Interim Geologic Map of the Cedar City NW Quadrangle, Iron County, Utah

by

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MAP UNIT DESCRIPTIONS

QUATERNARY

Alluvial deposits

Qal_1 **Stream deposits** (upper Holocene) – Stratified, moderately to well-sorted gravel, sand, silt, and clay deposited in stream channels, floodplains, and man-made flood conveyance channels; includes small alluvial-fan and colluvial deposits, and minor terraces less than 10 feet (3 m) above modern base level; 0 to 30 feet (0–10 m) thick.

Qaly **Young alluvial deposits** (Holocene to upper Pleistocene) – Moderately sorted sand, silt, clay, and pebble to boulder gravel deposited in low-gradient stream channels and floodplains; locally includes colluvium from adjacent slopes; incised by active stream channels; probably less than 20 feet (6 m) thick.

Qaf_1 **Level-1 fan alluvium** (Holocene to upper Pleistocene) – Poorly to moderately sorted, subangular to subrounded, clay- to boulder-size sediment deposited principally by debris flows and debris floods; deposits form active depositional surfaces, although locally the master stream may be deeply entrenched; equivalent to the upper part of younger fan alluvium (Qafy), but differentiated where deposits can be mapped separately; typically less than 30 feet (<9 m) thick, but coalesced deposits may exceed 100 feet (30 m) thick.

Qafy **Younger fan alluvium** (Holocene to upper Pleistocene) – Poorly to moderately sorted, non-stratified, subangular to subrounded, boulder- to clay-size sediment deposited at the mouths of streams and washes; forms both active depositional surfaces (Qaf_1 equivalent) and low-level inactive surfaces incised by small streams (Qaf_2 equivalent) that are undivided here; deposited principally as debris flows and debris floods, but colluvium locally constitutes a significant part of the deposits; small isolated deposits are typically less than a few tens of feet thick, but large, coalesced deposits are probably as much as 200 feet (60 m) thick.

Qafc **Coalesced fan alluvium** (Holocene to upper Pleistocene) – Similar to younger fan alluvium (Qafy) but forms large, coalesced fans in central Cedar Valley; typically exhibits a lower overall slope than younger fan alluvium; locally includes small eolian-sand deposits too small to map separately; unconsolidated to poorly consolidated basin-fill deposits are as much as 2000 (600 m) thick in central Cedar Valley in the northeast part of map (Hurlow, 2002); only the uppermost part of this basin fill is included in map unit Qafc, which is likely in excess of several tens of feet thick.

Qap **Pediment alluvium** (Holocene to middle Pleistocene?) – Poorly sorted, subangular to rounded, silt and sand to small-boulder gravel partially covering gently-sloping and deeply dissected erosional surfaces cut into quartz monzonite (Titpi) and upper Tertiary fan alluvium (Taf); deposited principally as debris flows, debris floods, and as ephemeral stream channel deposits; 0 to 30 feet (0–10 m) thick.

Qafo **Older alluvial-fan deposits** (Pleistocene) – Poorly to moderately sorted, non-stratified, clay- to boulder-size sediment with moderately developed pedogenic carbonate; forms broad, gently sloping, dissected surfaces; deposited principally as debris flows and debris floods; may contain clasts from rocks exotic to modern drainages; exposed thickness is less than 15 feet (<5 m).

QTaf **Basin-fill deposits** (Pleistocene to Pliocene) – Poorly to moderately sorted, non-stratified, subangular to subrounded, clay- to boulder-size sediment with moderately to well-developed calcic soils (caliche); forms deeply dissected surfaces with no remaining fan morphology; widely exposed in the Cross Hollow and North Hills (only extreme northern tip of the North Hills is in the southeast corner of the quadrangle) where exhumed as a fault-bounded horst blocks; prominent clasts include Tertiary volcanic rocks, pale-reddish-orange and light-pinkish-gray limestone and

calcareous mudstone of the Claron Formation, and yellowish-brown Cretaceous siltstone, sandstone, and coquina; includes lesser amounts of chalcedony and recycled quartzite; quartz monzonite clasts are common in the extreme western part of the Cross Hollow Hills, and are locally the dominant clast type in the North Hills (Biek and Hayden, 2013); deposits appear to be interbedded with at least two different lava flows in the eastern part of the Cross Hollow Hills (Knudsen, 2014a)—one of which yielded an $^{40}Ar/^{39}Ar$ age of 1.12 ± 0.08 Ma; deposited principally as debris flows; maximum exposed thickness is about 200 feet (60 m) in the western Cross Hollow Hills.

Colluvial deposits

Qc, Qc/Tbh, Qco

Colluvium (Holocene to middle[?] Pleistocene) – Poorly to moderately sorted, angular, clay- to boulder-size, locally derived sediment deposited principally by slope wash and soil creep on moderate slopes and in shallow depressions; locally includes talus and alluvium deposits too small to map separately; younger colluvial deposits (Qc) form active depositional surfaces; older colluvial deposits (Qco) cap ridge crests in the Eightmile Hills; Brian Head Formation is typically obscured by colluvium (Qc/Tbh) derived from the overlying Isom Formation (Tib); typically less than 20 feet (6 m) thick.

Eolian deposits

Qes **Eolian sand** (Holocene to upper Pleistocene) – Pale yellowish-gray to greenish-gray, moderately well- to well-sorted windblown sand and silt deposited in sheets, mounds, and small poorly-developed dunes; largely stabilized by vegetation; locally derived from deflation of playa and fine-grained distal-fan deposits; typically less than 15 feet (5 m) thick; larger stabilized dunes east of the Quichapa Lake playa are as much as 30 feet (9 m) thick.

Human-derived deposits

Qh, Qhm

Artificial fill (Historical) – Borrow material and engineered fill used to construct flood-control dams, retaining ponds and other uses; minor fill placed for roadways and building pads generally not mapped; includes extensive deposits of waste rock (Qhm) from open-pit mines near Granite Mountain and Three Peaks; variable thickness as much as 165 feet (50 m).

Playa deposits

Qp, Qp/Qafc

Quichapa Lake playa deposits (Holocene to upper Pleistocene) – Calcareous, saline, and gypsiferous light-gray clay, silt, and fine-grained sand deposited on the playa lake bed of Quichapa Lake; Qp/Qafc denotes very thin (generally less than 1 foot thick [0.3 m]) accumulations of clay, silt, and locally dried mats of filamentous algae over low-relief alluvial-fan deposits (Qafc); Qp/Qafc was deposited during high lake levels, including several flood events in historical time (Lips, 2010); extent of Qp/Qafc corresponds to the approximate highstand shoreline established during a 2005 flood event; central playa deposits (Qp) are probably at least 25 feet (8 m) thick.

Mass-movement deposits

Qms? **Queried landslide** (Holocene to upper[?] Pleistocene) – Suspected landslide mapped in the Eightmile Hills consisting of poorly sorted material derived from local volcanic-rock units; likely deposited by rotational and translational movement; probably less than 50 feet (15 m) thick.

Mixed-environment deposits

Qac **Alluvium and colluvium** (Holocene to upper Pleistocene) – Poorly to moderately sorted, clay- to boulder-size, locally derived sediment deposited in swales and small drainages by fluvial, slope-wash, and creep processes; gradational with alluvial and colluvial deposits; generally less than 20 feet (6 m) thick.

Qea **Eolian sand and alluvium** (Holocene to upper Pleistocene) – Light-gray to light-orangish-red, moderately to well-sorted, fine- to medium-grained eolian sand locally reworked by alluvial processes, and poorly to moderately sorted gravel, sand, and silt deposited in small stream channels; generally less than 20 feet (6 m) thick.

