Geologic Map of the Henderson Creek Quadrangle, Oneida County, Idaho

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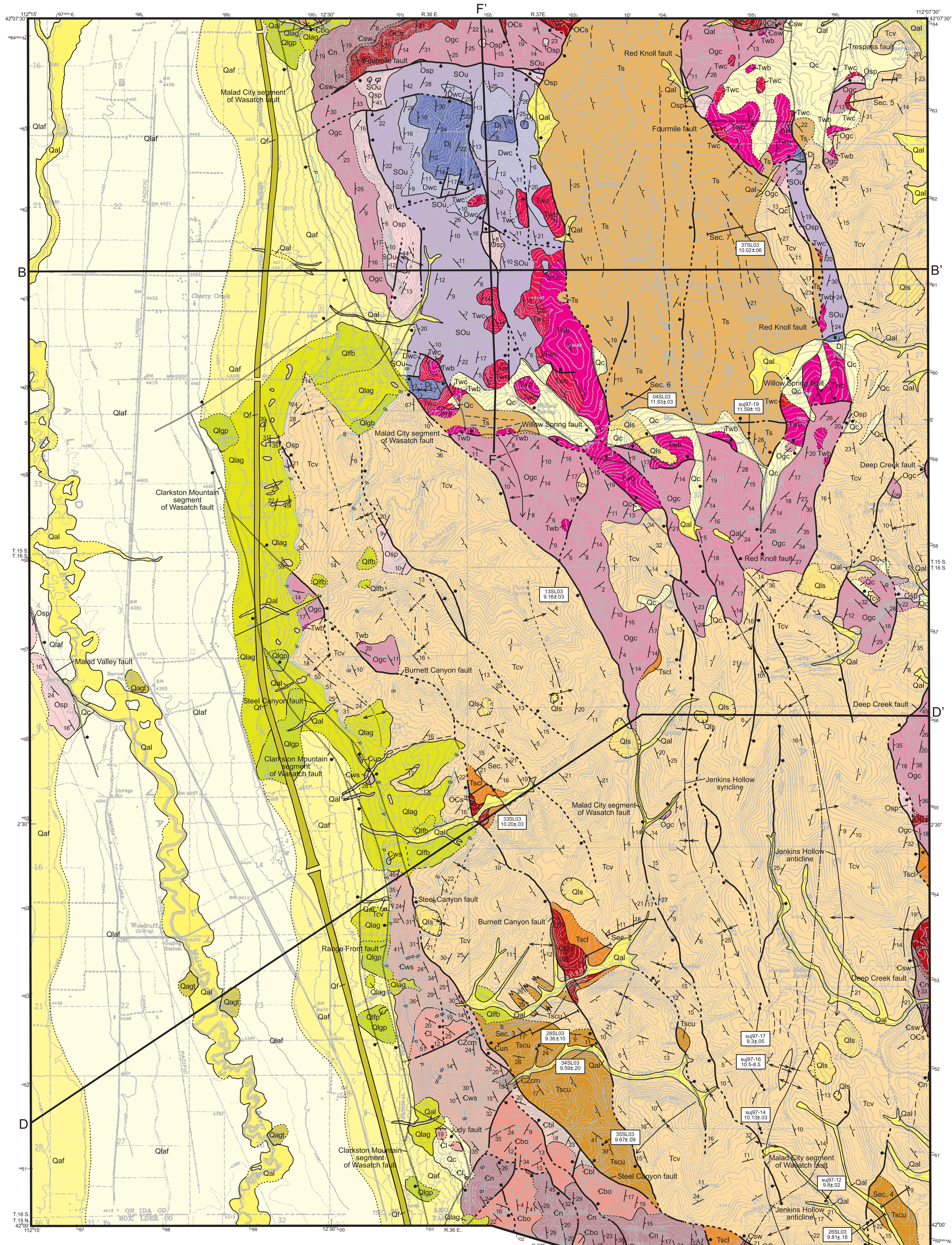
2004



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 1984 Magnetic North Declination at Center of Sheet (GN, MN; 0°48' 14 MILS; 16° 284 MILS)

SCALE 1:24,000
1 MILE; 1 KILOMETER
Contour Interval 40 feet.

QUADRANGLE LOCATION (IDAHO)

