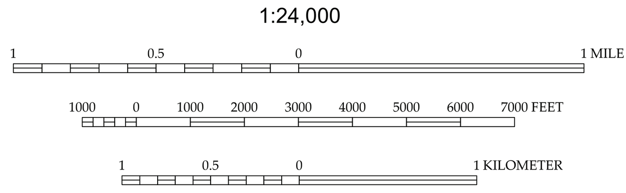
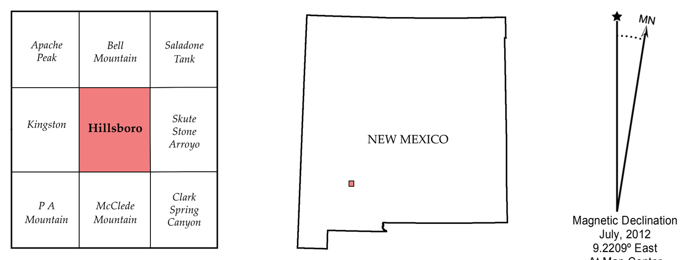
Base map from U.S. Geological Survey 1965, from photographs taken 1979, field checked in 1979. 1927 North American datum, Transverse Mercator projection. Reprojected to UTM projection NAD83 zone 13. 1000-meter Universal Transverse Mercator grid, zone 13, shown in blue.

1:24,000



CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929



Magnetic Declination July, 2012 9.2209° East At Map Center

Quadrangle Location

New Mexico Bureau of Geology and Mineral Resources
New Mexico Tech
801 Leroy Place
Socorro, New Mexico
87801-4796

[575] 835-5490

This and other STATEMAP quadrangles are available for free download in both PDF and ArcGIS formats at:

http://geoinfo.nmt.edu

New Mexico Bureau of Geology and Mineral Resources
Open-file Geologic Map 242

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Geologic Map of the Hillsboro 7.5-Minute Quadrangle, Sierra County, New Mexico

June, 2014

by
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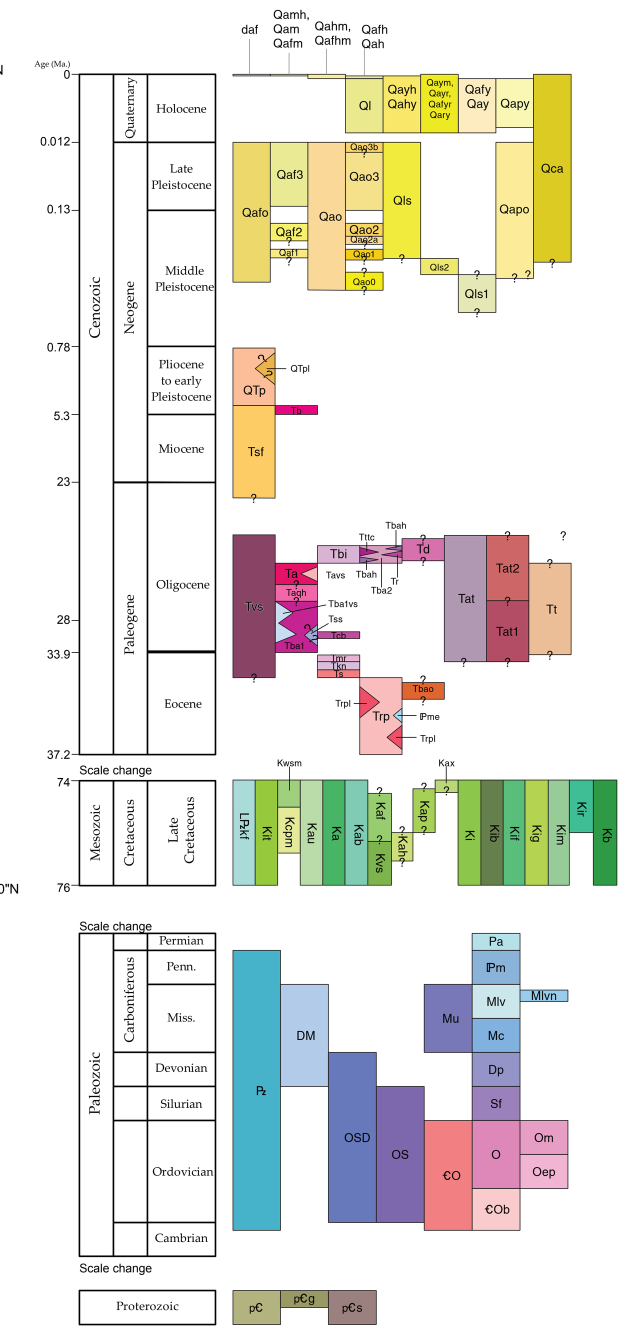
Comments To Map Users

A geologic map displays information on the distribution, nature, orientation, and age relationships of rock and deposits and the occurrence of structural features. Geologic and fault contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic quadrangle map may be based on any of the following: reconnaissance field geologic mapping, compilation of published and unpublished work, and photogeologic interpretation. Locations of contacts are not surveyed, but are plotted by interpretation of the position of a given contact onto a topographic base map; therefore, the accuracy of contact locations depends on the scale of mapping and the interpretation of the geologist(s). Any enlargement of this map could cause misunderstanding in the detail of mapping and may result in erroneous interpretations. Site-specific conditions should be verified by detailed surface mapping or subsurface exploration. Topographic and cultural changes associated with recent development may not be shown.

