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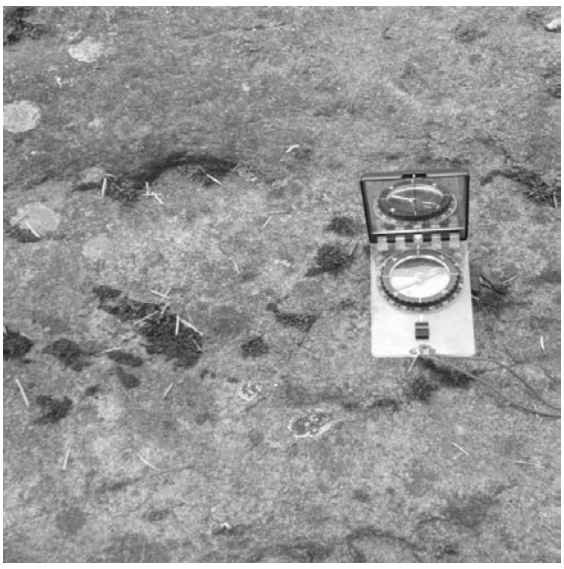
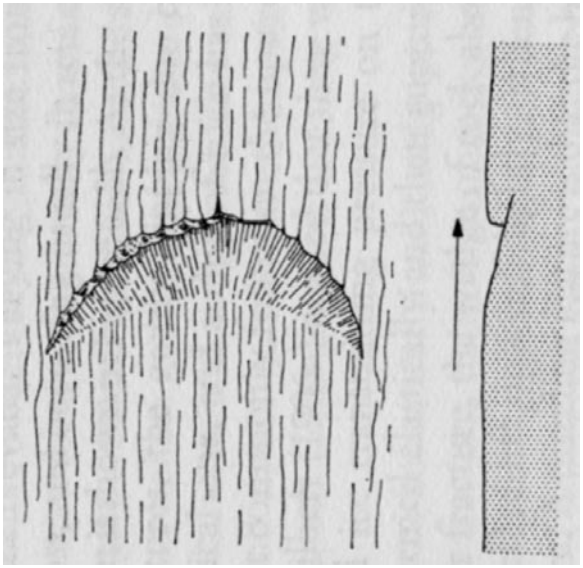
Gabriola's glacial drift—scratches and *roches moutonnées*

Nick Doe

Small-scale markings on rock faces are not something most people spend a lot of time looking at, but even microscopic scratches on old faces can provide fascinating hints of the rock's history. Besides striations and grooves, glaciers create crescentic gouges; nailhead striae; crag-and-tails (known as rat-tail striae when small); *roches moutonnées* with their stoss-and-lee surfaces; and more.[1]

Lindley S. Hanson





Above: a textbook crescentic gouge. Note the direction of the ice is up the page.

Left: The real thing. Picture from the Web.

Bottom left: Gabriolan versions, or so it seemed at the time. They actually have nothing to do with glaciation (see text) which explains why these are pointing in exactly the wrong direction (the camera is looking NW where the ice is supposed to have come from, not where it was going to).

According to the textbooks, these all give indications as to which way the ice was flowing; though to be honest, I found it pretty easy to find confusing examples, such as crescentic gouges pointing the "wrong" way, and *roches moutonnées* with steep slopes facing upstream giving them the profile usually identified with crag and tails.

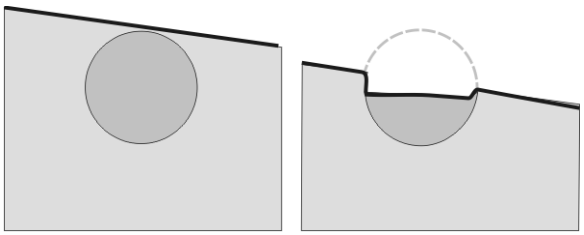
Small-scale glacial markings

Perhaps the most common small-scale markings left by ice on rock faces are *crescentic gouges*. The ice has forced a stone into the bedrock creating an indentation; however, eventually the forces

[1] Neal Iverson, *Morphology of glacial striae—implications for abrasion of glacier beds and fault surfaces*, GSA Bulletin 103, 10, pp.1308–16, 1991.

involved become too great and either the stone shatters or the ice gives way. The deepest side of the gouge indicates the downsteam direction of the ice.

