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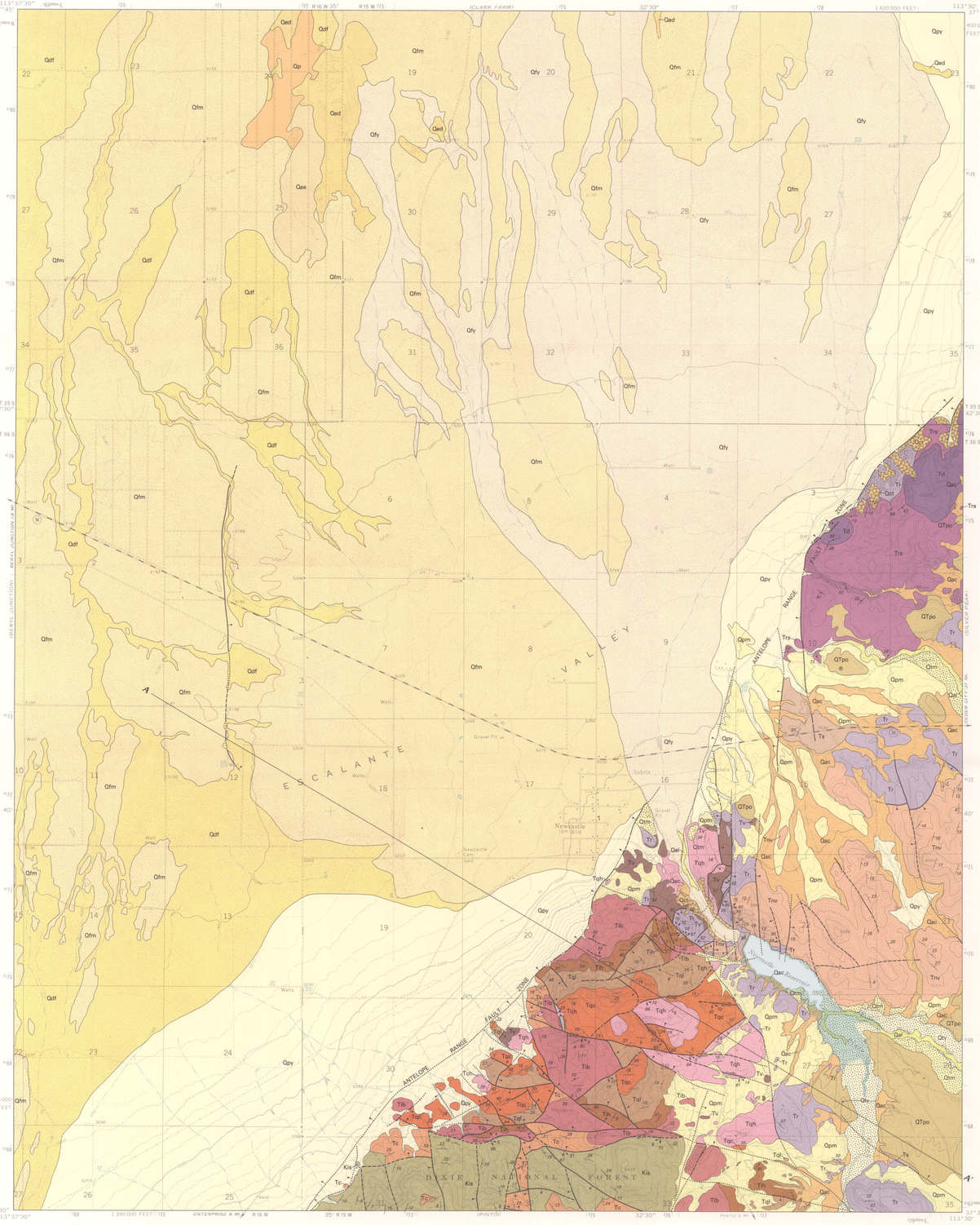
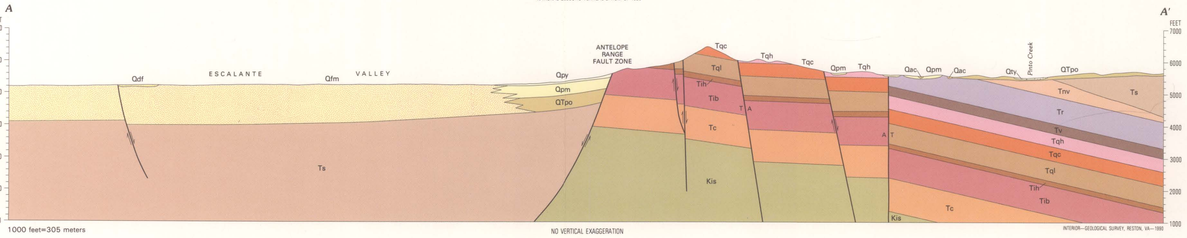
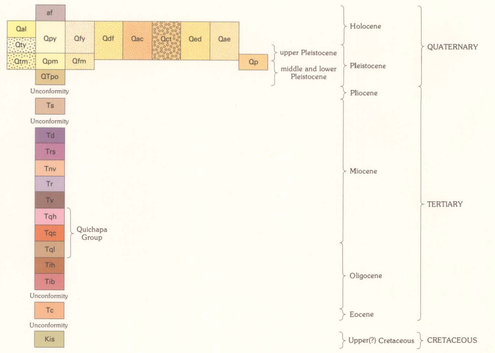
GEOLOGIC QUADRANGLE MAP
NEWCASTLE QUADRANGLE, UTAH
GQ–1690





CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

[Where necessary, isotopic ages given here have been recalculated using the IUGS decay constants (Steiger and Jäger, 1977). Rock classification is that of Le Bas and others (1986)]

af — **Artificial fill (Holocene)**—Dam of Newcastle Reservoir

Qal — **Alluvium (Holocene)**—Sand, silt, and gravel deposited in modern intermittent and perennial stream channels and on flood plains in the southeast part of map area. Maximum thickness about 3 m

Qpy — **Young piedmont-slope alluvium (Holocene and upper Pleistocene)**—Poorly to moderately sorted deposits of sand, gravel, and silt forming coalesced alluvial fans and pediments. Deposits grade from sandy gravel, containing cobbles and boulders near the mountain front, to gravelly sand, silt, and clay in distal parts. Includes modern alluvium of small streams and, in places, colluvium, alluvial sheet wash, and talus. Deposition partly spans the period of faulting along some segments of the Antelope Range fault zone. Thickness about 2 m in an excavation for a stock tank southwest of Newcastle (NE1/4 NE1/4 sec. 30, T. 36 S., R. 15 W.)

Qfy — **Young alluvial-fan deposits (Holocene and upper Pleistocene)**—Sand and subordinate pebble gravel, silt, and clay in the alluvial fan of Pinto Creek in Escalante Valley. Surface is generally inactive; exposed in stream cuts in modern arroyos. Includes, in northern parts of the map area, significant amounts of distal alluvial-fan deposits (Qdf) and patches of middle alluvial-fan deposits (Qfm) too small to map, as well as fine-grained alluvial sand and subordinate alluvium of small streams. Contacts gradational and approximately located, especially in northern part of map area. Maximum measured thickness about 3 m; maximum probable thickness 10 m

Qdf — **Distal alluvial-fan deposits (Holocene and upper Pleistocene)**—Silt and clay deposited in distal parts of the alluvial fans of Pinto Creek (Qfy) and of Shoal Creek to the west of the map area. Erosion, chiefly by sheet wash, of older alluvial deposits in Escalante Valley is also a source of material; this material is redeposited in swales and shallow, low-gradient channels. Most deposits are modern. Includes fine-grained eolian sand. Contacts gradational and approximately located. Maximum thickness unknown but probably several meters

Qac — **Alluvium and colluvium, undivided (Holocene and upper Pleistocene)**—Sand, silt, and gravel deposited in intermittent stream channels and flood plains and as colluvium in the southeast part of the map area. Includes alluvial-fan deposits, sheetwash alluvium, and talus. Estimated maximum thickness about 5 m

Qct — **Colluvium and talus, undivided (Holocene and upper Pleistocene)**—Mostly cobble, pebble, and boulder gravel on steep slopes below rock outcrops. Maximum thickness about 5 m

