Geologic Map of Ruby Dam Area
Southwestern Montana

Compiled and Mapped

by

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Introduction

This project was funded by the EDMAP program of the U. S. Geological Survey. Field studies, including geologic mapping and a gravity and magnetic survey, were conducted during the 2001 field season. These studies were undertaken to gain a better understanding of the geologic structure of the Ruby basin in the area of Ruby Dam in southwest Montana (Figures 1 and 2). Ruby Dam, which impounds Ruby Reservoir, lies within a seismically active region known as the Intermountain Seismic Belt. Delineation and detailed mapping of the Tertiary and Quaternary sediments has helped to understand better the occurrence of Quaternary faulting in the basin. No new faults of Quaternary age were recognized within the field area. However, a fault that offsets Quaternary deposits was newly mapped by the authors in a gravel pit two miles north of the north map boundary. This fault may change previously calculated ground acceleration values at the dam site, and may indicate a greater susceptibility of the dam to seismic activity than previously thought.

The geologic map in this report combines previous work that focused on the bedrock of the area with new mapping of the Tertiary and Quaternary deposits by the present authors. Mapping of the Archean rocks and the bedrock geologic structure in the Greenhorn Range is taken from Berg (1979) with very minor modifications (Figure 5). Mapping of the Paleozoic stratigraphic units and structure in the northern Ruby Range is taken from Tysdal (1976). An earlier stratigraphic and paleontologic study in the Ruby basin was conducted by Monroe (1976).

In addition to geologic mapping, gravity and magnetic data were acquired to aid in understanding structural and stratigraphic relationships beneath the valley floor. In the present study, three gravity surveys were run (Figure 3). Two of these were oriented approximately north-south, one on each side of Ruby Reservoir. The third survey was oriented approximately west-east across the valley; it passed along Garden Creek drainage on the west side of the reservoir and along the Barton Gulch drainage on the east side. The acquired data readily show the Greenhorn and northern Ruby Mountains range-bounding normal faults that define the Ruby basin; dip angles on these faults have both been calculated at approximately 60 degrees. The depth to bedrock in the valley is approximately 8,000 feet based on interpretation of the gravity data. These data correlate well with a previous gravity survey of the northern Ruby basin conducted by Burfeind (1967, p. 70-72), approximately two miles south from the present study area, in which fault-plane dip angles were similar and a basin depth to bedrock was approximately 7,000 feet.

Unit thicknesses of the formations of the Tertiary Bozeman Group, including the Renova Formation and overlying Sixmile Creek Formation, in the upper Ruby Basin were taken from Monroe (1976). Monroe indicates that the maximum total thickness of the group within the upper Ruby basin is approximately 3,700 feet based on his twelve composite measured sections; only one measured section exposed pre-Tertiary beds at its base. Monroe (1976) further states that this thickness is comparable to Bozeman Group thicknesses measured by earlier workers in the lower Beaverhead River basin and Jefferson River basin. This total thickness is much less than the apparent 8,000-foot thickness of sediments within the basin as indicated by our gravity data. Possibly the gravity data are incorrect, although they are similar to the Burfeind (1967) data. A more likely conclusion is that sedimentation into this structurally controlled developing basin was rapid and of high volume. Thus, the mudstone member (informal) of the Renova

Formation, oldest recognized unit of the Bozeman Group in this area, may overlie several thousand feet of older Tertiary deposits that are nowhere exposed.

Cross section A-A’

In the construction of cross section A-A’ across the Ruby basin, the following assumptions were made:

1. A regionally recognized angular unconformity is observed between the Sixmile Creek and Renova Formations of the Tertiary Bozeman Group (personal communication, Jeffrey D. Lonn, 2002). Its recognition here is based on (1) the consistently southeast-dipping Sixmile Creek Formation strata that overlie variable but predominantly northwest-dipping Renova Formation strata, and (2) observed folding within the Renova that must have occurred prior to deposition of the unfolded Sixmile Creek strata;

2. Southeast tilting of strata is associated with growth faulting during development of the basin (personal communication, Jeffrey D. Lonn, 2002);

3. Thickness of the Renova Formation (lower member of the Bozeman Group) is based on the composite measured sections of Monroe (1967) within the Ruby basin that record one locality where contact of the Renova with the underlying Paleozoic beds was exposed. Monroe (1967) gives a total Bozeman Group thickness of approximately 3,700 feet;

4. Basin-fill materials below the Renova Formation is older Tertiary deposits;

5. While our gravity data suggest that both basin-margin faults dip about 60º, surface mapping shows a much straighter trend on the east-bounding fault than on the west-bounding fault suggesting a steeper dip angle for the east-bounding fault, at least at the surface to near-surface depth. Burfeind (1967, p. 71) made a similar observation.

