

The Geology of the Hillsboro Quadrangle

AUTHOR AND ACKNOWLEDGEMENTS

Between February 16, 2016, and April 30, 2017, I wrote a series of blog posts describing the geology of the area covered by the Hillsboro 7.5 Quadrangle map. These blog entries were for the original Black Range website. Given the vagaries of digital publishing, those blog posts are no longer available. In this work I have resurrected the original material, reformatted it, and added additional information.

Although I have sought to minimize the use of personal pronouns in this work they have crept in from time to time. Generally they refer to me, in other cases the reference is obvious.

I am solely responsible for all errors of omission or commission.

R. A. Barnes
Hillsboro, New Mexico
October 2025

The original posts, and this work, would not have been possible without the substantial efforts made by Rebecca Hallgarth. She has accompanied me across many a hill and down many a wash, she has encouraged me (with subtle nuance), she has questioned my work, she has asked meaningful questions, and generally given me my leash.

This has been a long-term effort and many others have contributed in myriad ways. Among the most frequent and/or meaningful contributors have been Harley Shaw, Patty Woodruff, John Hawley, Rebecca Hallgarth, Jon Barnes, Steve Morgan, Nichole Trushell, Matilde Holzwarth, Lloyd Barr, and Steve Dobrott. Numerous others have also contributed.

The creators of the the draft Geologic Map of the Hillsboro 7.5 Minute Quadrangle (referred to elsewhere as “the geologic map”, and the accompanying report, were used as primary references, augmented by a variety of other sources (see the references and resources listing at pages 91 - 93).

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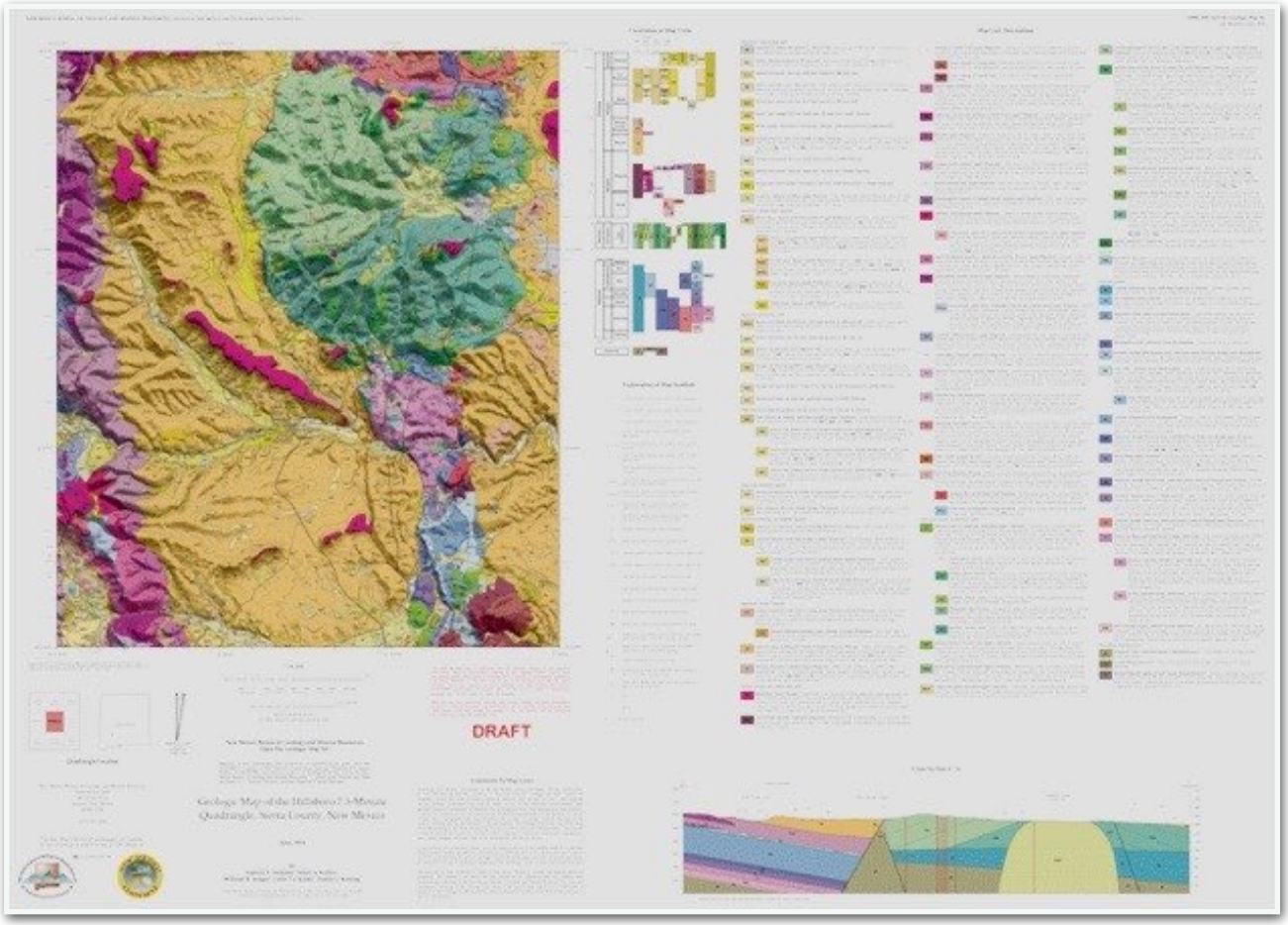
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A full-size .pdf of the Geologic Map shown above and the accompanying report are available at this link.

THE GENERAL GEOLOGY AND THE GEOLOGIC UNITS OF THE HILLSBORO QUADRANGLE

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The Geology of the Hillsboro Quadrangle

INTRODUCTION

Geology abounds within the area covered by the Hillsboro Quadrangle. Indeed, more than a billion and a half years of the earth's geologic history is represented in this small area. It takes no great leap of creativity to imagine the changes that can occur over that time span. "The Geologic Map" is a work of art, beautiful in itself, and a copy hangs on my office wall. All of that color is indicative of a geologic mess. A great area for those involved in geologic study, a difficult one for those who just want some semblance of understanding. Just what has happened here?

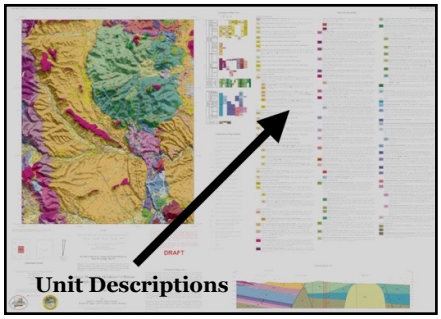
A thorough understanding of what has happened here can, I think, only be achieved with an animated sequence which covers that billion and a half years and shows the changes as they appear at the surface and below ground level. Such a device is well beyond my capability, and I have not seen a work which accomplishes such a task at scale. But imagine, in your mind's eye - it will help.

SETTING THE STAGE

Throughout this document there are references to the geologic map, the map unit descriptions, the cross-section, the geologic timeline, the Hillsboro Geologic Report, and study areas. Each is described below:

Geologic Map (or Map) - refers to the Geologic Map of the Hillsboro Quadrangle.

Map Unit Descriptions - each of the geologic units depicted on the map is described under the heading of "Map Unit Descriptions" in the upper right of the "geologic map" (see below).



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).

The description of the "Precambrian Basement Rock (Proterozoic) units are shown above, as an example.

The Geologic Report which accompanies the map was written by Jochems, Kelley, Seager, Cikoski, and Koning. It describes the geology of the quadrangle and its geologic history.

Study Areas - to assist in our understanding of the geology of the quadrangle we delineated small segments of the area covered by the map as study areas so that we could better understand the geology of that particular area.

Geologic Timeline - the "Correlation of Map Units" is in the center of the map/legend at the top (see the following page - "1" at top left and the larger detail at the upper right). It orients each geologic unit in terms of the geologic timeline. The youngest rocks are depicted at the top of the scale, the oldest at the bottom. In this paper, we will slowly work our way up the scale.

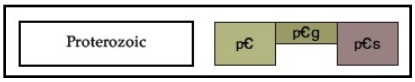
Cross-Section - A depiction of the underground geology of a line which crosses the map about a third of the way from the top (from A to A1 in the map detail below) is shown in cross-section at the bottom right of the geologic map (see the following page - "2" at the top left and the enlargement at the bottom).

This geology map is still in draft and subject to some change; it is an excellent resource - thanks to the State of New Mexico, and especially to those shown at the bottom right.

In organizing the workload associated with the study of the Hillsboro Geology map it quickly became apparent that organizing the field work around specific geographic areas would be useful in reducing the amount of field work, presenting the opportunity to discuss the relationships between different geologic units, and describing the various geologic symbols and markings used on a standard geologic map. These study areas were creatively named "Study Area 1, Study Area 2, etc."

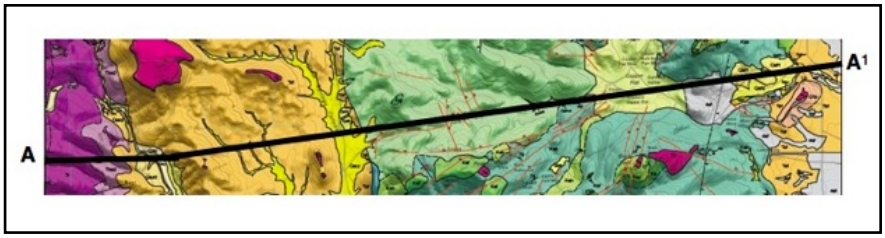
PROTEROZOIC

PRECAMBRIAN BASEMENT ROCK



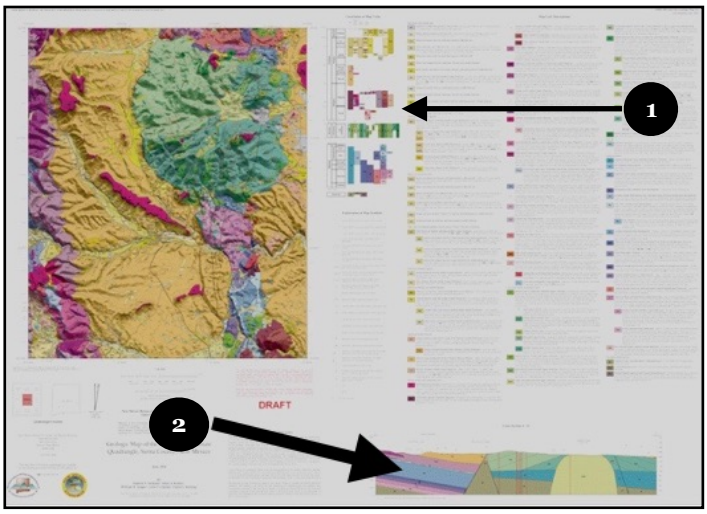
The oldest rock depicted on the Hillsboro Quadrangle Geologic Map is classified as "Precambrian Basement Rock". On the geologic timeline these rocks are at the very bottom in the "Proterozoic Eon" (see arrow on the Correlation of Map Units on the following page.

The Proterozoic Eon was the period before complex life became prevalent on Earth and covers the

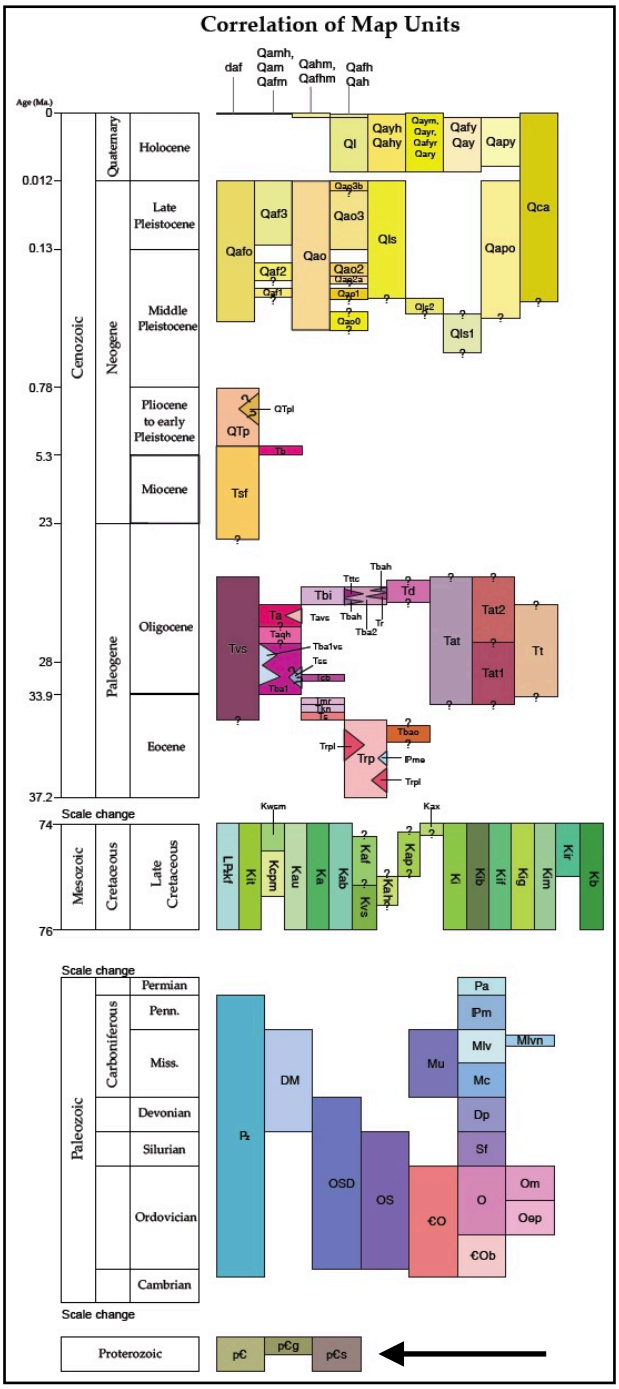


Andrew P. Jochems[1], Shari A. Kelley[1], William R. Seager[2], Colin T.Cikoski[1], Daniel J. Koning[1]

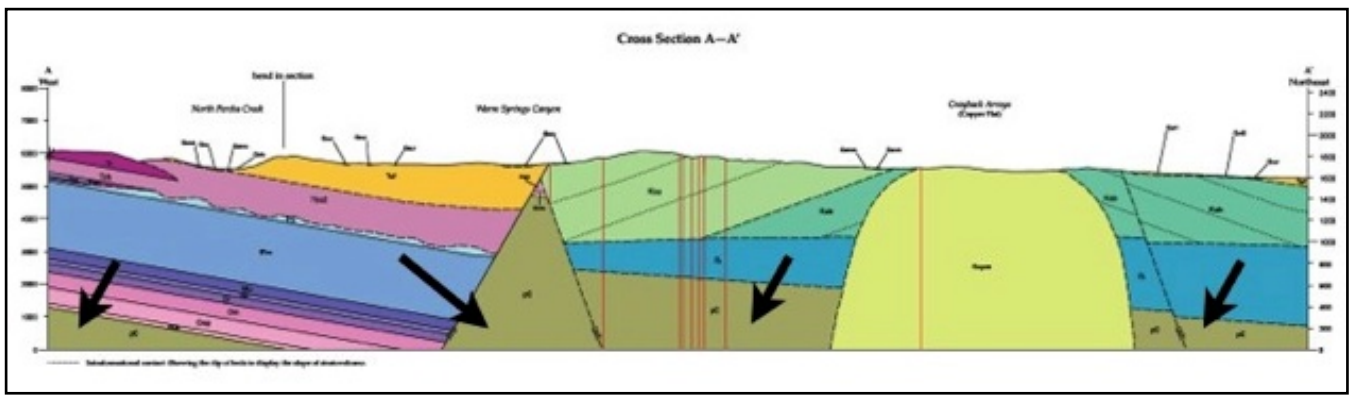
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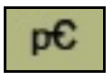


The location of the cross-section line on the geologic map is shown above. The actual cross section, as depicted at the lower right on the map sheet is shown below.



period between 2.5 billion years and 542 million years ago. It was during this period that multi-cellular organisms began to appear, in some cases creating mats of photosynthesizing bacteria which began to oxygenate the atmosphere. Glaciation is thought to have been widespread and the continental cratons (which are the old and stable portions of the continents) had finished forming.

There are three geologic units which are classified as Precambrian Basement Rock on the Hillsboro map. The first unit that we deal with is the Proterozoic unit which is thought to date from the Paleoproterozic to the Meso-proterozic Era (the period between 2.5 billion and 1 billion years ago) and is shown only in the cross-section on the map (cross section with arrows showing this material is shown at the bottom of the previous page). We have no images of this material since we chose not to dig a very deep shaft.



This material is composed of granite, gneiss, and schist. Granite is an igneous rock while the other two are metamorphic. In particular, gneiss is formed by the metamorphosis of granite, at higher temperatures and pressure than schist. Schist is formed during the metamorphosis of a number of minerals.

Symbols and colors on geologic maps follow the FGDC Digital Cartographic Standard for Geologic Map Symbolization.

STUDY AREA 1

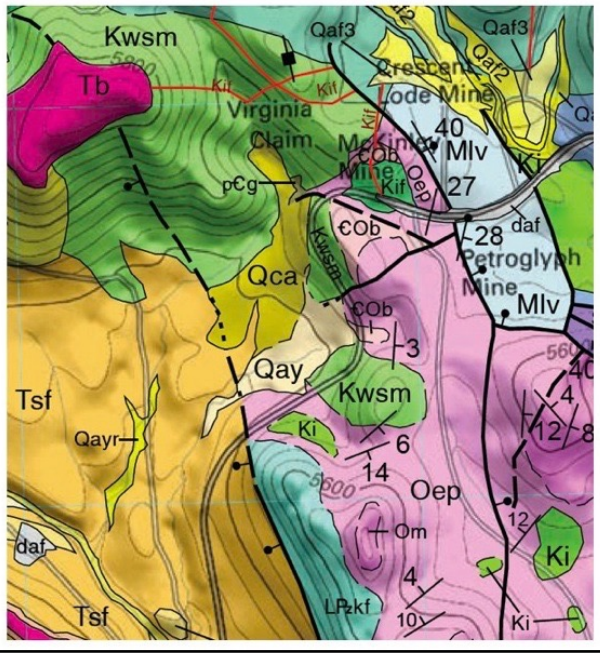
Study Area 1 is just east of Hillsboro and is where the earliest rock depicted on the Hillsboro Geologic Quadrangle Map is found at the surface (a geologic unit labeled as "pCg". This study area is about 1500 meters square and is shown at the right.

To say that the geology of this area is complex is one thing, to take a gander at "Study Area 1" is another. This is a small area, yet there are a number of geologic units present, lots of faulting, a real jumble.

These are the geologic units of Study Area 1 - arrayed from oldest to the youngest.



STUDY AREA ONE



PRECAMBRIAN BASEMENT ROCK

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

PALEOZOIC BEDROCK

COb **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.

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).

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).

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:

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.

CRETACEOUS VOLCANIC INTRUSIVE UNITS

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.

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).

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:

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.

Quaternary-Tertiary Basin-Fill

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.

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.

Older Alluvial Fan Deposits Graded To Stream Terraces of Percha Creek and Its Tributaries

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.

Quaternary Valley Bottom Units

Qayr — **Younger and recent (modern and historic) 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.

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.

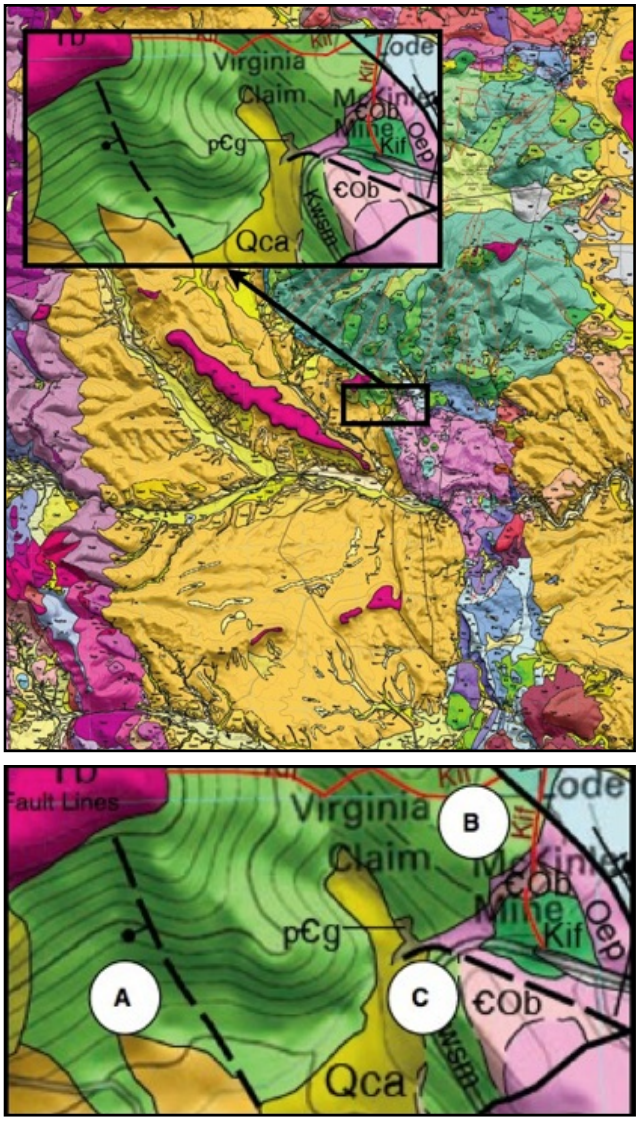
PRECAMBRIAN BASEMENT ROCK (GRANITE)

There are two other Precambrian Basement Rock material units which appear on the Hillsboro geologic map; both are on the surface. The first we discuss is the Granite (Mesoproterozic) material which is found in Study Area 1 near the crest of the hill on NM-152 east of Hillsboro (see maps at the right or UTM Zone 13 Northern Hemisphere 261750E 3646950N; Decimal Degrees - Latitude 32.934885 Longitude -107.54820, or if you are using the historical Degrees, Minutes, Seconds system - Latitude 32°56'05.5680" Longitude -107°32'53.4476"). This material is a pink to red granite (igneous rock), medium-grained, containing quartz, feldspar, and biotite. In the detail insert of the map (right), NM-152 (parallel gray lines) makes a loop into, and out of, the bottom right of the insert.

p€g

Shown on the insert are three types of dark lines. These lines depict faults which are in the immediate area of the granite precambrian basement rock. A fault is the place where rock has broken and moved so that materials which were immediately adjacent to each other are no longer in that position. Incredible forces create faults, and an area with many faults underwent tremendous upheaval at one time or another.

The fault line labeled "A" (a dashed line) is a normal fault which is known to exist but its exact location is



approximate. Note the small emblem immediately above the "A", referred to as a "ball and bar". It is on the "downthrown block" of the fault. In this case the mass of land to the left of the fault line is lower than the rock to the right of the fault. They were adjacent before the event(s) which created the fault occurred.

The fault line labeled "B" is a normal fault which is known to exist and its location is accurately plotted. Not visible on the insert is a "ball and bar" on the right side of this fault, indicating that the rock mass to the right of the line is lower than it was originally (before the activity which created the displacement). Fault lines "A" and "B" describe a significant (but local) event. The rock mass on the outside, to the left of fault "A" and to the right of fault "B" is lower than the rock mass on the inside of the faults (the outside rock masses were downthrown). This indicates that the rock mass between these two fault lines probably remained relatively stable and the rock masses on either side dropped. The break which occurred in the earth's crust at that time is shown by the fault lines.

The third fault line depicted on the insert ("C") is an "unspecified" fault which is known to exist at that approximate location. In this case this marking also serves as a contact line between two deposits.



There is only a small amount of this unit on the surface in the area of the Hillsboro quadrangle. It is unfoliated granite, pink to red in color, and contains quartz, feldspar, and biotite. It is thought to be from the Mesoproterozoic Era and assumed to be about 1.6 billion years old. I believe that this unit is in the foreground of the photograph above. My uncertainty goes to the point that it takes a practiced eye to tell some of this rock apart and sometimes the geologic units are not big and dramatic.

STUDY AREA 2 - TANK CANYON

The aptness (and quite frankly, brilliance) of the name for this study area came to me in a moment of repose, just before afternoon nap (errr, siesta). After all, I had named the first study area, "Study Area 1" why not....

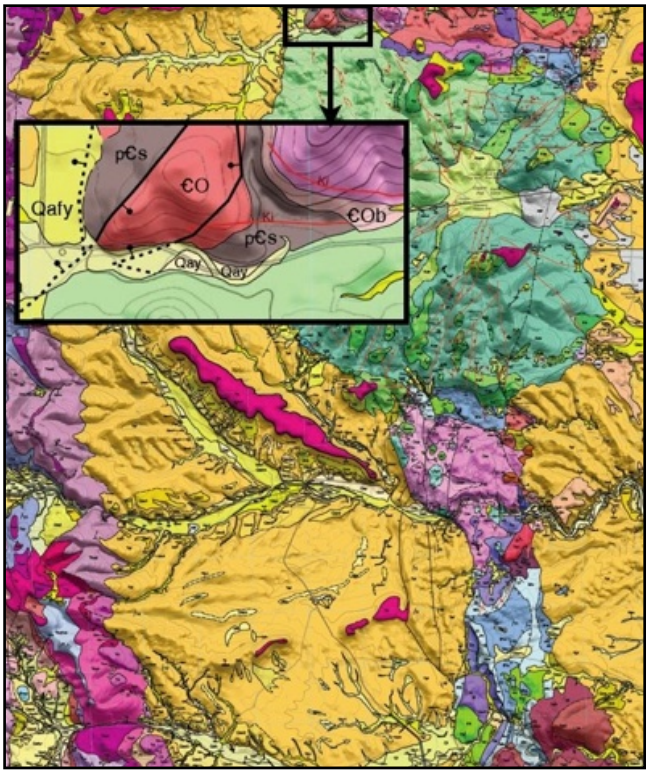
This geologic study area is on private property; permission to enter and signed waivers are required for entry. This study area, shown in detail at the right and on the following page, is just west of the Ladder Ranch access road and is traversed by a maintained dirt road.

PRECAMBRIAN BASEMENT ROCK (TANK CANYON)

Study Area 2 was identified because there is a unit of Quartzofeldspathic gneiss found in the area, the only surface rock of this unit within the Hillsboro Quadrangle. "Quartzofeldspathic gneiss" (is) "pale-brownish-gray, fine to medium-grained gneiss" (metamorphic rock) "containing 70% sericitized albite and 30% quartz. It may contain accessory biotite and ferric oxide minerals and features thin layers of hornblende schist that strike parallel to foliation observed in aggregated quartz granules."

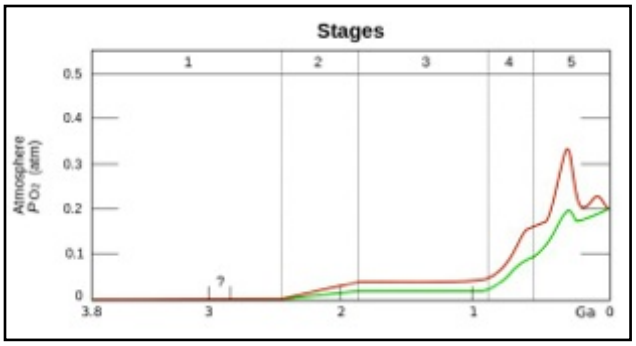
p€s

The Precambrian basement rock unit is about 1.6 billion years old. In geologic terms, that is pretty old stuff (the units discussed so far are the oldest depicted on this geologic quadrangle - see chart page 4). When this rock was forming there were about 450 days in a year, each day was about 20 hours long, and the "Oxygen Catastrophe" was probably over.



Prior to about 2.3 billion years ago bacteria were anaerobic and oxygen was toxic to them. Cyanobacteria, which dump oxygen into the atmosphere as a waste product, had evolved about 200 million years before the "Oxygen Catastrophe". The ever-increasing levels of oxygen in the atmosphere killed much of the anaerobic life on earth.

The graph at the top of the following page depicts the increase of oxygen in the atmosphere; time is shown on the scale across the bottom, the amount of oxygen in the atmosphere is depicted in the vertical axis, the red and green lines are different estimates of oxygen concentration, and the major "event stages" are shown across the top. During Stage 1 (roughly 4 billion to 2.5 billion years ago) there was virtually no oxygen in the atmosphere. From about 2.5 billion to 1.85 billion years ago



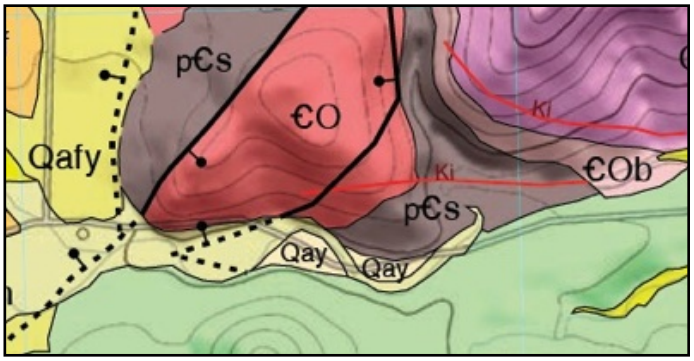
oxygen which was being produced by cyanobacteria was being absorbed by the oceans and rock (oxidation). In Stage 3 (from 1.85 billion to about 850 million years ago), the oceans were no longer capable of absorbing the oxygen being produced but oxidation on the land surface was sufficient to stop large increases of oxygen in the atmosphere. In Stage 4, the "sinks" filled to capacity and oxygen entered the atmosphere. (Graph from Heinrich D. Holland via Wikimedia Commons.)

This unit is very hard bedrock and there are numerous pools of water ("tanks") in the stream bed formed by this outcrop (see right).