Qed — **Eolian sand (Holocene and upper Pleistocene)**—Dune sand consisting mostly of calcium carbonate, and subordinate clastic material and gypsum derived from adjacent alluvial and lacustrine deposits. Dunes are downwind (north-northeast) from deflation basin deposits (Qae) from which the material was derived. Dunes lack well-developed dune form and are largely stabilized by vegetation. Includes deposits in small playas between dunes. Contacts gradational and approximately located. Maximum dune height about 5 m

Qae — **Alluvium and eolian deposits, undivided (Holocene and upper Pleistocene)**—Sandy deposits in deflation basins and lag material from underlying reworked alluvium. Includes reworked alluvium, minor lacustrine material, and eolian sand. Mapped only in northern part of map area. Contacts are gradational and approximately located. Maximum thickness about 3 m

Qay — **Young stream-terrace alluvium (lower Holocene and upper Pleistocene)**—Sand, silt, and minor pebble gravel deposited in intermittent and perennial stream channels and flood plains. Terrace surfaces about 2–3 m above modern channels. Mapped only in the Pinto Creek drainage. Exposed thickness 2–3 m but maximum thickness probably 10 m

Qtm — **Middle stream-terrace alluvium (Pleistocene)**—Gravel and subordinate sand and silt of intermediate age, deposited in stream channels and flood plains. Terrace surfaces 15–25 m above nearby modern channels. Includes fill terraces and strath terraces cut on older alluvial-fan deposits and bedrock. Maximum thickness about 20 m

Qpm — **Middle piedmont-slope alluvium (Pleistocene)**—Mostly sandy gravel of intermediate age, containing boulders and cobbles, that occurs as dissected higher remnants of piedmont-slope alluvium. Contains conspicuous pedogenic calcium carbonate. Includes interbedded stream-terrace alluvium (Qtm) along Little Pinto Creek. Maximum thickness at least 30 m

Qfm — **Middle alluvial-fan deposits (Pleistocene)**—Sand and silt occurring as dissected higher remnants of intermediate-aged alluvial fans in Escalante Valley. Derived largely from ancestral Pinto Creek, ancestral Shoal Creek, and other ancestral streams that drained areas to the south. Where exposed in gravel pits, consists of 1–1.5 m-thick sandy alluvium containing moderately to strongly developed pedogenic calcium carbonate (Ulrich, 1960) and of underlying sandy pebble gravel and interbedded sand at least 2 m thick. Becomes finer grained to the north; along the northern edge of the map area, the upper 1–2 m is chiefly fine sand, silt, and clay and probably contains a substantial eolian (loess) component. Locally has been extensively reworked by wind and sheet wash; deflation has locally removed upper soil layers and exposed lower layers of pedogenic calcium carbonate. Contacts gradational and approximately located, especially in northern part of map area; lower parts may be Pliocene. Includes the entire thickness of Quaternary basin-fill deposits, which attain a maximum thickness of more than 300 m (Mower, 1982)

Qp — **Playa deposits (Pleistocene)**—Fine-grained, tan, granular gypsum and sandy gypsiferous and calcium-carbonate-rich clay, silt, and sand exposed in deflation basins in Escalante Valley. Sample from the top of a bed, about 1 m thick, from NW1/4 SE1/4 sec. 24, T. 35 S., R. 16 W. contains 68 percent gypsum and 6 percent calcium carbonate (G.E. Christenson, unpub. data, 1987). Mapped only in northern part of map area, where contacts are gradational and approximately located. Thickness at least 3 m

QTpo — **Old piedmont-slope alluvium (Pleistocene and Pliocene?)**—Light-gray, tan, and light-yellow, poorly to moderately consolidated cobble, pebble, and boulder conglomerate and sandstone. Clasts are generally rounded and consist of all local volcanic rock units and quartzite from the Claron Formation (Tc), as well as some rock units not exposed in the map area. The most distinctive clasts are boulders of magnetite as much as 1 m in diameter derived from the Iron Springs mining district (Rowley and Barker, 1978); the closest source of this magnetite is Iron Mountain about 10 km east of the map area. High-level piedmont surfaces capping the deposit are highly dissected, but some remnants survive. Contains significant pedogenic calcium carbonate. Probably correlative with older alluvial-fan deposits of Shubat and Siders (1988, unit QTaf), which also contains magnetite boulders and which underlies extensive high-level dissected surfaces in the area to the east. Maximum exposed thickness about 30 m

