Roche Moutonnée in the Okanogan

By John C. Holden

Geomorphology is the branch of geology that studies land forms created by tectonic forces which are then sculpted by agents of erosion and deposition to create the scenery that we see today. In our area we have distinctive mountains and hills called roche moutonnée that were formed by the erosional action of moving ice sheets dominating the northern hemisphere during the past 1.8 million years. Ice sheets because there were probably about six of them that invaded our area all the way down to the upper Columbia Plateau. Each ice surge lasted about 100,000 years including about 10-15,000 years of relatively warm interglacial stages the last of which we are currently in.

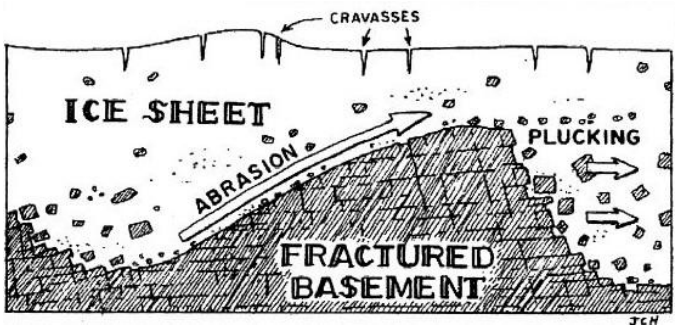

Figure 1 - Dynamics: how abraision and plucking by moving ice form roche moutonnées.

Figure 1 illustrates how roche moutonnées form. Continental glaciers erode in two ways: (1) by abrasion as the ice - thousands of feet thick – scraped over the basement rock under high pressure loaded with sand, gravel and boulders facilitating erosion by grinding and scraping, and (2) by plucking (sometimes called quarrying) where large and small blocks of the substrate are lifted out en masse and carried away The result of these two combined activities results in asymmetric mountains and hills as depicted in the illustration. The sides with a gentler slope (the stoss face, German for "pushed") are often artfully smooth and pleasing to the eye represents the direction from whence the ice came. The steeper lee face represents thither the ice flowed and are rough terrains posing challenges appreciated by rock climbers. Figure 1 is not to scale. During the glacial maximum 18,000 years ago the ice was several thousands of feet above the local roche moutonnées and, for that matter, over most of the other mountains in the Okanogan. Cracks undoubtedly formed on the upper surface of the ice as they do today on glaciers because at a depth of 165 feet, pressure allows the ice to flow as a highly viscous fluid but above that depth the ridged ice fractures forming crevasses.

After the ice melted the larger blocks plucked from the lee faces of roche moutonnées were often left behind as erratics - especially those that were plucked late in the glacier's story. Those plucked early-on were relentlessly ground into glacial flour. Erratics are usually cuboid in shape, or the rounded equivalents thereof, reflecting the fracture pattern of the parent basement rock. Most rocks in the earth's crust are fractured by three sets of mutually perpendicularly oriented fractures called “joints”. These are flat-sided cracks that define the cuboid form.

The term "roche moutonnée" means "fleecy rock" in French. During the 17th century, when the science of past continental glaciation was being developed in Europe, the shape of these distinctive mountains resembled (at least to some) the undulating swirls of hair in the elaborate wigs worn by aristocrats on the continent as well as in England that were slicked down with mutton fat. Hence, "mountains of sheep". British barristers to this day wear their curly mountains of sheep when practicing their craft (but they no longer use mutton fat.)

Roche moutonnées can be developed from any of the three rock types comprising the earth's crust: metamorphic, igneous, or sedimentary. In the Okanogan they occur mostly in the metamorphic Okanogan Highland Gneiss that dominates the geology east of the Okanogan Valley down to the Columbia River. The erosional process of roche moutonnée formation, is dramatically evidenced along the Okanogan Valley from Omak to Tonasket where waves of stoss face-lee face valley wall can be seen defining the east flank of the Okanogan Valley like frozen waves in solid rock. One would think the ice sheet flowed down from Canada purely in a southerly direction. However, along the Okanogan Valley and the Omak Lake Trench, there is a westerly component to the ice flow as suggested by the orientation of the roche moutonnées there. Figure 2 shows three of these at the mouth of Tunk Valley. Figure 3 shows one at the north end of Omak Lake Trench. Possibly much of the ice that fed the Okanogan Lobe was from the west off the Cascades. Interestingly enough further east in Aeneas Valley the roche moutonnée have an orientation indicating ice flow from the northeast! (Fig. 4). The piggyback moutonnées on Omak Mtn. Road indicate the ice flowed south there (Fig. 5).

Looking south on the west side of the Okanogan Valley, on Brewster Flat, two small roche moutonnées are developed on Igneous granite shown in figure 6. Like the Okanogan moutonnées, these also have a strong east-west orientation indicating ice flow from the Cascades. In the photo, several other even smaller moutonnée-shaped granite knobs are visible poking out through the smooth rounded till piles left behind by the last of the melting ice sheet.

By the way, those parallel horizontal lines on the till piles are 'bovine stroll lines' caused by extensive cattle grazing and are not a geological phenomenon. (Ed. Note:

While there is consensus that most of the of the lines are as described, there are a number of folks that think some of the lines are too horizontal and too regular to have been formed by wandering animals.)

All diagrams and photos for this article were provided by the author.

Figure 2 - Three roche moutonnées near the mouth of Tunk Valley.

Figure 3 - Looking north across Omak Lake at Deep Canyon roche moutonnée.

Figure 4 - Looking southeast from Aeneas Valley Road at several roche moutonnées.

Figure 5 - Three piggyback roche moutonnée visible looking east from the Omak Mtn. Road.

Figure 6 - Looking south on Brewster Flat at two small granite roche moutonnée.