6. Dip angles of the basin-margin faults probably decrease with depth, and may, in fact, intersect at some depth below the basin-fill deposits.

Gravity Data Employed in Modeling the Subsurface

The base station set up for the acquisition of the gravity data for this project was located just northeast of Ruby Dam. These data were corrected for the specific equipment used, gravity drift, latitude, ground elevation, terrain, and free-air. The data are not considered a “Bouguer” gravity survey because regional gravity was not removed; however, the influence of regional gravity is considered minimal.

Multiple gravity survey lines were run, taking advantage of existing roads, to provide an optimal coverage of the valley floor. Two survey lines were run approximately perpendicular to the valley and reservoir, one along Barton Gulch and one along Garden Creek (Figure 3). Two additional survey lines were run approximately parallel to the reservoir along the roads that run along each side of the reservoir. Additional lines were run to the northeast and south to provide better control for the planned three-dimensional mapping process (Figure 3). A three-dimensional gravity model was developed using the Surfer software package. Contouring was completed using Kriging equations. A cross section of the data was taken approximately perpendicular to the reservoir near the Barton Gulch and Garden Creek survey lines (Figure 4), providing the greatest density of data and thus the most reliable data for modeling. In this cross section, the data have greater resolution across the valley floor than on the eastern and western edges of the data, based on lack of data collection at the edges of the survey. The cross section was modeled using an in-house program written in the Geophysics Department at Montana Tech of the University of Montana.

The primary objective of the gravity survey was to determine the depth of the sediments within the basin (valley). Given the clear gravity low shown in the data, an initial model of a three- or four-sided body (the basin, or valley) should give useful depth and density values. A three-sided body (as in a valley or basin), closing at the same depth as a four-sided body, requires a greater density contrast (>0.5 g/cm^3 versus 0.3 to 0.4 g/cm^3) between the basin and the surrounding rock.

After using the gravity-low anomaly to account for the simple basin model, a few smaller anomalies remain. The data show a distinct “rise” (or shallowing) of the depth of the data contrast. This feature could be modeled as a more dense body in the middle of the valley floor, or as two less dense bodies along the basin’s margins. Bumps higher up along the basin margins are probably en echelon faults. Note that in the geologic cross section A-A’ of this report this basin-floor anomaly is not shown for lack of adequate geologic data to explain its occurrence. One possibility is that gravity data are insufficient along the valley margins to allow adequate definition of the anomaly there.

Efforts at more complex modeling of these gravity data for this valley have proved unrewarding. Without additional constraints from surface geology or drilling programs a definitive model is difficult.

