ABSTRACT

Photogeologic mapping and reconnaissance field investigations of the glacial geology in the Selway-Bitterroot Wilderness Area of Idaho and western Montana have revealed that multiple glaciations occurred in the region during the late Quaternary and that they were more extensive than previously believed. Two major glaciations are recognized, with a late episode of cirque glaciation.

The Grave Peak glaciation, the oldest and most extensive glaciation in the area, was characterized by ice caps and large valley glaciers. The later Canteen Creek glaciation was typified by alpine-type valley glaciers. The Legend Lake glaciation, the latest period of ice accumulation, was characterized by cirque glaciers. Periglacial processes were active during the late Wisconsinan and Holocene.

The formation of a detailed Quaternary stratigraphy and chronology for this region is hampered by the paucity of terminal moraines and other relative age-dating variables. A correlation with the established glacial sequences of other Rocky Mountain regions is not possible at this time.

INTRODUCTION

Although the glaciation of the mountains of Wyoming, Montana, and the Cascade Range in western Washington has been the subject of many investigations, the alpine glaciation of Idaho has been largely overlooked by geologists more interested in bedrock geology and mineral deposits.

The Selway-Bitterroot Wilderness Area and associated rugged, mountainous terrain in Idaho and conterminous western Montana (Figure 1) have been topographically modified by Pleistocene alpine glaciation. The objective of this paper is to describe the extent of multiple glaciations in the Selway-Bitterroot Wilderness Area and to compare the geomorphology with alpine glaciation in other mountains of northern Idaho. Photogeology and field mapping of the surficial geology reveal multiple glaciations in this region greater in extent than previously reported in the literature. The existence of a variety of glacier types, ranging from a mountain ice cap to cirques, is indicated by the geomorphology.

The wilderness area is drained by three major rivers, the Bitterroot on the east side of the continental divide and the Lochsa and Selway on the west side. It incorporates two major mountain masses, the Bitterroot Range and the Clearwater Mountains. The undulating plateau formed by the nearly accordant crests of the Clearwater Mountains (the "Idaho Penneplain" of Fenneman, 1931, and the Clearwater Plateau of later researchers) has an elevation of about 7,000 feet (2,135 meters), with several peaks in excess of 8,000 feet (2,440 meters). Peaks in the Bitterroot Range increase in elevation from north to south, with the highest elevation in the area at Trapper Peak (10,157 feet; 3,098 meters).

Climate in the wilderness region is related to the east-west elevation gradients across the area and the effect of maritime polar air masses that influence the annual precipitation originating from the west. Mean annual precipitation, mostly concentrated in the winter and spring, ranges from about 40 inches (102 centimeters) in the west to over 60 inches (152 centimeters) in the higher elevations of the Bitterroot Range. High elevations in the Bitterroot Range have a July temperature average of 60°F (16°C) and a January average of 18°F (-8°C) (Habeck, 1976).

Most of the study area is underlain by the Bitterroot lobe of the Idaho batholith (Armstrong, 1975; Hyndman and Williams, 1977). Metasedimentary rocks, correlated with the Precambrian Belt Super-group, occur primarily along the eastern and western edges of the wilderness (Ross, 1950; Reid and others, 1970; Greenwood and Morrison, 1973). Meta-igneous rocks, varying in composition from ultramafic to
Figure 1. Generalized map of glaciation in the Selway-Bitterroot Wilderness Area.
granitic masses and ranging in age from Precambrian to Mesozoic, intrude the metasediments in several areas (Greenwood and Morrison, 1973). Migmatites represent the contact zone between the late Mesozoic igneous rocks of the Idaho batholith and the meta-sedimentary and meta-igneous rocks of earlier time.

The structural geology of this area is complex and related to the emplacement of the batholith and secondary plutons. The most interesting structural feature is the eastern boundary of the Bitterroot Range. Many researchers have discussed the tectonic origin of the abrupt and straight mountain front (Lindgren, 1904; Greenwood and Morrison, 1973). The wilderness area has probably experienced uplift throughout late Cenozoic time.

PREVIOUS INVESTIGATIONS

Much of the previous geomorphology done in this region focused on Montana, the moraines of the southwestern Bitterroot Valley and features of Glacial Lake Missoula (Pardee, 1910, 1942). Lindgren (1904) described glacial features in this area and speculated on the glaciation of some other areas in Idaho. Stone (1900) noted the existence of glaciated terrain in this part of Idaho from reconnaissance work and recognized the lack of well-developed moraines and the possibility of piedmont glaciers. Alden (1953) described glacial geology of the Bitterroot Valley in detail. Weber (1972) tried to correlate the moraine sequences in the major southwestern Bitterroot Range canyons with the fluctuations in Glacial Lake Missoula. Weis and others (1972) noted glaciation in the Salmon River Breaks Primitive Area (now known as the River of No Return Wilderness).

