TRIP B1

BEDROCK EROSIONAL FORMS PRODUCED BY GLACIAL PROCESSES, NO. 2 MINE, GOUVERNEUR TALC CO., GOUVERNEUR, NEW YORK.

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INTRODUCTION

This trip takes place at the No. 2 (Arnold) open pit mine of the Gouverneur Talc Co. NYSGA last visited this location in 1971 on a trip led by J.S. Street (St. Lawrence University). He described a number of highly polished grooves, flutes, crescentic fractures, and striations present on bare bedrock surfaces (Street, 1971). Stops on this field trip will focus on the geologic setting of the region, history of pit operations, and a re-examination of the intriguing erosional forms present on both horizontal and vertical exposed bedrock surfaces. Our discussion will center on the nature and classification of these erosional forms, field evidence suggesting their possible origin, relationship to regional ice flow patterns, and their possible implications regarding subglacial processes and conditions.

History of Talc-Tremolite Mining and Regional Structural Framework

Talc-Tremolite mining has been continuously active in this area since the 1880's. The Arnold open pit is located in the immediate vicinity of some of this early mining. The abandoned Arnold mine at the north end of the present #2 pit and the Wight mine at the south end represent old underground operations that are a part of this early history. Changes in demand, property lines, company acquisitions, and the lack of accurate geological data have combined to account for the fact that the current ore body is still available to modern mining.

Current markets for this industrial filler material are predominantly in the ceramic and paint industries. The tremolite is used mostly in ceramics and the talc ores in paints. Their use as filler in flooring, caulking compounds, rubber, and many other products account for the remainder of the market.

The ore zone is identified by the no. "13" of a total of 16 stratigraphic layers in the Upper Marble Formation of the Precambrian Grenville series. It is this Upper Marble that exhibits the zones of mineralization and alteration that are commercially important. These well layered beds are the southeastern flank of an overturned anticlinal fold, which created a post erosional surface with a regional N-43-E strike and N-W dip of about 45-50 degrees, resulting in the older beds overlying the younger. These rocks have been highly metamorphosed and folded through 4 or 5 phases. A.E.J. Engle proposed that the tremolite was formed during metamorphism by dedolomitization of dolomite, a process that has almost completely obliterated the host rock. Underground relationships, such as the usual lack of direct contact of tremolite and calcitic marble, do not entirely support this theory. Another theory proposed that the talc-tremolite-anthophyllite schist is associated with evaporites in the Upper Marble Formation; the protolith of this unusually Mg-rich rock was probably a magnesite-bearing, siliceous evaporite. The evaporates of anhydrite and gypsum increase as a constituent of this unit down dip. Unit 12 is a relatively pure marble, usually coarse-grained, ranging in color from dead white to light gray. Unit 14 was described as quartzose calcitic marble by Engle, but subsequent underground mapping shows as many as fourteen possible subunits, many of which may be repetitions by folding. A relatively recent discovery within these marble units that support relationships of orientation has been the identification of "stromatolites" in unit 4. The fact that they were found upside down in the underground zinc mines confirms the direction of the youngest to oldest layers.

Geomorphic Setting and Glacial History

The open pit mine of the Gouverneur Talc Co. is located in the region known as the Frontenac Axis. It bridges the south and north sides of the flat-lying sedimentary rocks of the western St. Lawrence Lowland and consists of low relief, northeast-southwest trending ridge and valley topography resulting from differential erosion of Precambrian crystalline bedrock. The No. 2 mine occupies one of a series of linear valleys which extend from the Axis to the edge of Lake Ontario. Most of the linear valleys are sub-parallel to ice flow directions, but are more closely oriented down-dip in the direction of regional slope towards the Ontario Basin. The rock-walled linear valleys (as first named by Wilson (1904)) are 5-10 km in length, 0.5-1.0 km wide, and are best developed in the cuestaform remnants of the Black River Group to the southwest of the Axis.

Features relating to the most extensive glaciation recorded in the area can be found to the south on the upland of the Tug Hill Plateau . Streamline forms trending southeast record regional flow patterns probably formed during maximum glaciation of the region. A change in orientation of the streamline features on the northwestern edge of the Tug Hill suggests a subsequent shift in flow conditions and may correspond to late glacial movement of an ice lobe, identified here as the St. Lawrence- Lake Ontario Lobe, which was funneled into the Ontario Basin with its border "wrapped" around the Tug Hill sometime after the Port Huron advance (> 13 ka B.P.) (Street, 1966; Muller, 1978; Pair and Muller, 1990).

