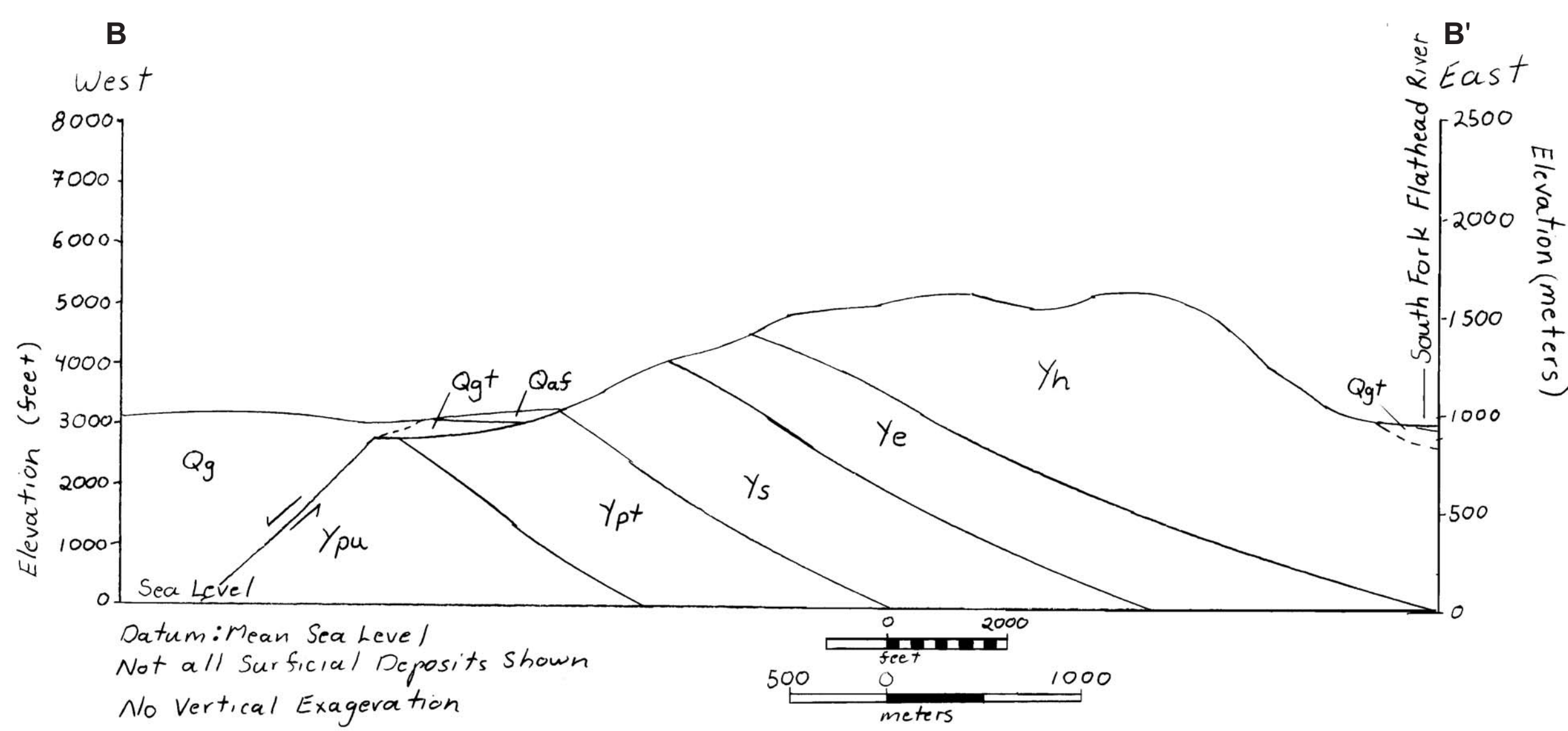
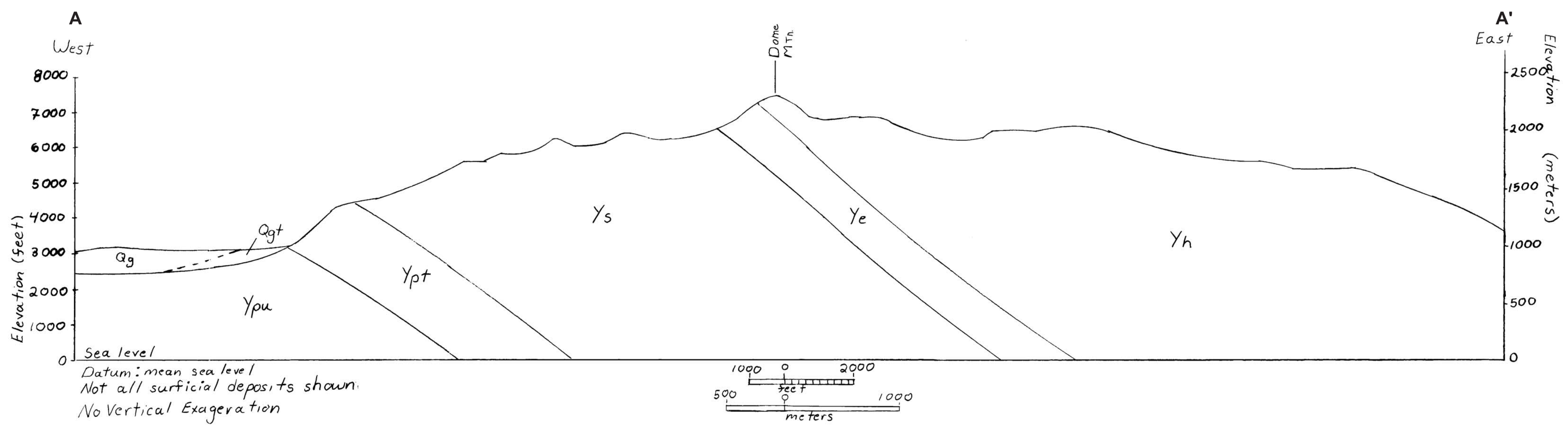
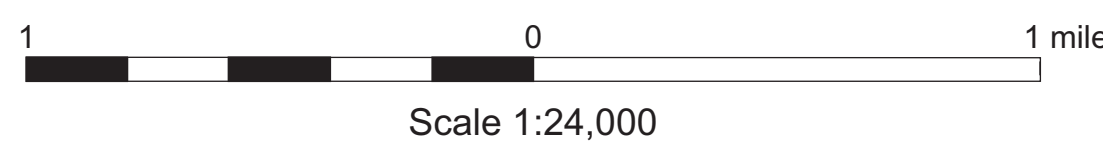