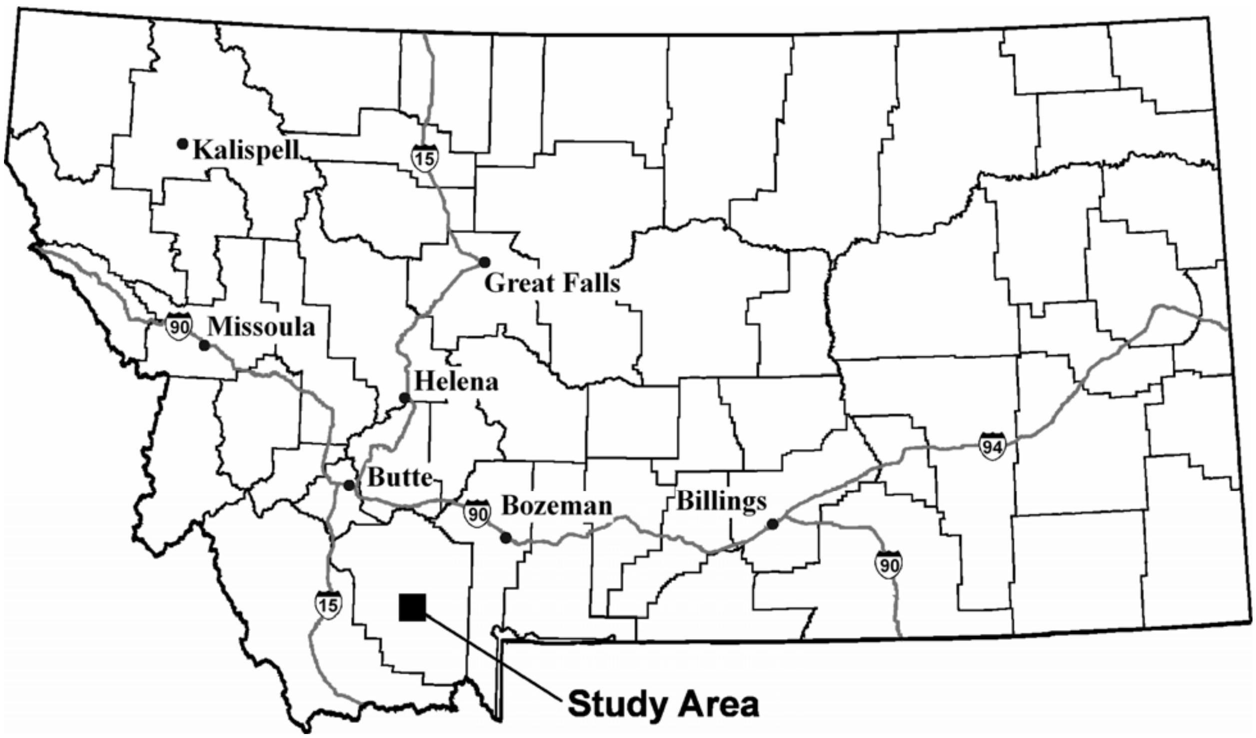

Figure 1. Location of the Ruby Dam within the state of Montana

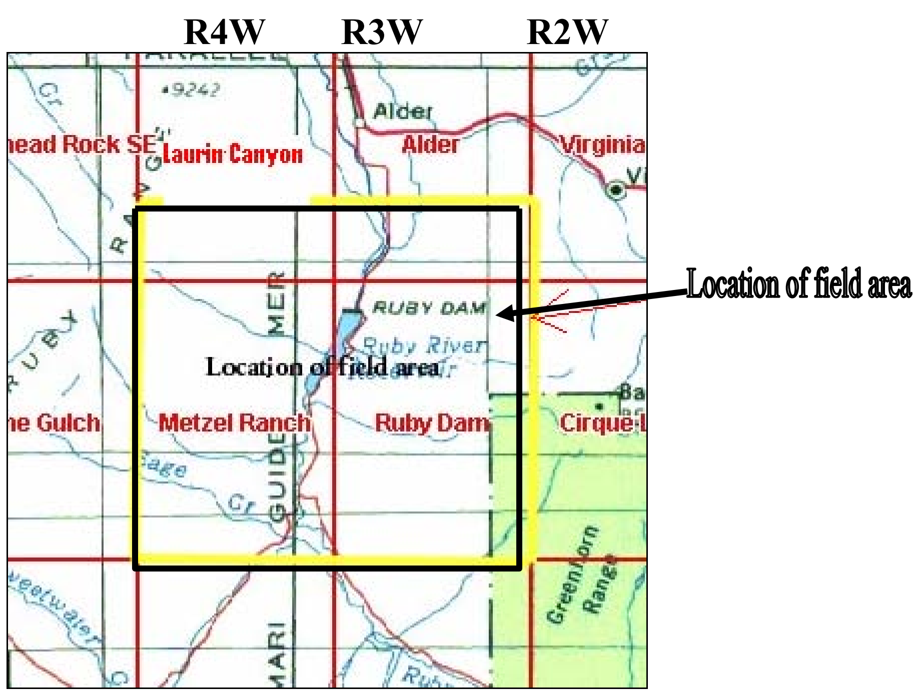

Figure 2. Location of study area in the Laurin Canyon, Alder, Metzel Ranch, and Ruby Dam 7.5’ quadrangles.