Thinning and wastage of the post-Port Huron ice mass constrained ice lobes to the Black River Valley and the Lake Ontario and St. Lawrence Lowlands (Muller and others, 1986). Secondary sets of striae with clear crosscutting age relationships, and ice marginal borders which parallel contours along the northern promontory of the Tug Hill and sides of the Black River Valley, attest to the sensitivity of the ice mass and its margins to local relief during ice marginal recession. The positions and morphology of former ice borders in the study area are functions of bedrock relief. The ice margin initially descended off the slope of the Tug Hill, and later, onto the low relief of the western St. Lawrence and eastern Lake Ontario Lowlands. Following northward encroachment by Glacial Lake Iroquois, ice-border morphology during recession was additionally influenced by deep water at the ice margin. Ice border features in the Lowland include subaqueous ice marginal fans and morainal banks, while in the upland, subaerial outwash plains and moraine-esker-outwash complexes typify recessional margins (Pair and Rodrigues, 1993). Detailed understanding of the deglacial setting in the Frontenac Axis is important and establishes that the erosional features described below were produced beneath an ice lobe fronting on a deep proglacial lake. They are therefore probably subglacial, rather than subaerial, in origin.

BEDROCK EROSIONAL FORMS

Description and Classification

The bedrock erosional forms which can be studied at the No. 2 mine are only those which have escaped the stripping and quarrying operations associated with ore extraction. The remaining forms can be found on most of the unweathered bedrock surfaces. Erosional forms are present on both horizontal pavements and on the preserved vertical headwall above the operating pit. For the purposes of discussion, the erosional forms and other associated features have been grouped into the following categories:

I. Chattermarks and Crescentic Fractures
II. Plucked Surfaces
III. Striations
IV. Grooves (>.5 m wide and deep)
V. Roches Moutonnees
VI. Crag-and-Tail forms
VII. Precipitates of calcium carbonate and cemented crusts
VIII. S-Forms (categories from Kor et al.(1991)):
    Transverse: Muschelbruch, Sichelwanne, Comma forms, Transverse Troughs
    Longitudinal: Spindle flutes, Cavettos, Furrows.
    Nondirectional: Undulating Surfaces, Potholes

Possible Origins

Many of the bedrock erosional forms present appear to be a direct result of the action of glacial ice. Forms most often attributed to crushing and fracture of bedrock such as the chattermarks and crescentic fractures were reported by Street (1971) and can still be observed on several of the remaining horizontal surfaces. Pressure melting and regelation, together with basal slip can readily explain the plucked surfaces, precipatates, and cemented crusts on both horizontal and vertical bedrock surfaces. Striations produced by glacial abrasion can be observed on virtually all of the unweathered surfaces. These include the insides of many overhanging ledges. In addition, Fred Totten reports that when the overburden was first stripped from these features in the 1960's, there were obvious 'tools' still associated with some of the grooves. Larger more complex features including the roches moutonnees and crag-and-tail forms present at the site reflect a combination of abrasion and plucking especially associated with several of the resistant intraclasts present within the marble units.

Other forms on the vertical bedrock face suggest processes other than those associated with the direct action of glacial ice. These are certainly the most controversial as to their origin. Similar forms were described by Sharpe and Shaw (1989) and a formal classification has been proposed by Kor et al. (1991). These S-Forms (sculpted forms) are a suite of erosion marks attributed by Kor et al. (1991) to the action of subglacial meltwater. "Broad sheetfloods of turbulent subglacial meltwater " (Shaw, 1989, p. 853) that were released catastrophically were invoked in explaining S-Forms, the linear valleys, and both depositional and erosional forms throughout the Lake Ontario Lowland and Frontenac Axis by Shaw and Gilbert (1990). This interpretation has been questioned by Muller and Pair (1992).

DISCUSSION

The bedrock erosional forms at the No. 2 Mine may provide information about subglacial processes and conditions. Pair and Muller (1990) suggested that the linear valleys in the region were initially the products of the structure and differential erosion of the rocks of the Frontenac Axis. These may have existed prior to the most recent glaciation but have been modified either by: a) glacial abrasion and plucking by ice; b) erosion by subglacial meltwater trapped between the relatively impermeable bed and the glacier, or c) some combination of both processes. The presence of such valleys would also have served as a conduit for available meltwater in a basal drainage system.

Field observations of the S-Forms present on the wall of the linear valley at the No. 2 Mine are suggestive of a medium other than glacial ice. Both the transverse and longitudinal forms display furrows with very sharp rims present on their up-ice (or up-current) sides, attached lateral furrows on either side which broaden and become more shallow with distance, and have sharp edges on highly curvilinear, often asymmetric forms. The morphology of such forms is remarkably similar to the scour which occurs around a bluff body or obstacle under conditions of unidirectional water flow. The distinct upstream and lateral furrows around the concretions strongly suggest separated flow and turbulent conditions. Such obstacle marks have been well described by Allen (1982) as forming in both fluvial and eolian environments. Further, consideration of the properties of the erosive agent responsible for the scour-forms also suggests an erosive agent of low viscosity. The sharp edges on highly curvilinear, often asymmetric forms, as pointed out by Allen (1982), as well as early workers like Chamberlin (1885), suggest that such behavior is unlikely for ice (Reynolds Numbers for ice have been estimated to be 1×10^{-13} (Sharpe and Shaw, 1989)) and is more readily ascribed to the action of a fluid. Corrasion by small volumes of sediment-charged subglacial meltwater satisfies the requirement for an erosive agent of low viscosity that could have produced the erosional forms described.