TERTIARY

Taf **Upper Tertiary fan alluvium** (Pliocene to Miocene) – Poorly to moderately consolidated, poorly to moderately stratified, subangular to subrounded, clay- to small boulder-size sediment exposed around the northern and western margins of Cedar Valley; prominent clasts include Tertiary volcanic rocks, recycled quartzite and chert pebbles, and locally, red and orange sandstone and siltstone derived from Mesozoic units to the east (Mackin and others, 1976); depositional form is not preserved and a gently sloping pediment surface is cut across much of the deposit; deposits are generally poorly exposed and covered by a veneer of younger, locally active pediment alluvium, and east of Eightmile Hills, by coalesced younger fan deposits (Qafy); although displaced by several northeast-trending normal faults, the deposit is generally little disturbed; 9 to 10 Ma basalt (Anderson and Mehnert, 1979) is interbedded with Taf-equivalent deposits about 15 miles to the north in the Enoch NE quadrangle (Rowley, 1975); interpreted to represent early basin fill deposited principally as debris flows, debris floods, and in ephemeral stream channels; about 60 feet (18 m) exposed in low hill east of Iron Springs Gap, but is likely several hundred feet thick where preserved beneath the valley floor.

unconformity

Tigs, Tigp, Titps, Titpp, Titpi, Tir

Granite Mountain and Three Peaks laccoliths and associated ore bodies (early Miocene) – Light-gray to greenish-brown, crystal-rich quartz monzonite porphyry of the Granite Mountain (Tigs, Tigp) and Three Peaks (Titps, Titpp, Titpi) intrusions, which have a similar age and composition; contains phenocrysts of plagioclase (andesine-labradorite), biotite, hornblende, pyroxene (diopsidic augite) in a groundmass of fine-grained quartz and potassium feldspar (Barker, 1995; Hacker and others, 2007); magnetite veins up to 8 feet (2.5 m) thick with accessory hematite and apatite are common throughout the intrusions; the intrusions have several lithologic phases: (1) a thin outer peripheral-shell phase (Tigp and Titpp) developed along the sides and top of the intrusions as a chilled border zone that is resistant to weathering and forms bold outcrops, (2) an interior phase (Titpi) of altered greenish-brown, coarse-grained monzonite exposed only at Three Peaks that is easily friable and weathers to rounded gruss-covered hills, and (3) an intermediate zone of selvage joints (Tigs and Titps) consisting of light-gray monzonite cut by subvertical joints that are bleached from less than 0.4 inch (<1 cm) to nearly 3 feet (1 m) on each side of the joint (Mackin, 1947, 1954, 1960; Bullock, 1973; Mackin and others, 1976; Hacker and others, 2007); map contacts between the various lithologic phases are from Mackin and others (1976); both laccoliths were intruded principally at the stratigraphic level of the Temple Cap Formation; Granite Mountain monzonite yielded a K-Ar age of 21.5 Ma (Armstrong, 1970) and the Three Peaks intrusion yielded an $^{40}Ar/^{39}Ar$ age of 21.76 ± 0.06 (Rowley and others, 2006); as much as 1000 feet (300 m) exposed.

The Granite Mountain and Three Peaks intrusions are part of the Iron Axis, a northeast-trending belt of early Miocene calc-alkaline laccoliths and concordant stocks that rose at about 22 to 20 Ma above the roof of an inferred large batholith (Blank and Mackin, 1967; Cook and Hardman, 1967; Rowley, 1998; Rowley and others, 1998). Most of the central quartz monzonite

plutons, including the Granite Mountain and Three Peaks intrusions, appear to be partly controlled by the northeast-striking, southeast-verging Sevier-age Iron Springs Gap thrust fault and were emplaced at shallow depths, mostly within about 1.2 miles (2 km) of the surface (Mackin and others, 1976; Van Kooten, 1988; Hacker and others, 2002, 2007; Rowley and others, 2006). The laccoliths probably formed rapidly following a two-stage emplacement process—injection of a sill immediately followed by inflation—at shallow crustal depth of less than 4000 feet (1200 m) based on stratigraphic reconstructions (Spurney, 1984; see also Hacker and others, 2002, 2007; Willis, 2002). Rapid inflation of the laccoliths commonly led to partial unroofing by gravity sliding, immediately followed by volcanic eruptions (Mackin, 1960; Blank and Mackin, 1967; Hacker and others, 1996, 2002, 2007; Hacker, 1998; Willis, 2002). The Three Peaks, Granite Mountain, and Iron Mountain intrusions make up the Iron Springs mining district and are associated with strata-bound replacement ores (Tir) found mainly in the Co-op Creek Limestone Member of the Carmel Formation. The tabular-shaped ore bodies contain finely crystalline magnetite (5–50%) and hematite with minor amounts of calcite, quartz, apatite, jarosite, limonite, and garnet (Mackin, 1947, 1954, 1960; Bullock, 1973). Extensive mining of replacement ore bodies and a few of the thicker magnetite veins has made the Iron Springs mining district the largest iron-producing district in the western U.S. (Mackin, 1947, 1954, 1960, 1968; Blank and Mackin, 1967; Bullock, 1973; Mackin and others, 1976; Mackin and Rowley, 1976; Rowley and Barker, 1978; Barker, 1995; Rowley and others, 2006).

Quichapa Group (lower Miocene to upper Oligocene) – Consists of three regionally distinctive ash-flow tuffs: in ascending order, the Leach Canyon Formation, Condor Canyon Formation, and Harmony Hills Tuff (Mackin, 1960; Williams, 1967; Anderson and Rowley, 1975; Rowley and others, 1995). A lens of Mount Dutton Formation volcanic mudflow breccia locally separates the Swett and Bauers Tuff Members of the Condor Canyon Formation.

Tqh **Harmony Hills Tuff** (lower Miocene) – Resistant, pale-pink to grayish-orange-pink, crystal-rich, moderately welded, dacitic ash-flow tuff; contains about 50% phenocrysts of plagioclase (63%), biotite (16%), hornblende (9%), quartz (7%), pyroxene (5%), and sanidine (trace) (Williams, 1967); disconformably overlies the Bauers Tuff; yielded an $^{40}Ar/^{39}Ar$ plateau age of 22.03 ± 0.15 Ma (Cornell and others, 2001); incomplete section is as much as about 200 feet (60 m) thick in the Eightmile Hills, similar to the 180 to 250 feet (55–75 m) reported by Mackin and others (1976).

The source of the Harmony Hills Tuff is unknown, but isopachs are centered on Bull Valley (Williams, 1967), suggesting that it was derived from the eastern Bull Valley Mountains, probably from an early, much more voluminous eruptive phase of the Bull Valley/Hardscrabble Hollow/Big Mountain intrusive arch as suggested by Blank (1959), Williams (1967), and Rowley and others (1995, 2008). Consistent with this interpretation is the fact that its age is nearly identical to that of those intrusions.

Tqcb **Bauers Tuff Member of Condor Canyon Formation** (lower Miocene) – Resistant, light-brownish-gray to pinkish-gray, densely welded, rhyolitic ash-flow tuff; contains about 10 to 20% phenocrysts of plagioclase (40–70%), sanidine (25–50%), biotite (2–10%), Fe-Ti oxides (1–8%), and pyroxene (<3%), but lacks quartz phenocrysts (Rowley and others, 1995); bronze-colored biotite and light-gray flattened lenticules are conspicuous in the upper, vapor-phase part of the tuff, and a basal vitrophyre 10 to 20 feet (3–6 m) thick is normally present; disconformably overlies the Leach Canyon Formation; incomplete type section is at Bauers Knoll (Mackin, 1960); about 150 feet (45 m) thick in the Eightmile Hills, similar to the 100 to 180 feet (30–55 m) reported by Mackin and others (1976).

