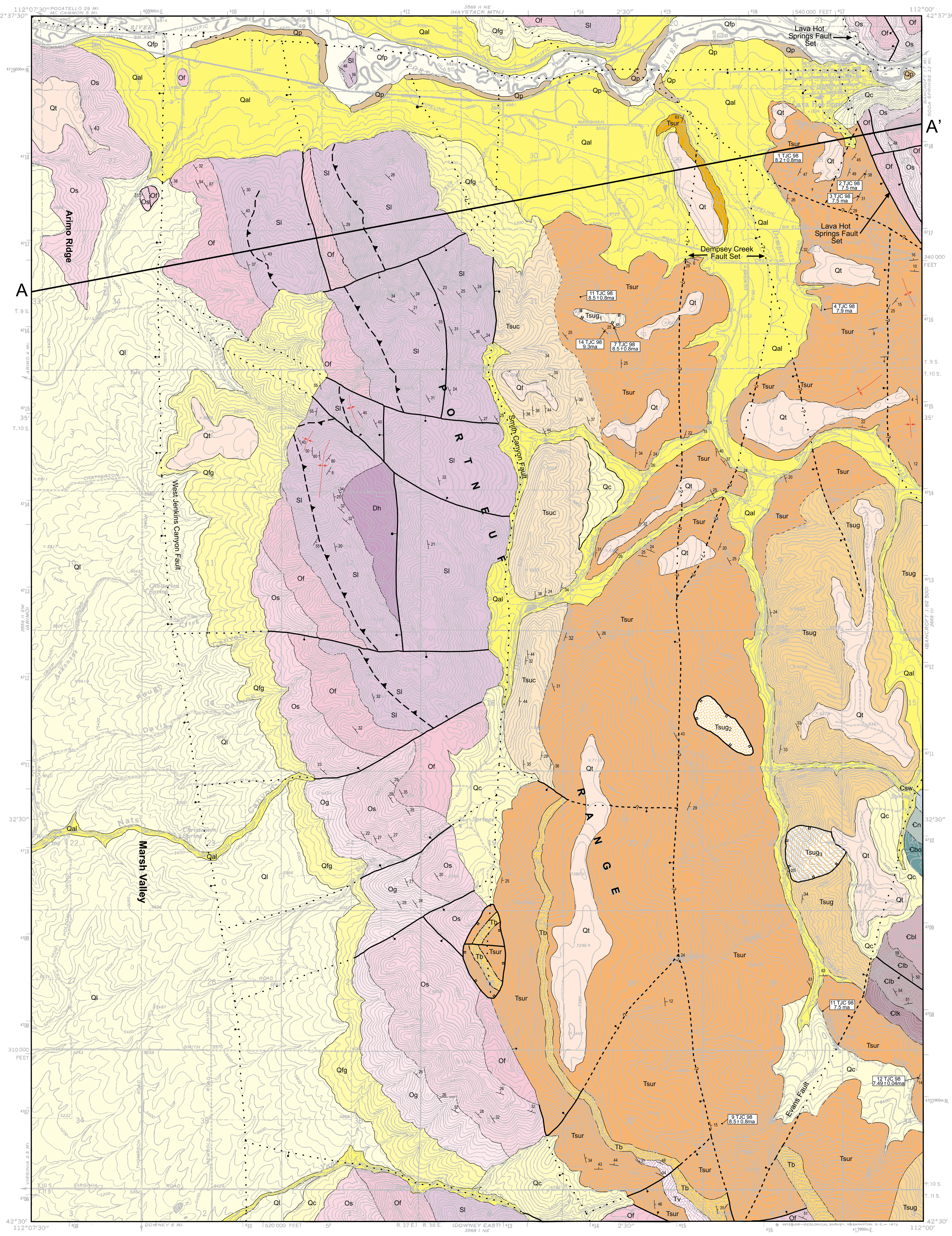
This Technical Report is largely derived from a map originally submitted as part of a master's thesis (Crane, 2000). Its content and format may not conform to agency standards.

Geologic Map of the Lava Hot Springs Quadrangle, Bannock County, Idaho

Tracy J. Crane[1], Paul Karl Link[1], and Steven S. Oriel[2]



Base map from USGS 1:24,000 digital raster graphic.