Ts — **Sedimentary basin-fill deposits (Pliocene? and upper Miocene)**—Tan and light-red, poorly to moderately consolidated, medium-bedded, pebble, cobble, and boulder conglomerate and sandstone. Locally contains blocks of volcaniclastic rocks of Newcastle Reservoir (Tnv) as long as 3 m. Clasts commonly subangular and probably represent coarse, rapidly deposited, fluvial basin-fill material along and west of the fault-bounded margin of the Escalante Valley. Thickness at least 300 m but probably considerably thicker under Escalante Valley (Cook and Hardman, 1967; Pe and Cook, 1980)

Td — **Dacite of Bullion Canyon (Miocene)**—Resistant, light-purple and light-gray, flow-foliated, crystal-rich dacitic lava flows of a volcanic dome. Characterized by large, abundant (about 40 percent by volume) phenocrysts of plagioclase, subordinate sanidine (as long as 1 cm), biotite, and quartz, and minor Fe-Ti oxides (Shubat and Siders, 1988, appendix), and large (as much as 1 cm in diameter) vesicular cavities lined with vapor-phase minerals, in a groundmass of devitrified glass. Informally named by Shubat and Siders (1988). K-Ar age on sanidine is 8.5±0.4 Ma (Shubat and Siders, 1988). Maximum thickness about 130 m

Trs — **Rhyolite of Silver Peak (Miocene)**—Resistant, purplish-gray, flow-foliated, rhyolitic lava flows and apparent volcanic domes. Base generally consists of flow breccia. Contains about 15–20 percent phenocrysts of sanidine and quartz, and minor biotite and Fe-Ti oxides (Shubat and Siders, 1988, appendix) in a groundmass of devitrified glass containing abundant small vesicles. Rock has been hydrothermally altered in many places, yet the overlying, slightly younger dacite of Bullion Canyon (Td) is not altered (Shubat and McIntosh, 1988). Informally named by Shubat and Siders (1988). K-Ar age on sanidine is 8.4±0.4 Ma (Shubat and Siders, 1988). Base not exposed; exposed thickness about 175 m

Tnv — **Volcaniclastic rocks of Newcastle Reservoir (Miocene)**—Dark-reddish-gray, dark-reddish-brown, and medium- to dark-brown, cobble, pebble, and boulder conglomerate and subordinate mudflow breccia and sandstone. Clasts subangular to subrounded and as much as 35 cm in diameter. Most clasts consist of older volcanic units in the area, especially Racer Canyon Tuff (Tr) and Harmony Hills Tuff (Tqh), as well as of the Claron Formation (Tc) and Iron Springs Formation (Kis). Most beds are grain supported and probably largely represent alluvial-fan deposits and subordinate mudflow breccia and stream channel and flood-plain deposits. Shubat and Siders (1988) named the volcaniclastic rocks of Newcastle Reservoir, which they correlated with the volcaniclastic "mine series" rocks of Siders (1985b). The volcaniclastic "mine series" rocks are the host for silver ore at the Escalante silver mine, west of Escalante Valley and about 8 km west of the map area. Forms a thick sequence in a belt about 25 km east-west by 8 km north-south (Siders, 1985a, b; Siders and Shubat, 1986; Shubat and Siders, 1988), and pinches out abruptly to the north and south; probably represents the fill in an east-trending Miocene depression, perhaps a graben. Upper limit on age indicated by a K-Ar age of 11.6 Ma on adularia from the main silver vein (Siders, 1985b), which cuts the map unit at the Escalante silver mine. Thickness at least 300 m in faulted, incomplete sections; upper part not exposed

Tr — **Racer Canyon Tuff (Miocene)**—Soft to resistant, light-gray and light-blue-gray, poorly to moderately welded, crystal-rich, rhyolitic ash-flow tuff. In some places, generally at the base of cooling units, includes minor beds of parallel-bedded airfall tuff and crosbedded pyroclastic-surge tuff. Contains locally abundant cognate pumice. Contains 1–6 percent conspicuous, mostly dark brown and dark gray, subangular lithic clasts that are generally less than 5 cm long and of vesicular, crystal-poor flow rock. Tuff consists of 20–35 percent phenocrysts of plagioclase and quartz, subordinate sanidine, biotite, and Fe-Ti oxides, and traces of clinopyroxene, hornblende, and sphene (Siders and Shubat, 1986). The quartz crystals locally are large (though generally less than 5 mm), deeply resorbed, and a light-purple or smoky color.