The photograph above is of the right (east) unit of the map at the right. To the west of this location is the old Meyer's homestead. They ranched in the area and had a business in Hillsboro in the late 1800 - early 1900 era. Human history of less than 150 years and all that remains are bits of glass, bits of pottery, a few nails, a post or two . . . (See a few photographs of the homestead on the following page.)



This unit is found at the northern edge of the geologic map, in Tank Canyon at UTM Zone 13 North Hemisphere 260275E 3653810N; Decimal Degrees - Lat: 32.99638 Long: -107.565757 Degrees, Minutes, Seconds - Latitude 32°59'46.9680" Longitude -107°33'56.7266". There are two fault lines shown on the detail insert of the type which we discussed above, indicating normal faults which are known to exist and which are accurately plotted. The "ball and bar" symbols indicate that the material between the faults has dropped down. Another type of fault line is visible on the detail image. The dotted line indicates a normal fault which is known to exist at this location but the exact location of the fault is concealed (in this case by deposits from the Holocene which occurred after the fault-creating event).

At the upper right of the map detail there are two solid red lines. These lines depict dikes at those locations ("identity and existence certain, location accurate"). Dikes are created when material intrudes existing rock, generally along seams. In this case the intruded material is "Ki", material from the Upper Cretaceous which we will cover later.

Other major strata in the study area include the units identified at the upper left on page 10.

The road up Tank Canyon, to the east of Study Area 2, passes through several large geologic units.

The study area, a satellite image of the study area, and a detail of the east end of the study area are shown at the bottom of page 10. Several other units were identified for review as part of our visit to Tank Canyon; each is identified by a letter of the alphabet in the geologic map detail at the bottom of page 10. The location of each unit is identified by several geographical location references and by diamonds placed on the geologic map indicating the location of the unit.





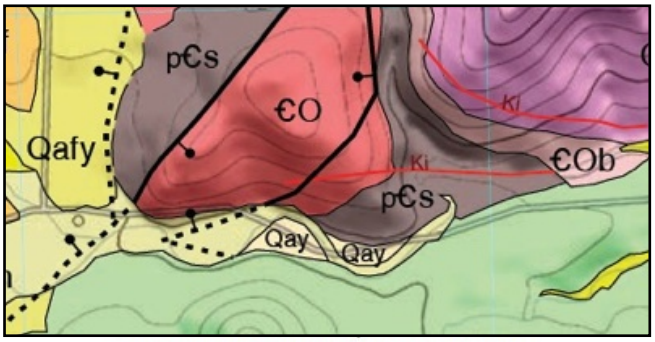








Meyer's homestead
Tank Canyon
Ladder Ranch



GEOLOGIC UNITS ALONG THE TANK CANYON ROAD

PALEOZOIC BEDROCK

€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.

€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.

B. UTM Zone 13 North Hemisphere 260500E 3653800N;
Lat: 32.99634 Long: -107.563348709543
Latitude N 32°59'46.8240" W Longitude -107°33'48.0554"

QUATERNARY ALLUVIAL FAN UNITS

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.

QUATERNARY VALLEY BOTTOM UNITS

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.

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.

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.

C. UTM Zone 13 North Hemisphere 265600E 3653500N;
Lat: 32.994745 Long: -107.50873312204202
Latitude N 32°59'41.0820" W Longitude -107°30'31.4392"

Qao2 Qao2a **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 13.6-13.8 m above modern grade, except for subordinate deposit **Qao2a** with a slightly higher tread height (~15-16 m). 1.7-2.0 m thick.

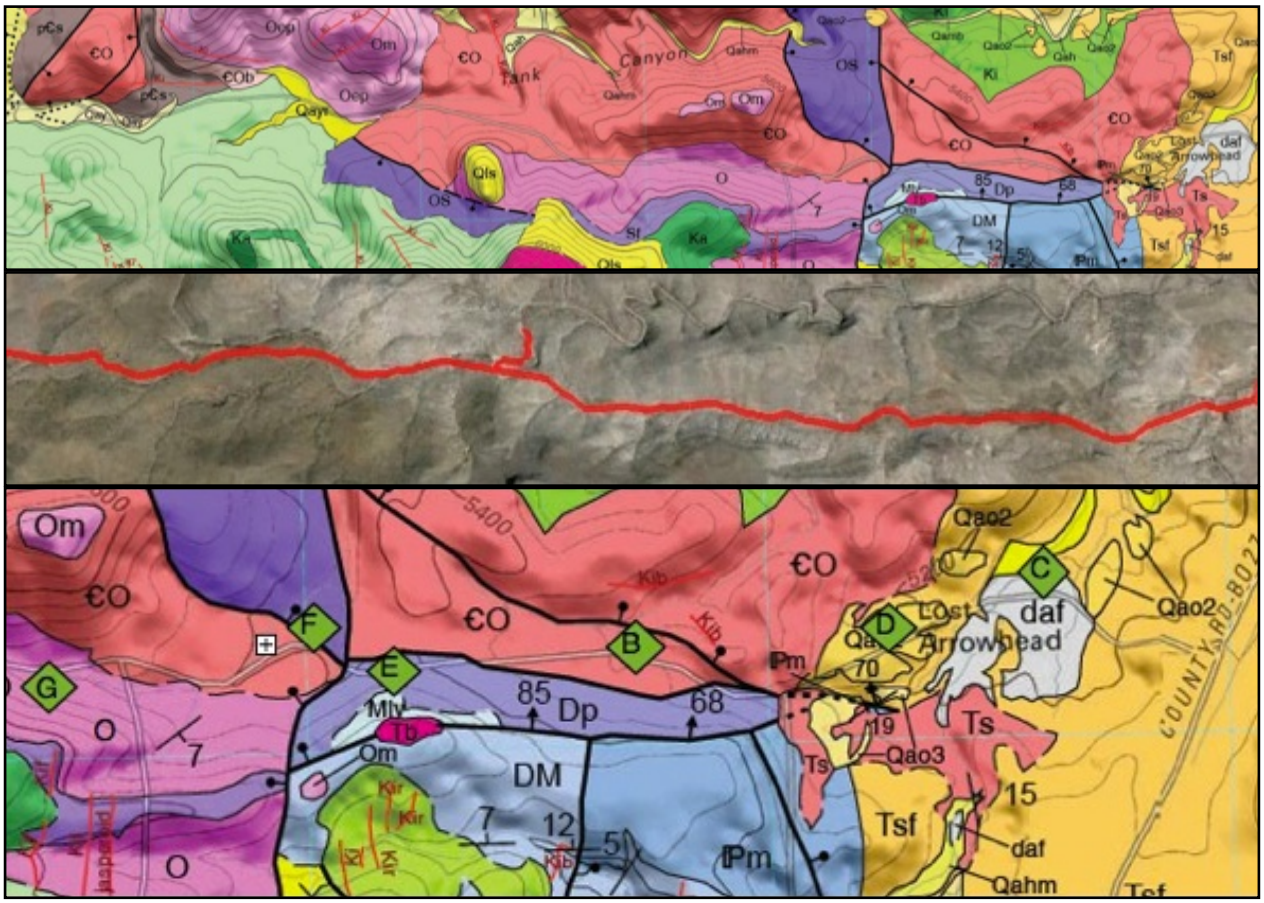
Qao2

D. UTM Zone 13 North Hemisphere 265300E 3653400N;
Lat: 32.993779 Long: -107.51191573857105
Latitude N 32°59'37.6044" W Longitude -107°30'42.8967"

€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.

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.

E. UTM Zone 13 North Hemisphere 264150E 3653375N;
Lat: 32.993306 Long: -107.52420706117529
Latitude N 32°59'35.9016" W Longitude -107°31'27.1454"

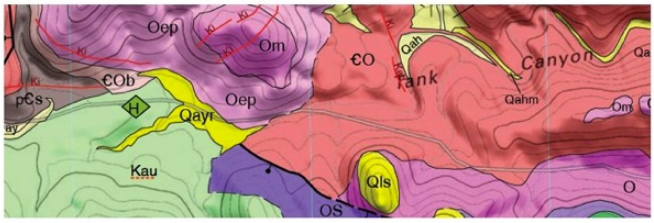


OS **Ordovician through Silurian strata, undivided (lower Ordovician through lower Silurian)** – Includes the El Paso Formation, Montoya Formation, and Fusselman Dolomite. Differentiated where identification of individual units is precluded by alteration. Mapped where **Dp** is conspicuously absent.

F. UTM Zone 13 North Hemisphere 264075E 3653425N;
Lat: 32.99374 Long: -107.52502192008677
Latitude N 32°59'37.4640" W Longitude -107°31'30.0789"

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).

G. UTM Zone 13 North Hemisphere 263250E 3653470N;
Lat: 32.993967 Long: -107.53385573042813
Latitude N 32°59'38.2812" W Longitude -107°32'01.8806"

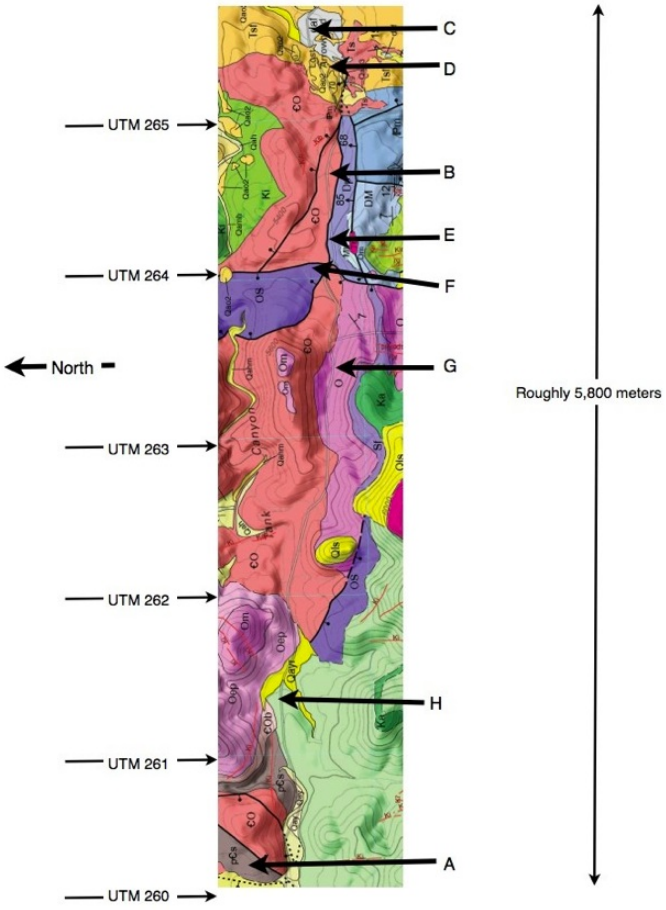


Oep **El Paso Formation (lower Ordovician)** – Medium- to dark-gray, thin- to thick-bedded, tabular, cherty, somewhat fossiliferous, packstone to lime mudstone. Pink to red chert may be laminated. Fossils include small bryozoans and sponges, ostracods, and horizontal burrows. Chert occurs in lacy networks. 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).

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

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.

H. UTM Zone 13 North Hemisphere 261250E 3653770N;
Lat: 32.996234 Long: -107.55532065375554
Latitude N 32°59'46.4424" W Longitude -107°33'19.1544"





A marble outcrop along this route is shown in the photograph above.

THE PALEOZOIC

BLISS FORMATION SANDSTONE
UPPER CAMBRIAN TO LOWER ORDOVICIAN

In our review of this geologic unit, we return to Study Area 1 - at the top of the hill coming out of Hillsboro. In the road cut at the crest of the hill, there are several geologic units exposed, as well as some excellent examples of faulting.

€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.

The Bliss Formation(€Ob) is described above. This location (see map at right), and Study Area 2, are the best (perhaps only) locations within the Hillsboro Geologic Quadrangle where this unit is found on the surface. It is also depicted in the cross-section which accompanies this map. In the photograph below, the Bliss Formation is on the left, truncated by a strong fault which can be seen in the middle portion of the photograph.



This geologic unit is from 500 (Upper Cambrian) to 475 million (lower Ordovician) years old. It is some of the oldest Paleozoic bedrock shown on the Hillsboro map.

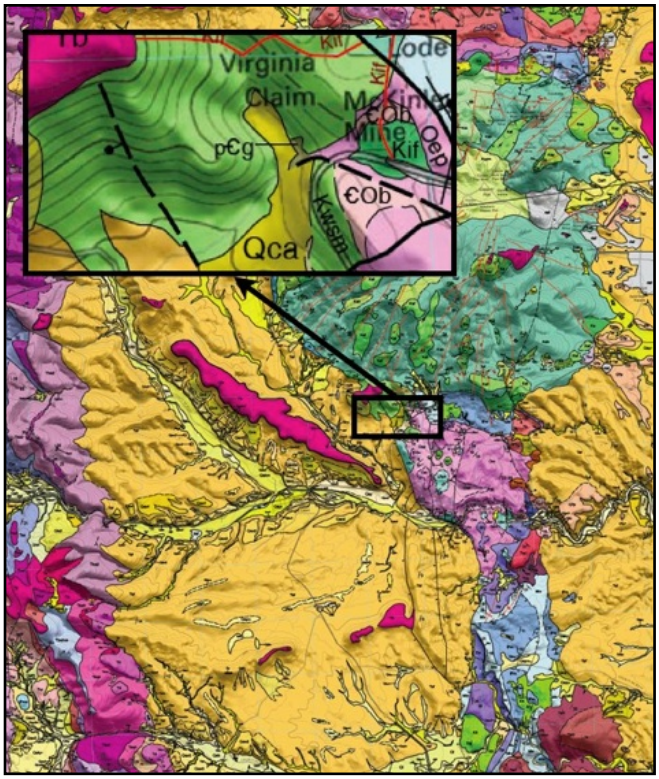
During the Cambrian there was a "rapid" diversification of life forms. The supercontinent, Gondwana, was breaking up at this time and Laurentia (what is now most of North America) was forming. The southwestern portion of Laurentia, where we are now located, was greatly affected by continental collisions.

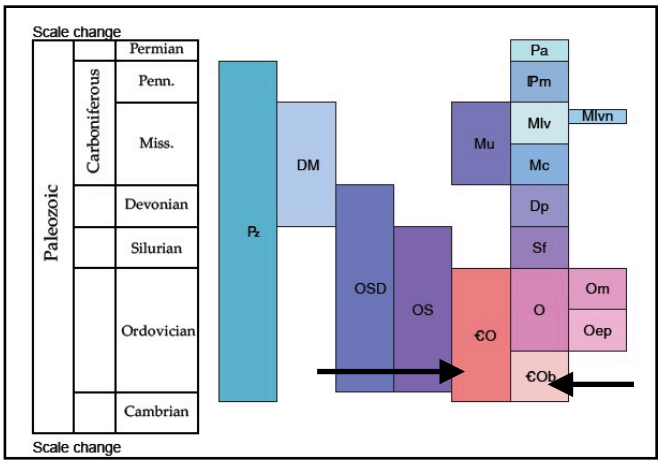
The Bliss Formation spans both the Cambrian and Ordovician Periods. During the Ordovician, sea levels were the highest during the entire Paleozoic and seas intruded into this area. Therefore, there tend to be many marine fossils in the finer grained geologic units. The Bliss Formation is made up of near-shore and beach sands; it grades into the El Paso limestone units.

€O - A GEOLOGIC MESS

€O is the geologic map symbol for a mess of rock, a particular mess of rock, a very old mess of rock. The geologic quadrangle of the Hillsboro area describes it so:

€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.





This geologic unit is not readily apparent on the Hillsboro map, but if you look in the upper righthand corner of the map you will see that quite a bit of it is on the surface in Tank Canyon (see earlier discussion).

This formation of Paleozoic bedrock is the designation for several distinct geologic units (Bliss Sandstone for instance) when they are found together but have undergone significant stresses and changes - a lot of shifting around. The earliest rock in this "formation" is about 500 million years old, so it has had a lot of time to be altered. The youngest rock in this unit is from the Upper Ordovician and dates to about 450 million years ago.

It is probably time to take a moment to demystify those geologic symbols a bit - € is the geologic map symbol for the Cambrian and O is the the geologic map symbol for Ordovician - so this unit spans the Cambrian and Ordovician periods.

The discussion of the Bliss Sandstone Formation noted a number of the major events of this period (through the lower Ordovician). Trilobites first appeared about



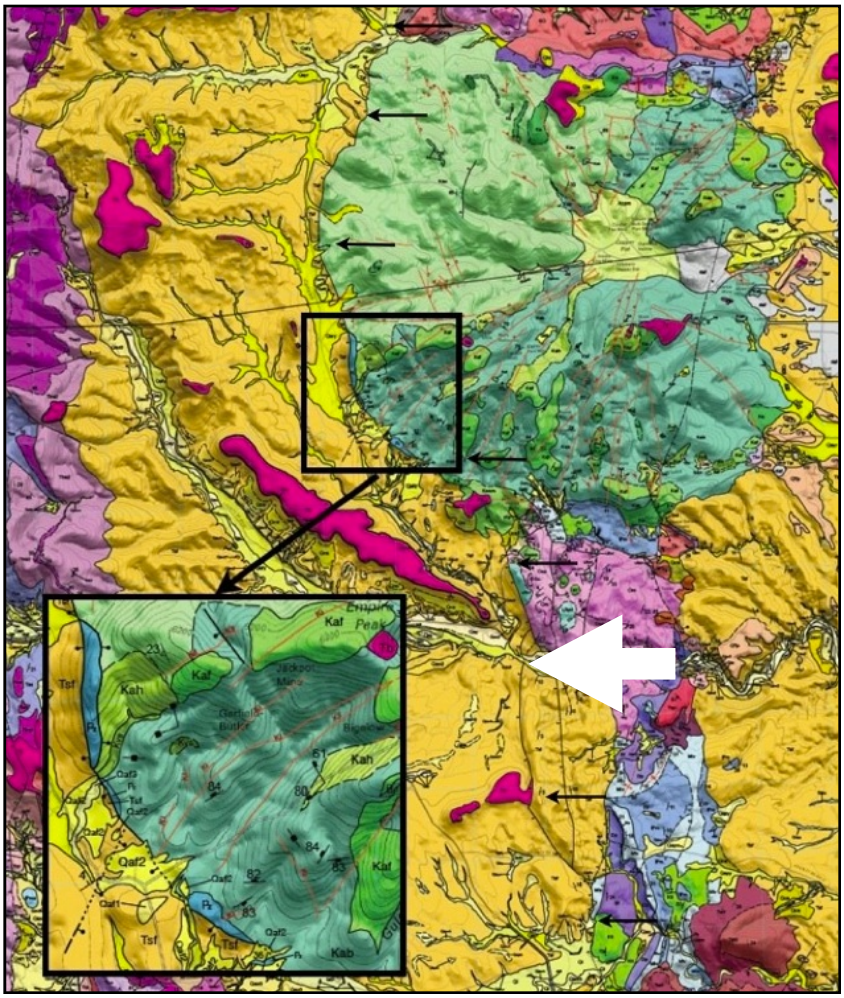
520 million years ago and were well established during the period spanned by this geologic unit. One of the most famous geologic formations (at least for me) is the Burgess Shale formation of British Columbia, Canada - in part because of the glorious trilobite fossils from that location.

The photograph above was taken in Tank Canyon in an area identified as €O on the map. The rock at the center right of the image is El Paso formation. The €O unit, by its very nature, is difficult to describe in the field. It is, after all a bit of this here and a bit of that over there.

STUDY AREA 3

As we continue our journey up the "Correlation of Map Units" chart on the Hillsboro geologic quadrangle map we encounter the "Pz" geologic unit. Like the two previous study areas, which were defined because they covered an area where a particular geologic unit occurred (a geologic unit which occurred in the quadrangle only at that location) Study Area 3 was selected because it is the only site on the map where the Pz geologic unit is located.

The study area includes several (see detail at right) interesting geologic features, such as the Berrenda Fault Zone. This fault zone is one of the most important, and defining, geologic features which appear on the geologic





map. It enters the map at about 107°34'0"W at the top, runs south through the eastern portion of the map area, and exits the map area at about 107°32'0". On the map on page 13, the location of the fault zone (generally more than one fault) is indicated by a series of arrows which transect the map on the center-right side. The large white arrow shows the location of the photograph above, one of the more dramatic geologic features of the area. Pictured is the western boundary fault of the Animas Uplift at the confluence of Warm Springs Wash and Percha Creek (the south slope of Percha Creek). Study Area 3 is shown as an insert on the map.

There are several mines within the study area, most of which are described on the Black Range website. These mines include the Bigelow Mine and the Garfield/Butler Mine Group. Descriptions of the area, in general, can be found at the Bigelow Mine Road and Garfield-Butler Mine Walk pages of the 2nd Edition, Volume 1, of Walks In The Black Range. See, also, the video collection at the Mines of the Hillsboro Mining District.

HILLSBORO FAULTS

For those of you who thought I was going to write about the people of Hillsboro, you will be sorely disappointed. The people of Hillsboro have no faults. The rock around Hillsboro, which has been here for a very long time, on the other hand, has a lot of faults, one of which is shown at the lower right. The following graphics are from the Report which accompanies the "Geologic Map of the Hillsboro 7.5 Minute Quadrangle, Sierra County, New Mexico", June 2014 (HillsboroReport.pdf). The report is 2.4 MB in size.

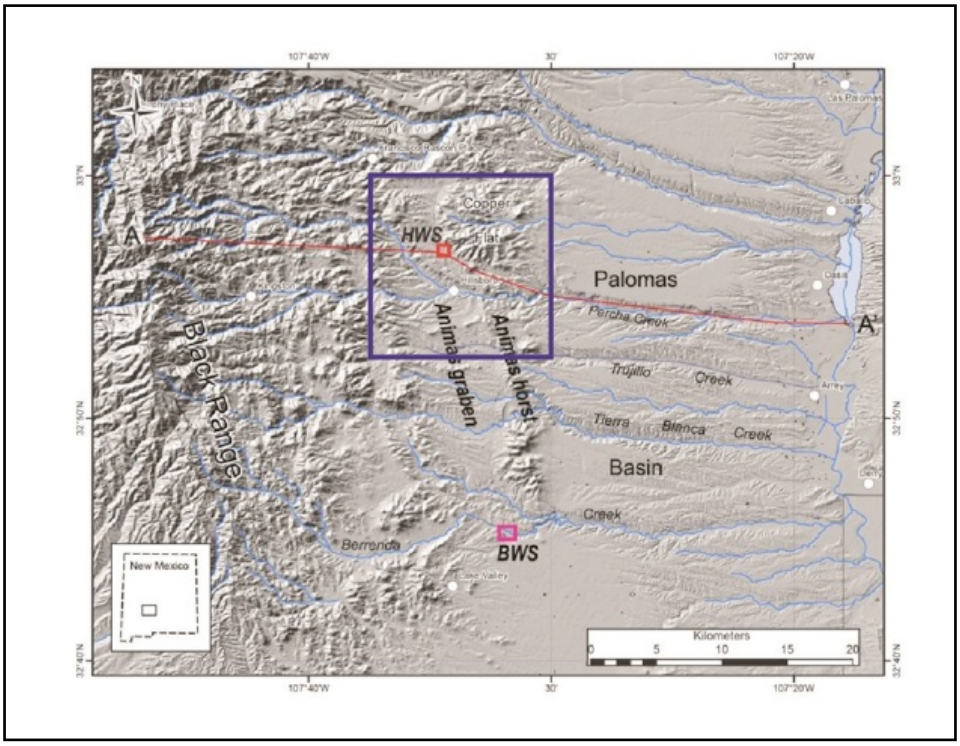
THE SETTING

The location of the Hillsboro Quadrangle is shown at the top of the next page, within the dark square. (Image from page 5 of the subject report.) The major drainages shown on the map are those of Percha and Trujillo Creeks. The town of Hillsboro lies roughly in the middle of the Quad, the Palomas Basin barely creeps into the map from the east, and the Animas Graben and Animas Horst features are both present within the map area.

The Rio Grande Valley is one of the great Rift Valleys of the world, perhaps not as famous as the East African Rift, or as big - but big enough to influence our lives. Rift valleys are formed by horst graben features and the geologic events which created them. Previously, we noted that there are geologic units within the area of the Quad which are bounded by normal faults. In the material we have looked at thus far, the areas to the east and west of the fault has been downthrown. The downthrown material is called a "Graben", the uplifted material is called "Horst". In the map at the top of the next page, the Animas Graben has been downthrown, while the Animas Horst (generally represented by the hills east of Hillsboro and east of NM-27) was uplifted. Horst-Graben features are found throughout the western United States and create our Basin and Range topography.

A note about terms is worthwhile at this point. Downthrown and uplifted are relative terms, they describe the relationship between the two strata. Both





may have moved or one may have remained stationary. Secondly, when we talk about events we are not talking about something the length of a concert at the Hillsboro Community Center. No we are talking about something that may have taken a much shorter time (think earthquake) or something that may have taken place over hundreds of thousands, or even millions, of years (think a Rolling Stones concert).

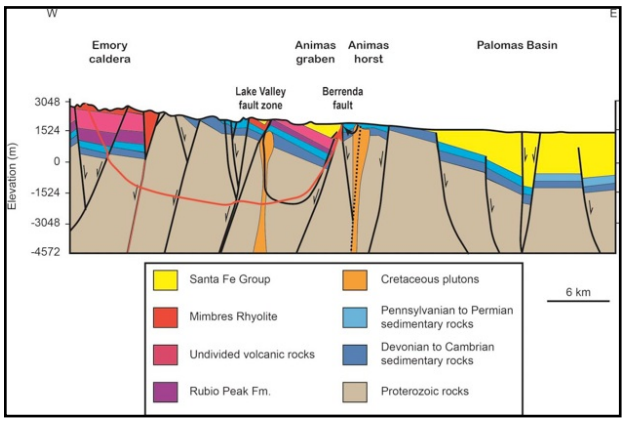
THE PARTICULARS

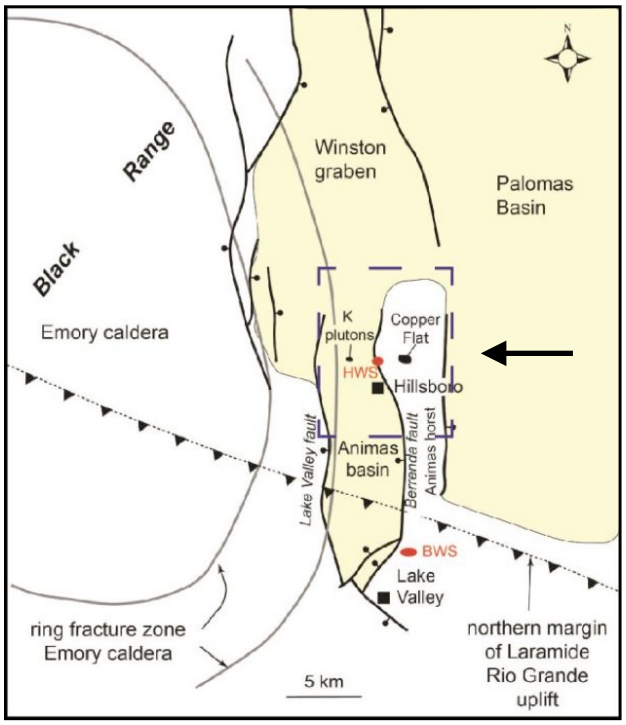
The top image in the right column is from page 6 of the subject report. This cross section is from the northern section of the quadrangle. There is a lot of faulting shown on the cross section, and associated with each of the major faults there are numerous smaller faults (shorter, shallower, you know - smaller). All of this faulting results in a lot of fractured rock. For those interested in mineralogy, all of that fracturing presents opportunity for mineral deposition.

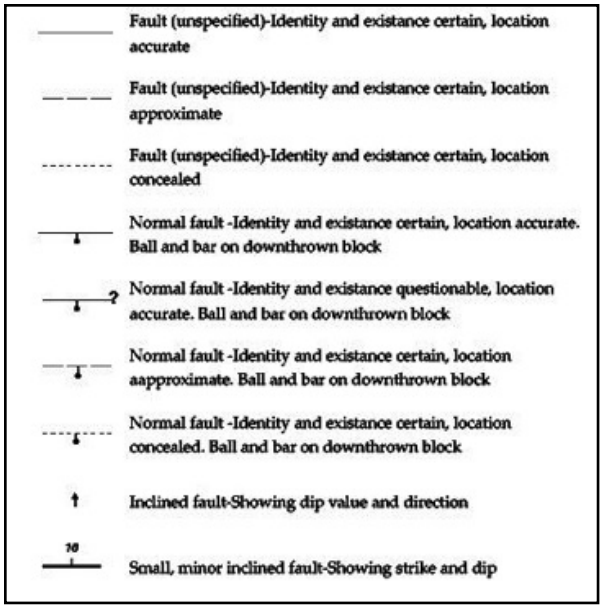
The image at the bottom of the right column is from page 5 of the subject report and shows the general geologic features of the area covered by the Hillsboro Quad (the box area outlined by a dashed line at the arrow). The Emory Caldera peeks in from the west. Even though it does not reach the Hillsboro Quad it had dramatic effects on the geology of this area (and not just the ring fracture zone which is found along the western edge of the Quad map).

The Animas Graben (Animas Basin) and Animas Horst are the large scale geologic features shown on the quadrangle map. The Animas Graben is bounded by the Lake Valley and Berrenda Faults. Or more accurately "fault zones", because there are scores of faults within the area of the Hillsboro Quadrangle.

The fault symbols shown on the Hillsboro Quad are listed at the top left of the next page and will be described as we encounter them later in this paper.

