

alpine glaciers along Dutch Flat Creek and the North Powder River in the Elkhorn Mountains, Northeastern Oregon

David Whitfield Morriss

Department of Geology, Washington and Lee University, Lexington, Va 24450

Faculty Sponsor: Bob Carson, Whitman College; David Harbor, Washington and Lee University

Introduction

In Northeastern Oregon in the Elkhorn Mountains, east of the Elkhorn Crest Ridge Trail and south of the Anthony Lakes ski area, two alpine glaciers carved the troughs into North Powder River (NPR) and Dutch Flat Creek (DFC) valleys. This project examines these glaciers for the purpose of mapping their extent and features. The morphology of moraines and the soils indicate these glaciers had two major advance during the Bull Lake glaciation (late Illinoian: $\sim 160 \pm 50$ kya) and three major advances in the Pinedale (late Wisconsin, 26-14kya) glaciation (Richmond, 1964. Crandell, 1967). In both periods, the glaciers converged in outwash, and came close to converging in ice. Slope and elevation analysis combined with field mapping construct a description of the glacial system and attempts to explain anomalous till distributions and moraine-like features.

Methods

Field reconnaissance was based on 7.5-minute quadrangle maps. Roadcuts, drainage ditches, shallow hand dug pits and root throws provided observations of the subsurface. Altimeters, Bruntons, and GPS units were used for precise orientation while contour maps and digital data were used to identify broad trends. Subsurface or surface boulder frequency were noted as high (patches of 10 or more boulders touching), low (a boulder here or there) or nil. Ice limits were mapped using dike-rock erratics, fluvial landscape control, deep soils, and grussified bedrock.

The upper ice limits were mapped by following a slope break visible at approximately 2450m on digital slope and contour maps. Bull Lake and Pinedale were differentiated by differences in soil, morphology, and relative position.

GIS software, a host of image manipulation programs, and scripts were used to analyze data from digital elevation models. Using Pinedale moraines PD 2&3 and PD 5&6 (Fig. 1) and a .7 ratio of accumulation area to total area, equilibrium line altitudes were calculated from a digitized map of the glacier ice limit. From the limits a glacial surface was interpolated using a spline utility. The data cell elevations from the surface were loaded into an array, sorted in ascending order, then divide at the 30th percentile. This method failed to create a plausible NPR ELA, whose accumulation area and ELA were recalculated using a digitizer on the Anthony Lakes 7.5-min. quadrangle. The error resulted from low elevations from where ice poured over into neighboring valleys. Drainage profiles were plotted in Excel from DEM cell data.

Results

| | DFC | NPR |
|-----------------|---------------------|---------------------|
| Total area | 20.1km ² | 36.1km ² |
| Accumulation | 14.1km ² | 25.3km ² |
| ELA | 2029m | 2023m |
| Length | 6.5km | 11.25km |
| Upper ice limit | 2492m | 2432m |
| Lower ice limit | 1255m | 1365m |

The results of this study focus on cirque shape and the depositional characteristic in an attempt to better understand the history of glaciation.

General. Both valleys cut into the center of the Bald Mountain Batholith and travel through only granite and granodiorite, with the exception of dikes and breccia (Pardee, 1909). A system of intersecting joints and sills intersect this area running northwest to southeast and northeast southwest (Bentley, 1974). Exposed bedrock in

the moraine complex follows the latter trend. Though shape and size of each valley differs, they have similar distributions of cirques and moraines and equilibrium line elevations. The drainage profiles show Dutch Flat Creek run over a higher elevation and steeper slope than the North Powder River. The drainages of the NPR are dendritic while DFC has more irregularly spaced of tributaries.

Accumulation Area. The Dutch Flat Valley has 8 cirques, while North Powder drainage has 12 developed cirques. In DFC, the cirque bottom elevations fall into three groups: around 2130 m, 2225 m, 2280 m-up. The largest cirque at 2130 m of elevation measures a kilometer from wall to wall (Fig 1.). The low areas along the DFC headwall at around 2456 m would have allowed ice to pass into Crawfish Creek, North Powder River, and Antone Creek. Shouldered arete walls and a persistent slope break slightly below 2490 m indicate the

maximum ice height in the area. In the NPR, cirque elevations range from 2135 m to 2255 m; they group around 2135 m, 2180 m, 2225 m. A slope break slightly below 2430 m marks the maximum ice elevation, and ice passed into DFC, the North Fork of the John Day, Cunningham Cove, and Cracker Creek. Moving up in elevation, the cirques' forms change from deep troughs to cup shaped to elongate and irregular. Often in these cirques rapid slope changes will blur the distinction between headwall and cirque floor, as in the Loy Mine cirque. (Fig 1).