Best exposed in a large hill near the southeast corner of the map area, where consists of at least three ash-flow cooling units. The uppermost cooling unit is the most widespread and is a multiple cooling unit more than 100 m thick characterized by quartz phenocrysts that are typically large (as long as 7 mm) and abundant. Consists at the top of light-gray, pink, and medium-tan, weathering to tan and brown, poorly to moderately welded tuff that grades into moderately welded tuff that forms a prominent ledge. The cooling unit contains about 2 percent dark lithic clasts rarely more than 1.5 cm long. Flattened cavities formerly occupied by pumice or glass fiamme but now containing vapor-phase minerals occur in the upper part of the cooling unit, whereas lower (in the ledge) there is a 30-m-thick zone of conspicuous 10 cm long black glass fiamme. The fiamme zone grades downward into moderately resistant, light-gray tuff containing gray and light-yellow, partially collapsed cognate pumice and progressively smaller and less abundant quartz phenocrysts. Progressively lower in the ledge, cognate pumice increases in abundance, to about 20 percent of rock volume and in masses mostly about 5 cm long; quartz also is less abundant, and the tuff is light gray and light tan and moderately resistant. The lower part of the cooling unit consists of massive, soft to moderately resistant, gray, poorly welded ash-flow tuff and, at the base of the uppermost cooling unit, it changes abruptly into white, fine-grained airfall tuff. The middle cooling unit, about 25 m thick, consists of soft, tan, poorly welded ash-flow tuff containing 1–3 percent conspicuous lithic clasts of Harmony Hills Tuff (Tqh) as long as 4 cm. The middle cooling unit contains the same types and ratios of phenocrysts as in the uppermost cooling unit but has much lower amounts, about 10 percent total phenocrysts. The middle cooling unit is underlain by a tan, nonwelded, 1.5-m-thick, locally crossbedded tuff of probable pyroclastic-surge origin, under which is a lag bed of subangular pebbles and cobbles of mostly Harmony Hills Tuff. The lowest cooling unit is probably a premonitory eruptive deposit that is at least 10 m thick (base not exposed); it consists of soft, light-gray, poorly welded ash-flow tuff containing about 25 percent tan cognate pumice as long as 15 cm and about 5 percent dark lithic clasts. It differs in mineralogy from typical Racer Canyon Tuff (that is, the uppermost cooling unit) in that it contains much smaller amounts of quartz and sanidine and slightly greater amounts of clinopyroxene, hornblende, and biotite.

The name Racer Canyon Tuff follows an unpublished member name suggested by Blank (1959) and later published by Cook (1960) for exposures in the eastern Bull Valley Mountains. Blank (1959) and Cook (1960) correlated it with the Kane Point Tuff Member (Mackin, 1960) of the Page Ranch Formation (Cook, 1957). Rowley and others (1979) abandoned the Kane Point Tuff Member in favor of the name Racer Canyon Tuff. The Racer Canyon Tuff is widespread east and west of the map area (Siders and Shubat, 1986). Biehl and Grant (1987) speculated that its caldera source lies along the western edge of Escalante Valley, about 7 km west of the map area, but this idea lacks supporting evidence (compare with Siders, 1985a, b; Siders and Shubat, 1986); unpublished mapping by M.A. Siders and P.D. Rowley suggests instead that the caldera is in the eastern part of the Caliente caldera complex, about 30 km southwest of the map area. The Racer Canyon Tuff is similar in lithology and age to the Hiko Tuff of Dolgoff (1963), derived from a caldera near Caliente, Nevada (Noble and McKee, 1972; Ekren and others, 1977; Rowley and Siders, 1988; Rowley and others, 1990), in the western part of the Caliente caldera complex and about 90 km to the west-southwest. Additional work, however, is needed to distinguish the two and to determine their relative ages.