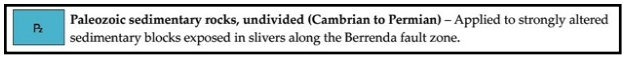




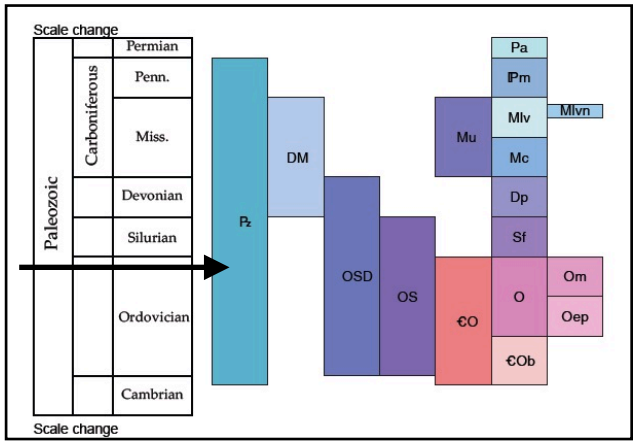


PZ - MORE GEOLOGIC MESS

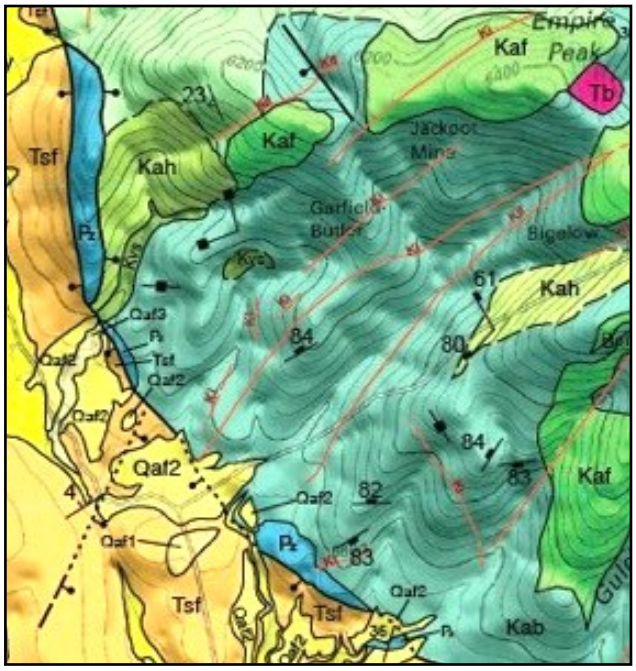
The Pz unit is shown in the cross section of this quadrangle but does not come to the surface along that line. The unit is described as:



Pz is the geologic map symbol for a very old mess of rock. We began our discussion of this geologic unit when we described Study Area 3. This geologic unit is not readily apparent on the geologic map, but if you look in the upper right-hand corner of the map you will see a large greenish/light blue block of color which is bounded by Warm Springs Canyon on the west. It is along the lower slopes of Warm Springs Canyon that this unit comes to the surface. It is bounded by faults of the Berrenda Fault Zone. At the most northerly place where this unit comes to the surface (upper left hand corner of the map at the upper right) the rock to the west is downthrown along the fault line. The rock to the east is, likewise, downthrown by the fault action which bounds the east side of the unit. The cross section transect of the map runs just north of this study area.



This formation of Paleozoic bedrock is the designation for several distinct geologic units when they are found together but have undergone significant stresses and changes - a lot of shifting around. The earliest rock in this "formation" is about 500 million years old, so it has had a lot of time to be altered. The youngest rock in this unit is from the Permian and dates to about 250 million years ago. The mixed up jumble of rock defined as Pz spans a period of 250 million years.



"P" is the geologic map symbol for the Paleozoic and "z" indicates that the unit spans the vast majority of the Paleozoic Era, see the Correlation of Map Units chart at the lower left.

Context! What does 250 million years imply, what is it that happened between the Cambrian and Permian periods? The Cambrian is perhaps best known for the Cambrian Explosion, during which the largest number of species evolved in the history of the Earth and the super-continent Rodinia began to break up. During the Ordovician, many of the species types present today evolved and the supercontinent Gondwana had formed. The Silurian period featured the evolution of vascular plants and the formation of four continents, including Laurentia (what is most of present day North America). The Devonian was a mixed bag for life on Earth. During the early part of the period large numbers of fishes evolved, trees first appeared on land, and seeds evolved as a means of propagation. But at the end of the Devonian the second mass extinction of life on Earth occurred, and 70% of all species then in existence went extinct. The Carboniferous is characterized by the significant evolution of plant types and the appearance of amniotic eggs, which allowed amphibians to wander away from the water. The end of this period was dominated by significant glaciation. And finally, the Permian: during this period, all of the land masses joined together to form the super continent Pangaea. Reptiles and mammal-types arose as major life forms on the land. The Permian ended with "The Great Dying" when 95% of all species went extinct (a lesson in just how significant greenhouse gases are). Now, stand on this rock and imagine all of the above. If this rock were sentient, how would it perceive its history?

The geology of the Black Range is often entwined with the human history of mining. To the north of the area covered by the Hillsboro quadrangle is the mining ghost town of Hermosa (now research center for Natural Curiosity). Several of the mines in this area were dug in the Pz geologic unit. The legend at the top left of the following page is taken from US Geological Survey

EXPLANATION

Mines

1 Wolford (Emerick)
2 Antelope–Ocean Wave
3 Protector
4 Pelican group
5 Palomas Chief
6 Nana
7 Flagstaff–American Flag

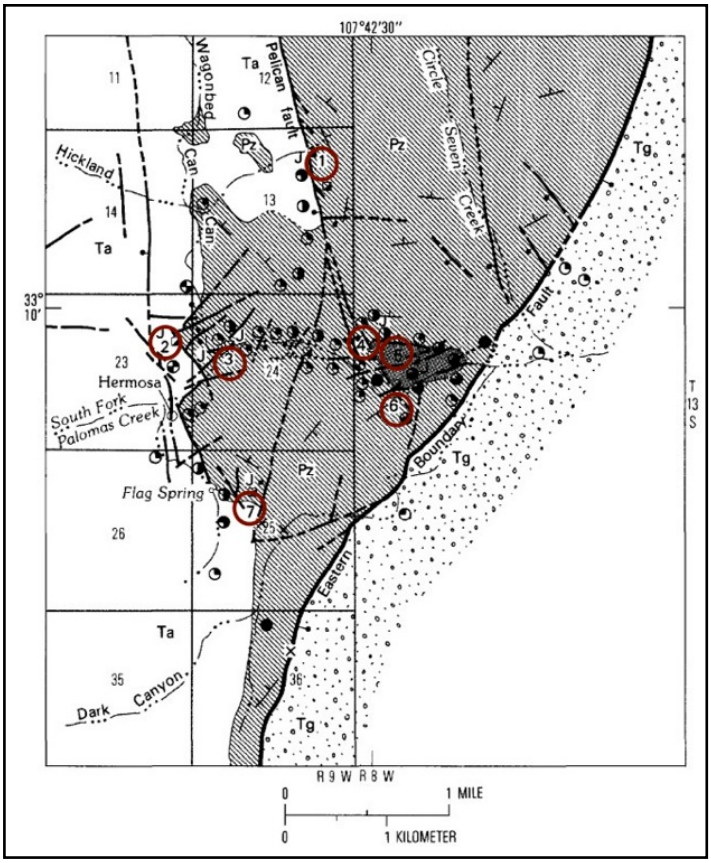
Tg — Tertiary gravel
Ta — Tertiary andesite
Pz — Paleozoic rocks (limestone and shale)
4 — Mine with number
× — Prospect
Major boundary fault
Fault—Dashed where inferred. Bar and ball on downthrown side
Approximate area of mineralized fault block
Contact
Strike and dip of beds

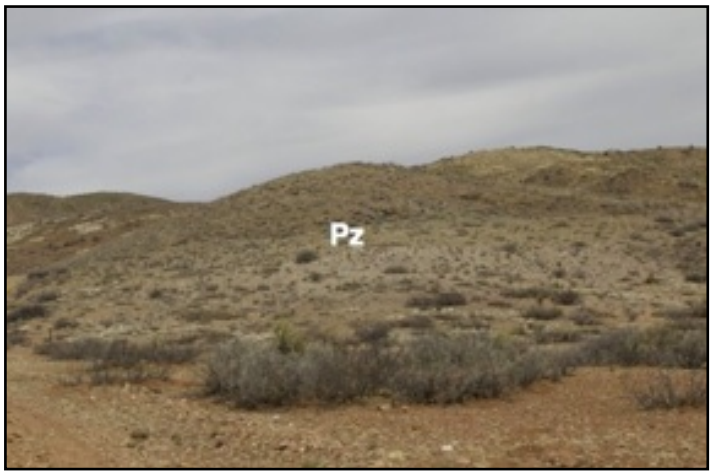
Geochemical Anomalies

J — Mineralized jasperiod sample

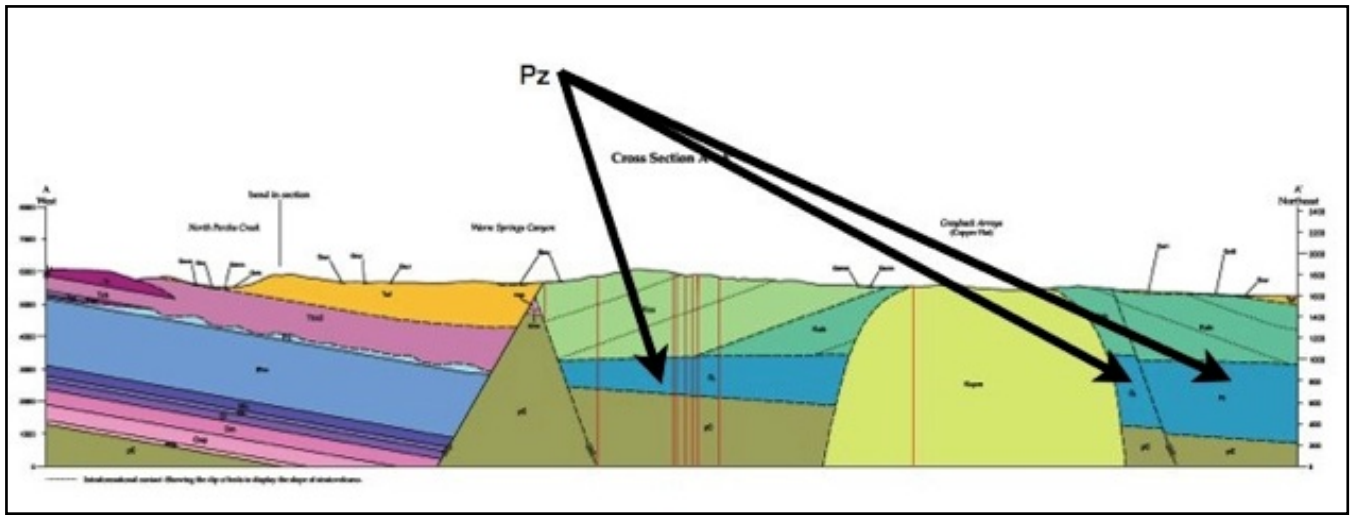
Anomalous stream-sediment samples

Lead anomaly
Copper+ molybdenum anomaly
Silver anomaly
Tin+ tungsten anomaly





The photograph to the right is of the Pz unit in Study Area 3, on the eastern slopes above Warm Springs Wash.

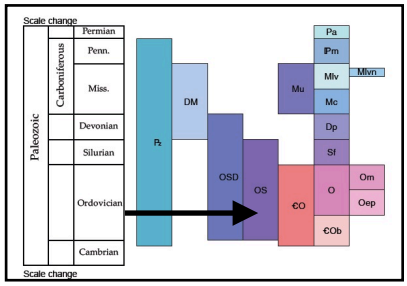


Bulletin 1876, "Mineral Belts in Western Sierra County, New Mexico, Suggested by Mining Districts, Geology, and Geochemical Anomalies" (1989), page 11. The map at the upper right on the previous page is from the same page/ source. Red circles have been added to the map to assist in locating the mines identified in the legend. Note the number of mines which are located in the Pz geologic unit. These mines are included on the Black Range website page about the Hermosa Mining District. On that page, the mines are listed, some of the minerals which were mined at each mine are identified, in some cases links provide descriptions and photographs of the minerals, and links are provided to articles in the Black Range Newspaper, published between 1882 and 1897. In several cases the articles give lengthy descriptions of the mines and geology of the area - as it was known at that time.

OS - MORE MESS

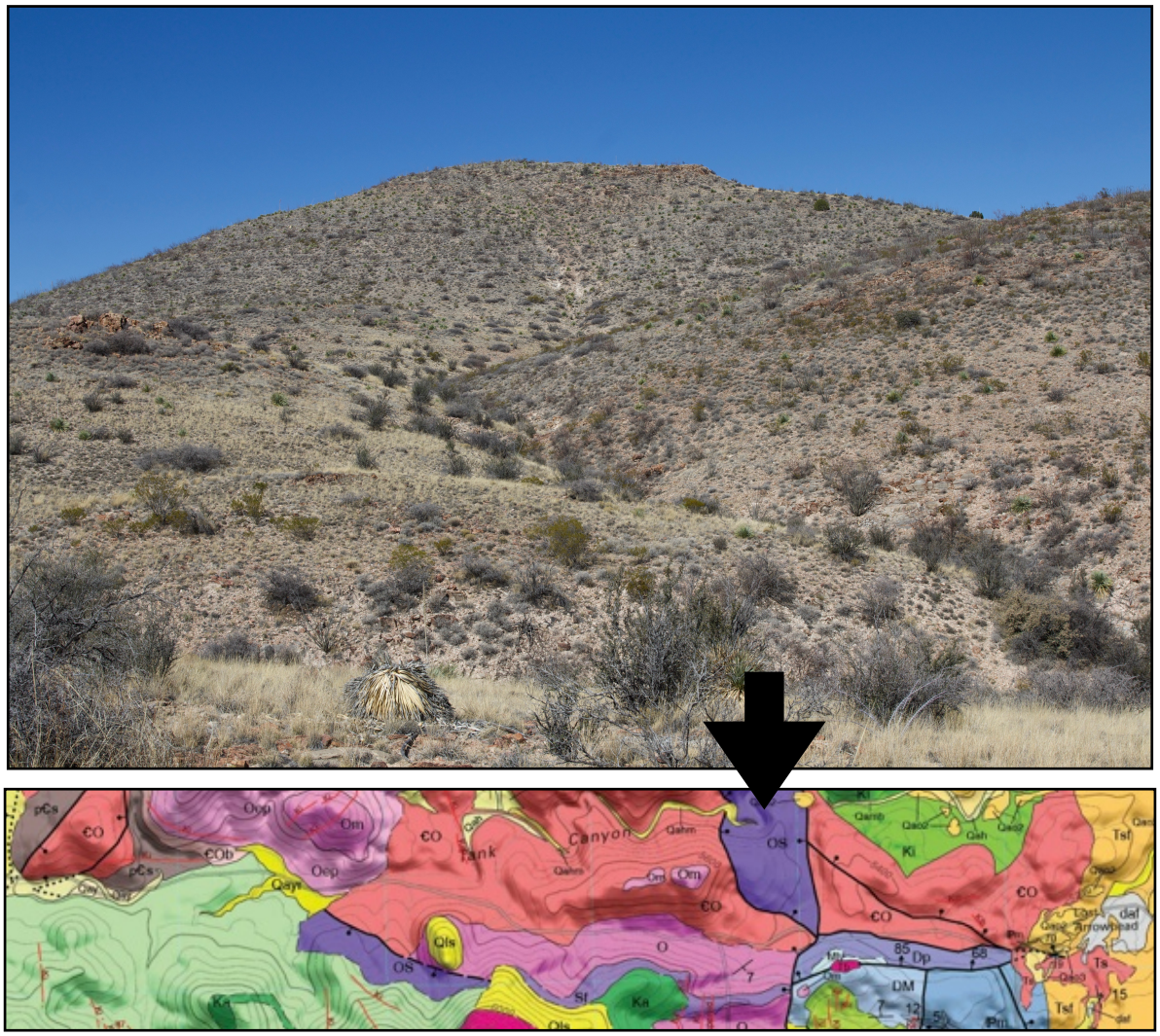
The location in the photograph below looks like any number of nondescript hillsides in the Black Range. And in a significant way, that is the point. The underlying rock is a jumble of strata, having gone through significant alteration and mix. The geology of our area has been violent, and that violence makes it difficult to discern discrete elements sometimes. The photograph is of an "OS" geologic unit in Study Area 2 - Tank Canyon, at the northern edge of the Hillsboro Quadrangle (see map below). Specifically, it is at UTM Zone 13 North Hemisphere 264075E 3653425N. The "OS" unit is along the upper edge, about 1/3 of the way from the right hand side of the map below.

We are slowly working our way up the stratigraphic chart below. The OS unit spans the Ordovician and Silurian periods (485 to 420 million years ago). See the entry on the "Pz" geologic unit for a discussion of what was happening during this period. In our area, the Ordovician includes the El Paso Group (Sierrite Limestone, Bat Cave Formation, Hitt Canyon Formation, and the McKelligon Limestone) and the Montoya Formation (Cable Canyon Member, Upham Member, Aleman Member, and the Cutter Member). The Silurian is typified by the Fusselman Formation in our area.



The "OS" geologic unit is defined on the Hillsboro Geologic Quadrangle Map as:

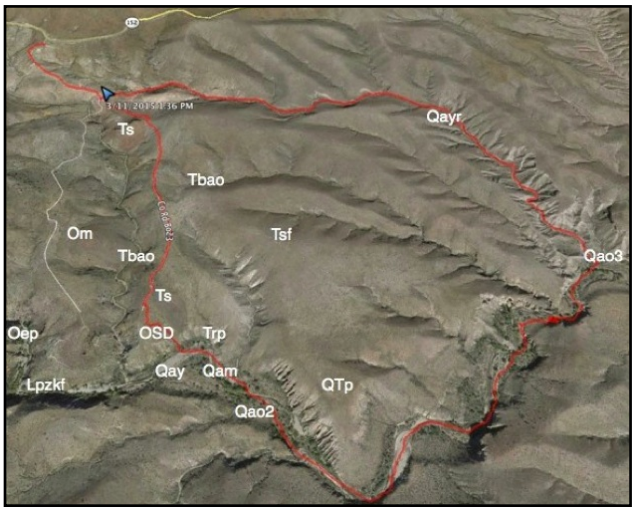
OS — **Ordovician through Silurian strata, undivided (lower Ordovician through lower Silurian)** – Includes the El Paso Formation, Montoya Formation, and Fusselman Dolomite. Differentiated where identification of individual units is precluded by alteration. Mapped where **Dp** is conspicuously absent.

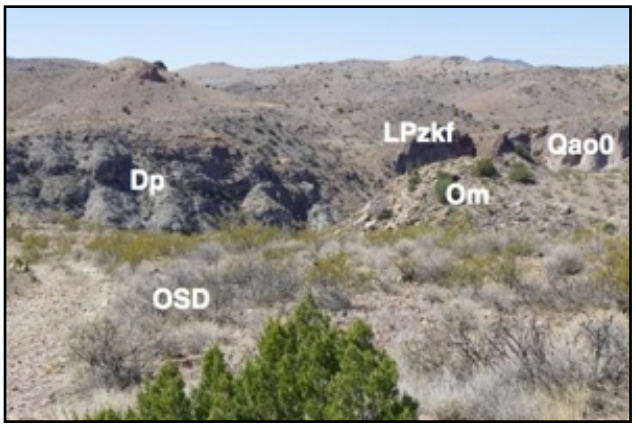


STUDY AREA 4

As with all of the other study areas, the identification of Study Area 4 was driven by the presence of a specific geologic unit. In this case, "OSD". People familiar with this area will recognize it as the Ready Pay gulch south of NM-152. The geologic jumble of the area is wonderful.

There are several "walks" which crisscross this area. See Volume 2 of *Walks In The Black Range*. The geologic richness of this area is shown directly below where we have taken the Ready Pay Gulch - Percha Box Loop trail description map and entered some of the geologic units which are found along the route. The photograph shows the view at the point where the western part of the trail overlooks Percha Creek.



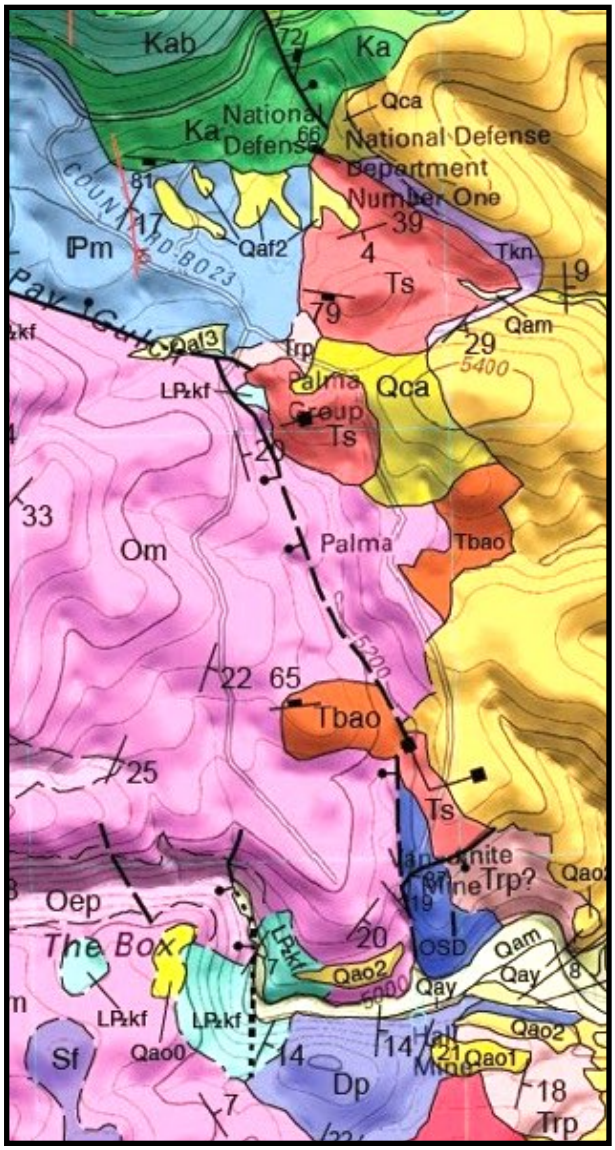


This mixture of geologic units creates some dramatic scenery; outcroppings, sheer cliffs, narrow canyons, and bottomlands.

A walk through this study area (shown above right) cannot be about geology alone. The area is also full of biology: wildflowers, wild turkeys, coyotes, an occasional mountain lion, bobcats, turkey vulture roosts . . .

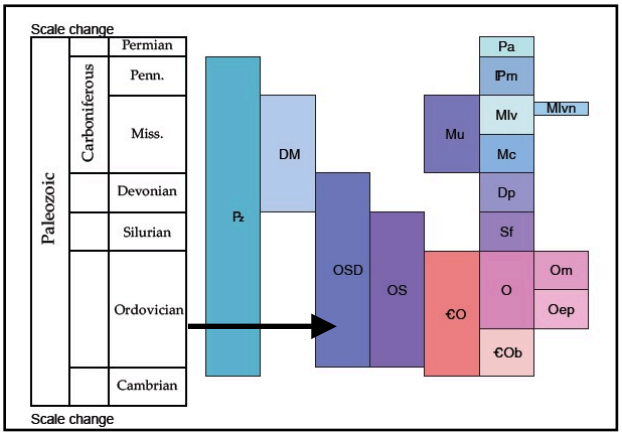
OSD

East of Hillsboro, there is an "intersection" of NM-152 and County Road B-023. The County Road is accessed through a gate and is an old mining road. It forks at an area which is the starting point for the trails mentioned in the description of Study Area Four. Taking the eastern fork of the road you eventually come to an overlook into

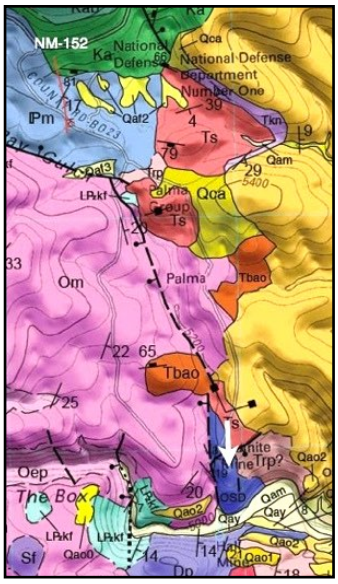


the Percha Box; at that point you will be in the middle of an OSD formation (see the dark blue unit near the bottom of the map above). The UTM location for this formation is about Zone 13 - 263900E by 3645000N.

This OSD unit is some of the oldest rock shown on the Hillsboro Quadrangle (see arrow at Correlation of Map Units below). It spans the Ordovician, Silurian, and Devonian periods (see description below), a period of roughly 130 million years (from about 488 mya to 359 mya). As such, this unit is composed of several geologic



formations (El Paso, Montoya, etc.) but has been significantly altered by the forces of the earth.



On the map to the right, a fault line is shown running down the arroyo to the west of the access road to this unit. It forms the western edge of the "OSD" geologic unit; another fault line runs through the central-right portion of the unit. The "OSD" unit is not shown on the cross-section which accompanies the Hillsboro Quadrangle Geologic Map. That cross section transects the northern part of the map.

Within 200 yards of the "OSD" unit there is rock from at least 11 other geologic units. To my untrained eye it can be difficult to distinguish them.

In the proximity of the "OSD" unit there are two lines with a black square at the end. The map legend describes this symbol as "small, minor vertical or near-vertical joint, from multiple observations at one locality - showing strike". The "strike" is "the direction or trend of a bedding plane or fault, as it intersects the horizontal". A joint is a break (or fracture) within rock when the rock has not moved (as it would have in faulting). Extensive faulting in this area is not the only source of rock fracturing; joints are prevalent throughout the area.

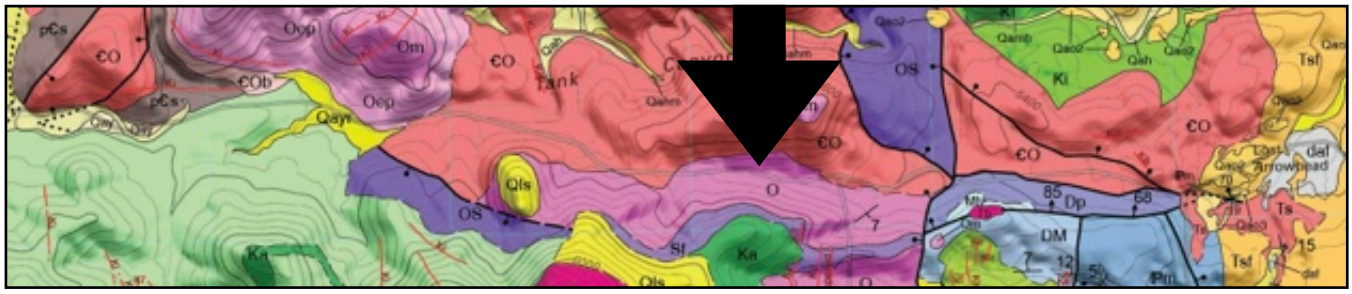
In this small area several types of faulting are documented. There are dotted lines with a "ball and bar" symbol on one side (normal faults, location is concealed, identity and existence are certain - ball and bar indicates the side of the fault which has rock downthrown); there are faults indicated by dashed lines (like the former except the location is approximate); and there are solid lines (indicating that the fault lines are accurately plotted). In several places on the map there are short straight lines with shorter lines intersecting them in the middle, with a number adjacent to the shorter of the two lines (22, 26, etc.). These symbols indicate a "small, minor inclined fault, showing strike and dip" (the number indicates the angle of dip). All of this is different from a dike.

A dike is formed when a fracture zone is filled by another type of rock, generally magmatic in our area. Dikes are indicated by red lines, as shown in the upper left of the map.

In the photo below, the "OSD" unit in Study Area 4 is in the foreground. The smaller photograph on the previous page was taken from a slightly different angle and demonstrates the significant number of other geologic units which are in the immediate area. This photograph is of the area which is south southwest of the "OSD" unit. The "Dp" unit is on the other side of the Percha Box from the "OSD" unit. Left of the "Om" unit, and in the bottom of the box are at least two other geologic units.

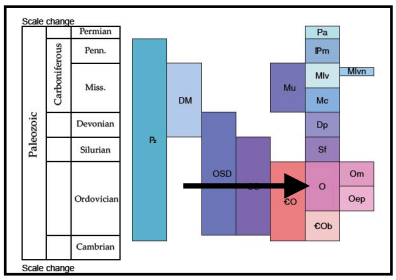
OSD	**Ordovician through Devonian strata, undivided (lower Ordovician through upper Devonian)** – Includes the El Paso Formation, Montoya Formation, Fusselman Dolomite, and Percha Shale. Differentiated where identification of individual units is precluded by alteration. Mapped in absence of upper Paleozoic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





"O"

The Ordovician Geologic Unit discussed here is located in Tank Canyon at UTM Zone 13 North Hemisphere 263250E 3653470N; Lat: 32.993967 Long: -107.53385573042813; or Latitude N 32°59'38.2812" W Longitude -107°32'01.8806". This particular site is on private land; permission and a waiver are required for entry. On the map of Study Area 2, shown above, this unit is roughly in the middle of the image. The photograph at the bottom left was taken at that locale.



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).

This geologic unit is undivided as to lower or upper Ordovician. There are other units shown on the quadrangle which are more specific. In addition, several other geologic units contain Ordovician aged rock (see correlation chart above). The Ordovician lasted about 45 million years, from about 488 million years ago (mya) to about 443 mya.

