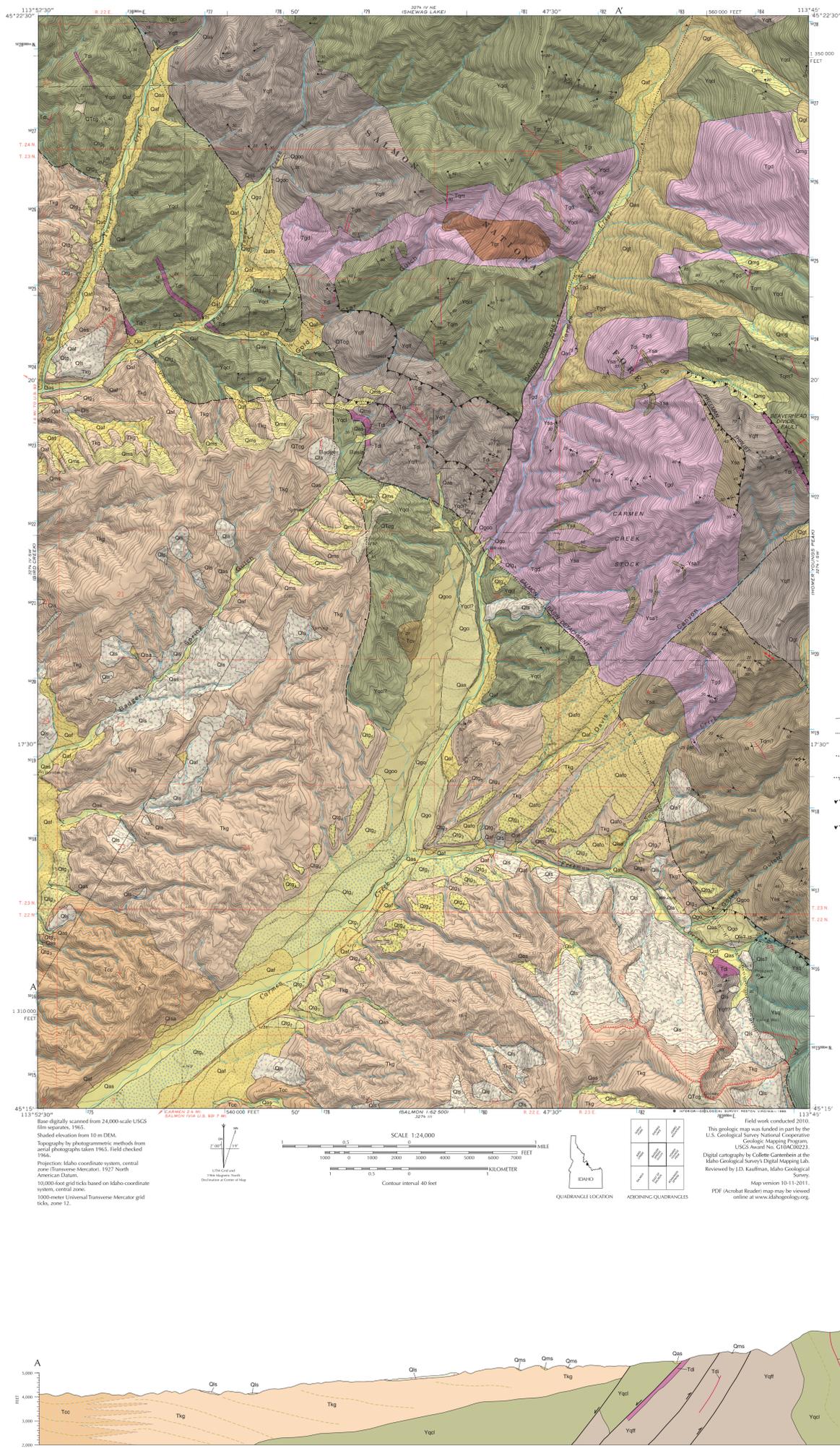
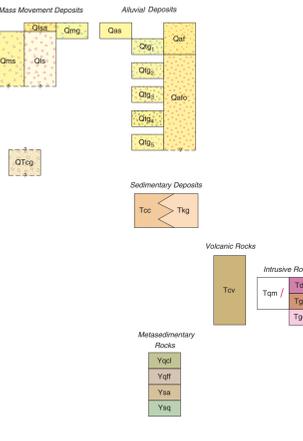


# GEOLOGIC MAP OF THE BADGER SPRING GULCH QUADRANGLE, LEMHI COUNTY, IDAHO

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## CORRELATION OF MAP UNITS



## DESCRIPTION OF MAP UNITS

The geologic map of the Badger Spring Gulch quadrangle shows bedrock units exposed at the surface or under thin surficial cover of soil and colluvium. Surficial alluvial, colluvial, glacial, and landslide deposits are shown where they are thick and of mappable areal extent. Mesoproterozoic sedimentary rocks, the oldest rocks in the map area, dominate bedrock of the Beaverhead Mountains along the east and north parts of the quadrangle. Tertiary sedimentary rocks form the undulating low hills and foothills that comprise most of the south and west half of the map area.