Samples of Racer Canyon Tuff have received the following isotopic ages: (1) a lead-alpha age of 19 Ma on zircon (Cole and others, 1959) apparently from Kane Point, about 5 km south-southeast of the map area; (2) 18.7±0.5 Ma on biotite from north of Gunlock, nearly 30 km south-southwest of the map area (Noble and McKee, 1972); (3) 20.8±0.5 Ma on biotite from Racer Canyon, nearly 25 km southwest of the map area (Noble and others, 1968; Noble and McKee, 1972); and (4) 19.2±0.8 Ma on biotite from the Mount Escalante area about 30 km west of the map area (Siders, 1990). The Racer Canyon Tuff exhibits huge thickness variations because it was deposited in topographic lows created partly by faults as well as between laccoliths emplaced at 22 Ma (Mackin, 1960). Maximum thickness in the map area is probably about 250 m, whereas in the Silver Peak quadrangle to the east it is as thick as 335 m (Shubat and Siders, 1988)

Tv — **Local volcanic rocks (Miocene)**—Dark-reddish-brown, dark-brown, medium-gray, and purplish-red, crystal-poor, andesitic volcanic mudflow breccia, lava flows, flow breccia, and fanglomerate from unknown local sources. Consists of small phenocrysts (10–20 percent by volume) of plagioclase, subordinate pyroxene, minor olivine and Fe-Ti oxides, and local hornblende in an aphanitic groundmass of the same minerals or in a groundmass of devitrified glass. Occupies the same stratigraphic level as the Irontown Member of the Page Ranch Formation, but the Irontown is of generally different lithology, being largely fanglomerate of older volcanic rocks deposited in a synclinal warp between two plutons in the Iron Springs mining district (Mackin, 1960). Maximum thickness about 100 m

Quichapa Group (Miocene and Oligocene)—Proposed as a group by Cook (1957) for a sequence of informally named regional ash-flow tuffs, Quichapa was lowered in rank to a formation by Mackin (1960), who named the members the Harmony Hills Tuff Member, Bauers Tuff Member, Swett Tuff Member, and Leach Canyon Tuff Member. Williams (1967) and Anderson and Rowley (1975) reinstated Quichapa to group status. Age is extended to include Oligocene based on recalculation of isotopic ages on the Leach Canyon Formation

Tqh — **Harmony Hills Tuff (Miocene)**—Resistant light-gray, tan, brownish-gray, and pink, moderately welded, crystal-rich, ash-flow tuff. Appears to form one compound cooling unit in the mapped area and locally contains a dark-gray, mostly devitrified basal vitrophyre. Contains light-gray and pink, cognate pumice as much as 10 cm long and 3 cm thick. A high-alkali andesite that consists of 35–50 percent phenocrysts of plagioclase, subordinate hornblende and biotite, and minor quartz, clinopyroxene, and Fe-Ti oxides in a groundmass of devitrified shards. Isopach data on the unit suggest a source in the Caliente caldera complex of Nevada-Utah (Williams, 1967). Elevated to formation status by Cook (1965). The average isotopic age is 21.6 Ma, based on five K-Ar ages on biotite and plagioclase by Armstrong (1970) and one on biotite by Noble and McKee (1972). The actual age of the Harmony Hills Tuff, however, may be closer to 22.5–22 Ma based on isotopic ages of plutons and ash-flow tuff in the Iron Springs district that postdate the Harmony Hills Tuff (Rowley and others, 1989). Thickness about 125 m

Tqc — **Condor Canyon Formation (Miocene)**—Defined by Cook (1965) to include in descending order two previously defined rhyolitic ash-flow tuff members, Bauers Tuff Member and Swett Tuff Member (Mackin, 1960). The Swett Tuff Member, which lithologically resembles the Bauers Tuff Member but has a different mineralogy, appears to be thin and locally missing in the map area. The two members were not mapped separately; the presence of the Swett Tuff Member at the base of the formation in the extreme southeast corner of sec. 20 and the SW1/4 sec. 29, T. 36 S., R. 15 W is confirmed by petrographic study.