Topography by photogrammetric methods from aerial photographs taken 1967. Field checked 1968.

Polyconic projection. 1927 North American datum
10,000-foot grid based on Idaho coordinate system, east zone, 1000-meter UTM grid ticks, zone 12.

Datum is mean sea level.

GN MN 0°43' 13 MILS 17° 302 MILS

UTM Grid and 1968 Magnetic North Declination at Center of Map

SCALE 1:24,000

1 MILE · 1 KILOMETER

Contour Interval 40 feet.

QUADRANGLE LOCATION

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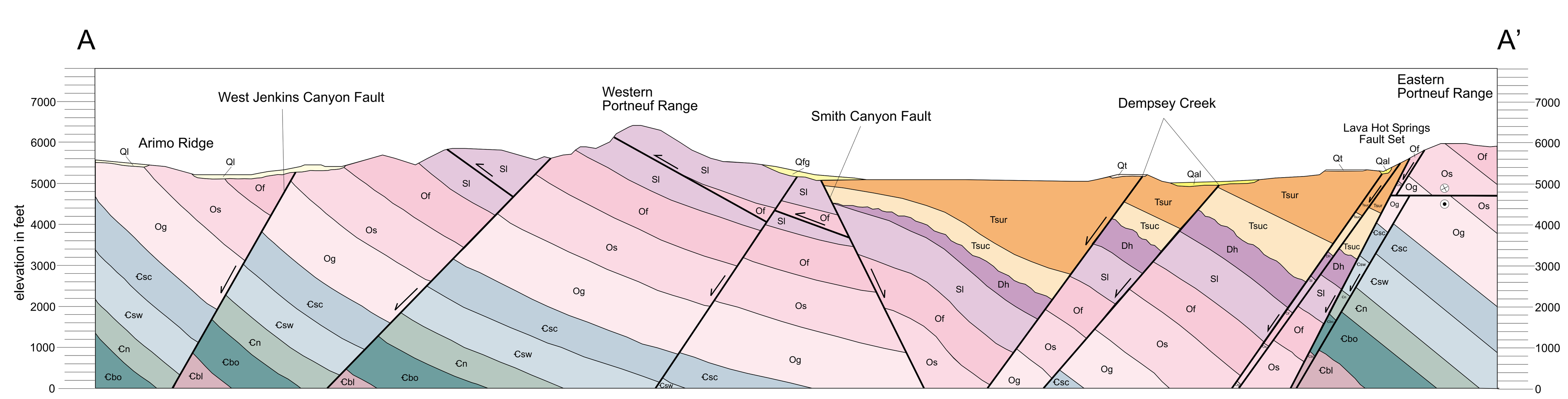
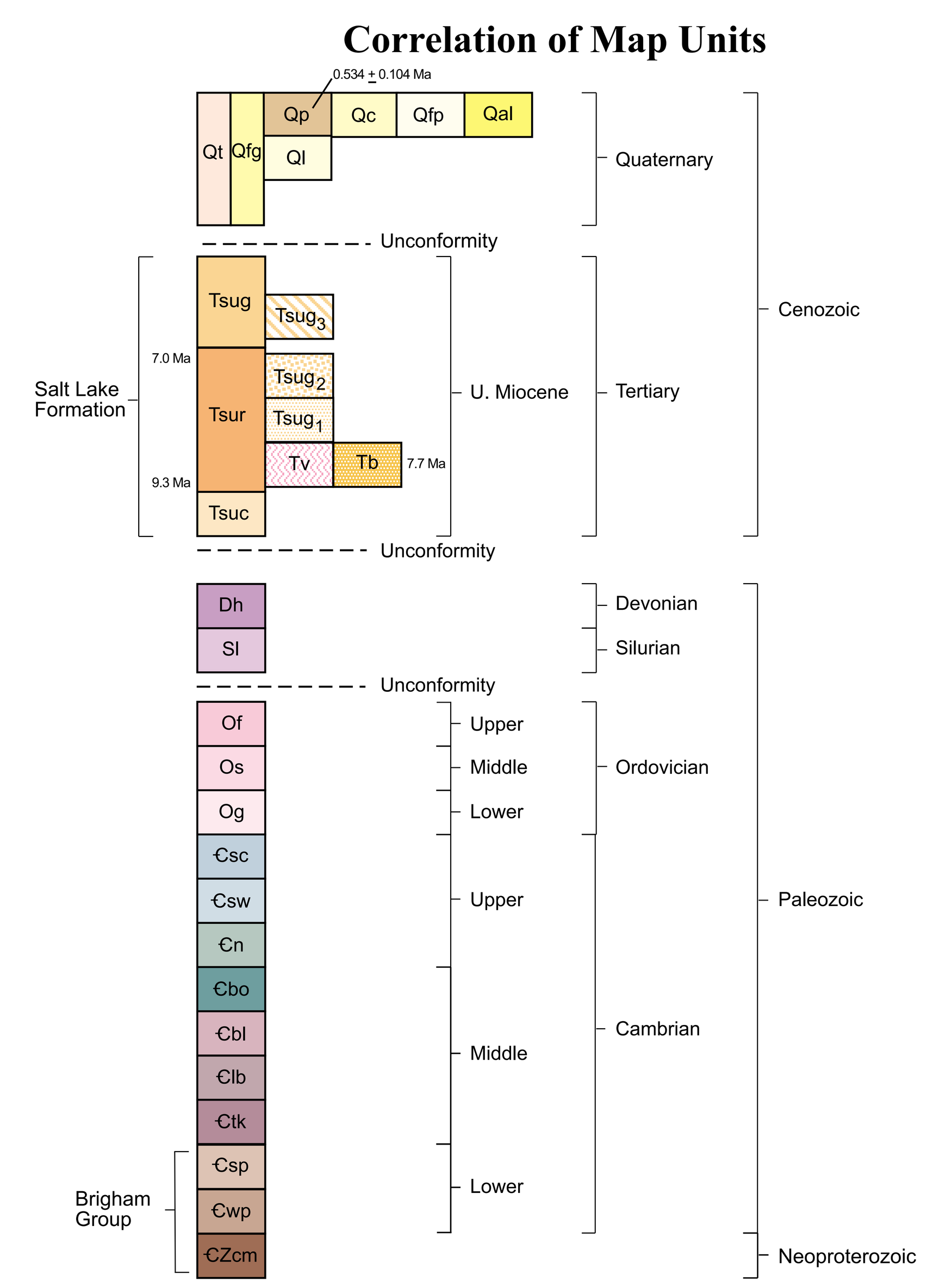
Map modified from Crane, T.S., 2000, M.S. Thesis, Idaho State University.