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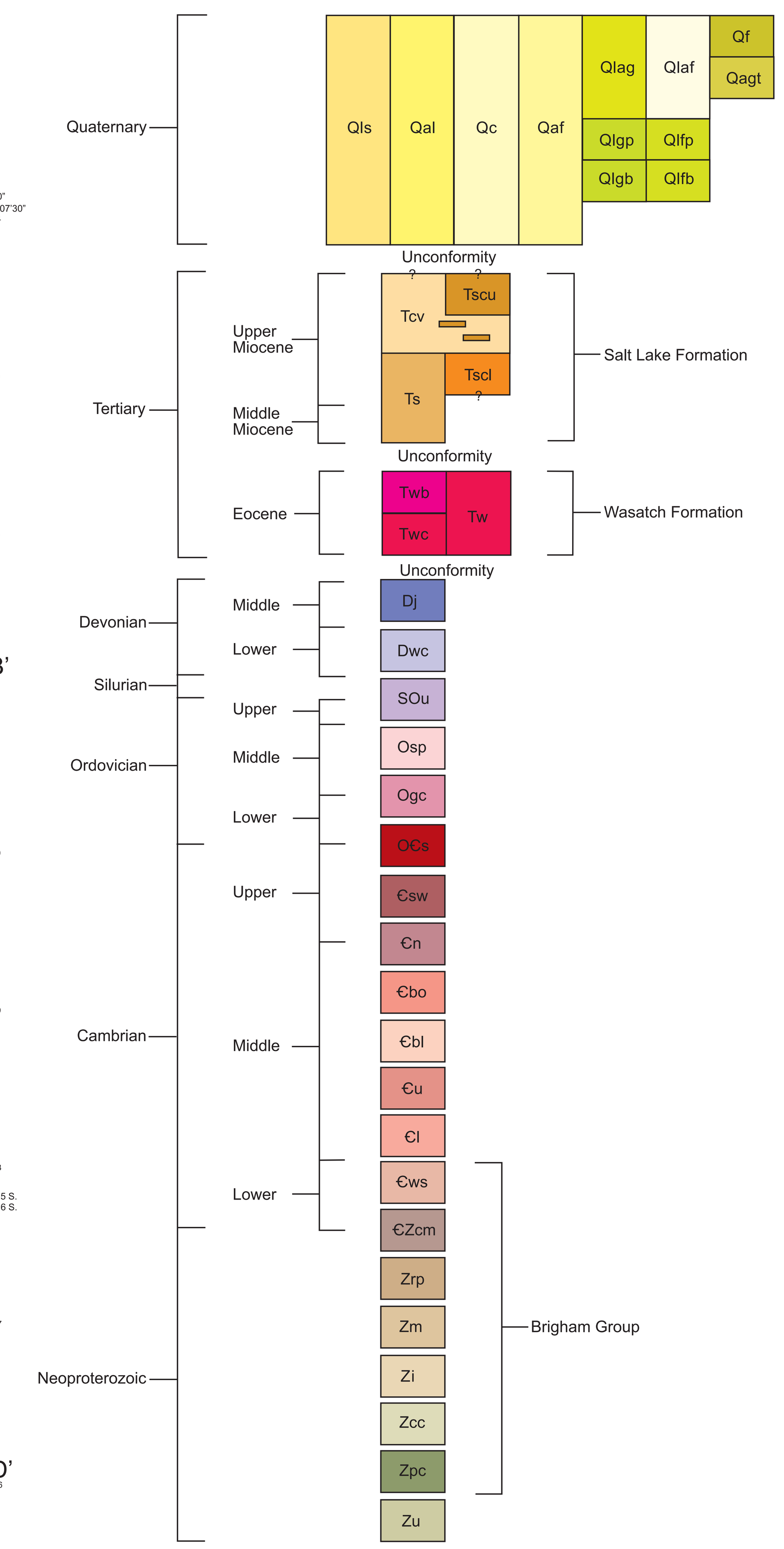
Digital cartography by Sean Long and Diana Boyack at Idaho State University Geology Department's GIS lab.
Layout by Sean Long at the Idaho State UniversityGeology Department's GIS lab.
From Long, S.P., 2004, M.S. Thesis, Idaho State University.

Correlation of Map Units



Map Symbols

Normal fault - dashed where approximated, dotted where concealed. Bar and ball on downthrown side.

Anticline - dashed where approximated, dotted where concealed. Arrow points in direction of plunge.

Syncline - dashed where approximated, dotted where concealed. Arrow points in direction of plunge.

Stratigraphic contact - dashed where approximated.

Lineament - visible on aerial photographs. Possible joint or fault.

Tcv facies boundary- dotted where concealed. Marks eastern boundary of tufa deposits.

Strike and dip of bedding. (16)

Approximate strike and dip of bedding - estimated from aerial photographs.

Headwall scarp of landslide.

Bonneville shoreline - uppermost level is at approximately 5120 feet. Multiple shorelines are locally present just below this elevation. (B)

Provo shoreline - level is at approximately 4780 feet. (P)

Fault motion indicators (Cross-sections only) — Toward; Away

Location of sample used for tephrachronology (Sample ID / Age)

Location of measured section

Description of Map Units

Quaternary

Qu — **QUATERNARY DEPOSITS,** undifferentiated **–** Shown only in cross-section; this unit represents undifferentiated Quaternary deposits in Malad Valley.

Qf — **ARTIFICIAL FILL** – Consists of subrounded gravel to boulder-sized clasts of mixed lithology, used in the construction of Interstate 15. Generally clast-supported, with a clay to sand-sized matrix. Up to 6m (20 ft) thick.

Qagt — **ALLUVIAL GRAVEL TERRACE REMNANTS** – Consist of moderately-sorted, subangular to subrounded, gravel to cobble-sized clasts of varied lithology, in a silt to coarse sand-sized matrix. Generally clast-supported and well-bedded. Tangential cross-bedding, lenticular beds, and clast imbrication are common. These deposits form round and flat-topped landforms in close proximity to the Malad River, 9m (30 ft) or less above the modern floodplain.

Qlaf — **LACUSTRINE and ALLUVIAL FINE-GRAINED DEPOSITS** – Consist of moderately to well-sorted clay, silt, and sand, with sparse subangular to subrounded gravel to cobble-sized clasts. Forms white to light or medium gray, clay and silt-rich, saline and alkaline soils. Commonly used for agricultural purposes.

Qlag — **LACUSTRINE and ALLUVIAL GRAVELLY DEPOSITS** – Consist of a mixture of locally-derived, moderately-sorted, subangular to subrounded, gravel to boulder-sized clasts, and moderately to well-sorted, subrounded to rounded gravel to cobble-sized redistributed clasts of mixed lithology. Matrix material is clay to fine sand-size, and generally light gray to tan. Forms a thin cover over Tertiary rocks along the range front. Mapped where it was impractical to differentiate lacustrine from alluvial deposits.

Qlfp, Qlfb — **LACUSTRINE FINE-GRAINED DEPOSITS** – Consist of white, tan, and light gray, moderately to well-sorted, poorly-laminated to massive, tuffaceous, silt to clay-size deposits. Locally contains redistributed and *in situ* lacustrine gravels. Mapped as Qlfp at and below the Provo shoreline level (4780 ft), and as Qlfb at and below the Bonneville shoreline level (5120 ft).

Qlgp, Qlgb — **LACUSTRINE GRAVEL DEPOSITS** – Consist of moderately to well-sorted, subrounded to rounded, gravel to cobble-sized clasts (pebble size is dominant), in a sand and silt-rich matrix. Beds of pebbly sand are also common. Generally well-stratified, with local large-scale planar foreset beds exhibiting .25-1.5m fining-upward sequences. Clast-supported beds are more common than matrix-supported beds. Mapped as Qlbp at and below the Provo shoreline level (4780 ft), and as Qlgb at and below the Bonneville shoreline level (5120 ft).