MAP UNITS

| | |
|-----|--|
| Qal | Alluvium of modern channels and flood plains |
| Qaf | Alluvial fan deposit |
| Qac | Alluvium-colluvium |
| Qc | Colluvium |
| Qta | Talus deposit |
| Qld | Landslide deposit |
| Qg | Glacial deposits, undivided |
| Qgt | Glacial till |
| Yh | Helena Formation |
| Ye | Empire Formation |
| Ys | Spokane Formation |
| Ypt | Pritchard Formation, transitional member, informal |



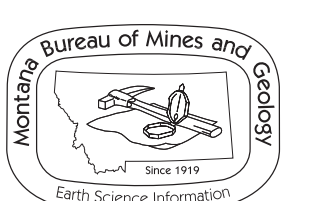
MBMG Open File No. 487

**Geologic Map of the
 Columbia Mountain Area
 Northwest Montana**

Compiled and mapped by Kathryn K. Clapp,
 Larry N. Smith, Mary M. MacLaughlin, and
 Carlyle R. Miller

2004

Support has been provided by the U.S. Geological Survey EDMAP Program under Contract Number 02-HQ-A5-0074.
 GIS production: Ken Sandau and Paul Thale, MBMG. Map layout: Susan Smith, MBMG.



Maps may be obtained from: Publications Office
 Montana Bureau of Mines and Geology
 1300 West Park Street
 Butte, Montana 59701-8997
 Phone: (406) 438-4167
 Fax: (406) 496-4451
 http://www.mbmng.mtech.edu

Geologic Map of the Columbia Mountain Area Northwest Montana

Geologic Mapping of Area
Kathryn K. Clapp¹
Dr. Larry N. Smith²
Dr. Mary M. MacLaughlin³

Geophysical Investigation
Carlyle R. Miller⁴

Montana Bureau of Mines and Geology
Open File Report MBMG 487

2004

- 1 Graduate student, Geological Engineering, Montana Tech
- 2 Montana Bureau of Mines and Geology
- 3 Associate Professor, Geological Engineering, Montana Tech
- 4 Graduate student, Geophysical Engineering, Montana Tech

Support has been provided by the United States Geological Survey EDMAP Program under Contract Number 02-HQ-AG-0074.

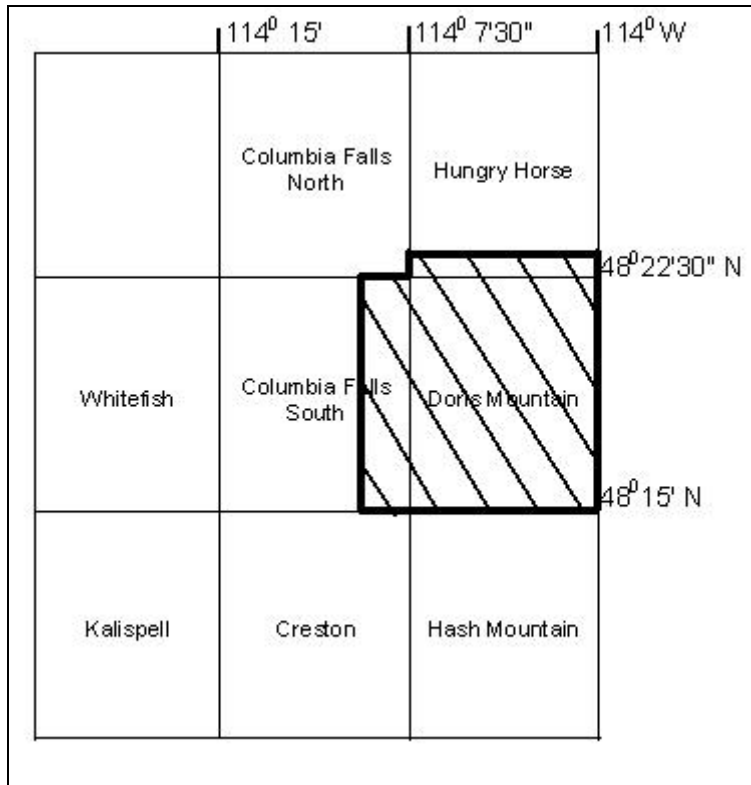


Figure 1. Location of the map area. Mapped area (cross hatched) covers the Doris Mountain quadrangle, the eastern part of the Columbia Falls South quadrangle, and the southwestern part of the Hungry Horse quadrangle.

Introduction

The research site lies at the far northern end of the Swan Range, just west of Hungry Horse, Montana (Figure 1). The site encompasses the Doris Mountain quadrangle, the eastern edge of the Columbia Falls South quadrangle and the southern edge of the Hungry Horse quadrangle; from here on this will be referred to as the Columbia Mountain area. Previous geologic mapping in the area has resulted in two contradicting interpretations of the geologic structure. Johns (1970) mapped northeast-southwest-trending normal faults in the range, whereas Harrison and others (1992) showed only northwest-southeast-trending normal faults. Anderson (2001) inferred a range-bounding normal fault located along the western margin of the Swan Range in the research area. Prior studies have failed to locate any surface features indicating the location of the inferred fault. Research in the area by Smith (2001) identified a group of large extension cracks near the crest of Columbia Mountain on a remnant block left by a late Pleistocene landslide.

