Interim Geologic Map of the Enoch Quadrangle, Iron County, Utah

by

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DISCLAIMER

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MAP UNIT DESCRIPTIONS

QUATERNARY

Alluvial deposits

Qal_1 **Stream deposits** (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; includes abandoned floodplains of Coal Creek in Cedar Valley; 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 broad deposits emanating from Winn Hollow in the Enoch graben may be several hundred feet thick.

Qaf_2 **Level-2 fan alluvium** (lower Holocene to upper Pleistocene) – Similar to level-1 fan alluvium (Qaf_1), but forms inactive, incised surfaces cut by younger stream and fan deposits; equivalent to the older, lower part of younger fan alluvium (Qafy); probably less than 30 feet (<9 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 and 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 up to 3900 feet (1200 m) thick in this map area in central Cedar Valley (Cook and Hardman, 1967; 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 older basin-fill deposits (Taf); deposited principally as debris flows, debris floods, and as ephemeral stream channel deposits; 0 to 30 feet (0–10 m) thick.

QTaf **Older fan alluvium** (Pleistocene to Pliocene) – Poorly to moderately sorted, non-stratified, subangular to subrounded, clay- to boulder-size sediment with poorly to moderately developed calcic soils (caliche); forms deeply dissected surfaces with no remaining fan morphology; widely exposed in the Red Hills where exhumed as a fault-bounded horst block; 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, and rare quartz monzonite;

overlain by a 1.0 Ma (Anderson and Mehnert, 1979) basalt flow (Qbe?) that likely originated from the Elliker Basin area; equivalent deposits at Cross Hollow Hills in the Cedar City quadrangle appear interbedded with a 1.1 Ma basalt flow (Knudsen, 2014); deposited principally as debris flows; rests on Tertiary Claron Formation and allochthonous blocks of Tertiary volcanic rocks (Tm) in the Red Hills; maximum exposed thickness is about 200 feet (60 m).

Colluvial deposits

Qc **Colluvium** (Holocene to upper 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 too small to map separately; includes older colluvium now incised by adjacent drainages; 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.

Playa deposits

Qp **Rush 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 Rush Lake; at least 10 feet (3 m) thick.

Mass-movement deposits

Qmt **Talus** (Holocene to upper Pleistocene) – Poorly sorted, angular cobbles and boulders and finer-grained interstitial sediment deposited principally by rock fall on or at the base of steep slopes capped by the Red Hills basalt flow (Qbrh); typically grades downslope into colluvium where impractical to differentiate the two; typically less than 30 feet (9 m) thick.

Qms, Qms(Qbrh)

Landslides (Historical to middle[?] Pleistocene) – Very poorly sorted, locally derived material deposited by rotational and translational movement; composed of clay- to boulder-size debris as well as large, partly intact, bedrock blocks; characterized by hummocky topography, numerous internal scarps, chaotic bedding attitudes, and meadows; undivided as to inferred age because even landslides having subdued morphology (suggesting that they are older, weathered, and have not experienced recent large-scale movement) may continue to exhibit slow creep or are capable of renewed movement if stability thresholds are exceeded (Ashland, 2003); age and stability determinations require detailed geotechnical investigations; large landslides east of Interstate 15 are composed mostly of Tertiary volcanic rocks and debris from the Brian Head Formation; large rotational slump blocks of Red Hills lava flow (Qms[Qbrh]) are mapped at the west margin of the Red Hills near the north edge of the map; thickness highly variable.

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-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.

Basaltic lava flows

Qbe? **Elliker Basin(?) lava flow** (lower Pleistocene) – Medium- to dark-gray, fine-grained olivine basalt mapped at the extreme southern end of the Red Hills, here tentatively correlated to the nearby Elliker Basin flow (Biek and others, 2012); vent area unknown, but minor scoria and blocky flow breccia is present on the north rim of Elliker Basin southwest of Summit, suggesting that a vent could underlie the basin (Biek and others, 2012); yielded K-Ar ages of 1.00 ± 0.16 Ma and 1.11 ± 0.11 Ma (Anderson and Mehnert, 1979); lava flow is less than 20 feet (6 m) thick.

Qbrh, Qbrhc

Red Hills lava flows and cinder cone (lower Pleistocene) – Medium- to dark-gray, fine-grained basaltic andesite with small olivine and plagioclase phenocrysts; lava flows (Qbrh) erupted from vents at three cinder cones (Qbrhc) in the Red Hills—one in the Enoch quadrangle and the other two in the adjoining Summit quadrangle (Biek and others, 2012); lava flow is cut by faults associated with the Red Hills horst and graben; yielded K-Ar ages of 1.28 ± 0.4 Ma (Anderson and Mehnert, 1979) and 1.30 ± 0.4 Ma (Best and others, 1980); lava flow is typically several tens of feet thick.