The Bauers Tuff erupted from the northwest part (Clover Creek caldera) of the Caliente caldera complex and covered an area of at least 8900 square miles (23,000 km^2) (Best and others, 1989b; Rowley and others, 1995) with an estimated volume of 740 mi^3 (3200 km^3) (Best and others, in preparation). The prefered $^{40}Ar/^{39}Ar$ age of the Bauers Tuff is 22.7 Ma (Best and others, 1989a) or 22.8 Ma (Rowley and others, 1995), which is also the $^{40}Ar/^{39}Ar$ age of its intracaldera intrusion exposed just north of Caliente, Nevada (Rowley and others, 1994b). Fleck and others (1975) reported a K-Ar age (corrected according to Dalrymple, 1979) of 22.7 ± 0.6 Ma (plagioclase) for Bauers Tuff Member on the Markagunt Plateau, east of Fivemile Ridge.

Tmd **Mount Dutton Formation, alluvial facies** (lower Miocene to upper Oligocene) – Light- to dark-gray and brown, andesitic volcanic mudflow breccia locally present between the 23.7 Ma Swett and 22.8 Ma Bauers Tuffs; Anderson and Rowley (1975) noted similar volcanic mudflow deposits at this stratigraphic horizon in the southwestern Black Mountains, about 30 miles (50 km) north of the map area; Anderson and Rowley (1975) defined the Mount Dutton Formation as consisting of most of the rocks exposed on the south flank of the Marysvale volcanic field—one of several voluminous calc-alkaline, subduction-related volcanic centers and underlying source plutons that characterized the West from Oligocene to Miocene time at this latitude (Lipman and others, 1972; Rowley and Dixon, 2001)—and divided it into complexly interfingering and cross-cutting vent and alluvial facies derived from clustered stratovolcanoes and dikes; 0 to about 75 feet (0–23 m) thick, somewhat less than that estimated by Mackin and others (1976).

Tqcs **Swett Tuff Member of Condor Canyon Formation** (upper Oligocene) – Pinkish-gray, densely welded, rhyolitic ash-flow tuff; like the Bauers Tuff, contains 5 to 15% phenocrysts of plagioclase (70 to 90%), minor biotite (10 to 20%), and Fe-Ti oxides (<7%), but lacks sanidine and clinopyroxene (Rowley and others, 1995; Best and others, in preparation); prominent vitrophyre is nearly as thick as tuff itself; basal part is locally vuggy, walls of vugs are typically dark reddish brown, and vugs commonly partly filled with chalcedony in the form of rosettes; weathers to grussy slope; typically 25 to 30 feet (7–9 m) thick, but is locally missing due south of Eightmile Pass and locally may be as much as about 50 feet (15 m) thick.

The source of the Swett Tuff is unknown, but it may have been derived from eruption of a caldera later destroyed by the Clover Creek caldera (Rowley and others, 1995). The total volume of the Swett Tuff is estimated to be about 90 mi^3 (400 km^3) (Best and others, in preparation) initially spread over an area of at least 2340 mi^2 (6000 km^2) (Rowley and others, 1995). The average of six K-Ar ages is 23.7 Ma (Armstrong, 1970).

Tql **Leach Canyon Formation** (upper Oligocene) – Grayish-orange-pink to pinkish-gray, moderately welded, crystal-rich rhyolite tuff that contains abundant white or light-pink collapsed pumice fragments and several percent lithic clasts, many of which are reddish brown; contains 25 to 35% phenocrysts of plagioclase, slightly less but subequal amounts of quartz and sanidine, and minor biotite, hornblende, Fe-Ti oxides, and a trace of pyroxene; disconformably overlies the Isom Formation; served as the principal detachment horizon for the Eightmile Hills gravity slide, which was triggered by emplacement of the 21.5 Ma Granite Mountain laccolith; 150 to 300 feet (45–90 m) thick in the Eightmile Hills.

The Leach Canyon Formation is widely agreed to be about 23.8 Ma (Best and others, 1993; Rowley and others, 1995; Biek and others, 2012). Its source is unknown, but it is probably the Caliente caldera complex because isopachs show that it thickens toward the complex (Williams, 1967; Rowley and others, 1995). The total volume of the Leach Canyon is estimated to be 830 mi^3 (3600 km^3), representing the largest eruption of the Caliente caldera complex (Best and others, in preparation).

Ti **Isom Formation** (upper Oligocene) – At its type area in the Three Peaks quadrangle just north of this map area, Mackin (1960) defined three members, a lower unnamed member, the Baldhills Tuff Member, and the upper Hole-in-the-Wall Tuff Member; Rowley and others (1975) redefined the Baldhills Tuff Member to include Mackin's lower unnamed member, and noted that the Baldhills consists of at least six cooling units. Both members, the thick Baldhills and the thin overlying Hole-in-the-Wall, are present at Eightmile Hills.

Regionally, many outcrops of all cooling units in the Isom Formation reveal secondary flow characteristics, including flow breccias, contorted flow layering, and linear vesicles such that the unit was considered a lava flow until Mackin (1960) mapped its widespread distribution (300 cubic miles [1300 km^3] today spread over an area of 9500 square miles [25,000 km^2] Best and others, 1989a) and found evidence of glass shards, thus showing its true ash-flow tuff nature. For that reason it is commonly referred to as a tufflava, and is also called a rheomorphic ignimbrite, an ash-flow tuff that was sufficiently hot to move with laminar flow as a coherent ductile mass—see, for example, Anderson and Rowley (1975, 2002), Andrews and Branney (2005), and Geissman and others (2010).

The Isom Formation is about 27 to 26 Ma on the basis of many $^{40}Ar/^{39}Ar$ and K-Ar ages (Best and others, 1989b; Rowley and others, 1994a). Its source is unknown, but isopach maps and pumice

distribution suggest that it was derived from late-stage eruptions of the 32–27 Ma Indian Peak caldera complex that straddles the Utah-Nevada border, possibly in an area now concealed by the western Escalante Desert (Rowley and others, 1979; Best and others, 1989a, 1989b). Estimated crystallization temperature and pressure of phenocrysts of the Isom is 950°C and <2 kbar (Best and others, 1993), and this relatively high temperature is supported by its degree of welding and secondary flow features.

Tih **Hole-in-the-Wall Tuff Member** – Medium-gray, commonly with reddish-gray hues, crystal-poor, densely welded, trachydacitic ash-flow tuff; small (1–3 mm) euhedral crystals constitute 10 to 15% or less of the rock and are mostly plagioclase (90%) and minor pyroxene and Fe-Ti oxides set in a devitrified-glass groundmass; exhibits pronounced subhorizontal lamination or platiness, which Mackin (1960) called "lenticules" and that locally are dark reddish brown to dusky red; lenticles are typically not as flattened as those of the Baldhills Member; Mackin and others (1976) reported that the Hole-in-the-Wall Member is 10 to 60 feet (3–18 m) thick at Eightmile Hills, with which we concur.

Tib **Baldhills Tuff Member** – Medium-gray, crystal-poor, densely welded, trachydacitic ash-flow tuff; small (1–3 mm) euhedral crystals constitute 10 to 15% or less of the rock and are mostly plagioclase (90%) and minor pyroxene and Fe-Ti oxides set in a devitrified-glass groundmass; exhibits pronounced subhorizontal lamination or platiness, which Mackin (1960) called "lenticules" and that locally are dark reddish brown to dusky red; almost everywhere fractured like glass, and so weathers to grussy, ledgy slopes; about 250 feet (75 m) thick at Eightmile Hills.

unconformity

Brian Head Formation (lower Oligocene to middle Eocene) – The Brian Head Formation is the oldest widespread Tertiary volcaniclastic unit in the region. On the nearby Markagunt Plateau, it disconformably overlies the Claron Formation (Biek and others, 2012) whereas farther east on the Sevier Plateau, Brian Head strata disconformably overlie the conglomerate at Boat Mesa. Sable and Maldonado (1997) designated a type section at Brian Head peak and divided the Brian Head Formation into three informal units, ascending: (1) nontuffaceous sandstone and conglomerate, (2) a volcaniclastic unit that has minor but conspicuous limestone and chalcedony, and (3) a volcanic unit, locally present in the northern Markagunt Plateau but not at the type section, characterized by volcanic mudflow breccia, mafic lava flows, volcaniclastic sandstone and conglomerate, and ash-flow tuff. Only their middle volcaniclastic unit is present in the map area, where it disconformably overlies a pebbly conglomerate interval that we tentatively assign to the conglomerate at Boat Mesa.