GLACIAL GEOLOGY

The complex glacial geology of the Selway-Bitterroot Wilderness Area is outlined broadly in this paper. Evidence for two major glaciations in most drainages can usually be recognized, followed by a period of cirque glaciation and periglacial activity.

The terms Pinedale, Bull Lake, and pre-Bull Lake Glaciations (Blackwelder, 1915; Richmond, 1965; Mears, 1974) have been avoided here because no definite ages can be assigned to deposits and because the correlation of surficial stratigraphic units from the Wind River Mountains of Wyoming with those of Idaho cannot be traced by continuous mapping or by lithologic characteristics from their type area (Pierce, 1979; Birkeland and others; 1979; Evenson and others, 1982 this volume).

Terminal moraines are common only in the valleys on the east front of the Bitterroot Range. The lack of terminal moraines or persistent till deposits throughout the Selway-Bitterroot area makes it difficult to correlate surficial stratigraphic units between drainages, and hampers the establishment of a comprehensive Quaternary stratigraphic sequence and chronology for this region. However, a similar sequence of advances can be recognized for the area, and a system for its recognition is valuable. Therefore, a local nomenclature based on observable criteria and relationships was established. Correlation of this nomenclature with other regions of the Rocky Mountains is not possible at this time.

The three glacial periods in the Selway-Bitterroot Wilderness Area have been informally named (Dingler, 1981) as the Grave Peak, Canteen Creek, and Legend Lake glaciations. The Grave Peak glaciation is the earliest recognizable episode. It was the most extensive and had at least four advances. The Canteen Creek glaciation was, in most places, less extensive and had at least two advances. The Legend Lake glaciation was a period of cirque glaciation. A recognizable period of periglacial activity occurred peripheral to glacial areas during the Legend Lake glaciation, or during a later time (Neoglaciation?).

The existence of a variety of glaciers is indicated by the geomorphology, including (1) a mountain ice cap in the Grave Peak area with its associated (2) piedmont lobe in the Big Sand Creek drainage and (3) associated outlet glaciers; (4) transverse glaciers; (5) alpine-type valley glaciers in most drainages that originate from catchment areas having an elevation of 6,000 feet (1,830 meters) or greater; and (6) cirque glaciers.

GRAVE PEAK GLACIATION

The Grave Peak glaciation is the oldest and most extensive ice accumulation recognized in the wilderness area. The geomorphology of the Grave Peak area, located in Idaho along the arcuate highland between The Crags and the northern Bitterroot Range, shows evidence of massive ice accumulations such as the Grave Peak ice cap, the associated Big Sand Creek piedmont lobe, and the extensive valley glaciers of Brushy Fork and East Fork of Moose Creek.

The ridge extending north and south of Grave Peak (NE 1/4 sec. 8, T. 35 N., R. 14 E.) was the central accumulation area of a mountain ice cap. Evidence for this ice cap is both morphological and depositional. The western side of this ridge is very smooth, and grades into a number of north-south trending
glacial troughs with no sharp breaks in slope. The
topography is equally well-rounded northwest of the
ridge, as shown by the smooth crest and southern
slopes of Tom Beal Peak (sec. 24, T. 36 N., R. 13 E.).
Erratics give depositional evidence of the ice cap.
Large erratics occupy the crest of the glacial headwall
above Walton Lakes and the slope southeast of Tom
Beal Park (Figure 2).

The maximum extent of this ice cap is difficult to
determine due to subsequent valley glaciation. To the
west, ice flowed into and accumulated in the Saturday
Creek valley as indicated by the smooth hills in the
interior of the basin and the rounded Saturday Ridge.
Outlet valley glaciers extended down Wind Lake and
Warm Springs Creeks to a stream elevation of 4,600
feet (1,403 meters). To the east, Lindgren (1904)
envisioned a neve field extending from Grave Peak to
Diablo Mountain (sec. 8, T. 34 N., R. 15 E.).
Morphology shows that the ice cap was larger than
this and that it extended and joined the Big Sand
Creek valley glacier and flowed through the valleys of
Jeanette and Dolph Creeks, and joined the East Fork
of Moose Creek valley glacier. After joining the
big Sand Creek, ice flowed into White Sand
Creek valley, forming a large piedmont lobe that
extended to an elevation near 4,200 feet (1,281
meters). The East Fork of Moose Creek valley glacier
extended to a stream elevation of 3,200 feet (976
meters) at this time, the lowest glaciation recognized
in the area.