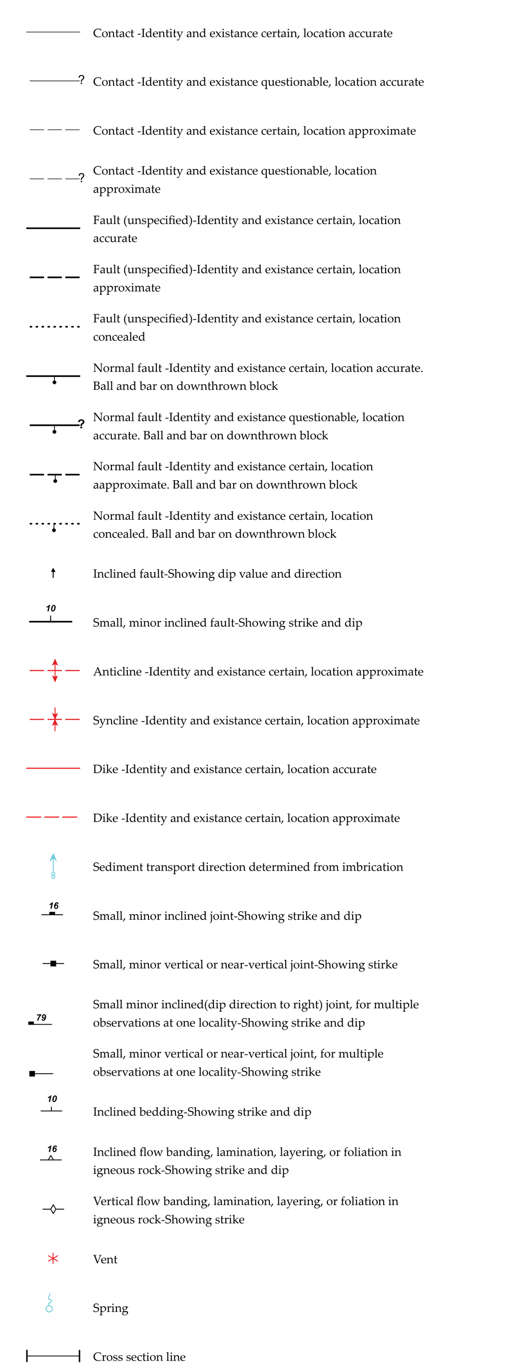
Cross sections are constructed based upon the interpretations of the author made from geologic mapping, and available geophysical, and subsurface (drillhole) data. Cross-sections should be used as an aid to understanding the general geologic framework of the map area, and not be the sole source of information for use in locating or designing wells, buildings, roads, or other man-made structures.

The map has not been reviewed according to New Mexico Bureau of Geology and Mineral Resources standards. The contents of the report and map should not be considered final and complete until reviewed and published by the New Mexico Bureau of Geology and Mineral Resources. 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 State of New Mexico, or the U.S. Government.

Correlation of Map Units



Explanation of Map Symbols



Map Unit Descriptions

Quaternary valley bottom units

daf **Disturbed or artificial fill (present to ~50 years old)** – Sand and gravel that has been moved by humans to form earthen dams, or has been removed for construction.

Qam **Modern alluvium (present to ~50 years old)** – Sandy gravel in ephemeral drainages subject to annual runoff. Retains bar-and-swale topography with up to 1 m of relief. Thickness is likely 3 m.

Qamh **Modern and historic alluvium, undivided (present to ~800 years old)**

Qah **Historic alluvium (~50 to ~800 years old)** – Sandy pebble to pebble-cobble gravel found in valley bottoms. Retains bar-and-swale topography with up to 30 cm of relief. May be horizontally laminated. Tread height 0.6-1.2 m above modern grade. Perhaps up to 2.5 m maximum thickness.

Qahm **Historic and modern alluvium, undivided (present to ~800 years old)**

Qahy **Historic and younger alluvium, undivided (~50 years old to middle Holocene)**

Qayr **Recent (modern and historic) and younger alluvium, undivided (present to middle Holocene)**

Qay **Younger alluvium, undivided (middle to upper Holocene)** – Gravelly sand underlying low-lying terraces in valley bottoms. Retains subdued bar-and-swale topography with 10-20 cm of local relief. Matrix is browner than that of **Qao**. Sandier than **Qah**, with greater cross-stratification. Tread height 1.6-1.8 m above modern grade. 3 m thick.

Qaym **Younger and modern alluvium, undivided (present to middle Holocene)**

Qayh **Younger and historic alluvium, undivided (~50 years old to middle Holocene)**

Qayr **Younger and recent (modern and historic) alluvium, undivided (present to middle Holocene)**

Ql **Lacustrine sediment (middle to upper Holocene)** – Gray, fine-grained sediment filling the valley of Trujillo Creek. Horizontally-laminated with weak ripple-lamination in sandier beds. Strongly calcareous, but only rarely exhibits stage I carbonate morphology. 6.1-9 m thick.

Quaternary stream terrace deposits

Qao **Stream terrace deposit, undivided (middle to upper Pleistocene)** – Imbricated, sandy gravel occurring in strath terrace deposits with surfaces higher than those associated with **Qay**. Clast compositions are dominated by Tertiary volcanic lithologies with subordinate Paleozoic sedimentary rocks. Locally subdivided into 3-5 deposits:

- **Qao3** **Third or youngest terrace (upper Pleistocene)** – Sandy pebble-cobble gravel with coarser matrix than **Qao2** and **Qao1**. Little to no pedogenic carbonate development. Tread is 6.2-8.5 m above modern grade, except for subordinate deposit **Qao3b** with a slightly lower tread height (~5 m). 1.7-3.8 m thick.
- **Qao2** **Second terrace deposit (middle Pleistocene?)** – Similar to **Qao1** deposit with variable varnish on clasts at surface and stage I+ carbonate morphology. Subordinate to **Qao1** and **Qao3** terrace deposits. Tread is 13.8-13.8 m above modern grade, except for subordinate deposit **Qao2a** with a slightly higher tread height (~15-16 m). 1.7-2.0 m thick.
- **Qao1** **First terrace deposit (middle Pleistocene?)** – Sandy pebble-cobble-boulder gravel with well-varnished clasts at surface. Matrix is browner than **Qao2** and **Qao3** deposits. May be variably deflated or mixed with eolian material at surface. Features stage I+ carbonate morphology. Tread is 20.8-21.5 m above modern grade. 2.1-4.1 m thick.
- **Qao0** **Oldest terrace deposit (middle Pleistocene?)** – Loose, subrounded to rounded cobbles and boulders on the south side of Percha Box. Tread is 36-38 m above modern grade. 1-2 m thick.