**INTRODUCTION**  
The Badger Spring Gulch 7.5' quadrangle spans an important fault zone previously thought to juxtapose two different Mesoproterozoic sedimentary rock packages. To the east and northeast, in the West Pioneer and Pindler Mountains (Figure 1), are exposures of rocks assigned to the Belt Supergroup (Ruppel and others, 1993; Lonn and McDonald, 2004), whereas to the southwest in the Lemhi Range and Salmon River Mountains are the reference sections of the Lemhi Group, Swager Formation, and Yellow-jacket Formation (Ross, 1934; Ruppel, 1975). In the intervening Beaverhead Mountains, both the stratigraphic and structural interpretations have been controversial among previous workers (Mackenzie, 1949; Tucker, 1975; Ruppel and others, 1993; Winton and others, 1999; Evans and Green, 2003; O'Neill, 2005; Tsydal and others, 2005). The Idaho Geological Survey and Montana Bureau of Mines and Geology have now mapped at 1:24,000 scale this important fault system to resolve Miss into the Badger Spring Gulch quadrangle in an attempt to reassemble some of the long-standing controversies.

**ALLUVIAL DEPOSITS**  
**Qas** **Sidestream alluvium (Holocene)**—Carmen and Freeman creeks: Subrounded to angular, moderately sorted and stratified pebbles to boulder sized gravel. Gravel clasts primarily quartzite and siltite. Foothill stream valleys and local drainageways: Angular to subrounded, poorly sorted, moderately stratified pebbles to cobble sized; includes minor sheet wash, colluvium, and fan deposits. Soils not developed to weakly developed. These sediments are 1-3 m (3-10 ft) thick.

**Qat** **Alluvial and debris-flow fan deposits (Holocene to Late Pleistocene)**—Angular to subrounded, poorly sorted, matrix-supported pebbles to boulder gravel in a sand, silt, and clay matrix. Soils undveloped to weakly developed. Commonly grades into, interfingers with, and caps side-stream alluvium (Qas). Thickness varies greatly, ranging from 1 to 24 m (3 to 80 ft). Soils vary from weakly to moderately developed.

**Qaf** **Older alluvial-fan deposits (Pleistocene)**—Angular to subrounded, poorly sorted, primarily matrix-supported pebbles to boulder gravel in a sand, silt, and clay matrix. Soils moderately to well developed. Commonly caps and interfingers with terrace gravel. The thickness varies greatly, ranging from 1 to 15 m (3 to 50 ft).

**Gravel terrace deposits**  
Gravel deposits of Pleistocene terraces are composed of moderately sorted and clast-supported sandy gravel. Clasts primarily subrounded to well-rounded pebbles, cobbles, and boulders of quartzite and siltite from the Beaverhead Mountains. Clasts of Tertiary granodiorite (Tgr) occur in terrace gravel north of Freeman Creek. Terrace deposits range from relatively thin (3-9 m; 10-30 ft) caps over stream-cut bedrock surfaces. Several levels of terraces and terrace remnants are preserved 2-140 m (10-460 ft) above the present-day streams. These record long-term episodic incision of the Salmon basin, which was probably driven by periodic glacial climate during the Pleistocene. Along the Beaverhead Mountain front and adjacent to the hills of Tertiary sediments, terrace gravels commonly are capped by and probably interfinger with alluvial fan deposits (Qaf and Qat), which are included in the terrace unit locally.

**Gravel of first terrace (Holocene to Late Pleistocene)**—Forms terrace 3-6 m (10-20 ft) above modern streams. Soils well developed.

**Gravel of second terrace (Late Pleistocene)**—Forms terrace 12-18 m (40-60 ft) above modern streams. Soils moderately developed.

**Gravel of third terrace (Middle Pleistocene)**—Forms terrace 30-55 m (100 to 180 ft) above modern streams. Soils well developed.

**Gravel of fourth terrace (Middle Pleistocene)**—Forms terrace 60-90 m (200-300 ft) above modern streams. Soils well developed.

**Gravel of fifth terrace (Early Pleistocene)**—Forms terrace 110-140 m (360-460 ft) above Carmen and Freeman creeks. Soils well developed.

