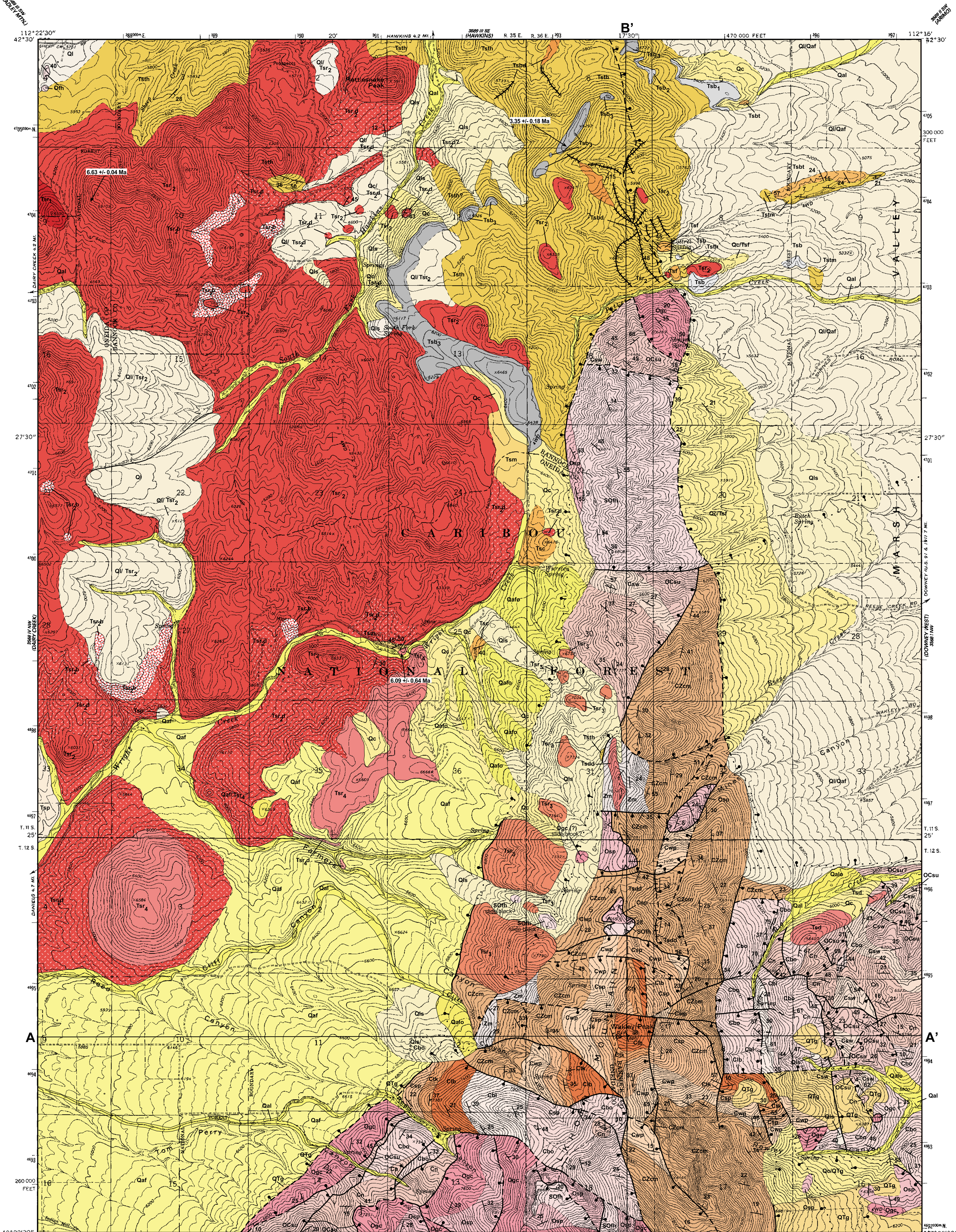
This Technical Report is largely derived from M.S. student mapping by Arron D. Pope and James J. Blair under the supervision of Paul Karl Link. Its content and format may not conform to agency standards.

Geologic Map of the Wakley Peak Quadrangle, Bannock and Oneida Counties, Idaho

Arron D. Pope, James J. Blair, and Paul Karl Link[1]

2001



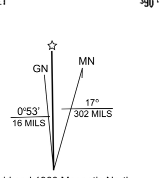
Base map from USGS digital raster graphic, 1968.

Control by USGS and NOS/NOAA.

Topography by photogrammetric methods from aerial photographs taken 1966. Field checked 1968.

Projection: Idaho coordinate system, east zone (transverse Mercator). 1927 North American Datum.

Datum is mean sea level.



UTM Grid and 1968 Magnetic North Declination at Center of Map

SCALE 1:24,000

1 ½ 0 1 MILE

1 .5 0 1 KILOMETER

Contour Interval 40 feet.

QUADRANGLE LOCATION

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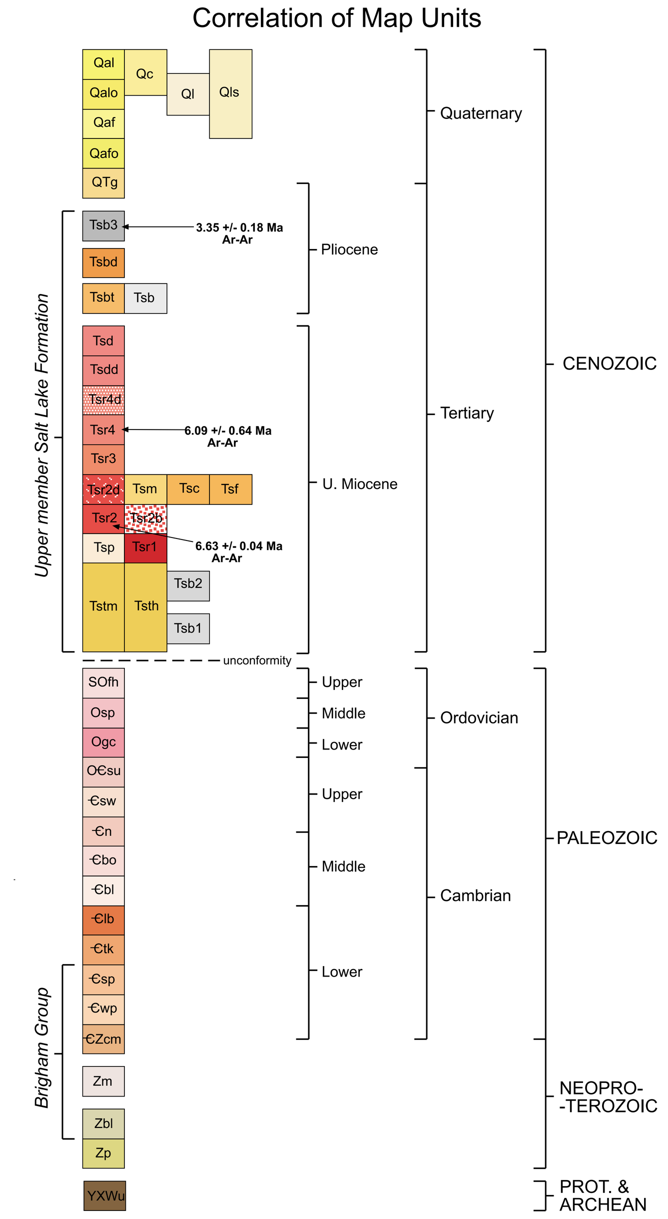
Digital cartography by Arron Pope and Diana Boyack at Idaho State University Geology Department's GIS lab.