Qaf — **ALLUVIAL FAN DEPOSITS** – Consist of poorly to moderately-sorted, angular to subrounded, gravel to boulder-sized clasts in a light gray to white, clay to sand-sized matrix. Deposited mainly by debris flows at the mouths of drainages (Biek et al, 2003). The alluvial fans form a coalesced alluvial apron, and are locally overlain by deposits of Lake Bonneville (Biek et al., 2003).

Qc — **COLLUVIAL DEPOSITS** – Consist of poorly to moderately-sorted, angular to subangular, clast and matrix-supported, locally-derived, clay to boulder-sized clasts. Deposited on hillslopes; generally unstratified.

Qal — **ALLUVIAL DEPOSITS** – Consist of poorly to moderately-sorted, subangular to rounded, gravel to boulder-sized clasts in a clay to sand-sized matrix. Deposits are generally matrix-supported, and locally finely-laminated. Deposited in stream channel and floodplain environments. Includes flat to gently-sloping surfaces adjacent to streams within modern drainages.

Qls — **LANDSLIDE DEPOSITS –** Composition is generally lacustrine strata of the Salt Lake Formation. May include rotated blocks, and/or slope failures of colluvial material. Hachure marks are on landslide head scarps.

Tertiary

Tu — **TERTIARY DEPOSITS,** undifferentiated **–** Shown only in cross-section; this unit represents undifferentiated Salt Lake Formation and Wasatch Formation deposits in Malad Valley.

Salt Lake Formation (Miocene)

Tscu — **UPPER CONGLOMERATE UNIT of the SALT LAKE FORMATION** (Upper Miocene) - Includes a main body of exposure and 5 interbeds within the underlying Cache Valley Member. Lithology is a subangular to subrounded, moderately-sorted, medium-bedded to massive, matrix-supported pebble to cobble conglomerate. Matrix material is white, light-gray, or green, locally calcareous, and consists of silt to medium sand-size tuffaceous material, with local quartz sand. Clast composition is variable, but overall is dominated by Lower Paleozoic carbonates and quartzites, with lesser dark-colored chert and Brigham Group clasts. The main body of exposure is locally rich in Upper Paleozoic clasts, especially near the base of the section. Recycled white to green Salt Lake Formation clasts are locally prevalent. Interbeds include white to tan micritic limestone, white, fine-crystalline limestone, blue, gray, or green primary tephra beds, white tuffaceous siltstone, and light-gray tuffaceous sandstone. Sedimentary structures include small-scale (2-3mm) tangential cross-bedding, scour surfaces in conglomerate beds, and 20 centimeter to 1 meter-scale graded bedding and upward-fining sequences. The lower contact with the Cache Valley Member is interfingering. An upper contact is not exposed. This unit is exposed in the southern part of the map area; the best exposures are in Trail Creek and Burnett canyons. A thickness of 381m (1250 ft) is estimated from cross sections and trigonometric calculations. Age obtained from tephrachronology is ~9.7-<9.3 Ma.

Tcv — **CACHE VALLEY MEMBER of the SALT LAKE FORMATION** (Upper Miocene) - Consists of a thick section of interbedded lacustrine limestones, tufas, and tuffaceous rocks. Tufas consist of light-gray (weathered) and tan to light-brown (fresh), medium to coarse-crystalline, thick-bedded to massive, and locally tuffaceous limestone. Tufas have distinct spongy, porous, or clastic textures. Dark-brown stringers of silicified material cause a rough weathered texture. Bedding is generally subplanar to wavy. Tufas form prominent ledges between 1-2m (3-5 ft) high. Rhizoliths are common, along with fossils and fossil hash of ostracodes, gastropods, and pelecypods. Micritic and fine-crystalline limestones are white to light-gray (weathered), white to tan (fresh), thin- to medium-bedded (5-30cm), and commonly tuffaceous. They have local vesicular textures and dark-brown silicified layers. Bedding is parallel to subparallel, with local stromatolitic laminations. Limestones contain similar fossils as the tufa but also commonly display white caliche nodules. Tuffaceous lithologies include white to light-gray, locally green, very fine-crystalline, thinly-laminated to thinly-bedded (.3-10cm), locally calcareous, moderately consolidated, parallel-bedded, reworked tuffaceous siltstone, and fine to coarse-grained, light- to medium-gray, reworked, tuffaceous sandstone. Primary tephra beds are generally light- to medium-gray, locally blue to green, very-fine to medium-crystalline, massively-bedded, locally poorly-laminated, and moderately consolidated. Rare gravel to cobble conglomerate beds, composed of dominantly Lower Paleozoic clasts, and locally rich in recycled Salt Lake Formation clasts, are present. The lower contact with the Skyline member is depositional and abrupt, and the lower contact with Tscl is interfingering. The Cache Valley member also sits in unconformable contact with Cambrian through Ordovician bedrock units. The upper contact with Tscu unit is interfingering. The Cache Valley Member has a widespread exposure; it dominates the south, northeast, and west-central parts of the map area. The member's thickness is estimated from cross section to be 610m (2000 ft) minimum. Age obtained from tephrachronology is ~10.2-<9.2 Ma.