A cause of confusion on Gabriola are common features in sandstone surfaces that look like crescentic gouges, but aren't. One in particular had me puzzled for weeks as it points in exactly the "wrong" direction. A back eddy in the ice perhaps? …not very convincing.



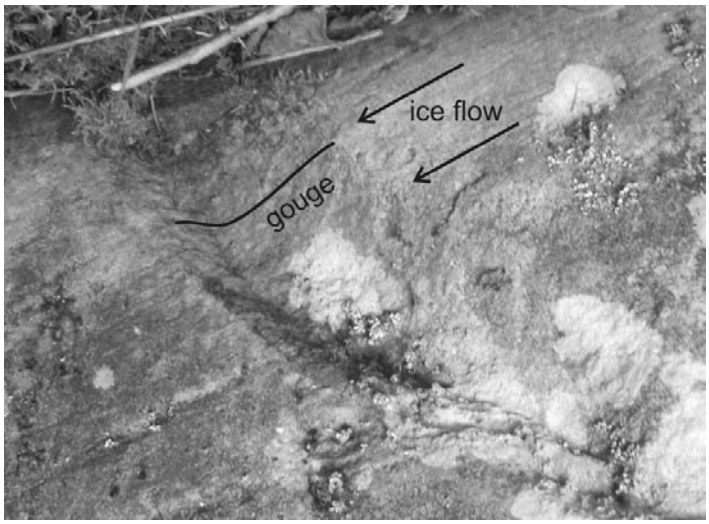
Concretions in sandstone are commonly spherical because the sandstone within them is cemented with *calcite*, a mineral that was formed from the halo of carbon-dioxide-rich groundwater created by microbes feeding on a morsel of organic matter buried in waterlogged sand before it became sandstone. Acidic run-off in the modern forest erodes the *calcite*, which chemically is calcium carbonate. On a slope, this creates a gouge that has nothing to do with glaciers.

The light dawned when I realized that these pseudo-CGs were all pointing uphill, no matter what the geographic direction. They are, in fact, small weak concretions. Concretions are cemented with *calcite,* so, in the forest, they erode faster than the parent rock because the runoff is acidic. Hence the upstream lip.

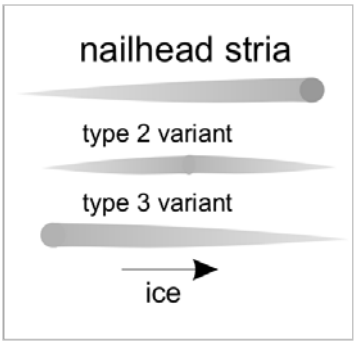
True crescentic gouges were not that easy to find and I'm glad I didn't have to find them to know which way the ice flowed.

Just as difficult to find were *nailhead striae*. These are the usually the same small size as striae and were created when grit was pushed deeper and deeper into the bedrock until it, or the ice, gave way or the grit rotated out of the groove. The head of the nail is on the downstream side. They are nearly always badly eroded on sandstone surfaces. Reversed nailhead striae also occur (see box below).

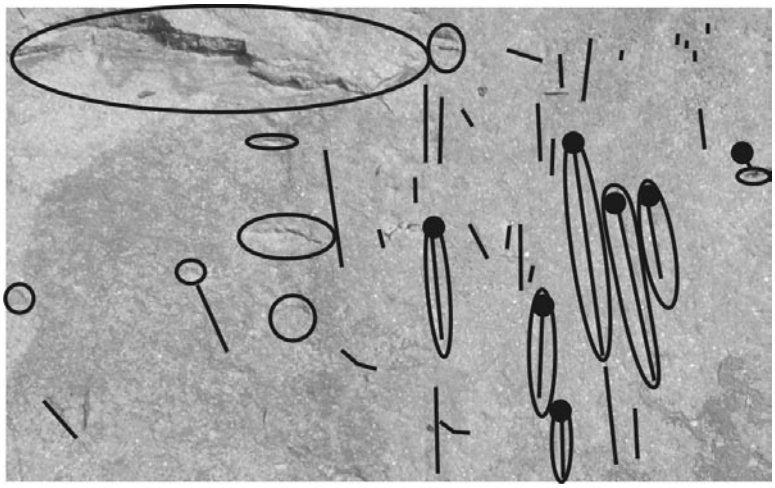
Crag-and-tails and the smaller rat-tail striae are formed when ice meets an obstacle that is resistant to erosion. Softer rock and till that is sheltered on the lee side of the crag or embedded granule forms the tapered tail. These are rare on Gabriola sandstone.