Quaternary alluvial fan units

Qafmh **Modern and historic fan alluvium, undivided (present to ~800 years old)** – Pebbly sand to sandy-pebble-cobble gravel in medium to thick, tabular beds. Unconsolidated, matrix-supported, and massive. Maximum thickness ~3 m.

Qafhm **Historic and modern fan alluvium, undivided (present to ~800 years old)**

Qafh **Historic fan alluvium (~50 to ~800 years old)** – Sandy gravel underlying lowest inset alluvial fans graded to the surface of **Qah**. Features more clast-supported beds than **Qafy**. Little or no soil development or varnishing of clasts at surface. 0.8-1.2 m thick.

Qafy **Younger fan alluvium (middle to upper Holocene)** – Sandy gravel underlying alluvial fans graded to the surface of **Qay**. Surface lies up to 2 m above that of **Qafh**. May be capped by 0.9-1 m soil profiles with 50 cm Bt horizons featuring clay films on clasts; may also include Btk horizons with stage I+ carbonate morphology. 2.2-3 m thick.

Qafyh **Younger and recent (modern + historic) fan alluvium, undivided (present to middle Holocene)**

Qafyr **Younger and recent fan alluvium, undivided (present to middle Holocene)**

Older alluvial fan deposits graded to stream terraces of Percha Creek and its tributaries

Qafo **Older alluvial fan deposits, undivided (middle to upper Pleistocene)** – Sandy gravel occurring in fan deposits graded to surfaces associated with **Qao1, Qao2**, and **Qao3**. Locally subdivided into three fan deposits:

- **Qaf3** **Alluvial fans graded to the level of Qao3 stream terraces (upper Pleistocene)** – Sandy-pebble or pebble-cobble-boulder gravel with more boulders than **Qaf1** and **Qaf2**. Commonly, overlain by soil profiles, 60 cm thick with lower Bk horizons exhibiting stage I+ to II carbonate morphology. 1.7-2.3 m thick.
- **Qaf2** **Alluvial fans graded to the level of Qao2 stream terraces (middle Pleistocene?)** – Sandy-pebble gravel and occasional, discontinuous lags of cobble-boulder gravel. More commonly matrix-supported than **Qaf1** and **Qaf3**. Calcic horizons or soil carbonate development not typically preserved due to surface erosion. Typical thickness ~4 m.
- **Qaf1** **Alluvial fans graded to the level of Qao1 stream terraces (middle Pleistocene?)** – Matrix-supported, massive, sandy gravel. Matrix is more yellowish-brown than **Qaf2** and **Qaf3** deposits. Deposit is poorly preserved due to erosion. Maximum thickness 3.5 m.

Quaternary piedmont deposits

Qapy **Younger piedmont alluvium (middle to upper Holocene)** – Matrix-supported, massive, pebbly sand. Rarely features weakly to non- to very weakly varnished pebble-cobble gravel. Occasional, stage I carbonate morphology in upper 20 cm. 1.7-2 m thick.

Qapo **Older piedmont alluvium (middle to upper Pleistocene)** – Clast- to matrix-supported, massive- to weakly imbricated, sandy gravel. Occasionally features stage II-III carbonate morphology. 2.2-3.6m thick.

Quaternary hillslope and landslide deposits

Qca **Colluvium and alluvium, undivided (middle Pleistocene to Holocene)** – Poorly sorted, silt to boulders forming aprons around highlands. Maximum thickness 8 m.

Qls **Landslide deposits, undivided (middle to upper Pleistocene?)** – Non-stratified, cobble-boulder gravel. Larger clasts may be oriented with their long axes pointed downslope. Underlies steep escarpments of Copper Flat andesite/breccia or **Tb**. Maximum thickness 10 m. West of Percha Creek narrows, two large landslide deposits are mapped individually:

- **Qls2** **Younger Percha Creek narrows landslide deposit (middle Pleistocene?)** – Poorly stratified, bouldery gravel that is occasionally reverse graded. Clasts often oriented with long axes parallel to slope. Matrix sand is comprised of 90% lithic grains. Deposit features blocks of andesite 10's of meters across with chaotic fracturing. Thickness unknown.
- **Qls1** **Older Percha Creek narrows landslide deposit (middle Pleistocene?)** – Poorly stratified, bouldery gravel, similar to **Qls2**, but occupying a lower landscape position. Deposit contains boulders on 2-3° slopes up to 1 km away from steep escarpments of source exposures. Hummocky landscape underlain by deposit has distinct run-out toes and occasional lobes of open-framework cobbles and boulders. Thickness unknown.

Quaternary-Tertiary basin-fill

QTp **Palomas Formation of the Santa Fe Group (lower Pliocene to middle Pleistocene)** – Sandy gravel and conglomerate in clast-supported, medium to very thick, tabular, massive to imbricated beds. Contains greater percentages of cobbles and boulders than **Tsf**. Forms gentle to moderate slopes and ledges. Maximum thickness 13 m.

- **QTpl** **Palomas Formation limestone (lower Pliocene to middle Pleistocene)** – Tan to gray, fine- to medium-grained crystalline limestone. Unidentifiable bivalve shells are preserved near the top of the exposure. 3-5 m thick.