Digital Cartography by Diana Boyack and Beau Johnson
Idaho State University, Digital Mapping Lab.



Correlation of Map Units



Unit Descriptions

Qfp **FLOOD PLAIN (Holocene)--** Portneuf River flood plain deposits.

Qal **ALLUVIUM (Holocene)--** Unconsolidated sand, silt, mud and gravel from the Portneuf river and its tributaries. Thickness 0 - 35 (?) m.

Qfg **ALLUVIAL FAN GRAVELS (Holocene and Pleistocene) --** Poorly consolidated, boulder to pebble sized angular clasts deposited on the flanks of bedrock ranges. Thickness 0 - 30 m.

Qc **COLLUVIUM (Holocene and Pleistocene) --** Poorly consolidated, boulder to pebble sized clasts in a finer grained matrix. Thickness 0 - 10 m.

Ql **LOESS (Pleistocene) --** Unconsolidated silt that mantles lowlands. Thickness 0 - 20 m.

Qp **BASALT OF PORTNEUF VALLEY (Middle Pleistocene) --** Grey, massive, vesicular, tholeiitic basalt. Present as a narrow, sinuous flow along the course of the Portneuf River. Probable origin was the Blackfoot lava field to the northeast. Exposures display columnar jointing and form cliffs. The basalt of Portneuf Valley yielded a K-Ar date of 0.583 $\pm$ .104 Ma (Scott et al. 1982).