Qb **Quaternary basalt** (Pleistocene?) – Small, isolated remnant of dark-gray, crystal-poor basalt flow west of the Rush Lake playa; overlies a gently-sloping planar erosional surface cut into well-cemented, fine-grained silt and sand (Taf); overlain by young pediment alluvium (Qap); may represent the distal end of the Red Hills flow (Qbrh), implying a more extensive flow underlies Cedar Valley near Rush Lake; less than 15 feet (5 m) thick.

TERTIARY

Taf **Oldest 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 (Rowley, 1975); Thomas and Taylor (1946) mapped the brownish-gray to orangish-gray, well-cemented gravel and sand interbedded with orangish-red clay, silt, and sand exposed in the northwest part of the quadrangle as Wasatch Formation (Claron Formation), and although these deposits locally appear similar to the Paleogene strata, the presence of volcanic clasts confirms that these deposits are part of much younger basin-fill deposits (Taf); 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 (Qap); although displaced by several relatively minor northeast-trending normal faults, the deposit is generally little disturbed; 9 to 10 Ma basalt (Anderson and Mehnert, 1979) is interbedded with Taf about 5 miles (8 km) 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; less than 130 feet (40 m) exposed, but is likely greater than 1000 feet (300 m) thick where preserved beneath the valley floor (Rowley, 1975).

Markagunt Megabreccia (lower Miocene) – Chaotic mass of Miocene and Oligocene volcanic rocks interpreted to be part of the Markagunt Megabreccia (Anderson, 1993; Sable and Maldonado, 1997a; Biek and others, 2012) that covers several hundred square miles in the central and northern Markagunt Plateau (Biek and others, 2012); in this map area, typically consists of highly attenuated slivers of Tertiary volcanic units recognized as members of the Quichapa Group and Isom Formation, which are described individually

below; masses consisting of very thin slivers of volcanic rocks too thin to map at 1:24,000 scale are mapped as Tm; smectitic clays of the Brian Head Formation likely provided the weak shear surface for downslope movement of the blocks; typically forms low, rubble-covered hills; locally covered by old fan alluvium (QTaf); interpreted as basal gravity-slide deposits derived from the catastrophic failure of oversteepened slopes associated with the pre-caldera inflation of the Marysville volcanic field between about 20 and 22 Ma by Biek and others (2012).

Tm(Tqh)

Markagunt Megabreccia, Harmony Hills Tuff component (lower Miocene) – 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); normally overlies the Bauers Tuff disconformably; source of the Harmony Hills Tuff 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 the $^{40}Ar/^{39}Ar$ plateau age of the Harmony Hills is 22.03 ± 0.15 Ma (Cornell and others, 2001), nearly identical to that of those intrusions; incomplete sections are less than 50 feet (15 m) thick.

Tm(Tqcb)

Markagunt Megabreccia, Bauers Tuff Member of Condor Canyon Formation component (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; disconformably overlies the Leach Canyon Formation; derived from the northwest part (Clover Creek caldera) of the Caliente caldera complex and at the time of its eruption, covered an area of at least 8900 square miles (23,000 km^2) (Best and others, 1989b; Rowley and others, 1995); the preferred $^{40}Ar/^{39}Ar$ age of the Bauers Tuff Member 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 (Rowley and others, 1994b); Fleck and others (1975) reported less-reliable K-Ar ages of 22.1 ± 0.6 Ma (plagioclase) and 20.7 ± 0.5 Ma (whole rock) for Bauers Tuff on the Markagunt Plateau; typically highly attenuated; highly attenuated and incomplete sections are less than 25 feet (8 m).

Tm(Tql)

Markagunt Megabreccia, Leach Canyon Formation component (upper Oligocene) – Light-pinkish- to orangish-gray, poorly to moderately welded, crystal-rich ash-flow tuff that contains abundant lithic clasts, including distinctive reddish-brown cinder fragments and white to pale-yellow pumice fragments; 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 pyroxene; disconformably overlies the Isom Formation; 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); is widely agreed to be about 23.8 Ma (Best and others, 1993; Rowley and others, 1995; Biek and others, 2012); exposed thickness is less than 50 feet (<15 m).

Tm(Ti) **Markagunt Megabreccia, Isom Formation component** (Upper Oligocene) – Medium-gray to reddish-brown, crystal-poor, densely welded, trachydacitic ash-flow tuff; weathers to platy outcrops and gruss-covered hills; 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); is about 26 to 27 Ma on the

basis of many $^{40}Ar/^{39}Ar$ and K-Ar ages (Best and others, 1989b; Rowley and others, 1994a); maximum exposed thickness is about 250 feet (75 m).

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 whereas farther east on the Sevier Plateau, Brian Head strata disconformably overlie the conglomerate at Boat Mesa (Biek and others, 2012). Sable and Maldonado (1997b) 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 the white member of the Claron Formation.