This geologic map is the result of a research project conducted during the summer of 2002 under a grant from the U. S. Geological Society EDMAP program. Research was conducted by a group of Montana Tech students and faculty, along with staff from the Montana Bureau of Mines and Geology, to accomplish three major objectives:

- 1) Map the geology and dominant fault patterns in the Columbia Mountain area,
- 2) Determine the location of the inferred range-bounding normal fault using geophysical (gravity and magnetic) surveys, and
- 3) Map a group of large tension cracks near the crown of a paleolandslide located along the western flank of Columbia Mountain.

The field mapping was conducted by air-photo interpretation and on foot over the Columbia Mountain area, and by road access along the perimeter of the area. The mapped area is bounded on the west by the Flathead valley, which is relatively flat and characterized by glacial till and kettles, and stabilized sand dunes. The northern end of the map area is bounded by Badrock Canyon where an excellent stratigraphic section is exposed of the upper Ravalli Group and lower Middle Belt carbonate. Hungry Horse Reservoir borders the eastern side of the area and covers all recent deposits. The southern boundary is marked by the southern extent of the Doris Mountain quadrangle. It is hoped that these data will be useful in assessing the seismic potential and landslide hazards of the area.

Overview

Columbia Mountain is an east-northeast-dipping fault block located on the eastern side of the Flathead valley (Figure 2). Bedrock geologic units in the area consist of Belt Supergroup rocks, including the Pritchard and Spokane Formations of the upper Ravalli Group and the overlying Empire and Helena Formations of the lower Middle Belt carbonate. The Empire Formation is a transitional unit between the Ravalli Group and Middle Belt carbonate. The overlying Helena Formation forms the spine of Columbia Mountain and other local peaks.

The slopes along Columbia Mountain are covered with colluvial material that exhibits recent downslope movement as demonstrated by numerous boulders leaning against trees and trees that have grown around lodged boulders. Many trees are not vertical but tilted away from vertical slope at varying angles. Areas of slumped ground and springs are common near the contact of the Grinnell and Empire Formations.

Gravity and magnetic surveys were conducted along the base of the range to locate the inferred range-bounding fault (Figure 2). Stations were located along eight survey lines, three running north-south for 8000 meters and five running east-west for 6000 meters west of the range front. All survey lines were located along the county road system as shown in Figure 2. Primary results indicate that a northeast-trending normal fault dipping west at 56° to 60° is located approximately 900 meters west of the range front. Results of the survey are discussed separately by Miller (2003). Although not confirmed by mapping or geophysical surveying, a north-south-trending normal fault may exist under surficial deposits between the mapped fault and the range front. This possible fault is not shown on the map, but is inferred to define the north-south escarpment of the northern Swan Range (Anderson, 2001).

During deglaciation of the valley approximately 12,000 ^{14}C yr BP, a massive landslide was emplaced due to failure of one of the interfluves on the western flank of Columbia Mountain (Smith, 2001). The scarp of the slide extends 1100 meters up the side of Columbia Mountain where a remnant block was left at the crest. The remnant block is crossed by large cracks trending to the south-southwest that exhibit recent movement. GPS mapping was done of all forty-six cracks identified. Sizes of the cracks ranged from 1 to 13 meters in depth, 1 to 25 meters in width, and 5 to 148 meters in length. All cracks were filled to some degree with colluvial materials, making absolute determinations of depth impossible. A slope stability study was carried out to ascertain the current stability of the remnant block. Results indicate that movement may occur under high seismic loads and high ground-water conditions. A full discussion can be found in MacLaughlin and others (2003).