Layout by Arron Pope at the Idaho State University Geology Department's GIS lab.

Correlation of Map Units



DESCRIPTION OF MAP UNITS

Qal **Alluvium (Holocene)** – Unconsolidated gravel, sand, and mud deposited in the channels and floodplains of the perennial and larger intermittent streams. Thickness ~0 – 30 (?) ft (0 – 9 m).

Qalo **Older Alluvium (Holocene to Pleistocene (?))** – Unconsolidated gravel, sand, and mud. Mapped where the deposits are topographically higher than any active streams and the associated modern alluvium. Thickness probably < 30 ft (9 m).

Qls **Landslide and Slump Deposits (Holocene to Pleistocene (?))** – Unconsolidated angular to subrounded pebble- to boulder-size clasts in a matrix of finer grained material. Three major landslides are mapped in this area. The slide block in Sec. 1, T.11S., R.35E. is composed of basalt and Salt Lake tuffaceous material (Tsth). In Sec. 31, T.11S., R.36E., the slide block is complex, with clasts composed of local bedrock, rhyolite and dacite, and Salt Lake fallout ash (Tsth (?)). Parts of this deposit are actively slumping. The slide block in Sec. 21, T.11S., R.36E. is composed of alluvial fan gravels (Qaf) and/or colluvium and Tertiary fanglomerate (Tsf). Several smaller slide blocks are mapped where typical landslide morphology is clearly discernable. Thickness is highly variable.

Qc **Colluvium (Holocene to Pleistocene)** – Poorly consolidated to unconsolidated angular to subangular pebble- to boulder-size clasts in a matrix of finer grained material. Mapped only where the identity of the underlying rock is unclear. Thickness unknown, probably < 15 ft. (5 m).

Ql **Loess (Pleistocene)** – Unconsolidated windblown silt mantling the alluvial fan gravels, and locally Tertiary volcanics, in the lowlands. Thickness unknown, probably < 30 ft (9 m).

Qaf **Alluvial Fan Gravels (Holocene to Pleistocene)** – Crudely stratified unconsolidated pebble- to locally boulder-sized gravel in a sandy to muddy matrix. Fan gravels are in most places mantled by loess of varying thickness, though locally exposed in the more incised drainages, and where wind has removed the loess cover.

Qafo **Older Alluvial Fan Gravels (middle Pleistocene (?))** – Unconsolidated to moderately indurated pebble- to cobble-size gravel in a sandy to muddy matrix. Where partially indurated, the cement is calcareous. These alluvial fan gravels are highly incised, and where they abut the younger fan gravels (Qaf) they are topographically higher. Mapped primarily by the clear morphology seen on the topographic base and more obviously on aerial photos. Thickness unknown, probably < 200 feet (61 m).

QTg **Older Gravels (Pliocene (?) to Pleistocene (?))** – Unconsolidated matrix-supported pebble- to boulder-size gravel in a sandy to muddy matrix. Pebbles and cobbles are usually of limestone and quartzite. Boulders (up to 2 meters) are of quartzite. Quartzite is Swan Peak Quartzite, except the exposures north of Rowley Canyon in the southeast corner of the map area, where the quartzite is Sedgwick Peak Formation and possibly Camelback Mountain Quartzite, and the cobbles and pebbles include shale from the Bloomington Formation, which is clearly exposed beneath and uphill from the exposure in the W ½, Section 9, T.12S., R.36E. In the southeast map area, the exposures may be fill surfaces, possibly related to other similar preserved surfaces around the area. In the southwest map area, the exposures may simply be the largest boulders collected at the head of the alluvial fans during formation of either or both Qaf or Qafo. This unit includes unit Tsd of Oriel et al., (1991), which consists of unsorted clastic and volcaniclastic material along the mountain front south of this map area. Thickness variable, from 10 to at least 50 feet (3 to 15 m) or more.

SALT LAKE FORMATION (PLIOCENE TO UPPER MIOCENE)

Regionally extensive basin-filling sediments, generally composed of tuff, conglomerate, limestone, and mudrock. Usually divided into a lower member, an Arbon Valley Tuff-correlative middle member, and an informal upper member (Link and Stanford, 1999).

Salt Lake Formation, Upper Member (Pliocene to Upper Miocene) – Tuffaceous conglomerate, rhyolitic fallout and water-reworked tuff, rhyolite, dacite, basaltic andesite, and basalt lava flows/dikes, local pumiceous sandstone and marl. In the Wakley Peak quadrangle, the Upper member is divided into several units. The rhyolite fallout tuffs (Tsth and Tstm) appear to be the oldest local Tertiary units. The Arbon Valley Tuff, part of the Middle Member of the Starlight Formation (Salt Lake Formation equivalent north of this area), is not recognized in the field area. Units of the Salt Lake Formation mapped near the Wakley Peak quadrangle are all part of the Upper member (Link and Stanford, 1999). Tephrachronological analyses on tuffs from the nearby Lava Hot Springs area, which are similar to units (Tsth) and (Tstm), yield ages from about 9.3 to 7.0 Ma (Crane, 2000). Therefore, all Tertiary units in this map area are considered to be part of the Upper member of the Salt Lake Formation. Combined thickness of Ts is up to 4000 feet (1219 m).

Tsb3 **Basalt Flow (Pliocene)** – Dark-gray to black basalt flow. Abundant small (<2mm) plagioclase phenocrysts, and less abundant olivine. Flow margins exhibit columnar jointing, forming 10 to 20 foot high cliffs. A sample from flow Tsb3 yields an $^{40}Ar/^{39}Ar$ age of 3.35 ± 0.18 Ma. The flow surface tilts about 5-degrees to the east. Thickness up to 40 feet (12 m).

Tsbd **Basaltic Dikes (Pliocene (?))** – Dikes of black to yellowish-brown (weathered) diabase and basalt. Degree of crystallinity increases from the margin of the dike toward the center, from fine-crystalline basalt to coarse-crystalline diabase. Phenocrysts include plagioclase, olivine, and pyroxene. Zeolites commonly fill fractures and cavities. Highly weathered dikes are commonly identified as thick orange-brown to yellowish-brown mafic sand and clay mixture in gullies. Locally preserved as dense, resistant ledges intruded into tuffs of Hawkins Basin volcanics. Significant alteration of the Tsth tuffs occurs where numerous dikes intrude in close proximity to each other, but otherwise the baked zone is thin if identifiable. Dike thicknesses are from 10 to 100 feet (3 to 30 m), most closer to 10 feet.