Biek and others (2012) summarized radiometric ages for the formation that show it to be about 33 to 37 Ma; regionally it is disconformably overlain by the 30 Ma Wah Wah Springs Formation or, as in this map area, by the 26 to 27 Ma Isom Formation. Eaton and others (1999c) and Korth and Eaton (2004) reported on Duchesnean (middle Eocene) vertebrate fossils in lower Brian Head strata of the Sevier Plateau. The Brian Head Formation is thus early Oligocene to latest middle Eocene.

Tbh **Middle volcaniclastic unit** – White to light-gray volcaniclastic mudstone, siltstone, silty sandstone, sandstone, conglomerate, volcanic ash, micritic limestone, and multi-hued chalcedony; exceptionally poorly exposed in this map area; sandstone is commonly bioturbated with pencil-size root or burrow casts that weather out in relief; conglomerate clasts are quartzite, limestone, and chert—surprisingly, clasts of intermediate-composition volcanic rocks are virtually absent, except for rare pebbles at the top of the section in the SW1/4 section 32, T. 35. S., R. 12 W.; chalcedony is various shades of white, gray, yellow, red, black, and brown, typically has a white weathering rind, is commonly highly brecciated and resilicified, typically occurs in beds 1 to 3 feet (0.3–1 m) thick but locally as much as 8 feet (2.5 m) thick, is locally stained by manganese oxides, and likely resulted from silicification of limestone beds (Maldonado, 1995; Sable and Maldonado, 1997; Schinkel, 2012); chalcedony is almost always highly fractured, but some is useful for lapidary purposes (Strong, 1984); equivalent to the upper part of Mackin and others' (1976) informal member E of their Claron Formation; because of abundant bentonitic clay derived from weathered volcanic ash, this unit weathers to strongly swelling soils (unlike the underlying Claron Formation) and regionally forms large landslide complexes (for example, on the nearby

Markagunt Plateau; Biek and others, 2012); deposited in low-relief fluvial, floodplain, and lacustrine environments in which large amounts of volcanic ash accumulated (Sable and Maldonado, 1997); about 500 feet (150 m) thick at its type section on Brian Head peak (Sable and Maldonado, 1997; Biek and others, 2012; Rowley and others, in preparation) and probably of similar thickness in the structurally complicated Eightmile Pass area.

unconformity

Tbm **Conglomerate at Boat Mesa** (middle Eocene) – Light-gray pebbly conglomerate and conglomeratic sandstone and minor white to light-gray conglomeratic limestone overlain by yellowish-brown sandstone and pebble to cobble sandstone; clasts are rounded black chert, brown, white, and gray quartzite, and bluish-gray Paleozoic limestone; no volcanic or intrusive clasts are present; in the limestone intervals, clasts commonly appear to float in a carbonate mud matrix, but otherwise the conglomerates are clast supported; equivalent to the lower part of Mackin and others' (1976) informal member E of their Claron Formation; named for exposures at Boat Mesa in Bryce Canyon National Park where it is about 100 feet (30 m) thick (Bowers, 1990) and tentatively used here for lithologically similar strata that occupy the same straigraphic position; as much as 100 feet (30 m) thick on the southwest flank of the Sevier Plateau, and only a few feet to perhaps 10 feet (3 m) thick on the Markagunt Plateau (Biek and others, 2012), but this conglomeratic interval is at least 300 feet (90 m) thick in this map area.

The conglomerate at Boat Mesa represents deposits of braided stream channels and minor floodplains incised into the Claron Formation. Bowers (1990) suggested the conglomerate at Boat Mesa was Oligocene and Davis and Pollock (2010) thought it was Oligocene or Miocene, but lack of volcanic clasts suggests latest middle Eocene age, confirmed by an overlying 36.51 ± 1.69 Ma volcanic ash in the Brian Head Formation on the nearby Markagunt Plateau (Biek and others, 2012); Biek and others (2012) also reported a U-Pb detrital age on zircon of 37.97 +1.78 /- 2.70 Ma (Gary Hunt, UGS, written communication, March 7, 2012; UGS and A2Z, Inc., 2013) for the unit on the southwest flank of the Sevier Plateau. This sample also yielded a Middle Jurassic U-Pb peak of about 168 Ma from a coherent group of 34 detrital zircon grains, indicating that Middle Jurassic volcanic or intrusive rocks provided a significant source of sediment to the formation even though it lacks such clasts locally.

unconformity

Claron Formation (Eocene and Paleocene)

Claron Formation strata are among the most visually arresting rocks in southwestern Utah, being prominently displayed at Cedar Breaks National Monument and Bryce Canyon National Park among other places. However, because the formation lacks a type section and was named for relatively poor exposures in the Iron Springs mining district (Leith and Harder, 1908), the nomenclatural history of these rocks is complicated as described by Biek and others (2012). In the Iron Springs district the Claron Formation was subdivided into five informal members by Mackin (1954), Mackin and others (1976), and Mackin and Rowley (1976), from lowest to highest: (1) resistant purplish-red limestone, shale, sandstone, and conglomerate of member A, (2) red, poorly resistant shale, sandstone, and conglomerate of member B, (3) white, poorly resistant sandstone, limestone, shale, and minor conglomerate of member C, (4) thick-bedded white limestone of member D, and (5) white sandstone, shale, limestone, and conglomerate of member E. We generally follow the nomenclature of Mackin and others (1976), although we note that members A and B likely represent the informal pink member of the Claron Formation described on the Markagunt Plateau and in the Red Hills by Biek and others (2012). Similarly, Mackin and others' (1976) members C and D may be equivalent to the informal white member of the Claron Formation (Biek and others, 2012). The lower part of Mackin and others' (1976) member E is here assigned to the conglomerate at Boat Mesa (Tbm), and the upper part of member E to the Brian Head Formation (see descriptions for units Tbm and Tbh above). As now defined, the Claron Formation lacks volcanic clasts or ash-flow or ash-fall tuff.

Claron strata were deposited in fluvial, floodplain, and lacustrine environments of an intermontaine basin bounded by Laramide uplifts; the pink member (members A and B) is almost wholly fluvial and the white member (members C and D) is both lacustrine and fluvial (Goldstrand, 1990, 1991, 1992, 1994; Bown and others, 1997). Much of the pink member, and clastic parts of the white member,

were greatly modified by bioturbation and pedogenic processes, creating a stacked series of paleosols (Mullett and others, 1988a, 1988b; Mullett, 1989; Mullett and Wells, 1990). Claron strata rest unconformably on Middle Jurassic Co-op Creek Limestone of the Carmel Formation and are deformed in the SW1/4 section 28, T. 35. S., R. 12 W., apparently by the underlying Iron Springs thrust fault, thus indicating continued movement on the Iron Springs thrust fault into early Claron time (Mackin, 1947). Similar relations were reported by Anderson and Dinter (2010) and Biek and others (2012) in the Parowan Gap area 18 miles (29 km) to the northeast. The age of the white member is well constrained as late middle Eocene (Duchesnean land mammal age) based on sparse vertebrate fossils and constraining U-Pb zircon ages of overlying strata (Biek and others, 2012, and references therein), but the maximum age of the mostly nonfossiliferous pink member is poorly constrained as Eocene to Paleocene(?) (Goldstrand, 1994). Biek and others (2012) noted that the lower part of the pink member is likely Paleocene in age, but given its paucity of datable materials, could not rule out the possibility of a latest Cretaceous age.

Tcd **Member D** (Eocene) – White, light-gray, and pale-yellowish-gray, poorly bedded micritic limestone locally containing intraformational rip-up clasts; resistant and so forms prominent ledge; may be correlative with the upper limestone interval of the white member described by Biek and others (2012) on the Markagunt Plateau and Red Hills; upper contact is unconformable with the overlying conglomerate at Boat Mesa; about 30 feet (10 m) thick.

