



Unit Descriptions

Qbt: Bishop Tuff. Salmon-pink to brown and white rhyolite tuff with abundant round to subangular pumice fragments. Fragments contain abundant phenocrysts of quartz and sanidine, and sparse biotite; characterized by elongate vesicles or tubules, giving fresh surfaces a fibrous or silky appearance. Minor small fragments of rhyolite and obsidian; less commonly other volcanic and plutonic rocks. Commonly consolidated (partly-welded in upper part, unconsolidated in lower part; layered white ash-fall tuff locally at base). Qbt drapes Qtc and Mzg. Eruption age: 766.6 ± 3.1 ka (Chamberlain et al., 2014). Modified description from Krauskopf and Bateman (1977).

Qtc: Tuff of Taylor Canyon. Mostly brilliant white poorly bedded, weakly (5%) phyrlic rhyolite tuff with abundant white angular to subround pumice fragments, mostly less than 5 cm in diameter, with small tubular vesicles. Locally abundant fragments of rhyolite and obsidian, angular to subangular, mostly small but a few up to 2 m in diameter; very locally a few granodiorite cobbles. In most exposures, sorting and layering poor; locally conspicuous crossbedding. Generally poorly exposed. Underlies Qbt and incised alluvial fans and overlies Qbst and incised fluvial terraces. Modified description from Krauskopf and Bateman (1977). ⁴⁰Ar/³⁹Ar sanidine age: 1936.12 ± 12.65 ka (this study). Age correlates to explosive eruptions of the Glass Mountain volcano on the northeastern rim of Long Valley caldera, ~8 km southwest of Black Mountain (Metz and Mahood, 1985).

2% Qtz (<2 mm)
2% Plag (<2 mm)
1% San (<1 mm)
<1% Bt (≤1 mm)
Aphanitic glassy matrix

Qbst: Benton Stream tuff. Outcrops above angular unconformity with MPbsg as a 10 m, 5° NE dipping, white cliff overlooking Benton Stream and the Benton Hot Springs. Weathering brilliant white, white on a fresh surface, friable, moderately-well indurated 10 m thick, weakly phyrlic (4%) ash-sized rhyolite tuff. Pumice fragments abundant in upper layers. Contains ~0.2 to 0.4 m thick lenses of rounded gravel and pebbles. Matrix has abundant tuff, and some layers consist chiefly of white aphanitic tuff. ⁴⁰Ar/³⁹Ar sanidine age from tuff in basal 1 m in progress.

1% Bt (≤1 mm)
1% Hbl (≤1 mm)
1% Qtz (≤1 mm)
1% San (≤1 mm)
Aphanitic glassy matrix

Pvc: Cinder cone. Typically cone-shaped exposure of red weathered vesicular breccia blocks, gravel to cobble sized basalt cinder, pebble to cobble sized scoria, and scarce volcanic bombs. Warren (2014) reported an ⁴⁰Ar/³⁹Ar groundmass recoil model age of 2.94 ± 0.06 Ma. Modified description from Warren (2014).

Pb: Basalts, undifferentiated. Weathering tan to reddish or dark brown, medium to dark gray on fresh surface, flaggy columnar outcrop, weakly to moderately (4-12%) phyrlic basalt lava.

Pbp: Pyroxene basalt. Weathering tan to dark brown, medium to dark gray on fresh surface, flaggy columnar outcrop, weakly (9%) phyrlic basalt lava. ⁴⁰Ar/³⁹Ar groundmass weighted mean age: 3.29 ± 0.02 Ma.
5% Cpx and Opx (<3 mm)
2% Ol (<2 mm)
2% Plag (<2 mm)
<1% glomerocrysts of cpx, ol, plag defining clusters ≤4 mm
Microcrystalline groundmass

Pbo: Olivine basalt. Weathering tan to dark reddish brown, medium to dark gray on fresh surface, flaggy columnar outcrop, weakly (4%) phyrlic basalt lava. Nagorsen-Rinke et al. (2013) reported an ⁴⁰Ar/³⁹Ar groundmass plateau age of 3.28 ± 0.03 Ma and an ⁴⁰Ar/³⁹Ar groundmass recoil model age of 3.39 ± 0.03 Ma from two samples of this unit.
4% Ol (<2 mm, skeletal)
<1% Plag
Trachytic microcrystalline groundmass