**MASS MOVEMENT DEPOSITS**  
**Qla** **Deposits of active landslides (late Holocene)**—Unstratified, poorly sorted silt, clay and gravelly silt clay. Deposited by slumps, slides, and debris flows from slope failures in Tertiary sediments. Directly related to and formed after development of water ditches and irrigation.

**Qlc** **Landslide deposits (Holocene to Pleistocene)**—Unstratified, poorly sorted silt, clay and gravelly silt clay. Deposited by slumps, slides, and debris flows that primarily occur in Tertiary sediments and along fault zones. For some, maps show the landslide scarp and the headwall (steep area adjacent to and below the landslide scarp) from which material broke away (see Symbols).

**Qms** **Mass-movement deposits (Holocene to Pleistocene)**—Angular to subangular poorly sorted silt and clayey gravel. Includes solifluction deposits, colluvium, and some alluvial fans.

**Qmg** **Mass movement and glacial deposits unaffiliated (Holocene to late Pleistocene)**—Angular to subangular poorly sorted boulder to large boulder gravels. Forms proglacial ramparts and slumps derived from moraine remnants and frost-wedged debris on high, glaciated valley walls. Includes some alluvial-fan gravel and young glacial and periglacial deposits. Deposits are as thick as 15 m (50 ft).

**GLACIAL DEPOSITS**  
**Qgl** **Till deposits of last local glacial maximum (Pleistocene)**—Poorly sorted sandy to clayey boulder till. Clasts subangular to subrounded. Forms and moraines and recessional moraines. Primarily Late Pleistocene. Glaciation equivalent. Includes young till deposited in or just below former floors up to 2,440 m (8000 ft) and local deposits of outwash. Soils weakly developed. Deposits are as thick as 25 m (80 ft).

**Qgp** **Outwash gravels of last local glacial maximum (Pleistocene)**—Angular to rounded, poorly to well-sorted sandy cobble to boulder gravel. Boundary poorly sorted component probably attributable to debris avalanches associated with glacial and periglacial conditions. In the Carmen Creek valley, grades into gravel of first terrace (Qg1) near the confluence with Freeman Creek. Ages equivalent to till deposits (Qgt) that correlate with the late Pleistocene. Glaciation. Soils weakly developed. Deposits are 3-9 m (10-30 ft) thick. Probably overlies stream-cut surface on bedrock. Unit includes alluvial-fan deposits that cap and may interfinger with outwash.

**Qgo** **Outwash gravels older than last local glacial maximum (Pleistocene)**—Angular to rounded, poorly to well-sorted sandy cobble to boulder gravel. In the Carmen Creek valley, grades into gravel of second terrace (Qg2) near the confluence with Freeman Creek. Probably time equivalent to early Pleistocene or older Glaciation. Soils moderately well developed. Deposits are 1-12 m (10-40 ft) thick. Probably overlies stream-cut surface on bedrock. Unit includes alluvial-fan deposits that cap and may interfinger with outwash.

**Qgt** **Colluvial and glacial deposits (Early Pleistocene to Pleistocene)**—Boulders, cobbles, and boulder gravel that cap high-angle foothills and overlie erosion surface on Tertiary sediments. Primarily colluvium with large, lag surface boulders; original deposits probably include till, pediment gravel, and crevasp and lag deposits derived from Tertiary conglomerate (Tgc). Soils of original surface eroded away. Deposits are 12-24 m (40-80 ft) thick.

## STRUCTURE

Two major structures, the Beaverhead Divide fault and the Freeman thrust, enter the map area from the southeast and appear to be introduced out by the Carmen Creek stock. Their continuation west of the Carmen Creek fault is not as well defined. A third major fault runs east through the Carmen Creek stock. A fourth, the Salmon basin detachment, is to the southwest of the first two and the stock.

## BEAVERHEAD DIVIDE FAULT ZONE

The Beaverhead Divide fault was first described by Mackenzie (1949) who referred to the structure as the Miner Lakes fault. Anderson (1959) mapped its extension northwest of Miner Lakes and Tucker (1975) extended it southward. Ruppel and others (1993) interpreted it as a major structure separating the Missoula Group to the northeast from the Mesoproterozoic Yellow-jacket Formation and Lemhi Group to the southwest. Evans and Green (2003) mapped it as a thrust reactivated as a normal fault, separating Missoula Group from Lemhi Group. More recently, O'Neill (2005) interpreted it as a low-angle normal fault that has been rotated to vertical with non-metamorphosed upper plate rocks now to the northeast and metamorphosed lower plate rocks now to the southwest. Our mapping to the south and east suggests that the Beaverhead Divide fault is a zone of both ductile and brittle deformation. In quadrangles to the southeast, we mapped two strands of the Beaverhead Divide fault. The western strand, characterized by chlorite-bearing siltite, separates weakly foliated, east-dipping vertical conglomeratic quartzite (Tqc) on the northeast from strongly foliated and tightly folded medium-grained quartzite on the southwest. The median-grained quartzite is thought to be the lowest part of the Yggf unit. The western strand is a zone of 33-45° south-west-dipping mylonitic foliation. It separates the medium-grained quartzite and Yggf. This ductile shear zone contains mafic dikes (Tfd) that exhibit foliation parallel to that of the shear zone. Similar dikes persist west of the Carmen Creek stock in a zone of shear and brecciation that may be the western continuation of the Beaverhead Divide fault zone. There, in contrast to the southeast, Yggf and Ygf are not as foliated and locally are not separated by a fault. This suggests that the fault is not as regionally significant as previously thought.