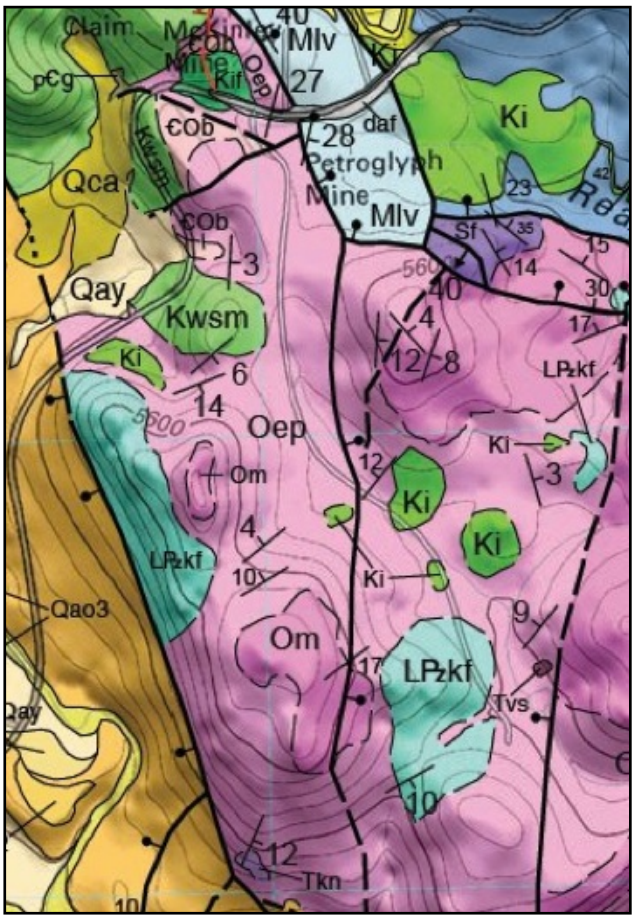
In our area this period was characterized by encroaching and retreating seas which were typically shallow. As a result there is a fair amount of shoreline deposit intermixed with the sea bed rock. In general, marine life (trilobites, corals, et al.) flourished in this area during that time. Primitive fish were evolving during this period and there is evidence that plants and terrestrial arthropods were taking a foothold on the land surface. Our area was part of Gondwana during this period.



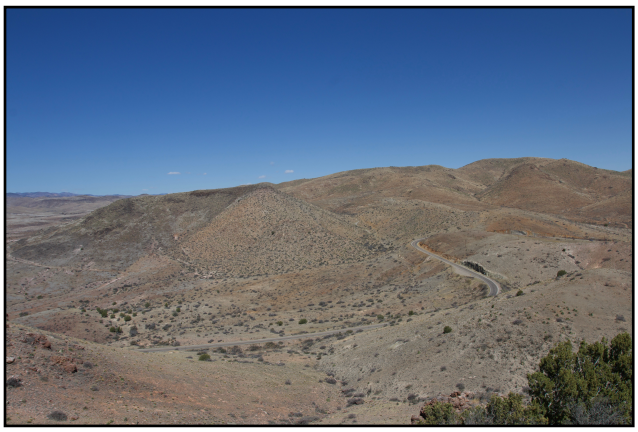
STUDY AREA 5

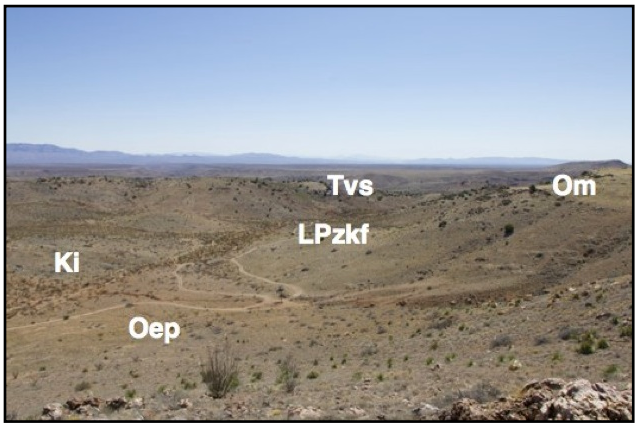
Study Area 5 is immediately south of Study Area 1 (see map below). In the top left photo on the following page all of Study Area 1 can be seen. The vantage point is from Study Area 5, looking north. The bottom left photograph on the following page was taken from the same spot as the first photo, only 180° to the south. This vantage point is on a hilltop in the northwest quadrant of Study Area 5 and shows most of Study Area 5. Some of the geologic units in Study Area 5 are shown on this photograph. The proximity of these Study Areas highlights the geologic complexity of this area.

Study Area 5 is one of my favorite spots for an afternoon stroll. The old mining road which runs (roughly) down the middle of the area is what we call the "Vulture Road" because it terminates in an overlook of the Percha Box where it is easy to find Turkey Vultures during the summer. During good wildflower years this walk can take ages as you meander from one flower to the next.



This study area is dominated by an "Oep" geologic unit. The map of this study area has two geologic map symbols shown on other maps in this series but not referenced previously in this paper. The first is the solid line which forms the boundary of some color blotches. This is a contact line between geologic units when the area of contact's existence is certain and the location is accurate. In other cases the line is dashed, indicating that the existence and identity of the contact is certain but the location is approximate.

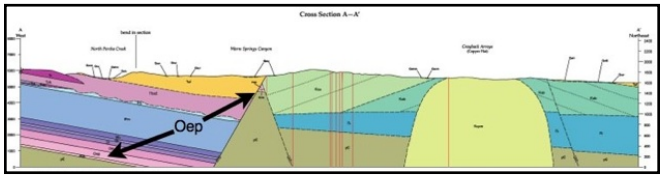




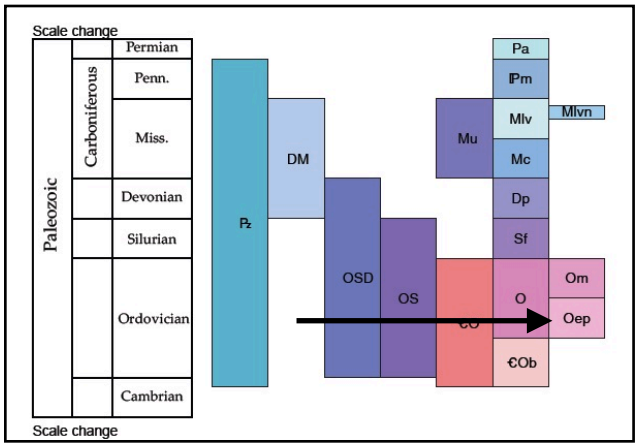
THE EL PASO FORMATION - "OEP"

The El Paso Formation ("Oep") was formed during the lower Ordovician, from about 488 mya to about 471 mya. As you can see in the "Correlation of Map Units" chart, we are still working with some of the oldest rock in the area. Small fossils, as described below, are sometimes found in this formation.

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).



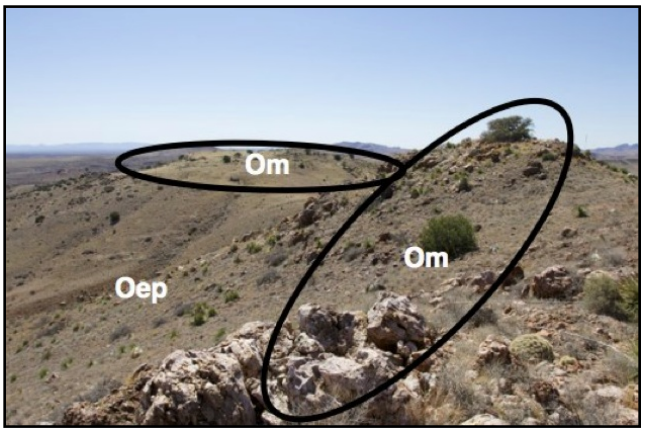
The El Paso Formation takes up most of the surface of Study Area 5. Otherwise it is largely absent from the Hillsboro Geologic Quadrangle. It is also shown in the cross-section which accompanies the map (see above).



The two areas where "Oep" is shown on the cross-section are separated as a result of faulting. The Proterozoic rock ("pЄ"), - mostly granite, gneiss, and schist - which underlies Warm Springs Canyon was upthrust, carrying a bit of Oep with it.

The El Paso Formation is part of the shallow sea calcium carbonate strata which extend from this area, through central Texas (Ellenburger Formation) to New York.

In the photograph below, taken from the top of the hill in the left center of the study area, the Oep unit is seen below the Om rock.



In the photograph at the top left on the following page, the El Paso Formation rock makes up most of the slope in the foreground, with "OM" rock being found at the top of the hill. The northern portion of the El Paso Formation rock found here extends into Study Area 1 and is visible in the road cut at the top of the hill east of Hillsboro.

GEOLOGY TRAIL ONE - WARM SPRINGS CANYON

Studying the geology of the Hillsboro area is a great excuse for taking a walk. In this case, a short walk which parallels NM-152 east of Hillsboro. Not only is this walk a wonderful example of the cross-country options of this area, but it meanders through several geologic units.

The walk begins at the crest of the hills east of Hillsboro and heads downhill to the windmill at the beginning of the Hillsboro Transfer Station Road. The distance (one-way) is only 1.2 miles and the elevation drop is only 320 feet. It is an easy amble across loose rock, so the typical precautions should be taken and typical "dangers" are present/possible (e.g., twisted ankles and rattlesnakes).



This walk is a trip through time. pЄg is Proterozoic (as in a billion years ago), Oep is Ordovician (485 - 443 million years ago), Kwsm is late Cretaceous (ca. 70 million years ago), Tsf is from the Miocene (ca. 20 million years ago), Tb is from the Pliocene (ca. 2.5 million years ago), Qca is from the late Pleistocene (150,000 years ago), and the other "Q's" are from the Holocene (generally younger than 100,000 years old).

In more recent times, the "Virginia Claim" (see photograph below) exists near the beginning of the walk (see below). In addition to Gold; Cerussite, Ilmenite, Vanadinite, and Wulfenite were found at that location.



Just north of the "Qca" indicator on the map, there are examples of the type of "improvements" that miners, from the late 1800s and early 1900s, made in this area to perfect their claims (photos in right column).

During the colder months, walks in this area are about the geology. As summer approaches more and more of the walks will be about biology. Something for every season here.

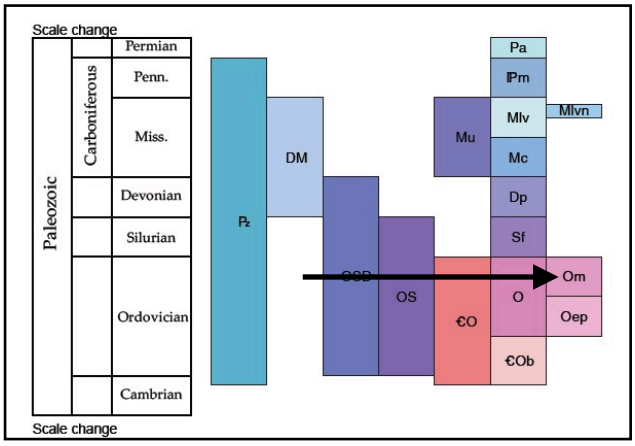
THE MONTOYA FORMATION - "OM"





The Montoya Formation ("Om") was formed during the period between 471 mya and 443 mya, during the middle and upper Ordovician. These are the last Ordovician rock formations that we will be dealing with in this paper.

The Montoya Formation is found at the top of the hills on the west side of the map of Study Area 5, seen previously. The photograph at the top of page 22 was taken at the top of these hills. The photograph at the top



left on page 23 shows the Montoya Formation and its relationship with the El Paso Formation (these two formations are the primary Ordovician units in our area). Another angle of this hill is shown at the center right on page 22.

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).

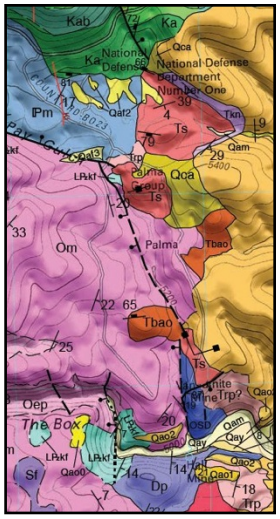
The Montoya Formation is composed of the Cable Canyon Member, Upham Member, Aleman Member, and Cutter Member. In "Conodonts of the Montoya Group, Mud Springs Mountains, New Mexico" David G. Evans and James E. Barrick (Proceedings of the New Mexico Geological Society 63rd Annual Field Conference) describe some of the fossil findings which are being used to describe the boundary between the Aleman Member and the Cutter Member - and the nature of that boundary.

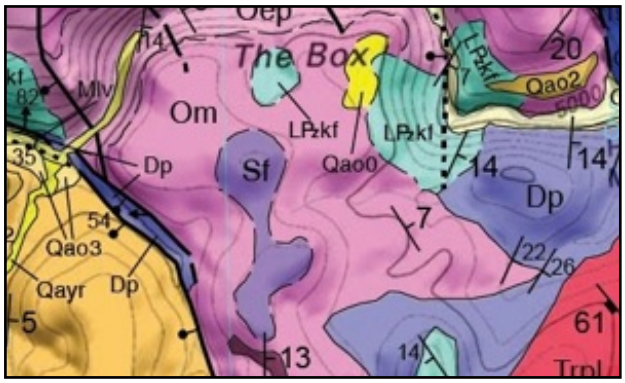
The NM-27 - Hillsboro to Nutt Auto Tour describes the geology along this route - including the locations of the Montoya Formation farther south.

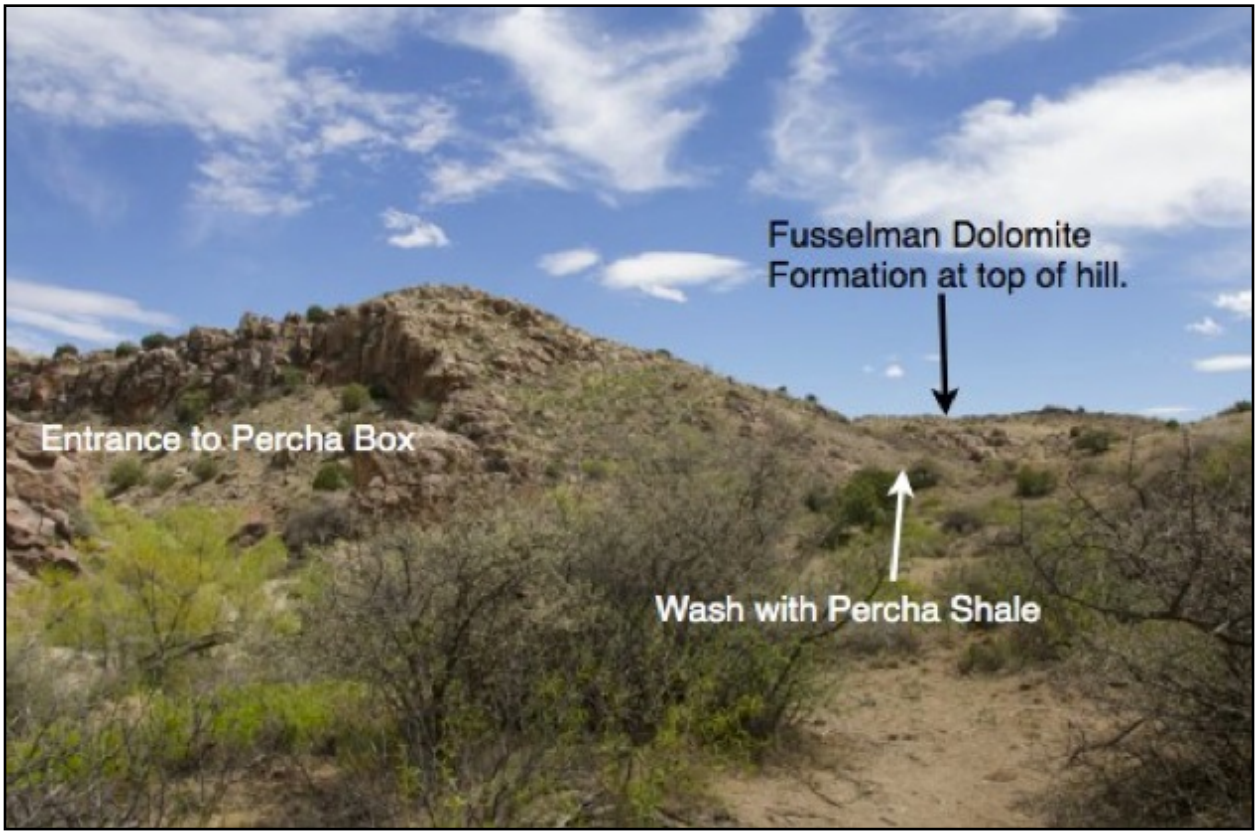
FUSSELMAN DOLOMITE ("SF")

The geologic unit of Fusselman Dolomite ("Sf") is in Study Area 4, roughly in the center of the map at the right, at UTM location Zone 13 263000 E by 3644500 N.

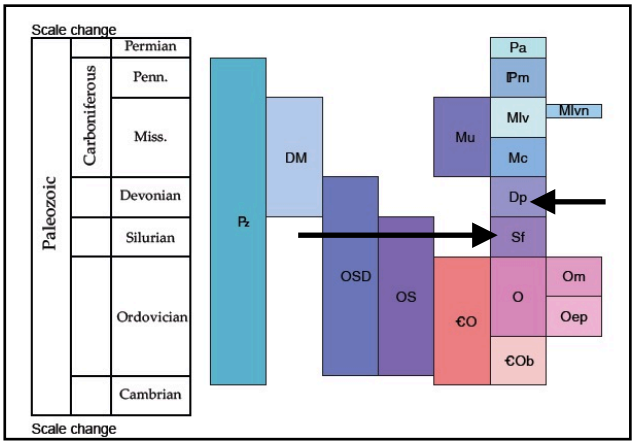
Starting at the confluence of Warm Springs Wash and Percha Creek, follow the Percha Creek drainage eastward until the entrance of the Percha Creek Box is reached, then up a well defined drainage (see photo below), through a deposit of Percha Shale ("Dp"). Percha Shale is from the Devonian Period and is, thus, younger rock than the Fusselman Dolomite on the hilltop. The explanation of how this interesting juxtaposition occurred awaits a later discussion. Leaving the Percha Shale which is in the bed of the wash, the route turns east, and uphill, to the crown of two hills. The Fusselman Dolomite unit is quite large in this area. The photograph below gives the general lay of the land. Later in this paper we discuss the walk to this formation and discuss the Percha Shale geologic unit. The photograph was taken just beyond an old corral which is near the entrance to "The Box". Although three other geologic units ("Pz", "OSD", and "OS") on the Hillsboro Geologic Quadrangle contain rock from the Silurian period, the Fusselman Dolomite unit is the only one which is restricted to the Silurian.







The Silurian Period lasted from 443.7 mya to 416 mya. During this period there was substantial melting of glacial formations and correspondingly, dramatic increases in sea level. It was the start of a period of relative stabilization of the Earth's climate.



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.

This particular rock is relatively fossil-free. However, the Silurian was very active biologically, including significant diversification of sea life, evidence of the first fresh water fish, and the "first good evidence of life on land". This included the development of vascular plants which are the foundation of terrestrial ecology.

There are no recognized subcomponents of the Fusselman Formation.

The Fusselman Formation is more prevalent and more obvious during the drive south on NM-27, south of the Hillsboro Quadrangle. The NM-27 - Hillsboro to Nutt Auto Tour describes the geology along this route.

Photographs on this page: Fusselman Dolomite unit taken along the ridge referenced here.



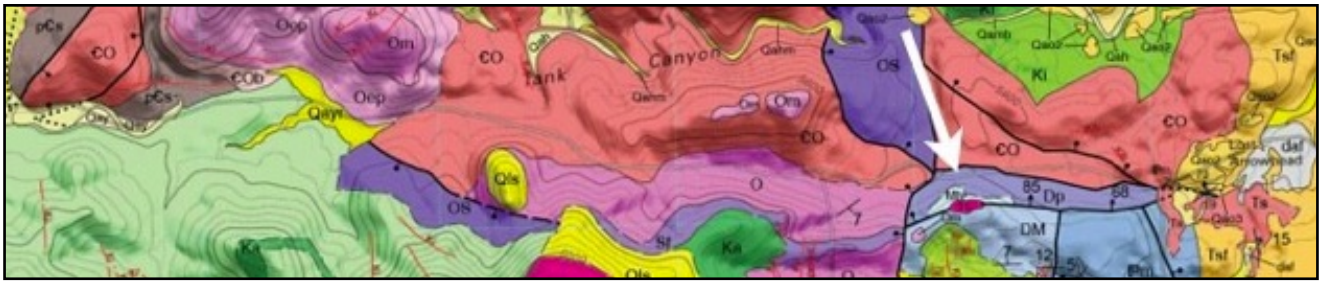
PERCHA SHALE "DP"

There are four geologic units ("Pz", "DM", "OSD", and "Dp") in the Hillsboro Geologic Quadrangle which have rock aged to the Devonian Period. Only the "Dp" unit, Percha Shale, is restricted entirely to the Devonian. As noted on the "Correlation of Map Units" chart (left) we are still trawling around in the oldest rocks of our area and have a long way to go before we reach the recent alluvium.

The Devonian period lasted from about 416 mya to about 359 mya; it is divided into the Lower Devonian (416 mya to 397.5 mya), the Middle Devonian (397.5 to 385.3 mya), and the Upper Devonian (385.3 mya to 359.2 mya). As the Earth is about 4.6 billion years old, more than 90% of its existence had elapsed by the start of the Devonian.

Living things grew rapidly in terms of diversity, complexity, and size during this period. The first land-living vertebrates and the first terrestrial arthropods





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.

evolved during this period. In the seas, corals and shell fish were plentiful. The first jawed fish appeared during the Middle Devonian.

The land mass which was to become New Mexico (and the rest of North America) was joined with the future Europe at this time near the Equator. Most of the land mass of "Euramerica" was covered in shallow seas. Locally, a large deposition of gray limy sediment occurred. It was this sediment which would become Percha Shale.

Although such sediment is perfect for the formation of fossils, Percha Shale is relatively fossil poor. The end of the Devonian, when one of the five great mass extinctions of life occurred, was an especially difficult period for marine life.

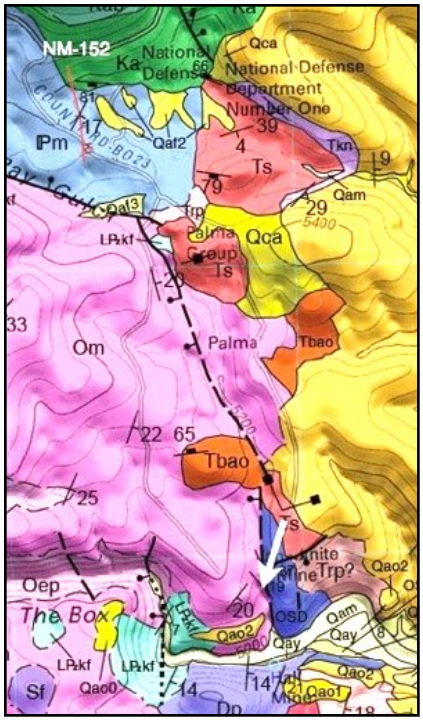
For the purposes of this assessment, three Percha Shale sites were visited. The first was in Study Area 2, in Tank Canyon (see geologic map above) at UTM Zone 13 North Hemisphere 264150E 3653375N; or Lat: 32.993306 Long: -107.52420706117529; or Latitude N 32°59'35.9016" W Longitude -107°31'27.1454". The photographs shown on the this page were taken at that site.

The second site was in Study Area 4, at the location shown on the geologic map at the top left on the following page. There is a large Percha Shale deposit on the south side of the Percha Creek drainage at this location.

Note at this point the "Sf" (Fusselman Dolomite) unit in the lower left of the map (at the top left of the next page) and the two fault lines immediately to its east. The Percha Shale deposit is younger than the Fusselman Dolomite deposit and lower in elevation. The right most fault shows that the western side of the rock mass





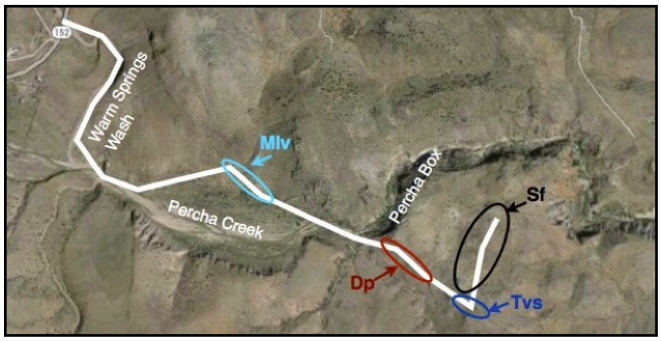


was down-thrust; that fault cannot explain the relative positions of these two geologic units. It is possible that the left fault displaced the land masses, but that is not indicated on the map (it may be that there was no displacement or that it is not known if there was displace-ment). Other faults to the north of the Fusselman Dolomite clarify the situation no more.



The Percha Shale formation in Study Area 4 is the large gray mass near the center of the photograph above.

The third Percha Shale site we visited is the one described below in the section entitled "Geologic Trail Two". At this location the Percha Shale unit is bounded by two faults, both of which indicate that the land mass to the west of the fault was down-thrust. Those faults would explain the relative position of the two units, on the western side of the Fusselman Shale. The Percha Shale photographs on the next page were taken at this location.

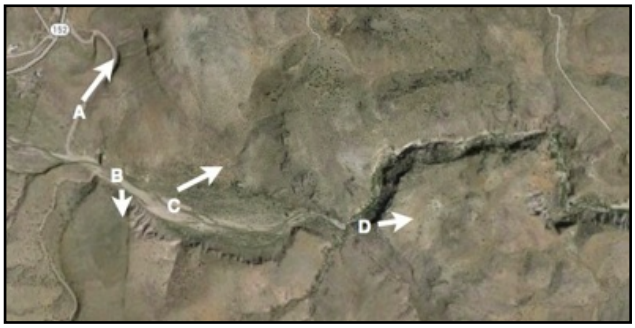


GEOLOGIC TRAIL TWO

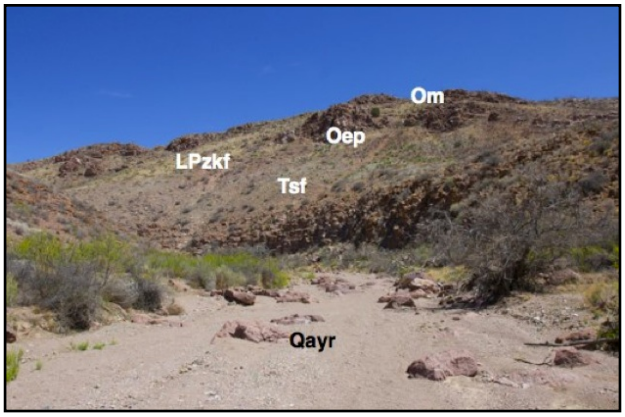
This "geologic ramble" describes the on-site visit to the Fusselman Dolomite ("Sf") Formation which overlooks the Percha Box (described above). On the map at the bottom left the walk to the "Sf" site is shown as a white line, starting at the culverts under NM-152, east of Hillsboro. The walk follows Warm Springs Wash to Percha Creek and then downstream to the entrance of the Percha Box. At that point the route turns southeast up a well defined wash and then uphill (first southeast and then northeast).

Along the way there were stops at an "Mlv" (Lake Valley Limestone) geologic unit, a deposit of "Dp" (Percha Shale), a "Tvs" geologic unit (volcaniclastic deposit from the Oligocene), and finally the Fusselman Dolomite ("Sf") unit on the top of the hills.

There is a great deal of geology along this walk. The photo key map, below, shows the point where the following photographs were taken and the direction of the photograph.



The first photograph, directly below, was taken from "A". We are looking back up Warm Springs Wash, in the area where it has opened back up, from Percha Creek. "Om" is the Montoya Formation, "Oep" is the El Paso Formation, "LPzkf" is karst fill from the Cretaceous, "Tsf" is the Santa Fe Group predating the Palomas Formation from the Miocene, and "Qayr" is alluvium (middle Holocene to present).



The photograph at the bottom left of page 28 was taken from location "B" and is of the Western Boundary Fault of the Animas Uplift.

The photograph at the bottom right on page 28 was taken from location "C", near the ruin of a small rock and adobe structure with well. The units shown here have been discussed above, except for "Qay" which is alluvium from the middle to upper Holocene and "Qah" which is historic alluvium.

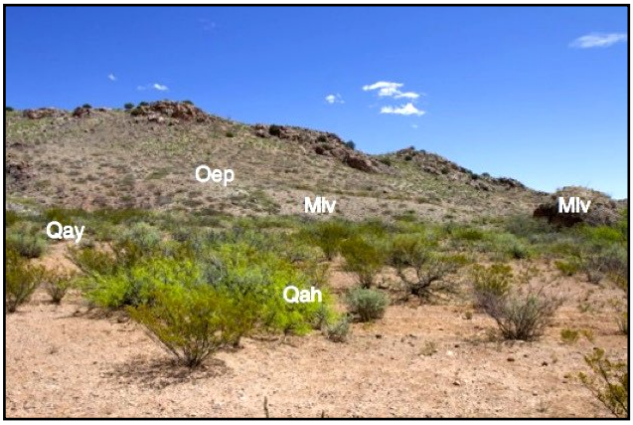




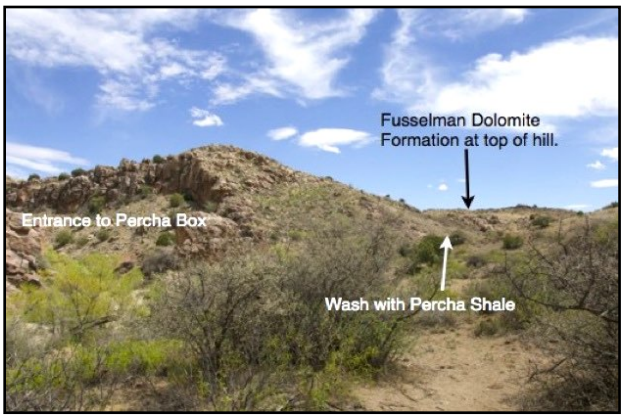


Above: Percha Shale deposits from location shown in red on the map at the lower left on the previous page.