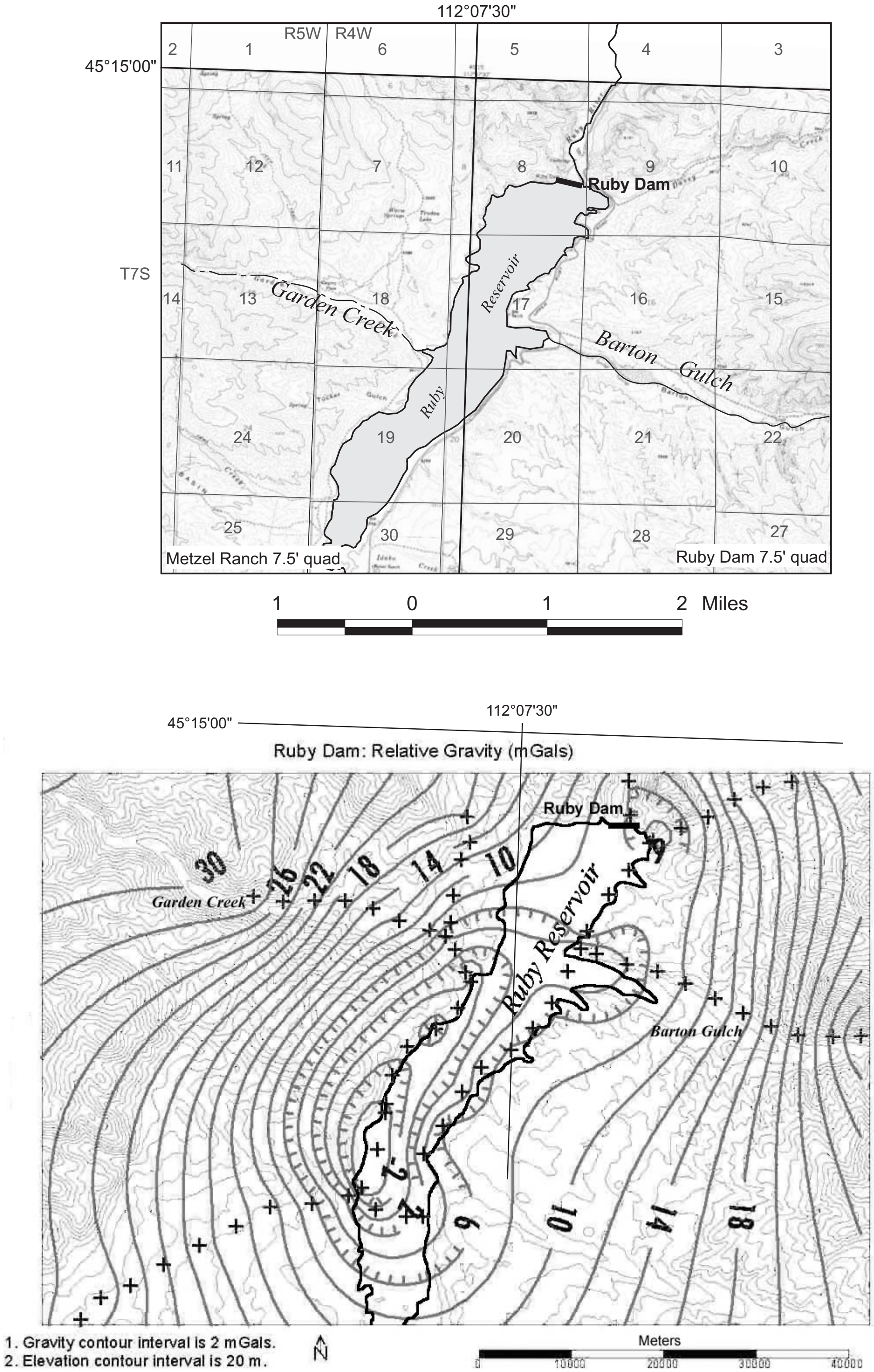

Figure 3. Gravity map of the Ruby basin. Contours superimposed over topography are relative gravity with 2-milligal spacing. Plus signs (+) indicate locations of stations where gravity was collected.