Tsb **Basalt Flow (Pliocene (?))** – Three dark-gray to black basalt flows are divided youngest to oldest (Tsb3 to Tsb1) based on apparent stratigraphic level with respect to each other. The relative age of (Tsb) could not be determined with respect to the other basalts. Abundant small (< 2mm) plagioclase phenocrysts, and less abundant olivine and pyroxene. Also common are incorporated basaltic scoria and occasional xenoliths of what appears to be quartzite and shale or tuff (Tsth?). Clastic inclusions are most common near the top and bottom of the flow. The scoria within the flow, and the proximity to the large deposit of unit (Tsbt) suggest a correlation between the two units. Forms 10 to 20 foot high cliffs. Thickness is less than 40 feet (12 m).

Tsbt **Basaltic Tuff (Pliocene (?))** – Layered rusty-brown (palagonitized) to black basaltic scoria lapilli and peperite deposits, exposed in alluvial fan gullies on the east side of the range. Occasional pebble- to cobble-size basalt clasts. Local cm-scale palagonite layers. 0 to 5% clay and silt matrix. Up to 80 feet (24 m) thick, exposed.

Tsd **Dacite Flow (Upper Miocene)** – Medium- to dark-gray porphyritic dacite flow. Phenocrysts of ~15% plagioclase, 1% orthopyroxene, <1% hornblende, and <1% clinopyroxene, by volume. Matrix (microlites, and <10% glass by volume) is commonly banded to streaked (cm-scale) dark-gray and red, similar to Tsr4. Banding and streaks are often convoluted. Exhibits weak flow jointing. Found preserved in one location on the west side of the range. Distinguished from other similar volcanic units (Tsr3 and Tsr4) by geochemical analyses. Thickness from 20 to < 200 feet (6 to < 61 m).

Tsdd **Dacite Dike (Upper Miocene)** – Light- to medium-gray porphyritic dacite dikes. Phenocryst assemblage and glass content similar to that of dacite flow (Tsd). Found on and near the ridgeline (Sec. 31, T.11S., R.36E and Sec. 5, T.12S., R.36E.) intruding the bedrock. Exhibits platy jointing. Any bake zone is obscured by colluvium. This is the probable source for the dacite flow (Tsd), determined by geochemical correlation and proximity to the flow. The largest dike is up to 500 feet (152 m) thick, thinning to the south.

Tsr4d **Rhyolite Debris Flow Deposit (Upper Miocene)** – Pebble to boulder (up to 1-meter diameter) clast-supported breccia. Subangular to subrounded clasts of only hornblende-bearing glassy rhyolite (Tsr4) in a tan to light brown sandy mud matrix. A small outcrop at the perlite loading facility along Wright Creek Road has a lower scoured contact with marls of Tsm. Thickness is about 20 feet (6 m), thinning to the west where mapped.

Tsr4 **Rhyolite Flow (Upper Miocene)** – Hornblende-bearing rhyolite flow. Porphyritic with a glassy matrix. Phenocrysts of 10 to 15% plagioclase, 1 to 2% hornblende, and <1% orthopyroxene by volume. Glass content from ~10 to 85%, depending on location on flow. Matrix is commonly banded to streaked (cm-scale) dark-gray and red. Banding and streaks are often convoluted. Boulders on the flow surface exhibit 3 to 5 cm chilled margins. Easily distinguished from Tsr2 by lack of biotite and presence of hornblende. Distinguished from Tsr3, and Tsd primarily by geochemical and thin-section analyses. A sample from flow Tsr4 yields an $^{40}Ar/^{39}Ar$ age of 6.09 ± 0.64 Ma. Preserved thickness from 100 to 600 feet (30 to 183 m).

Tsr3 **Rhyolite Flow (Upper Miocene)** – Light- to medium-gray porphyritic rhyolite flow. Phenocrysts of ~15% plagioclase, ~5% orthopyroxene, and < 1% hornblende by volume. Glassy matrix mostly devitrified to equigranular masses. Commonly columnar jointed, 3 to 10 inches (8 to 25 cm) in diameter, and otherwise massive to blocky or platy jointed. Found perched on bedrock on the east side of the range. Appears to be cut by the western range-bounding normal fault. Distinguished from other similar volcanic units (Tsr4 and Tsd) by geochemical and thin-section analyses. Thickness is difficult to determine, but probably less than 200 feet (61 m).

Tsf **Fanglomerate (Upper Miocene)** – Almost clast-supported, massive to locally weakly bedded, well-indurated conglomerate, found on the west side of the range. Subrounded to subangular pebbles to dominantly cobbles of mostly Garden City Limestone and chert in a medium-gray to tan calcareous mud matrix. Strong calcareous cement. Forms ledges, where exposed. No tuffaceous beds or matrix was found. Possibly correlative with Tsc on the west side of the range. Thickness < 400 feet (122 m), exposed.

Tsc **Conglomerate (Upper Miocene)** – Clast- to matrix-supported conglomerate. Subrounded to subangular pebble- to cobble-sized clasts of mostly tuff, some rhyolite (Tsr2), some bedrock (mostly dolomite, some quartzite). Found locally abutting or overlying Tsr2d (Sec. 19, T.11S., R.36E.). Possibly correlative with Tsf on the east side of the range. Thickness unknown, at least 100 feet (30 m).

Tsm **Marl (Upper Miocene)** – White marl, composed of calcareous (diatomaceous (?)) mud. Weakly indurated, and moderately to highly fractured. A fossilized fish vertebra and several fish rib bones were found at the only well-exposed outcrop, found at the east end of the perlite facility on Wright Creek Road. At this locale, the upper contact is in angular unconformity with unit (Tsr_4d), and the lower contact is in angular unconformity with unit (Tsr_2d). Thickness unknown, at least 20 feet (6 m).

Tsr2d **Rhyolite Debris Flow Deposit (Upper Miocene)** – Matrix- to rarely clast-supported, thin-bedded to massive rhyolite and pumice debris deposits. Subangular to angular, granule- to large cobble-sized clasts are composed only of biotite-bearing rhyolite (Tsr2) in all forms (flow-banded, perlitized, obsidian, etc.). Locally (along Wright Creek Road) the clasts are dense biotite-bearing pumice blocks. White, light-gray, or tan friable massive to locally thinly bedded matrix (rarely with weak calcareous cement) is composed of mostly pumice and some silt. At the perlite loading facility along Wright Creek Road, the sediments include thick (meters) beds of marl. The lower contact is not exposed. An upper contact at the perlite facility is a scoured angular contact between marl and an unmappable small outcrop (10 m by 2 m) of unit Tsr4d. The upper contact with the youngest rhyolite flow (Tsr_4) is largely obscured by colluvium. Forms slopes. Total thickness is unknown, and is likely highly variable. Thickness varies from 0 to 500 feet (0 to 152 m), exposed.