However, the above assertion must be carefully balanced by critical considerations of the volume and thickness of the flows necessary to have produced the forms described. A water depth greater than the relief of the S-forms is all that is required to produce the incised features on the vertical face. Further, most of the S-Forms have been subsequently striated. This suggests that the degree of separation of the glacier sole from the bed, or decoupling, was very limited, and only a moderate water depth (cm's only) was needed to produce the forms observed. We suggest that any available meltwater would have been channelized around bedrock highs and that turbulent conditions and therefore most of the meltwater erosion would have been restricted to the sides and bottom of the valley. Pair and Muller (1990) suggested that meltwater flows may have produced small-scale meltwater erosion forms with relatively small volumes of water present as channelized meltwater focused into bedrock lows and that the rock-walled, linear valleys functioned as tunnel valleys for subglacial drainage. Such an interpretation may provide a viable explanation for the presence at the No. 2 Mine of bedrock erosional forms attributable to both abrasion by ice and to water.

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ROAD LOG

The road log begins at the intersection of Park Street and Route 11 in the center of Canton.

Persons using this log in the future should be aware that the field trip stops within the No. 2 Mine are located on private property that is owned by the Gouverneur Talc Co. Permission must be obtained from the company to access this property.

Cumulative mileage	Miles from last point	Route description
Start		Junction of Main Street (Route 11) and Park Street in the center of Canton. Follow Route 11 signs out of Canton towards Gouverneur.
23.8	23.8	In Gouverneur turn left on Route 58 towards Fine.
28.8	6.0	Turn right onto Route 812 and proceed south.
30.6	.8	Turn left into the No. 2 Mine and bear left along the pit road **Watch out for very large ore trucks on the same road.**
31.1	.5	Park and walk to the bedrock knob overlooking the pit.

STOP 1:. North end of pit

At this stop mine geologists will discuss the tectonic framework of the Northwest Adirondack Lowlands, provide a overview of the mineralogy and stratigraphy at the pit, and summarize the history of mining operations.

Return to vehicles and retrace route along pit road.

31.6	.5	Turn left at the far end of the pit and descend onto the remaining bedrock floor of the valley.Park and assemble near the bedrock knob.

STOP 2: South end of pit.

NOTE: Please stay off the bedrock faces directly above the open pit. Beware of slippery footing on the vertical face. Many of the forms are best viewed from the road !

At this stop we will examine the bedrock erosional forms present on both horizontal and vertical surfaces at this end of the No. 2 Mine. Discussion will focus on the regional glacial setting, proposed classification of the forms, the possible origin of these intriguing forms.

Possible questions for discussion:

1. Do differences in the bedrock lithology control the location and distribution of the various bedrock erosional forms ?
2. Can embedded 'tools' frozen in the ice abrade with smooth, sharp surfaces and produce all of the erosional forms present ?
3. What do these forms say about the plastic nature of glacial ice at several scales ?
4. What is the significance of these erosional forms occurring on the sides of the linear, rock-walled valley that includes the No. 2 Mine ?

Return to vehicles, go back out and turn right on 812.

32.4	.8	Turn left onto Route 58 and proceed back to Gouverneur.
38.4	6.0	Turn left on Route 11 towards Watertown.
47.0	8.6	Turn right onto Fox Ranch Road.
47.6	.6	Turn right onto Co. Road 24 towards Oxbow.
50.6	3.0	Enter Oxbow, turn left onto Pulpit Rock Road.
51.0	.4	Park on the right and walk to Pulpit Rock.

STOP 3: Pulpit Rock.

Discussion at this stop will address the possible origin of the well known Pulpit Rock.

Return to vehicles and continue southwest on Pulpit Rock Rd.

54.2	3.2	Turn right onto Hull Road.
55.0	.8	Turn right onto Vroom Creek Road. We are in the bottom of another of the linear, rock-walled valleys common to this region.
58.2	3.2	Turn right onto Co. Road 24 and return towards Route 11.
59.0	.8	Bear right to stay on Co. Road 24.
61.8	2.8	Turn left onto Fox Ranch Road.
62.5	.6	Turn left onto Route 11 and return to Canton.

END OF LOG