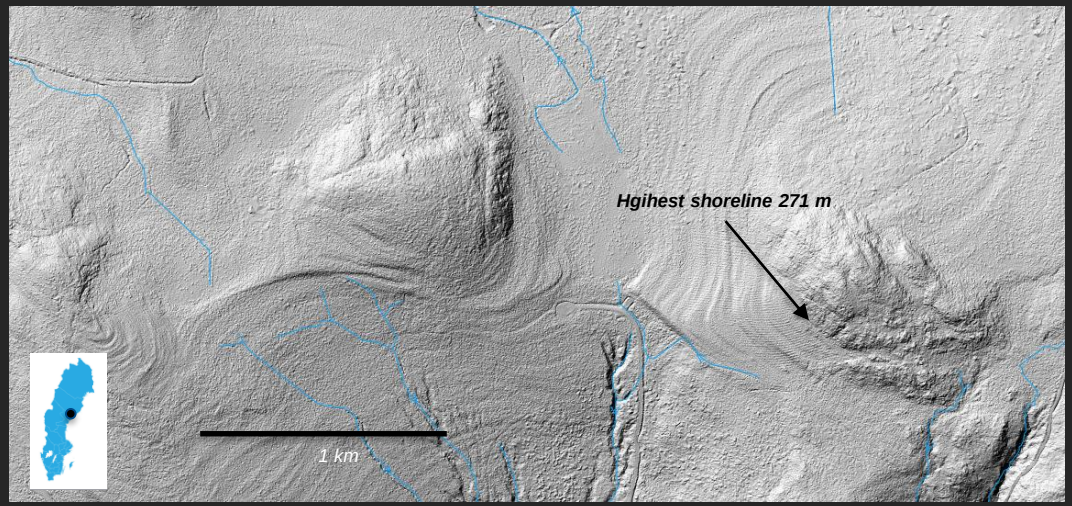


Crag-and-tails draped with De Geer moraines NE of Umeå, Sweden, (Swedish Lantmäteriet)

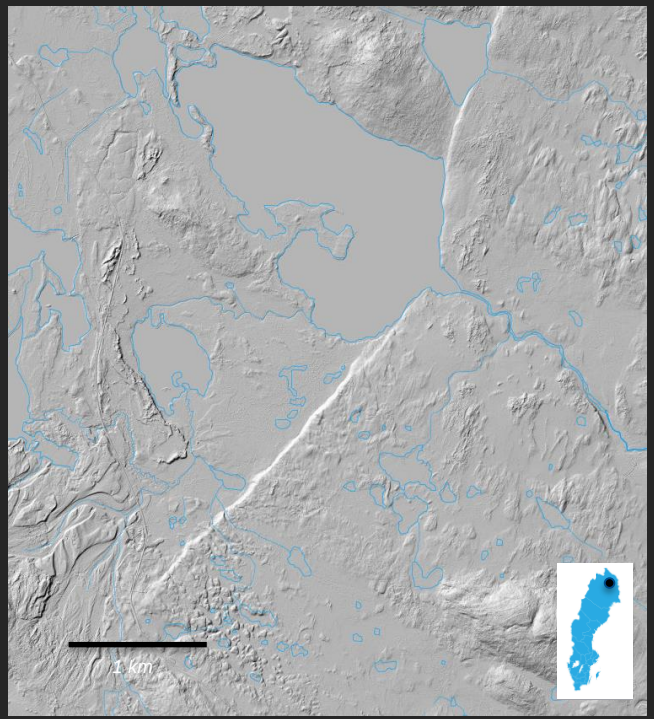


Evenly spaced De Geer moraines northeast of Skövde, Sweden, (Swedish Lantmäteriet)

4b. Particularly important are a range of ‘mesoscale’ landforms that are better seen with LiDAR: De Geer moraines, crag-and-tail ridges, low-relief lineations, post-glacial faults, glacial hummocks, and raised shorelines to name a few. A spate of research has come out recently on such features.