Tsr2b **Rhyolite Breccia (Upper Miocene)** – Auto-brecciated perlitized biotite-bearing rhyolite (Tsr2). Angular perlite clasts from granule- to cobble-sized. Locally, matrix is glassy and pink to reddish-pink. Elsewhere matrix is light-gray, with additional clasts of obsidian and flow-banded rhyolite. Thickness is highly variable, from 0 to 200 feet (0 to 61 m), exposed.

Tsr2 **Rhyolite Flow (Upper Miocene)** – This biotite-bearing rhyolite comprises the majority of the volcanic rock in the map area. Typically light-gray, with common orange-tan to buff colored discontinuous banding (mm- to cm-scale). Phenocrysts of 1 to 2% subhedral plagioclase (<2 mm), 1 to 2% euhedral biotite (up to 2 mm), ~1% anhedral quartz, and <<1% hornblende. Contains from 0 to 5% by volume granule- to pebble-sized obsidian (Apache tears) within the matrix. Sharp texture ranges from glassy (locally spherulitic) to completely devitrified to completely perlitized. Massive to flow jointed to weakly columnar jointed. A sample from flow Tsr2 yields an $^{40}Ar/^{39}Ar$ age of 6.63 ± 0.04 Ma. Exposed thickness up to 1000 feet (305 m).

Tsr1 **Rhyolite Flow (Upper Miocene)** – The non-biotite-bearing rhyolite is only identified in Sec. 9, T.11S., R.35E. Medium- to light-gray. Massive to weakly flow-banded. Exhibits a phenocryst assemblage similar to Tsr2, except for a conspicuous lack of biotite. May be associated with clasts in pumice deposits (Tsp) to the south. Exposed thickness about 200 feet (61 m).

Tsp **Rhyolitic Pumice (Upper Miocene)** – Layered to massive primary rhyolitic pumice lapilli deposits. Little to no ash. Occasional dense pumice block breccia. Clasts of obsidian and non-biotite-bearing devitrified rhyolite are found at the Hess Pumice pit just west of the map area along Wright Creek Road. The pumice seen in the pit wall is layered and normally graded, with occasional pumice blocks and bombs. Biotite in the pumice is rare. Non-biotite bearing rhyolite clasts may be associated with flow Tsr1 to the north. Thickness ~100 feet (30 m), exposed. Greater thicknesses exposed west of map area.

Tsb2 **Basalt Flow (Upper Miocene)** – Dark-gray basalt flow. Abundant small (<2mm) plagioclase phenocrysts, and less abundant olivine. Appears to be intercalated in water-reworked tuffs of (Tsth). Thickness less than 40 feet (12 m), though difficult to determine as the flow is mostly obscured by colluvium.

Tsb1 **Basalt Flow (Upper Miocene)** – Dark-gray basalt flow. Abundant small (<2mm) plagioclase phenocrysts, and less abundant olivine. Appears to be intercalated in water-reworked tuffs of (Tsth), but stratigraphically lower than (Tsb_2). Thickness less than 40 feet (12 m), though difficult to determine as the flow is mostly obscured by colluvium.

Tstm **Marsh Valley Tuffs (Upper Miocene)** – Interbedded tuffs and calcareous mud and fine sands found in fan gullies on the east side of the range. Moderately to weakly indurated. Tuffs are white to light-gray and from < 10% to >90% glass shards, with clay, silt, and carbonate making up the difference. Exposed thickness 40 to 80 feet (12 to 24 m).

Tsth **Hawkins Basin Tuffs (Upper Miocene)** – Massive to thin-bedded waterlain, water reworked, and local fallout, vitric to crystal vitric tuff. Waterlain and reworked tuffs are silt to clay rich. Glass shards are mostly devitrified. Preserved crystals are mostly quartz, and possibly some sanidine. Color varies considerably, from light-tan, to light-gray, to light-green. Locally contains carbonized plant fragments. Typically forms smooth slopes and valleys. Outcrop is poor. Typically only the silicified tuffs crop out, in which case they are usually intimately fractured such that bedding (if present) is unidentifiable. Silicification is most prominent proximal to dikes of unit (Tsbd). Exposed thickness up to 1000 feet (305 m). Total thickness is unknown, as the base of the unit is never exposed.

SOfh **Laketown Dolomite and Fish Haven Dolomite, Undifferentiated (Silurian to Upper Ordovician)** – Medium- to light-gray, mottled, medium- to thick-bedded, bioclastic dolostone, with sparry calcite-filled molds of bioclasts. Dominantly medium-crystalline. Rugose and colonial corals are common. Locally up to 50% dark to light gray chert nodules and stringers. The two formations are here undifferentiated. Elsewhere, the Fish Haven Dolomite is dominantly dark-gray, while the Laketown Dolomite consists of light- and dark-gray dolostone beds. Sharp lower contact with the Swan Peak Quartzite is above the highest quartzite of that formation. Combined thickness at least 1800 feet (549 m), determined from cross-section.

Osp **Swan Peak Quartzite (Middle Ordovician)** – White, occasionally light-pink or light-green, dominantly thick-bedded quartzite. Fine- to medium-grained vitreous quartz arenite. Grain boundaries are commonly indistinguishable. Other clastic and carbonate members of this formation described elsewhere are not identified in this map area. Lower contact with Garden City Formation is between the topmost limestone of that formation and the lowest quartzite bed of the Swan Peak Quartzite. Ledge and cliff former. Cobbles and boulders are commonly found at the heads of the alluvial fans (Qaf). Thickness 800 feet (244 m), determined from cross-section.

Ogc **Garden City Formation (Middle to Lower Ordovician)** – Light- to dominantly medium-gray, thin- to medium-bedded, fine-crystalline limestone. Common tan to light orange, thin (mm-scale) silty interbeds. Uncommon intraformational conglomerate. Commonly oolitic and oncolitic. Rare gastropods. Characteristically abundant (up to 50%) dark-gray to black chert nodules near top of formation. Lower contact with St. Charles Formation is approximately above the last dolostone bed of that formation, or above which there is a significant increase in frequency of silty interbeds. Thickness 1000 feet (305 m), determined from cross-section.

St. Charles Formation

OꞒsu **Upper Member (Lower Ordovician to Upper Cambrian)** – Medium-gray, thin- to dominantly medium-bedded, fine- to locally medium-crystalline dolostone and lesser limestone. Common tan to light-orange silty interbeds, though these are far less frequent than in the overlying Garden City Formation. Limestone is locally oolitic to oncolitic. Nodules to stringers of light-gray to grayish-black chert are common. The lower contact with the Worm Creek Member of the St. Charles Formation is directly above the highest occurrence of arkosic sandstone of that member. Thickness 1300 feet (396 m), determined from cross-section.

Ꞓsw **Worm Creek Member (Upper Cambrian)** – Tan to light-gray, fine- to medium-grained arkosic sandstone and limey arkosic sandstone, with interbedded limestone and dolostone. Feldspar grains in the sandstone are partially altered to clay, commonly iron-stained. Lower contact is below the lowest sandstone bed of this member. Thickness 400 feet (122 m), determined from cross-section.