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 (1999) 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, light-gray, and pale-yellow sandstone, and limestone, with lesser amounts of varicolored mudstone, conglomerate, and multi-hued chalcedony; sandstone is commonly volcaniclastic with locally abundant biotite creating a white-and-black speckled appearance; limestone commonly contains gray and light-bluish-gray chert layers; mudstone intervals exhibit swelling soils suggesting a volcanic ash component; the formation is typically nonresistant, poorly exposed, and extensively covered by colluvium derived from overlying volcanic units; equal to the upper 100 feet (30 m) of Rowley and Threet's (1976) Claron Formation; deposited in low-relief fluvial, floodplain, and lacustrine environments in which large amounts of volcanic ash accumulated (Sable and Maldonado, 1997b); overlying Tertiary volcanic units, here, interpreted to be allochthonous as part of the Markagunt Megabreccia, cut out nearly all of the Brian Head Formation near Clark's Canyon; an incomplete section south of Clark's Canyon is about 100 feet (30 m) thick.

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, but because the formation lacks a type section and was named for incomplete, fault-bounded exposures in the Iron Springs mining district, the nomenclatural history of these rocks is complicated as described by Biek and others (2012). Following the nomenclature of Biek and others (2012), I mapped five informal lithostratigraphic units described below: an upper white member (which is itself divided into an uppermost mudstone interval, an upper limestone interval, a middle mudstone and sandstone interval, and a lower limestone interval) and the lower pink member. Claron strata were deposited in fluvial, floodplain, and lacustrine environments of an intermontaine basin bounded by Laramide uplifts; the pink member is almost wholly fluviatile and the white member is both lacustrine and fluviatile (Goldstrand, 1990, 1991, 1992, 1994; Bown and others, 1997). Anderson and Dinter (2010), Biek and others (2012), and Knudsen (2014) showed that east-vergent, Sevier-age compressional deformation continued into lower Claron time in southwestern Utah. 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 nonfossilferous 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 yet rule out the possibility that they are latest Cretaceous.

Tcwt **Uppermost mudstone, siltstone, and sandstone interval of white member** (upper and middle Eocene) – Varicolored and commonly mottled, pale-reddish-orange, reddish-brown, moderate-orange-pink, dark-yellowish-orange, grayish-pink, and similarly hued calcareous mudstone and siltstone, locally with minor fine-grained silty sandstone and micritic limestone; indistinguishable in lithology and color from the middle white member (Tcwm) of the Claron Formation; forms a brightly colored slope on top of the upper limestone interval of the white member; contact with overlying Brian Head Formation placed at the top of a pale-red limy siltstone of the white member, above which is white and light-gray volcaniclastic mudstone and sandstone of the Brian Head Formation; an incomplete section near the mouth of Clarks Canyon is about 140 feet (43 m) thick.

Tcwu **Upper limestone interval of white member** (Eocene) – White, pale-yellowish-gray, pinkish-gray, and very pale orange micritic limestone, locally containing intraformational rip-up clasts; typically poorly bedded and knobby weathering; locally vuggy with calcite spar and commonly cut by calcite veinlets; resistant and so forms prominent ledge and flat ridge tops; upper conformable contact with Tcwt corresponds to a pronounced color change from white to very pale orange micritic limestone below to brightly colored reddish-orange mudstone and siltstone above; about 30 feet (10 m) thick.

Tcwm **Middle mudstone, siltstone, and sandstone interval of white member** (Eocene) – Varicolored calcareous mudstone and siltstone, and minor fine-grained calcareous sandstone similar to the uppermost clastic interval (Tcwt); weathers to a poorly exposed slope; upper conformable contact corresponds to a pronounced color change from brightly colored reddish-orange mudstone and siltstone below to white to very pale orange micritic limestone above; Eaton and others (2011) reported sparse late middle Eocene (Duchesnean Land Mammal Age) vertebrate fossils from this unit on the eastern Markagunt Plateau; about 65 feet (20 m) thick.

Tcwl **Lower limestone interval of white member** (Eocene) – Micritic limestone similar to the upper white limestone interval (Tcwu); forms cliff or steep, ledgy, white slope above more colorful but typically subdued slopes of the pink member (Tcp); upper conformable contact corresponds to a pronounced color change from white to very pale orange micritic limestone below to brightly colored reddish-orange mudstone and siltstone above; about 30 feet (10 m) thick.

Tcp **Pink member of the Claron Formation** (Eocene and 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; limestone is poorly bedded, microcrystalline, generally sandy with 2 to 20% fine-grained quartz sand, and is locally argillaceous; sandstone is thick-bedded, fine- to coarse-grained, calcareous, locally cross-bedded quartz arenite; mudstone is generally moderate reddish-orange, silty, calcareous, contains calcareous nodules, and weathers to earthy, steep slopes between ledges of sandstone and limestone; pebbly conglomerate forms lenticular beds typically 5 to 15 feet (2–5 m) thick containing rounded quartzite, limestone, and chert pebbles and cobbles; only 80 feet (24 m) exposed north of Winn Hollow, although the pink member is about 1000 feet (300 m) thick at Cedar Breaks National Monument (Biek and others, 2012).

unconformity

CRETACEOUS

Kw **Wahweap Formation** (Upper Cretaceous) – Not exposed; about 1000 feet (300 m) thick near mouth of Fiddlers Canyon in the adjacent Cedar City quadrangle (Knudsen, 2014), but the formation thins abruptly to the north where it appears to be only a few tens of feet thick in Parowan Canyon (Biek and others, 2012).