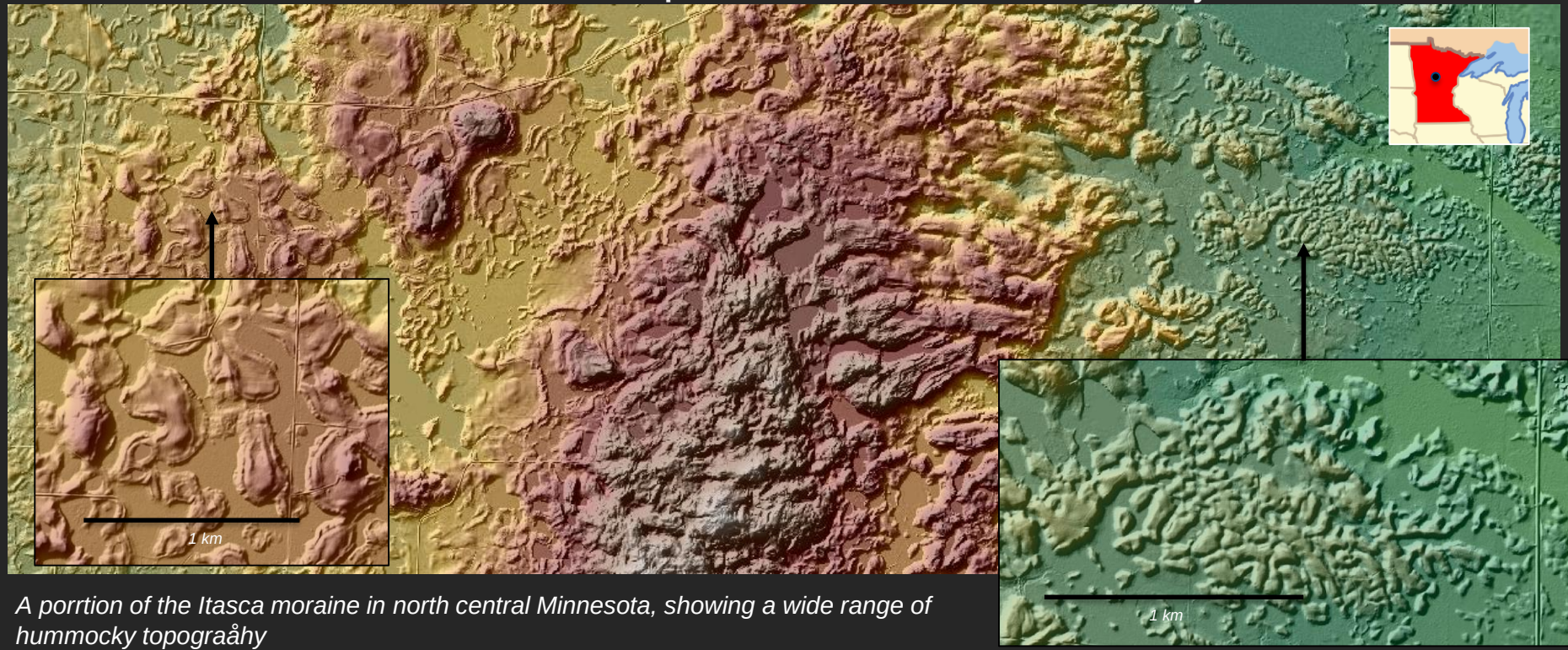


Raised shorelines of the Baltic along the Swedish east coast, southwest of Örnsköldsvik, including the highest shoreline, here at 271 m



Merasjärvi post-glacial fault scarp (Smith, and others, 2018, GFF), 30 km WNW of Junusuando

