Drift noses: an unusual drumlin form

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Abstract

Drumlins and related streamlined subglacial features (e.g. flutes, drift drumlins, roches moutonnées, whalebacks, rock-cored drumlins, and crag and tails) have had innumerable papers written on their possible origins. Mentioned briefly by Boulton (1987), drift-nosed drumlins are landforms that have received relatively little attention. Examples of these features can be found on the Belcher Islands in Hudson Bay, Nunavut, Canada; based on this location Boulton (1987) argued that the drift noses occur where a bedrock scarp blocked the passage of the drift mass. We apply the term drift noses to similar features found in Clarks Fork Valley, northwestern Wyoming, and in south-central Sweden. All three locations had ice at least 1 km thick. In Wyoming drift noses composed of lodgment till lie on the stoss sides of resistant granitic outcrops. Many drift noses, long rock-cored drumlins, and crag & tails occur in Sweden where individual rock cores are at the stoss ends, the centers, or the lee ends of the features. We attempted physical modeling of these features using a wooden box (our glacial trough) with water-saturated sediment and a small heated copper obstacle on the bottom. For sediment we used Palouse loess (mostly silt) or Vashon lodgment till (with pebbles removed). A groove formed on the bottom of a block of ice (our glacier) as it was shoved past the “bedrock” obstacle. Although no significant drift noses formed, crag & tails developed downglacier of the obstacle, apparently by water-saturated sediment flowing into the groove on the bottom of the glacier. Our only “drift nose” formed as modeling clay was shoved past the obstacle; this suggests that viscosity and/or cohesion may be significant factors controlling the formation of drift noses. We could not determine what other factors might be important; possibilities include water content of the drift, particle size, ice temperature and velocity, and size and shape of the bedrock obstacle.

Scandinavian and Laurentide Continental Ice Sheets; Yellowstone Mountain Ice Sheet

During the Pleistocene Ice Age, both continental ice sheets and mountain glaciers grew and decayed many times. Although the drift noses may have formed during earlier glaciations and been eroded during interglaciations, their present topography is likely a consequence of the last glaciation. During the Last Glacial Maximum about 20-25 thousand years ago, these sites were buried under at least 1 kilometer of ice, with glaciers flowing toward the south in Sweden, southwest at the Belcher Islands, and southeast in Clarks Fork Valley. The ice disappeared from the sites about 15-10 thousand years ago.

Drift Drumlins

A drift drumlin is a ridge of glacial sediment formed by ice moving over the glacial bed (Benn and Evans, 1998). Many drumlins are composed of till, but some have cores of bedrock or preexisting drift. Drumlin length typically ranges between 0.6 and 2 kilometers, with length/width ratios ranging from 2 to 3.5 (Ritter et al., 2011). There are multiple models for drumlin genesis but no consensus in the literature. The possible models include: drumlins as erosional landforms sculpted by ice, drumlins as depositional landforms dependent on debris rheology, and drumlins as depositional features formed in “cavities cut into the basal ice by meltwater floods” (Ritter et al., 2011, p.393). Considerable discussion is found in the Drumlin Symposium (Menzies and Rose, 1987).

Methods

Having identified similar features in three widely separated locations, we studied the glacial history and geomorphology of the three areas to unearth similarities and differences and attempt to explain the origin of these unusual landforms. Using Google Earth Pro, and other aerial and ground images, we measured lengths, widths, and heights of the drift noses. In the field in Wyoming we examined drift noses in terms of dimensions, composition, and ice flow direction. For the modeling experiment we constructed a wooden trough with dimensions of 48 cm long by 9 cm wide by 4 cm deep. A hole was drilled midway along the trough floor in which we inserted a steel bolt, and later a piece of copper tubing attached to a heating apparatus below, to model the bedrock obstacle encountered by the ice. The trough was filled to the height of the obstacle with partially saturated sediment, which was either Vashon lodgment till or Palouse loess. To create our “glacier” we filled a half-gallon carton with water and froze it; the ice block was then placed in the trough where we manually applied downward and forward pressure on the ice toward the obstacle. We continued applying pressure until the ice block reached the other end of the trough, where we carefully lifted the block to see if any potential drumlinoids had formed surrounding the obstacle.