Tscl — **LOWER CONGLOMERATE UNIT of the SALT LAKE FORMATION** (Middle? and Upper Miocene) - Consists of a thin layer of poorly-exposed conglomerate, with clast lithologies that vary significantly between exposures. Conglomerates are poorly to moderately-sorted, pebble to cobble-size, and subangular. Bedding is medium to thick and matrix-supported. Matrix material is white, light-gray, or green, locally calcareous, consists of silt to fine-sand size tuffaceous grains, and is locally rich in subrounded quartz sand grains. Clast composition varies significantly, but overall, Lower Paleozoic limestone, dolomite, quartzite, and chert dominate. Lesser amounts of Proterozoic and Upper Paleozoic clasts are also present. Locally, the conglomerate contains a significant percentage of recycled Salt Lake Formation clasts. Interbedded lithologies include laminated tuffaceous siltstone, medium-bedded micritic limestone, and massive tephra. This unit sits unconformably on Cambrian and Ordovician rocks in the map area. The upper contact with the Cache Valley Member is gradational over a short stratigraphic distance (up to 15m (48 ft)). The lower conglomerate unit is only exposed in the southern part of the map area; the best exposures are in Burnett and Muddy Creek canyons. Its thickness varies from 0 to 66m (0 to 215 ft), as measured from outcrop. Age obtained from tephrachronology is >10.2 Ma.

Ts — **SKYLINE MEMBER of the SALT LAKE FORMATION** (Middle and Upper Miocene) - Consists of poorly-exposed tuffaceous conglomerate, with interbedded tephra beds and local interbedded limestone. Conglomerate clasts are pebble to cobble-size, subangular, and poorly-sorted overall. Matrix material is white, light-gray, and olive-green, locally calcareous, and consists of silt to fine sand-size tuffaceous material. Rare outcrops are medium-bedded, and matrix-supported beds are most common. Clasts are dominantly lower Paleozoic carbonates and quartzites, with local concentrations of tuffaceous Salt Lake Formation clasts. Tephra beds are light- to medium-gray, blue or green, moderately to well-consolidated, and medium-grained. Tephra deposits can be up to 5m (15 ft) thick, and commonly grade laterally into matrix-rich tuffaceous conglomerate. Thin-bedded, reworked tuffaceous sandstone interbeds are locally present. Fine-crystalline and micritic white limestone interbeds are also locally present, with a 90m (295 ft) section of limestone near the base of the section. The unit sits in unconformably on the Wasatch Formation and on Lower Paleozoic bedrock. The depositional upper contact with the lacustrine Cache Valley is abrupt. The Skyline member is exposed only in the northern part of the map area; the best exposures are along Skyline Road. Thickness is estimated from cross sections to be up to 685m (2250 ft). Age obtained from tephrachronology is ~12.0-10.0 Ma.

Wasatch Formation (Eocene)

Tw — **WASATCH FORMATION,** undifferentiated (Eocene) – Shown only in cross-section, this unit represents a combination of Twc and Twb. Thickness varies from 0 to 183m (600 ft).

Twb — **WASATCH FORMATION QUARTZITE BOULDER BED UNIT** (Eocene) – This unit is defined by high concentrations of very-poorly sorted, subrounded, white quartzite boulders derived from the Ordovician Swan Peak Quartzite. No outcrops were exposed in the map area, observations are based on float only. Clast sizes range locally from gravel to very large boulders up to 6.25m (20 ft) in diameter. Clast angularity ranges between subangular to well-rounded. Clast lithology is dominated (>95%) by Ordovician quartzite, but float of black chert pebbles, and minor amounts of cobble to boulder-sized Paleozoic dolomite and brown chert are locally present. These beds overlie the red conglomeratic facies of the Wasatch Formation, and unconformably overlie Lower Paleozoic bedrock units. The lower contact is poorly-exposed, but is interpreted to be an irregular surface based on variations in thickness of the underlying conglomerate. The boulder beds are found in the central and northwest parts of the map area, to the north and south of an Eocene fault. The thickness is highly variable; the maximum thickness is estimated from outcrop to be >151m (495 ft).

Twc — **WASATCH FORMATION CONGLOMERATE UNIT** (Eocene) – Consists of pebble to cobble conglomerate, with a distinct red to brown, mud to sand-rich matrix. Beds are medium to thick-bedded, form slopes and small ledges, are commonly matrix-supported, and contain subangular to subrounded clasts overall. Exposures are locally matrix-rich, commonly with mud and silt between subangular to subrounded fine to medium-sized quartz grains. Clasts are dominantly Lower Paleozoic limestone and dolomite, with lesser black chert and red siltstone and tan fine-grained sandstone. Contains local interbeds of red-brown to tan, medium-bedded sandstone, and thin-bedded siltstone. The unit unconformably overlies lower Paleozoic bedrock units; this contact is irregular and cuts across topography with significant relief. The conglomerate is only exposed in the northwest and central parts of the map area. The best exposures are in Willow Spring canyon. Its thickness is highly variable; the maximum thickness is estimated from outcrop to be >157m (515 ft).

Paleozoic

PZu — **PALEOZOIC DEPOSITS,** undifferentiated **–** Shown only in cross-section; this unit represents undifferentiated deposits in Malad Valley.

Devonian

Dj — **DEVONIAN JEFFERSON FORMATION, HYRUM MEMBER** (Middle Devonian) - Consists of medium- to dark-gray (fresh and weathered), thin- to thick- bedded, fine-crystalline, fossiliferous limestone, and interbedded light-gray-weathering, light to medium-gray, medium- to thick-bedded dolomite. The limestone is locally mottled, contains common tan to brown silty partings, and is locally fossil-rich. Long, linear, white chain corals, and algal laminations are common. Gray and white chert nodules are locally present. This unit forms ledges, brown platy talus, and brown to red soils. The basal contact is placed at the first medium- to dark-gray fossiliferous limestone above the prominent ledges of white, red-weathering Water Canyon limestone. A complete section is not exposed; a minimal cross-sectional thickness of 107m (350 ft) is estimated. A previous study in the map area measured a minimal thickness of 135m (447 ft) (Axtell, 1967).