Tsf **Santa Fe Group predating the Palomas Formation (Miocene-Pliocene)** – Pebbly sand/sandstone, pebble-granule gravel/conglomerate, and pebble-cobble gravel/conglomerate in matrix-supported, thin to thick, tabular, massive to weakly cross-stratified beds. Generally finer-grained than **QTp** (clasts and matrix). Common silica-cemented beds form prominent ledges and small cliffs. Maximum thickness 204 m.

Tt **Thurman Formation (middle to upper Oligocene)** – Pebbly to silty sandstone and pebble-cobble conglomerate, in thickly- to medium-laminated, broadly cross-stratified beds. Unit fills in small paleovalley cut into **Taqh, Tba1**, and **Tkn** in southwestern part of quad. Silty, very fine-grained sand occurs in laminated beds. Approximately 30 m thick.

Tertiary volcanic and volcaniclastic units

Tb **Basalt flows (lower Pliocene)** – Dark-bluish to very dark-gray or black, aphanitic to aphanitic-porphyritic, fine- to medium-grained basalt. Forms columnar-jointed ledges and cliffs capping mesas. Phenocrysts include 3-7% pyroxene, 0-5% plagioclase, and 1-3% olivine. Dense to somewhat vesicular; commonly contains amygdules filled by silica and/or zeolites. The Warm Springs Canyon basalt was dated by Seager et al. (1984) at 4.2 ± 0.1 Ma ($^{40}K/^{40}Ar$). Maximum thickness 40 m.

Tvs **Volcaniclastic deposits, undivided (Oligocene)** – Stratigraphically isolated pockets of volcaniclastic debris flows on Paleozoic rocks south of Copper Flat. May contain pebbles and granules of dacite with hornblende and biotite. 1-5 m thick.

Tat **Andesite of Trujillo Peak (upper Oligocene?)** – Dark-gray to purplish-brown, aphanitic to aphanitic-porphyritic, fine- to medium-grained andesite. Forms steep rubbly slopes and ledges below Trujillo Peak. Locally subdivided into 2 units:

- **Tat2** **Upper andesite of Trujillo Peak** – Alternately dense and scoriaceous to vesicular. Vesicles contain silica or calcite amygdules. Lacks hornblende phenocrysts. Approximately 80 m thick.
- **Tat1** **Lower andesite of Trujillo Peak** – Non-vesicular and strongly foliated. Approximately 120 m thick.

Td **Dacite (upper Oligocene)** – Medium- to dark-gray, hackly weathering, porphyritic-aphanitic, fine-to coarse-grained, dacitic lava flows, and block and ash breccia. Forms ledges and steep, rubbly slopes. Phenocrysts include 8% plagioclase, 3-4% pyroxene, trace to 5% quartz, trace biotite, and trace hornblende. Non-vesicular and foliated; coarser grained, and less foliated in upper 15 m (49 ft). Breccia is composed of monolithologic clasts with 10-15% total phenocrysts of sanidine, biotite, hornblende, quartz, and zoned potassium feldspar. Maximum thickness is 35 m.

Tttc **Tuffaceous volcaniclastic sediment of Tank Canyon (upper Oligocene)** – Laminated, tabular beds of weakly sorted volcaniclastic conglomerate with minor volumes of laminated fine-grained ash beds, ignimbrites, and fluvial conglomerate and sandstone. Laminated, hyperconcentrated deposits are interbedded with conglomerates and sandstone with fluvial cross-bedding and scoured channels. 30 to 60 m thick.

Tr **Rhyolite (upper Oligocene)** – Porphyritic rhyolite flows that are variably massive to flow banded. In the thicker parts of the section, the flows are more crystal rich (15-25%) and pink at the top, and more crystal poor (3-10%) and gray near the base. Block and ash deposits near the base are common. Phenocrysts include sanidine, quartz, biotite, and hornblende. The rhyolite flow unit is intercalated with **Tba2** and may correlate with Tr4 of Seager et al. (1982). This unit was included in T4ba by Seager et al. (1982). Variable in thickness, ranging from 15 to 120 m; thins toward the south.

Tba2 **Younger basaltic andesite (upper Oligocene)** – Mafic flows with a black to dark-gray aphyric to crystalline matrix and 1-2% phenocrysts of plagioclase laths, subrounded olivine, and pyroxene. Flows are commonly strongly foliated in the core and vesicular at the top. North of Percha Creek narrows, this unit correlates to T4ba of Seager et al. (1982). 300 m thick.

Tbi **Basaltic andesite dike (upper Oligocene)** – Mafic dike with a black to dark-gray, aphyric matrix and 1-2% phenocrysts of plagioclase, olivine, and pyroxene that appears to be the feeder for one of the younger basaltic-andesite flows.

Tbah **Hydromagmatic deposits in younger basaltic andesite (upper Oligocene)** – Gray, sandy hydromagmatic deposit with tabular, laminated, weakly graded bedding with white to pink altered clasts that make up 2-3% of the rock. 1 m thick.

Ta **Aphanitic trachyandesite (upper Oligocene)** – Massive to variably foliated, vesicular, aphanitic to aphanitic-porphyritic, fine-grained trachyandesite. Phenocrysts include < 3% total plagioclase, biotite, hornblende, and pyroxene. May contain small quartz xenocrysts. Vesicles may contain acicular zeolites. ~98 m thick

- **Tavs** **Volcaniclastic debris flows with quartz-hornblende andesite/dacite clasts (upper Oligocene)** – Well indurated, heterolithic volcaniclastic debris-flow deposit containing blocks up to 0.5 m in diameter. Blocks are poorly sorted, angular, and are found in a pink, sandy matrix. Other intervals may consist of fine-grained sandstone containing 3-5% granules of volcanic rocks, including **Taqh**. Maximum thickness ~27 m.

Taqh **Quartz-hornblende andesitic to dacitic flows and flow breccias (upper Oligocene)** – Aphanitic andesite and dacite flows and flow breccias. Phenocrysts include 1-2% total quartz, pyroxene, plagioclase, and altered hornblende. May contain disseminated magnetite. Breccia is clast- to matrix-supported and contains angular blocks up to 0.5 m in diameter. = 50 m thick.