Depositional Area. Differences in soil composition and moraine morphology allowed for the distinction of two major ages of glaciation along with several subdivisions. The older till contains ghost clasts of varying decomposition ranging from crumble to the touch to slicable by trowel. Found in right lateral moraines BL (Bull Lake) 1,2 along the NPR and in BL right lateral 3 and left lateral 4,5 along DFC, a centimeter of organic material, a layer of sand and gruss rich in fines around 50 cm deep (10yr5.3 to 10yr6.4 dry-structureless, noncalcareous, nonsticky), and then parent material consisting of rotted clasts up to boulder size, fines, sand and gruss (10YR6.3 dry-noncalcareous, nonsticky, nonplastic) covers these features. Most of these clasts can be easily cut with a trowel and range in size between 25-100 cm where distinguishable. This till is similar to Crandell's Bull Lake Drift Unit T at Lake Wallowa except it lacks clay (Crandell, 1967). Richmond also described rotted cobbles as a characteristic of Bull Lake till in the Wasatch Mountains, but in quartz monozite instead of diorite (Richmond, 1964).

The younger till has intact, solid clasts, making digging impossible in most areas. Generally a thin layer organic material, and then around 30 cm of gruss, sand, occasionally volcanic ash and loess form the first two horizons of soil. Below these layers, the fabric supports the till, with clasts of ranging from gravel to boulder size. The medium to coarse matrix has a sandy grayish color (2.5Y7.2 dry). The loose consistency, lack of decomposed clasts, the large size of clasts, and relative lack of soil development matches Richmond's evidence for Pinedale (PD) till in the Wasatch (Richmond, 1964).

The moraine morphology of the BL moraines has a mellower sloped sided and drainage dissection along the more exposed side, such as the east side of BL 1. Lengths for BL 1,2,3,4,5 are respectively, 2.75, 1.1, 1.0, 1.1, 1.2 km; Pinedale moraines obscure observation of the full lengths. Boulder are sparsely distributed on top of BL 1 along Clap Meadow and rolled from PD 1 36 m above to the west (see discussion). Elsewhere, almost no surface boulders appear on any of the DFC BL moraines; root throws and road cuts give some exposure to till with rotted, but recognizable boulders. Figure 1 displays all mapped Pinedale and Bull Lake moraines.

Pinedale (PD) moraines have steep sides, up to 45° along the interior walls, and drainages do not significantly dissect them. Right laterals PD 1 and PD 2 are the longest, stretching 5.5km from 1926 m to 1365 m in elevation; the two stand 120 m above the river before bifurcating at 1689 m. On the west side of NPR, the PD 3 left lateral moraine matches the elevation of the northern extent of PD 1 and 2, but is a smaller feature (1.5km) composed of Pinedale till over Bull Lake till. The Pinedale till is around 10 to 20 m deep over Bull Lake till on this feature judging from roadcuts; Pinedale till is 65 m deep where PD 1 and 2 intersect BL 1. Two smaller recessional moraines form the inner terminus (PD 4); the stream breaches them at an elevation of 1525 m.

DFC PD moraines follow the same pattern: left lateral moraines PD 7 and 8 bifurcate into separate moraines at an elevation of 1705 m (PD 6 splits again at 1415m) while right lateral moraines PD5 and 6 bifurcate at 1830m. Both sets of left and right lateral moraines start at an elevation of 1850 m, and PD 5 at 1765 m; PD 7 ends at 1585m, PD 8 at 1340 m, and PD 6 at 1340 m. Pocked with depressions, a till plug clogs the valley at the elevation of 1580 m, marking the terminus of the late Pinedale in this valley. Dutch Flat Creek cuts through this plug from an elevation of 1580 m down to 1525 m.

PD 9 stretches from an elevation of 1330m 1.5km to the northeast to an elevation of 1280 m. It stands 35 m above the North Powder River and 30 m above Dutch Flat Creek that flank it to the southeast and northwest. Till on the ridge has a 30 cm thick layer of loess over Pinedale cobbles of high enough frequency to prevent digging. Unlike other Pinedale moraines, this moraine has a flat top. The south east side is steep (>30°), and strewn with fluvial gravel of quartzite, basalt, and metagabbro belonging to a preglacial drainage system. Similar gravels are found to the East in the Crawfish Lake quadrangle. Outwash surrounds the ridge on all sides. (Fig 2.)

Meltwater from the Pinedale glaciation cut channels into Bull Lake till at the north end of moraine BL 5. A meltwater channel also cuts across the northeast side of the terminal plug in DFC. Pinedale outwash covers from the recessional moraines of the NPR and the terminal plug of DFC to the confluence of the two streams. Near the mouth of the DFC trough, prospectors mined this outwash for gold, diverted minor drainages and created new channels. Outwash consists of fist to watermelon sized cobbles of granite punctuated by boulders. Where undisturbed, 90cm loess covers granite boulders and in fills the gaps. The flat meadow areas indicate periods of water stagnation, possible caused by ice or moraine damming.