The Bauers Tuff Member is a resistant, crystal-poor, densely welded ash-flow tuff. A compound cooling unit, it consists mostly of an upper vapor-phase zone of light-gray and light-blue-gray homogeneous ash-flow tuff containing bronzy biotite and white pumice, grading downward into a brownish-red, reddish-purple, brown, and reddish-tan lenticulite zone containing abundant thin, gray ash-flow tuff lenticules as long as 2 m. The lenticulite zone passes abruptly downward into a lustrous black basal vitrophyre, as thick as 2 m, which is locally devitrified to crumbly orange rock. Consists of 10–20 percent phenocrysts of plagioclase, lesser sanidine, minor biotite and Fe-Ti oxides, and traces of clinopyroxene in a groundmass of mostly devitrified shards. Caldera source was predicted, largely on the basis of isopach data, by Williams (1967) to be in the Caliente caldera complex; this hypothesis was recently confirmed (Rowley and Siders, 1988). Average isotopic age is 22.3 Ma based on two K-Ar ages on biotite and sanidine by Armstrong (1970) and one K-Ar age on plagioclase by Fleck and others (1975). Maximum thickness about 140 m

The Swett Tuff Member is a resistant, crystal-poor, densely welded ash-flow tuff. A simple cooling unit consisting of light-red to brownish-red tuff, it locally contains a crumbly, orange and dark-gray, mostly devitrified basal glass zone, and consists of 10–15 percent phenocrysts of plagioclase and minor biotite and Fe-Ti oxides. Caldera source was predicted by Williams (1967) to be in the Caliente caldera complex; this is probably true based on similar chemistry of the Swett and Bauers Tuff Members and on rock types similar to both in the Caliente caldera complex (Rowley and others, 1990). The average isotopic age is 23.7 Ma, based on six K-Ar ages on biotite and plagioclase by Armstrong (1970). Thickness as much as 10 m

Tql — **Leach Canyon Formation (Oligocene)**—Soft to moderately resistant, pink, tan, light-purple, reddish-brown, and light-gray, poorly to moderately welded, crystal-poor, rhyolitic ash-flow tuff. Contains abundant light-gray and tan cognate pumice as long as 5 cm and distinctive, mostly red and reddish brown, subangular lithic clasts as much as 6 cm in diameter but generally less than 1 cm in diameter. Comprises several compound cooling units: the upper, less welded units belong to the Table Butte Tuff Member and the lower, more welded units belong to the Narrows Tuff Member (Williams, 1967; Anderson and Rowley, 1975). Members were not mapped separately. Consists of 10–20 percent phenocrysts of plagioclase, quartz, and sanidine, and minor biotite, Fe-Ti oxides, and hornblende in a groundmass of mostly devitrified shards. Isopach data on the unit suggest a source in the Caliente caldera complex (Williams, 1967). Elevated to formation status, as Leach Canyon Tuff, by Cook (1965); called Leach Canyon Formation by Williams (1967) and Anderson and Rowley (1975). Average isotopic age is 24.7 Ma based on three K-Ar ages on biotite, sanidine, and plagioclase by Armstrong (1970), but there is significant variation in these ages (22.9–26.7 Ma). Age is changed from Miocene to Oligocene based on recalculation of isotopic ages and using 24 Ma as the Miocene-Oligocene boundary. Incomplete section is about 160 m thick; in the adjacent quadrangle to the east, it is about 150 m thick (Shubat and Siders, 1988)

Isom Formation (Oligocene)—Source, presumably a caldera, is unknown. Isopach data suggest a source somewhere along the northern and western edge of Escalante Valley of Utah and Nevada, with a best estimate for the area north of Modena, which is about 30 km west of the map area (Best and others, 1989). If so, the source is covered by Tertiary and Quaternary basin-fill sedimentary rocks and volcanic rocks. Defined by Mackin (1960)

Tih — **Hole-in-the-Wall Tuff Member**—Resistant, medium-red, densely welded, crystal-poor, trachydacite ash-flow tuff containing abundant vesicles of about 1–2 mm diameter. Also contains light-gray ash-flow tuff lenticules as long as 2 m and as thick as 4 cm. One simple cooling unit; upper parts are locally flow foliated. Consists of 5–10 percent phenocrysts of plagioclase and minor clinopyroxene and Fe-Ti oxides in a devitrified groundmass of shards. Defined by Mackin (1960). Thickness about 50 m