Tba1 **Older basaltic andesite (lower to upper Oligocene)** – Medium-bluish or purplish-gray to dark-gray, porphyritic-aphanitic to porphyritic, fine- to coarse-grained andesite. Forms ledges and small cliffs. Phenocrysts include 2-10% pyroxene, 3-8% plagioclase, 5% olivine, and trace to 6% hornblende. Dense to vesicular; vesicles filled by chalcedony or drusy quartz. Strongly foliated in middle intervals; occasionally flow-banded in aphanitic intervals. Correlates to units Tpl of Hedlund (1977) and T4ba of Seager et al. (1982). Dated by Seager et al. (1984) at 28.1 ± 0.6 Ma ($^{40}K/^{40}Ar$). Approximately 470 m thick.

- **Tba1vs** **Volcaniclastic debris flows interbedded with basaltic andesite (lower upper Oligocene)** – Maroon-brown volcaniclastic conglomerate, in poorly stratified, medium-to very-thick beds. Massive to weakly imbricated. Clasts include very poorly sorted, mostly subangular pebbles, cobbles, and boulders of aphanitic to porphyritic-aphanitic, plagioclase-phyric andesite. Finer-grained intervals may display flow-banding. Matrix contains 5-10% plagioclase, 5% hornblende, and 2% quartz phenocrysts. Forms ledges and very steep, rubbly slopes. Maximum thickness 102 m.

Tss **Lacustrine sediment (lower to upper Oligocene)** – Silty sandstone and sandy siltstone in thick laminae and thin beds that are horizontally laminated to planar or trough cross-bedded. Siltstone contains dark-brown laminations of clayey silt occurring at 2-10 mm intervals. Weathers into chips containing coarse, angular biotite grains. Common limonite concretions and lenses up to 8 cm wide. Maximum thickness 37 m.

Tcb **Caballo Blanco Rhyolite Tuff (lower Oligocene)** – Cross-section only. White to light-gray, crystal-rich ash-flow tuff. Phenocrysts include sanidine, oligoclase, and quartz that constitute 25-35% of rock. Common lithic fragments. $^{40}K/^{40}Ar$ dated at 29.8 ± 0.8 Ma (Seager, 1984). Maximum thickness approximately 91 m.

Tmr **Mimbres Peak Formation rhyolite (upper Eocene)** – Light-purplish-gray, dense, strongly flow-banded, aphanitic rhyolite. Laterally(?) grades into very light-gray weathering, light-tan, flow-banded, porphyritic-aphanitic, brecciated block and ash-flow tuff west of Percha Creek narrows. Phenocrysts there include up to 5% sanidine. May contain spherulites. $^{40}Ar/^{39}Ar$ dated at 34.32 ±0.11 to 34.22 ± 0.16 Ma (O'Neill et al., 2002). Maximum thickness 52 m.

Tkn **Kneeling Nun Tuff (upper Eocene)** – Gray to dark-maroon-brown, porphyritic, moderately to densely welded ash-flow tuff. Forms ledges or bold cliffs throughout quadrangle. Phenocrysts include 6-24% quartz, trace to 6% biotite, trace to 4% hornblende, and trace to 2% plagioclase. Phenocryst content increases up section. Non- to slightly vesicular, with moderately to strongly flattened pumice in welded sections. Lower intervals contain spherulites 1-4 cm in diameter. $^{40}Ar/^{39}Ar$ dated at 35.34 ± 0.10 Ma (McIntosh et al., 1991). 7-156 m thick.

Ts **Sugarlump Tuff (upper Eocene)** – Pinkish- to tannish-white, non- to somewhat-welded, porphyritic-aphanitic to porphyritic, fine- to coarse-grained, lithic-rich ash-flow tuff. Forms moderate to steep slopes. Phenocrysts include 3-15% quartz, trace-9% biotite, and 0-6% hornblende. Lithic fragments make up to 35% of visible grains and occur as coarse ash to lapilli. Common pinkish-tan pumice fragments up to 3 cm. Densely welded in upper 1.5-12 m. Interbedded with gray, very thin- to thin-bedded, weakly cross-bedded, poorly sorted, subangular to subrounded, medium- to coarse-grained sandstone. Clastic grains are up to 70% quartz. $^{40}Ar/^{39}Ar$ dated at 35.63 ± 0.15 Ma (McIntosh et al., 1991). Maximum thickness 35 m.

Tbao **Older basaltic andesite (Eocene)** – Dark-gray, weathering grayish-tan, foliated to dense, porphyritic-aphanitic, fine-grained basaltic andesite. Forms slopes and occasional ledges. Phenocrysts include 4-6% plagioclase and 2-4% pyroxene. Perhaps correlative to **Trpl**. Maximum thickness approximately 37 m.

Trp **Rubio Peak Formation (Eocene)** – Whitish to medium-dark-gray to greenish, thin- to thick-bedded, typically massive, poorly to moderately sorted, silty, very fine- to coarse-grained volcaniclastic sandstone with occasional horizontally-laminated siltstone or lenses of conglomerate. Interbedded with andesitic lava flows with 4-5% total phenocrysts. Maximum thickness 55 m. Locally subdivided into 2 interbedded units:

- **Trpl** **Andesite flows of the Rubio Peak Formation** – Medium-gray, dense, flow-layered andesite with 10% plagioclase, 4-5% hornblende, and trace biotite phenocrysts. Altered, massive, light-gray lava contains < 2% plagioclase and 4-5% total phenocrysts; mafic minerals are altered to clay.
- **IPme** **Exotic block of Magdalena Group limestone** – Observed in Trujillo Park Canyon. Transported during major landslide event(s). See **IPm** description.