Tcc **Member C** (Eocene) – White and light-tan calcareous sandstone and siltstone, varicolored mudstone, and minor limestone and conglomerate; sandstone is typically friable; an interval of interbedded tan pebbly sandstone and varicolored mudstone near the base resembles upper Iron Springs Formation; limestone is very pale reddish-gray or grayish-blue, locally mottled, and commonly contains intraformational rip-up clasts; a few orangish-red-weathering conglomerate beds contain white, light-gray, and red chert clasts up to 1 foot in diameter; typically poorly exposed, but well exposed in the Eightmile Pass area; about 350 feet (105 m) thick northeast of Granite Mountain and thins northward to 100 to 250 feet (30–75 m) thick in the Three Peaks quadrangle (Mackin and others, 1976; Mackin and Rowley, 1976).

Tcb **Member B** (Eocene and Paleocene?) – Varicolored and commonly mottled, reddish-orange, reddish-brown, and purplish-red calcareous mudstone, sandstone, conglomerate, and limestone; mudstone is moderate reddish orange, silty, calcareous, and contains calcareous nodules; sandstone is thick-bedded, fine- to coarse-grained, calcareous, locally cross-bedded quartz arenite; distinctive conglomerate forms lenticular beds typically 5 to 15 feet (2–5 m) thick containing 80% rounded blue, light-blue-gray, and reddish-blue limestone pebbles, with minor amounts of red and gray quartzite and chert pebbles; limestone is poorly bedded, microcrystalline, and is locally argillaceous; likely represents the upper part of the pink member mapped in quadrangles to the east (e.g., Knudsen, 2014a, 2014b; Biek and Hayden, 2013; Biek and others, 2012); contact with overlying member C corresponds to a pronounced color change from reddish-orange slope-forming mudstone of member B to white and light-tan-weathering ledgy sandstone of member C; about 400 feet (120 m) thick northeast of Granite Mountain and thins northward to 100 to 200 feet (30–60 m) thick in the Three Peaks quadrangle (Mackin and others, 1976; Mackin and Rowley, 1976).

Tca **Member A** (Paleocene?) – Varicolored and commonly mottled, pale-reddish-orange, reddish-brown, moderate-orange-pink, dark-yellowish-orange, and grayish-pink sandy and micritic limestone, calcite-cemented sandstone, calcareous mudstone, and conglomerate that weather to colluvium-covered slopes; similar to member B strata, but contains a greater component of conglomerate and limestone which form a series of resistant ridges; its overall lighter reddish-orange color and tendency to form ridges distinguishes member A strata from member B strata in aerial photographs; a 0 to 50-foot-thick (0–15 m) red basal conglomerate marks the unconformable lower contact with the Iron Springs Formation; rests on Co-op Creek Limestone of the Carmel Formation and appears to be deformed by the underlying Iron Springs Gap thrust fault in the SW1/4 section 28, T. 35. S., R. 12 W.; likely correlative with the lower part of the informal pink member of the Claron Formation mapped in adjoining quadrangles to the east (Knudsen, 2014a, 2014b; Biek and Hayden, 2013; Biek and others, 2012); 200 to 300 feet (60–90 m) thick,

but only about 100 feet (30 m) thick near the Iron Springs Gap thrust fault; thickens abruptly northward to 450–750 feet (140–230 m) thick in the Three Peaks quadrangle (Mackin and Rowley, 1976).

unconformity

CRETACEOUS

Ki **Iron Springs Formation** (Upper Cretaceous, Santonian or lower Campanian to Cenomanian) – Interbedded, ledge-forming, calcareous sandstone, siltstone, conglomerate and less-resistant, poorly exposed varicolored mudstone; includes several 1- to 5- foot-thick (0.3–1.5 m) limestone beds near its base; yellowish-brown to reddish-brown sandstone and siltstone beds are typically cross-bedded, locally display soft-sediment deformation, locally contain thin chert-pebble-rich zones, and range from quartz arenite to litharenite (Fillmore, 1991; Goldstrand, 1992); lenticular conglomerate beds in the lower part of the formation are as much as 50 feet (15 m) thick and contain pebble to cobble clasts of quartzite, chert, and limestone; a 5- to 40-foot-thick (1.5–12 m) basal conglomerate consists almost entirely of red, orange, white, and gray quartzite and chert clasts; gray, greenish-gray, and maroon mudstone is rarely exposed between thick tabular beds of sandstone and conglomerate; near its base, several blue and bluish-gray limestone beds with abundant rip-up clasts are interbedded with sandstone, conglomerate, and mudstone; subdivided into eight informal units by Mackin (1947) and into upper, middle, and lower members by Mackin and others (1976), who noted that contacts between their informal units are gradational and placed arbitrarily since the individual members are largely laterally discontinuous and not everywhere contemporaneous—due to these mapping difficulties in addition to poor exposures and structural complications, we leave the formation undivided; the quadrangle lacks a complete section, but the Iron Springs ranges from 0 (where it is locally eroded away in the hanging wall of the Iron Springs Gap thrust fault) to probably at least 3000 feet (0–915 m) thick (Mackin, 1947; Mackin and others, 1976); regionally, the formation is 3500 to 4000 feet (1070–1220 m) thick in the Pine Valley Mountains (Cook, 1960).

Iron Springs strata were deposited principally in braided-stream and floodplain environments of a coastal plain (Johnson, 1984; Fillmore, 1991; Eaton and others, 2001; Milner and others, 2006), but near its base, also includes freshwater limestone (Mackin, 1947; Mackin and others, 1976) deposited in shallow lakes. In the Red Hills 17 miles (27 km) to the northeast, Eaton (1999) and Eaton and others (2001) correlated the Iron Springs Formation with the Dakota Formation, Tropic Shale, and Straight Cliffs Formation, but we found little resemblance among the Dakota-Straight Cliffs interval of the Red Hills/Markagunt Plateau and Iron Springs strata in the Iron Springs/Three Peaks area. The abundance of generally unfossiliferous limestone and apparent complete absence of coquina beds and carbonaceous/coal zones are particularly anomalous for Upper Cretaceous strata mapped regionally to the east. The bulk of the formation, above the lower section that includes limestone and thick conglomerate beds, consisting of monotonous interbedded reddish-brown sandstone and varicolored mudstone does resemble the Wahweap Formation mapped at the western edge of the Markagunt Plateau by Knudsen (2014a); age is from Goldstrand (1994).

Unconformity(?)

Km **Marshall Creek breccia** (Cretaceous?) – Distinct limestone breccia, named the Marshall Creek breccia by Mackin (1947), commonly exposed between maroon and tan sandstone of the Crystal Creek Member of the Carmel Formation and the basal chert-pebble conglomerate of the Iron Springs Formation; consists of angular pebble to boulder clasts of bluish-gray and pale-blue limestone floating in a brown to pale-orange limy siltstone matrix; locally, clasts are imbricated and resemble accumulations of rip-ups; the siltstone matrix is resistant to weathering and commonly stands up to 2 inches (5 cm) in relief above adjacent limestone clasts; clasts up to several feet across, and rare outcrops of minimally disturbed strata indicate the unit was originally deposited as alternating thin interbeds of lime and silt; includes plastically deformed beds; silt matrix commonly includes floating clasts of well-rounded, red, gray, and cream pebbles of chert derived from overlying Iron Springs conglomerate; described as fanglomerate-mudflow breccia and talus consisting of limestone clasts derived from locally uplifted Homestake Member (Co-op Creek Limestone) by Mackin (1947), but here interpreted to comprise intraformational rip-up clasts and sediment softly deformed in situ via subaqueous sliding, perhaps triggered by nearby tectonic activity along the Sevier

orogenic front; deformation occurred soon after the deposition of at least the basal conglomerate of the Iron Springs Formation and while both units were still in a partially lithified state; age is uncertain but because Marshall Creek and basal Iron Springs were deformed prior to lithification and because the original character of the Marshall Creek, before being deformed, resembles limestone beds in the lower part of the Iron Springs Formation, we consider the limestone to be only slightly older than basal Iron Springs conglomerate and that perhaps it should be considered to be part of the Iron Springs Formation; 0 to 80 feet (0–24 m) thick.

unconformity

JURASSIC

Carmel Formation (Middle Jurassic) – Nomenclature follows that of Doelling and Davis (1989); deposited in a shallow inland sea of a back-bulge basin, together with the underlying Temple Cap Formation, the first clear record of the effects of the Sevier orogeny in southwestern Utah; age from Imlay (1980).

