GEOLOGY OF TENDERFOOT CREEK EXPERIMENTAL FOREST LITTLE BELT MOUNTAINS, MEAGHER COUNTY, MONTANA

By

Mitchell W. Reynolds U.S. Geological Survey Reston, Virginia 22092

Geographic Setting

The Tenderfoot Creek Experimental Forest in the west-central part of the Little Belt Mountains occupies a transition zone in the west-central part of the Mountains-a transition from rolling mountain parks with rounded peaks that rise about 500 feet above the upland of the range to deeply incised canyons that drain the west end of the Mountains. The Experimental Forest is bisected by Tenderfoot Creek, which is incised as deeply as 2400 feet into the upland. The steep inner canyon of Tenderfoot Creek opens upward onto narrow parks, which are rimmed on the north and south by, rounded peaks that rise to elevations of about 7200 to 7600 feet. At the east end of the experimental forest, the divide of Onion Park separates drainage flowing east into Belt Creek from drainage flowing west into Tenderfoot Creek and the Smith River. Quartzite Ridge, Williams Mountain and Woods Mountain on the south, and the ridge of Iron Mountain north of Tenderfoot Creek enclose the Tenderfoot Creek drainage. Thus the Experimental Forest covers the upper end of a west-sloping basin that drains steeply into the Smith River, about 12 miles to the west. This geographic setting is controlled by the resistance to erosion of rock units that underlie the area and by young geologic uplift of the mountains. These controls are described in the following account of the geology of the experimental forest.

Geology Of The Tenderfoot Creek Experimental Forest

The geology of the Tenderfoot Creek Experimental Forest is simple in terms of the rock and sediment units present and the geologic structure of the area. By contrast, the geologic history records a complex series of events that has influenced both the succession of rock units and the erosion that has produced the present physiography of the area. In succession this report summarizes the rock units exposed in the area, the surficial sediments that mantle the forest, and the history of events that led to the present configuration. The accompanying reconnaissance bedrock geologic map (figure 1) shows the generalized distribution of rock units underlying the forest. Figure 2 shows the generalized distribution of surficial materials across the area. Both figures are generalized to show the geologic features at a scale of 1:50,000 (approximately 1.2 inches per mile). The geologic units are described from oldest to youngest.

Early Proterozoic Gneiss The oldest rocks are exposed in the canyon of Tenderfoot Creek from about 1,100 m east of Stringer Creek to near Lost Stove Creek on the west. The gneiss is more widely exposed east of the Experimental Forest in the vicinity of Neihart, Montana, and southwest of the area in the drainage of Moose Creek, south of the south-bounding divide of the Experimental Forest. The gneiss forms the basement rock of the Little Belt Mountains on which a thick succession of younger stratified rocks rests.

The oldest exposed rock is medium gray to medium-light gray, medium to coarsely crystalline hornblende biotite gneiss. Thin laminae of biotite schist coarse feldspathic biotite schist are present locally in the gneiss. Pegmatite dikes of pink orthoclase feldspar, with plagioclase feldspar and quartz, are scattered to common, generally parallel to the gneissic foliation. The composition and textures of the gneiss suggest that it was derived by metamorphism from ancient feldspathic volcanic or foliated intrusive igneous rocks. Although no distinct evidence was seen that some of the gneiss could have been derived by metamorphism of sedimentary rocks, some schistose laminae might originally have been volcanic siltstone laminae or mafic tuff beds.

Generally foliation in the gneisses trends north-northeast to east-northeast. The crystalline rocks split blocky to support steep canyon walls; blocks of the gneiss form coarse talus cones built out from the steep exposures. Fractures and locally open vugs in quartz-rich laminae and foliation provide limited pathways for the movement of water through these crystalline rocks.

The age of the premetamorphic rocks from which the gniesses were derived is not known with certainty. Radiometric age determinations on zircon crystals from the gneiss are about 2.4 billion years (earliest Proterozoic), suggesting that age for the original rock. A metamorphic event that reset the age of other minerals in the rock has been dated as about 1.84 billion years before present. The surface on which younger stratified rocks of Cambrian age rest across the gneiss in the area of the Experimental Forest seems to be a sharp, nearly flat surface. It represents early pronounced faulting, uplift, and erosion of the Earth's crystalline crust, likely between about 800 and 600 million years before present. However, stratified rocks younger than the gneiss, including the Neihart quartzite and other strata of the Middle Proterozoic Belt Supergroup, overlie the gneiss in the vicinity of Neihart and across areas west, south, and locally east of the Little Belt Mountains. The site of the Experimental Forest was likely on the faulted margin of the ancient uplift.

