Pinedale Glaciation of the Clarks Fork and Crandall Creek Valleys, Park County, Wyoming

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INTRODUCTION

The Yellowstone ice sheet, centered in northwestern Wyoming, was the most extensive Pleistocene glacier complex south of the Cordilleran-Laurentide ice sheets. During the glacial periods of the Quaternary, portions of this ice sheet complex occupied the Clarks Fork and Crandall Creek valleys of Park County, WY. The Clarks Fork lobe had major accumulation areas within the Beartooth Mountains (near Granite Peak) and on the Beartooth Plateau, and other minor accumulation zones within certain valleys of the Absaroka Range (Carson et al, 1996). At its maximum, this lobe covered 550 square kilometers, and extended 75 kilometers from its accumulation area (see fig. 1). The major accumulation area for the Crandall valley glacier was within the Absarokas, just east of Yellowstone National Park (Carson et al, 1996). It flowed into the Clarks Fork valley 40 kilometers south of Granite Peak during the late Pleistocene (see fig. 3). There is abundant evidence that shows that both were present near the junction of the Clarks Fork of the Yellowstone River and Crandall Creek valleys. The purpose of this study is to determine the sequence in which each glacier occupied this junction.

FIELD WORK

Techniques: A comprehensive study of the Clarks Fork and Crandall Creek valleys was conducted primarily by mapping moraines, meltwater channels, flood bars and flood surfaces. Lithologic pebble counts were made on moraines and till mounds to determine the source region of the ice that deposited them. Striae were also measured to reconstruct the most recent ice flow directions.

Pebble counts involved the identification of 100 or more clasts within each moraine or till mound. Only clasts between 2 and 50 cm were counted, and counts were usually done in road or trail cuts, or where gophers had dug a significant hole within the moraine or till mound. This allowed a more accurate account of the till within a landform, instead of just the cobbles that ended up on the surface. These pebble counts gave approximate percentages of volcanics, carbonates, granites and sandstones within the till. Different percentages of these clasts indicated different origins, associated either with the Clarks Fork lobe, or with the Crandall valley glacier.

Moraines or till mounds believed to have been produced by the Clarks Fork ice contain mostly Precambrian granites and gneiss from its source area near Granite Peak in the Beartooth Mountains. Along the southwest side of Clarks Fork valley, this glacier could have also plucked volcanics and limestones from cliff walls, and has tributary glaciers that originate within the Absaroka Range. Because of these additions, one expects to see some volcanics and limestones within the Clarks Fork till.

Till associated with Crandall ice is volcanic and limestone rich. The ice originated within the Absaroka Range, and flowed through a valley lined with Paleozoic limestones. Some Crandall drift may also contain Crandall intrusive rocks, which should not be in Clarks Fork till. Crandall till can also contain a small amount of granite and gneissic rocks, from the reworking of erratics left within the Crandall valley by the Clarks Fork lobe, which advanced into the Crandall valley before the latest Crandall glacier advance.

Results/Discussion: The data collected in the field indicated three separate phases during the Pinedale glacial period. Each phase is characterized by a different glacier, or combination of glaciers, dominating the junction of the Clarks Fork and Crandall valleys (see figs. 1-3). The two main glaciers of this region seem to be out of phase.

During the early to the middle portions of the Pinedale glacial period, Clarks Fork lobe, advancing south from the Beartooth Range, covered most of the study area (fig. 1). The presence of crystalline erratics, transported far into the Crandall Creek valley, is strong evidence for a very large Clarks Fork glacier. This glacier extended far down the Clarks Fork canyon into the Bighorn Basin. The Crandall valley glacier was mysteriously restricted to the valleys of Crandall Creek, just north and south of Hurricane Mesa.

Later in the Pinedale, there is a small amount of evidence that suggests that the Crandall and Clarks Fork glaciers were confluent in the lower Clarks Fork valley (fig. 2). A possible medial moraine, along with large volcanic erratics found well east of what were believed in the field to be Crandall terminal moraines, could have been deposited by Crandall ice. It is unclear whether the Crandall glacier ever entered Lodgepole valley, either during this phase or during the Crandall Readvance. A carbon-14 date, taken within the remnants of a glacial lake inside Lodgepole valley, indicates a date just prior to the Pinedale maximum of 22630+/- 120 years ago.

During the third phase, the Crandall valley glacier readvanced eastward, far into Clarks Fork valley, from its accumulation zone in the Absarokas (fig. 3). Today, one can see that Crandall till, dominated by volcanics and limestones, covers the junction of the Clarks Fork and Crandall creek valleys. At that time, Crandall ice was the major glacier at this junction, and it is the Clarks Fork ice that had mysteriously shrunken into the upper reaches of its valley.