The last photograph in this series, below, was taken from location "D". The entrance to the Percha Box is shown on the left, the wash with Percha Shale is shown immediately ahead, and the Fusselman Dolomite unit is shown at the top of the ridge, center right.

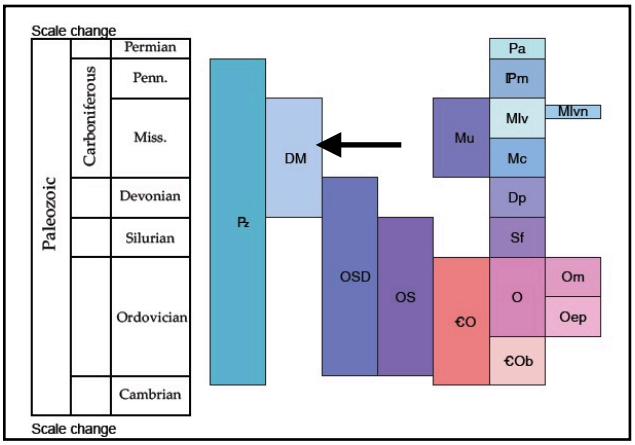


DEVONIAN THROUGH MISSISSIPPIAN STRATA - "DM"

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.

The "DM" geologic unit described here appears on the Hillsboro Geologic Quadrangle only in the northeast quadrant, in Study Area Two (see below).

This geologic unit spans the upper Devonian through the Mississippian (385 mya to about 346 mya). The Carboniferous Period includes both the Mississippian and Pennsylvanian Periods. As such, this unit (in this area) includes both Percha Shale and Lake Valley Limestone, but they are greatly altered and difficult to separate in areas large enough to scale on the map. The Lake Valley formation is named after Lake Valley south of Hillsboro and north of Nutt.



The Devonian we have discussed earlier. The Mississippian was a period in which warm seas were constantly retreating and advancing in our area, thus the marine limestones which typify this period in North America.

The Lake Valley Limestone beds are rich in marine fossils. They, and the Magdalena Group, from the Pennsylvanian, are the richest fossil-bearing strata from the Paleozoic in our area. Crinoids and brachiopods are most common in the Lake Valley Formation.

The Lake Valley Formation is best viewed and explored during the drive south on NM-27, south of the Hillsboro Quadrangle. See the NM-27 - Hillsboro to Nutt Auto Tour Page for details.

The photograph below is of a Crinoid found by Steve Morgan near Kingston, NM, in strata of this formation.



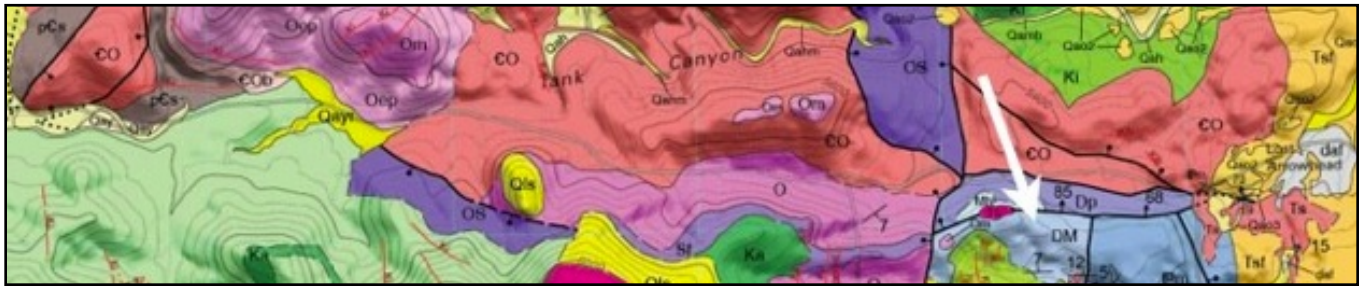
MISSISSIPPIAN ROCK - "MU"

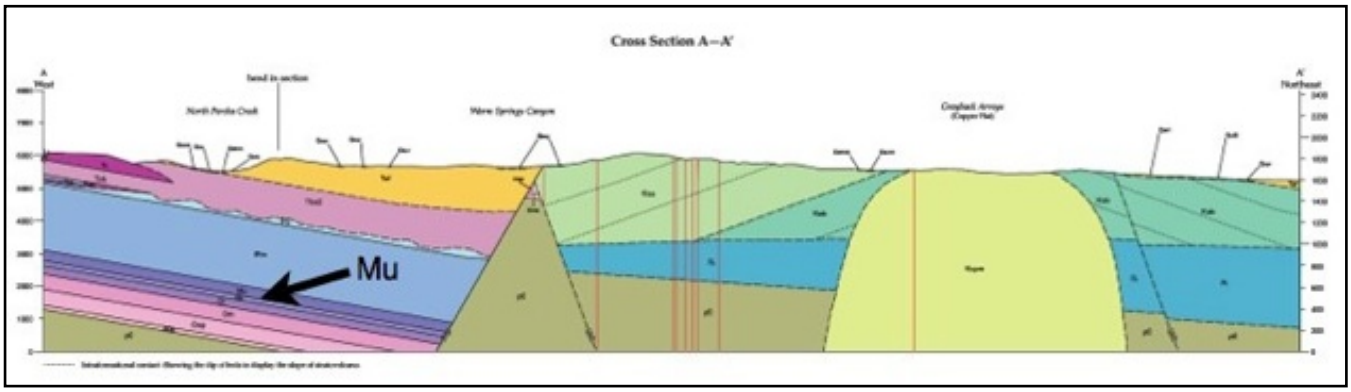
The undivided strata from the lower Mississippian identified as "Mu" on the Hillsboro Geologic Quadrangle does not rise to the surface within the area covered by this map. It is only shown in the cross-section (see following page) which accompanies the map.

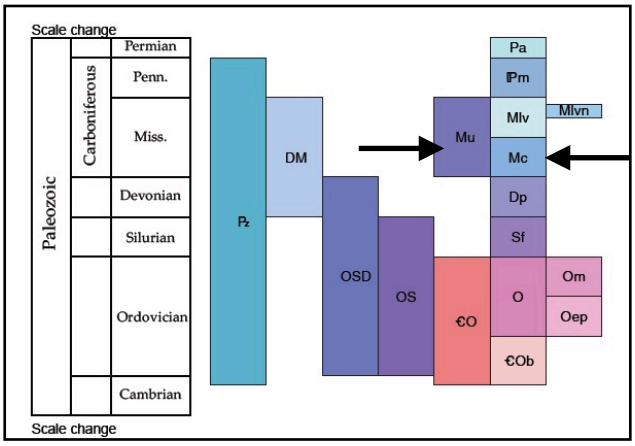
Mu	**Mississippian strata, undivided (lower Mississippian) –** Cross-section 94 m in cross-section.

Geologic units "Pz" and "DM" which include material from the Mississippian Period were covered earlier. In our area, three specific geologic units have been identified for the Mississippian Period. They are "Mlv" which is the Lake Valley Limestone unit from the lower Mississippian; the "Mlvn" unit (the Nunn Member from the lower Mississippian); and the "Mc" unit, the Caballero Formation, also from the lower Mississippian. We will discuss these geologic units later.

An excellent discussion of these units in total (Mu) and specifically (Mlv, Mlvn, and Mc) can be found in *Sedimentary Petrography and Depositional Environments of the Type Section of the Mississippian Lake Valley Formation, Sierra County, New Mexico* by Karl Krainer and Spencer Lucas (it is not as daunting as the title makes it seem).







CABALLERO FORMATION - "Mc"

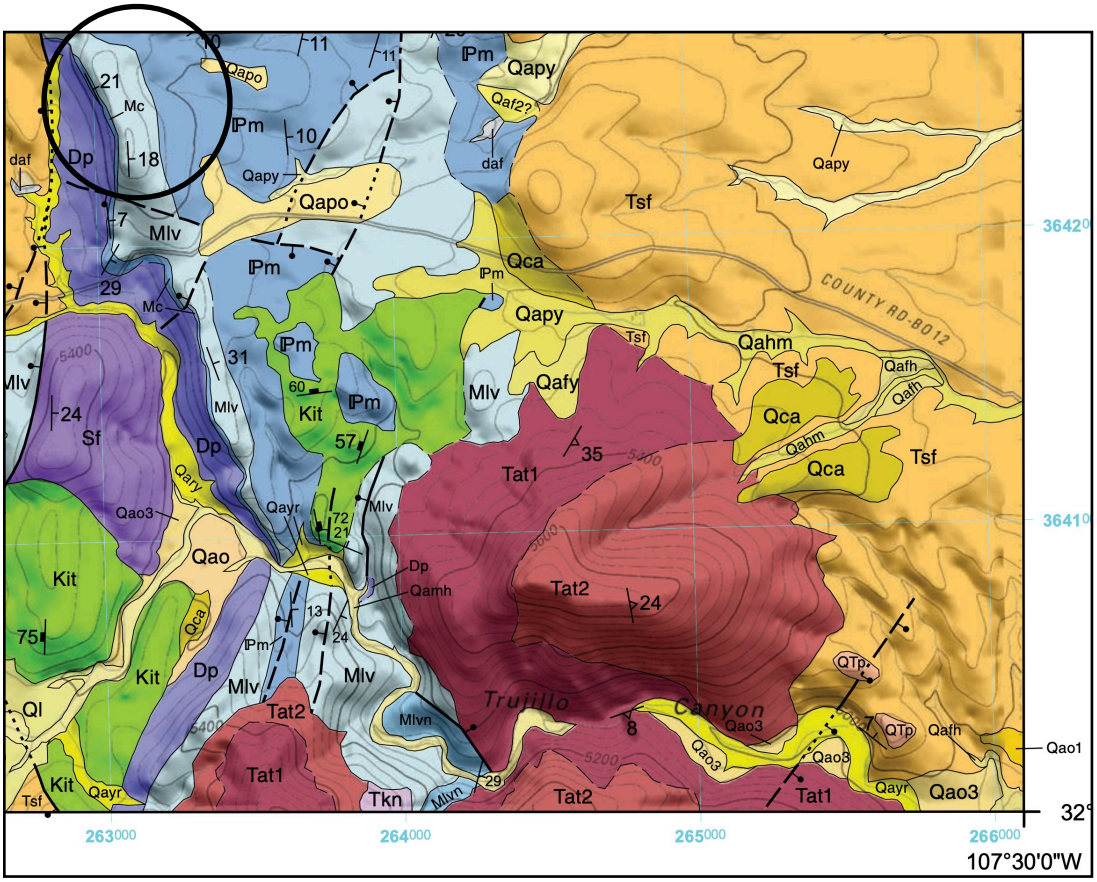
Mc	**Caballero Formation (lower Mississippian)** – Dark-gray, medium- to thick-bedded, massive to cross-stratified or laminated, cherty, fossiliferous limestone. Commonly an arenaceous to marly packstone (O'Neill et al., 2002). Chert occurs as dark-colored masses and networks. Fossils include crinoid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

The Caballero Formation ("Mc") was formed during the lower Mississippian (from about 358 mya to about 346 mya). During that period our area was covered in shallow warm seas. It is for that reason that this particular formation tends to be rich in crinoid fossils. It does not appear on the cross-section of the Hillsboro Geologic Quadrangle. Indeed, it appears on the quadrangle only as a small section on private land in the southeast quadrant of the map at about UTM Location Zone 13 263150E by 3641850 N (see map below).

The best study area for Mississippian period rock is not in the Hillsboro Geologic Quadrangle area but farther south. For more information about these units in that area see the NM-27 - Hillsboro to Nutt Auto Tour Page. I feel good about not having to dig a hole in the ground to give you a picture of this material.

Rock from this period is generally called Tournaisian in Europe, Tangbagouan in China, and Kinderhookian in North America.

As noted in our discussion of the more general "Mu" geologic unit, an excellent discussion of the Mlv, Mlvn, and Mc geologic units can be found in Krainer and

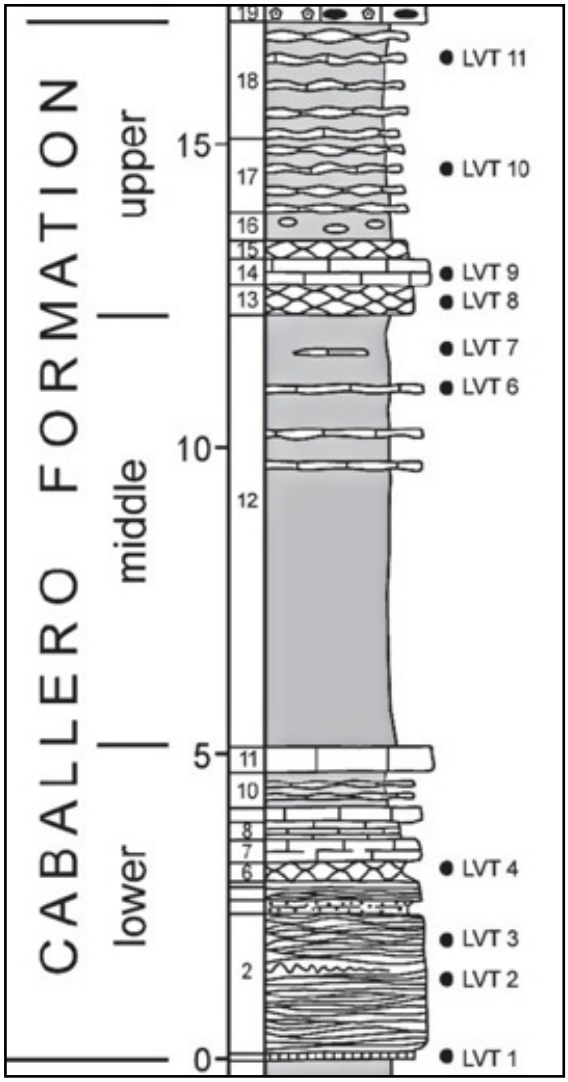


Lucas (see page 29). Their study was made at Apache Hill, just north of the Lake Valley townsite, on the east side of NM-27.

Krainer and Lucas' discussion of the Caballero Formation makes a point which is often lost on a lay person like myself. Geologic formations are not always monolithic. The stack shows clearly that the Caballero Formation is made up of different types of rock and that the rock has a significant range of physical and chemical attributes. Specifically, shale, limestone, and siltstone (in various forms) are all found in this formation - but note that they are all sedimentary in nature.

The photograph below was taken at Apache Hill just north of Lake Valley. The whole hillside can be good for fossils, although it tends to be more "dramatic" at the top - which is a great place for a picnic on a warm day.
In this photograph, the Caballero Formation is in the foreground, below the Lake Valley Formation. (The rock cliffs are the Alamogordo Member of the Lake Valley Formation; a narrow band below that is the Andrecito Member of the same formation).





LAKE VALLEY LIMESTONE - Mlv

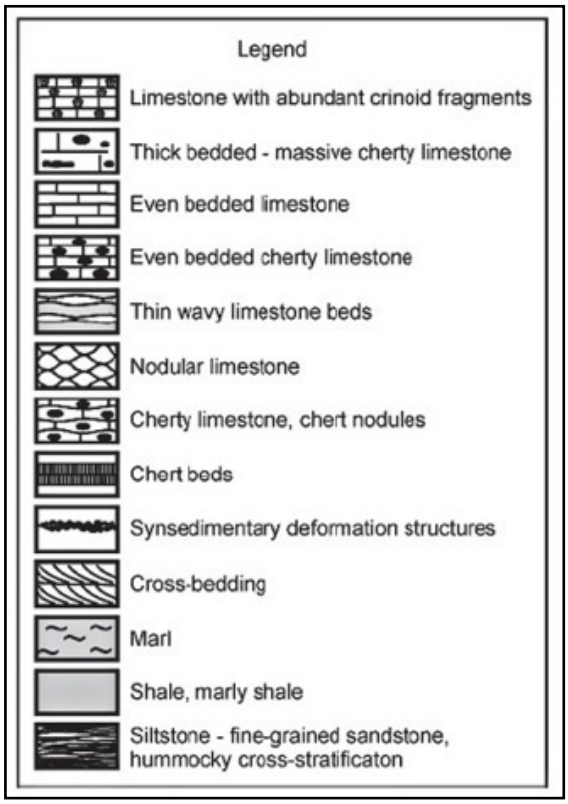
The Lake Valley Limestone, "Mlv", site pictured in the left center of the photograph at the top of the next page is found at about UTM Zone 13 -- 262100E by 3644850N along the walk described as Geologic Trail Two (page 27). This location is east of Hillsboro near the entrance to the Percha Box (see map at the center left of the next page).

Relatively speaking, this is a tiny sliver of strata. The best study area for Mississippian period rock is not in the

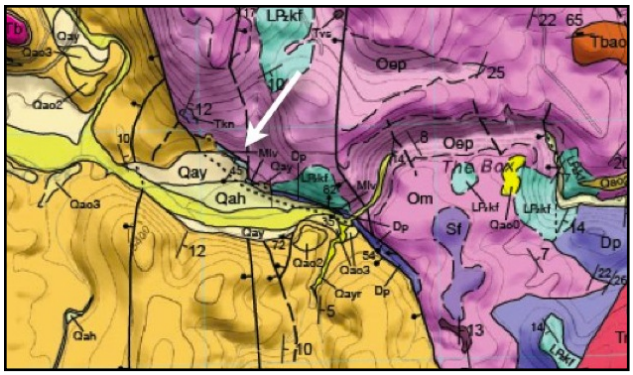
Mlv **Lake Valley Limestone (lower Mississippian)** – Dark- to light-tannish-gray, thin- to thick-bedded, massive to horizontally laminated, cherty, fossiliferous, occasionally marly limestone with subordinate siltstone and mudstone. Chert weathers to dark-orange-brown and occurs as crusts, lacy networks, 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:

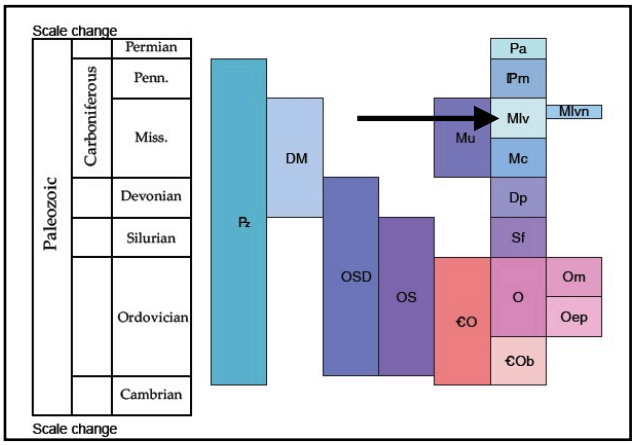
Hillsboro Geologic Quadrangle area but farther south. For more information about these units in that area see the NM-27 - Hillsboro to Nutt Auto Tour Page of the Black Range website.

The rock from the Mississippian Period, in our area, is pretty much limited to the Lake Valley Formation dating from 360 mya to 320 mya. During this time most of this









area was covered in shallow warm seas which tended to encroach and retreat leaving the wonderful limestone we find here.

As noted in our discussion of the more general "Mu" geologic unit, an excellent discussion of the Mlv, Mlvn, and Mc geologic units can be found in Krainer and Lucas (see page 29). Their study was made at Apache Hill. Specifically, "the base of the section is at UTM zone 13, 259270E, 3624884N and the top is at 259202E, 3624275N." (from cite above).

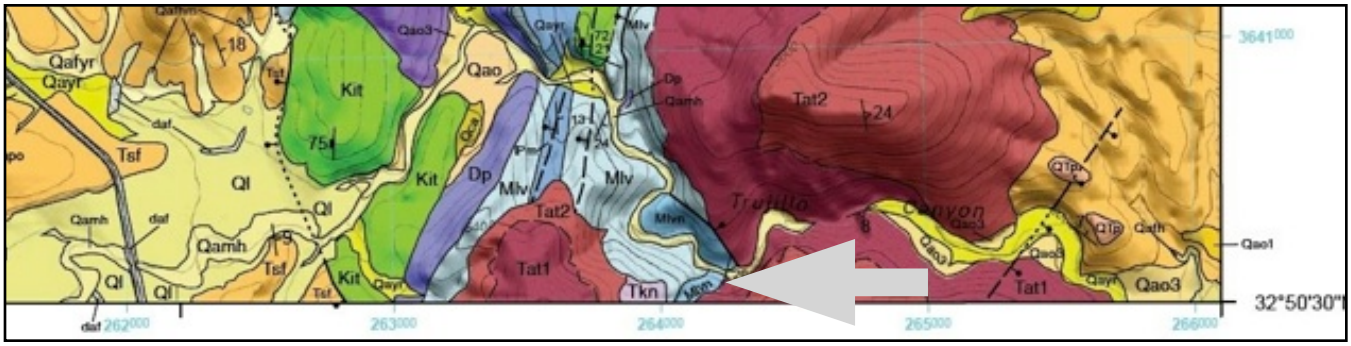
The detail of the Hillsboro Geologic Quadrangle (from "Geologic Trail Two") shown at the center left shows the small sliver of Lake Valley Limestone. It also shows the extensive amount of faulting that has occurred in this area. During an afternoon stroll a person could wander through some of the most complex geology in this area.

The Lake Valley Limestone Formation is composed of four "members", the Andrecito Member, the Alamogordo Member, the Nunn Member, and the Tierra Blanca Member. See the Krainer and Lucas work (cite above) for a detailed description.

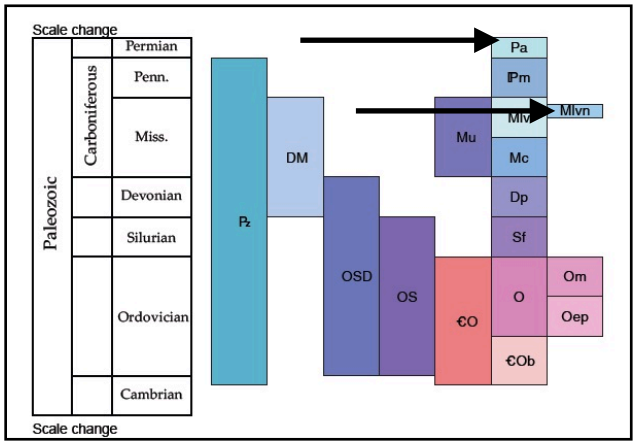
At the reference site, the Lake Valley Limestone contains many small veins of intruded material and small fossils (see the photograph at the top of the following page).

NUNN MEMBER OF THE LAKE VALLEY FORMATION - Mlvn

As mentioned above, the Lake Valley Formation is composed of four members. The "youngest" of the members to appear on the Hillsboro Geologic



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.





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.

Quadrangle is the Nunn member which appears in a small section of the map in the lower right, near Trujillo Canyon, on private property (see map above).

The Nunn Member dates from about 360 mya to about 340 mya. During this time most of this area was covered in shallow warm seas which tended to encroach and retreat leaving the wonderful limestone we find here.

As noted in our discussion of the more general "Mu" geologic unit, an excellent discussion of the Mlv, Mlvn, and Mc geologic units can be found in Krainer and Lucas (see cite on page 29). Their study was made at Apache Hill, just north of the Lake Valley townsite, on the east side of NM-27. Specifically, "the base of the section is at UTM zone 13, 259270E, 3624884N and the top is at 259202E, 3624275N." (from cite above). The National Geologic Map Database describes this as the "Type section of the Nunn Member: on Apache Hill, at the type section of Lake Valley Formation, near Lake Valley, in NE/4 NW/4 sec. 21, T. 18 S., R. 7 W., Sierra Co., NM (Laudon and Bowsher, 1949)."

The Nunn Member has many crinoid fossils. See Elizabeth C. Rhenberg's dissertation, "*Systematics, Phylogenetics, and Biogeography of Early Mississippian Camerate Crinoids of the Nunn Member, Lake Valley Formation, in south-central New Mexico*" for an extensive discussion of these fossils.

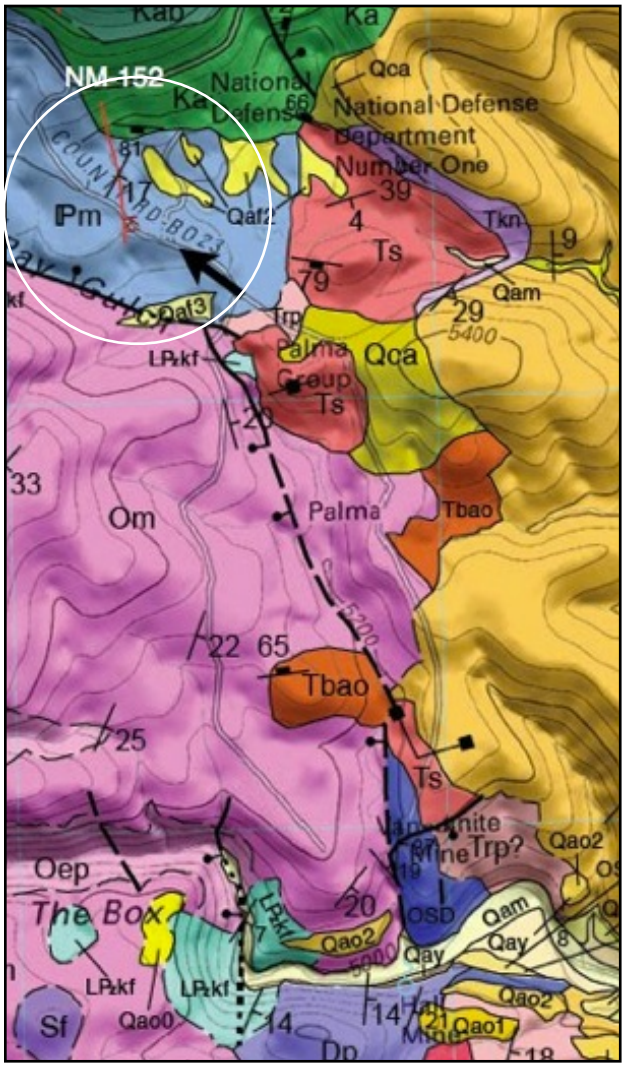
The Nunn Member of the Lake Valley Formation is just above the rock cliffs (the Alamogordo Member of the Lake Valley Formation) in this photograph of Apache Hill.

THE MAGDALENA GROUP - IPm

The Magdalena Group represents the Pennsylvanian Period in the area covered by the Hillsboro Geologic Quadrangle. The Pennsylvanian Period lasted for about 23 million years (322 mya to 299 mya) and in our area was characterized by intruding and retreating warm shallow seas, much like the Mississippian Period. There are significant marine fossils (listed in the geologic unit description above) in the Magdalena Group.

For more information about Pennsylvanian Period geologic units in our area see *The Pennsylvanian Red House Formation, Central Sierra County, New Mexico* by Spencer Lucas, Karl Krainer, James Barrick, and Justin Spielmann.

This geologic unit can be found in Study Area 4 (see map and photograph in the left column of the next page), just south of NM-152, where it passes through the curves just east of Hillsboro. The south side of this unit is formed by a normal fault, the Magdalena unit being downthrown; the "Om" rock to the south of this unit is older. To the north, there are younger units - basaltic intrusions and andesite flows. To the east there is a Sugarlump Tuff formation. To the west, the "Ki" unit is also intrusive. Thus, to the east, north, and west of the subject unit the surface is covered by lava flows and intrusions; to the south lies older rock, from which it is separated by a fault line. The unit, itself, is not geologically complex. There are no faults or dikes which run through it, for instance.



THE ABO FORMATION - "PA"

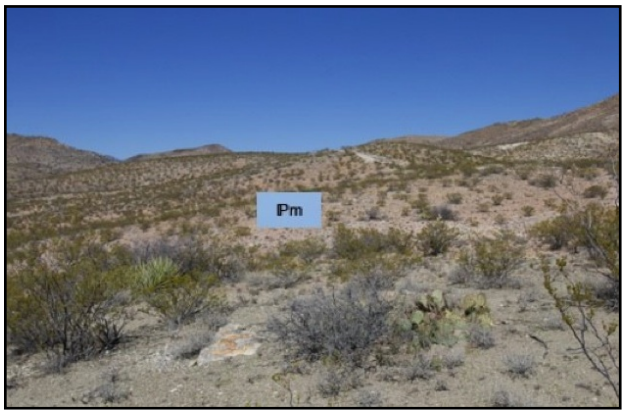
Pa	**Abo Formation (lower Permian)** – Cross-section only. Reddish-brown to light-brown sandstone interbedded with grayish-red shale and siltstone. Approximately 121 m thick in the Black Range; top is likely eroded in cross-section.

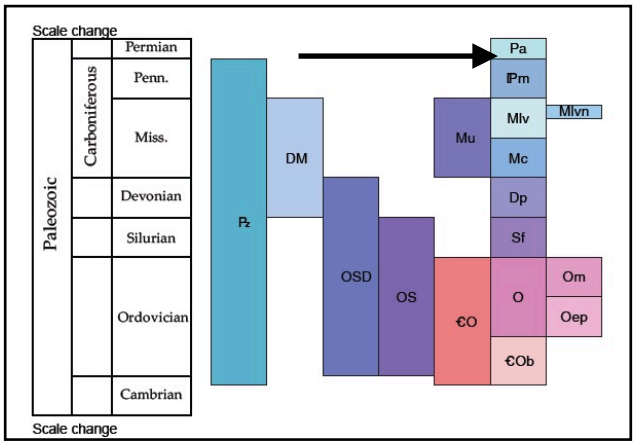
We end our survey of the Paleozoic with a fizzle. The Abo Formation, the representative of the Permian Period on the Hillsboro Geologic Quadrangle, does not come to the surface within the area of the quadrangle. It is found only on the cross-section (see below) which accompanies the map.