Pbc: Glomerocrystic olivine basalt. Weathering tan to dark brown, medium to dark gray on fresh surface, flaggy columnar outcrop, moderately (12%) phyrlic basalt lava. This study reports an ⁴⁰Ar/³⁹Ar groundmass plateau age of 3.40 ± 0.01 Ma and ⁴⁰Ar/³⁹Ar groundmass recoil age of 3.41 ± 0.04 Ma from two samples of this unit. Warren (2014) reported an ⁴⁰Ar/³⁹Ar groundmass recoil age of 3.41 ± 0.02 Ma. Nagorsen-Rinke et al. (2013) reported an ⁴⁰Ar/³⁹Ar groundmass recoil model age of 3.13 ± 0.02 Ma and ⁴⁰Ar/³⁹Ar groundmass plateau age of 3.43 ± 0.01 Ma from two samples of this unit.
5% Ol (<3 mm, euhedral)
3% Cpx (<3 mm)
2% Plag (<3 mm)
2% glomerocrysts of cpx, ol, plag defining clusters ≤4 mm
Trachytic microcrystalline groundmass

Pah: Hornblende andesite. Weathering tan to dark brown, medium to dark greenish gray on a fresh surface, flaggy columnar outcrop, weakly phyrlic (9%) andesite lava. Dike outcrops on Mzg along the crest of the Benton Range, north and south of the basalt field in the southeastern map area. Hogan (2014) reported ⁴⁰Ar/³⁹Ar groundmass ages of 3.46 ± 0.01 and 3.47 ± 0.01 Ma from samples of this unit.

3% Plag (<2 mm)
2% Bt (<2 mm)
2% Hbl (<2 mm)
2% Fe/Ti oxides (<1 mm)
<1% Cpx (<1 mm), Apatite (<1 mm)
Trachytic microcrystalline groundmass. Dike has equigranular crystalline groundmass with 35% chlorite

Distinguishing Features

Pink poorly consolidated outcrop, ≥10 m thick, that drapes incised alluvial fans, Qtc, and Mzg in the eastern map area.

Poorly consolidated white tuff, 10 to 15 m thick where it drapes Pliocene lavas and Qbst, and 2 to 3 m thick where it drapes incised fluvial terraces.

Outcrops in one location as a white ash cliff above Benton Stream, visible looking north from Highway 120 by Benton Hot Springs.

Red cone-shaped eruptive sites. Abundant scoria and pumice.

Basalt lava rich in cpx with rare glomerocrysts in hand sample and thin section.

Basalt lava with abundant ol phenocrysts. Lacking glomerocrysts and cpx phenocrysts.

Basalt lava with more ol than cpx and glomerocrysts in hand sample and thin section. Only Pliocene basalt map unit with ≥1% glomerocrysts.

Andesite lava and dikes with hbl phenocrysts. Dikes are not heavily eroded. They form shark fin outcrops in Mzg.

Unit Descriptions

Pbb: Boring basalt. Weathering tan to dark brown, medium to dark gray on fresh surface, flaggy columnar outcrop, weakly (6%) phyrlic basalt lava. ⁴⁰Ar/³⁹Ar groundmass recoil age: 3.53 ± 0.06 Ma (this study).
2% Cpx (<1 mm)
2% Ol (<1 mm, skeletal)
2% Plag (<1 mm)
Trachytic microcrystalline groundmass

MPg: Stream deposit. Fluvial gravel and cobble deposit containing poorly sorted well rounded plutonic, volcanic, and metamorphic clasts. Stream deposit lies between undifferentiated Mesozoic granite and Pliocene pyroxene basalt lava flow.

MPbsg: Benton Stream gravel and cobble deposit. Partly consolidated tuffaceous gravel and sand deposit with conspicuous lenticular bedding; locally crossbedded with interbeds of pebbles and cobbles of rhyolite and granitic rocks with lesser aplite and fine-grained mafic dike material, rounded to subrounded, mostly less than 8 cm in diameter but a few up to 30 cm; granitic material mostly altered, exhibiting significant epidote and kaolinite alteration. Bedding dips 17° E. Directly overlain by an angular unconformity, dipping 17° E, and Qbst, dipping 5° NE.