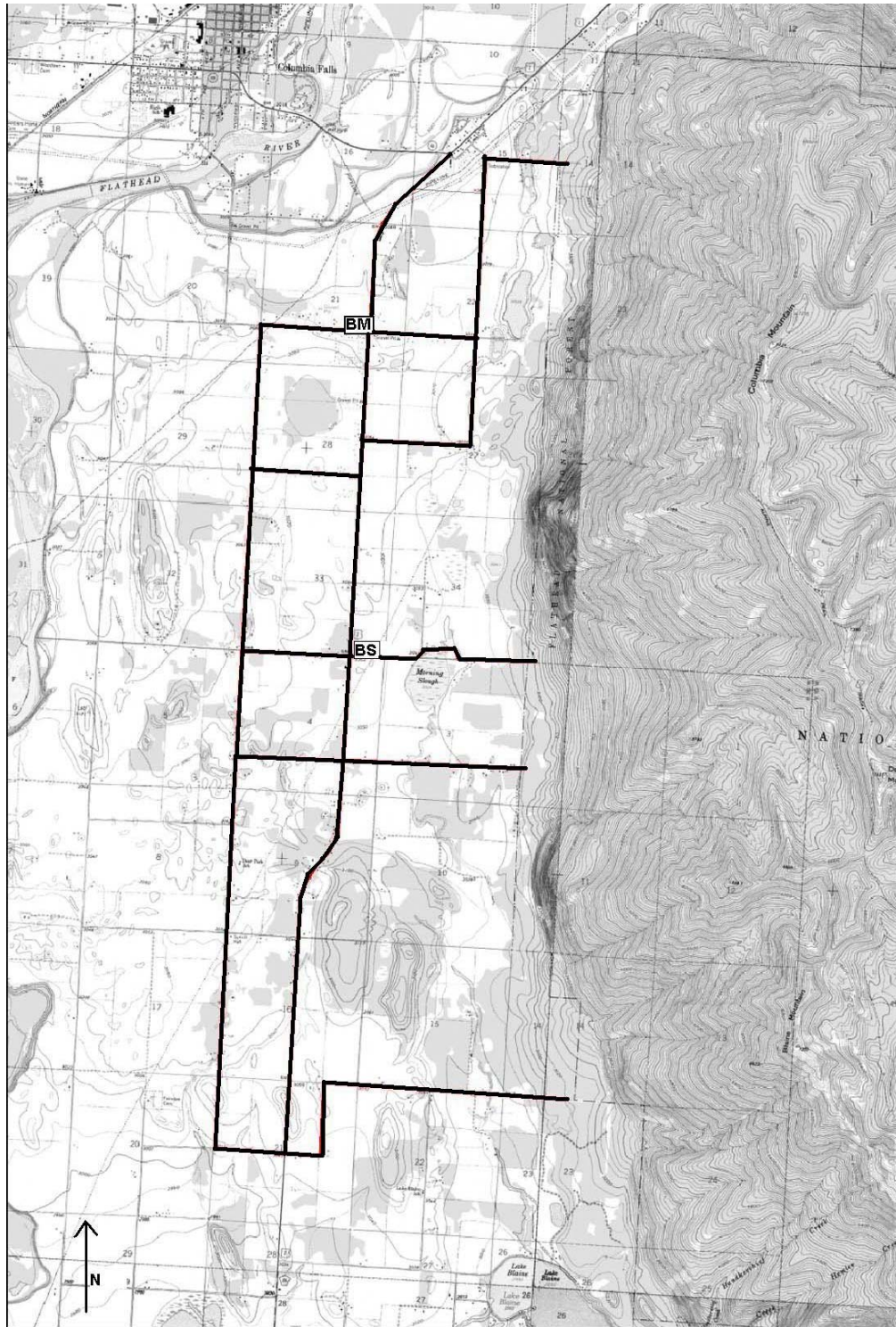
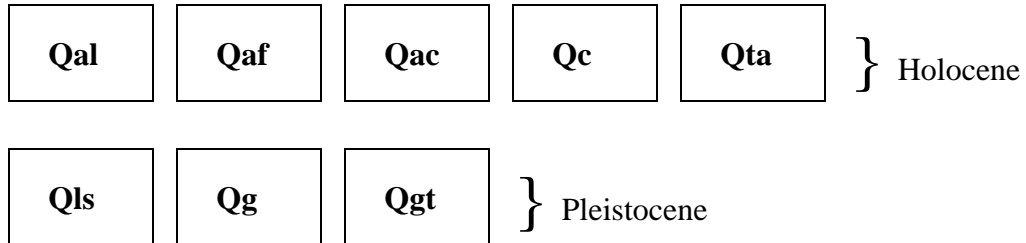


Figure 2. Location of geophysical survey lines. All survey lines were located along county roads. Stations are approximately a quarter mile apart with stations located at each intersection and curve. The bench mark point (BM) for the GPS survey and Base station (BS) for the gravity and magnetic surveys are labeled. The city of Columbia Falls is to the upper left.