Qt **TERRACE DEPOSITS (Pliocene - Pleistocene) --** Terrace deposits of remnant Os boulders to cobbles, may occur at multiple levels, lower level terraces may be covered by 5-10 m of loess.

$Tsug_3$ **GRAVITY SLIDE BLOCK (Late Miocene - Early Pliocene) --** Grey, unidentified, Cambrian limestone gravity slide block in the upper part of the Salt Lake Formation. Slide block is within 100 m of the contact between the middle and upper units of the Salt Lake Formation.

Tsug **SALT LAKE FORMATION (Upper unit, upper member) (Late Miocene - Early Pliocene)** Brown to grey conglomerate, sandstone, and clay-siltstone. Conglomerate is massive to thickly bedded with inversely graded, well- rounded clasts of Paleozoic quartzite and dolomite as well as intraformational clasts from Tsug, Tsur and Tsuc. Clasts range in size from boulder (up to 10 m) to granule size in a limey, grey, fine sand matrix. Sandstone is a reddish-grey, bedded to thickly laminated, with lenses of massive silt. Clay-siltstone is a grey, thinly bedded, unit with occasional 1cm thick paleosol layers. Forms steep slopes with thin soil cover. Thickness unknown.

$Tsug_2$ **GRAVITY SLIDE BLOCK (Late Miocene - Early Pliocene)**--Syndepositional slide block within the middle conglomerate of the Salt Lake Formation in sec. 16, T10S, R38E, Slide block is brecciated Og and Os, and forms a prominent ridge.

$Tsug_1$ **GRAVITY SLIDE BLOCK (Late Miocene - Early Pliocene)**--Syndepositional slide block within the middle conglomerate of the Salt Lake Formation in sec. 31, T9S, R38E, and sec. 32 T9S, R38E. Slide block is brecciated Os and Of, and forms a prominent ridge.

Tb **TERTIARY BASALT (Late Miocene)** -- Grey, massive basalt that makes up a prominent linear ridge in the south-central half of the Lava Hot Springs quadrangle. The basalt has yielded a K-Ar date of 7.7+/- 0.3 Ma (Marvin et al. 1989).

Tv **MAFIC ERUPTIVE CENTER (Late Miocene) --** Strongly dissected basalt cinder cone. Cinders are red to blue-grey, well agglutinated, and cut by a number of phaneritic dikes.

Tsur **SALT LAKE FORMATION (Middle unit, upper member) (Late Miocene)** Light tan to grey conglomerate, sand, silt, clay and ash. Conglomerate ranges from boulder to pebble size, clast to matrix supported, massive to thinly bedded, with Paleozoic clasts along with intraformational clasts from Tsur and Tsuc, matrix is a fine grained mix of calcium carbonate and volcanic ash. Sand beds range from orange to green, fine to coarse grained, well lithified to unlithified, planar to cross-bedded fluvial and lacustrine sands. Silts are typically orange, thinly laminated with planar bedding and occasional clast inclusions up to 3 cm. Clays are light grey to light green, planar volcanic ash with occasional ripple mark, gastropoda and mollusca fossils. Volcanic ash is medium sand to silt sized, and rhyolitic. Ash occurs as both primary and reworked lacustrine deposits. Units occur in no specific order or pattern, and represent a dominantly fluvial to shallow lacustrine environment. Forms gentle slopes. Thickness appears to be 1000 - 1200 m.

Tsuc **SALT LAKE FORMATION (Lower unit, upper member) (Middle - Late Miocene)** Grey to light grey, conglomerate and sandstone. Conglomerate is dark to medium grey, boulder to granule conglomerate. Bedding typically is thick to massive, matrix supported with inverse grading and lenses of sand. Clasts are angular to subrounded Paleozoic and Proterozoic limestones, dolomites, quartzites and siltstones. Sandstone is grey to light grey, massive to medium bedded, coarse sand with angular to subrounded quartz and carbonate grains. Sandstone contains lenses of conglomerate, and may or may not grade upward from, or into, the conglomerate. Forms steep slopes and cliffs. Thickness is 300 -500? m.