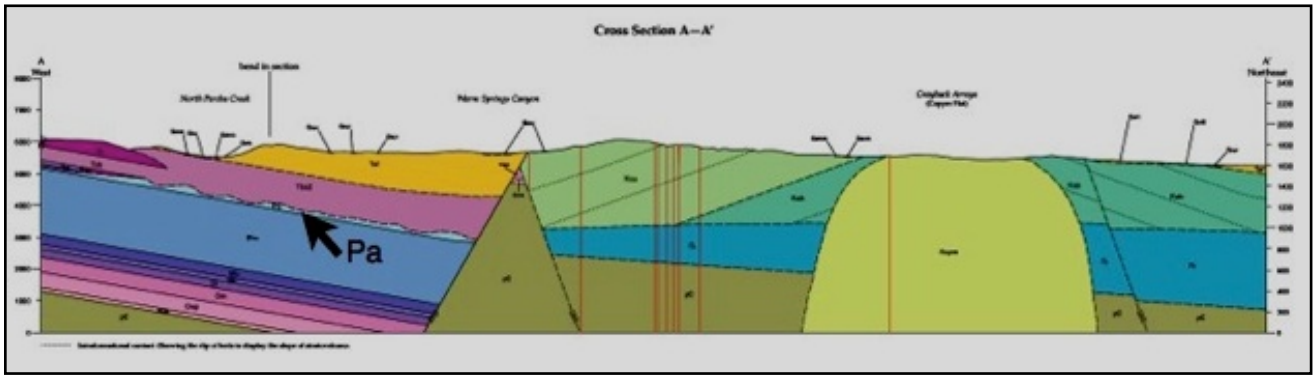
Although the warm shallow seas were still intruding and retreating in our general area during the Permian, the Abo Formation consists of terrestrial deposits; apparently the seas were in retreat. Although there are no marine fossils found in this geologic unit some terrestrial animal and plant fossils have been found in the formation, as have animal tracks at other locations.

Although not in the Hillsboro Quadrangle, *The Lower Permian Abo Formation in the Fra Cristobal and Caballo Mountains, Sierra County, New Mexico*, by Spencer Lucas, Karl Krainer, Dan Chaney, William DiMichele, Sebastian Voigt, David Berman, and Amy Henrici is an excellent reference about this formation in our general area.

There was significant glaciation at the start of the Permian, followed by general warming. There was considerable diversity in both the land and sea fauna of this period. But the Permian did not end in a "fizzle". The end of the Permian, and the Paleozoic in general, saw the most extensive mass extinction in the past 600 million years.





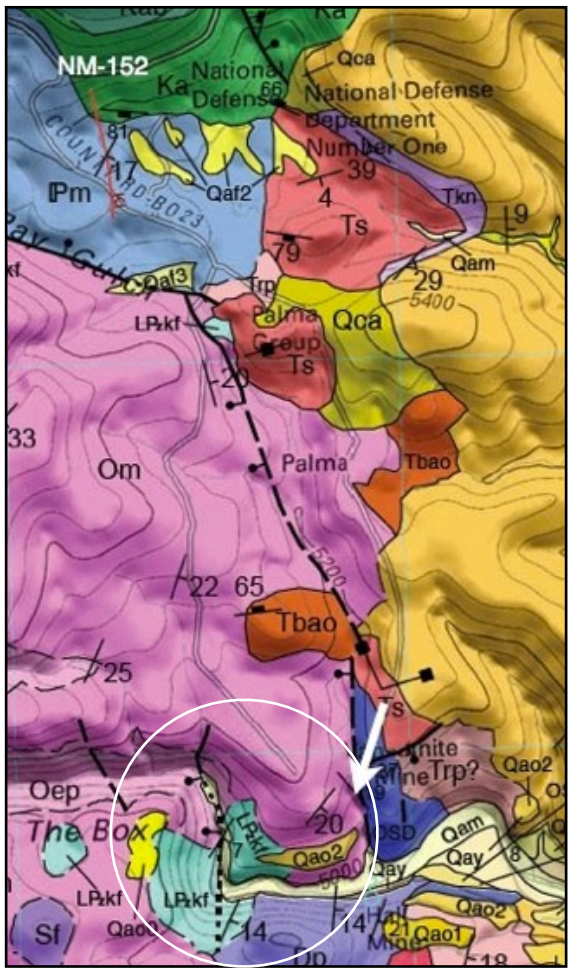


THE MESOZOIC (CRETACEOUS)

LPZKF - KARST FILL FROM THE CRETACEOUS

What happens when a karst (cave, sinkhole) fills up and forms a major geologic deposit? You get "LPzkf". This geologic unit from the Cretaceous is found in the vicinity of the Percha Box in Study Area 4, Study Area 5, and along Geology Walk 2. The location of the formation in Study Area 4 is shown below. The photographs on the next page were taken at that location.

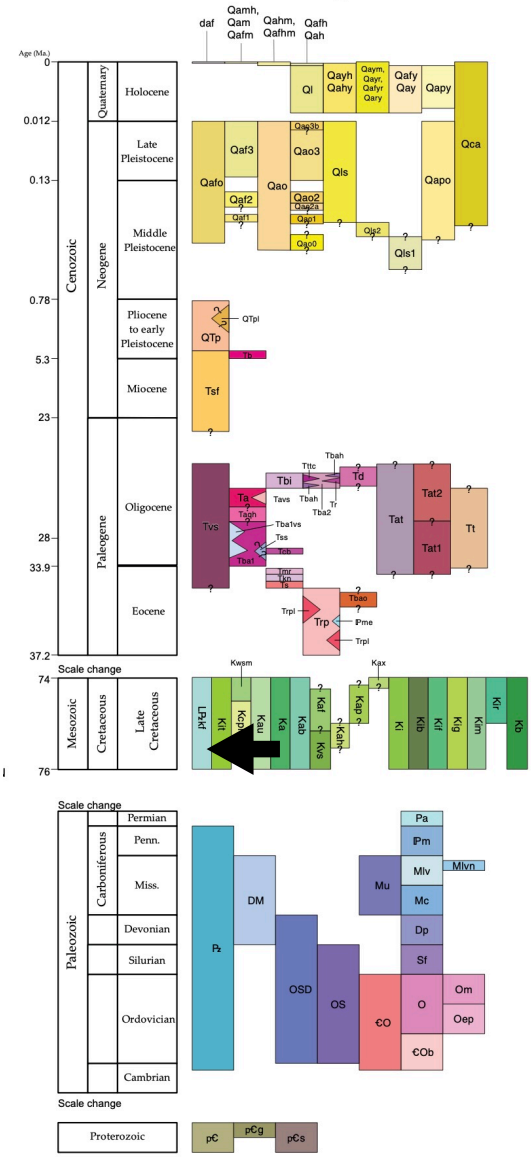
This geologic unit is from the Late (or Upper) Cretaceous, formed from 76 mya to 74 mya. The next oldest geologic units in our area date from the Permian, which ended 251 mya. This gap in time, from 251 mya to 76 mya is discussed in *The Sub-Cretaceous Unconformity in New Mexico* by Steven Cather. In our area, there are no representative geologic units on the surface from the Triassic, Jurassic, or Lower Cretaceous.



This unconformity is, by its presence - that is, the absence of rock -- a major geologic feature in our area. For a discussion of the Upper Cretaceous in our area see: *Upper Cretaceous Stratigraphy and Biostratigraphy of South-Central New Mexico* by Stephen Hook, Greg Mack and William Cobban.

The LPzkf geologic unit — in fact, all of the Cretaceous geologic units found on the Hillsboro Geologic Quadrangle — had formed by the time the Cretaceous-

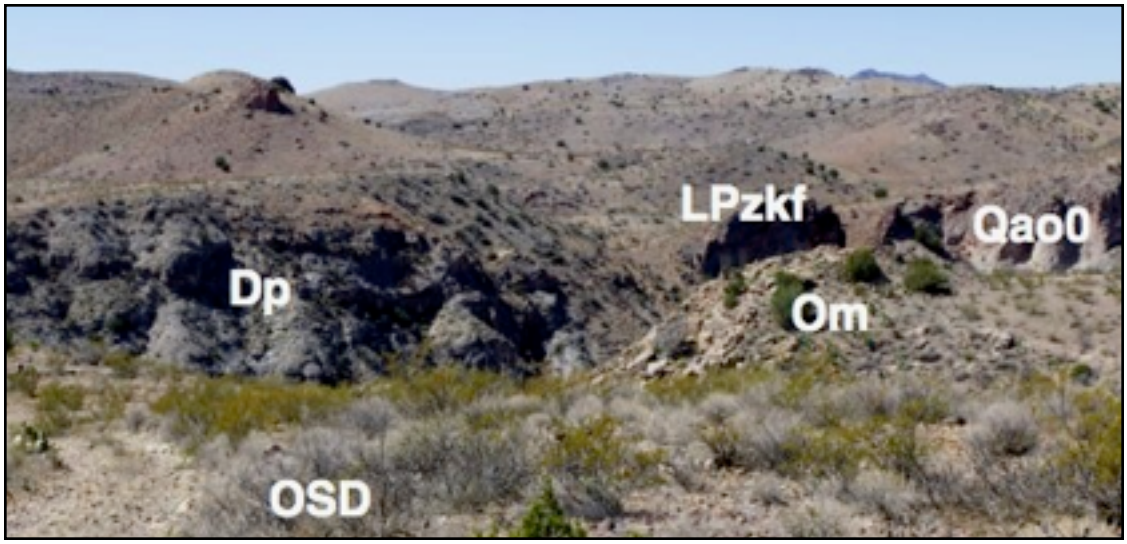
Correlation of Map Units



Tertiary extinction (when the dinosaurs were "wiped out") occurred. There is another major unconformity in our area, following the Cretaceous period referenced here, between 74 mya and 37 mya. Remember, it is not that nothing happened during the periods spanned by these unconformities, it is that there is no geologic evidence present during a period of unconformity -- and remember that unconformities are both spatial and temporal. In other locations, there is ample evidence of the events which transpired during these times.

Although rock from the Cretaceous is typically rich in fossil specimens, that is not true of this specific geologic unit.

By the time the LPzkf geologic unit had formed, Pangea had broken into several smaller continents. The tectonic shift created greater biological isolation and led to a proliferation of species. Adding to the geologic change, the global climate became cooler.





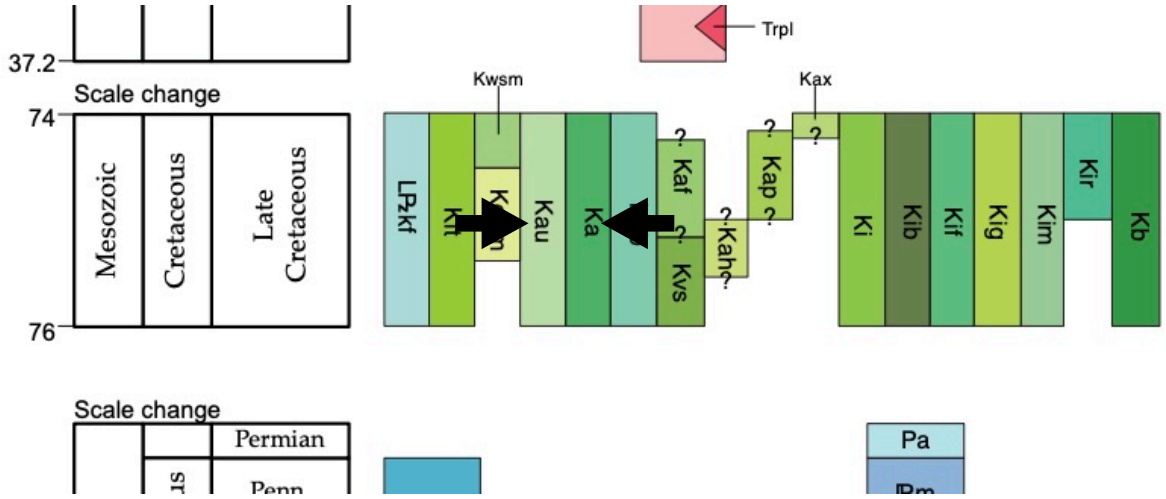
UPPER CRETACEOUS ANDESITE FLOWS - "KA"

A big T-Rex chomping down on your favorite poodle was not the only violence you would see if you time-traveled back to the Upper Cretaceous, 76 mya to 74 mya. There was a great deal of geologic disruption going on in our area at that time. The geologic unit we discuss here is generally referred to as "andesite of Copper Flat" (see description from the Hillsboro Geologic Quadrangle below) and has been dated to 75.4 mya (+/- 3.5 million years) by McLemore et al. using 40A/39A dating methods (McLemore, V.T., Munroe, E.A., Heizler, M.T., and McKee, C., 1999, *Geochemistry of the Copper Flat porphyry and associated deposits in the Hillsboro mining district, Sierra County, New Mexico, USA*, *Journal of Geochemical Exploration*, v. 67, p. 167-189).

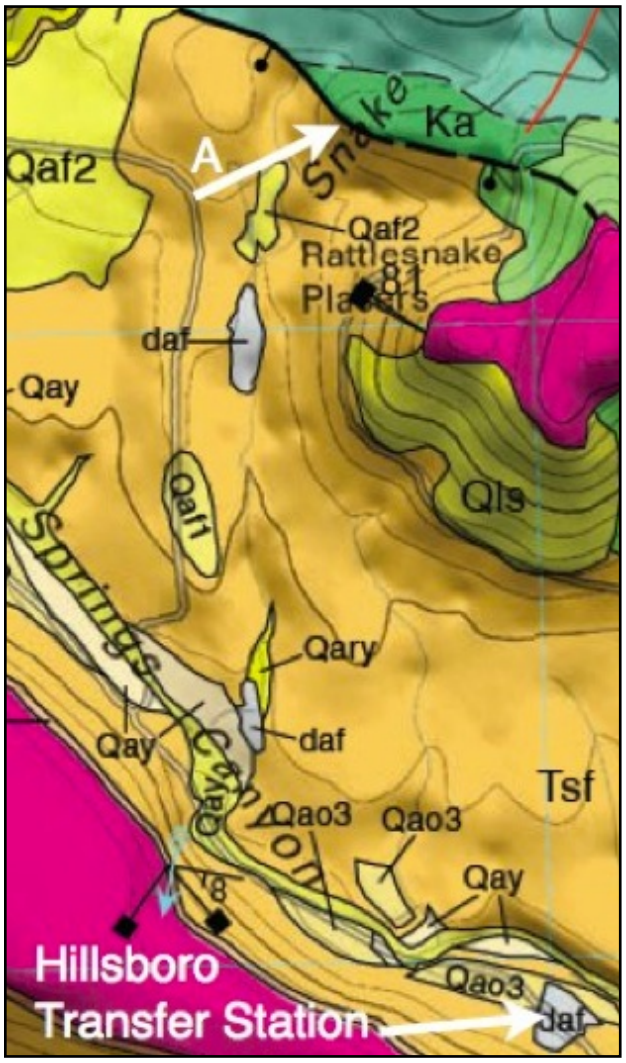
Ka	**Andesite flows and flow breccia of Copper Flat, undivided (upper Cretaceous)** – Grayish green to medium-bluish or dark-gray, porphyritic-aphanitic to porphyritic, fine- to coarse-grained andesite. Forms ledges or moderate to steep, rubbly slopes. Phenocrysts include 4-17% plagioclase, 0-8% hornblende, 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:

This andesite unit is one of several units associated with vulcanism during the Upper Cretaceous at the Copper Flat location. The report which accompanies the Hillsboro Geologic Quadrangle states that "seven distinct volcanic or volcaniclastic facies" were mapped in that area (p. 13, Hillsboro Report). During later periods there was additional volcanic activity in this area.

The relative time frame for this geologic unit is shown in the Correlation of Map Units chart from the Hillsboro Geologic Quadrangle (at the top of the following page). The detail, on the following page, from that map shows



the approximate location ("A") from which the photograph (right column) was taken and the direction of the photograph. This outcrop is found at UTM Zone 13 260761.94E by 3647510.18N. Another outcrop of this geologic unit is found at the northern end of Study Area 4.



Andesite, like basalt, is an extrusive volcanic rock. It falls within the general category of what many would call "lava" and more specifically "intermediate lava".

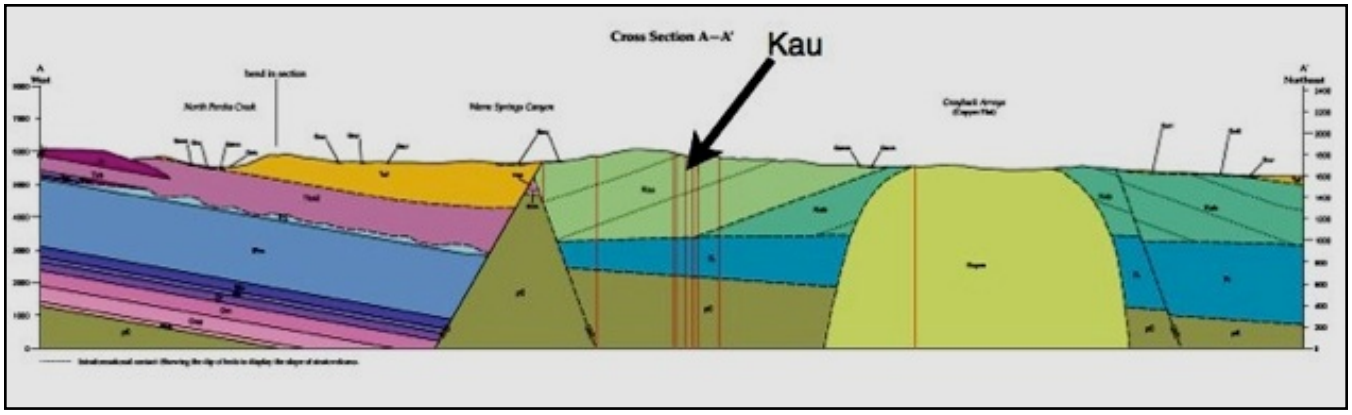


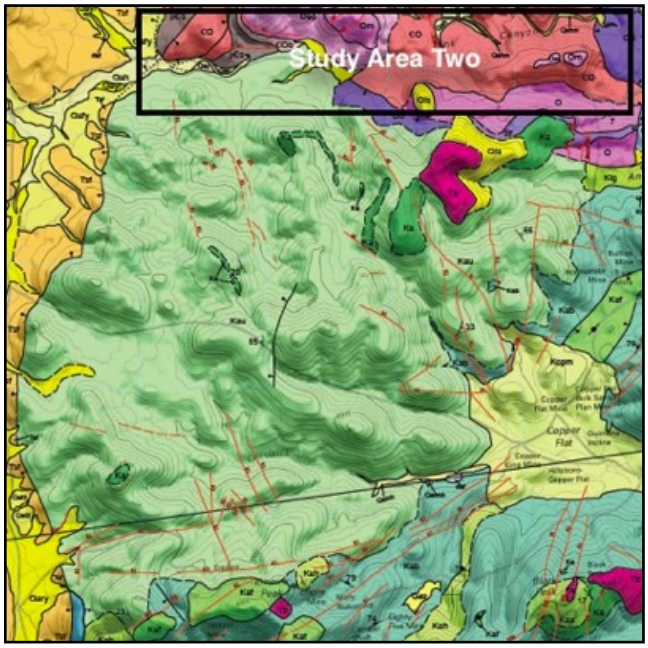
In *Cretaceous Dinosaurs in New Mexico*, Spencer G. Lucas, Andrew B. Heckert, and Robert M. Sullivan describe the various sites in New Mexico which have evidence of dinosaurs during the Cretaceous. So yes, the Disney stereotype of the period, dinosaurs walking around munching on plants and each other, volcanoes erupting, lava flowing, etc. - yes, that is a fairly accurate picture of what was happening in the Hillsboro area about 75 mya.

VOLCANICLASTIC DEPOSITS AND LAVA FLOWS ON THE NW SIDE OF COPPER FLAT - "KAU"

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 (**Kj**) 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.

The northeast quarter of the Hillsboro Geologic Quadrangle Map is dominated by the geology of the Copper Flat area. In the detail from that map (next page center left), Study Area Two (Tank Canyon) is at the top. Below Study Area Two there is a massive geologic unit in a light lime green color; this is a Kau formation (see geologic unit description above - also from the Hillsboro Geologic Quadrangle). The Copper Flat Mine is the "yellow blob" along the right hand side of the map, about a third of the way up from the bottom. This unit is from the Upper Cretaceous, 76 mya to 74 mya, and has been dated to about 75 mya. It is volcanic in origin. This unit is indicated on the "Correlation of Map Units" chart to show its temporal relationship to other geologic units on the map.





In the detail from the quadrangle (above) there is a straight line which crosses the map on a downward diagonal, starting about a third of the way up from the bottom right of the map. This line describes the cross-section (top of page) which was taken for this map. The Kau geologic unit is shown to be both large in surface area and thick.



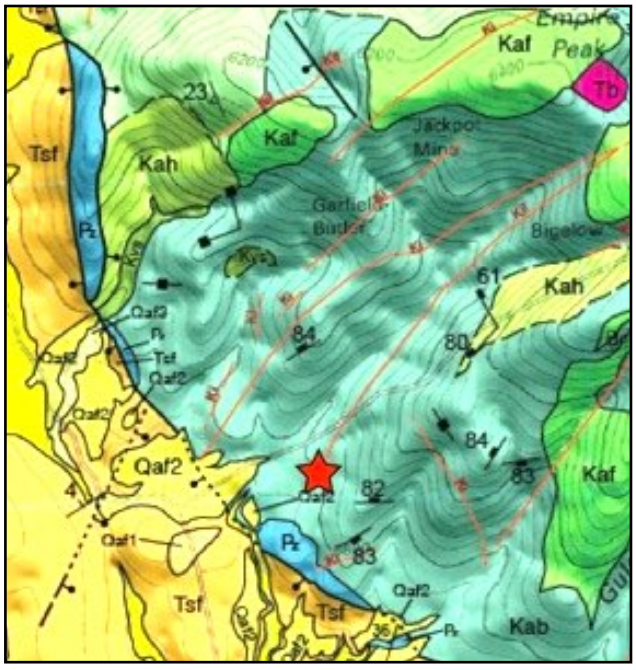
The photograph above was taken in Study Area Two at UTM Zone 13 North Hemisphere 261250E 3653770N; Lat: 32.996234 Long: -107.55532065375554; or if you wish ---- Latitude N 32°59'46.4424" W Longitude -107°33'19.1544".

"KAB" - LAHARIC FLOW BRECCIA - NEAR BIGELOW MINE

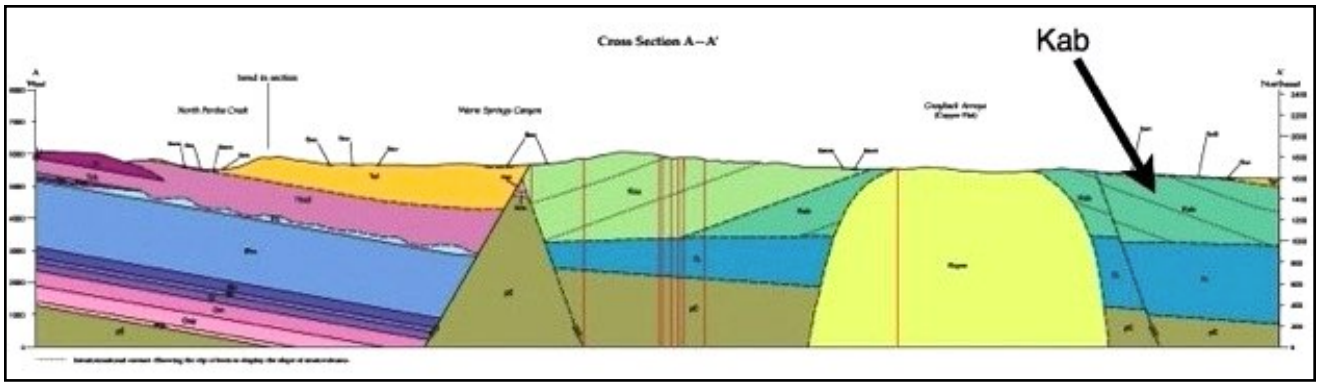
The Report which accompanies the Geologic Map (p. 13) notes that "Andesite and laharic breccia of Copper Flat were deposited on the flanks of a stratovolcano ~75 Ma (Seager, 1986; McLemore et al., 2000). In total, seven distinct volcanic or volcaniclastic facies were mapped. The most prominent of these is laharic flow breccia (Kab)...."

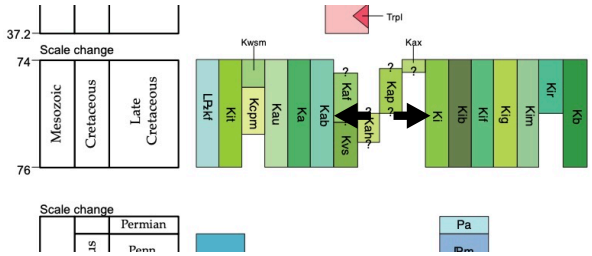
Kab	**Laharic flow breccia of Copper Flat** – Dark-purplish-gray, mostly matrix-supported, massive, non-vesicular volcaniclastic breccia composed of angular to subangular, pebbles and cobbles. Pebble content increases up-section. Protruding fragments form rough weathered surfaces. Exhibits rare trough 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**.

The "Kab" geologic unit (description from the Geologic Map of the Hillsboro Quadrangle above) is a massive unit which is prominent to the south of the "Kau" unit discussed earlier. The site that we visited was to the southeast of Empire Peak. The star on the detail of the geologic map below indicates the approximate location of the photographs taken in Study Area Number 3 (following page). In these two photographs the "Kab" unit is in the foreground. The UTM coordinates are: Zone 13 260173.66 E by 3647510.31 N.



When we think of the late Cretaceous we often see, in our mind's eye, volcanos in the background and a meat-









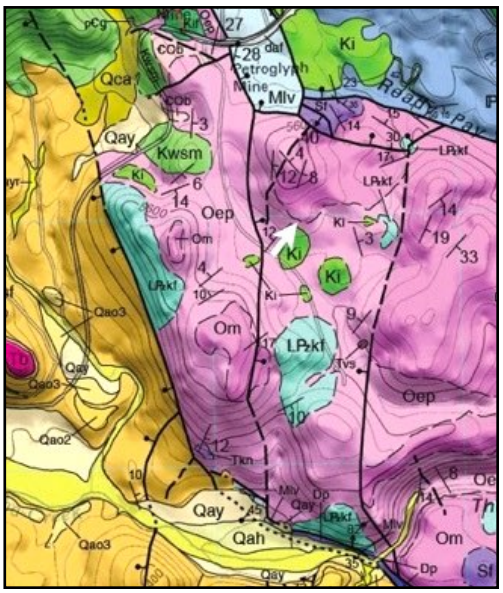
eating dinosaur bearing down on us in the foreground. I'm not saying that isn't a true vision. But the scenery may also have included an *Alphadon*, which was a primitive marsupial, only about a foot long. At the other extreme, we might have seen an *Alamosaurus* ("Ojo Alamo lizard") a tad longer at 70 feet. Among the others we might have seen was the *Kritosaurus*, a duck-billed dinosaur.

As I roamed the slopes of what was to become Empire Peak, I would have been reasonably comfortable with all of the above, perhaps even the vulcanism. I probably would not have been comfortable with the meat-eaters. Perhaps a *Caenagnathus* would have wandered down from the north. Even though it weighed no more than a mere 210 pounds, I don't think I would have been a good match - perhaps a better meal - and that would have been problematic. *Tyrannosaurus rex* may also have been around; they weighed in at something like 7 tons. They would probably have been in a bad mood. Like Pluto which once thought it was a planet, the *Tyrannosaurus rex* was once thought to be the largest carnivorous dinosaur - but alas, along came *Giganotosaurus* and *Carcharodontosaurus* (which also had longer names).

"KI" - UPPER CRETACEOUS INTRUSIVE ROCKS

The photograph at the top of the next page was taken in Study Area No. 5, at the approximate location of the white arrow in the detail of the Hillsboro Geologic Quadrangle Map (right) - arrow indicates direction of view.

The volcanic activity in the area of this map was significant at this time. My personal experience with vulcanism is limited. I have climbed a few volcanoes, looked into a number of bubbling caldrons, smelled some awful steam vents, and done the tourist stuff at Yellowstone and similar venues. Probably the most significant personal experiences I have had with vulcanism center around Mt. St. Helens. In the days before the big blast I would stand at my window on the 15th floor of a building in Portland and watch as huge plumes of ash would rise in the form of mushroom clouds above the mountain, rising well into the air traffic patterns - causing adjustments. A helicopter flight into the blast area, shortly after the event, was dramatic.

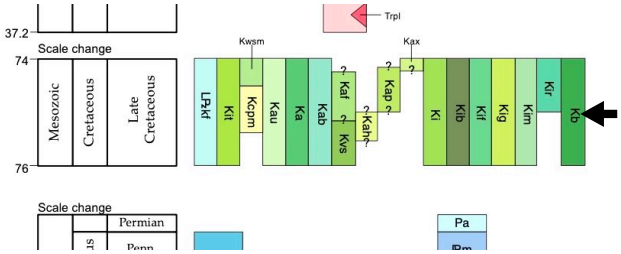




Ki **Intrusive rocks of Copper Flat, undivided (upper Cretaceous)** – Greenish-gray to dull-grayish-green, weathering light-tan to dark-orange-brown, aphanitic-porphyritic to porphyritic, fine- to slightly coarse-grained dikes and plugs intruding andesitic flows and flow breccia of Copper Flat as well 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:

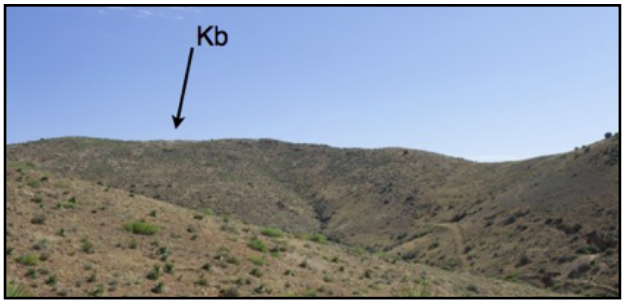
KB - BASALTIC INTRUSION OF COPPER FLAT

At the very head of Ready Pay Gulch, on the top of the hill, there is a "Kb"geologic unit (location of the unit on a detail of the map at the upper right and the temporal location of the unit in the "Correlation of Map Units" below - all from the Geologic Map of the Hillsboro Quadrangle).