Figure 1. Drift nose locations
Credit: Google Earth

Table 1. Characteristics of drift noses

Location	Glacier type	Ice thickness (km)	Approximate dimensions		
			Length (km)	Width (km)	Height (m)
Wyoming	valley glacier	1	0.2	0.1	10
Nunavut	ice sheet	3	1	0.3	5
Sweden	ice sheet	2	1.6	0.4	5

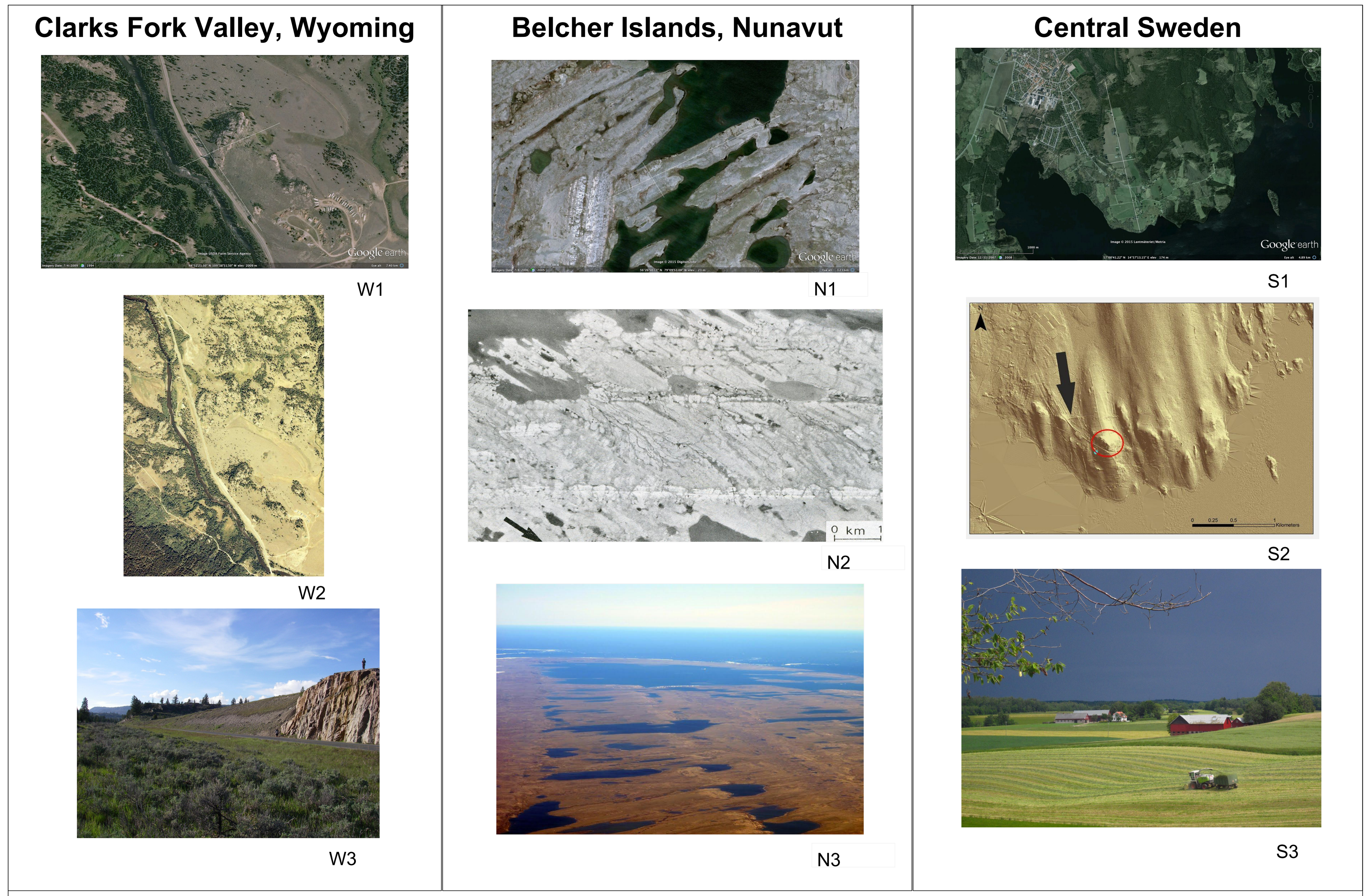
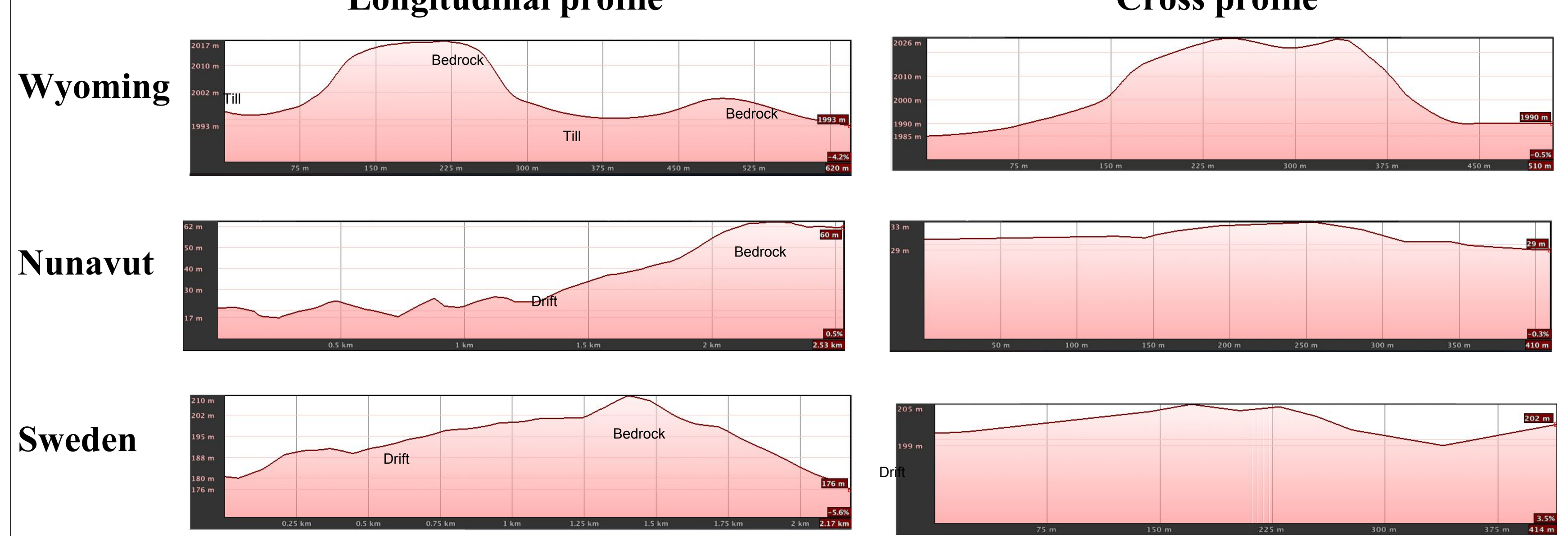