Jcx **Crystal Creek Member** (Middle Jurassic) – Thin- to medium-bedded, reddish-brown siltstone, mudstone, and fine- to medium-grained sandstone; locally gypsiferous; forms vegetated, poorly exposed slopes; best exposed at the abandoned Lindsay Hill mine (now part of the Iron County landfill); exposures on the north flank of Granite Mountain and near the Three Peaks intrusion include a considerable component of cream and very pale-red sandstone and siltstone beds up to 15 feet (5 m) thick, especially near the top of the member; upper contact with Marshall Creek breccia, where present, or basal conglomerate of the Iron Springs Formation is sharp; mapped as "Entrada" formation by Mackin (1947) and as the banded member by Mackin and others (1976); deposited in coastal-sabkha and tidal-flat environments (Imlay, 1980; Blakey and others, 1983); about 200 feet (60 m) thick in the northeastern foothills of Granite Mountain.

Jcc **Co-op Creek Limestone Member** (Middle Jurassic) – Thin- to thick-bedded, light-blue-gray and yellowish-gray micritic limestone and minor calcareous siltstone and shale that weather to steep, ledgy slopes; includes a distinctive 5- to 10-foot-thick (1.5–3 m) mud-cracked and rippled argillaceous limestone at the top (Mackin, 1947); contains fossil hash, and sparse crinoids and bivalve fragments; is the host rock for the hematite ore bodies of the Iron Springs mining district; mapped as Homestake Limestone by Leith and Harder (1908) and correlated to the "limestone member" (Co-op Creek Limestone Member) of the Carmel Formation in the Marakagunt Plateau by Mackin (1947, 1954); Mackin (1947) attributed intense brecciation of Co-op Creek Limestone (mapped separately as "disturbed Homestake" by Mackin [1947], and as "crackled phase of the Homestake Limestone" by Mackin and others [1976]) in sections 21 and 28, T. 35. S., R. 12 W. to in situ deformation associated with local uplift that occurred after deposition of the "Entrada" sandstone (Crystal Creek Member) and before deposition of the Iron Springs Formation; because our mapping shows that the brecciated Co-op Creek Limestone everywhere rests on top of Iron Springs Formation as part of the upper plate of the Iron Springs Gap thrust and related faults, we consider the brecciation to be associated with transport above the Sevier-age thrust fault; deposited in a shallow-marine environment (Imlay, 1980; Blakey and others, 1983); about 280 feet (85 m) thick.

Jt **Temple Cap Formation** (Middle to Lower Jurassic) – Light- to dark-gray, light-orange-brown, or olive, fine-grained, calcareous sandstone and siltstone; typically forms a thin band of poor outcrops of light-orangish-brown platy fragments between light-blue Co-op Creek Limestone and light-gray quartz monzonite; everywhere exposed, it is in contact with quartz monzonite intrusions, and thus typically has altered grains and exhibits hornfels-grade contact metamorphism (Mackin, 1947, 1954; Mackin and others, 1976); tentatively correlated with non-eolian sandstone, siltstone, and mudstone with gypsum of the Manganese Wash Member of the Temple Cap Formation mapped near Cedar City (Knudsen, 2014a) and the Pine Valley Mountains-Gunlock area (Sprinkel and others, 2011), although we observed no gypsum in the Iron Springs area; gypsum may have been removed by thrust faulting and/or emplacement of intrusions that later

followed the Temple Cap horizon; deposited in coastal-sabkha and tidal-flat environments (Blakey, 1994; Peterson, 1994); Sprinkel and others (2009) and Kowallis and others (2011) reported that the Temple Cap Formation ranges from about 179 to 171 Ma based on several $^{40}Ar/^{39}Ar$ and U-Pb zircon ages; maximum exposed thickness is about 50 feet (15 m).

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The geologic map of the Cedar City NW quadrangle by Mackin, Nelson, and Rowley, published in 1976, provided a firm foundation for our new map of this same area. Major additions of our mapping include new structural interpretations based on recent research on laccolith emplacement, the discovery in the Eightmile Hills of a gravity slide shed off the Granite Mountain laccolith, more detailed mapping of surficial deposits that will support the creation of a geologic hazard map folio of the greater Cedar Valley area, and the discovery of numerous fault scarps and earth fissures in Cedar Valley. We thank Pete Rowley (Geologic Mapping, Inc.) and Dave Hacker (Kent State University) for sharing their considerable knowledge of the Cenozoic geology of the region. Bill Lund (Utah Geological Survey [UGS]) helped map earth fissures. Grant Willis and Mike Hylland (both UGS) reviewed the map and we are grateful for their collective wisdom.

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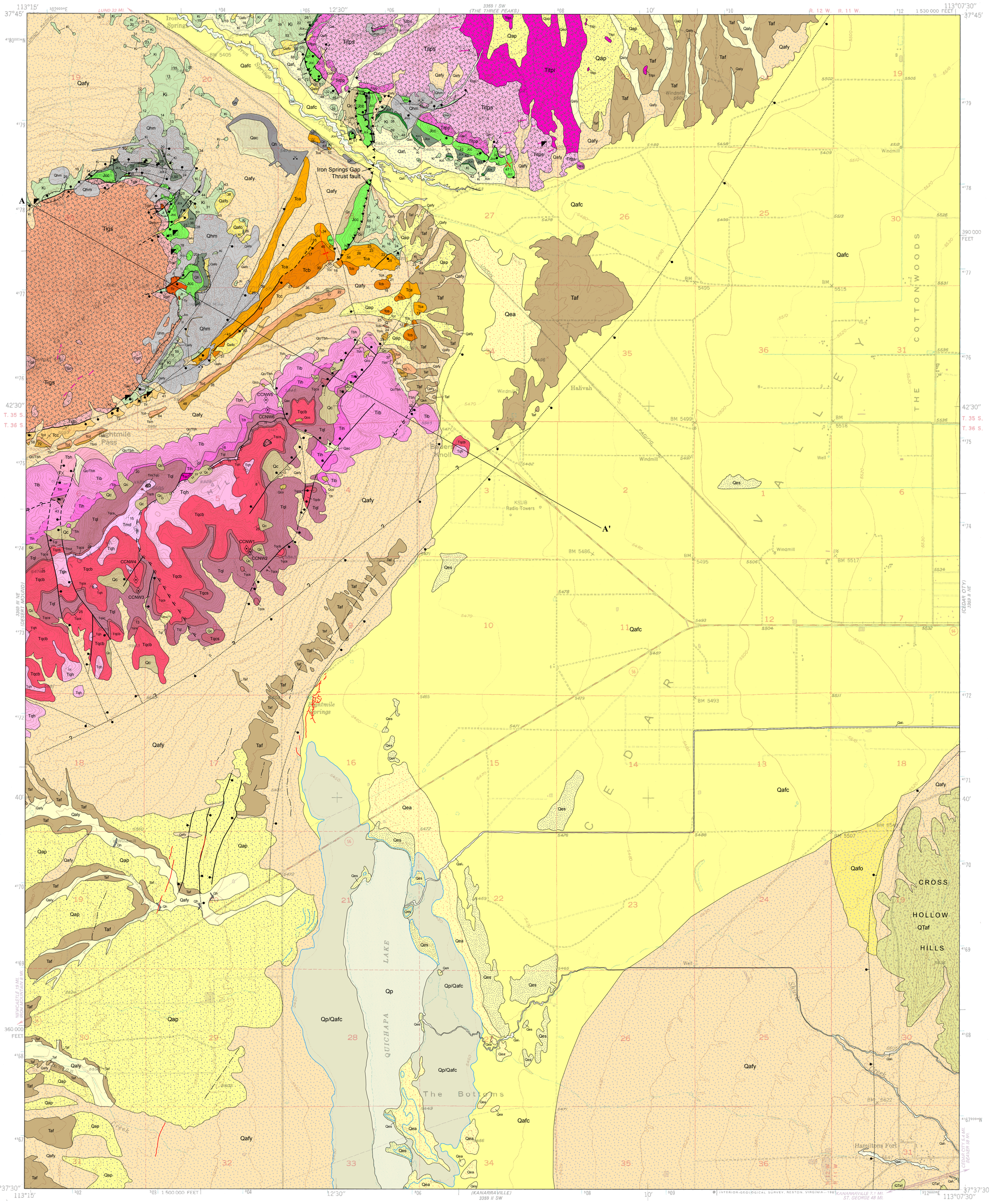
Plate 1
Utah Geological Survey Open-File Report 627
Interim Geologic Map of the Cedar City NW Quadrangle