Mab: Andesite lava flow breccia. Weathering brownish-red to gray, typically outcropping 2 to 3m thick, with rare deposits up to 20 m thick, well-indurated andesite lava flow breccia with abundant poorly sorted angular fragments, gravel to boulder sized, in an aphanitic brown matrix. Little sorting; unstratified except for crude bedding locally. Local variation in thickness is an indicator of how far the breccia travelled from source. Thickness should increase near the vent. Modified description from Tertiary andesite breccia, a unit described in Krauskopf and Bateman (1977).

Map: Purple andesite. Weathering reddish purple to brown, dark gray on fresh surface, knobby, crumbly outcrop, moderately phyrlic (15%) altered andesite lava.
15% Plag (≤2 mm)
<1% Cpx (≤1 mm), Hbl (≤1 mm), 1% Ol (≤1 mm), 1% Opx (≤2 mm)
Aphanitic glassy groundmass

Mrt: Rhyolite tuff. Weathering reddish tan to white massive outcrop, white on fresh surface, moderately welded, moderately phyrlic (14%) rhyolite tuff. Krauskopf and Bateman (1977) mapped much of this unit as a Tertiary andesite tuff, which is inconsistent with the quartz and sandine mineralogy. ⁴⁰Ar/³⁹Ar sanidine age: 22.42 ± 0.05 Ma (this study).
10% Qtz (<2 mm)
3% Devitrified pumice (≤5 mm)
2% Plag (<1 mm)
2% San (≤1 mm)
<1% Bt (<1 mm)
Aphanitic glassy matrix

Jap: Aplitic dike. Dikes and irregular masses of sugary-textured aplite, grading locally into alaskite and minor pegmatite. Outcrops in Mzg with joints dipping moderately west. Modified description from Krauskopf and Bateman (1977).

Trdg: Diorite and gabbro dikes. Mostly light green and black colored coarse-grained crystal rich (38%) hornblende-plagioclase dikes with secondary sphene and epidote. Fine grain crystals on cooling margins, coarse grain at the center of dike, green crystalline groundmass with vesicles containing calcite. Presence of epidote indicates greenschist facies alteration. Outcrops in Mzg with joints dipping moderately west. Modified description from Krauskopf and Bateman (1977).
25% Chlorite (<2 mm)
7% Fe/Ti Oxides (<1 mm)
4% Epidote (<1 mm)
1% Plag (<1 mm)
1% Vesicles containing calcite (<2 mm)
<1% Hbl (<1 mm), Sphene (<1 mm), 1% Apatite (<1 mm)
Crystalline groundmass

Mzg: Mesozoic granite, undifferentiated. Undifferentiated Triassic granodiorite of the Benton Range and Jurassic granite of Casa Diablo Mountain (Krauskopf and Bateman, 1977). Jurassic granite outcrops tannish orange. Weathered Jurassic granite outcrop have orange rind of crumbly sand sized gross. Triassic granodiorite outcrops gray and is less eroded than Jurassic granite. Flat, linear, smooth epidote green surfaces in granite typically indicate fault planes or joints.

Distinguishing Features

Basalt lava with lack of phenocrysts > 1 mm in hand sample and thin section. Phenocrysts > 1 mm are rare in hand sample.

Well-rounded cobbles sandwiched between the Mesozoic granite and Pliocene basalt lava unconformity.

Gravel and cobble deposit overlain, in angular unconformity, by unit Qbst.

Lava flow breccia.

Altered andesite lava that outcrops reddish purple to brown with a knobby to crumbly texture.

Welded rhyolite tuff with devitrified yellow pumice in hand sample and thin section. Forms boulders and erodes downslope, depositing a poorly consolidated colluvium on hillslopes.

Sugary white crystalline dikes cutting granite.

Eroded olive green mafic dikes in Mzg. Abundant chlorite, epidote, Fe/Ti oxides, with sphene in thin section. Dikes appear as a scum of green mafic rock in granite. They do not form shark fins.

Mineral abbreviations: Bt- Biotite; Cpx - clinopyroxene; Hbl - Hornblende; Ol - olivine; Opx - orthopyroxene; Plag - plagioclase feldspar; Qtz - Quartz; San - Sanidine