Cambrian Flathead Sandstone Across the Tenderfoot Creek area, the Flathead Sandstone of Middle Cambrian age, rests unconformably on the Early Proterozoic gneiss. The Flathead Sandstone is fine- to coarse-grained sandstone cemented with quartz. Pebbles of red and white quartzite as large as 2 cm across are present locally in the sandstone. Beds of sandy siltstone, a few centimeters thick, are interbedded with the sandstone, and increase in abundance toward the top of the Flathead. Grains in the sandstone are quartz, polycrystalline quartz, microcline, orthoclase, scattered plagioclase, and common to abundant iron oxides, including hematite and magnetite. The grains of the sandstone, generally well rounded, are coated with hematite. The sandstone is trough cross-laminated to thinly cross bedded. The Flathead ranges in thickness from about 275 to 450 feet thick.

The Flathead Sandstone is generally firmly cemented and forms ledges or steep slopes. The Flathead underlies the steep slopes at the top of the inner canyon of Tenderfoot Creek. Because of the silica cement, the sandstone splits flaggy to blocky so that fragments form talus cones or remain in clayey soils as angular fragments. Cementation makes the sandstone tight, likely with low permeability. Fractures and weakly cemented laminae in the upper part are likely the principal sites of water storage and transmission in the unit. Water percolating downward through overlying shales emerges as seeps at or near the contact between the shales above and the silica-cemented sandstone below.

About 7 miles east of the Tenderfoot Creek Experimental Forest, the Middle Proterozoic Neihart Quartzite, which has some characteristics similar to the Flathead, underlies the unconformity at the base of the Flathead Sandstone. Similarly, in Moose Creek drainage, south-southwest of the Experimental forest, the Neihart Quartzite underlies the Flathead Sandstone, but is truncated beneath the Flathead in that area. The truncated edge projects northeast to east-northeast under younger strata between those areas, and the Neihart Quartzite is considered absent in the area of the Experimental Forest. Both the apparent absence of a significant erosional break in the quartz-cemented sandstones present, and the upward gradation of the sandstone into siltstone, claystone, and sandy siltstones that locally contain fossils in the forest area demonstrate that the quartzitic sandstone overlying the Early Proterozoic gneiss is the Middle Cambrian Flathead Sandstone.

Middle Cambrian Wolsey Shale The rolling park areas of the Experimental Forest, including Harley and Onion Parks, are underlain by dark to medium dark gray and dark greenish-gray clayey siltstone, claystone, and sandy siltstone assigned to the Wolsey Shale. The stratigraphic and Middle Cambrian age assignment are based on the superposition of the strata on the quartzite and on trilobite and small brachiopod fragments exposed in rock quarried on the edge of the forest area.

The Wolsey Shale is poorly exposed across the area. It consists of sandy siltstone, siltstone and silty claystone in exposures of the lower part. Based on the presence of silty limestone fragments higher in the section, the Wolsey also contains laminae and very thin beds of silty and sandy limestone. Wolsey strata are very thinly and thinly laminated and split shaly to platy. As much as 400 feet of Wolsey seems to be present north of Tenderfoot Creek, but the thickness may include thin, poorly exposed porphyritic rhyodacite sills of Eocene age (see below) and thin limestone beds of the lower part of the Middle Cambrian Meagher Formation.

The Wolsey Shale weathers to form clay-rich soils and subdued slopes. The slopes are mantled with colluvial fragments and fine alluvial sediment derived from resistant rocks of the ridges bounding the basin on the south and north. Shaly rocks of the Wolsey have apparent low permeability, but are abundantly fractured. During wet times of the year, water saturates areas of low relief and emerges as seeps along the margins of colluvial and alluvial sediments in thin aprons on the Wolsey. Locally anomalous concentrations of calcium carbonate in water associated with the Wolsey may be derived from dissolution of thin limestone beds and concretions in the Wolsey.

Sedimentary rocks younger than Middle Cambrian have been eroded from the area of upper Tenderfoot Creek. However, rocks ranging in age from Late Cambrian through Cretaceous are exposed west, north, east, and locally south of the Little Belt Mountains. Small outcrops of gravel containing pebbles and cobbles of the Paleozoic and Mesozoic strata are present on high ridges south of the Lost Fork of the Judith River, southeast of the Tenderfoot Creek Experimental Forest. Clasts of those gravels demonstrate that the younger strata were originally present across the site of the present Little Belt Mountains but were eroded from the range crest probably during middle and late Tertiary time.

Eocene Porphyritic Rhyodacite Capping the ridge bounding the north flank of the Tenderfoot Creek Experimental Forest from near Harley Park northwest is medium dark to medium gray porphrytic rhyodacite, which weathers pale-grayish orange to light gray. The rock intrudes shales of the Wolsey and Park (?) formations as sills 3 to 15 meters thick. The rock consists of quartz and scattered plagioclase phenocrysts in a matrix of very finely crystalline alkalic and some sodic feldspar with scattered to common biotite and rare hornblende and scattered very fine quartz. The mafic minerals are commonly altered to iron oxides.