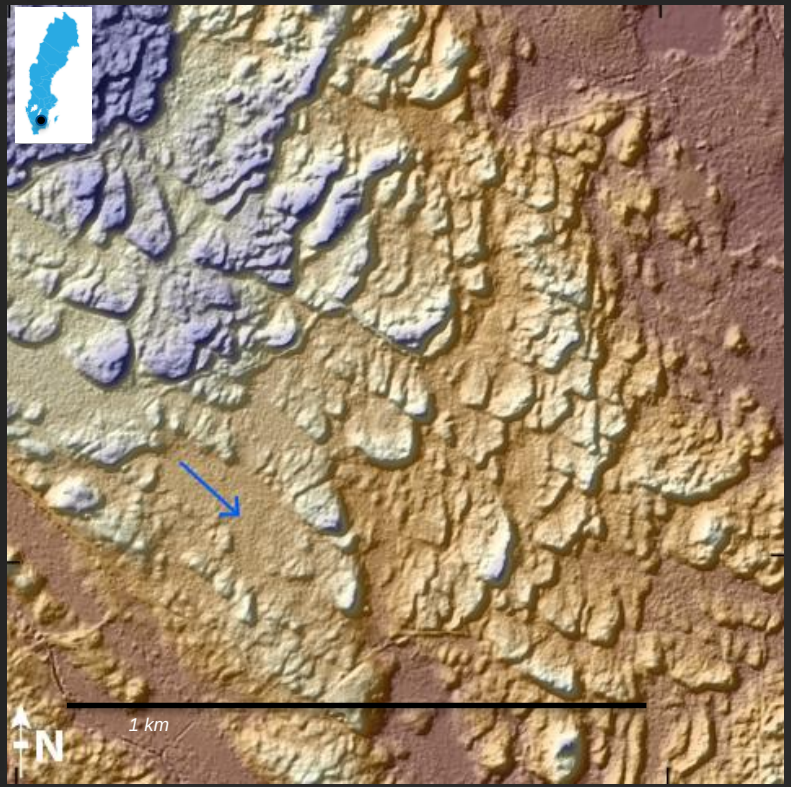
4c. Particularly important are a range of ‘mesoscale’ landforms that are better seen with LiDAR: De Geer moraines, crag-and-tail ridges, low-relief lineations, post-glacial faults, glacial hummocks, and raised shorelines to name a few. A spate of research has come out recently on such features.



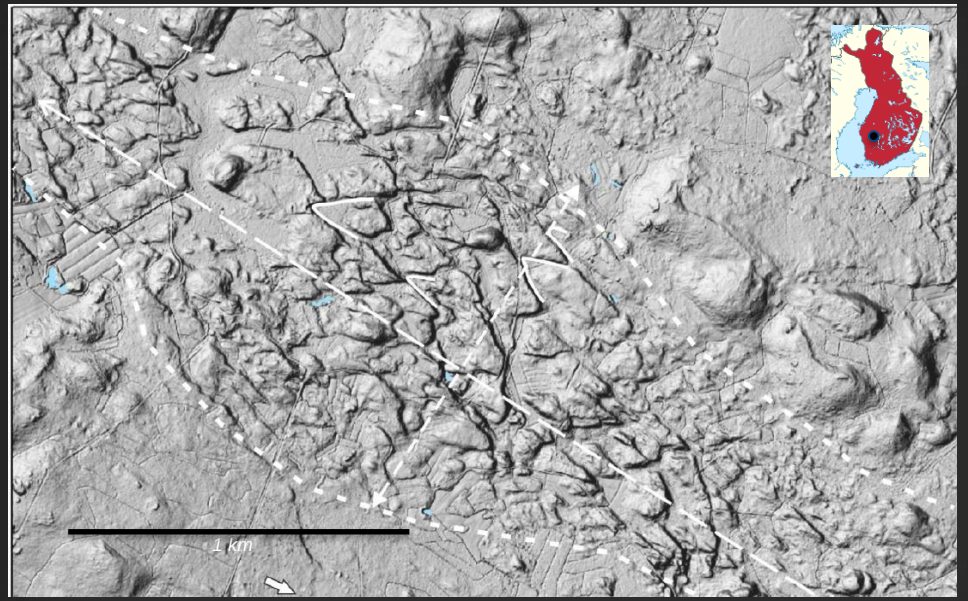
A porrtion of the Itasca moraine in north central Minnesota, showing a wide range of hummocky topograåhy

Visit our ‘murtoo’ talk at EGU2020-10537

5. LiDAR images also have the potential of revealing landforms new to glacier science, of which ‘murtoos’ are an example.