Tib — **Baldhills Tuff Member**—Moderately resistant to resistant, medium- to dark-purplish-gray, purplish-red, medium-tan, medium-reddish-tan, medium-purple, and black, densely welded, mostly crystal-poor, trachydacite ash-flow tuff, especially in the upper part, and crystal-poor lava flows and flow breccia, especially in the lower part. Ash-flow tuff locally contains vesicles, linear vesicles, and light-gray ash-flow tuff lenticules. Locally includes beds of volcanic mudflow breccia, conglomerate, and sandstone. Consists of 5–20 percent phenocrysts of plagioclase and minor clinopyroxene and Fe-Ti oxides in a devitrified groundmass. Defined by Mackin (1960); redefined by Anderson and Rowley (1975) to include an underlying sequence of similar rocks that Mackin (1960) left as an unnamed member of the Isom Formation. Average isotopic age is 25.8 Ma based on a K-Ar whole-rock age by Armstrong (1970) and a K-Ar age on plagioclase by Fleck and others (1975). Exposed as incomplete sections, at least 180 m thick; in the northern Antelope Range 5–10 km east of the map area, thickness at least 300 m (Shubat and Siders, 1988)

Tc — **Claron Formation (Oligocene and Eocene)**—Moderately resistant, pink, purplish-red, light-gray, white, tan, and light-yellow, medium- to thick-bedded, fluvial and lacustrine sandstone and limestone, and subordinate conglomerate and siltstone. Clastic beds locally contain volcanic detritus. Clasts in conglomerate beds are as large as 15 cm in diameter and consist largely of black and gray limestone and subordinate quartzite and light-green sandstone. Sandstone beds locally crossbedded. Algal heads several centimeters in diameter and algal filaments occur in some limestone beds. Most primary fluvial and lacustrine beds have been heavily modified and bioturbated during development of B soil horizons after sediment deposition (Mullett and others, 1988a, b; Mullett, 1989). Exposed as incomplete sections, at least 160 m thick; about 300 m thick in adjacent quadrangle to the east (Shubat and Siders, 1988)

Kis — **Iron Springs Formation (Upper? Cretaceous)**—Soft to moderately resistant, light-brown, light-yellow, and light-gray, thin- to thick-bedded, crossbedded, medium- to coarse-grained lenticular continental sandstone and soft interbedded shale, and subordinate, moderately resistant conglomerate, limestone, and carbonaceous shale. Most clasts in conglomerate are light-gray quartzite. Exposed as incomplete sections, at least 200 m thick; about 1,100 m thick in the adjacent quadrangle to the east (Shubat and Siders, 1988)

Contact

Fault—Showing dip direction and dip angle of fault plane (barbed arrow) and rake direction and rake angle of slickensides (diamond arrow), where known. Bar and ball on downthrown side, where relative offset is known. Crosshatched where fault zone is wide. Dashed where approximately located; dotted where concealed; queried where location uncertain. Normal, oblique, and strike-slip faults, with opposed arrows showing relative direction of strike-slip movement. On cross section, opposed arrows show relative movement for predominantly dip-slip faults, whereas T (toward) and A (away) show relative movement for predominantly strike-slip faults

Gravity-slide block

Hydrothermally altered rock—Argillically altered rock. Propylitically altered rock not shown

Strike and dip of beds

Inclined

Horizontal

Strike and dip of flow foliation

GEOTHERMAL RESOURCES

A small area near the town of Newcastle was formerly designated a "Known Geothermal Resource Area" by the U.S. Department of the Interior. Although there are no modern hot springs in the area, shallow water wells have encountered warm and hot water and the church and several other buildings in the Newcastle area are geothermally heated. Recently, several large greenhouses just west of Newcastle have begun to grow tomatoes and tropical plants, utilizing this heat source. The hot water (about 70–80°C) comes from a depth of about 150 m; the geothermal reservoir is discussed by Rush (1983), Mabey and Budding (1987), and Budding and Bugden (1986).

The Antelope Range fault zone, named by Shubat and Siders (1988), is a major structural feature of relatively youthful age that strikes in a general north-south direction, as do most of the youngest faults in the area (Siders and Shubat, 1986). The fault zone and extensional fractures related to it probably control the geothermal resource and allow rapid migration of hot water from depth. Large gravity lows in Escalante Valley just west of the fault zone have been interpreted to indicate thick upper Cenozoic basin fill with vertical offset along the fault of about 3 km (Cook and Hardman, 1967; Pe and Cook, 1980). The Antelope Range fault zone cuts other faults in the area (Shubat and Siders, 1988) and displaces volcanic rocks as young as 8.5 Ma and surficial deposits as young as Holocene or late Pleistocene.

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