Straight Cliffs Formation (Upper Cretaceous)

Peterson (1969) divided the Straight Cliffs Formation into four members in the Kaiparowits Basin: in ascending order, the Tibbet Canyon, Smoky Hollow, John Henry, and Drip Tank Members. Only the John Henry and Tibbet Canyon Members are exposed in the Enoch quadrangle.

Ksd **Drip Tank Member** (Upper Cretaceous) – Not exposed; thickness ranges from 10 to 25 feet (3–8 m) in the adjacent Cedar City quadrangle (Knudsen, 2014).

unconformity

Ksj **John Henry Member** (Upper Cretaceous) – Yellowish- to reddish-brown, fine- to medium-grained subarkosic sandstone and siltstone and interbedded, locally mottled, gray, brown, and reddish-brown mudstone; rippled siltstone near the base of member; woody material and leaf impressions are locally abundant; deposited in fluvial and floodplain environments of a coastal plain (Eaton and others, 2001); together with the underlying Smoky Hollow and Tibbet Canyon Members, forms an overall regressive sequence following the last marine incursion of the Western Interior Seaway (see, for example, Eaton and others, 2001; Moore and Straub, 2001; Tibert and others, 2003); only about 150 feet (45 m) exposed in an incomplete section on the western edge of the Markagunt Plateau, but is about 450 feet (135 m) thick in the adjacent Cedar City quadrangle (Knudsen, 2014).

unconformity

Kss **Smoky Hollow Member** (Upper Cretaceous) – Not exposed; about 250 feet (75 m) thick in adjacent Cedar City quadrangle to the south (Knudsen, 2014).

Kst **Tibbet Canyon Member** (Upper Cretaceous) – Yellowish-brown, medium- to thick-bedded, generally planar bedded, fine- to medium-grained quartzose sandstone and interbedded gray mudstone, carbonaceous shale, and thin to thick beds of oyster coquina; generally forms bold cliffs, but here, expressed as a series of flatirons partially covered by extensive landslides (Qms) on the west edge of the Markagunt Plateau; represents initial progradational (overall regressive) strata of the Greenhorn Cycle deposited in shoreface, beach, lagoonal, and estuarine environments adjacent to a coastal plain (Laurin and Sageman, 2001; Tibert and others, 2003); about 300 feet (90 m) exposed in an incomplete section, but is about 650 feet (200 m) thick in the adjacent Cedar City quadrangle (Knudsen, 2014).

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REFERENCES

Anderson, J.J., 1993, The Markagunt megabreccia—large Miocene gravity slides mantling the northern Markagunt Plateau, southwestern Utah: Utah Geological Survey Miscellaneous Publication 93-2, 37 p.

Anderson, J.J., and Rowley, P.D., 1975, Cenozoic stratigraphy of the southwestern High Plateaus of Utah, *in* Anderson, J.J., Rowley, P.D., Fleck, R.J., and Nairn, A.E.M., editors, Cenozoic geology of southwestern High Plateaus of Utah: Geological Society of America Special Paper 160, p. 1–52.

Anderson, L.P., and Dinter, D.A., 2010, Deformation and sedimentation in the southern Sevier Foreland, Red Hills, southwestern Utah, *in* Carney, S.M., Tabet, D.E., and Johnson, C.L., editors, Geology of south-central Utah: Utah Geological Association Publication 39, p. 338–366.

Anderson, R.E., and Mehnert, H.H., 1979, Reinterpretation of the history of the Hurricane fault in Utah, *in* Newman, G.W., and Goode, H.D., editors, 1979 Basin and Range Symposium: Rocky Mountain Association of Geologists and Utah Geological Association, p. 145–165.

Ashland, F.X., 2003, Characteristics, causes, and implications of the 1998 Wasatch Front landslides, Utah: Utah Geological Survey Special Study 105, 49 p.

Best, M.G., Christiansen, E.H., and Blank, R.H., Jr., 1989a, Oligocene caldera complex and calc-alkaline tuffs and lavas of the Indian Peak volcanic field, Nevada and Utah: Geological Society of America Bulletin, v. 101, p. 1076–1090.

Best, M.G., Christiansen, E.H., Deino, A.L., Gromme, C.S., McKee, E.H., and Noble, D.C., 1989b, Excursion 3A—Eocene through Miocene volcanism in the Great Basin of the western United States: New Mexico Bureau of Mines and Mineral Resources Memoir 47, p. 91–133.

Best, M.G., McKee, E.H., and Damon, P.E., 1980, Space-time-composition patterns of late Cenozoic mafic volcanism, southwestern Utah and adjoining areas: American Journal of Science, v. 280, p. 1035–1050.