The sills are within a nearly continuous northwest-trending zone of sills that extends from Kings Hill and Porphyry Peak southeast of the Tenderfoot Creek area to the area of this report at the same approximate stratigraphic position.
Alteration precludes determination of the radiometric age of the sills in the Tenderfoot Creek area. However, the U.S. Geological Survey has dated sills from the same zone at Kings Hill as about 47.3 to 48.5 million years (Ma) old (Eocene) (H. H. Mehnert and M. S. Reynolds, 1983). The age coincides with the time of intrusion of laccoliths, stocks and sills on the north flank and in the center of the Little Belt Mountains (Weed, and Weed and Pirsson, 1900, and numerous authors since).

Tertiary rocks younger than Eocene. Tertiary rocks younger than about 47 Ma are not known in the central part of the Little Belt Mountains. South-southeast of the Tenderfoot Creek area basalt caps some ridges on the north and south flanks of Sheep Creek drainage. The basalt is considered equivalent to basalt farther south and southwest that have been dated as about 31 Ma (Oligocene). West-southwest down the west plunge of the Little Belt Mountains, deformed ash-flow and airfall tuffs with interbedded basalt breccia have been dated as about 26 Ma (U.S. Geological Survey, H. H. Mehnert and M. W. Reynolds, written communication, 1984). Deformation of those beds demonstrates tilting and uplift of at least the western part of the Little Belt Mountains as middle Miocene or younger. Normal faulting as young as Pliocene (5-3 Ma) has displaced rocks in valleys southwest of the Tenderfoot Creek area.

Quaternary deposits. Three general units of Quaternary sediments are distinguished in the Tenderfoot Creek Experimental Forest: (1) Talus, (2) thin mantles of colluvium derived from bounding ridges and mixed with alluvium; and (3) clay-rich soil developed on the Wolsey Shale.

Talus derived from ledges and rocky faces of Proterozoic gneiss and Flathead Sandstone is banked against walls of the canyon of Tenderfoot Creek and locally clogs the creek. Talus blocks in the stream channel trap sand and silt transported during internals of high water flow.

Thin braided and fan-shaped deposits of colluvium and alluvium cover slope of ridges and the parks in the forest area. Sediment clasts range from silt and sand size to angular fragments several centimeters across and, adjacent to the ridges, angular clasts as large as 10-20 cm across. The coarse sediment is reworked by sheet wash into braided patterns of coarse debris in low ridges with finer debris in channels. Porosity and permeability of the mixed colluvial and alluvial deposits is high. During wet intervals, water flowing through these coarse sediments emerges along contacts with the clay soils or onto clayey flat areas. The contrasting sediment grain size between the units seems to control the distribution of grasses and broad- leafed plants in the park areas. However, trees grow on both the colluvial/alluvial sediment and the clay-rich soils.

Clay soil and silty clay soil is developed on the Wolsey Shale across rolling park areas. The thickness of the soils ranges from 0 to about 2 meters.

Geologic Structure. Rocks of the Experimental Forest area have been uplifted and faulted, but retain a relatively simple geologic structure. Strata of the Flathead Sandstone and Wolsey Shale are nearly flat lying or dip 1-2 degrees south on the south side of Tenderfoot Creek. These rocks unconformably overlie the Early Proterozoic gneisses, which were strongly deformed and eroded before deposition of Middle Proterozoic strata of the overlying Belt Supergroup, which were originally deposited across the gneiss. Uplift and erosion during the time interval about 0.8-0.65 billion years ago caused strata of the Belt Supergroup to be eroded from the Tenderfoot Creek area before subsequent deposition of the Middle Cambrian rocks.

During Eocene (Tertiary) time, sills of porphyritic rhyodacite were intruded into the Wolsey and overlying shales of the Cambrian succession. There are remnants of those sills cap ridges on the north border of the Experimental Forest, and they are nearly flat-lying.

On the west end of the forest area, Cambrian and younger beds dip westward on a broad plunging anticline toward Smith River. Rocks of Upper Cambrian, Devonian, and Mississippian ages crop out successively in the canyon of Tenderfoot Creek west toward the River.

Cambrian strata along the southeast and south flank of the Experimental Forest are faulted downward to the north (Tenderfoot Creek block) approximately 500-600 feet with respect to rocks of Quartzite Ridge. Strata on that Ridge are broken by north and northwest- trending fractures, some with fault displacements as much as 100 feet. The north-trending small faults cannot be traced through the Wolsey Shale of the park bench. Those faults maybe conduits for the movement of groundwater from the southern rim of the Tenderfoot Creek basin toward the Creek.