Correlation Chart of Map Units Columbia Mountain Area

Quaternary



Unconformity

Middle Proterozoic

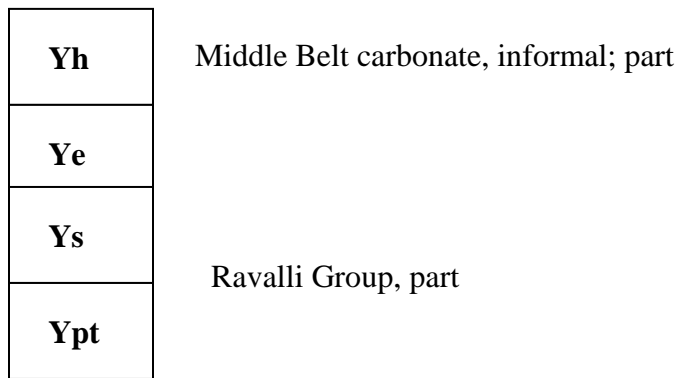


Figure 3. Correlation chart of units mapped in Columbia Mountain project area.

Description of Map Units

Quaternary

- Qal** Alluvium of modern channels and floodplains (Holocene) – Light- to medium-brown and grayish-brown sand and silt with lesser amounts of clay, pebbles, and cobbles along active stream valleys; contains minor amount of colluvium along the bases of steep slopes; thickness averages 9 meters (30 feet).
- Qaf** Alluvial fan deposit (Holocene) – Grayish-brown and light- to dark-yellowish-brown silt, sand, pebbles, cobbles, and boulders deposited in fan-shaped landforms downslope from canyon mouths; thickness ranges from 0.3 to 18 meters (1 to 60 feet).
- Qac** Alluvium-colluvium deposit (Holocene) – Includes alluvial deposits along with significant amounts of colluvial material deposited by sluffing and non-fluvial transport events; found downslope from canyon mouths of steep intermittent streams.
- Qc** Colluvium deposit (Holocene) – Raveled materials consisting of cobbles, boulders, and minor amounts of soil matrix; deposits cover bedrock; currently moving under force of gravity; locally vegetated.
- Qta** Talus deposit (Holocene) – Angular rock cobbles and boulders accumulated at the base of exposed outcrops from where they were derived; non-vegetated to sparsely vegetated.
- Qls** Landslide deposit (Pleistocene) – Poorly graded pebbles, cobbles, and boulders in a light- to dark-brown matrix of sand and silt; clasts are mostly angular and subangular; deposited by gravity sliding of unconsolidated material to a position near the base of a hill or mountain slope; surface of unit is typically uneven and lobate in form.
- Qg** Glacial deposit (Pleistocene) – Undifferentiated glacial deposit. Deposits include till, outwash, and other glacial deposits.
- Qgt** Glacial till (upper Pleistocene) – Predominantly granules, pebbles, cobbles, and boulders supported by a matrix of light-gray, light-brownish-gray, pale-yellowish-brown, grayish-orange, and pale-brown, compact sandy or silty loam (diamicton) deposited by active glacial ice; minor amounts of stratified sand and gravel (drift) deposited by flowing water; clasts are typically rounded or subrounded; more resistant clasts are commonly striated; crests of glacial landforms include drumlins and moraines; occurs as a veneer over Belt Supergroup rocks in most mountainous areas; glaciofluvial channels cut across the unit, including

across some of the drumlins and moraines; thickness averages 26.5 meters (90 feet) and locally more than 76 meters (250 feet).