A true Gabriolan crescentic gouge. The white areas are lichen. Until recently, it was buried, which helped preserve the detail.



Striae are formed when grit is forced into the bedrock. Nailhead striae terminate abruptly when the grit rotates, breaks, or the ice gives way. In type 2 variants, ploughing increases until the grit rotates or shatters, and then decreases. In type 3 variants, grit is abraded after contact or pushed back into the ice leaving reversed nailheads.



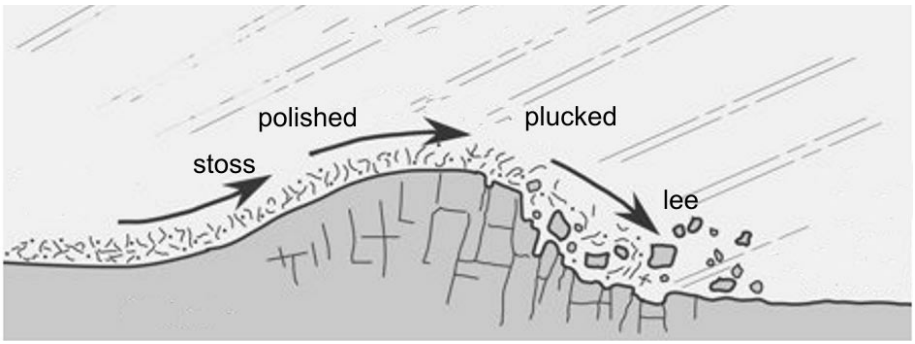
Right: The fascinating world of glacial scratches on Gabriola. Gouges and nailhead striae (type 1), mostly only seen on your hands and knees and when the sandstone surface has only recently been exposed. Field of view is about 12 inches.

Roches moutonnées

A *roche moutonnée* (sheep rock), sometimes called a "whaleback", is a rocky landform, oriented in the direction that a glacier once flowed. The upstream or stoss side (from the German *stoß*, impacted), is gently sloping and smooth, and the downstream, or lee side (old English, sheltered), is steep and rough.

Smooth polished surfaces occur where the ice was under increasing pressure because of an obstruction or an uphill incline. At the bottom of the glacier, the increasing pressure on the ice made the ice viscous or even liquid. It's the sort of ice that exists beneath skaters' blades. Finer sediments in the ice then scoured and polished the rock.

The rough broken surfaces occur where the pressure was suddenly relieved. Any water in the ice instantly re-froze and, in doing so, it sometimes welded the glacier to the bedrock. Subsequent movement of the glacier could then drag chunks of bedrock out of position. This is particularly effective if the rock is already fractured. This process is known as "plucking".



The classic *roche moutonnée* structure. The upstream side is gently inclined and polished; the downstream side is steeper and broken.

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Once you have developed an eye for the distinctive profile of *roches moutonnées* you begin to see them everywhere, but they may not all be glacial landforms. Folding of the bedrock in the Eocene 42- and 55-million years ago and subsequent non-glacial erosion can imitate the profile. Local examples of landforms that might or might not be entirely glacial are (*top left*) Woodley Range seen from Cassidy Airport; and (*bottom left*) Cedar with Dodd Narrows on the right. The islet (*near left*) off Link Island is however the real thing.

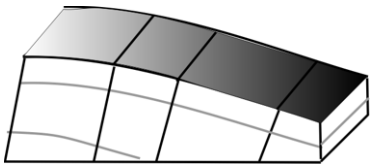
Textbook examples of *roches moutonnées* are hard to find on Gabriola for several reasons; one being that the island has been glaciated from more than one direction. Whaleback Rock* shown here is a good example. Its main axis lies parallel to the strait (NW is on the *left*, SE on the *right*), but it has some striae from the NE on the NE-facing side in addition to many from the NW. The NW end of the rock, the upstream end, is smooth sandstone; the SE end, the downstream end, is broken and strewn with boulders.