Ꞓn **Nounan Dolomite (Upper to Middle Cambrian)** – Medium- to dominantly light-gray, medium-bedded, sugary dolostone. No fossils identified. Uncommon to rare silty interbeds. Rare limestone and sandstone beds. Typically crops out as monotonous, medium-bedded dolostone. Lower contact is above topmost shale beds of the Bloomington Formation. Thickness is difficult to determine in this map area, but is 1500 feet (457 m) to the southeast in the Malad Summit quadrangle (Link, 1982).

Ꞓbo **Bloomington Formation (Middle Cambrian)** – This formation is divided into an upper shale unit, and a lower limestone unit. The upper unit is thin-bedded khaki to gray-green to olive-green shale, with characteristically common pebble- to cobble-size gray-green oblate micrite nodules. Forms slopes. The lower unit is dominantly medium-gray, thin- to typically medium-bedded, oolitic, oncolitic, fine-crystalline limestone, with abundant tan to light-orange silty partings, and lesser tan to gray-green shale interbeds (no micrite nodules). Forms ledges. Limestone is similar in appearance to that of the Garden City Formation, with which it can be confused if the bounding stratigraphy is unknown. Lower contact is above the topmost dark gray limestone beds of the Blacksmith Limestone. Thickness is difficult to determine in this map area, but is 1000 feet (305 m) to the southeast in the Malad Summit quadrangle (Link, 1982).

Ꞓbl **Blacksmith Limestone (Middle Cambrian)** – Medium- to dominantly dark-gray, medium-bedded to massive, fine-crystalline limestone. Locally bioclastic, typically oolitic or oncolitic. Rare tan silty interbeds. Distinguished from other limestones by the lack of silty interbeds, and the typically dark-gray color. Lower contact is above the topmost shale beds of the Lead Bell Shale, above which dark-gray limestone is overwhelmingly dominant. Thickness 1475 feet (450 m), determined from cross-section.

Ꞓlb **Lead Bell Shale (Middle Cambrian)** – Interbedded shale, siltstone, sandstone, and limestone. Claystone is dominant, particularly in the lower section. Thinly laminated claystone is dark-gray and brown near the bottom, and green to tan up section. Sandy siltstone and sandstone interbeds are common throughout the section, more so near the top. Sandstone is locally quartzitic and/or calcareous. Limestone beds mostly medium-gray, thin- to medium-bedded, locally oolitic and oncolitic, also more common in the middle and top of the section. Lower contact with the Twin Knobs Formation is above the last ledge of medium- to light-gray limestone of that formation, and below the first thick sequence of shale of this formation. Thickness 950 feet (290 m), determined from cross-section.

Ꞓtk **Twin Knobs Formation (Middle Cambrian)** – Divided into a bottom quartzite and limestone unit, a middle siltstone unit (not found in this map area), and an upper limestone unit. The lower unit is 50% limestone with interbedded quartzite and sandstone. The limestone is brown to gray-brown limestone to sandy or silty limestone. Sandstone is green to dominantly light- to medium-brown, fine-grained, calcareous, moderately sorted, though often silty. Thin- to medium-bedded quartzite interbeds are similar in appearance to that of the underlying Sedgwick Peak Formation, <10 feet (3 m) thick, locally discontinuous, found mostly near the base of the formation, and uncommonly throughout. The thin (~20 feet (6 m), elsewhere) middle green siltstone unit as described by Oriel and Armstrong (1971), is not found, or exposed, in this map area. The upper *Girvanella*-bearing unit is medium-bedded, medium- to light-gray ledge to cliff forming fine-crystalline limestone, commonly oolitic, 100 to 200 feet (30 to 61 m) thick. Lower contact with the Sedgwick Peak Formation is below the first limestone beds of the Twin Knobs Formation. Thickness 250 feet (76 m), possibly thicker, determined from cross-section.

BRIGHAM GROUP (Link et al., 1985)

Ꞓsp **Sedgwick Peak Formation (Lower Cambrian)** – Dominantly green (rarely pink to shades of light-brown), thin- to medium-bedded quartzite, and uncommon siltstone and shale interbeds. Quartzite is fine-grained with scattered coarse quartz grains. Diagnostic *Planolites sp.* bedding-parallel burrows are common in the green quartzite. Shale is tan, brown, or light-green argillite to sandy siltstone. Lower contact with the Windy Pass Argillite is at the base of the first quartzite ledge above which quartzite is overwhelmingly dominant. Thickness 500 feet (152 m), determined from cross-section.

Ꞓwp **Windy Pass Argillite (Lower Cambrian)** – Tan to medium-brown, sometimes light-green sandy argillite. Shale is typically micaceous (usually muscovite) mudstone, with up to 40% quartz grains (fine- to medium-grained). Slope former. Near the top of the formation, beds of light-brown to green quartzite are common, eventually grading into the dominantly quartzite of the overlying Sedgwick Peak Formation. Lower contact with the Camelback Mountain Quartzite is placed above the last prominent bed of quartzite of that formation. Thickness 750 feet (229 m), determined from cross-section.

ꞒZcm **Camelback Mountain Quartzite (Lower Cambrian to Neoproterozoic)** – White to tan to pink, thick-bedded to massive, medium-grained to granular, locally conglomeratic quartzite. Moderately to poorly sorted quartz arenite beds, locally cross-bedded. Uncommon conglomerate (more common near base) is matrix-supported with white to red, well-rounded quartz pebbles in a medium-grained to granular quartz arenite matrix. The top of the formation is characterized by ~30 feet of micaceous sandy shale, followed by an equally thick, or thicker, section of quartzite. Distinguished primarily by color from the Mutual Formation (dominantly grayish-red) and Sedgwick Peak Formation (dominantly green). Distinguished from the Swan Peak Quartzite by having more visible grain boundaries and being less well sorted. Lower contact with Mutual Formation is below a thick, clast-supported pebble- to cobble-conglomerate at the base of the Camelback Mountain Quartzite. Clasts are quartz and chert. This contact is often difficult to identify, though it was found exposed in Sec. 12, T.12S., R. 35E. along the east side of the lowest switchback of the jeep trail. Thickness is difficult to determine accurately in the map area due to pervasive overthickening along common bed-parallel normal faults; it is 1500 feet (457 m) in the Malad Summit quadrangle to the southeast (Link, 1982).

Zm **Mutual Formation (Neoproterozoic)** – White, tan, pink, to dominantly grayish-red, medium- to thick-bedded quartzite and conglomeratic quartzite. Quartzite is medium-grained to granular and moderately sorted quartz arenite. Clast- to matrix-supported quartz-pebble conglomerate is common near the top of this formation. Distinguished from other quartzites by its grayish-red color, though in Sec. 31, T.11S., R.36E., the color is similar to that of the overlying Camelback Mountain Quartzite, which may be a product of bleaching associated with the intrusion of the nearby dike (Tsdd). Only the upper part of the Mutual Formation is exposed in this area. Thickness 1200 feet (366 m) in the Malad Summit quadrangle to the southeast (Link, 1982).