LABORATORY WORK

One would expect that two glaciers, in the same general region and with similar climates and levels of precipitation, would advance and retreat somewhat simultaneously. There are several hypotheses that might explain this nonsynchronous advance and retreat:

1. The accumulation areas experienced different climates, allowing one glacier to accumulate or ablate faster than the other.
2. The two glaciers experienced the same climate change, but because of their respective glacial or valley geometries, they reacted differently to this change.
3. During the Pinedale glacial period, the drainage divide of one the glaciers (most likely the Clarks Fork glacier) was altered. This would either increase or decrease the size of its accumulation area.

Techniques: The equilibrium-line altitudes (ELAs) of both the Clarks Fork and the Crandall glaciers during several phases of the glacial period were reconstructed using simple glaciological models. The limits of glaciers were traced using the program Envi 2.7 onto the 3-arc-second U.S.G.S. Cody West and Billings West digital elevation model (DEM) files with grid-cell resolutions of 93m. Ice limits were estimated from terminal moraines found in the field near the Crandall/Clarks Fork valley junction, and from present drainage divides.

These DEM data were analyzed using Envi 2.7 and Microsoft Excel to produce a graph of the area-altitude distribution of the subglacial surface for both glaciers at each stage. These graphs were analyzed to determine ELAs using the Median Bedrock Elevation (MBE) method. Under this method, proposed by Manley (1997), the ELA is approximated as the median bedrock elevation underneath the glacier.

The ELAs were then raised in increments of 100 meters to simulate an increase in temperature, or a decrease in accumulation during deglaciation. The results of this test were used to estimate how the area of each glacier would respond to a change in climate, assuming that the glaciers maintained an ELA at its median bedrock elevation during this climate change.

The mass balance of the Clarks Fork glacier was modeled to determine if a change in drainage divide would significantly alter its size. This mass balance was estimated by multiplying the DEM-derived area by an assumed accumulation gradient above its steady-state ELA. The accumulation gradients were determined assuming that this gradient was linearly proportional to its altitude above the ELA. Therefore, the area 50 meters above a glacier's ELA will experience roughly one-third of the net accumulation that the area that is 150 meters above the ELA would. The area of the glacier was given by Envi 2.7 in the units of DEM points. Each point is roughly equivalent to 93 square meters.

Results/Discussion: Hypothesis 1: The ELAs during the Crandall Readvance of both the Crandall and the Clarks Fork glaciers are very similar (~2600m), indicating that the climate during this phase of glaciation was similar within the accumulation areas of both glaciers. During the Pinedale maximum, however, they are significantly different. The Clarks Fork ELA is much lower than the Crandall ELA, suggesting that the Clarks Fork accumulation zone was either in a colder climate, or receiving more precipitation. Because the accumulation areas are at similar elevations and they are relatively near each other, their average temperatures, and altitude v. temperature relationships, should be almost identical. The snowfall each area should also be similar, unless there is something preventing precipitation from getting to the accumulation area of one of the glaciers.

A precipitation shadow is caused by any topographic high which 'blocks' precipitation from neighboring lower areas. While the Clarks Fork glacier was at its maximum, an ice sheet on the Yellowstone plateau was located just southwest of the Crandall accumulation zone in the Absarokas (fig. 1)(Pierce, 1979), possibly causing the

Crandall accumulation zone to receive far less precipitation and snowfall than 'normal'. During the mid-late Pinedale glaciation, the Yellowstone ice sheet was reduced to 30-50% of its maximum (Pierce, 1979). This deglaciation may have dramatically reduced the effect of this precipitation shadow upon the Crandall ice accumulation zone. Therefore, the Crandall valley glacier could finally expand into the Clarks Fork valley, while the Clarks Fork ice appears to have retreated.

Hypothesis 2: This hypothesis was tested by using area-altitude distribution graphs to analyze the geometries of each of the valleys containing the glaciers under study. If the Clarks Fork accumulation area was extremely sensitive to climate change, then the ice might retreat more quickly than the Crandall glacier. The area-altitude distribution graphs, however, revealed that it is actually the Crandall valley glacier that would likely be more sensitive to climate change. A dramatic rise in temperature would cause the glacier to retreat much more quickly than the Clarks Fork ice, which is the opposite of what is shown by evidence collected in the field.

Hypothesis 3: As mentioned earlier, a large and thick ice cap existed just west of the Absaroka Range at the Pinedale maximum (fig. 1). This thick ice cap might have forced ice to flow from the Beartooth Range down the Clarks Fork drainage (Locke, 1995). According to Pierce (1979) this ice sheet was very sensitive to climate change, and might have melted before the valley glaciers originating within the Beartooths or the Absarokas (the Clarks Fork and Crandall glaciers). When the ice sheet started to retreat, ice might have started to flow down the Soda Butte Creek drainage instead of the Clarks Fork River drainage. Figures from mass balance graphs have shown that this change in the drainage divide could effectively eliminate 28% of the snow that the Clarks Fork accumulation area can collect. Because of this change in drainage pattern, it might appear that the Clarks Fork lobe was retreating much faster than the Crandall valley glacier during this stage of the Pinedale glacial period. This hypothesis, and hypothesis 1, are the two most likely explanations of why the Crandall valley glacier and the Clarks Fork ice lobe are out of phase.