Figure 2. Images of drift noses and related forms.
Credits: W1, N1, S1: Google Earth. W2: 1980 Air Photo, U.S. Department of Agriculture. W3: Carson. N2: Boulton, 1987. N3: Timothy K, Nearing Sanikiluaq on Flaherty Island, Panoramio 2012. S2: Dowling. S3: kadege59, Hay Harvest, flikr 2014.

Figure 3. Profiles of drift noses



Note: Lines of profile in Figure 2: W1, N1, S1. The longitudinal profiles are aligned so that ice movement is from left to right. (Profiles to different scales.)
Credit: Google Earth

Photo 1: Researcher applies pressure onto the block of ice.

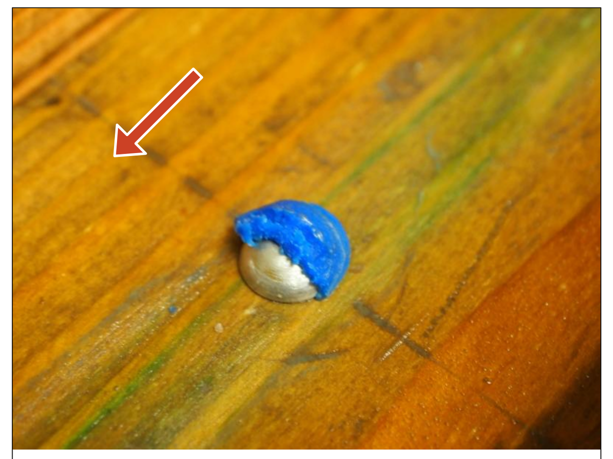


Photo 2: Drift nose in trial 1 using modeling clay. Arrow indicates direction of ice movement.