Cretaceous volcanic and intrusive units

Ki **Intrusive rocks of Copper Flat, undivided (upper Cretaceous)** – Greenish-gray to dull-grayish-green, weathering light-tan to dark-orange-brown, aphanitic-porphyritic to porphyritic, fine- to slightly coarse-grained dikes and plugs intruding andesitic flows and flow breccia of Copper Flat as well as Paleozoic carbonate units north and south of Copper Flat. Phenocrysts include 5-12% plagioclase, trace to 6% hornblende, 1-5% pyroxene, and trace biotite. May contain accessory pyrite up to 0.75 mm. Dikes are commonly 4-8 m wide, but may be up to 38 m wide (McLemore etal., 1999). Subdivided into 5 intrusive facies:

- **Kib** **Biotite-phyric intrusive rocks** – White to pink to yellowish-white dikes with 5% phenocrysts of potassium feldspar, hornblende, and biotite ± pyroxene that are 3 mm across in a fine- to medium-grained, equigranular matrix.
- **Kif** **Feldspar-phyric intrusive rocks** – Green-gray, weathering pistachio-green, poorly outcropping, and aphanitic-porphyritic. Phenocrysts include 3-5% sanidine and trace quartz; may feature a plagioclase-rich groundmass. South of Copper Flat, **Kif** plugs contain 5% feldspar phenocrysts in a black, equigranular, fine-grained matrix with clots of pyroxene up to 10 mm across. Correlates to unit Kql of Hedlund (1977).
- **Kig** **Gabbroic intrusive rocks** – Dark-gray to black plug with dark-gray plagioclase and pyroxene forming a fine- to medium-grained, equigranular matrix.
- **Kim** **Monzonitic intrusive rocks** – Equigranular plug with a gneissic fabric near its margin. Contains xenoliths of gabbro near its margin. Medium-grained, equigranular matrix is composed of plagioclase, potassium feldspar, and biotite; quartz is not present. Chilled margin is porphyritic with potassium feldspar and altered biotite.
- **Kir** **Rhyolitic intrusive rocks** – Pink to white dikes and plugs with 5% phenocrysts of quartz, sanidine, biotite, and hornblende in an aphanitic to medium-grained equigranular matrix. Mapped as Tql (Tertiary quartz latite) by Hedlund (1977).

Kit **Intrusive rocks of Trujillo Creek (upper Cretaceous)** – Dark-bluish-gray, porphyritic, fine- to medium-grained andesite. Forms rubbly knobs and small ledges. Phenocrysts include 8-10% plagioclase, 5-6% hornblende, and 2-4% pyroxene. Hornblende and pyroxene may show graphic texture with plagioclase. Correlates to intrusive andesite Tii of Seager (1986) and hornblende andesite and latite (Krp) of Hedlund (1977). Maximum thickness 54 m.

Kwsm **Warm Springs quartz monzonite (upper Cretaceous)** – Whitish-gray, ledge- to bouldery-slope-forming, non- to slightly vesicular, occasionally dense, porphyritic, equigranular, fine- to medium-grained quartz monzonite. Phenocrysts include 15-20% quartz, 9-12% biotite, 5-8% sanidine, and trace to 2% plagioclase. McLemore et al. (1999) dated this unit at 74.4 ± 2.6 Ma ($^{40}Ar/^{39}Ar$). Total thickness unknown.

Kcpm **Copper Flat quartz monzonite (upper Cretaceous)** – Porphyritic, fine- to medium-grained, plutonic quartz monzonite. Phenocrysts include 10-20% plagioclase and trace pyroxene and pyrite. McLemore et al. (1999) dated this unit at 74.93 ± 0.66 Ma ($^{40}Ar/^{39}Ar$). Total thickness unknown.

Kau **Volcaniclastic deposits and lava flows on the northwestern side of Copper Flat, undivided (upper Cretaceous)** – Lava flows (labeled/assumed to be **Ka**) and dikes (**Ki**) in this area were determined using photogrammetry and have not be field checked due to restricted land access. **Kau** is likely dominated by volcanic deposits with a few interbedded andesite flows.

Ka **Andesite flows and flow breccia of Copper Flat, undivided (upper Cretaceous)** – Grayish green to medium-bluish or dark-gray, porphyritic-aphanitic to porphyritic, fine- to coarse-grained andesite. Forms ledges or moderate to steep, rubbly slopes. Phenocrysts include 4-17% plagioclase, 0-8% hornblende, 0-5% biotite, and 0-5% pyroxene. Plagioclase phenocrysts up to 2 cm are found in upper intervals. Vesicularity increases up section. May contain xenoliths of intermediate to silicic compositions. McLemore et al. (1999) dated an andesite flow at 75.4 ± 3.5 Ma ($^{40}Ar/^{39}Ar$). Hedlund (1977) cites total thickness of andesite flows as 830 m based on drill core data. Locally divided into seven volcanic or volcaniclastic subunits:

- **Kax** **Pyroxene-phyric andesite flows of Copper Flat** – Crystal-rich lava with conspicuous 5-7 mm pyroxene phenocrysts on weathered surfaces. Phenocrysts include plagioclase and potassium feldspar in addition to pyroxene. These lavas are exposed beneath **Tb** on Black Peak; contact metamorphism there caused copper mineralization in fractures in **Kax** on the east side of the peak. Underlain by fine-grained andesite flows. = 35 m thick.
- **Kap** **Plagioclase-phyric andesite flows of Copper Flat** – Gray, porphyritic, fine- to coarse-grained andesite. Forms ledges atop ridges of **Kaf**. Phenocrysts include 20-25% plagioclase, 4-7% pyroxene, and trace biotite. Contains 2-5% lithic fragments and trace to 3% disseminated magnetite. Non-vesicular and moderately foliated.
- **Kaf** **Potassium feldspar-phyric andesite flows of Copper Flat** – Greenish-gray, hypidiomorphic granular, fine- to very coarse-grained andesite. Forms ledges, steep rubbly slopes, and some hilltops. Phenocrysts include 15-17% sanidine megacrysts, 6% plagioclase, 2-3% pyroxene, and 1-2% hornblende. Dense/non-vesicular.
- **Kah** **Hornblende-phyric andesite flows of Copper Flat** – Medium to dark-gray, porphyritic-aphanitic, fine- to medium-grained andesite. Forms small benches below **Kaf** and **Kap**. Phenocrysts include 3-8% hornblende, 4-6% plagioclase, and trace pyroxene. Some what dense/non-vesicular to slightly vesicular. Propylitization increase down-section. Plagioclase content may increase down-section where unit interfingers with **Kab** or **Kau**.
- **Kvs** **Volcaniclastic debris flows of Copper Flat** – Greenish-gray debris flows with clasts that are light-colored and fine-grained. Most clasts are < 4 cm, though some are up to 0.5 m across. A few clasts are porphyritic lava with 3-4% pyroxene and plagioclase phenocrysts; the unsorted deposits are matrix supported and the clasts are angular. Maximum exposed thickness is 20 m.
- **Kab** **Laharic flow breccia of Copper Flat** – Dark-purplish-gray, mostly matrix-supported, massive, non-vesicular volcaniclastic breccia composed of angular to subangular, pebbles and cobbles. Pebble content increases up-section. Protruding fragments form rough weathered surfaces. Exhibits rare trough cross-bedding in finer-grained intervals. Groundmass/matrix typically aphanitic. May contain jumbled blocks of andesite 10's of meters across. May interfinger with **Kaf, Kah**, and/or **Kau**.

Kb **Basaltic intrusion of Copper Flat** – Porphyritic intrusion; crystal-rich with 10-15% Ca-plagioclase < 2 mm long. Minor pyroxene. Occurs in a dike and sill, the latter approximately 3 m thick.

Karst fill

LPzkf **Karst fill (Cretaceous?)** – Localized deposits usually found in the Ordovician El Paso or Montoya formations that contain fragments of red siltstone, blocks (10's of meters across) of Upper Paleozoic limestone and chaotically deformed Percha Shale in a red, silty matrix. Sinkholes may have formed during the emplacement and mineralization of the plutons at Copper Flat. The largest deposit on the east end of Percha Creek Box is about 300 to 400 m in diameter and is atleast 60 m thick.

Paleozoic bedrock

Pz **Paleozoic sedimentary rocks, undivided (Cambrian to Permian)** – Applied to strongly altered sedimentary blocks exposed in slivers along the Berrenda fault zone.

Pa **Abo Formation (lower Permian)** – Cross-section only. Reddish-brown to light-brown sandstone interbedded with grayish-red shale and siltstone. Approximately 121 m thick in the Black Range; top is likely eroded in cross-section.

IPm **Magdalena Group (upper to middle Pennsylvanian)** – Pink to brownish-gray, very thin- to thick-bedded, massive, somewhat cherty, sparsely fossiliferous limestone with subordinate siltstone, mudstone, and shale. Fossils include bryozoans, echinoderm fragments, fusulinids, ostracods, and brachiopods. Brachiopods common up-section. Bioturbated by horizontal burrows. Altered or metamorphosed to jasperoid, skarn, and marble along margins of Copper Flat volcanic system. 130-255 m thick.

Mu **Mississippian strata, undivided (lower Mississippian)** – Cross-section 94 m in cross-section.

DM **Devonian through Mississippian strata, undivided (upper Devonian through lower Mississippian)** – Includes the Percha Shale and Lake Valley Limestone. Differentiated where identification of individual units is precluded by alteration, or where access to exposures was denied. Mapped in northern quad.

Mlv **Lake Valley Limestone (lower Mississippian)** – Dark- to light-tannish-gray, thin- to thick-bedded, massive to horizontally laminated, cherty, fossiliferous, occasionally marly limestone with subordinate siltstone and mudstone. Chert weathers to dark-orange-brown and occurs as crusts, lacy networks, and lenses. Crinoid stems often in such abundance as to form crinoid "hash." Other fossils include small echinoderm fragments and brachiopods. Forms series of ledges and small cliffs above slopes of **Dp**. Maximum thickness 84 m. Locally subdivided into the crinoid-rich Nunn Member:

- **Mlvn** **Nunn Member** – Medium-gray, thin- to medium-bedded, massive limestone with many large crinoid fragments and rare chert nodules. Abundance of crinoids gives unit the appearance of a crinoid "hash." Often marly and coarsely crystalline (O'Neill et al., 2002). Maximum thickness 36 m.

Mc **Caballero Formation (lower Mississippian)** – Dark-gray, medium- to thick-bedded, massive to cross-stratified or laminated, cherty, fossiliferous limestone. Commonly an arenaceous to marly packstone (O'Neill et al., 2002). Chert occurs as dark-colored masses and networks. Fossils include crinoid and other echinoderm fragments. 8-10 m thick.

OSD **Ordovician through Devonian strata, undivided (lower Ordovician through upper Devonian)** – Includes the El Paso Formation, Montoya Formation, Fusselman Dolomite, and Percha Shale. Differentiated where identification of individual units is precluded by alteration. Mapped in absence of upper Paleozoic carbonates (**Mc, Mlv**, and **IPm**), typically in fault zones.

Dp **Percha Shale (upper Devonian)** – Dull grayish green to yellowish gray to black, fissile, calcareous shale. Interbeds with light-purplish-gray, very thinly bedded to laminated, non-calcareous siltstone. Forms moderate to steep slopes below ledges and small cliffs of **Mlv**. Fossiliferous in its upper ~15 m, containing fenestelloids and other bryozoans, as well as numerous brachiopods. Features limestone nodules upper 6-10 m. Maximum thickness 102 m.