Zbl **Lower Brigham Group, Undifferentiated (Neoproterozoic)** – Shown only in cross-section, the lower formations of the Brigham Group (Inkom Formation, Caddy Canyon Quartzite, and Papoose Creek Formation) presumably underlie the Mutual Formation in this map area. Thickness is estimated at 1600 feet (488 m), based on thicknesses described in the Oxford Peak and Malad Summit quadrangles to the southeast (Link, 1982).

Zp **Pocatello Formation, Undifferentiated (Neoproterozoic)** – Shown only in cross-section, the members of the Pocatello Formation (Upper, Scout Mountain, and Bannock Volcanic Members) presumably underlie the lower formations of the Brigham Group (Zbl) in this map area. Thickness is estimated at 6000 feet (1829 m), based on thicknesses described in the Oxford Peak and Malad Summit quadrangles to the southeast (Link, 1982).

YXWu **Metamorphic Rocks, Undifferentiated (Mesoproterozoic, Paleoproterozoic and/or Archean)** – Older metamorphic rock in cross-section only.

SYMBOLS

Contact: dashed where approximately located

Normal fault: bar and ball on hanging wall, dashed where approximately located, dotted where concealed

Low-angle normal fault: teeth on hanging wall, dashed where approximately located

Trace of dikes when very thin (< 20 feet)

43 Strike and dip of bedding surfaces

Sense of slip indicators for faults in cross-section. Arrow point indicates out-of-page slip. Arrow feathers indicate into-page slip.

GEOLOGIC HISTORY

The Wakley Peak 7.5' quadrangle, Idaho is located within the southern Bannock Range, about 50 kilometers south of Pocatello, Idaho and the southern border of the Eastern Snake River Plain. It lies in the northeastern Great Basin region, and is part of the northern Basin and Range physiographic province. The rocks of the southern Bannock Range are Neoproterozoic to Lower Cambrian dominantly shallow-marine to fluvial siliciclastic rocks of the Brigham Group (Link et al, 1987; Oriel and Armstrong, 1971) and Lower Cambrian to Silurian dominantly shallow-marine carbonate rocks (Link, 1982; Platt, 1985; Armstrong and Oriel, 1986; Oriel et al., 1991). Within the map area, evidence for at least three episodes of Miocene to Pliocene extensional faulting is preserved.

Mesozoic Compressional Deformation

The rocks of the Wakley Peak quadrangle belong to the Paris thrust plate of the Late Cretaceous Sevier orogenic belt (Armstrong and Oriel, 1986), and here roughly overlie the Malad Ramp, a frontal footwall ramp of the Paris thrust (Link et al, 1985; Burgel et al, 1987; Rodgers and Janecke, 1992). Because of the location of the Malad Ramp beneath or just west of this quadrangle, Neoproterozoic to Silurian rocks are exposed here, compared with the younger Paleozoic and Mesozoic rocks exposed to the west. Evidence for Cretaceous compressional deformation in the study area is restricted to low-amplitude, long-wavelength folds, and local cleavage developed in the argillites of the Windy Pass Argillite and Sedgwick Peak Formation. No thrust faults are identified in the map area. The nearest exposed Cretaceous thrust faults are an unnamed back-thrust fault ~20 km to the northeast in the Lava Hot Springs 7.5' quadrangle, Idaho (Crane et al., 2001), and the Putnam and Bear Canyon thrusts east of Pocatello (Kellogg, 1992; Kellogg et al, 1999, Riesterer et al., 1999) ~30 km to the north-northeast.

Miocene to Pliocene Extensional Deformation

The Late Miocene to Pliocene upper member (post 10.2 Ma) of the Salt Lake Formation consists of conglomerates and lacustrine calcareous mudstones, intercalated with regionally expansive rhyolitic fallout and reworked tuff, as well as locally erupted Late Miocene to Pliocene volcanic rock. The upper member fills basins that formed in response to Basin and Range extensional deformation (Rodgers and Janecke, 1992; Link and Stanford, 1999). Throughout the map area, three or more generations of Neogene normal faulting are recorded (Pope et al, 2000; Pope and Link, 2000; Pope, 2002).

The oldest phase of extension, approximately 9.3 Ma to less than 7.0 Ma (Crane, 2000; Crane et al., 2001), includes low-angle faults, which we show to have been rotated to near horizontal by subsequent Basin and Range extensional faulting. Remnants of the faults are preserved as isolated hanging wall blocks of Ordovician strata (commonly, though not always, highly brecciated) bounded on all sides by footwall Neoproterozoic strata (Sections 6, 16, and 17, T.12S., R.36E.; Sections 31 and 32, T.11S., R.36E.). These faults include the New Canyon fault of the Bannock detachment system (Janecke and Evans, 1999), mapped to the southeast in the Malad Summit and Oxford quadrangles (Link, 1982), and which places Cambrian and Ordovician carbonates on Neoproterozoic quartzites.

A second late Miocene extensional phase is recorded by the east-west striking and north-south striking normal faults found throughout the range. Generally, the east-west faults cut the north-south faults, but this is not always the case. It is therefore difficult to divide the two into discrete events. It appears that north-south faults initiated first, and east-west faults initiated later as north-south faults became less active. This relation is also found elsewhere in the Bannock and Portneuf Ranges (Link and Stanford, 1999). Our cross-sections show these faults merging with the basal Bannock detachment fault. Alternatively, it is possible that the faults are listric and sole into the basal fault.

The third and youngest extensional phase, latest Miocene (?) to Pleistocene, produced the range-bounding normal faults on both sides of the Elkhorn Range. The range is therefore a horst, and an extensional culmination of the three phases of faulting. Nearly all bedrock strata in the map area dip east, suggesting that greater total slip has occurred along the western range-front fault. This western fault is the northern extension of the active Wasatch normal fault. The Wasatch Fault may extend as far north as Pocatello and Arbon Valley, Idaho, along the southern margin of the Eastern Snake River Plain. An older, northeast-trending splay of this fault, originating in Sec. 12, T.12S., R.35E., extends across the range, and is cut by a younger east-west trending fault that places Ordovician strata to the north on Neoproterozoic strata to the south.

In the southwest region of the map area there is a subdued west-dipping fault scarp preserved between the bedrock and the prominent alluvial fans, suggesting that the most recent activity along this fault segment is Pleistocene or younger. The eastern range-bounding fault is largely inferred from study of aerial photographs. Two pieces of field evidence also suggest its existence. Along the northern margin of the range on the east side are remnants of Tertiary fanglomerate (Tsf). The fanglomerate is likely the remnant of the head of a Tertiary alluvial fan which filled the basin created by this fault. Also, and more compelling, the youngest (3.35 ± 0.18 Ma) basalt flow (Tsb_3) is offset about 440 feet (134 m) across a northeast dipping normal fault. We deduce that this fault is the northern extension of the east side range-bounding fault.