Best, M.G., Scott, R.B., Rowley, P.D., Swadley, W.C., Anderson, R.E., Gromme, C.S., Harding, A.E., Deino, A.L., Christiansen, E.H., Tingey, D.G., and Sullivan, K.R., 1993, Oligocene-Miocene caldera complexes, ash-flow sheets, and tectonism in the central and southeastern Great Basin, *in* Lahren, M.M., Trexler, J.H., Jr., and Spinosa, C., editors, Crustal evolution of the Great Basin and Sierra Nevada: Field trip guide, Geological Society of America, Cordilleran and Rocky Mountain Sections meeting, p. 285–311.

Biek, R.F., Rowley, P.D., Anderson, J.J., and Maldonado, F., Moore, D.W., Eaton, J.G., Hereford, R., and Matyjasik, B., 2012, Interim geologic map of the Panguitch 30' x 60' quadrangle, Garfield, Iron, and Kane Counties, Utah: Utah Geological Survey Open-File Report 599, 124 p., 3 plates, scale 1:62,500.

Blank, H.R., Jr., 1959, Geology of the Bull Valley district, Washington County, Utah: Seattle, University of Washington, Ph.D. dissertation, 177 p.

Bown, T.M., Hasiotis, S.T., Genise, J.F., Maldonado, F., and Bowers, E.M., 1997, Trace fossils of *Hymenoptera* and other insects, and paleoenvironments of the Claron Formation (Paleocene and Eocene), southwestern Utah, *in* Maldonado, F., and Nealey, L.D., editors, Geologic studies in the Basin and Range-Colorado Plateau transition in southeastern Nevada, southwestern Utah, and northwestern Arizona, 1995: U.S. Geological Survey Bulletin 2153, p. 43–58.

Cook, K.L., and Hardman, E., 1967, Regional gravity survey of the Hurricane fault area and Iron Springs district, Utah: Geological Society of America Bulletin, v. 78, p. 1063–1076.

Cornell, D., Butler, T., Holm, D., Hacker, D., and Spell, T., 2001, Stratigraphy and $^{40}Ar/^{39}Ar$ ages of volcanic rocks of the Pinto quadrangle, Colorado Plateau transition zone, SW Utah [abs.], *in* Erskine, M.C., Faulds, J.E., Bartley, J.M., and Rowley, P.D., editors, The geologic transition, High Plateaus to Great Basin—a symposium and field guide (The Mackin Volume): Utah Geological

Association and Pacific Section of the American Association of Petroleum Geologists, Utah Geological Association Publication 30, p. 420–421.

Eaton, J.G., Hutchinson, J.H., Holroyd, P.A., Korth, W.W., and Goldstrand, P.M., 1999, Vertebrates of the turtle basin local fauna, middle Eocene, Sevier Plateau, southcentral Utah, *in* Gillette, D.D., editor, Vertebrate paleontology in Utah: Utah Geological Survey Miscellaneous Publication 99-1, p. 463–468.

Eaton, J.G., Laurin, J., Kirkland, J.I., Tibert, N.E., Leckie, R.M., Sageman, B.B., Goldstrand, P.M., Moore, D.W., Straub, A.W., Cobban, W.A., and Dalebout, J.D., 2001, Cretaceous and early Tertiary geology of Cedar and Parowan Canyons, western Markagunt Plateau, Utah, *in* Erskine, M.C., Faulds, J.E., Bartley, J.M., and Rowley, P.D., editors, The geologic transition, High Plateaus to Great Basin—a symposium and field guide (The Mackin Volume): Utah Geological Association and Pacific Section of the American Association of Petroleum Geologists, Utah Geological Association Publication 30, p. 337–363.

Eaton, J.G., Tibert, N.E., and Biek, R.F., 2011, First mammals and ostracodes from the Paleogene Claron Formation, southwestern Utah: Geological Society of America Abstracts with Programs, v. 43, no. 4, p. 77.

Fleck, R.J., Anderson, J.J., and Rowley, P.D., 1975, Chronology of mid-Tertiary volcanism in High Plateaus region of Utah, *in* Anderson, J.J., Rowley, P.D., Fleck, R.J., and Nairn, A.E.M., editors, Cenozoic geology of southwestern High Plateaus of Utah: Geological Society of America Special Paper 160, p. 53–62.

Goldstrand, P.M., 1990, Stratigraphy and paleogeography of Late Cretaceous and Early Tertiary rocks of southwest Utah: Utah Geological Survey Miscellaneous Publication 90-2, 58 p.

Goldstrand, P.M., 1991, Tectonostratigraphy, petrology, and paleogeography of the Upper Cretaceous to Eocene rocks of southwest Utah: Reno, University of Nevada, Ph.D. dissertation, 205 p.

Goldstrand, P.M., 1992, Evolution of Late Cretaceous and early Tertiary basins of southwest Utah based on clastic petrology: Journal of Sedimentary Petrology, v. 62, no. 3, p. 495–507.

Goldstrand, P.M., 1994, Tectonic development of Upper Cretaceous to Eocene strata of southwestern Utah: Geological Society of America Bulletin, v. 106, p. 145–154.