## FREEMAN THRUST

The Freeman thrust, first mapped in the adjoining quadrangle to the east (Lonn and others, 2008), is exposed north of Davo Canyon near the east edge of the map. Three fault places Ysa in the hanging wall against Ygf in the footwall. It is characterized by a 45° west-dipping mylonite zone that was introduced by Eocene granodiorite (Tgr) to the north and south. The Freeman thrust was not recognized west of Carmen Creek.

## UNNAMED THRUST FAULTS WEST OF CARMEN CREEK

Two poorly constrained faults are mapped west of Carmen Creek in an area with sparse outcrops. Local mylonitic zones, breccias, and numerous north-west-striking Tfd dikes indicate faulting in the area, but the exact location of the structures remains unknown. The northeastern of the two faults is possibly the western extension of the Beaverhead Divide fault in that it locally places Ygf over Ygf.

## FAULT INTRODUCED BY CARMEN CREEK STOCK

The Ygf/YgfC contact is offset in an apparent right-lateral sense across the western arm of the Carmen Creek stock. This relationship suggests that the rock imbricated along a pre-existing east-northeast fault that had the orientation of the Stock. It is unknown whether this is a strike-slip fault, or a down-on-the-southeast reverse or normal fault, and whether it formerly extended east of Carmen Creek.

## CARMEN CREEK FAULT

The upper part of Carmen Creek is controlled by a steep fault. This appears to be one of a set of northeast-trending brittle faults that postdate the ductile fabrics. It is interpreted to be a down-on-the-west normal fault based on the smaller, presumed higher level exposure of the Carmen Creek stock on the west. However, left lateral offset of south-west-dipping Beaverhead Divide fault and its suspected continuation contradicts this sense of motion. Its relationship to the Salmon Basin detachment is unclear, but it is interpreted to be an older structure.

## SALMON BASIN DETACHMENT

The Salmon basin detachment forms the range front in the eastern part of the map. Topographic expression is less apparent in the west. The fault is marked by repetition of the YgfC unit in the central part of the map and the YgfC unit in the southeast corner. Both are carried by the fault from the northeast to the southwest. The detachment is exposed in the road northwest of the intersection with the Carmen Creek road. The fault is characterized by gneiss and a foliation defined by numerous closely spaced shear surfaces dipping roughly 35° to the south.

## INTERPRETATION

To the southeast along the Beaverhead Divide and Freeman faults the rocks were penetratively deformed during contraction that stacked older strata of the Lemhi subbasin eastward over younger strata of the same sequence. It is uncertain whether the two faults moved synsynchronously or progressively. The observation to the southeast that the Freeman thrust cuts and deforms cleaved Ygf strata suggests that some of its movement post-dates at least some cleavage formation and possibly some of the uplift on the Beaverhead Divide fault. Generally low dips in the current map area and lack of penetrative cleavage in the west suggest that the deformation to the south that produced these faults, the cleavage adjacent to them, and the steep dips was locally controlled and not fundamental to these faults. Localization may have been due to an indenter from the west or a buttress to the east that did not extend north to this map area. How much if any of this deformation postdates Cretaceous contraction is unknown. Eocene extension allowed some of the thrust stacking to relax, but not enough to completely restore the original stratigraphy. The last motion appears to have been normal faulting on the eastern strand as interpreted by Evans and Green (2003), and on the western one as indicated by deformation of Ygf along it. Most extension likely was accommodated by the Salmon Basin detachment and faults within the basin. Slip on the detachment must have been over 5 km (3 mi) for Ygf in its hanging wall to have originated north-east of the Beaverhead Divide fault or in the south of Freeman Creek intruded near that fault. The hanging wall would also have carried the higher parts of the Beaverhead Divide and Freeman faults into the basin, so the Salmon Basin detachment must be entirely younger than 46 Ma.

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