We concur with Janecke and Evans (1999), who suggest that rocks of the Wakley Peak quadrangle lie in the hanging wall of the regional Bannock detachment system. The breakaway fault for this system is thought to be the Valley Fault (Sacks and Platt, 1985) in the Cottonwood Basin to the east across Marsh Valley in the southern Portneuf Range. Janecke and Evans have located and documented offset of rocks of the Salt Lake Formation across two detachment faults (Clifton and New Canyon) in the Deep Creek half-graben, Malad City East 7.5' quadrangle, Idaho. Our cross-sections show the older low-angle faults to be remnants of this fault system.

Southern Hawkins Basin Volcanism

The Wakley Peak quadrangle contains the Miocene to Pliocene volcanic center of southern Hawkins Basin. R.A. Carlson (1968) generated a planimetric map encompassing most of the volcanic center as part of a M.S. thesis at Idaho State University. Recent mapping by Pope, Blair, and Link has resulted (with helpful consultations with Dr. Scott S. Hughes, ISU Geology) in reidentification of certain volcanic units (Tsr_3, Tsr_2) and first time identification of several others (Tsr_4, Tsr_4d, Tsd, Tsdd, Tsr_2d, Tsr_1, Tsbt, and Tstm). The volcanic center can be divided into roughly two phases: an older (~6 to 7 Ma) rhyolitic dome complex phase, and a younger (~3 Ma) basaltic phase.

The volcanic units on the east side of the range are not in stratigraphic contact with units on the west side, making it difficult to compare their relative ages. Field relations suggest that the tuff of Hawkins Basin (Tsth) is the oldest Tertiary volcanic unit on the west side of the range. Basaltic (diabase) dikes intrude Tsth, and may have fed one or more of the basalt flows, though this relationship cannot be confirmed by preliminary geochemical analyses of the units. Two basalt flows (Tsb_1 and Tsb_2) are intercalated with the tuff, and a younger basalt flow, Tsb_3 (3.35 ± 0.18 Ma), caps the sequence. In Sec. 3, T.11S., R.35E., rhyolite Tsr_2 (6.63 ± 0.04 Ma) is preserved directly atop Tsth. The uppermost basalt appears to have flowed around parts of the rhyolite flow, suggesting the upper basalt is younger, which is borne out by the geochronology. The rhyolite flow, Tsr_4 (6.09 ± 0.64 Ma), on the west side of the range rests on a debris flow unit (Tsr_2d) composed entirely of angular to sub-angular clasts of rhyolite Tsr_2 in a pumiceous matrix, suggesting that rhyolite Tsr_4 is younger than rhyolite Tsr_2. The rhyolite flow Tsr_3 is more difficult to place into the stratigraphic arrangement presented above. The flow is not in direct contact with any other volcanic unit. We call it younger than Tsr_2 in part because there seems to be a distinctly linear geochemical progression from older more rhyolitic volcanic rocks to younger more dacitic rocks. Flow Tsr_3 is cut by the western range-front fault, demonstrated by the obvious scarp in Section 1, T.12S., R.35E. Tsr_4 may have flowed over the top of the downdropped Tsr_3 flow, as no part of the Tsr_4 flow is found on the east side of the fault. We hypothesize that the dacitic dikes (Tsdd) on and near the ridgeline fed the dacite flow on the eastside of the range. The dacitic dikes may have intruded along pre-existing faults with in the range.

Quaternary Mass Wasting

Mass wasting associated with Tsth has resulted in several extensive landslides. In Sections 1 and 12, T.11S., R.35E., basalt overlying weaker tuffs (Tsth) failed catastrophically, resulting in extensive landslide deposits. Along the western flank of the range in the central map area, a series of landslides is preserved, and some slumping is still active. Debris of Tsth can be found within this landslide deposit, and the boundaries of the landslide conform to the distribution of rhyolite Tsr_3. It is tantalizing to suggest that a slope covered by Tsth tuffs was destabilized by the overburden of Tsr_3 and subsequent seismic activity, resulting in multiple pulses of sliding.

GEOCHEMISTRY AND GEOCHRONOLOGY

$^{40}Ar/^{39}Ar$ radiometric age determinations on three samples from volcanic units of the Hawkins Basin volcanic center were performed by the New Mexico Geochronology Research Laboratory in September, 2000, using their conventional technique. Results are presented below. Of note, the basalt (Tsb_3) is the first Pliocene basalt flow to be found in the Marsh Valley area.

Because of the macroscopic similarities between many of the volcanic units within the Hawkins Basin volcanic center, we performed ICP-MS and INAA geochemical analyses on 22 volcanic rock samples in order to help clarify relationships between the volcanic rocks. As a result we were able to make correlations between certain units, rule out correlations between other units, and better classify all the volcanic rock types. The three graphs presented below are representative of our conclusions. Samples from the same units are represented by the same symbol. Note that the two basaltic andesite samples shown on the TAS diagram were taken from a flow just west of the quadrangle, near the Hess Pumice mine, and are not described further here. Refer to Pope (2002) for the complete geochemical analysis.

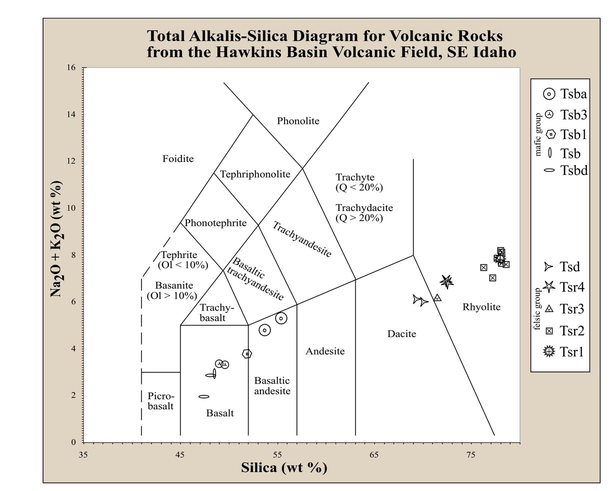
There are two apparent linear trends amongst the samples from the rhyolitic center and the samples from the basaltic center, represented best in the TAS diagram. This may be a result of fractionation within basaltic and rhyolitic source magmas, and/or magma mixing. The overlapping ages of the two rhyolitic samples (Tsr_2 and Tsr_4) allow for the possibility of a common, evolving rhyolitic source magma. The young Pliocene age of Tsb_3, and the stratigraphic locations of Tsb_1 and Tsb_2 within the older Late Miocene tuffs (Tsth) do not readily support a common basaltic source magma. It is more likely, therefore, that there were two episodes of basaltic volcanism, one prior to and one after rhyolitic volcanism.