OS **Ordovician through Silurian strata, undivided (lower Ordovician through lower Silurian)** – Includes the El Paso Formation, Montoya Formation, and Fusselman Dolomite. Differentiated where identification of individual units is precluded by alteration. Mapped where **Dp** is conspicuously absent.

Sf **Fusselman Dolomite (lower to middle Silurian)** – Light- to dark-gray, thin- to thick-bedded, massive to weakly laminated, sparsely fossiliferous, cherty, dolomitic wackestone. Forms a series of ledges and slopes. Purplish-gray chert, weathers orange to reddish-brown and occurs in veins, crusts, lenses, and beds 1-7 cm thick. Less cherty in upper part. Contains occasional brachiopods that are commonly silicified. Brecciated jasperoid beds near the top of the formation. Approximately 22 m thick.

€O **Cambrian through Ordovician, undivided (upper Cambrian through upper Ordovician)** – Includes the Bliss Sandstone, El Paso Formation, and Montoya Formation. Differentiated where identification of individual units is precluded by alteration.

O **Ordovician strata, undivided (lower to upper Ordovician)** – Ordovician strata exposed in the Hillsboro quadrangle commonly feature pervasive alteration to jasperoid, skarn, or marble (McLemore et al., 1999). Brecciated jasperoids containing clasts of limestone and chert are common in the vicinity of the Percha Creek box. Where unaltered, these rocks are whitish to very dark-gray, thin- to medium-bedded, commonly wavy bedded dolostone and limestone. Total thickness 286 m (Hedlund, 1977).

- **Om** **Montoya Formation (middle to upper Ordovician)** – The base of the Montoya Formation is marked by the 3 to 12 m thick Cable Canyon Sandstone, a poorly sorted quartz arenite with angular, very fine to fine-grains, and subrounded-medium grains. Sandstone is typically overlain by dark gray, thin-bedded, tabular, massive, non-fossiliferous, sparsely cherty dolostone. Chert occurs as crusts. May be altered to a strata-bound jasperoid or metamorphosed to marble. Contains solitary coral and few brachiopods. Total thickness of 140 m (Hedland, 1977).
- **Oep** **El Paso Formation (lower Ordovician)** – Medium- to dark-gray, thin- to thick-bedded, tabular, cherty, somewhat fossiliferous, packstone to lime mudstone. Pink to red chert may be laminated. Fossils include small bryozoans and sponges, ostracods, and horizontal burrows. Chert occurs in lacy networks. The El Paso below the Cable Canyon Sandstone has gastropods, horn coral, stromatolites, and tiny brachiopods. The El Paso just above the Bliss Sandstone has burrows and poorly preserved brachiopods. Total thickness of 146 m (Hedlund, 1977).

€Ob **Bliss Formation (upper Cambrian to lower Ordovician)** – Very dark-bluish-gray, well-indurated, tabular, horizontally to ripple cross-laminated, very well-sorted, subrounded to rounded, very fine- to fine-grained quartzose sandstone. May be a quartzite with a poorly sorted sandstone protolith containing 95% quartz and 5% altered grains. Features common vertical burrows occasionally replaced by chert. ~40 m.

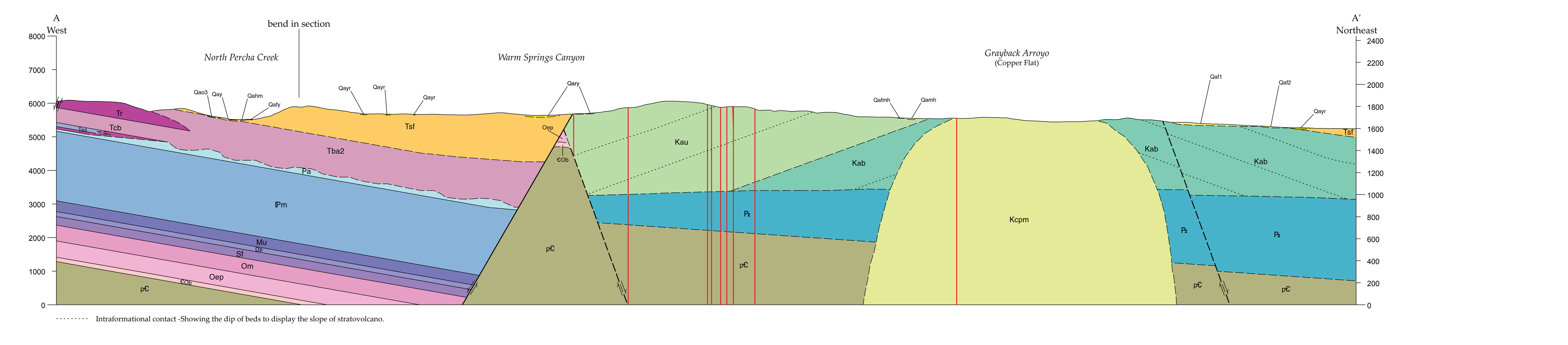
Precambrian basement rock

p€ **Proterozoic rocks, undivided (Paleo- to Mesoproterozoic?)** – Cross-section only. Includes granite, gneiss, and schist.

p€g **Granite (Mesoproterozoic?)** – Pink to red, medium-grained granite containing quartz, feldspar, and biotite.

p€s **Quartzofeldspathic gneiss of Tank Canyon (Paleoproterozoic?)** – Pale-brownish-gray, fine- to medium-grained gneiss containing 70% sericitized albite and 30% quartz. May contain accessory biotite and ferric oxide minerals. Features thin layers of hornblende schist that strike parallel to foliation observed in aggregated quartz granules (Hedlund, 1977).

Cross Section A—A'



Intraformational contact -Showing the dip of beds to display the slope of stratovolcano.