Dwc — **DEVONIAN WATER CANYON FORMATION** (Early Devonian) - Consists of medium- to light-gray, light-gray- to white-weathering, aphanitic to fine-crystalline, thin- to medium-bedded dolomite, and interbedded light- to medium-gray, thick-bedded, fine-crystalline, ledge-forming, red-orange weathering limestone. Minor light tan to brown, medium-grained, well-sorted, subrounded sandstone, interbedded with brown shale, is also present in the lower part of the unit. Fine laminations are locally present in the dolomite. The unit forms <1m (1-3 ft) thick ledges and slopes, with occasional limestone ledges up to 3m (10 ft) thick. Red to orange soils are common, and are derived from weathered limestone beds. A 3m (10 ft) thick ledge of intraformational breccia is locally present at the top of the unit. The basal contact is placed at the lowest white-weathering dolomite above the massive gray dolomites of the Silurian Laketown Dolomite. Unit t hickness obtained from cross-section is 107m (350 ft). Previous studies in the map area estimated this thickness at 76m (250 ft) (Axtell, 1967).

Silurian

SOu — **ORDOVICIAN FISH HAVEN DOLOMITE and SILURIAN LAKETOWN DOLOMITE,** undifferentiated (Upper Ordovician to Upper Silurian) - Consists of dark- to light-gray, dark- to medium-gray-weathering, medium- to coarse-crystalline dolomite. It is generally medium- to very thick-bedded, with massive and hackly weathering (Biek et al., 2003). Light-gray, white, tan, and black chert stringers and nodules are common; locally the unit can be up to 30% chert. Rare beds of nearly completely silicified dolomite are also present. Rugose and tabulate corals, as well as crinoid stems, are present throughout (Biek et al., 2003). The unit forms pinnacles, cliffs, and hackly ledges. Talus is commonly gravel-size, rounded, and sandy-textured. The basal contact is abrupt with the vitreous white quartzite of the Swan Peak Formation, and is considered to be a regional disconformity (Oaks et al., 1977). The thicknesses of these two units are variable; no complete section exposed in the map area, so a minimum thickness is estimated to be 488m (1600 ft), based on cross-section constraints.

Ordovician

Osp — **ORDOVICIAN SWAN PEAK QUARTZITE** (Middle Ordovician) - The lower part of this unit consists of tan to brown, light brown-weathering, fine-grained, massive-weathering, vitreous quartzite, interbedded with brown to dark gray micaceous shale and siltstone. It is generally slope-forming and poorly-exposed. The basal contact is placed above the highest chert-rich limestone of the Garden City Formation. The upper part is the Eureka Member, which consists of white to pink, light-gray to white-weathering, thick-bedded (70-100 centimeters) to massive, fine-grained quartz arenite. This member forms distinct massive gray cliffs. Planar bedding and cross-bedding are present (Biek et al., 2003). Vertical worm burrows, common heavy brecciation, and angular to subrounded boulder talus are common features of this unit. It is commonly present as fault-bounded slices in major fault zones. Its thickness was measured from outcrop to be 168m (550 ft).

Ogc — **ORDOVICIAN GARDEN CITY FORMATION** (Middle to Lower Ordovician) - The lower two thirds of this unit consists of medium-gray, tan to blue-gray-weathering, medium- to coarse-crystalline, thin- to medium-bedded, fossiliferous limestone. The presence of common brown to light-tan silty partings results in platy, tan-colored talus. Local tan chert nodules are present. Intraformational conglomerate beds containing subrounded to rounded, locally imbricated, 0.5 to 5 cm rip-up clasts are common and diagnostic. The upper one-third consists of medium-gray, light-gray weathering, medium- to thick-bedded, medium-crystalline, fossiliferous limestone and interbedded dolomite, with abundant black chert nodules and stringers. Chert can locally make up 50% of the rock (Biek et al., 2003). Overall, this unit forms 1-2m (3-5 ft) ledges separated by slopes. The presence of intraformational conglomerate and black chert distinguishes this unit from the underlying St. Charles Formation. The basal contact is placed above the highest gray dolomite of the St. Charles Formation. Thickness was measured from outcrop to be 381m (1250 ft).

Cambrian

€un — **CAMBRIAN DEPOSITS,** undifferentiated – Three fault-bounded blocks of limestone in the southwest part of the map area are mapped as undifferentiated Cambrian deposits. They consist of medium- to dark-gray, medium-gray to tan-weathering, fine-crystalline, thick-bedded to massive limestone and dolomite. These fault blocks are locally heavily-brecciated and deformed, so unit identification is difficult. No upper or lower contacts are exposed. One horse has a maximum thickness of ~75m (~245 ft).

O€s — **CAMBRIAN and ORDOVICIAN ST. CHARLES FORMATION (UPPER MEMBER)** (Upper Cambrian to Lower Ordovician) – The lower part of this unit consists of medium-gray, light- to medium-gray to tan- weathering, thin- to medium-bedded, fine- to medium-crystalline, cherty limestone. The unit contains common silicified tan to brown silty partings, which results in thin, platy brown talus. Locally contains abundant tan to brown chert nodules, and generally forms slopes and ledges. The upper part consists of medium-gray (both fresh and weathered), thick-bedded to massive, medium- to coarse-crystalline, cliff-forming dolomite (Biek et al., 2003). The dolomite is commonly mottled to light- and dark-gray (Biek et al., 2003), and contains abundant tan to white chert stringers and nodules. Sedimentary structures include planar laminae, ripple cross-stratification, and minor intraformational conglomerate (Biek et al., 2003). Beds of fossil hash can contain gastropod, brachiopod, trilobite, and conodont fragments (Evans, in prep.). The basal contact is abrupt, and is placed above the highest sandstone bed of the Worm Creek Member. The thickness of this unit was measured from a full section to be 200m (655 ft). A study to the south found a thickness of 240m (787 ft) (Biek et al., 2003).

€sw — **CAMBRIAN WORM CREEK MEMBER of the ST. CHARLES FORMATION** (Upper Cambrian) - Consists of white to tan, brown- to tan-weathering, fine- to medium-grained, medium- to thick-bedded, massively-weathering, slope- to ledge- forming, feldspathic sandstone. Minor silty and sandy limestone interbeds are locally present (Biek et al., 2003). Subangular, chalky, white-weathering feldspar grains are a diagnostic feature of this unit. The sandstone is locally planar-bedded, and is commonly brecciated. The lower contact is placed below the lowest sandstone layer, and above the sandy and silty limestone of the upper Nounan Formation. This contact can vary from abrupt to gradational; in some areas the Nounan Formation is gradually replaced by arkosic quartzite. Complete sections in the map area show the unit to be between 15-21m (50-70 ft) thick. The cross-sectional thickness of this unit is exaggerated to 30m (100 ft).