This geologic map was funded by the Utah Geological Survey and the U.S. Geological Survey, National Cooperative Geologic Mapping Program, through USGS STATEMAP awards number G11AC20249 and G12AC20226. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

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INTERIM GEOLOGIC MAP OF THE CEDAR CITY NW QUADRANGLE, IRON COUNTY, UTAH

by

Tyler R. Knudsen and Robert F. Biek

2014

11°82′
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 2013

1 0.5 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 0.5 0 1 KILOMETER
CONTOUR INTERVAL 20 FEET

Base from USGS Cedar City NW 7.5' Quadrangle (1949)
Projection: UTM Zone 12
Datum: NAD 1927
Spheroid: Clarke 1866

Project Manager: Bill Lund
GIS and Cartography: Tyler R. Knudsen

1	2	3
4		5
6	7	8

1. Avon SE
2. The Three Peaks
3. Enoch
4. Desert Mound
5. Cedar City
6. Stoddard Mountain
7. Kanarraville
8. Cedar Mountain

ADJOINING 7.5' QUADRANGLE NAMES

UTAH GEOLOGICAL SURVEY
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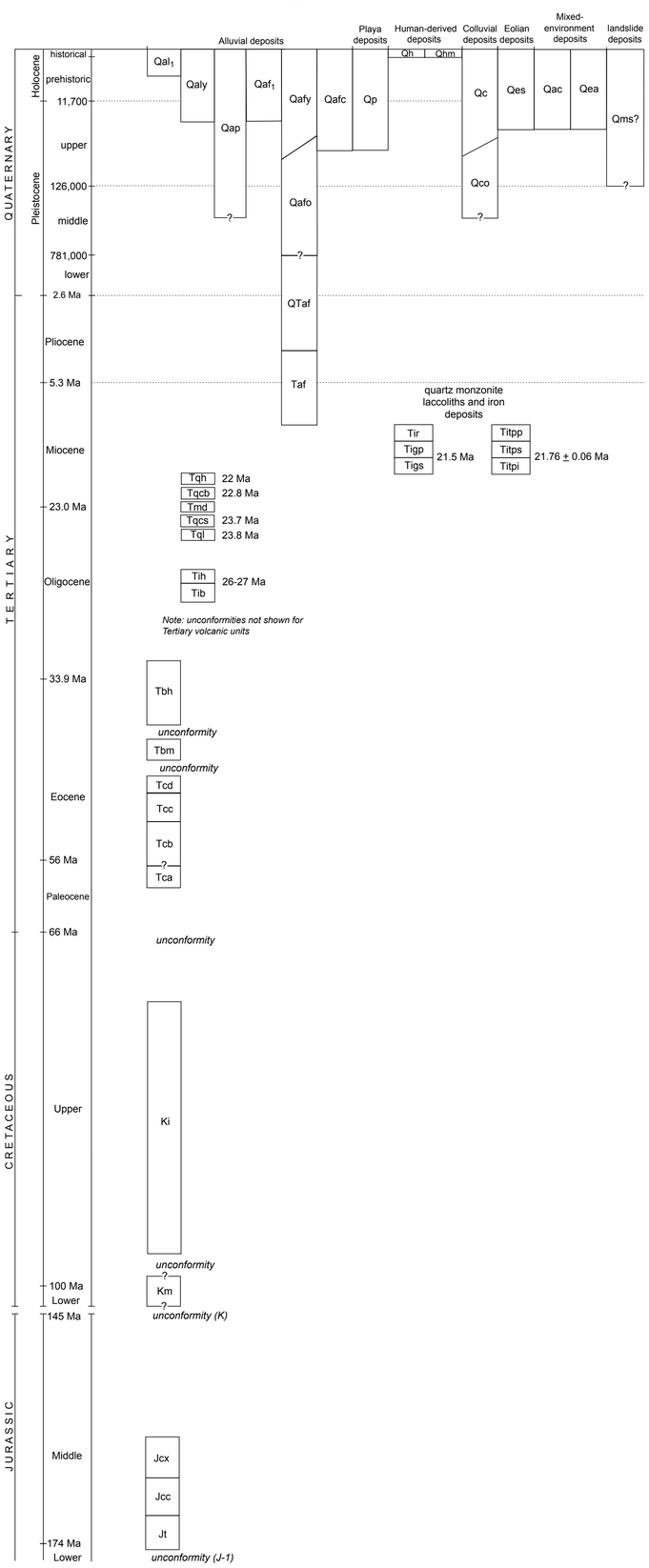
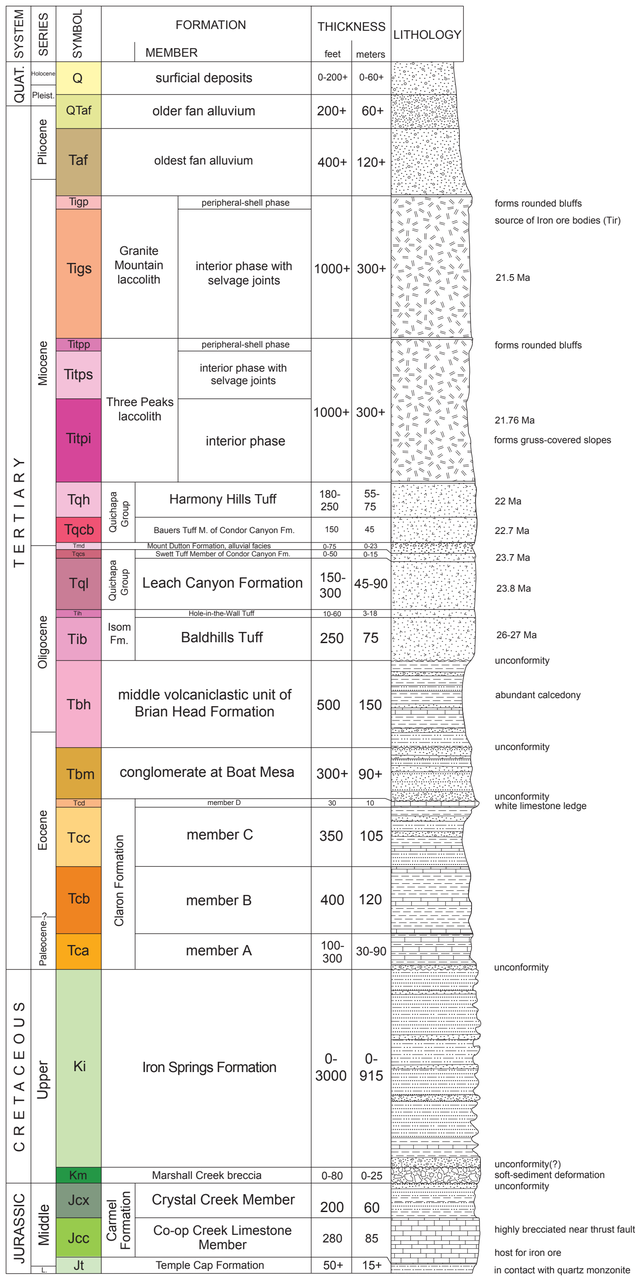
Plate 2
Utah Geological Survey Open-File Report 627
Interim Geologic Map of the Cedar City NW Quadrangle