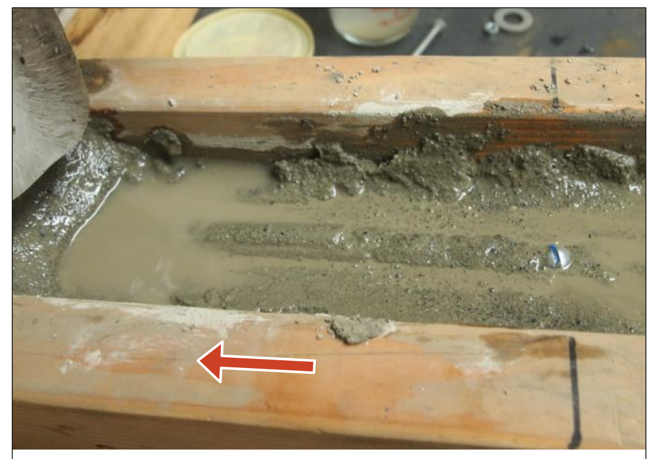


Photo 3: Crag & tail formed in trial 8 using Vashon till.

Photo 4: Crag & tail formed in trial 4 using Vashon till.

Table 2. Results of modeling experiment

Trial	Sediment type	Obstacle height	Drumlinoid (drift nose or tail) formed?
1	Modeling Clay	3 mm	Drift nose formed with modeling clay (photo 2)
2	Loess	22 mm	Inconclusive; obstacle too high
3	Loess	1.5 mm	Yes; subtle tail
4	Loess	2.5-3 mm	Yes; prominent tail, 18-22 mm in length (photo 4)
5	Till	3 mm	Yes; subtle tail
6	Till	3 mm	Inconclusive
7	Till	3 mm	Yes; prominent tail, 4-5 mm tall and 15 cm long
8	Till	8 mm	Yes; prominent tail, 6-7 mm tall and 9 cm long (photo 3)

Discussion

Drift nose drumlins are only mentioned in the literature once in a paper by Boulton (1987); he includes a photo of a drift nose on the Belcher Islands in Hudson Bay. We also identified and characterized forms in northwest Wyoming and south-central Sweden. In most settings, the drift noses are “upglacier” of resistant bedrock and include tails, such as those in crag and tails, on the “downglacier” side. Unlike most drift drumlins and roches moutonnées, which commonly have a relief of 100 meters, the drift noses do not have a relief of more than 10 meters. In Nunavut and Sweden the length and width of drift noses is comparable with those of crag and tails. The sparse drift noses in Wyoming are composed entirely of lodgment till; they do not have as much relief as nearby roches moutonnées. Drift drumlins (e.g. on Sun Prairie, Wisconsin) may have a relief of more than 30 meters. Based on striations on bedrock in Wyoming, drift noses are oriented parallel to ice flow. The drift noses in Nunavut and Sweden were only investigated remotely, and no determination of subglacial mechanisms for the formation of the features was made. Drift noses occur in close proximity to crag and tails and roches moutonnées. What subglacial processes are needed to create the variety of landforms in close proximity? We agree with Boulton’s idea that drift must pile up against a rock obstacle. In Clarks Fork Valley, Wyoming, roches moutonnées are the primary positive landform, and drift noses occur only locally.

In our modeling experiments, we were unable to successfully model the formation of a drift nose with sediment. Of our 8 trials, 2 provided no results, and 5 trials yielded drift tails of sediment. In each trial either loess or till accumulated on the downglacier side of the obstacle, making a long ridge. No sediment was deposited on the upglacier side of the obstacle to make a drift nose. The entire length of the bottom of the ice had a groove the depth and width of the obstacle. It appears that pressure at the base of the ice caused water-saturated sediment to flow into the groove to make the crag and tails.

The modeling clay experiment yielded a formation more closely resembling a drift nose. This suggests that viscosity and/or cohesion may be significant factors controlling the formation of drift noses.

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