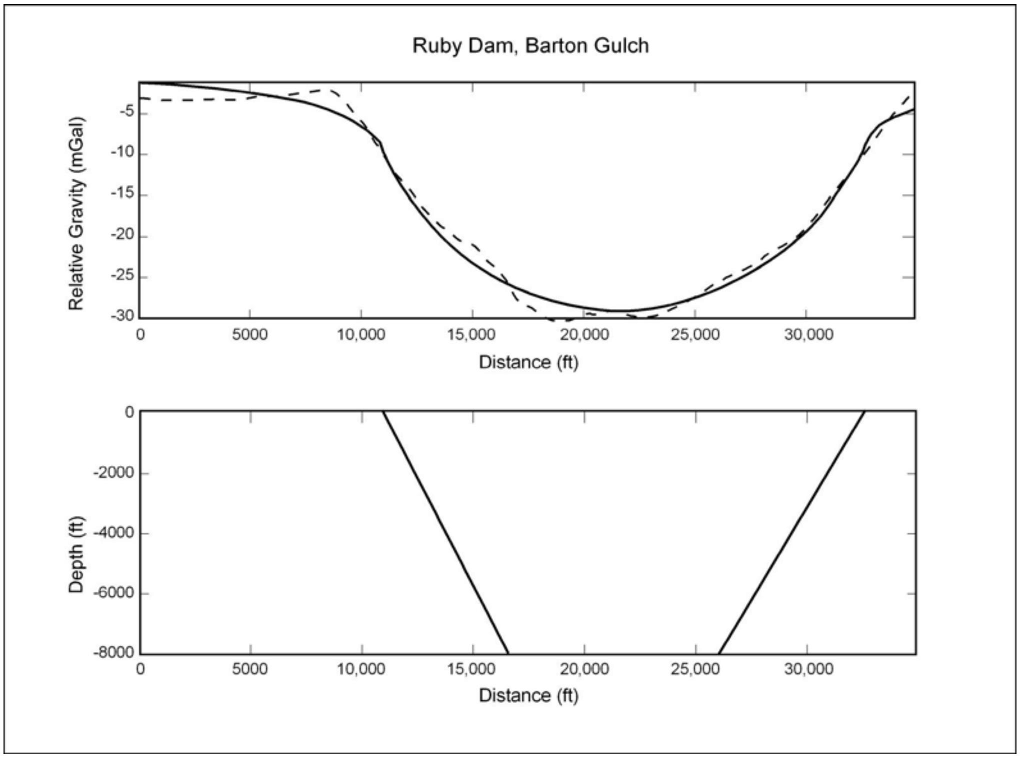

Figure 4. Gravity profile along cross section A-A’, through Garden Creek and Barton Gulch (see map, Plate 1). The top plot shows the gravity data in mGals; solid line represents initial data; dashed line represents the derived model of the data. The bottom plot shows the basin geometry model in feet below the surface.