Hurlow, H.A., 2002, The geology of Cedar Valley, Iron County, Utah, and its relation to ground-water conditions: Utah Geological Survey Special Study 103, 74 p., 2 plates.

Knudsen, T.R., 2014, Interim geologic map of the Cedar City 7.5-minute quadrangle, Iron County, Utah: Utah Geological Survey Open-File Report 626, scale 1:24,000.

Knudsen, T.R., and Biek, R.F., 2014, Interim geologic map of the Cedar City NW quadrangle, Iron County, Utah: Utah Geological Survey Open-File Report 627, scale 1:24,000.

Korth, W.W., and Eaton, J.G., 2004, Rodents and a marsupial (*Mammalia*) from the Duschesnean (Eocene) of the Sevier Plateau, Utah, *in* Dawson, M.R., and Lillegraven, J.A., editors, Fanfare for an uncommon paleontologist—papers on vertebrate evolution in honor of Malcolm C. McKenna: Carnegie Museum of Natural History Bulletin, no. 36, p. 109–119.

Laurin, J., and Sageman, B.B., 2001, Cenomanian-Turonian coastal record in SW Utah, U.S.A.—orbital-scale transgressive-regressive events during oceanic anoxic event II: Journal of Sedimentary Research, v. 77, p. 731–756.

Mackin, J.H., 1960, Structural significance of Tertiary volcanic rocks in southwestern Utah: American Journal of Science, v. 258, no. 2, p. 81–131.

Moore, D.W., and Straub, A.W., 2001, Correlation of Upper Cretaceous and Paleogene(?) rocks beneath the Claron Formation, Crow Creek, western Markagunt Plateau, southwest Utah, *in* Erskine, M.C., Faulds, J.E., Bartley, J.M., and Rowley, P.D., editors, The geologic transition, High Plateaus to Great Basin—a symposium and field guide (The Mackin Volume): Utah Geological Association and Pacific Section of the American Association of Petroleum Geologists, Utah Geological Association Publication 30, p. 75–95.

Peterson, F., 1969, Four new members of the Upper Cretaceous Straight Cliffs Formation in southeastern Kaiparowits region, Kane County, Utah: U.S. Geological Survey Bulletin 1274-J, p. 1–28.

Rowley, P.D., 1975, Geologic map of the Enoch NE quadrangle, Iron County, Utah: U.S. Geological Survey Map GQ-1301, scale 1:24,000.

Rowley, P.D., Hacker, D.B., Maxwell, D.J., and Boswell, J.T., 2008, Interim geologic map of the Utah part of the Deer Lodge Canyon, Prohibition Flat, Uvada, and Pine Park quadrangles (east part of the Caliente 30' x 60' quadrangle), Iron and Washington Counties, Utah: Utah Geological Survey Open-File Report 531, 21 p., 1 plate, scale 1:24,000.

Rowley, P.D., Mehnert, H.H., Naeser, C.W., Snee, L.W., Cunningham, C.G., Steven, T.A., Anderson, J.J., Sable, E.G., and Anderson, R.E., 1994a, Isotopic ages and stratigraphy of Cenozoic rocks of the Marysvale volcanic field and adjacent areas, west-central Utah: U.S. Geological Survey Bulletin 2071, 35 p.

Rowley, P.D., Nealey, L.D., Unruh, D.M., Snee, L.W., Mehnert, H.H., Anderson, R.E., and Gromme, C.S., 1995, Stratigraphy of Miocene ash-flow tuffs in and near the Caliente caldera complex, southeastern Nevada and southwestern Utah, *in* Scott, R.B., and Swadley, W C, editors, Geologic studies in the Basin and Range–Colorado Plateau transition in southeastern Nevada, southwestern Utah, and northwestern Arizona, 1992: U.S. Geological Survey Bulletin 2056, p. 43–88.

Rowley, P.D., Shroba, R.R., Simonds, F.W., Burke, K.J., Axen, G.J., and Olmore, S.D., 1994b, Geologic map of the Chief Mountain quadrangle, Lincoln County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-1731, scale 1:24,000.

Rowley, P.D., Steven, T.A., Anderson, J.J., and Cunningham, C.G., 1979, Cenozoic stratigraphic and structural framework of southwestern Utah: U.S. Geological Survey Professional Paper 1149, 22 p.

Rowley, P.D., and Threet, R.L., 1976, Geologic map of the Enoch quadrangle, Iron County, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-1296, scale 1:24,000.

Sable, E.G., and Maldonado, F., 1997a, The Brian Head Formation (revised) and selected Tertiary sedimentary rock units, Markagunt Plateau and adjacent areas, southwestern Utah, *in* Maldonado, F., and Nealey, L.D., editors, Geologic studies in the Basin and Range-Colorado Plateau transition zone in southeastern Nevada, southwestern Utah, and northwestern Arizona, 1995: U.S. Geological Survey Bulletin 2153, p. 7–26.

Thomas, H.E., and Taylor, G.H., 1946, Geology and ground-water resources of Cedar City and Parowan Valleys, Iron County, Utah: U.S. Geological Survey Water Supply Paper 993, 210 p., scale 1:312,500.