Peterson, et al, JoM, 2017



Mäkinen et al, QSR, 2017

6a. But LiDAR also raises the challenge of geomorphic classification. For example, glacial hummocks and glacial hummocky topography are a mesoscale landform that is known for its high variability. This variability, made more dramatic with new LiDAR images, along with the polygenetic origin of landforms called 'hummocks' reveals a weakness in our terminology that needs to be acknowledged and dealt with.

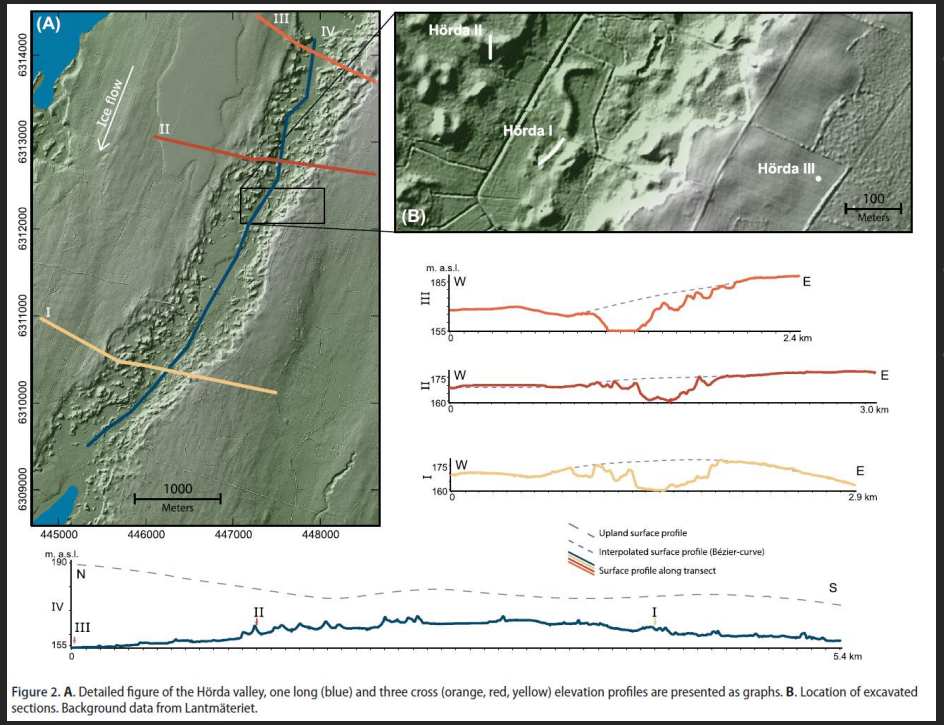


Figure 2. **A.** Detailed figure of the Hörda valley, one long (blue) and three cross (orange, red, yellow) elevation profiles are presented as graphs. **B.** Location of excavated sections. Background data from Lantmäteriet.