CORRELATION OF MAP UNITS



LITHOLOGIC COLUMN



MAP SYMBOLS

- Contact, dashed where approximately located
- Normal fault, dashed where approximately located, dotted where concealed; queried where uncertain; bar and ball on down-dropped side
- Thrust fault, dashed where approximately located, dotted where concealed; teeth on upper plate
- Gravity-slide fault, dashed where approximately located, dotted where concealed; barbs on upper plate
- Mine pit extent
- Earth fissure related to ground subsidence; queried where uncertain
- Shoreline of Quichapa Lake; may coincide with geologic contacts
- Lineament
- Strike and dip of inclined bedding
- Approximate strike and dip of inclined bedding
- Sand and gravel pit
- Quarry
- Adit
- Prospect
- Vertical shaft
- CCNW1 Sample location and number, see table 1
- Magnetite vein

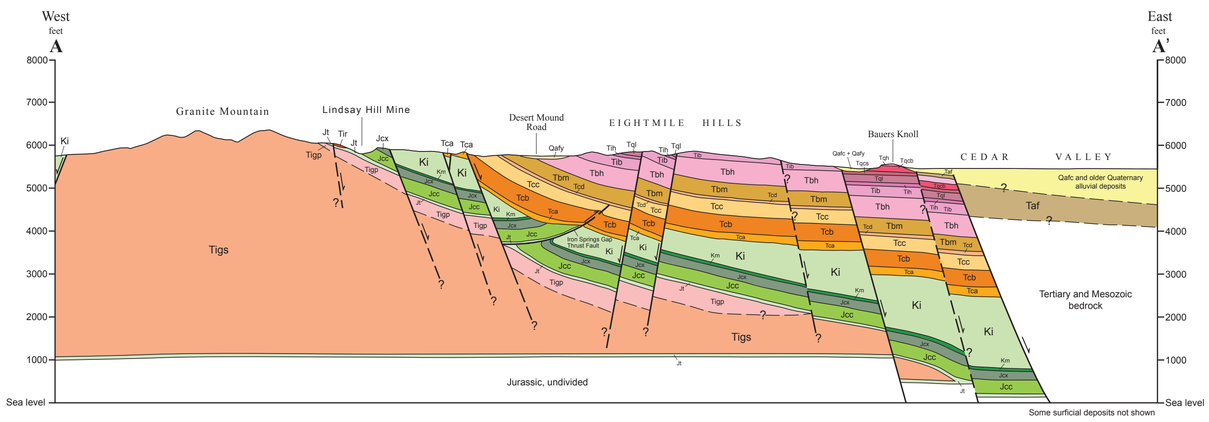


Table 1. Major- and trace-element whole-rock geochemistry for volcanic rocks in and near the Cedar City NW quadrangle.

Sample No.	Formation Name	Map Symbol	Rock Type	Latitude	Longitude	Lab Used	SiO2	Al2O3	Fe2O3	CaO	MgO	Na2O	K2O	Cr2O3	TiO2	MnO	P2O5	SrO	BaO	LOI	Total	Ba	Ce	Cr	Cs	Dy	Er	Eu	Ga	Gd	Hf	Ho	La	Lu	Nb	Nd	Pr	Rb	Sm	Sn	Sr	Ta	Tb	Th	Tl	Tm	U	V	W	Y	Yb	Zr	Ag	As	Cd	Co	Cu	Mo	Ni	Pb	Sc	Zn
CCNW3	Swett Tuff	Tqcs	rhyolite	4173409	302883	ALS Chemex	71.5	13.99	1.73	1.47	0.51	3.79	5.29	<0.01	0.34	0.05	0.059	0.02	0.14	0.94	99.82	1285	116.5	10	4.56	4.2	2.39	1.42	18.9	5.38	8.9	0.87	61.5	0.39	16.2	44.4	13.35	168.5	7	2	252	1.2	0.76	21.7	0.6	0.36	4.64	20	2	24.2	2.36	332	<0.5	7	<0.5	<1	26	2	27	55	4	74
CCNW4	Bauers Tuff	Tqcb	rhyolite	4173515	302898	ALS Chemex	70.68	14.53	1.69	1.55	0.36	3.76	5.54	<0.01	0.3	0.05	0.051	0.03	0.15	1.03	99.71	1325	117	10	5.67	3.62	2.07	1.27	19	4.51	8.9	0.74	65.3	0.35	15.2	42.1	13.3	204	6.31	1	325	1.2	0.63	33.6	0.5	0.33	6.52	26	3	21.4	2.18	319	<0.5	11	<0.5	<1	3	2	<1	26	3	34
CCNW5	Bald Hills Isom	Tih	trachyte	4175620	304457	ALS Chemex	67.03	15.12	3.65	1.79	0.38	3.52	5.84	<0.01	0.8	0.03	0.193	0.04	0.16	1.3	99.85	1365	192.5	<10	10.2	6.23	3.37	2.07	21	8.45	12.9	1.2	101	0.49	25.7	69	20.9	250	11.15	2	377	1.6	1.12	42.6	0.5	0.49	7.37	44	3	31.7	3.26	477	<0.5	9	<0.5	2	8	4	<1	29	7	65
CCNW6	Hole-in-the-Wall Isom	Tih	rhyolite	4175513	304466	ALS Chemex	68	13.74	2.28	3.04	0.38	3.53	5.41	<0.01	0.5	0.04	0.098	0.02	0.13	2.78	99.94	1080	120.5	<10	5.95	4.48	2.46	1.42	18.4	5.86	9.8	0.83	61.4	0.37	17.1	44.7	13.25	204	7.49	<1	232	1	0.8	30.6	<0.5	0.36	6	23	3	23.2	2.4	342	<0.5	10	<0.5	<1	7	1	<1	24	4	49
CCNW1	Bauers Tuff	Tccb	rhyolite	4173907	304247	ALS Chemex	70.74	14.65	1.79	1.4	0.34	3.81	5.61	<0.01	0.31	0.05	0.053	0.03	0.15	0.75	99.67	1320	122.5	<10	4.64	3.67	2.1	1.28	18.6	4.66	8.8	0.7	64.8	0.34	15.6	40.5	12.7	208	6.29	1	322	1	0.62	36.2	0.5	0.33	6.51	22	3	19.6	2.22	302	<0.5	8	<0.5	<1	3	2	<1	26	3	31
CCNW2	Swett Tuff	Tqcs	rhyolite	4173864	304278	ALS Chemex	70.92	14.33	1.87	1.59	0.44	3.98	5.12	<0.01	0.36	0.04	0.077	0.03	0.15	0.75	99.65	1300	119.5	<10	4.11	4.33	2.44	1.4	19.1	5.53	9.3	0.84	60.2	0.38	16.3	41.4	12.5	169	6.99	1	287	1	0.77	22.9	0.6	0.38	4.85	19	2	22.8	2.5	323	<0.5	9	<0.5	<1	1	2	<1	26	3	54

Notes: Major oxides reported in weight percent by X-Ray Florescence; minor and trace elements by Inductively Coupled Plasma-Mass Spectrometry in parts per million.
Latitude and longitude of samples based on NAD83.
LOI = Loss on ignition.
Rock names based on the TAS classification diagram of LeBas and others (1986).