€n — **CAMBRIAN NOUNAN FORMATION** (Upper and Middle Cambrian) - The lower part of this unit consists of light- to medium-gray, light- to dark gray-weathering, thick-bedded to massive, medium to coarse crystalline, ledge and cliff-forming dolomite. The dolomite is locally mottled, and can contain recrystallized oncolites, oolites, and algal laminations (Biek et al., 2003). The basal contact is marked by a prominent break in slope; it is placed above the slope-forming brown shale and limestone of the upper Bloomington Formation (Biek et al., 2003). The upper part consists of dark-gray, medium- to dark-gray-weathering, thin- to medium-bedded, fine- to medium-crystalline, ledge- and slope-forming, silty and sandy limestone. Light to medium-gray dolomite interbeds are common. The limestone contains thin, brown silty and sandy partings, occasionally weathers red, and can locally be thick-bedded to massive. The very uppermost part of the unit becomes very sandy as it grades into the Worm Creek Member of the St. Charles Formation. Thickness was measured from outcrop to be 420m (1375 ft).

€bo — **CAMBRIAN BLOOMINGTON FORMATION** (Middle Cambrian) - This formation consists of three stratigraphic subunits. The lowest is the slope-forming Hodges Shale Member, which consists of interbedded dark to olive-green, laminated shale, and medium-gray, fine-crystalline, thin-bedded, locally oolitic limestone (Biek et al., 2003). The basal contact is defined by an abrupt change in slope between the dark-gray, cliff-forming limestone of the Blacksmith Formation, and the slope forming Hodges Shale Member. The middle subunit is an unnamed limestone member, consisting of medium-gray, light to medium-gray weathering, medium- to thick-bedded, cliff and ledge-forming limestone. The limestone is locally oncolitic, with 1-2 cm dark-gray oncolites, can have a local coarse-grained oolitic texture, and often contains beds of intraformational conglomerate, with rounded clasts ranging from 1 to 4 cm in diameter. The upper member is the slope-forming Calls Fort Shale Member, and consists of tan, brown-weathering, laminated to thin-bedded shale and micaceous siltstone, with interbedded medium-gray, medium-bedded limestone (Biek et al., 2003). Greenish-gray, rounded micrite nodules are a diagnostic feature of this subunit. Oolitic textures and intraformational conglomerate are common in the limestone interbeds. Thickness was measured from outcrop to be 350m (1150 ft).

€bl — **CAMBRIAN BLACKSMITH LIMESTONE** (Middle Cambrian) – Consists of medium- to dark-gray, dark-gray-weathering, medium- to thick-bedded, aphanitic to fine-crystalline, ledge- to cliff- forming, silty limestone. The unit is commonly massive-weathering, and mottled. Tan to orange silty partings are present near the top. The unit forms distinctive dark-gray cliffs. Also present are oncolites, trilobite fragments, oolites, fucoidal markings, and local intraclastic conglomerate (Link, 1982). The basal contact is not exposed in the map area, and the upper contact is abrupt with the green shale of the Bloomington Formation. A complete section is not present; the minimum exposed thickness is about 170 meters (560 feet). Cross-sectional thickness is 380m (1245 ft), based on a study to the north (Carney, 2002).

€u — **UTE FORMATION** (Middle Cambrian) – Shown only in cross-section, the Ute Formation presumably lies below the Blacksmith Limestone and above the Langston Formation. A thickness of 75m (245 ft) is assigned for this unit.

€l — **LANGSTON FORMATION** (Middle Cambrian) – The lower part of this unit consists of medium-gray, medium- to blue gray-weathering, fine- to medium- crystalline, thick to very-thick-bedded sandy limestone. It locally weathers orange to red due to thin silty partings. This unit weathers to a rough texture, and forms ledges and cliffs. Its basal contact is abrupt with the green argillite of the Windy Pass and Sedgwick Peak formations. This unit is correlative with the Twin Knobs Limestone of Idaho stratigraphy (Oriel and Armstrong, 1971). The upper part consists of black to greenish-gray, fissile, micaceous, slope-forming, fossiliferous claystone and shale, with medium- to dark-gray, medium-bedded limestone interbeds. This lithology is only exposed in a fault-bounded and colluvium-covered block, with no upper and lower contacts exposed. This shale lithology is considered equivalent to the upper Langston and lower Ute formations (Oriel and Armstrong, 1971), but is mapped as the upper part of the Langston Formation in this study. It is assumed to be equivalent to the Lead Bell Shale of Idaho stratigraphy, and the Spence Shale of Utah stratigraphy. A complete section is not exposed; a minimum thickness of about 100m (330 ft) is present. Total thickness is estimated at 150m (490 ft), based on regional studies (Wright, 1999).

€ws — **WINDY PASS ARGILLITE and SEDGWICK PEAK QUARTZITE,** undifferentiated (Lower Cambrian) – Consists of interbedded quartzite and argillite, combined into one map unit. The quartzite is red, dark brown, and green, fine- to medium-grained, moderately sorted, medium- to thick-bedded, and micaceous. It contains subangular to subrounded quartz grains, with fine to very fine-grained muscovite, and fine to medium feldspar grains, in an iron-stained cement. It is locally laminated and cross-bedded, and forms distinctive dark-brown ledges and cliffs. The argillite is green to tan, micaceous, and laminated to thin-bedded, with horizontal worm burrows. Mica grains are very-fine to medium-grained. The argillite is common as thick to very-thick layers between quartzite beds, but sections up to 15m (50 ft) thick are locally present. The argillite generally forms slopes and ledges. The basal contact of this combined unit is placed above above the highest white to tan vitreous quartzite bed of the Camelback Mountain Quartzite. A complete section is not exposed; the minimum exposed thickness is 268 meters (880 feet). The total thickness is estimated at 300m (984 ft), based on a study to the northeast (Carney, 2002).