* the rock lies in the Pylades Channel off the south end of Mudge and the north end of Link (east of Grassy Islet). The rock was likely known to the Snunéymux^{w} as *qwunus* (whale) and some geologists also call *roches moutonnées* "whalebacks".

Roche moutonnée features

The simple form of a *roche moutonnée* is, in my experience, fairly rare on Gabriola for a couple of reasons.

The first is that the island was glaciated from two, possibly even three, directions during the last ice age. Each direction eroded the rocks anew, and removed, re-distributed, or buried any rubble left over from earlier ice movements. The second is that the sandstone bedrock was heavily fractured perpendicular to bedding planes long before the Pleistocene,[2] and these fractures, along with the bedding planes themselves, encouraged the ice to remove blocks of bedrock that were far more angular ("blocky") than would have been had the bedrock been unfractured *granite*.



Cliff formed by severe erosion of a fractured fold. Erosion by ice is likely, but other agents may also be involved.

Despite this, polished sandstone planes resembling stoss sides, and likely created in identical fashion, are common on the island, as are rugged cliffs with boulder fields at the bottom resembling lee sides. Gentle inclines with abrupt and rugged drop-offs are not however necessarily *roches moutonnées*.[3] Healthy suspicion is especially called for if the landforms are large and linear. They may be a concealed thrust fault (unlikely on Gabriola) or a normal fault; or they may be the upturn of a fold that has been severely eroded over many millions of years by a variety of agents. Cliffs in rock that is fractured perpendicular to the bedding-planes (common in the Gulf Islands) may have been created by removal of rock by ice; and the cliffs may also have been created by undercutting, the older rock exposed at its base (commonly shale) being less resistant to weathering than the rock above it (commonly sandstone).[4]

The origin of the term roche moutonnée

Various sites on the web give different explanations for the origin of the term *roche moutonnée*—sheep rock. Without doing the research,[5] I can't be sure which might be right, but I can offer the following thoughts.

Without doubt, the worst explanation I have come across is that the term refers to the fact the rocks when scattered in a field have the appearance of being grazing sheep. This is misleading because a *roche moutonnée* can be any size including being very much larger than a sheep.

The second most dubious explanation, but one that is common, is that it refers to the fact that in the 18th-century, it was fashionable for men to smooth the front part of their wigs with fat, leaving curls at the back. And the fat that they used was mutton fat.

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[2] N.A. Doe, *Gabriola's fractures—their origins*, *SHALE* 20, pp.3–12, April 2009.

[3] Some geologists prefer to reserve the name for landforms created solely by ice, but hills or even mountains that may have existed before the onset of glaciation and have been heavily eroded in *roche moutonnée* fashion, are common in our area. My preference is therefore to use the term fairly loosely.

[4] Mudrock (shale), which often underlies sandstone in the Gulf Islands, weathers faster than sandstone because it has a higher density of fractures and bedding planes. These reduce the rock's resistance to erosion by the sea, and they also allow the ingress of air and water, which accelerates chemical and freeze-thaw weathering. H.M. French, *The Periglacial Environment*, p.39, Longman, 1976.

[5] The term was first used by H.B. de Saussure in 1787.

I have a couple of problems with this. One is that it appears from what I have read that men far more often powdered their wigs than used fat. The other is that much of the point of wearing a wig was that it simplified hygiene. Head lice were a big and unavoidable problem in those days, and by shaving one's natural hair and wearing instead a washable and readily inspectable wig the problem could be controlled. Smearing the wig with fat in such circumstances wouldn't seem to be a good idea.

The explanation that appeals to me most, even if not true, is that the term refers to the general 18th-century hair style, whether using natural hair or a wig, that involved brushing the hair straight back from the forehead, leaving curls at the back. And this "sheep style"—*à la mode moutonnée*—was so-called because of its resemblance to the off-the-face fleece of sheep.

If you don't like this idea, try surfing the web. You'll find several other explanations.

While we're at it, we might also note the etymology of the word "stoss", the upstream polished side of a *roche moutonnée*. The word is German, *stoß* (stoss) meaning in this context "impacted". "Lee" is a good old English word meaning sheltered, usually used to indicate downwind or sheltered from the wind, but in the case of a *roche moutonnée*, the downstream, rugged side, of the glacial landform. ◊

Articles: