Geologic map of the Surveyors Ridge area, Clearwater and Shoshone Counties, Idaho

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Introduction

The Clearwater metamorphic core complex in northern Idaho contains some of the most deeply-exhumed rocks in the Cordilleran orogen. Evidence for Eocene exhumation of the Clearwater complex along a brittle-ductile normal fault is well-constrained along the Jug Rock shear zone and the Widow Mountain shear zone, both located to the west of the map area. In the eastern part of the Clearwater complex, however, the exhumation history and structural evolution remain cryptic. Doughty et al. (2007) postulated that the east-bounding normal fault of the Clearwater complex was the Collins Creek fault, originally mapped by Hietanen (1968). However, they did not present any structural or thermochronological evidence to support this claim. Additionally, recent U-Pb zircon geochronology of intrusive bodies in the Clearwater complex that were originally mapped as Cretaceous by Hietanen (1968) has revealed that these bodies are instead Paleoproterozoic to Archean in age (Lewis et al., 2011). The metasediments surrounding these intrusive bodies, previously mapped by Hietanen (1968) as part of the Mesoproterozoic Belt Supergroup, are thus also previously unknown exposures of basement. Therefore, the stratigraphic relationships within the Clearwater complex need to be reassessed.

Geologic mapping, microstructural analyses, and U-Pb zircon geochronology performed in 2011 show that the Surveyors Ridge area, located in the Bathtub Mountain, Peggy Peak, Pole Mountain, and Mallard Peak 7.5' quadrangles, contains four previously unidentified normal faults, as well as previously unknown exposures of Paleoproterozoic orthogneiss, basement metasediments, and pre-Belt quartzite. The Collins Creek fault is mapped as a high angle normal fault that juxtaposes calc-silicate gneiss and quartzite of the Wallace formation on the hanging wall against quartzite of the Ravalli Group on the footwall, with no evidence of high strain. $^{40}Ar/^{39}Ar$ biotite cooling ages from both the footwall and hanging wall of the Collins Creek fault yield Cretaceous ages, and it is therefore not the east-bounding fault of the Clearwater complex, as postulated by previous workers (Table 1).

Four northeast-southwest trending faults were identified during the course of this mapping, all of which contain microstructural evidence for high-strain and ductile deformation of the footwall, as well as Eocene footwall $^{40}Ar/^{39}Ar$ mica cooling ages (Table 1). These faults are heretofore collectively known as the Surveyors Ridge fault zone. This set of faults includes: the Saddle, Lookout, Collins Peak, and Surveyors faults. The Surveyors fault is the easternmost fault of this set, and thus considered to delineate the eastern boundary of the Clearwater complex. The large break in $^{40}Ar/^{39}Ar$ muscovite cooling ages across the fault supports this interpretation. Though further mapping is needed, it is likely that each of these faults connects to the dextral St. Joe fault to the north. The southward extent of these faults is unknown.

Description of Map Units

Intrusive Rocks

Granite (Tertiary to Cretaceous) - Granite and pegmatite. A small body of unfoliated two-mica granite pegmatite south of Mallard Peak is likely Tertiary in age and contains phenocrysts of feldspar up to 3 cm in diameter. A large foliated granite stock in the Collins Creek drainage in the southern part of the map area was mapped and described by Hietanen (1968) and is interpreted to be Cretaceous in age.

Amphibolite (Cretaceous to Paleoproterozoic) - Fine-grained, foliated amphibolite. A small pluton approximately 1.5 miles west of Sawtooth Peak was mapped by Hietanen (1968) and has been described as consisting of plagioclase and hornblende, with or without augite and biotite. Two sills in the eastern part of the map area contain abundant hornblende, plagioclase, and biotite, as well as chlorite, epidote, and calcite, which are alteration products. The ages of these bodies are uncertain, but are most likely between Cretaceous and Mesoproterozoic.

Amphibolite (Neoproterozoic to Mesoproterozoic) - Fine- to medium-grained foliated garnet amphibolite sills. Contains hornblende, plagioclase, quartz, and garnet. Epidote and chlorite occur as alteration products. Garnet crystals are 3-5 mm in diameter. Sills of this type in the map area occur solely within the quartzite of Fawn Lake and Mallard Peak basement schist, and thus may be predate the Belt Supergroup, possibly correlating to 1587 Ma garnet amphibolite sills in the Goat Mountain area (Doughty and Chamberlain, 2007). Alternatively, these sills may correlate to mafic sills found in the Neoproterozoic Windermere Supergroup or Mesoproterozoic Belt Supergroup (R. Lewis, personal communication, 2012).

Granodiorite/amphibolite (Paleoproterozoic) - *Xgd*: Mallard Peak orthogneiss. Medium-grained foliated biotite granodiorite, with plagioclase, quartz, biotite, and microcline, with or without hornblende. Zircon from the pluton southwest of Mallard Peak yields a $^{206}Pb/^{207}Pb$ crystallization age of 1870 ± 9 Ma. *Xam*: Medium-grained hornblende biotite amphibolite with plagioclase, hornblende, and biotite (Figure 1). A small amphibolite body intrudes the larger granodiorite pluton southwest of Mallard Peak.The age of this body is assumed to be Paleoproterozoic, as it exhibits the same east-west striking foliation as the surrounding pluton, which differs markedly from the dominant northwest-southeast striking foliation in the map area. This fabric likely developed during magma intrusion in the Paleoproterozoic.

Metasedimentary Rocks

Wallace schist (Mesoproterozoic) - Fine-grained, crenulated garnet-biotite schist and phyllite. Garnet porphyroblasts are subhedral to euhedral and range in size from 0.1 mm to 2 cm in diameter. Euhedral staurolite and kyanite porphyroblasts are locally abundant. Pseudomorphs of muscovite and/or biotite after kyanite and/or staurolite are present in some localities.

Wallace quartzite (Mesoproterozoic) - Fine-grained calc-silicate gneiss and quartzite, dominantly comprised of fine- to medium-grained actinolite gneiss. Scapolite-bearing layers in massive quartzite are present but rare, with scapolite crystals ranging in size from 0.5 cm to 3 cm in diameter. Amphibole-rich layers are present near Elk Prairie, with small, randomly-oriented prismatic amphibole needles up to 3 mm long. The contact with the overlying Wallace schist is gradational, as this unit becomes increasingly micaceous up-section.

Ravalli Group quartzite, undifferentiated (Mesoproterozoic) - Thin-bedded, fine-grained, friable feldspathic quartzite interbedded with layers of fine-grained micaceous quartzite. Quartz-rich layers range in thickness from 3 to10 cm, while more micaceous layers range in thickness from 1 mm to 5 cm. More massive, competent layers of fine-grained feldspathic white quartzite are interbedded with the friable, more micaceous quartzites described above. The more competent quartzite layers are mica-poor, and bedding thickness ranges from 2 to 10 cm.

Prichard schist (Mesoproterozoic) - Coarse-grained garnet biotite schist. In the west-central part of the map area, near Surveyors Ridge Lookout, Martin Peak, and Collins Peak, anhedral to subhedral garnet porphyroblasts are abundant, ranging in size from 1 to 6 cm in diameter. Small (< 1 mm) porphyroblasts of staurolite, are locally present. The contact between the Prichard schist and the Ravalli Group quartzite in this part of the map area is interpreted to be a fault, based on the trend and plunge of downdip lineations and the juxtaposition of highly strained garnet staurolite schist of the Prichard Formation against relatively low strain quartzite of the Ravalli Group. In the northern part of the map area near Surveyors Peak, the Prichard schist is a fine- to medium-grained garnet-biotite schist interbedded with layers of gray, fine-grained micaceous quartzite. The quartzite layers of this unit exhibit a friable texture. Bedding thicknesses range from 2 to 30 cm. Garnet porphyroblasts are subhedral to euhedral and range in size from 1 to 2 cm in width.This unit becomes increasingly quartzitic up-section, as garnet-bearing schistose layers dominate the bottom part of the section and become less frequent up-section. The contact between this unit and the overlying Ravalli Group quartzite is thus interpreted to be depositional.

Fawn Lake quartzite (Mesoproterozoic) - Coarse-grained, foliated, feldspar-poor quartzite. Quartz grains range in size from 1 to 12 mm in width, but are reduced to the range of 1 to 5 mm in width in high-strain zones on the footwall of normal faults. Biotite and muscovite flakes are common and range in size from 0.5 to 3 mm, and form distinct down-dip stretching lineations near normal faults. Subhedral garnet porphyroblasts occur locally and range in size from 2 to 15 mm in width. On a north-south trending ridge west of Skyland Lake, garnet crystals appear to have been stretched and form a distinct down-dip lineation along with mica grains. Small staurolite porphyroblasts (< 1 mm in width) are evident in thin section and aligned with the foliation. The basal part of this unit is marked by a thin (~30 m thick) layer of coarse-grained garnet±ferous schist underlain by an equally thin layer of feldspar-poor quartzite, which in turn is underlain by feldspathic basement schist. This contact between the quartzite to underlying basement is well exposed on the southern slope of Mallard Peak. Detrital zircon age spectra show a strong peak at 1800 Ma and minor late Proterozoic and Archean populations, which are similar to the detrital zircon populations of the Neihart quartzite in Montana, which is a mature quartz arenite that pre-dates the Belt Supergroup (Figure 2, 3, 4; Ross and Villeneuve, 2003). The contact between this unit and the overlying Prichard schist in the vicinity of Surveyors Ridge Lookout is mapped as a normal fault (Lookout Fault), based on the presence of downdip mica lineations and strongly deformed quartz and mica fish, which are evident in thin section. Near Martin Peak, this fault splays to the southwest and may also splay to the southeast, past Fawn Lake and off of the map area. However, this contact in the area south of Martin Peak may instead be depositional in nature.

Mallard Peak basement schist and gneiss (Paleoproterozoic to Archean) - Basement schist and gneiss of the Mallard Peak basement complex consists of three distinct rock types: 1) coarse-grained feldspathic garnet schist, 2) banded gneiss that is characterized by alternating fine-grained quartzofeldspathic and coarse-grained biotite-rich domains and 3) calc-silicate gneiss. The coarse-grained garnet schist is typically more feldspathic than schist of the Prichard formation in the map area. Garnet porphyroblasts are anhedral to subhedral, and range in size from 2 mm to 5 cm in diameter. The layers of the banded gneiss range in thickness between 3 cm to 30 cm. The fine-grained quartzofeldspathic layers contain abundant muscovite but very little biotite (<1%). The biotite-rich layers locally contain subhedral to euhedral garnet porphyroblasts, ranging in size from 2 mm to 5 cm in diameter. Kyanite blades 1 to 3 cm long are locally abundant. Calc-silicate gneiss is sparsely interbedded with the garnet schist and banded gneiss, and contains quartz, plagioclase, biotite, muscovite, epidote, titanite, and ilmenite. The age of these metasediments ranges from Paleoproterozoic to Archean.

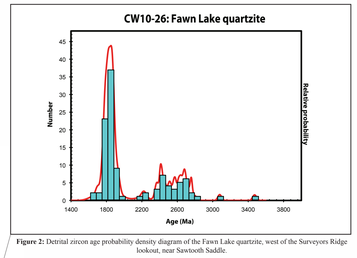
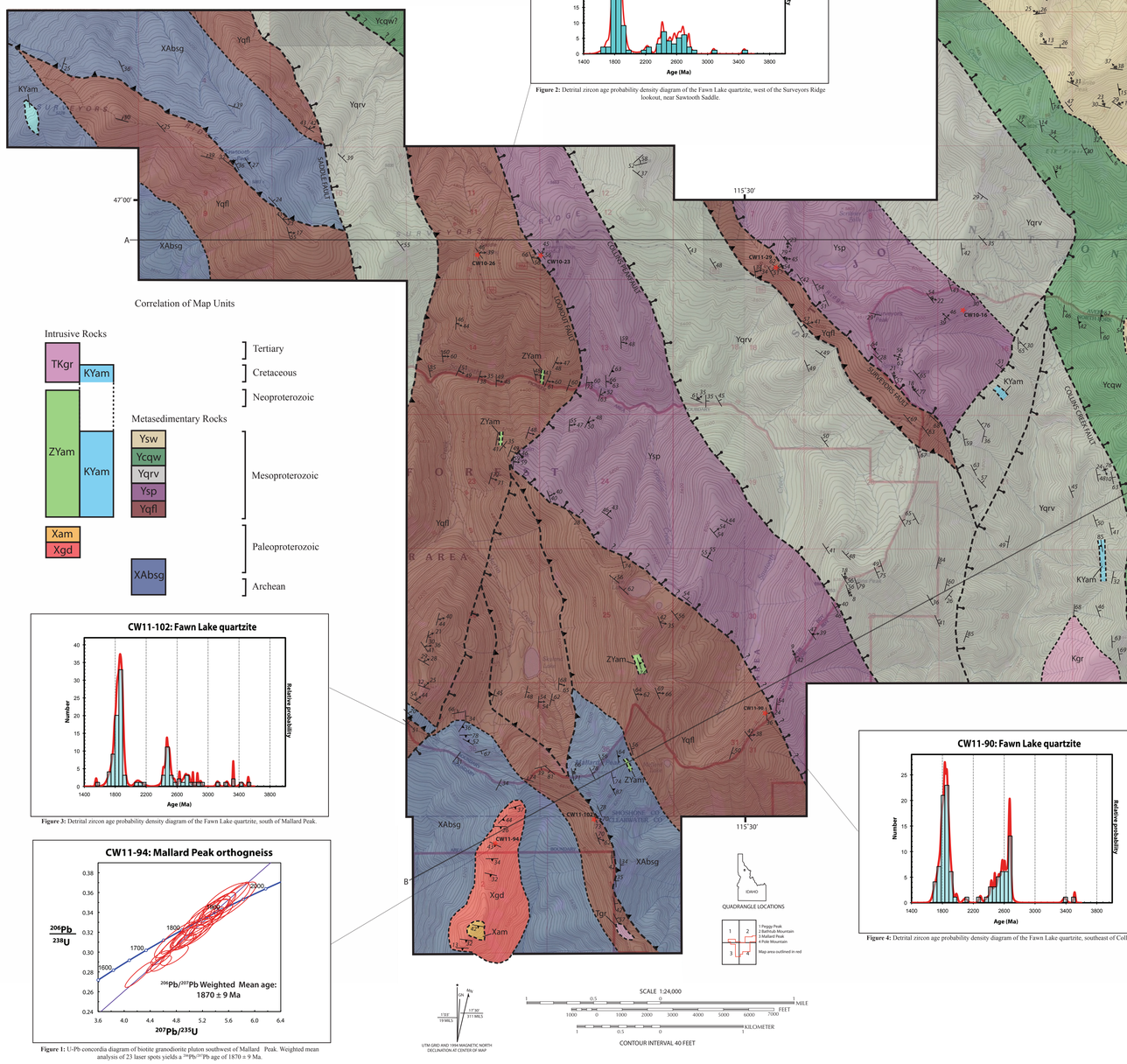