Middle Proterozoic

Yh Helena Formation (lower formation of the Middle belt carbonate) – Cyclic bedding is common, forming bands of gray to black argillite or gray dolomitic siltite that weathers to a tan color, alternating with dense limestone that weathers to orange-brown and exhibits a pitted or molar-tooth structure with stromatolite beds in places. Lower portion includes white to tan quartzite beds with varying amounts of cubic pyrite. Basal contact is transitional, grading into pale-blue to light-green siliceous argillite and siltite beds of the underlying Empire Formation. Basal contact placed at the bottom of the lowest significant dolomitic siltite.

Ye Empire Formation (transitional between upper Ravalli Group and Middle Belt carbonate) – Thinly bedded to laminated, dark- to light-green and locally pale-blue argillite and silty argillite and siltite. Discontinuous, white, coarse-grained quartzite beds and lenses about seven centimeters thick occur with crossbedding and mud chips common in these beds. Bedding is wavy to planar and discontinuous. Ripple marks, syneresis cracks, and mud chips are common in places. Upper part of the formation is more carbonate-rich with interbedded dolomite, limestone and black argillite lithologies common in the Helena Formation. Lower contact is transitional with the Spokane Formation, grading into thinly bedded to laminated, dark-red to maroon argillite and siltite of the underlying Spokane Formation. Basal contact placed at the base of the lowest light-green to pale-blue argillite bed with thickness greater than 0.3 meters (1 foot).

Ys Spokane Formation (upper member of the Ravalli Group) – Thinly bedded to laminated, red to maroon-gray, coarse-grained argillite and siltite. Discontinuous, white to tan, coarse-grained quartzite beds about 10 centimeters thick are common, often containing mud chips and exhibiting crossbedding. Mud-cracks are common. Thin beds (less than 0.3 meters thick) of dark- to light-green argillite and silty argillite are common in the upper portion. Formation is more resistant than the overlying Empire Formation.

Pritchard Formation (Lower member of the Ravalli Group)

Ypt Transitional member – Only uppermost transitional member is exposed in the map area. Interlaminated light- and dark-gray siltite. Weathers to give a rusty orange-red appearance. Outcrops in area form a loose shaly slope. Average thickness is about 320 meters (1050 feet) in the map area.

Ypu Upper member – Shown in cross section only, to indicate inferred rocks of the Pritchard Formation that are not exposed in the map area.

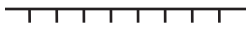
Map Symbols



Contact; dashed where approximate or inferred; dotted where concealed



Fault-normal; dashed where approximate or inferred; dotted where concealed; bar and ball on downthrown side.



Delineation of landslide scarp



Tension cracks



Ice marginal channels



Strike and dip of bedding; degrees of dip indicated



Strike and dip of joints; degrees of dip indicated



Strike of vertical joints

References

- Anderson, L.W., 2001, Seismotectonic study for Hungry Horse Dam, Hungry Horse Project, and Gibson Dam, Sun River Project, Montana: Bureau of Reclamation Seismotectonic Report 2001-5, Seismotectonics and Geophysics Group, Denver, Colorado.
- Harrison, J.E., Cressman, E.R., and Whipple, J.W., 1992, Geologic and structure maps of the Kalispell 1 x 2-degree quadrangle, Montana, and Alberta and British Columbia: U.S. Geological Survey Miscellaneous Investigations Series Map I-2267, scale 1:250,000.
- Johns, W.M., 1970, Geology and Mineral Deposits of Lincoln and Flathead Counties, Montana: Montana Bureau of Mines and Geology Bulletin 79, 182 p.
- MacLaughlin, M., Clapp, K., O'Connell, L., and Smith, L., 2003, Numerical modeling of the Columbia Mountain landslide, northwestern Montana, U.S.A.: 38th Annual Symposium on Engineering Geology and Geotechnical Engineering, Elfass, Norris and Watters, p. 119-134.
- Miller, C., 2003, Gravity survey, modeling and interpretation near Columbia Mountain, Montana: 38th Annual Symposium on Engineering Geology and Geotechnical Engineering, Elfass, Norris and Watters, p. 265-279.
- Smith, L.N., 2001, Columbia Mountain landslide: late-glacial emplacement and indications of future failure, northwestern Montana, U.S.A.: Geomorphology, p. 309-322.