Dh **HYRUM DOLOMITE (Middle Devonian) --** Thin- to medium-bedded, finely laminated, dark blue-grey, weathering dull brown, finely to very finely crystalline dolomite. Contains beds of light grey thin- to thick-bedded dolomite and some thin beds of light-grey medium crystalline limestone. Forms slopes and cliffs less than 10 m in height. Thickness 500m. (Oriel, 1965).

Sl **LAKETOWN DOLOMITE (Middle -Upper Silurian) --** Medium to massively bedded light-grey, weathering white, coarse crystalline to fine-grained dolomite, with fossil hash of crinoids and mollusks. This unit is present in the center section of the quadrangle, where it is repeated by normal faults. Forms slopes and cliffs less than 10 m in height. Thickness 250-350m. (Oriel, 1965, Schwarze, 1959).

Of **FISH HAVEN DOLOMITE (Upper Ordovician) --** Massive to thick, poorly bedded, bedding, dark blue-grey, weathering medium dusty grey, fossiliferous dolomite. Unit has *Halycytes*, mollusks and crinoids present throughout. Contains thinly bedded rip-ups and red-orange to black chert in 10 cm thick, bedding parallel stringers. Forms slopes. Thickness 320m.

Os **SWAN PEAK QUARTZITE (Middle Ordovician) --** White, red and orange quartzite. Massive to thinly bedded with planar bedding and cross-bedding. Weathers white to red, contains *Cruziana* and *Scolithos* trace fossils. Forms prominent ridges and slopes. Thickness 320 -380 m.

Og **GARDEN CITY FORMATION (Lower Ordovician) --** Medium grey limestone and dolomite. Thick to medium bedded, with abundant chert nodules and beds. Orange to black chert beds comprise up to 50% of the upper part of unit. Strongly bioturbated with *Cruziana* within fossil hash of ostracods and some packstone beds. Forms low slopes. Thickness is 430 m.

€sc **ST. CHARLES LIMESTONE (Upper member) (Upper Cambrian) --** Light-grey to medium grey dolomite, thin to thickly bedded, with intraformational conglomerate and chert. Includes an upper unit of dark-grey thin to medium bedded limestone. Forms slopes and ridges. Thickness 290 m. (Oriel, 1965).

€sw **ST. CHARLES LIMESTONE (Worm Creek Member) (Upper Cambrian) --** White to pink quartzite, grading down to medium grey, sandy dolomite and dolomite. Quartzite is medium to thick-bedded, dolomite is medium to thick-bedded and crystalline. Forms slopes and ridges. Thickness 290 m. (Oriel, 1965).

€n **NOUNAN LIMESTONE (Upper Cambrian) --** Medium to light-grey dolomite. Thin-bedded, medium to coarsely crystalline, with thin to medium bedded bands of dark-grey silty limestone, calcareous sandstone, and limestone conglomerate. Forms slopes. Thickness is 215 m. (Oriel, 1965).

€bo **BLOOMINGTON FORMATION (Upper Cambrian) --** Micaceous green mudstone and claystone. Thickness 320m. (Oriel, 1965).

€bl **BLACKSMITH LIMESTONE (Middle Cambrian) --** Upper part is a medium grey to buff limestone, oolites and recrystallized fossils present in some beds. Lower part is a medium gray thin to medium bedded limestone. Thickness 425m. (Oriel, 1965).