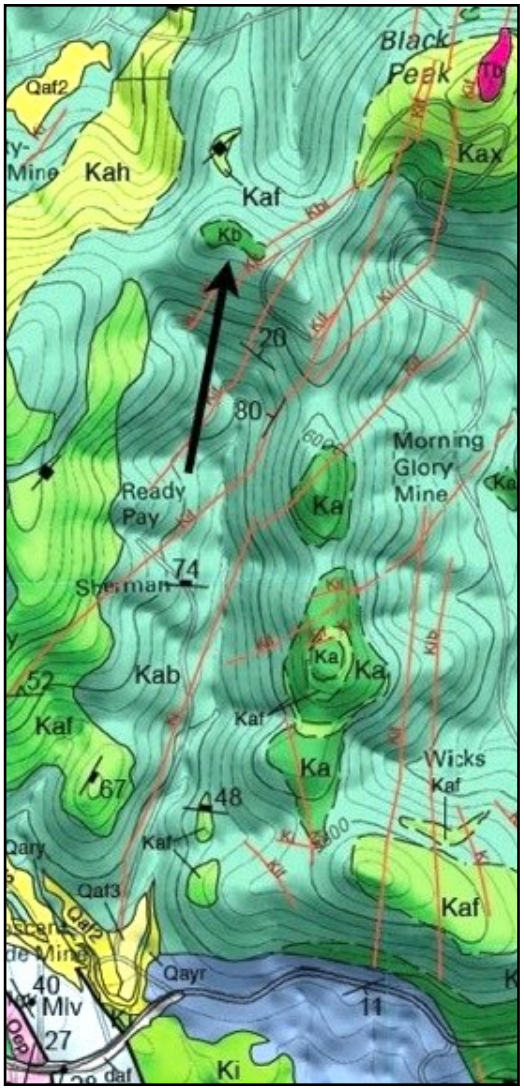


The Report which accompanies the Geologic Map (p. 15) notes that there is a "single outcrop of basaltic (but olivine-poor) composition west of Black Peak." This unit is the result of one of several volcanic events during the late cretaceous.

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.



In the Ki discussion, I mentioned my experience with the Mt. St. Helens, Washington eruption. Following a period of daily "H-bomb" plumes in the sky north of Portland, following exclusion notices, people saying they would not leave the exclusion area, hand wringing, the placement of scientific equipment, and careful watching - the north side of the mountain blew out killing people who refused to leave the exclusion area, people camped near the exclusion area (the blast spread far beyond the exclusion area), and scientists working on the mountain. There were massive mud, silt, and water flows. The glaciers



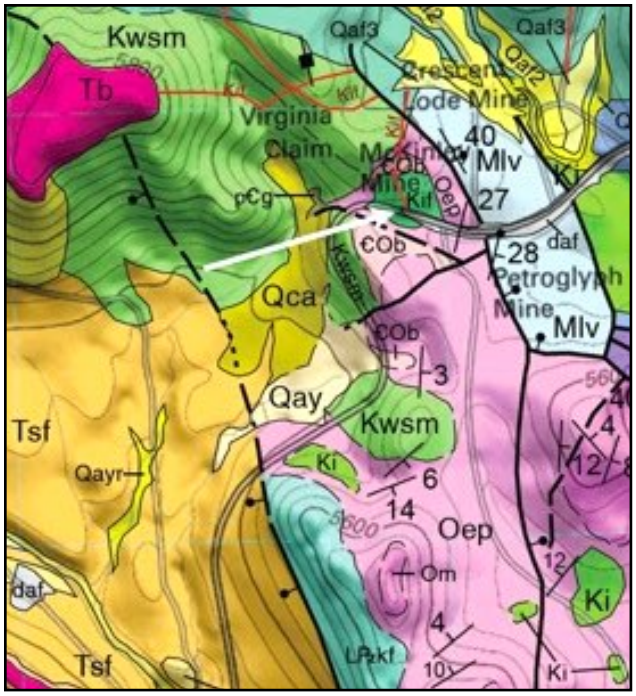
vanished in an instant and so did all large life for miles to the north of the mountain. The event took minutes. That is not much in geologic time.

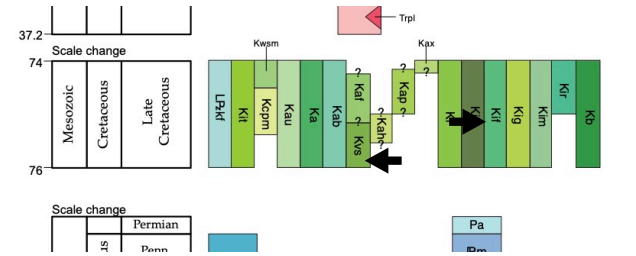
KIF - FELDSPAR-PHYRIC INTRUSIVE ROCK

NM-152 roadcuts open windows into a number of geologic eras as the road enters the foothills east of Hillsboro and continues across the Black Range to the west. As a person travels east out of Hillsboro, crosses Warm Springs Wash, and climbs the hill on NM-152 there are several very interesting roadcuts - including the one at the top of the hill which exposes feldspar-phyric intrusive rock (Kif). The detail from the Geologic Quadrangle for the Hillsboro area (at the top of the following page) shows the exact location of the unit. The description contained on the map, for this unit, is shown below the map detail.

This rock is often found in dikes in our area; there are 34 radial dikes which start at Copper Flat. Note that this unit was referred to as Kql by Hedlund in his 1977 study. As I have mentioned before, the Mesozoic period was very active in this area, lots of lava flows, eruptions, and magma intruding along the broken edges of rock units.

This geologic unit is between 74 and 76 million years old - during the Mesozoic. The volcanic activity which was occurring at this time is not the activity which is generally described as creating the Mogollon-Datil





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).

Volcanic field which covers much of the Gila, east to the Rio Grande River. Volcanic activity during the period 24 to 40 million years ago led to the creation of that field.

The area just east of Hillsboro, between Hillsboro and the Copper Flat pit, is a mosaic of geology. One moment you can walk across exposed limestone, the next you can be studying volcanic strata. It is no wonder that some universities bring their field classes to this area.

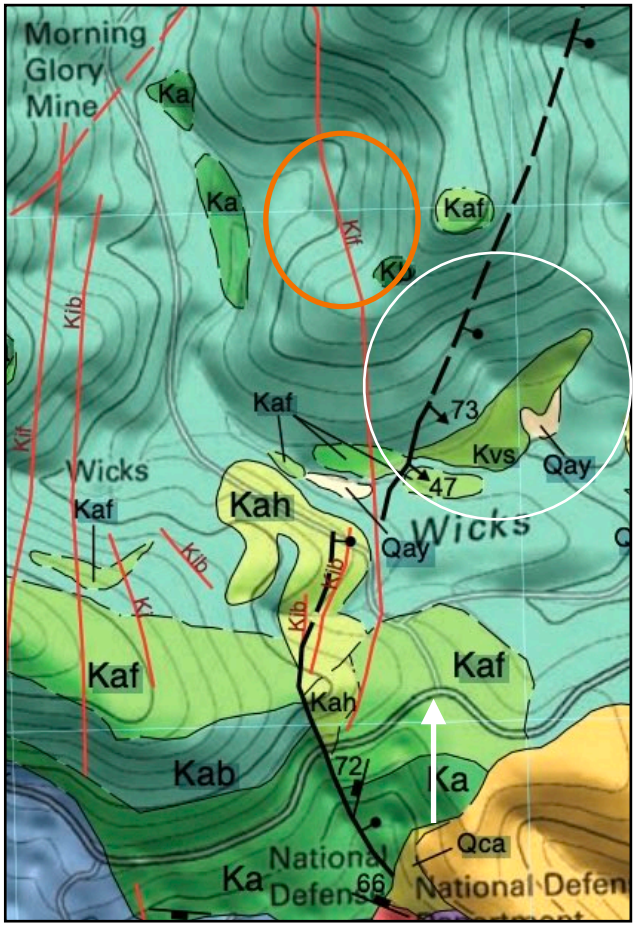
The photograph directly below shows the point where NM-152 crests the saddle and descends westward into Warm Springs. The photograph at the bottom is a closer view of the area at the crest.



KVS - VOLCANICLASTIC DEBRIS FLOWS OF COPPER FLAT

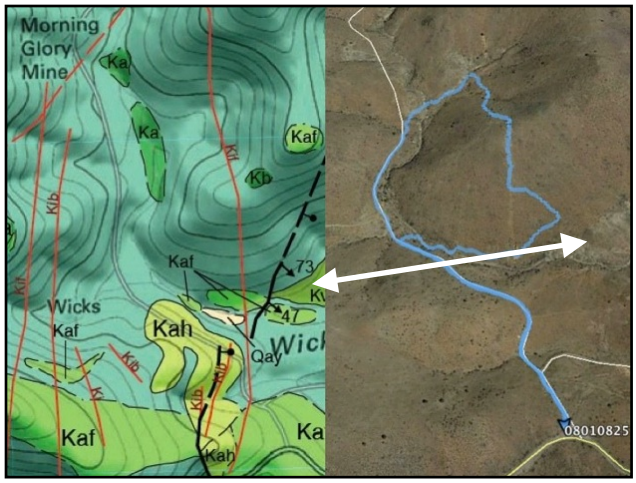
Just north of the North Wicks Canyon road gate, off NM-152, east of Hillsboro, there are some examples of the Kvs geologic unit. There are not many of these geologic units in the area covered by the Hillsboro Quadrangle Geologic Map. The "intersection" of NM-152





and the North Wicks Canyon road is seen on the map above, at the white arrow. At center right of this detail there is a Kvs formation within a white circle. Kvs units extend from that location eastward, down Wicks Gulch.

Several "mines" were developed along a dike, a Kif geologic unit, to the west of the fault at the top center of the geologic map detail (see orange circle).



The photo at the top right is of the Kvs unit immediately above the word "Wicks" (in "Wicks Gulch" on the map above). In this photo, the Kvs unit is in the foreground down to the wash. Beneath your feet it looks like the second image from the top, at the right. This rock was formed in the Mesozoic - Late Cretaceous, about 76 million years ago. The fault line indicates that this unit was down-thrust during the faulting episode.





The unit is described as:

Kvs — Volcaniclastic debris flows of Copper Flat – Greenish-gray debris fl light-colored and fine-grained. Most clasts are < 4 cm, though some a few clasts are porphyritic lava with 3-4% pyroxene and plagioclase p deposits are matrix supported and the clasts are angular. Maximum

On the geologic map detail (above left) there are several Kif and Kib dikes shown; the major veins which the miners were following in this area were along these dikes. The Kvs unit dates from the same general time period as these dikes.

Previously, I have commented about the active volcanic scene of this era, the flows, the eruptions, molten rock creeping along fractures in the rock - and the megafauna which roamed the area at the time. This is a time and place which would have been magical and probably a bit scary.

There were smaller creatures in the area. Perhaps ***Chronomyrmex medicinehatensis***, an extinct species of ant, or its kin was crawling about. Perhaps not. Many insects are known from single specimens - in this case, one which was discovered in Canada and first described in 2013.

During the Late Cretaceous most of the western United States was a land mass. Shallow seas were to the east in what are now the Great Plains. Occasional intrusions of water were not unknown in this area, however.

Lepidopterans, early moths and butterflies or their kin, first appeared in this period as did ants, aphids, grass-hoppers, and termites.

Alas, you probably did not spend all your time looking at the ants. ***Aetodactylus halli*** may have been flying overhead, or ***Alamodactylus byrdi***, or ***Bennettazhia oregonensis***, or ***Comodactylus ostromi***, or any of many other species. Birdwatching was more of a contact sport in those days.

During July of 2016, during our wet period, we had 1.01 inches of rain at our house in Hillsboro - well on our way to another year of drought. It was wetter in the Late Cretaceous; the hillsides were covered with many more luxuriant plants than we see today.

Altogether, it was a very different place than what we see when we look out our windows today. In one regard, however, there is a marked similarity. Both then and now, we are unincorporated.

KIB - BIOTITE-PHYRIC INTRUSIVE ROCKS

The diggings along the eastern side of North Wicks Canyon were along a "Kif dike". Along the western side of North Wicks Canyon there are other dikes radiating from Copper Flat. One of these dikes is a "Kib" formation, and it is along this dike that most of the diggings and mines on that side of the canyon have occurred (Wicks Mine is located along this vein).

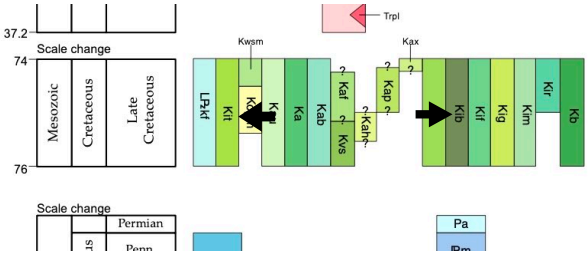
On the Hillsboro Quadrangle Geologic Map, "Kib" is defined as:

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.

On the detail from the Geologic Map on page 42, the Kib dike runs north and south parallel to the left edge of the map detail. The photograph below is of the more southerly of the diggings along that dike.



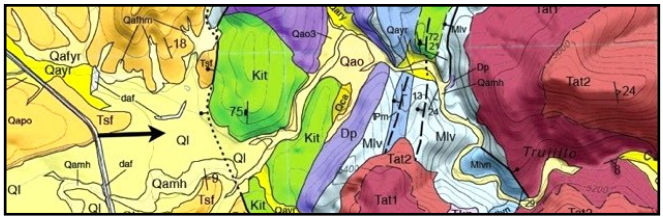
On the geologic time scale, see below, this geologic unit is contemporaneous with the units we have been discussing of late.



KIT - TRUJILLO CREEK INTRUSIONS

Traveling south from Hillsboro, on NM-27, you can see some grass- and forb-covered hills to your left as you approach Trujillo Creek. Those hills are the Kit geologic unit from the Upper Cretaceous.

On the detail from Hillsboro Geologic Quadrangle Map (see top right) the arrow indicates the location from







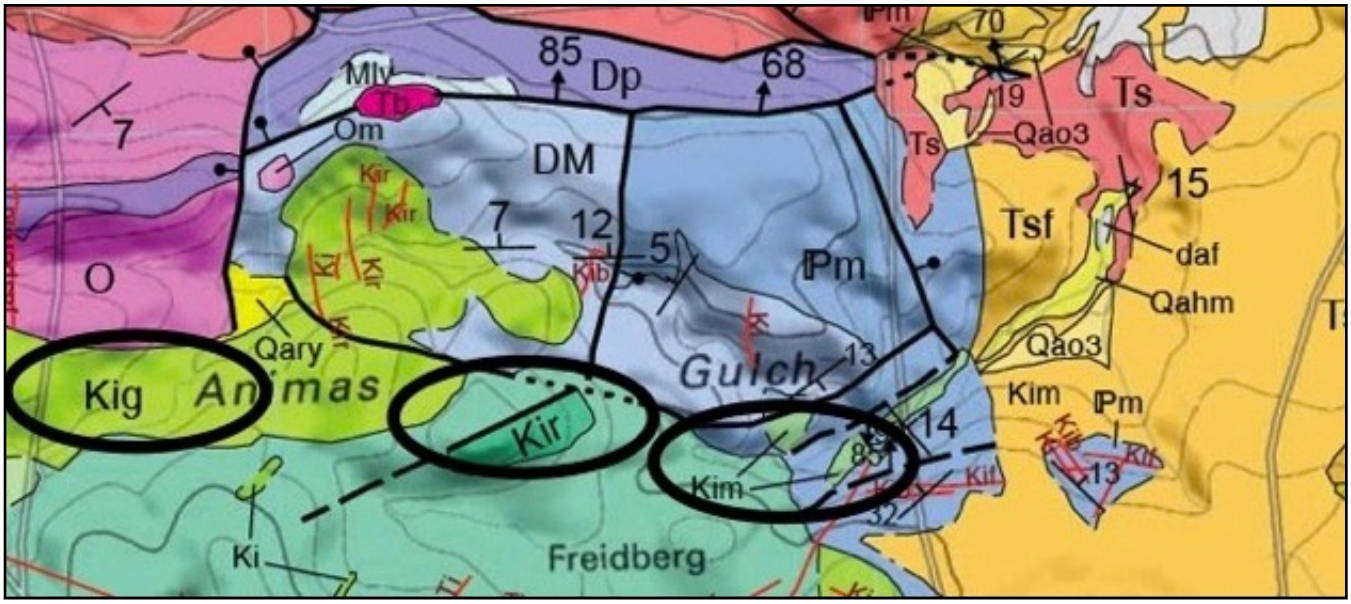
which the photographs shown below the map were taken and the direction of the shots.

The Hillsboro Geologic Quadrangle Map describes them as follows:

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.

The following quote is from the Report which accompanies the Geologic Map (p. 15): "Near Trujillo Creek, intrusive andesite (Kit) has an apatite fission-track (AFT) age of ~64 Ma (Table 1, Kelley and Chapin, 1997). Clasts of this intrusive body have been recovered in the upper Cretaceous-Paleocene(?) McRae Formation and the Paleocene(?)-Eocene Love Ranch Formation near the Caballo Mountains, implying that an extensive sequence of volcanic and intrusive rocks related to the Copper Flat stratovolcano once blanketed the landscape far to the east (Seager and Mack, 2003). Thus, the intrusive andesite of Trujillo Creek may have been locally exposed . . . during the early Tertiary, whereas AFT data for the Copper Flat porphyry suggest that it remained buried until the late Oligocene/early Miocene (Kelley and Chapin, 1997)."

The Kit formation at this location is 63.7 million years old (+/- 4.5 million). The vulcanism which we have come to associate with the Copper Flat area was sometimes quite widespread.



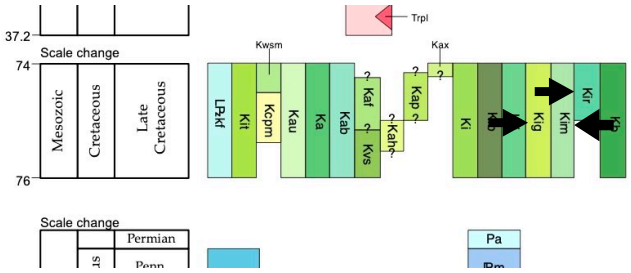
MORE CRETACEOUS INTRUSIVE UNITS - KIG, KIM, AND KIR

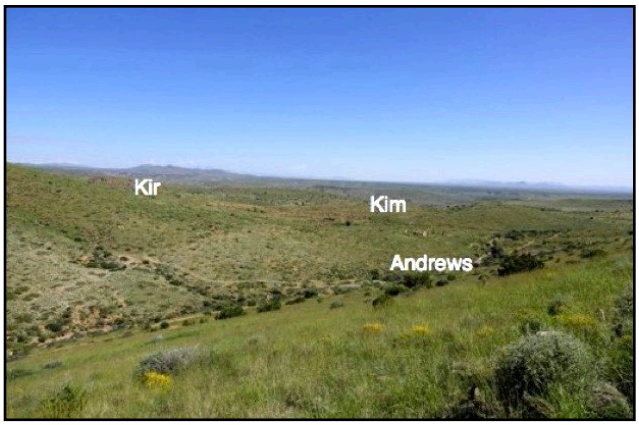
From the north side of Animas Peak, east of Hillsboro, it is possible to see (barely) three more of the intrusive units from the Cretaceous. Kig and Kim date from 76 to 74 mya, while Kir dates from 75 to 74 mya.

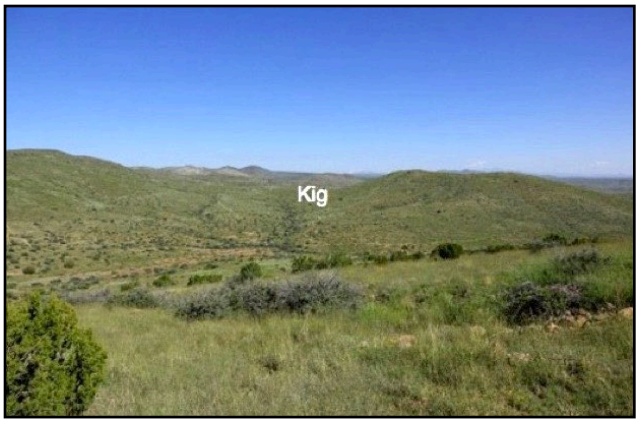
On the Geologic Map, Kig is defined as "Gabbroic intrusive rocks – Dark-gray to black plug with dark-gray plagioclase and pyroxene forming a fine- to medium-grained, equigranular matrix." Kim is defined as "Monzonitic intrusive rocks – Equigranular plug with a gneissic fabric near its margin. Contains 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." And, Kir is defined as "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)."

The detail from the Geologic Map, above, shows the locations of these units north of Animas Peak. There was a fair amount of mining (mostly hard rock) which went on in this general area, as miners searched for the types of minerals found at Copper Flat just to the south. Notable mines in the area included El Oro or Golden Rule, Republic, Freidberg, and Wisconsin. And as with other mining activities in this area, it is often difficult to sort them out now.

These units are just north of the mining ghost town of Andrews. The drive in to Andrews is documented in an auto tour video. The photographs to the right show the locations of these units, as seen from the north slope of Animas Peak, above Andrews.

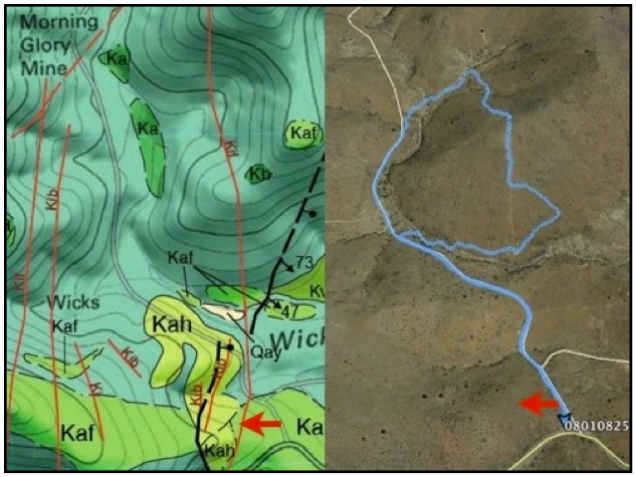




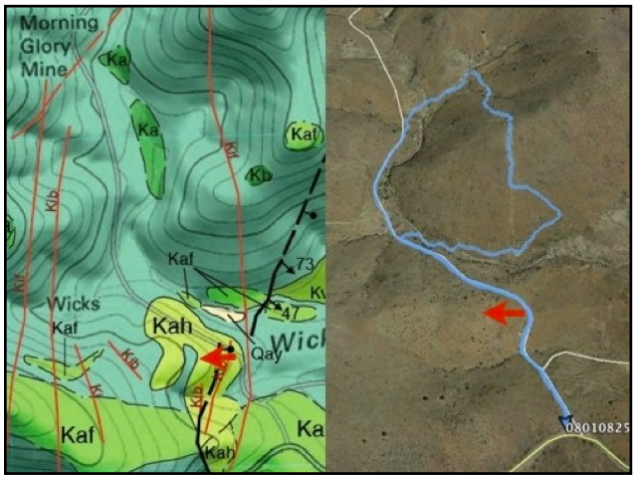


KAH - HORNBLEND-PHYRIC ANDESITE FLOWS

The Kah geologic unit on the Hillsboro Quadrangle Geologic Map comes to the surface at the start of North Wicks Canyon. In the map detail from the Geologic Map (top right on the following page) the red arrows show the location where the photographs to the right of the map were taken and the direction of the shot.









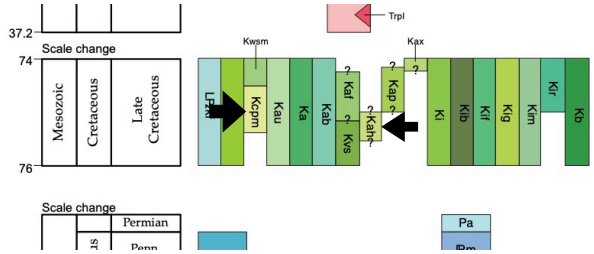
See also: [Walks in the Black Range Vol. 1](#).

The shaft shown below is located in the Kah formation just below the red arrow in the image above. Formerly a mine shaft, it has moved on to its new unauthorized life - one of the local garbage dumps. Much of the rock here is reddish, mixed in with darker gray rock.

The Map describes the unit as:

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**.





KCPM - COPPER FLAT QUARTZ MONZONITE

Probably no bit of geology on the east side of the Black Range has created as much controversy as the quartz monzonite at Copper Flat, geologic symbol Kcpm. Rather than delve into the geology of this particular geologic unit and its associated units I will refer you to an excellent discussion by Virginia McLemore et al., Geochemistry of the Copper Flat porphyry and associated deposits in the Hillsboro mining district, Sierra County, New Mexico, USA

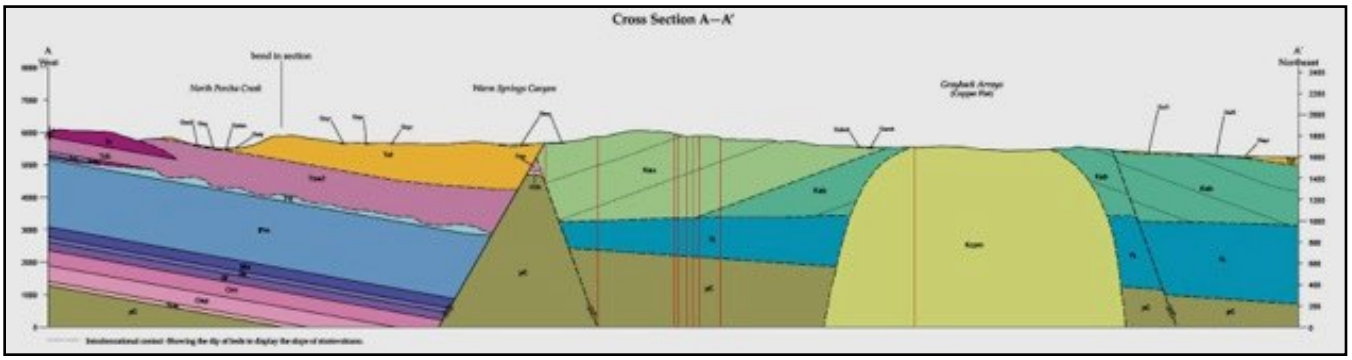
The Hillsboro Geologic Quadrangle Map describes this geologic unit as:

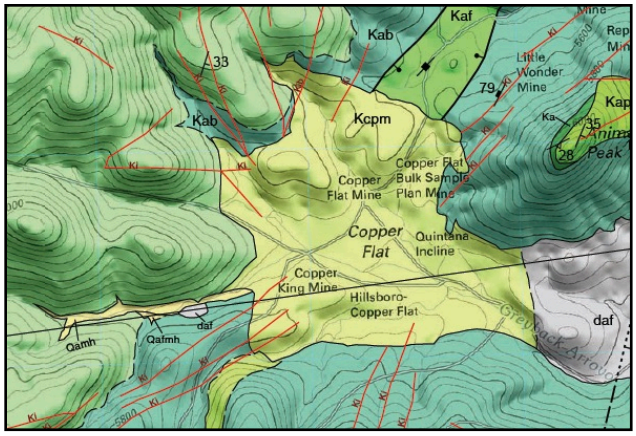
> Kcpm — **Copper Flat quartz monzonite (upper Cretaceous)** – Porphyritic, fine- to medium-grained, plutonic quartz monzonite. Phenocrysts include 10-20% plagioclase and trace pyroxene and pyrite. McLemore et al. (1999) dated this unit at 74.93 ± 0.66 Ma ($^{40}Ar/^{39}Ar$). Total thickness unknown.

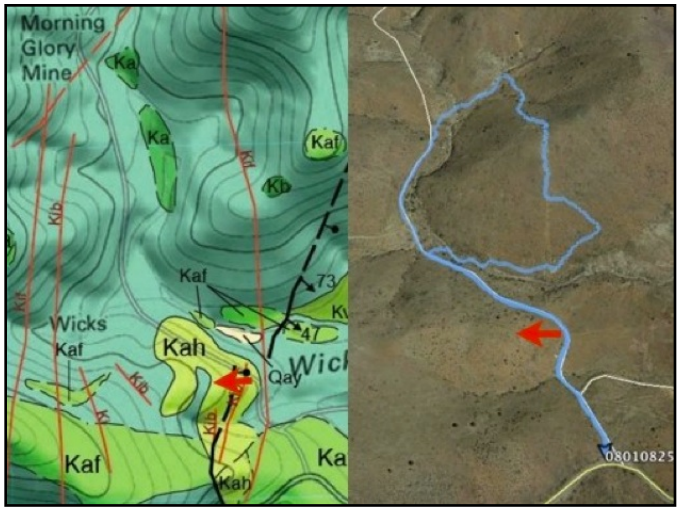
The Copper Flat Copper Mine (shown below in a photo from 2016), especially the current mining proposal, is very controversial in this area, and everything associated with it is suspect in the minds of many. The study of the proposal (Draft Environmental Impact Statement) performed by the Bureau of Land Management lacked substance and an appreciation of fact. That has not helped the situation and has created barriers to effective communication about the Copper Flat issue. It is, however, a fact of life.