- Hummocks in the bottom of a tunnel valley composed of subglacial traction till
- Draped with an esker
- Interpretation: hummocks formed by subglacial-meltwater erosion

Peterson, et al, GFF, 2018

Hummock example #1 (see also slide 9)

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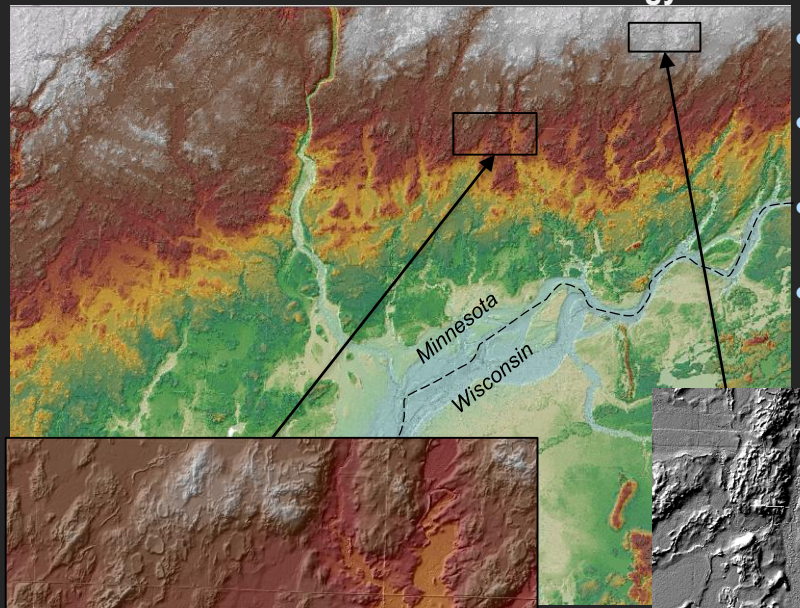
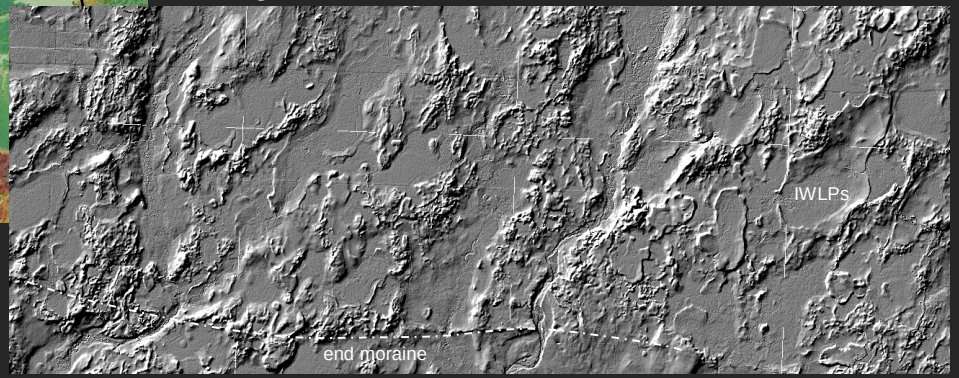


- Hummocks formed by the Superior Lobe
- Numerous 'islands' of hummocks, sharp ridges
- Ice-walled-lake plains present
- Interpretation: likely formed by stagnant ice, but why this distribution?