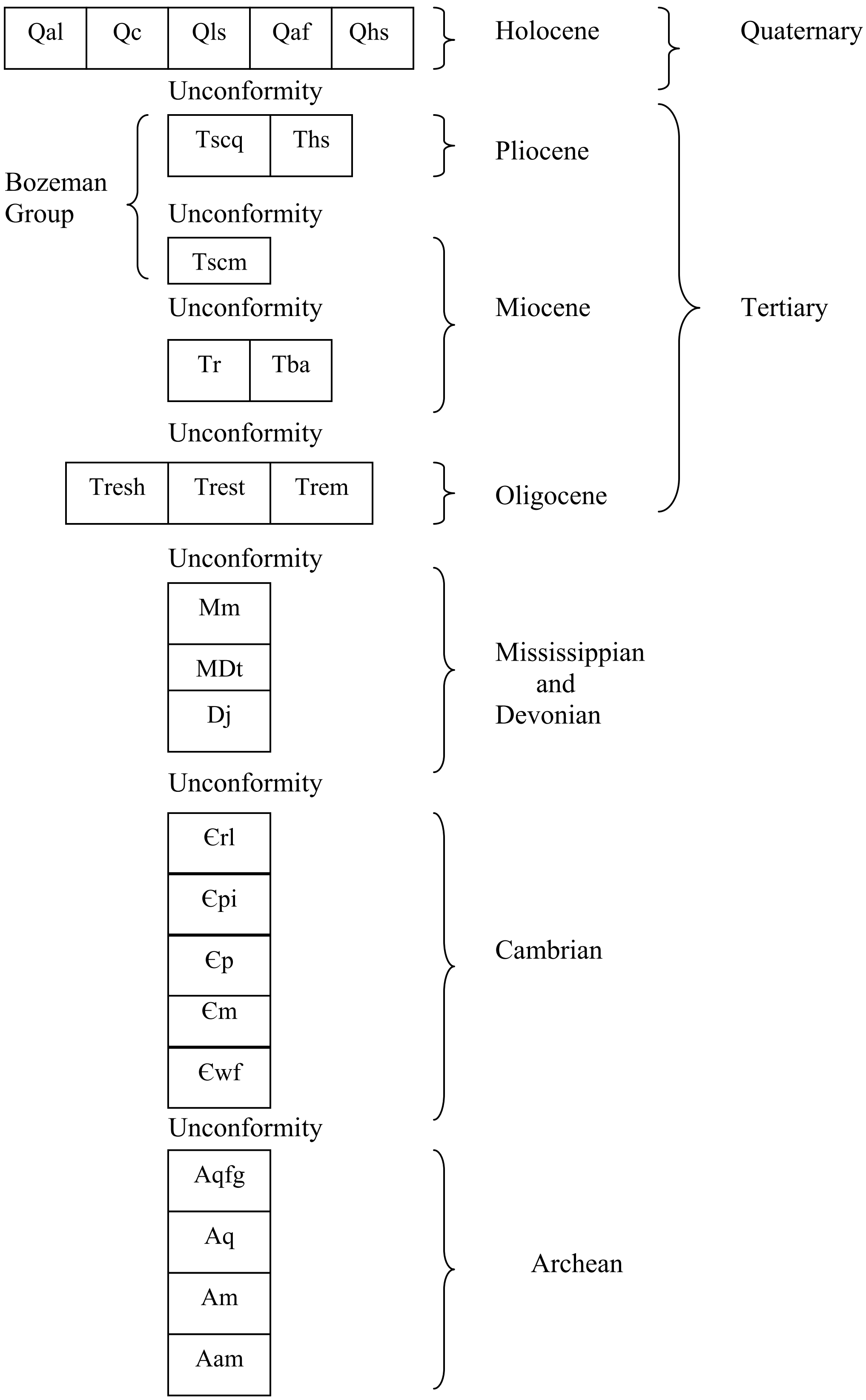

Figure 5. Correlation of rock units in study area

Description of Map Units

Qal **Alluvium (Holocene)** – Fluvial deposits of unconsolidated gravel, sand, silt, and clay. Restricted to the Ruby River and its main tributaries.

Qc **Colluvium (Holocene)** – Heterogeneous deposits of unconsolidated boulder- to silt-size material; occurs near base of steep slopes and cliffs.

Qls **Landslide deposit (Holocene)** – Bedrock fragments mixed with soil; occurs where poorly consolidated material on a slope is under-cut by a stream; exhibits stepped or hummocky terrain.

Qaf **Alluvial fan deposit (Holocene)** – Fluvially deposited boulder- to clay-size material; found on northeastern edge of Ruby Range.

Qhs **Hot springs deposit (Holocene)** – Calcium carbonate; one spring still actively depositing calcium carbonate west of reservoir at Trudu Lake.

Ths **Hot springs deposit (Pliocene)** – Calcareous tufa and travertine found along fault zones along western side of Ruby Valley; as much as 500 ft thick.