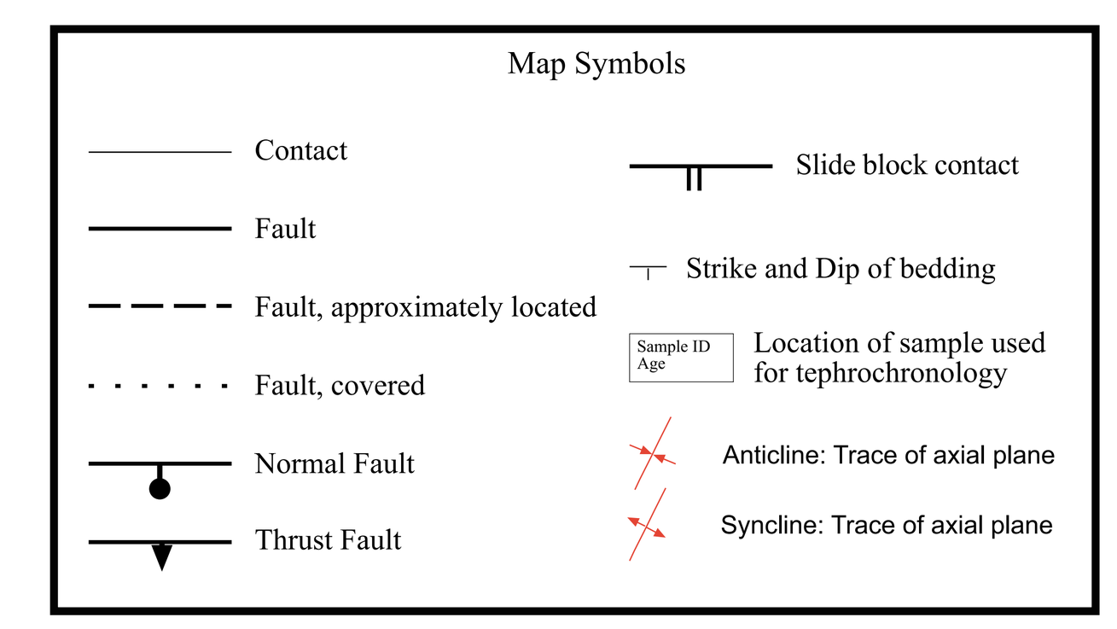
€lb **LEAD BELL SHALE (Middle Cambrian) --** Green and black, interbedded mudstone. Thickness 130m. (Oriel, 1965).

€tk **TWIN KNOBS LIMESTONE (Middle Cambrian) --**Light-grey, trilobite bioclastic limestone Thickness 190 m. (Oriel, 1965).

€sp **SEDGWICK PEAK QUARTZITE (Lower Cambrian) --** Green and tan quartzite, medium-bedded, fine- to medium-grained, with some argillaceous interbeds, Thickness 150 m. (Oriel, 1965).

€wp **WINDY PASS ARGILLITE (Lower Cambrian) --** Phyllite and phyllitic argillite, and siltite green, brown and tan, some quartzite interbeds. Thickness 230 m. (Oriel, 1965).

€Zcm **CAMELBACK MOUNTAIN QUARTZITE**, Lower quartzite member, (NeoProterozoic) -- White tan and buff in upper and middle parts, purple, pink and gray in lower part, very fine- to very coarse-grained quartz arenite. Thickness >480 m. (Oriel, 1965).



Sample number	Estimated Age	Correlated Regional Bed	Perkins' correlative
1tjc98	8.2$\pm$0.8 Ma		rv89-10
2tjc98	~7.5 Ma (?)		onn94-629
3tjc98	~7.5 Ma (?)		onn94-629
4tjc98	7.9$\pm$0.8 Ma	Rush Valley ash bed	
5tjc98	-------	limestone with trace ash	-------
6tjc98	7.0$\pm$0.1 Ma	Cub River ash bed	
7tjc98	8.5$\pm$0.8 Ma		rv88-11
8tjc98	-------	limestone with trace ash	-------
9tjc98	8.5$\pm$0.8 Ma		rv88-11
11tjc98	8.5$\pm$0.8 Ma		rv88-11
12tjc98	7.49$\pm$0.04 Ma	Faust ash bed	
13tjc98	~7.5 Ma (?)	Inkom ash bed?	
14tjc98	~9.3 Ma (?)	Pony Express ash bed?	

Table 1: Table of chemostratigraphic correlations of ash beds. Data obtained by M. Perkins at University of Utah(Crane, 2000).

Geologic History--Lava Hot Springs Quadrangle

The Lava Hot Springs quadrangle contains Cambrian and Neoproterozoic quartzose sandstone and carbonate rock overlain by Ordovician and Silurian quartzite, dolomite and limestone, deposited in the Cordilleran miogeocline. A thick sequence of the upper member of the Salt Lake Formation, containing Miocene to Pliocene conglomeratic fluvial sediments interbedded with fallout tuff, and deposited in the Dempsey Creek half-graben, rests with slight unconformity above Devonian and Silurian rocks. The map area was deformed during Mesozoic contraction and at least two phases of Neogene extension, the first during 10 to 7 Ma formation of the Bannock Detachment system,(Janeche and Evans, 1999) and the second during Pliocene to Recent Basin and Range high-angle faulting.