Grussified bedrock marks vertical and horizontal limits of glaciation for the Pinedale. Lying in between moraines PD 1 and PD 6, a small northeasterly trending bedrock ridge (Medial Ridge) lies sheared by both glaciers. The meltwater cut on BL 5 reaches grussified bedrock, showing the till cover to be less than 12 m deep. Due west of the confluence, grussified bedrock at the ridge base marks the Bull Lake ice limit for Dutch Flat.

Linear groups of steep or low slope indicate extensions of certain moraines and outwash channels as well areas of water stagnation. Slope maps show Moraine PD 1 reintersected moraine BL 1, and extended farther than BL 1 to the north east. High boulder frequencies and PD outwash found in clear cuts along the edge of Bulger Flat also indicate a further extension of the PD 1, possibly down to below an elevation of 1340 m.

Feature PD 9 is flanked by flat bottomed, steep-sided channels on either side. Southwest of PD 9, a large low slope area extends from inside the NPR trough mouths to Bulger Flat and the beginning top of PD 9. Both channels begin at 1340 m. The walls of the channels extend linearly to the northeast for 1.2km. These channels then converge 1.75 km southwest of the confluence of Dutch Flat Creek and Antone Creek, another glacial valley.

At an elevation of 1315 m, Dutch Flat Creek takes a dogleg due east following a gentle bend to the north; this bend is similar in shape to the bends in Dutch Flat Creek at the till plug, and the North Powder River at the recessional moraines. In both troughs, areas of low slope precede downstream plugs or moraines that the streams have since breached, indicating a period of coverage by still water.

Discussion

The history of glaciation in these two valley fits Richmond's history of glaciation in the Wasatch; two Bull Lake stages with rotted till and mellow features, and three stages of Pinedale with fresh till and undissected features (Richmond, 1964). The extent of glaciation for both periods comparable, as seen by the moraines, while the size of the giant DFC cirque and BL 1 indicate the Bull Lake glaciation scraped out the most material. The large steep Pinedale lateral moraine build upon the dissected Bull Lake features. The current upper ice line slope break is a remnant of the late Pinedale, pocked by shallower alcove than eastern cirque.

Clapp Meadow. Clapp Meadow has an unusually high frequency of boulders composed of granodiorite and breccia over Bull Lake till indicating the ice rafting over the Bull Lake moraine. PD 1 dammed this area to create this pond.(Fig. 2) This accounts for the meltwater channel and the area's low slope.

PD 9. PD 9 a.k.a. Rolling Barrel Ridge is flatter on top like a Bull Lake moraine, but has intact subsurface boulders and steep sides like a Pinedale moraine; it is linear like a lateral moraine, but lacks a left or right partner. The mellow slope of the top of the ridge and its unusually steep sides suggests that it is a smaller feature cut from a larger flatter older one. The exposure of fluvial sediments in an area blanketed almost by Pinedale Outwash indicates a radical removal material.

Medial Ridge to the southwest aligns with Rolling Barrel Ridge, and the granite may extend under Rolling Barrel Ridge. This granite may have helped the ridge withstand the Bull Lake and Pinedale to acquire a thick cover of till or outwash over its earlier fluvial deposits. Though no exposures were found to confirm the composition of the ridge, the amount of loess suggests this ridge is a stack of outwash, from the Pinedale period and possibly the Bull Lake period. In one likely scenario, the terminus of the NPR first Pinedale stage and the terminus of the DFC second Pinedale stage created ice-dammed lakes above the eastern and western channels respectively. The overflow of these lakes cut the deep long channels down to near bedrock. Exact dating is necessary to identify the exact sequence of events in this area, especially along Rolling Barrel Ridge, and the ends of PD 8 and PD 1.