Bozeman Group, upper

Tscq **Sixmile Creek Formation, quartzite pebble conglomerate member, informal (Pliocene)** (modified after Monroe, 1976) – Conglomerate interbedded with sandstone and tuff. Conglomerate clasts are mainly subangular quartzite and average 1 inch in diameter; matrix is calcareous sandstone that consists primarily of medium-grained, subangular quartz. Tuff is white- to light-gray and contains abundant glass shards and pumice fragments; tuff deposits are as thick as 20 ft with as much as 500 ft of lateral extent. Thickness is approximately 1,400 ft.

Tscm **Sixmile Creek Formation, metamorphic fanglomerate member, informal (Miocene)** (modified after Monroe, 1976) – Thick sequence of fanglomerate that contains large subangular pebbles, cobbles, and boulders chiefly of gneiss and schist. The unit consists of 49% conglomeratic sandstone, 28% conglomerate, 15% tuff, and 8% siltstone and limestone; sandstone and conglomerate are tuffaceous, with up to 50% pyroclasts. The sand is composed mainly of quartz and glass shards. Tuff is white to light-gray and contains abundant glass shards and pumice fragments.

Tr **Rhyolite (Miocene)** – Light-gray to pink with aphanitic texture; outcrop appears to be a volcanic neck; only one outcrop, located just northeast of the Ruby Dam.

Tba **Basalt (Miocene)** – Generally composed of lath-shaped plagioclase phenocrysts enclosed in aphanitic groundmass; small outcrops throughout map area.

Bozeman Group, lower

Tresh **Renova Formation, shale member, informal (Oligocene)** (modified after Monroe, 1976) – Light-tan in color, and consists mainly of shale with thin layers of claystone, siltstone, and sandstone. Clay composition is smectitic. Sandstone and siltstone are made chiefly of poorly sorted, subangular quartz grains.

Vertebrate fossils are present within the member; best exposure is found in Fossil Basin. Thickness is approximately 435 ft.

Trest **Renova Formation, siltstone member, informal (Oligocene**) (modified after Monroe, 1976) – This unit is very similar to the shale member except that percentages of rock types differ. Siltstone makes up over half of the member and mudstone and sandstone are major constituents. Siltstone is pinkish to olive-gray and poorly lithified; moderately sorted and subangular. Sandstone is composed entirely of quartz and biotite; it exhibits medium grain size and moderate sorting, and grains are subangular. Mudstone component is chiefly smectite clay with minor sand and silt grains. Thickness is uncertain but greater than 400 ft.

Trem **Renova Formation, mudstone member informal (Oligocene)** (modified after Monroe, 1976) – This unit is similar to both the siltstone and shale members except that mudstone is the major component and sandstone and siltstone are minor constituents. Mudstone is generally yellowish-green and composed of smectite; it exhibits popcorn weathering that makes it easily identifiable. Sandstone and siltstone have the same lithology as described for the siltstone member.

Mm **Madison Group (Mississippian)** (from Tysdal, 1976) – Group contains two formations: (1) <u>Mission Canyon Limestone</u>, a pale to dark-yellowish, medium- to thick-bedded, cliff-forming limestone that is 1,370 ft thick; (2) <u>Lodgepole Limestone</u>, a dark-yellowish-brown, medium-bedded, fossiliferous limestone that contains chert nodules and measures 594 ft thick.

MDt **Three Fork Formation (Mississippian and Devonian)** (from Tysdal, 1976) – Upper member is grayish-orange, thin- to medium-bedded calcareous siltstone; lower member is thin- to thick-bedded solution breccia and ledge-forming fossiliferous limestone. Thickness of formation is 150 ft.

Dj **Jefferson Formation (Devonian)** (from Tysdal, 1976) – Upper member forms ledge of pale yellowish-brown massive dolomite breccia and is approximately 65 ft thick. Lower member is interbedded yellowish-brown, medium- to thick-bedded dolomite weathering to a rubbly dolomite. Thickness of formation ranges from 250 to 268 ft.

Ꞓrl **Red Lion Formation (Cambrian)** (after Tysdal, 1976) – Consists of pale yellowish-brown, thinly bedded dolomite, finely crystalline, thinly bedded dolomite, and light-gray, thin- to thick-bedded dolomite with columnar stromatolites locally. Thickness ranges from 0 to 170 ft.