Paleozoic Sequence

The lowest exposed rocks are coarse-grained quartz and sandstone of the Cambrian and Late Proterozoic Camelback Mountain Quartzite of the Brigham Group (Oriel and Armstrong, 1971; Link et al., 1985). Overlying Cambrian strata include shallow marine carbonate and mudstone. The Cambrian units only crop out in a small area in the W. 1/2 of sec. 27, T. 10 S., R. 38 E.

The Ordovician and Silurian systems in the map area comprise the bedrock peaks of the southern Portneuf Range, which trend north-south through the center of the quadrangle. The oldest Ordovician unit is the shallow carbonate platform Garden City Formation. The contact between the Garden City Formation and the overlying Swan Peak Quartzite is exposed in the southern part of the map area. The Swan Peak Quartzite is a thick sequence of resistant pink to white quartzite, containing *Scolithos* trace fossils, suggesting deposition near storm wave-base. The contact between the Swan Peak Quartzite and the overlying dark-gray Fish Haven Dolomite is exposed in the NE 1/4, SW1/4, NW1/4, sec. 13 T. 10 S., R. 37 E. The overlying Laketown Dolomite is readily distinguished from the Fish Haven by its pale-gray color and coarse-crystalline texture and massive weathering pattern. The gradational contact is exposed just north of the map area,in the NE 1/4 sec. 13 T. 9 S., R 38. E. (Schwarze, 1959).

Cenozoic Sequence

Regionally in the Pocatello 1:100,000 quadrangle, the Late Miocene-Pliocene Salt Lake Formation is a thick sequence of fluvial, lacustrine and tephra deposits (Link and Stanford, 1999). In the Lava Hot Springs 1:24,000 quadrangle, three informal units are exposed, all within the upper member of the Salt Lake Formation. The upper member regionally lies above the 10.2 Ma Arbon Valley Tuff Member of the Starlight Formation, which correlates with the middle member of the Salt Lake Formation. Within the map area, the lower unit of the upper member Salt Lake Formation (Tsuc) contains boulder conglomerate and interbedded sandstone, deposited as east-derived medial to distal fanglomerate and associated braided stream deposits. Coarse-grained detritus was derived from adjacent Paleozoic highlands uplifted on the footwall of the northern extension of the Bannock Detachment fault (Janecke and Evans, 1999), this detritus was transported westward into the newlyforming Dempsey Creek half-graben.

The contact between the lower and middle unit (Tsur) is not well exposed, but appears to be a rapid gradation from conglomerate to finer grained fluvial conglomerate, sandstone, and tephra deposits and interbedded minor lacustrine limestone. The source of the rhyolitic tephra deposits in the middle unit was explosive volcanism on the eastern Snake River Plain, 60 km to the north (Perkins et. al, 1998). The 8.0 to 7.5 Ma (Marvin and et al., 1989) Yago Creek basalt eruptive center and basalt lava flow (Tsv and Tsb) is present within the middle unit, in the southern part of the map area. The middle unit also contains two map-scale Paleozoic slide blocks.

The contact between the middle unit and upper unit (Tsug) is an abrupt change to coarse, well-rounded, boulder conglomerate. The source of clasts in the upper unit was the uplifted Portneuf Range near Sedgwick Peak to the east, and recycled clasts of the underlying unit Tsur.

Deformation

Late Paleozoic and Mesozoic rocks were eroded as the area was uplifted above the east-vergent Late Cretaceous Paris-Putnam thrust (Sacks and Platt, 1985; Rodgers and Janecke, 1992; Camilleri et al., 1997). The regional Mesozoic structure was a broad, regional, north-south trending anticline within the Putnam thrust plate, of which the Portneuf Range makes up the west-dipping limb.