The Grave Peak ice cap and its outlet valley

glaciers apparently covered an area of approximately
200 square miles (520 square kilometers). No evidence
was found in the wilderness for other ice caps.

In the northern Bitterroot Range, a large valley
glacier existed in the Brushy Fork drainage with
tributary glaciers descending from the upper Brushy
Fork valley and the Spruce Creek drainage (Figure
1). The glacier in the valleys of Spruce Creek and its
North Fork overtopped the north wall in the Lily
Lake area (sec. 13, T. 38 N., R. 16 E.) and coalesced
with the west-flowing Brushy Fork valley glacier to
form a large body of ice.

Portions of this valley glacier overflowed north-
ward into the Dick Creek drainage, and other portions
flowed around (and possibly over) Skookum Butte
into the East Fork of Lolo Creek drainage. Most of
the valley glacier flowed west in the Brushy Fork
drainage, but some ice formed a piedmont lobe in the
Packer Meadows area, directly east of Lolo Pass. An
end(?) moraine in Packer Meadows is cut by Forest
Service Road No. 373 approximately 0.25 mile (0.4
kilometer) east of the U.S. Highway 12 turnoff at
Lolo Pass (SE¼ sec. 15, T. 38 N., R. 15 E.).

Thick ice accumulations are associated with the
existence of the Brushy Fork valley glacier during the
Grave Peak glaciation. Ice thicknesses in the North
Fork of Spruce Creek had to exceed 1,200 feet (366
meters) in order to overtop the drainage divide in the
Lily Lake area. In the Skookum Butte area, an ice
thickness of over 1,200 feet (366 meters) polished the
wall northwest of Granite Lake and overrode the

Figure 2. Granitic erratics on the slope southeast of Tom Beal Peak deposited during the Grave Peak glaciation.
whaleback forms at the head of the Dick Creek valley (sec. 6 and W½ sec. 5, T. 38 N., R. 17 E.).

At least four advances during the Grave Peak glaciation are indicated by nested lateral moraines in the Warm Springs Creek valley (secs. 4, 5, 8, and 9, T. 35 N., R. 13 E.; Table 1).

The degree of soil development, useful as a relative age-dating method, shows that till deposits of the Grave Peak glaciation have a depth of weathering up to 20 inches (51 centimeters). This is deeper than any soils recognized on deposits of younger glaciations, although not all deposits show a uniform degree of development due to the effects of alpine climate, varying topography, and the influence of younger horizons of volcanic ash.

**CANTEN CREEK GLACIATION**

Areas affected by the Grave Peak glaciation have been topographically modified by a later, less extensive period of alpine-type valley glaciation informally named the Canteen Creek glaciation. Geomorphic evidence for this latest major glaciation includes the enormous area of glacially carved, youthful alpine topography and a number of drainages with lateral moraines upvalley from the terminal areas of earlier glaciations. Major drainages with catchment areas above 6,000 feet (1,830 meters) have been affected by this glacial episode.

The Canteen Creek glaciation was less extensive than the Grave Peak glaciation in both the volume and the length of valley glaciers. No evidence was found for the presence of ice caps of other large ice masses in the wilderness area related to this later glacial episode.

A minimum of two advances during the Canteen Creek glaciation are indicated by nested lateral moraines in the valleys of Canteen Creek (Figure 3; secs. 8, 9, 16, and 17, T. 32 N., R. 10 E.) and Walton Creek (sec. 11, T. 36 N., R. 14 E.), and by terminal (?) moraines in the Warm Springs Creek valley (NE¼ sec. 21 and NE¼ sec. 27, T. 35 N., R. 13 E.).

Soils that have developed on till deposits from the Canteen Creek glaciation generally have a thinner B horizon and a thinner cover of loess and volcanic ash than those formed on Grave Peak glacial deposits. Although the reconnaissance soil investigation of this study reveals variations in different age soils, it could not be determined whether the Canteen Creek glaciation followed a significant soil-forming episode or whether it represents a readvance following a waning of the large ice masses and other glaciers of the Grave Peak glaciation.