Hummock example #2

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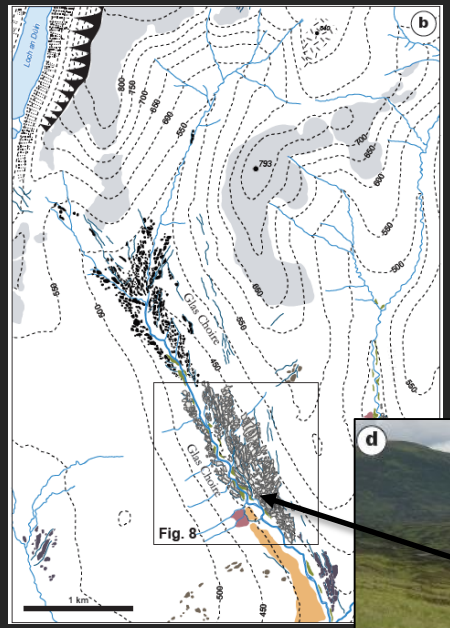
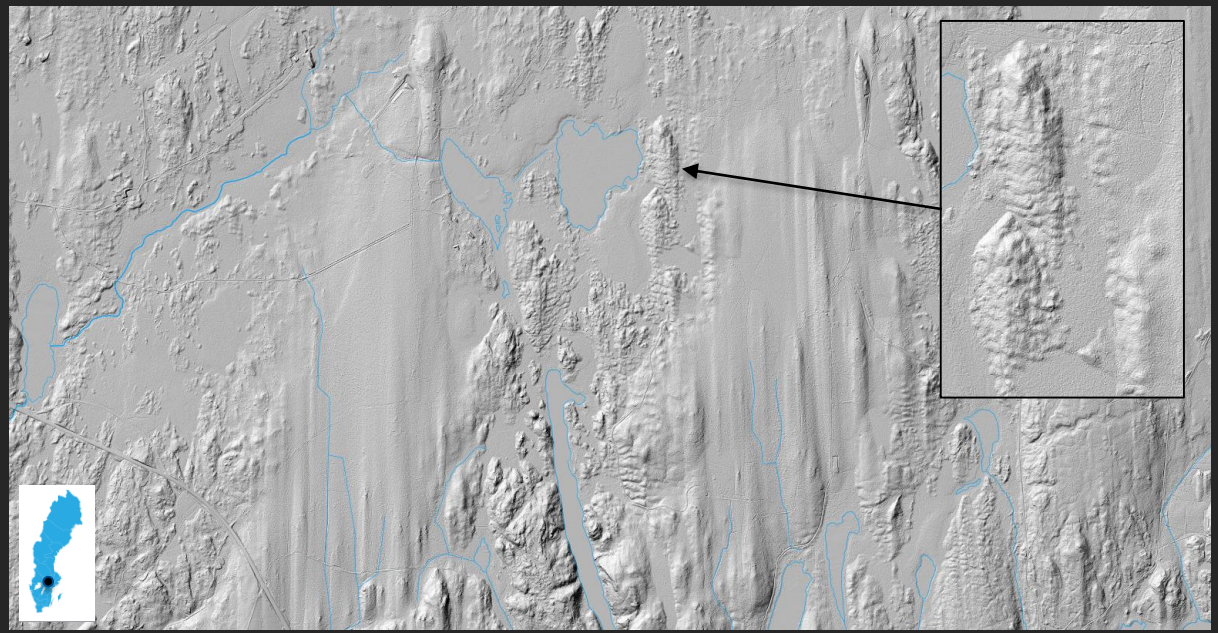


- 'Hummocky moraine' mapped in the central Scottish Highlands
- Interpreted as sediment masses (till and outwash) incised by ice-marginal and proglacial drainage, leaving a hummocky pattern

Chandler, et al, Geomorphology, 2019

Hummock example #3

6d. But LiDAR also raises the challenge of geomorphic classification. For example, glacial hummocks and glacial hummocky topography are a mesoscale landform that is known for its high variability. This variability, made more dramatic with new LiDAR images, along with the polygenetic origin of landforms called 'hummocks' reveals a weakness in our terminology that needs to be acknowledged and dealt with.



- *'Hummock-ized drumlins'* northeast of Karlskoga, Sweden
- Hummocks appear to have formed after the drumlins
- Draped with supraglacial sediment? Eroded subglacially? Fractured subglacially?

Hummock example #4

Des Moines Lobe, Iowa, hummocks

Till in a southern Sweden hummock

Challenges of LiDAR for hummocks (and other glacial landforms)

- We need to create meaningful terminologies for hummocks (and potentially other glacial landforms) in all their varieties
- To call them ’equifinal’ is to miss the point; their variety and modes of genesis are too great
- We need to avoid falsely ’shoehorning’ new forms into existing terminologies that might be misleading/wrong (like, *hummocks = dead-ice*)
- We also need to avoid a plethora of meaningless terms that classify shapes without connection to or leading to understanding
- Machine-recognition may or may not help
- We could learn from planetary geomorphologists(?); the Earth is as strange as Mars
- Landform composition is essential