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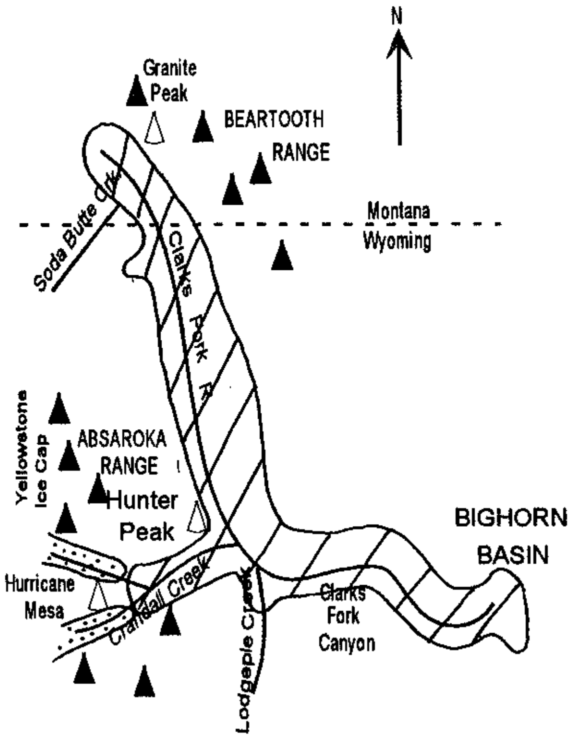

Figure 1: Early-mid Pinedale

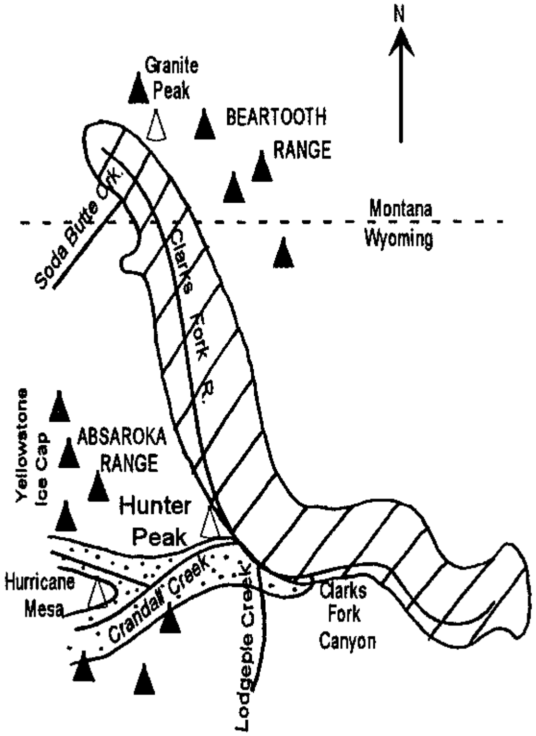

Figure 2: Pinedale Maximum

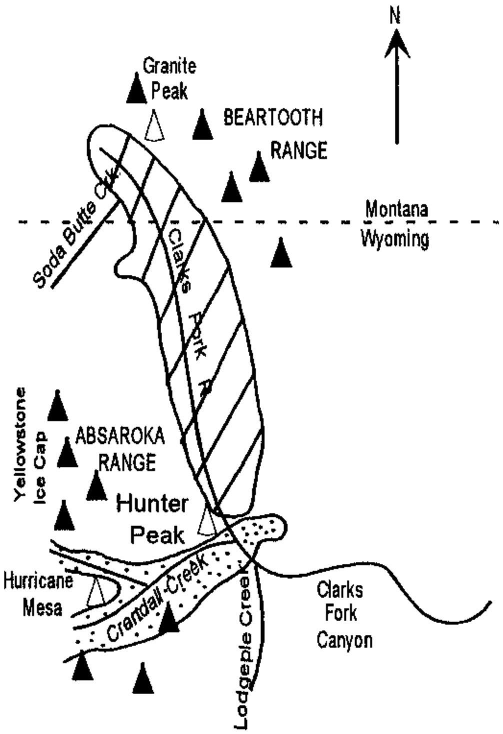

Figure 3: Crandall Readvance

▨ CLARKS FORK ICE LOBE

⠿ CRANDALL VALLEY GLACIER