**LEGEND LAKE GLACIATION**

The latest glaciation in the Selway-Bitterroot Wilderness Area was a period of cirque glaciation, as

<table>
<thead>
<tr>
<th>Typical Areas</th>
<th>Location</th>
<th>Moraines Elevations (feet)</th>
<th>Soil Development</th>
<th>Surface Morphology</th>
<th>Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tom Baal Creek</td>
<td>Grave Peak Area</td>
<td>8,300-6,400</td>
<td>mature</td>
<td>erratics, ground moraine</td>
<td>N-SW</td>
</tr>
<tr>
<td>Warm Spring Creek</td>
<td>Grave Peak Area</td>
<td>5,900-4,600</td>
<td>mature (?)</td>
<td>four broad-crested, nested laterals</td>
<td>N (all)</td>
</tr>
<tr>
<td>Walton Creek</td>
<td>Grave Peak Area</td>
<td>4,300-3,900</td>
<td>mature (?)</td>
<td>broad-crested lateral</td>
<td>N</td>
</tr>
<tr>
<td>Canteen Creek</td>
<td>The Crags</td>
<td>5,700-4,200</td>
<td>immature</td>
<td>two narrow-crested laterals</td>
<td>WSW</td>
</tr>
<tr>
<td>Warm Springs Creek</td>
<td>Grave Peak Area</td>
<td>3,450-3,150</td>
<td>immature (?)</td>
<td>two small, knobby terminals</td>
<td>WNW</td>
</tr>
<tr>
<td>Legend Lake</td>
<td>The Crags</td>
<td>6,720</td>
<td>immature</td>
<td>bouldery, narrow-crested</td>
<td>NNE</td>
</tr>
<tr>
<td>Crystal Lake</td>
<td>The Crags</td>
<td>6,150</td>
<td>immature</td>
<td>bouldery, narrow-crested</td>
<td>N</td>
</tr>
<tr>
<td>Spruce Lake</td>
<td>southwestern Bitterroot Range</td>
<td>6,700</td>
<td>immature</td>
<td>bouldery, narrow-crested</td>
<td>ESE</td>
</tr>
</tbody>
</table>
indicated by the ubiquitous cirque lakes dammed by moraines (Table 1, Figure 4). This glacial episode is informally named the Legend Lake glaciation after a moraine-dammed lake (sec. 35, T. 33 N., R. 10 E.).

Moraines that formed during the Legend Lake glaciation occur on cirque lips or a short distance downvalley and are typical Neoglacial positions. Soils on these deposits, although poorly developed, are able to support vegetation. The capacity of these soils to support vegetation may be an effect of the regional climate, or may indicate that the deposits are older than Neoglacial because Neoglacial deposits in the Rocky Mountains usually do not support substantial vegetation. The later hypothesis may be substantiated in a study by Mehringer and others (1977) which showed that sedimentation began approximately 12,000 years ago in a cirque of the Bitterroot Mountains south of this study area. In either case, the age of the Legend Lake glaciation is in doubt until more detailed studies are undertaken.

PERIGLACIAL FEATURES

Periglacial processes were active in the study area, either peripheral to glaciers during the late Wisconsinan or during Neoglaciaion. Sorted stone circles in outwash deposits and debris islands are found on till in The Crags, and a number of rock glaciers are located in cirques along the eastern Bitterroot Range.

SUMMARY

Multiple glaciations in the Selway-Bitterroot Wilderness Area of Idaho and western Montana were greater in extent than has been described in the literature. Two major glaciations are recognized, followed by an episode of cirque glaciation. Respectively, these have been informally named the Grave Peak, Canteen Creek, and Legend Lake glaciations. Periglacial processes were active in the study area, either peripheral to glaciers during the late Wisconsinan or forming during Neoglacialiation, or both.

The Grave Peak glaciation was the most extensive and had at least four pulses. The geomorphology of the study area was influenced by numerous glaciers of various morphologies during this episode, including a mountain ice cap in the Grave Peak region and its associated piedmont lobe in Big Sand Creek, transection glaciers, and alpine-type valley glaciers in numerous drainages such as the large ones in the Brushy Fork and East Fork of Moose Creek.
The Canteen Creek glaciation was less extensive and had at least two advances. Alpine-type valley glaciers were prevalent during this ice advance. The Legend Lake glaciation was characterized by cirque glaciers.

The paucity of terminal moraines and other deposits for relative age-dating limited our ability to correlate surficial stratigraphic units between drainages, and hampers the establishment of a comprehensive Quaternary stratigraphic sequence and chronology for this region. The glacial record of this region cannot be correlated to the glacial sequences of other Rocky Mountain regions at this time.

REFERENCES


Habeck, J. R., 1976, Forests, fuels and fire in the Selway-Bitterroot Wilderness, Idaho: Proceedings of the Montana Tall Timbers Fire Ecology Conference and Fire and Land Management Sympo-