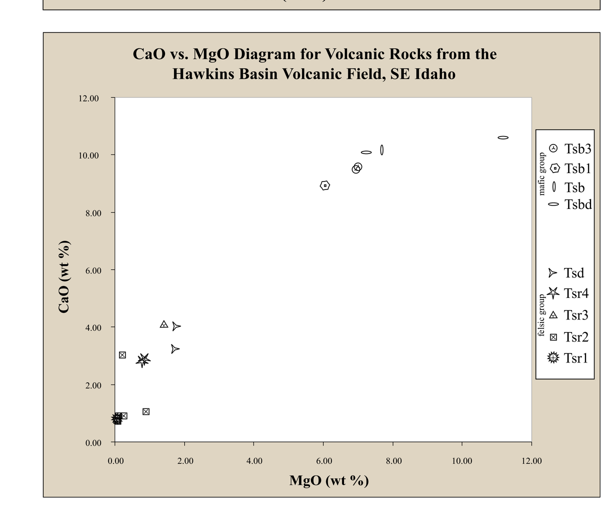
$^{40}Ar/^{39}Ar$ Geochronology

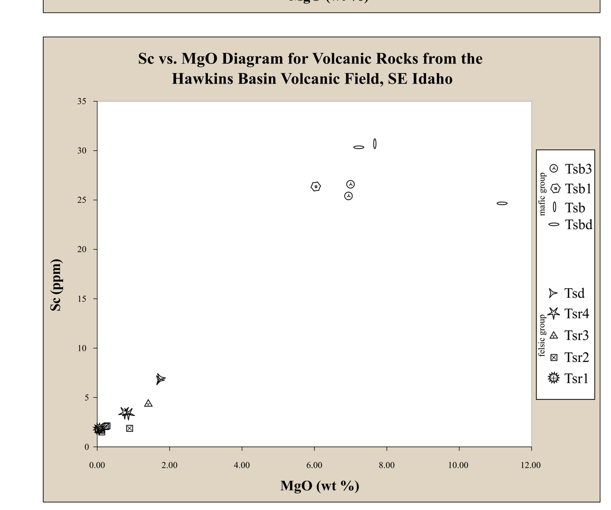
Samples	Age	Latitude	Longitude
Tsb3	3.35 +/- 0.18 Ma	N42° 29.286'	W112° 18.045'
Tsr4	6.09 +/- 0.64 Ma	N42° 26.177'	W112° 19.338'
Tsr2	6.63 +/- 0.04 Ma	N42° 28.983'	W112° 22.041'

Geochemical Data

Samples	SiO_2(wt%)	MgO(wt %)	Na_2O+K_2O(wt%)	CaO(wt%)	Sc(ppm)
Tsba	53.71	-----	4.78	-----	-----
	55.37	-----	5.29	-----	-----
Tsb3	49.48	6.86	3.32	9.36	25.4
	49.00	6.90	3.38	9.46	26.6
Tsb1	51.89	5.98	3.76	8.80	26.3
Tsb	48.45	7.58	2.94	10.05	30.8
Tsbd	48.08	7.14	2.86	9.94	30.3
	47.42	11.07	1.95	10.47	24.6
Tsd	70.01	1.70	6.00	3.23	6.78
	69.24	1.74	6.16	4.02	6.98
Tsr4	72.35	0.85	6.93	2.89	3.42
	72.47	0.77	6.83	2.82	3.46
Tsr3	71.48	1.41	6.14	4.04	4.25
Tsr2	76.23	0.21	7.49	3.02	2.02
	78.12	0.10	7.64	0.88	2.09
	77.98	0.05	8.17	0.72	1.76
	77.64	0.27	7.87	0.90	2.11
	77.96	0.10	8.19	0.78	1.69
	78.09	0.05	8.10	0.74	1.67
	78.51	0.10	7.61	0.78	1.51
	77.26	0.89	7.03	1.06	1.87
Tsr1	77.97	0.05	7.83	0.78	1.78







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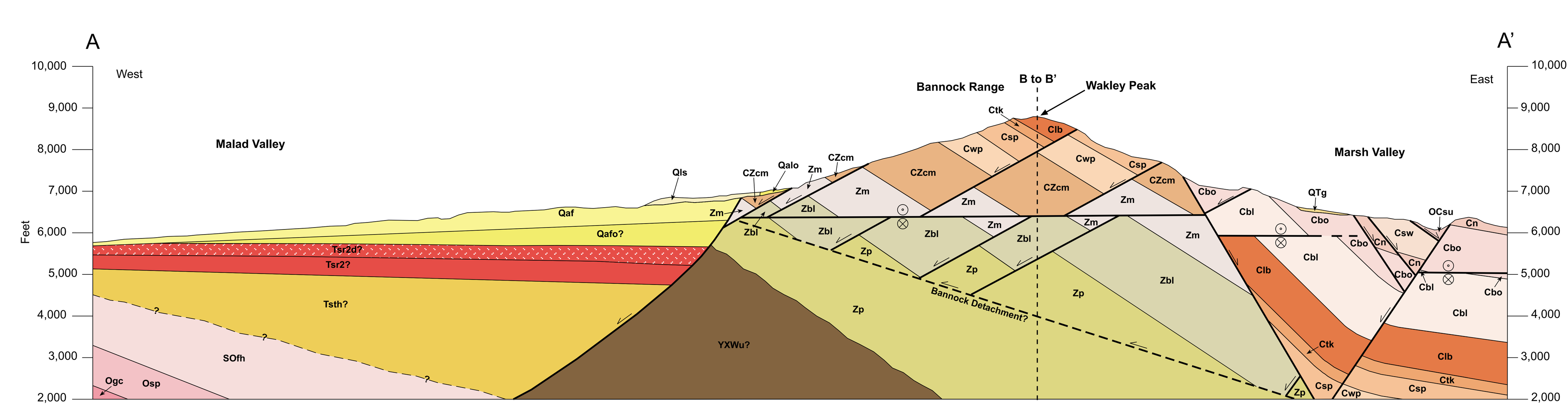

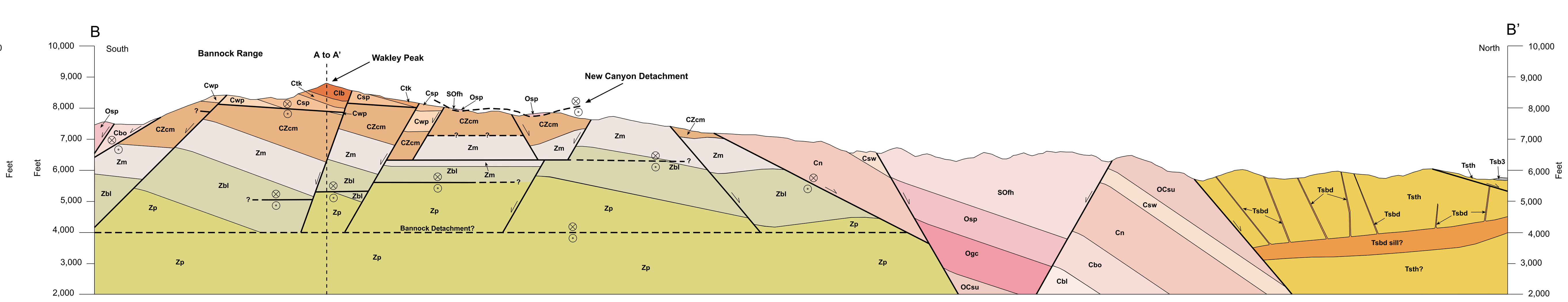

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