Figure 2: Detrital zircon age probability density diagram of the Fawn Lake quartzite, west of the Surveyors Ridge lookout, near Sawtooth Saddle.



Correlation of Map Units

Figure 3: Detrital zircon age probability density diagram of the Fawn Lake quartzite, south of Mallard Peak.

Figure 1: U-Pb concordia diagram of biotite granodiorite pluton southwest of Mallard Peak. Weighted mean analysis of 23 laser spots yields a $^{206}Pb/^{207}Pb$ age of 1870 ± 9 Ma.

Figure 4: Detrital zircon age probability diagram of the Fawn Lake quartzite, southeast of Collins Peak.

Map Symbols

- Strike and dip of bedding
- Strike and dip of foliation
- Trend and plunge of crenulation lineation
- Trend and plunge of mineral lineation
- Trend and plunge of small-scale fold axis; dip of fold limbs
- Normal fault, dashed where approximately located. Ball and bar on downthrown side.
- Thrust fault, dashed where approximately located. Teeth on upper plate.
- Depositional/intrusive contact, dashed where approximately located.
- Uncertain contact, may be a fault or a depositional contact.
- CW11-29 $^{40}Ar/^{39}Ar$ or U-Pb sample number and location

Sample Number	Latitude, Longitude	Location	Structure	Rock unit	Muscovite cooling age (Ma)
CW10-26	46 56.695 115 32.599	Sawtooth Saddle	footwall of Lookout fault, hanging wall of Saddle fault	Yqfl	51.3 ± 1.2
CW10-23	46 59.652 115 32.011	Surveyors Lookout W115 32.011	footwall of Collins Peak fault, hanging wall of Lookout fault.	Ysp	51.8+1.0
CW11-29	46.59.574 115.29.730	Surveyors Ridge, ~1.2 km NW of Surveyors Peak	footwall of Surveyors fault, hanging wall of Collins Peak fault.	Yqfl	44.2 ± 2.0
CW10-16	46.59 277 115.27.956	Surveyors Ridge, ~1 km E of Surveyors Peak	footwall of Collins Creek fault, hanging wall of Surveyors fault.	Ysp	58.8 ± 1.3

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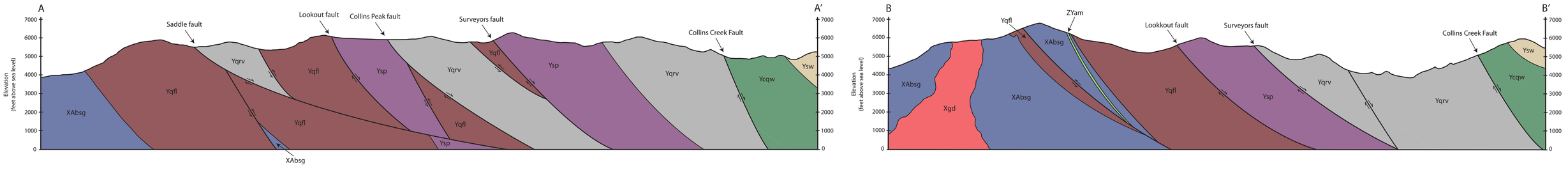

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