Minor shortening was accommodated by an anomalous west-vergent thrust that overthickens the Silurian Laketown Dolomite in Jenkins Canyon on the west flank of the southern Portneuf Range (Allexan, 1979; Crane, 2000). An extensive breccia zone and overturned beds in the Laketown, along with a syncline-anticline pair, crop out in sections 1 and 12 T. 10 S. R. 37 E., and sections 25 and 36 T. 9 S. R. 38 E. The antithetic thrust fault may have formed above a southern lateral ramp of the Narrows sub-plate of the Putnam thrust exposed in the Portneuf Range to the north (Kellogg et al., 1999; Riesterer et al.,2000).

The area most likely remained as an erosional highland until initiation of Late Miocene Basin and Range Extension on the Bannock Detachment system, before 10 Ma (Janecke and Evans, 1999). The Dempsey Creek half-graben occupies the hanging wall of north-striking, west-dipping, syndepositional normal faults, above the Bannock Detachment system (Janecke and Evans, 1999). The master breakaway for this fault system is approximately 4 kilometers east of the Lava Hot Springs quadrangle in the Fish Creek Range (Sedgwick Peak 1:24,000 quadrangle). Syntectonic deposition of the upper member, Salt Lake Formation occurred as the northern continuation of the hanging-wall "Swan Lake block" moved westward away from the footwall (Sacks and Platt, 1985; Janecke and Evans, 1999).

Immediately following initiation of extension, the lower unit of the upper member, Salt Lake Formation, was deposited. It contains tuffs with >9.3 to 7.0 Ma tephrochronologic correlations (Table 1, M. Perkins, University of Utah, written communication, 2000).

The east-west canyon of the Portneuf River in the northern part of the quadrangle may follow a Mesozoic tear fault or lateral ramp that was reactivated during the Late Mioceneas a synthetic transfer zone (*sensu* Faulds and Varga, 1998). The synthetic transfer zone offsets the southern Portneuf Range, eastward to the north. Movement on the transfer zone is interpreted to have occurred from ~9.3 to <7.2 Ma. These age constraints are based on the lowest tephra date in the study area and offset of Tertiary basalt (Tb) in the southern part of the Haystack Mountain, Idaho, quadrangle (Schwarze, 1959).

The Dempsey Creek fault set (a.k.a. Barb fault set; Crane, 2000) is a related set of normal fault splays that formed during the first phase of Late Miocene to early Pliocene extensional faulting. The set is contemporaneous with deposition of Salt Lake Formation. Movement on the Dempsey Creek fault set is interpreted to have begun during deposition of the Salt Lake Formation, and continued until after deposition of the formation.

The second phase of Late Miocene to early Pliocene extension is shown by a number of post-depositional, west-dipping normal faults (including the Lava Hot Springs and Evans faults) that cut the Salt Lake Formation. The Lava Hot Springs fault is truncated at the transfer zone and places Ordovician Fish Haven Dolomite against the middle unit (Tsur) of the Salt Lake Formation. The Evans fault places Cambrian rocks against the upper unit (Tsug) of the Salt Lake Formation and offsets the Tb basalt.

Early Pliocene tilt-block faulting on the West Jenkins Canyon fault (Allexan, 1979) and Smith Canyon fault is most likely the last structural event in the area. The West Jenkins Canyon fault is a west-dipping high-angle, normal fault that down-drops Arimo ridge and Marsh Valley to the west (Allexan, 1979). The Smith Canyon fault is an east-dipping, high-angle, normal fault that cuts earlier Dempsey Creekt faults at depth, and down-drops the Dempsey Creek half-graben to the east.

Pleistocene History

Quaternary incision and backfilling in the map area formed broad fill-cut terraces on Salt Lake Formation, as near the Lava Hot Springs golf course and airport. This was followed by Late Pleistocene aeolian loess deposition and emplacement of the 580 ka basalt of Portneuf Valley (Scott et al. 1982). Significant hydrothermal activity persists in the town of Lava Hot Springs, with hydrothermal conduits along the east-striking transfer zone faults. Travertine deposits follow the course of the Portneuf River and appear to become younger to the east, suggesting that the hydrothermal activity has migrated eastward along the course of the Portneuf River.

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