Neoproterozoic

€Zcm — **CAMELBACK MOUNTAIN QUARTZITE** (Neoproterozoic to Lower Cambrian) – Consists of white to pink to tan, medium to coarse-grained, moderately-sorted, thick to very-thick bedded, vitreous white quartzite. This unit contains cross-bedding, and lacks the thick green micaceous argillite beds of €ws. It is also distinguished from the overlying quartzite by its white color and vitreous appearance. The upper contact is placed below the lowest micaceous argillite layer, and above the first appearance of vitreous quartzite. Only the uppermost 30m (100 ft) are exposed in the map area; cross-sectional thickness is 430m (1410 ft), based on its thickness in the Clifton quadrangle (Carney, 2002).

Zrp — **ROCKY PEAK MEMBER of the CAMELBACK MOUNTAIN QUARTZITE** (Neoproterozoic) – Shown only in cross-section, this unit presumably underlies the Camelback Mountain Quartzite in the map area. Thickness is estimated at 122m (400 ft), based on a study to the northeast (Carney, 2002).

Zm — **MUTUAL FORMATION** (Neoproterozoic) - Shown only in cross-section, this unit presumably underlies the Rocky Peak member of the Camelback Mountain Quartzite in the map area. Thickness is estimated at 366m (1200 ft), based on a study to the northeast (Carney, 2002).

Zi — **INKOM FORMATION** (Neoproterozoic) - Shown only in cross-section, this unit presumably underlies the Mutual Formation in the map area. Thickness is estimated at 61m (200 ft), based on a study to the northeast (Carney, 2002).

Zcc — **CADDY CANYON FORMATION** (Neoproterozoic) - Shown only in cross-section, this unit presumably underlies the Inkom Formation in the map area. Thickness is estimated at 122m (400 ft), based on a study to the northeast (Carney, 2002).

Zpc — **PAPOOSE CREEK FORMATION** (Neoproterozoic) - Shown only in cross-section, this unit presumably underlies the Caddy Canyon Formation in the map area. Thickness is estimated at 274m (900 ft), based on a study to the northeast (Carney, 2002).

Zpu — **POCATELLO FORMATION,** undifferentiated (Neoproterozoic) - Shown only in cross-section, this undifferentiated unit presumably underlies the Papoose Creek Formation in the map area. Minimum cross-section thickness is 122m (400 ft).

Geologic History

The Henderson Creek 7.5' quadrangle in southeast Idaho contains part of the Malad Range on its east side and part of Malad Valley on its west side. The southern boundary of the map area is part of the Idaho-Utah border. New geologic mapping performed in this study provides evidence for multiple Mesozoic-Cenozoic deformational events.

Bedrock strata in southeast Idaho include volcanic and sedimentary rocks of the Neoproterozoic Pocatello Formation and Brigham Group, overlain by westward-thickening Neoproterozoic and Paleozoic sedimentary rocks of the Cordilleran Miogeocline (Armstrong and Oriel, 1965; Link, 1982). These strata were deformed and translated to the east above the Paris-Putnam thrust, during the early Cretaceous to Paleocene Sevier orogeny (Coogan, 1992). The Paris-Putnam thrust sheet is the westernmost and oldest of the major Sevier thrust sheets.

During the Sevier orogeny, the regional-scale Cache-Pocatello Culmination formed above a ramp of the Paris Thrust (Rodgers and Janecke, 1992). The west half of this structure is exposed in the map area as the NNW-trending Malad Ramp anticline. An east-striking normal fault set with pre-Eocene to Eocene ages formed in the north half of the map area. Faults of this set accommodated ~8% N-S extension. Some structures of this set, such as the Fourmile fault, may be tear faults associated with thrusting.

The Eocene Wasatch Formation consists of a red pebble conglomerate (Twc) overlain by unconsolidated quartzite boulder-rich beds (Twb), both of which thicken toward the Willow Spring fault. The presence of Mesozoic clasts in the conglomerate indicates an eastern source area and a probable fluvial origin. The overlying boulder beds formed as coarse, unconsolidated, mud-rich beds north of the fault, and as a thin, unconsolidated rubble sheet to the south (Biek et al., 2001). These beds represent locally-derived deposits that formed during the dissection of a widespread exposure of the Swan Peak Quartzite (Osp) in the footwall of the Willow Spring fault. East of the map area, near the Idaho-Wyoming border, the Wasatch Formation was deposited in piggyback basins over major thrust faults (Coogan, 1992). Within the Henderson Creek quadrangle, this unit is interpreted as a synextensional deposit of the east-striking Willow Spring fault.

The Salt Lake Formation is the name given to widespread, generally poorly-exposed, Middle Miocene to early Pliocene deposits in southeast Idaho and northern Utah. In the map area, the formation is Middle to Upper Miocene in age, and includes four members that accumulated in dynamic basins associated with a NNW-striking fault set. The ~11.9-10 Ma Skyline member (Ts) is a thick, poorly-exposed tuffaceous conglomerate. This member was deposited as alluvial fans in an isolated half graben called the Skyline Subbasin, which is bound by the Red Knoll and Trespass growth faults. These faults die out to the south, causing the member to pinch out. A >10.2 Ma, poorly-exposed, tuffaceous lower conglomerate unit (Tscl) was deposited in a shallow basin in the south part of the map area. The presence of Upper Paleozoic clasts within this unit suggests a western source area. The ~10.2-<9.2 Ma Cache Valley Member (Tcv) consists of carbonate and tuffaceous deposits of a widespread, shallow lake system. Ledge-forming, fossil-rich tufa deposits, which are only exposed in proximity to the Steel Canyon fault, are interpreted as a lake-margin facies. A ~9.7-<9.3 Ma, tuffaceous upper conglomerate unit (Tscu) interfingers with the Cache Valley Member, and represents a coarse basin-margin facies in close proximity to the Steel Canyon fault. These facies changes provide evidence that the Steel Canyon fault was active from ~10.2-<9.2 Ma.