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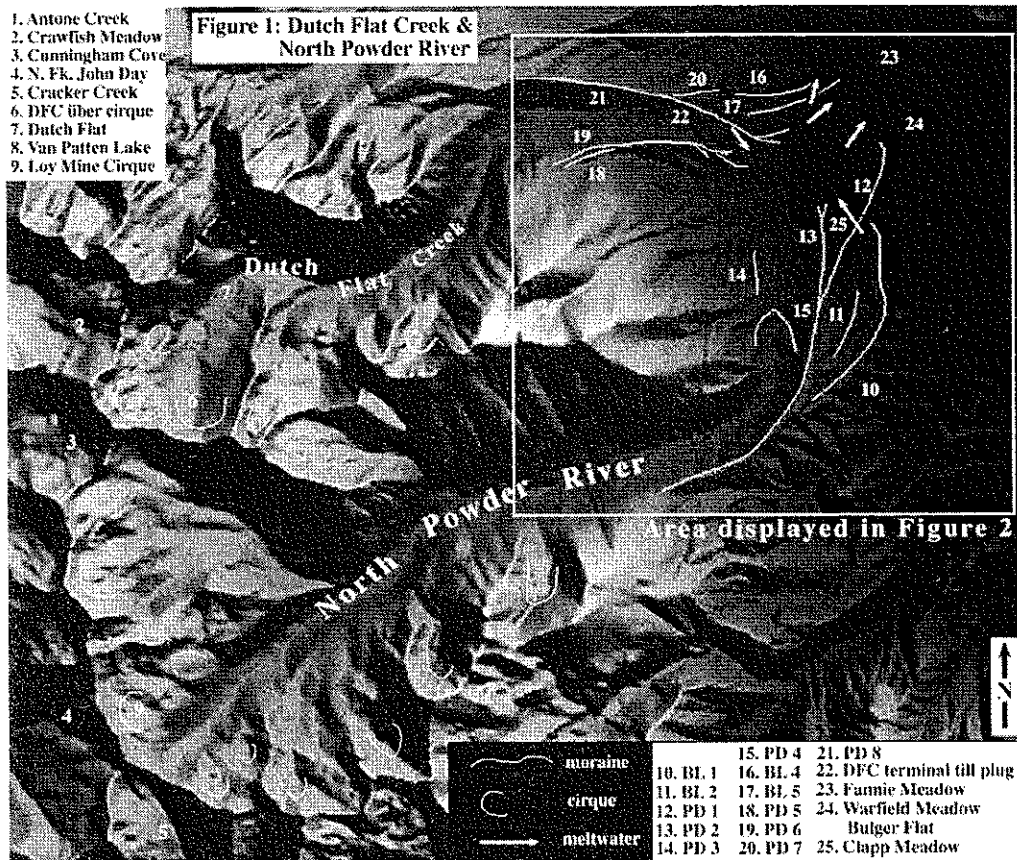


Figure 1:
Dutch Flat Creek
and North Powder
River:
This aspect map
displays the entire
area of study.
Numbers
correspond to
features referred to
in the abstract.

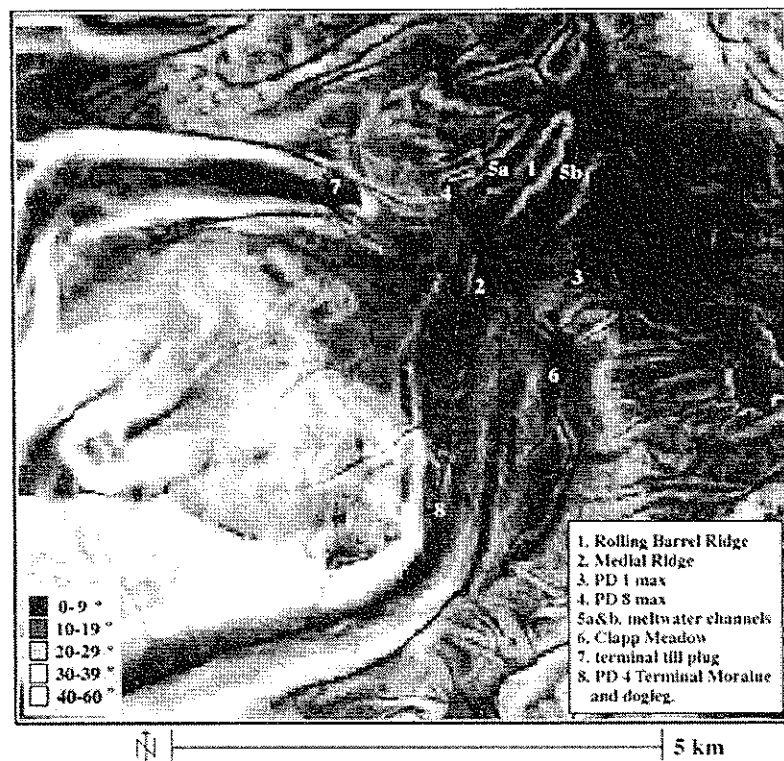


Figure 2: Slope map of the moraine complexes: Numbers refer to features from the discussion. Notice the difference in slope across Rolling Barrel Ridge as opposed to other major moraines. Note PD 1's intersection with Clapp Meadow and the extension of this slope down to the meltwater channels. Also note the position of Medial Ridge, which indicates Pinedale ice limits in the southeast for DFC and north and west for the NPR.