Ꞓpi **Pilgrim Dolomite (Cambrian)** (after Tysdal, 1976) – Upper third is pale yellowish-brown, thin- to medium-bedded sandy dolomite; lower two-thirds marked by massive outcrops of thinly bedded dolomite with interlayered one-quarter- to 2-inch-thick units of yellowish, shaly, laminar dolomite. Thickness ranges from 259 to 390 ft.

Ꞓp **Park Shale (Cambrian)** (after Tysdal, 1976) – Grayish-olive, finely micaceous clay shale with dolomite nodules in upper part; locally contains coquina limestone nodules in basal part. Thickness ranges from 150 to 196 ft.

Ꞓm **Meagher Limestone (Cambrian)** (after Tysdal, 1976) – Dolomite or limestone depending on location. Dolomite is chiefly yellowish-brown and limestone is mediumgray. Upper and lower thirds are mainly thin-bedded and mottled; middle third is thin- to medium-bedded and forms ledges and cliffs. Thickness ranges from 565 to 745 ft.

Ꞓwf **Wolsey Shale and Flathead Sandstone, undivided (Cambrian)** (from Tysdal, 1976) – Wolsey is mainly olive-green and reddish-brown, micaceous clay shale with siltstone in basal part; thickness ranges from 58 to 100 ft. Flathead is light-brown to orange, fine- to medium-grained quartz sandstone in beds 12 to 25 inches thick with basal conglomerate; thickness is approximately 52 ft.

Aqfg **Quartzofeldspathic Gneiss (Archean)** (modified after Berg, 1976) – Contains three compositions of gneiss: biotite-quartz-feldspar, quartz-feldspar, and hornblende-quartz-feldspar. Quartz is the most abundant mineral but plagioclase and microcline are abundant components and garnet is a minor constituent; biotite-quartz-feldspar gneiss is the most abundant, and foliation is defined by biotite-rich layers.

Aq **Quartzite (Archean)** (modified after Berg, 1976) – Coarse-grained quartzite that contains small amounts of microcline and biotite. Quartzite layers are found throughout the map area; the largest seen was approximately 5 ft thick and could be traced for nearly one-half mile.

Am **Marble (Archean)** (modified after Berg, 1976) – Dominantly reddish-brown, coarsely crystalline, calcareous or dolomitic marble. Marble layers are contained within the quartzofeldspathic gneiss and amphibolite assemblage; dolomitic marble is more prevalent than calcareous marble. Thickness ranges from 10 to 500 ft.

Aam **Amphibolite assemblage (Archean)** (modified after Berg, 1976) – Dark-greenish-black, medium- to coarse-grained, hornblende-rich amphibolite is the prevailing rock type. Metagabbro is also present; it consists of augite and plagioclase, is medium-grained, and found in lenses. Granulite is also present; it is composed of quartz, garnet, hornblende, and apatite and exhibits granoblastic texture.

Acknowledgements

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References

Berg, R.B., 1979, Precambrian geology of the west part of the Greenhorn Range, Madison County, Montana: Montana Bureau of Mines and Geology Map GM 6, Scale 1:28,160.

Burfeind, W.J., 1967, A gravity survey investigation of the Tobacco Root Mountains, Jefferson Basin, Boulder Batholith, and adjacent areas of southwestern, Montana: Bloomington, University of Indiana, Ph.D. dissertation, 90 p.

Monroe, J.M., 1976, Vertebrate paleontology, stratigraphy, and sedimentation of the upper Ruby Basin, Madison County, Montana: Bloomington, University of Indiana, Ph.D. dissertation, 301 p.

Ruppel, E.T., O'Neill, J.M., and Lopez, D.A., 1993, Geologic map of the Dillon 1°x 2° quadrangle, Idaho and Montana, U.S. Geological Survey Map I-1803-H, scale 1:250,000.

St. Jean, Z.C., Geologic mapping in the Ruby Dam area, southwest Montana, with emphasis on earthquake hazards: Butte, Montana Tech of The University of Montana, M. S. thesis, 76 p.

Tysdal, R.G., 1976, Geologic map of the northern part of the Ruby Range, Madison County, Montana: U.S. Geological Survey Map I-951, scale 1:24,000.