The Miocene NNW-striking fault set that is associated with the Salt Lake Formation accommodated about 16% E-W extension during the Middle and Upper Miocene. These structures include the planar and listric growth structures mentioned above, and were associated with internal hanging wall deformation of Salt Lake Formation deposits. Twenty extensional folds were identified in Salt Lake Formation deposits in the map area. The Jenkins Hollow anticline formed from double rollover over two oppositely-dipping listric faults, the Miocene Steel Canyon fault and the Pliocene-Quaternary Deep Creek fault. The Jenkins Hollow syncline may have formed over a fault bend in the Deep Creek fault. Other extensional folds probably formed in relation to the large, listric Steel Canyon fault or from younger deformation.

Pliocene-Quaternary structures are the third and youngest fault set in the map area. They accommodated an estimated 9% E-W extension for a total of 25% E-W extension of the map area since the Miocene. The Wasatch fault is a major, active Pliocene-Quaternary structure that forms the major topographic features within the map area. This fault consists of two separate segments that form a 2-3 kilometer-wide *en echelon* right-step. The relay ramp formed by this step defines a segment boundary between the Malad City and Clarkston Mountain segments of the Wasatch fault (Machette et al., 1992). Gravity studies in Malad Valley show that the northern basin bound by the Malad City segment is deeper than the southern basin bound by the Clarkston Mountain segment (Eversaul, in prep.), and that a concealed NE-striking fault is probably present at the northern boundary of the relay ramp. Pliocene-Quaternary deposits, including surficial sediments of glacial Lake Bonneville, fill the basins created by the two segments of the Wasatch fault.

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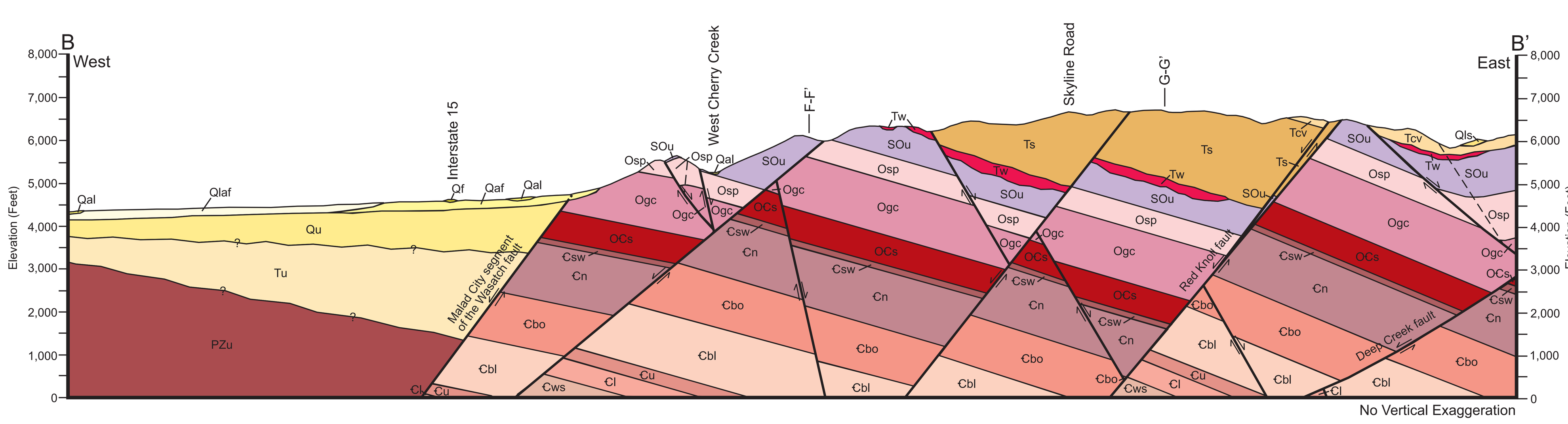

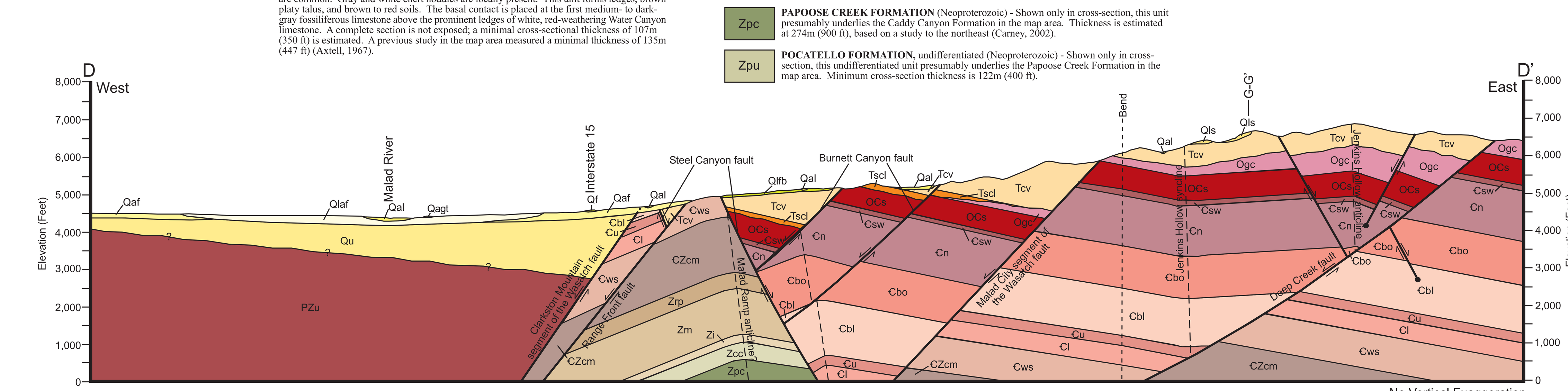

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