Tibert, N.E., Leckie, R.M., Eaton, J.G., Kirkland, J.I., Colin, J.P., Leithold, E.L., and McCormic, M.E., 2003, Recognition of relative sea-level change in Upper Cretaceous coal-bearing strata—a paleoecological approach using agglutinated foraminifera and ostracods to detect key stratigraphic

surfaces, *in* Olson, H.C., and Leckie, R.M., editors, Micropaleontological proxies for sea-level change and stratigraphic discontinuities: Society of Economic Paleontologists and Mineralogists Special Publication no. 75, p. 263–299.

Williams, P.L., 1967, Stratigraphy and petrography of the Quichapa Group, southwestern Utah and southeastern Nevada: Seattle, University of Washington, Ph.D. dissertation, 141 p.

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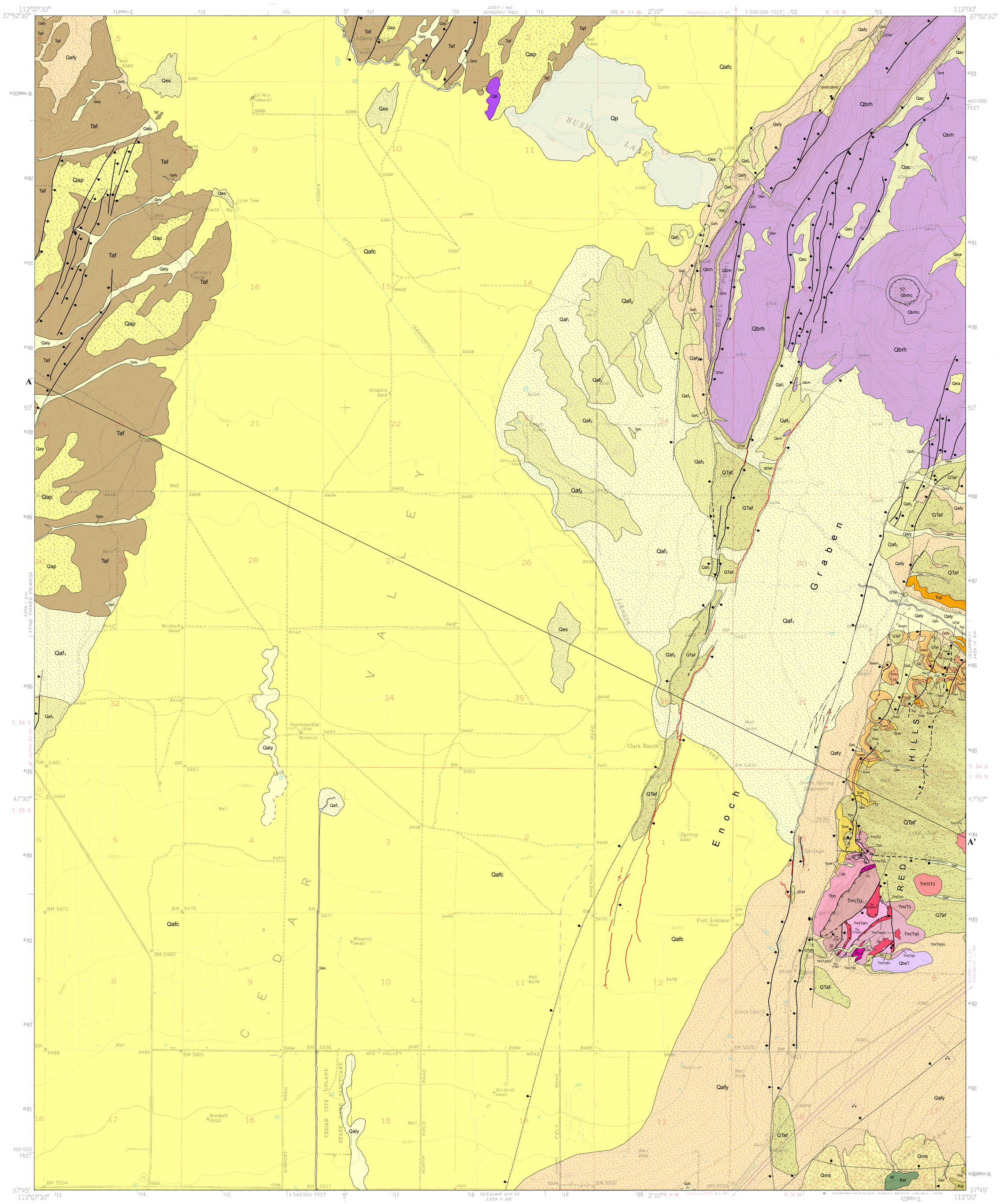

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INTERIM GEOLOGIC MAP OF THE ENOCH QUADRANGLE, IRON COUNTY, UTAH

by

Tyler R. Knudsen

2014

11°81'
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 10 FEET

Base from USGS Enoch 7.5' Quadrangle (1950)
Projection: UTM Zone 12
Datum: NAD 1927
Spheroid: Clarke 1866

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

1	2	3
4	·	5
6	7	8

1. Enoch NW
2. Enoch NE
3. Parowan Gap
4. The Three Peaks
5. Summit
6. Cedar City NW
7. Cedar City
8. Flanigan Arch

ADJOINING 7.5' QUADRANGLE NAMES

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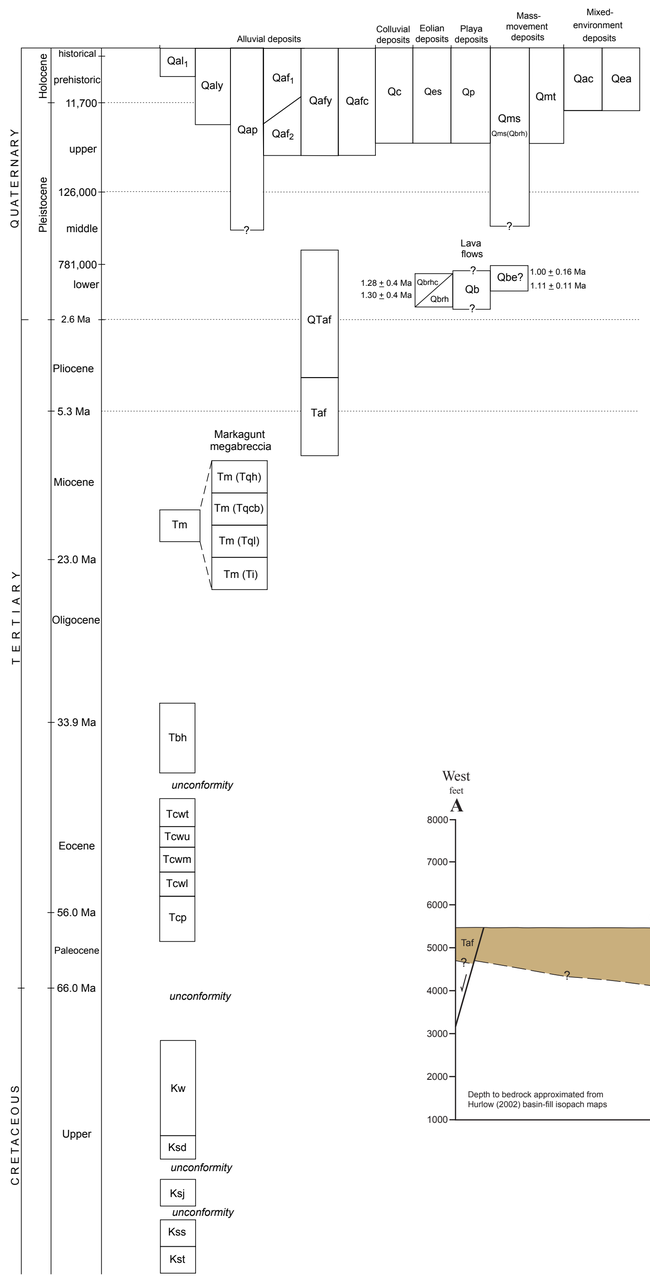
CORRELATION OF MAP UNITS



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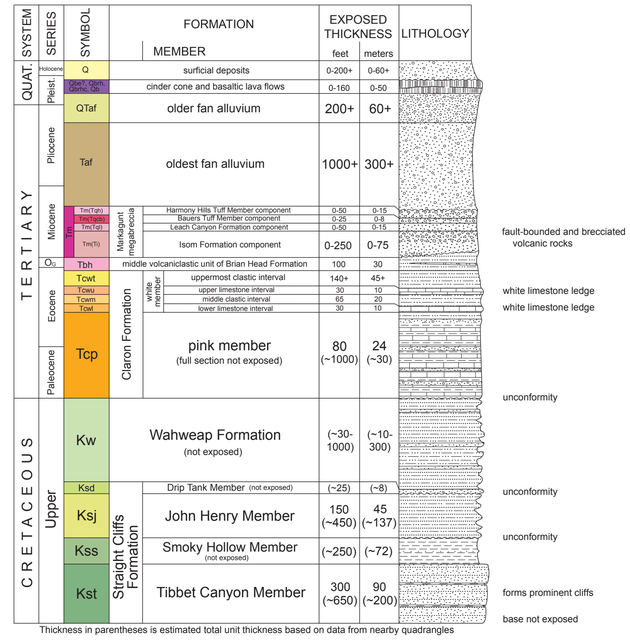

Thickness in parentheses is estimated total unit thickness based on data from nearby quadrangles

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
- Gravity-slide fault, dashed where approximately located, dotted where concealed; barbs on upper plate
- Cinder cone crater rim
- Earth fissure related to ground subsidence; queried where uncertain
- Lineament
- Strike and dip of inclined bedding
- Approximate strike and dip of inclined bedding
- Sand and gravel pit
- Quarry (cinder)