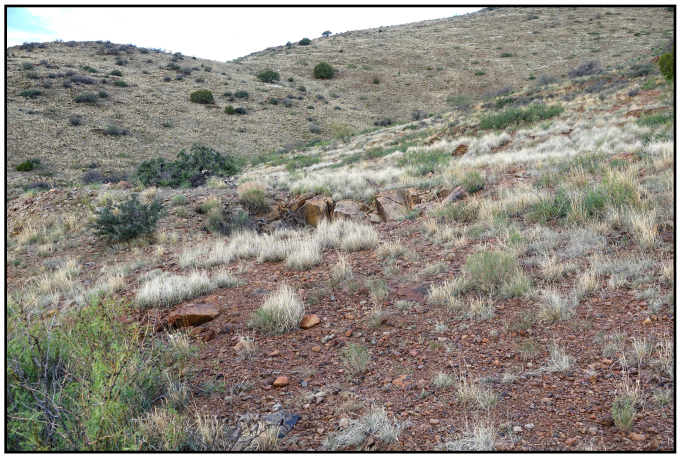
Part of the problem with any discussion of the Quartz Monzonite unit at Copper Flat is that it is rather poorly studied. For all of the cited work in the area and the definitely stated opinions, there are still obvious gaps in our understanding of this geologic structure. That











could be said about much of the geology of the world and especially those sites which have significant geologic complexity, like that of the eastern Black Range.

I once had to chastise someone because of some loose fact finding on his part. His response, with an "aw shucks" smile was "Well, it's damn near a fact." That pretty much sums up our knowledge of this unit.

A detail from the geologic quadrangle, showing the surface unit, is directly above. This unit is shown in the cross section at the bottom of the previous page (the large yellow blob about 1/3 of the way from the right edge).

Note that this monzonite unit is the obvious starting point of the many dikes which mark the rupture lines of this area. It is along these dikes that the mining activity (other than at Copper Flat) has occurred. One of the arguments put forth to support mine development is that the Copper Flat mining activity is self contained - "what happens in Copper Flat stays in Copper Flat, contamination of ground water is not possible". I wonder what the company-funded geologists think happens along all of those dikes?

KAF - POTASSIUM FELDSPAR-PHYRIC ANDESITE DEPOSITS

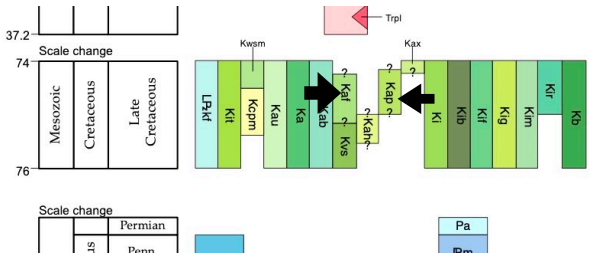
In the map detail from the Hillsboro Quadrangle Geologic Map (top right) and trail route for the east dike diggings, the red arrow shows the location where the photograph at center right was taken and the direction of the shot. In the discussion of the Kah unit, this map and photograph pair was used to describe that unit. Whereas the Kah unit is in the foreground of the photograph, the Kaf unit is up slope on the left.

On the Hillsboro Quadrangle Geologic Map, Kaf is defined as: "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."

Other andesitic facies associated with the Copper Flat area include the Kah (hornblende), Kap (plagioclase), and Kax (phenocrysts) geologic units. The feldspar units are the most common and are assumed to have been deposited in the middle timeframe of the volcanic flows.

I have not done an extensive ground survey of this unit, so I am not able to state whether or not there are particular types of flora associated with it.

For the most part, these "K" geologic units are associated with the hills surrounding the Copper Flat Kcpm unit and are evidence of significant volcanic activity during the Late Cretaceous. These units and the large number of dikes which radiate from the Kcpm unit at Copper Flat also indicate that the area around the mine is much more porous than some geologists, employed by the companies who have wanted to mine there, have asserted.



THE EL ORO, ANDREWS, AND KAP

Northeast of the Copper Flat Copper Mine, which is itself northeast of Hillsboro, is the old mining town of Andrews. Andrews has more "intact" structures (next page) than the usual ghost towns in this area, which typically are evidenced by some old nails and a few pieces of wood.

Most of Andrews is shown in the top photograph on the following page. A closer view of the major structure on the north side of the wash at Andrews is shown in the bottom photograph. A closer view of the structure at the bottom center in the top photograph is shown on page 49. That structure is on the south side of the mining area at Andrews (on the north slope of Animas Peak).







Most of the slope going down into town from the right is part of a Kap geologic unit.

The Hillsboro Quadrangle Geologic Map describes Kap as "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."

I have long believed that of the mining sites in our area, Andrews is the most worthy of maintaining. Not only are there several buildings at the site but there are significant mine workings. The mine workings are diverse and apparent, something quite rare in our area, and could "easily" be translated into the mining history of the Hillsboro Mining District.

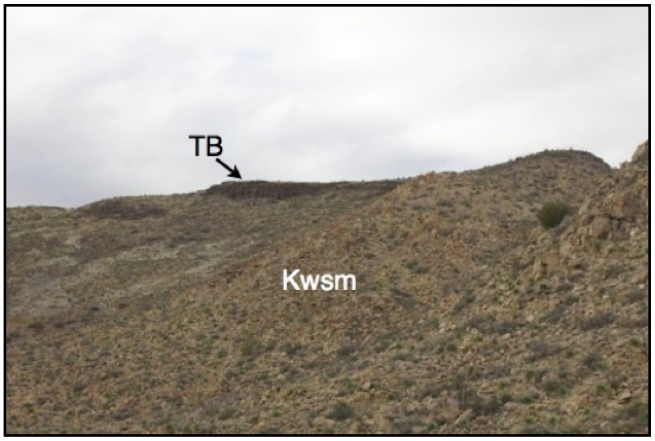
KWSM - STUDY AREA ONE

The description of the Kwsm geologic unit, from the Hillsboro Quadrangle Geologic Map, is shown below.

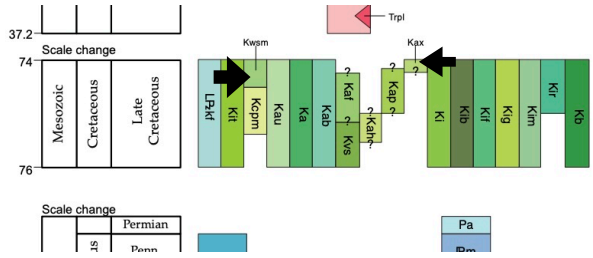
Kwsm	**Warm Springs quartz monzonite (upper Cretaceous)** – Whitish-gray, ledge- to bouldery-slope-forming, non- to slightly vesicular, occasionally dense, porphyritic, equigranular, fine- to medium-grained quartz monzonite. Phenocrysts include 15-20% quartz, 9-12% biotite, 5-8% sanidine, and trace to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

The formations described here are in Study Area One, just east of Hillsboro, and are shown at center right.

The age of this geologic unit, and its temporal relationship to other units, is shown on the "Correlation of Map Units" chart to the right. In 1999, McLemore et al. dated this unit to 74.4 million years ago with a possible error of 2.6 million years.



The dinosaurs of the Late Cretaceous were truly massive, aggressive, very T-Rex. There are those cults which believe that humans and dinosaurs coexisted, that all of those flaky Hollywood movies of the 1950s were real. These folks have even established museums to "prove their point". Of course, they have never been able to prove the point since there is nothing to prove. At least that is what we all thought until an unnamed but usually reliable source photographed evidence of human-





dinosaur co-existence just east of Hillsboro in 2014 - see photograph above.

There are rumors that some of these cults want to build a multi-billion dollar museum on the site, but we have been unable to confirm the existence of such an effort. Nor, have we been able to relocate the dinosaur and maiden in the photograph. This may be bad news, especially for the maiden. If you happen to drive down the hill coming into Hillsboro from the east, look to your south, that is the area where the dinosaur and maiden were last seen. A reward has been offered for the dinosaur by the folks at Our-Cult-Is-Your-Cult. (Frankly, we are quite sure they do not expect to have to pay.)

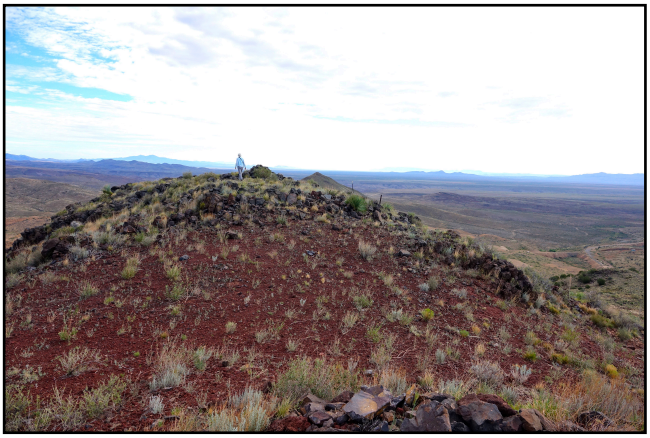
KAX - PYROXENE-PHYRIC ANDESITE FLOWS

The Hillsboro Quadrangle Geologic Map describes the Kax formation as "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. Up to 35 meters thick."

As shown on the "Correlation of Map Units" chart on the previous page, this is the youngest Mesozoic era rock depicted in the Hillsboro Quadrangle. There is a significant unconformity between this unit and the oldest rock from the Cenozoic - Paleogene - Eocene. Kax is dated to about 74 million years ago and the oldest rock from the Cenozoic is dated to about 37.2 million years ago.

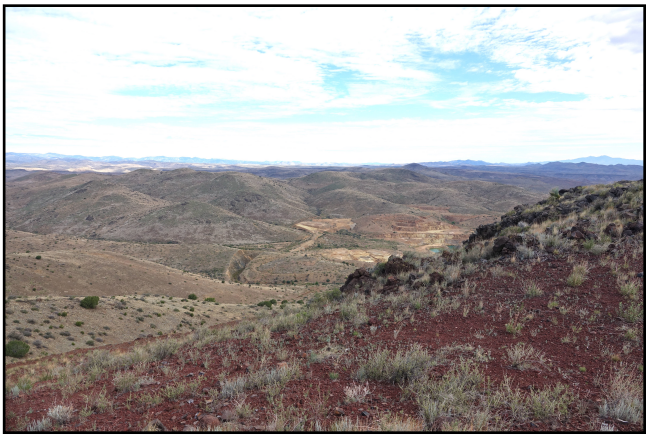


The photograph below was taken from the top of Black Peak the Kax geologic unit is in the foreground.





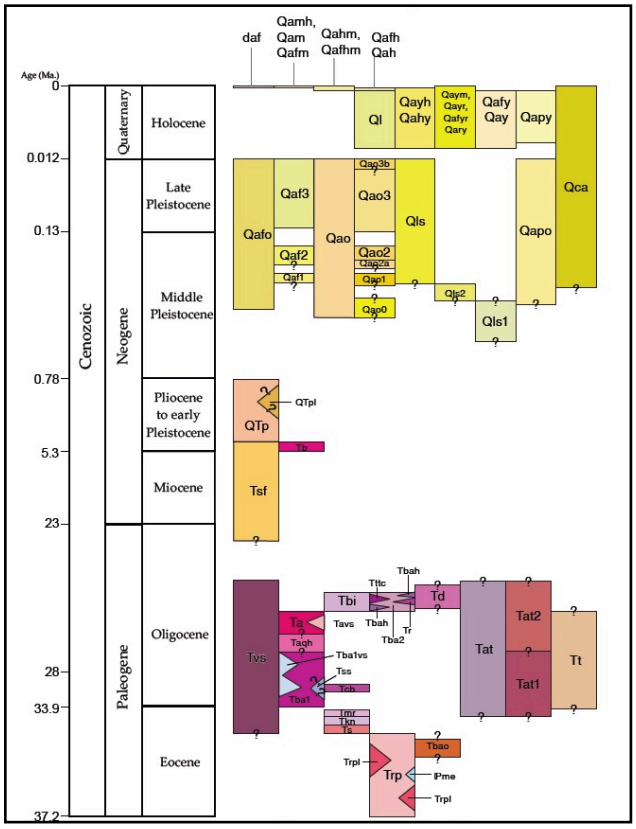
The photograph immediately above shows some of the diggings in this geologic unit, near the summit of Black Peak. The photograph was taken from the west flank of the summit hill, looking east. Black Peak is located south/southwest of the Copper Flat Copper Mine.



The detail of this area at left, from the Geologic Map, shows the Kax and Tb units discussed above.

Black Peak has a double summit, two hills separated by a short trough. The bottom photograph is taken from the western summit looking northeast. A portion of a Tb unit is visible at the center right of the photograph; this unit slopes down the northeast side of the mountain. Beyond the unit and below, it is possible to see a portion of the Copper Flat Copper Mine.

THE CENOZOIC

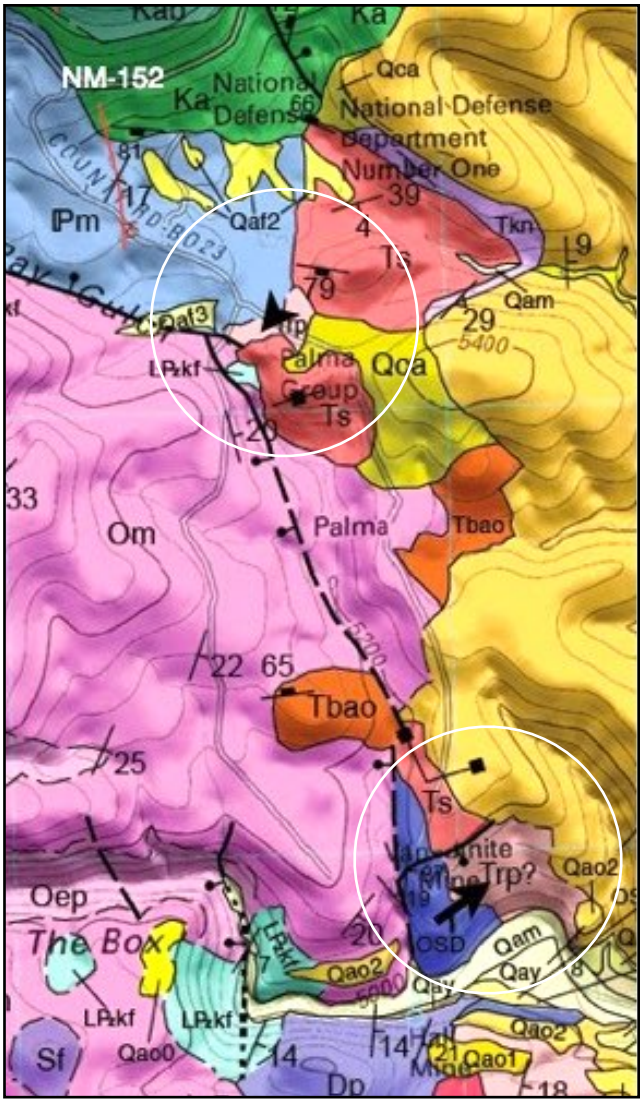


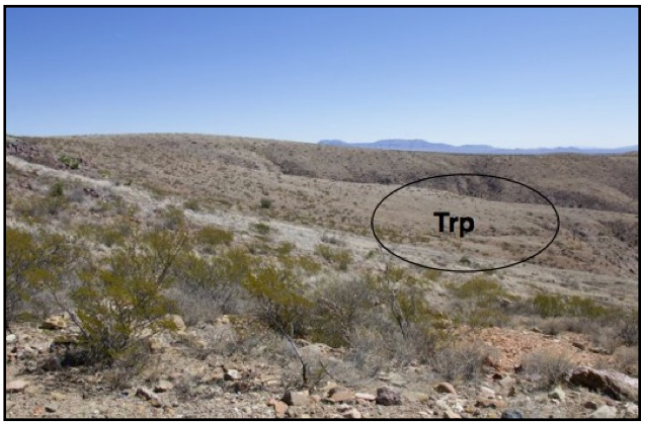
TRP - THE RUBIO PEAK FORMATION

On the Hillsboro Quadrangle Geologic Map the Rubio Peak Formation (Trp) is described as "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. Inter-bedded with andesitic lava flows with 4-5% total phenocrysts. Maximum thickness 55 m. Locally subdivided into 2 interbedded units".

The two photographs of the Trp geologic unit shown on this page were taken in "Study Area Four" at the points indicated by arrows (within the white circles) on the map detail at the upper right. The photograph below is taken at the "top arrow", the other at the "bottom arrow".

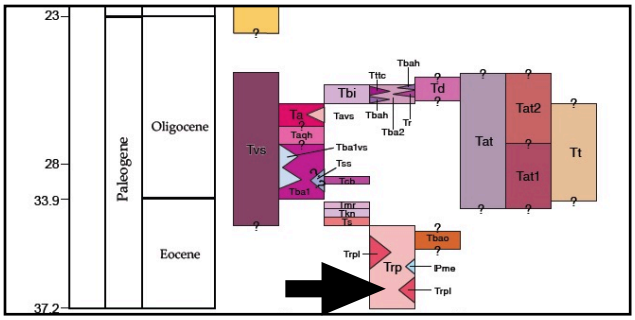






The Trp geologic unit is the oldest rock from the Eocene Epoch in our area, dating from about 37.2 million years ago to about 34.2 million years ago. The Eocene is part of the Paleogene Period which is in turn part of the Cenozoic (which brings us to the current date). The Eocene Epoch, in turn, is divided into various ages. The Trp unit spans the Bartonian and Priabonian Ages.

The "Geologic Map of the Hillsboro 7.5 Minute Quadrangle, Sierra County, New Mexico, Report" by Andrew P. Jochems, Shari A. Kelley, William R. Seager, Colin T. Cikoski, and Daniel J. Koning, June 2014, New Mexico Bureau of Geology and Mineral Resources,



Open-file Digital Geologic Map OF-GM 242, p.17, states:

"The Rubio Peak Formation (Trp) is the oldest Tertiary volcanic/volcaniclastic unit exposed in the Hillsboro quadrangle and consists of volcaniclastic sandstone and siltstone interbedded with plagioclase-phyric andesite. The formation typically underlies gentle to moderate slopes, and may include large, exotic blocks of Pennsylvanian limestone transported during laharic debris flows. One such block is observed on the west side of Trujillo Park Canyon. Ages for the Rubio Peak Formation range from 46.3 to 36.7 Ma, including both lava flows and older clasts found in laharic breccia (Loring and Loring, 1980; Clemons, 1982; McMillan, 2004). (See more recent dating on previous page.)

Deposition of the Rubio Peak Formation was succeeded by large-scale eruption of ignimbrites and rhyolite. In the Hillsboro area, these volcanic facies were mostly sourced from the 35.3 Ma Emory caldera to the west (Figure 2), although the 35.6 Ma Sugarlump Tuff (Ts) is not regionally extensive and may have been sourced from a more distant caldera (McIntosh et al., 1991; Chapin et al., 2004)."

The Rubio Peak Unit was named by W. E. Elston in 1953, after a prominent butte found on the Dwyer Quadrangle (Grant County, New Mexico). The Unit has been discussed in a number of papers (see the National Geologic Map Database for a partial listing). "General Geology of Santa Rita Quadrangle Grant County, New Mexico, Geologic Survey Professional Paper 555", U. S. Department of the Interior, William R. Jones, Robert M. Hernon, and Samuel L. Moore (pp.101-103), has a nice description of this unit as it appears in the Santa Rita Quadrangle (see below left and on the following page). It continues on page 103: "Figure 35 shows that silica content in flows in the Rubio Peak Formation is intermediate between that in the basaltic andesites and that in the rhyolite tuffs. The flows in the Rubio Peak Formation are chemically similar to the sill rocks and to the granodiorite forming the Hanover lobe of the Hanover-Fierro pluton."

similar to most of the hypabyssal rocks of Late Cretaceous and early Tertiary age. However, the intrusive suite does not include a rock type as mafic as the Miocene(?) basaltic andesite (Bear Springs Basalt of Elston, 1957), the youngest igneous rock in the quadrangle. This fact is also obvious in figure 13, a normative mineral plot of several intrusive and extrusive rocks.

RUBIO PEAK FORMATION

The Rubio Peak Formation crops out in the southeast and southwest corners of the Santa Rita quadrangle. Beyond the quadrangle to the southeast it underlies a broad belt extending through the northwestern and central parts of the Dwyer quadrangle. In this belt it is reported to be as much as 3,200 feet thick, and possibly 5,000 feet thick (Elston, 1957). The Rubio Peak Formation probably extends westward beneath the younger volcanic rocks of the Cobre Mountains and the Hurley East quadrangle, because it is present in the valley of Whitewater Creek and in Bayard Canyon. The formation was believed by Elston (1957, p. 19) to fill a structural basin that reaches its maximum depth in the northwestern part of the Dwyer quadrangle. Farther west, north, and northwest, beyond the margin of the basin, the upper beds of the formation were deposited on a surface that had strong relief, and some of the topographic highs of that time were not covered. Such a high evidently existed over much of the south-central part of the Santa Rita quadrangle, for the formation is not present there.

The unevenness of the surface beneath the Rubio Peak Formation accounts for the variability in the thickness of the formation. The maximum thickness in the Santa Rita quadrangle is about 870 feet. Two series of flows aggregate about 600 feet.

Westward from the Mimbres fault, the Rubio Peak Formation lies on successively younger rocks—the Fusselman Dolomite of Silurian age to the quartz diorite sills of Late Cretaceous(?) age (Kuellmer, 1956). This truncation of older beds suggests that the southwest homoclinal dip of the older rocks west of the Mimbres fault developed prior to deposition of the Rubio Peak Formation in Miocene(?) time. The Rubio Peak Formation seems to be overlain conformably by Sugarlump Tuff throughout the Santa Rita quadrangle, but Elston (1957, p. 23–24) stated that in the Dwyer quadrangle the contact is unconformable in some places and conformable in others. He also stated, and showed on his map (pl. 1), that the two formations interfinger in the area of Mimbres. The white tuffs and tuffaceous gravels lying between the two groups of flows in the southeast corner of the Santa Rita quadrangle might be considered as an interfingering of Sugarlump Tuff on lithologic grounds alone, but the authors saw no reason at the time of mapping to consider it as such. The upper contact of the Rubio Peak Formation is arbitrarily placed at the top of the highest rhyodacite flow or at the top of the highest dark-colored poorly sorted conglomerate such as is exposed in Bayard Canyon and in the Bayard area.

Neither Elston (1957) nor Jicha (1954) described typical stratigraphic sections of the Rubio Peak Formation, because many of the flows are of such limited extent that no one section could be considered typical. In the Santa Rita quadrangle the basal part of the section consists of poorly sorted coarse gravels derived from sedimentary and igneous rocks of the adjacent area. In Bayard Canyon and for a mile or two farther west, the pebbles and boulders in the gravel are largely fragments of andesite breccia, mafic porphyry dikes and plugs, and a hornblende quartz diorite sill that crop out to the north and northwest. Fragments of magnetite, tactite, skarn, and metal sulfides were looked for but not found. If drainage were dominantly toward the southeast, the eroded parts of the ore bodies of the Central district might be concentrated in the gravels of the basal part of the Rubio Peak Formation beneath Rustler Canyon. Immediately west of the Mimbres fault, the base of the Rubio Peak Formation is characterized by a red sandy shale (Elston, 1957, p. 19). Neither the base nor the gravel beds are well exposed farther west. The following section is characteristic of the formation in the southeast corner of the Santa Rita quadrangle.

Rubio Peak Formation

[Near section *I-I'*, pl. 2]

	Thickness (feet)
Sugarlump Tuff.	
Rubio Peak Formation:	
Porphyritic rhyodacite flows: two massive dark-gray slightly vesicular flows separated by oxidized very vesicular material marking the top of the lower flow and by detrital rock. The flows contain phenocrysts of glassy feldspar, dark pyroxene, and red-brown iddingsite pseudomorphs of olivine phenocrysts	200–400
White lithic and pumiceous tuff grading to tuffaceous gravel, and interfingering thin flows of andesite. Lithic fragments are mainly andesite and older lithic tuff. Mineral framgents are biotite, chalcedony, sanidine, and frosted subrounded quartz grains	100–200
Porphyritic flows similar to upper flows	100–200
Semiconsolidated gravel derived from sedimentary and intrusive formations in the area immediately to the north	0–70
Angular unconformity.	
Cretaceous sedimentary and intrusive rocks.	

A DIFFERENT VIEW OF HILLSBORO GEOLOGY

The study of the area covered by the Hillsboro Quadrangle Map has come with its own set of issues and "hardships". Sometimes the geology of the quadrangle is dramatic and obvious. However, some of the geologic units within the area of the Quadrangle can be very difficult to discern. Not only is the geology, for the most part, covered in the same dirt, gravel, loose rock, and plants - "they all look alike to me" - but the units, themselves, are often very similar (maybe not to trained geologists, but to me). I have struggled with "how do I show it", "how do I present the material with a reference which people can use to understand the geology", "how do I present the material so readers can find what I am talking about - on the ground, not in the ether"? Typically, when I have searched out a geologic unit I have included detail and landscape photographs of the area to provide reference and included a detail from the Hillsboro Quadrangle Geologic Map. This approach has been successful but it has not done everything that I thought might be possible, however ill-defined "possible" was in my mind.

The image at the bottom left on the next page is what the Hillsboro Quadrangle looks like on Google Earth. Google Earth is a wonderful tool, with lots of definition (zoom in and see great detail) and the ability to view an area from a variety of angles. I have routinely

The white tuffaceous layers which occur in the central part of the quadrangle were also found farther east, and were mapped by Elston with the Sugarlump, which they resemble lithologically. Deposition of both formations may have occurred simultaneously.

The flows within the Rubio Peak Formation are generally fine grained, porphyritic, and dark pink, lavender gray, purple, brown, or black (Elston, 1957); most weathered surfaces are gray, with tinges of red or brown. Phenocrysts are plagioclase (zoned from andesine to labradorite), basaltic hornblende (lamprobolite), zoned augite (average composition according to Elston, p. 22, $(Ca_{44}Mg_{44}Fe_{20})Si_2O_6$)), and hypersthene or bronzite. Plagioclase and augite are generally unaltered. Accessory minerals are biotite, apatite, magnetite, zircon, sphene, and, rarely, quartz and "iddingsite." The groundmass is either finely crystalline or glassy; where crystalline it consists largely of andesine laths but contains some potassium feldspar (Elston, 1957, p. 22). Detailed optical properties and chemical composition of the constituent minerals were given by Elston (p. 21–23) and need not be repeated here. The two specimens from the flows within the Santa Rita quadrangle that were examined microscopically by the authors are similar to the more mafic varieties in the Dwyer and Lake Valley quadrangles. They contain andesine and labradorite, augite, magnetite, apatite, green antigorite or biotite, and wedges of "iddingsite." Small rectangular grains of serpentine may be pseudomorphic after an orthopyroxene. In one thin section the matrix is brown glass, and numerous inclusions of brown glass and other minerals occur within some labradorite phenocrysts. In another section the matrix is in large part a felted mass of andesine microlites, and minute grains of augite and magnetite are disseminated throughout. Some grains of "iddingsite" and serpentine are presumably pseudomorphic after olivine. No hornblende, biotite, potassic feldspar, or quartz was present in the thin sections examined, but hornblende and biotite were observed in some flows during mapping. The thin flows intercalated in the white tuffaceous layers have little or no "iddingsite," and the feldspar seems to be less calcic.

The nature of the pyroclastic rocks in the formation to the southeast was described by Elston (1957, p. 21–23):

> Individual flows or breccia lenses are up to 50 feet thick. Flow breccias commonly grade into flow rock. The pyroclastic rocks consist of bedded and reworked tuffs, crystal tuffs, sandy tuffs, and conglomeratic tuffs with boulders as large as 5 feet in diameter. The conglomeratic tuffs contain subrounded fragments of all earlier flows. As a result of reworking, some tuffs resemble detrital sediments. Andesite or latite breccias that show no evidence of reworking were deposited usually in irregular mounds or in beds of short lateral extent.
>
> Tuffs have the same phenocryst minerals as flows, but the crystals are better formed; many have a sharply angular appearance, as if they had been fractured mechanically. Groundmasses consist of uncompressed shards, vitreous in some specimens and devitrified in others. Perlitic fractures are common.

Samples from three flows within the Rubio Peak Formation were analyzed by Elston (1957), and the results are shown in this report (table 17, cols. 1–3). An average of the three analyses appears in column 4, and can be compared with the analysis in column 5, which is the average of analyses of 115 rhyodacites and rhyodacite-obsidians by Nockolds (1954, p. 1014).

The flows within the Rubio Peak Formation were classified on a modal basis by Elston (1957) and Jicha (1954) as hornblende latites and pyroxene andesites, but in this report they were classified as rhyodacites because of the abundance of normative quartz, about 15 percent. (See table 17.)

TABLE 17.—*Chemical analyses and norms of flows in the Rubio Peak Formation*

	1	2	3	4	5
Chemical analyses					
SiO_2	62.43	59.37	61.88	61.23	66.27
Al_2O_3	16.50	16.17	16.46	16.38	15.39
Fe_2O_3	4.32	4.49	3.48	4.09	2.14
FeO	.43	1.20	.72	.78	2.23
MgO	1.78	3.00	1.66	2.15	1.57
CaO	4.55	5.12	4.75	4.80	3.68
Na_2O	4.10	3.46	4.08	3.88	4.13
K_2O	2.87	2.81	4.00	3.23	3.01
H_2O+	1.52	1.80	.59	1.30	.68
H_2O-	.86	.86	.73	.82	
TiO_2	.70	1.01	.45	.72	.66
P_2O_5	.29	.36	.25	.30	.17
MnO	.08	.07	.10	.08	.07
CO_2			1.02		
Total	100.43	99.72	100.17	99.76	100
Normative minerals					
Quartz	16.50	14.70	13.26	14.82	20.8
Orthoclase	17.24	16.68	23.91	19.28	17.8
Albite	34.58	29.34	34.58	32.83	35.1
Anorthite	18.07	20.29	14.73	17.69	14.5
Corundum					1.3
Wollastonite	.81	.93	1.04	.92	3.9
Enstatite	4.50	7.50	4.77	5.59	1.3
Ferrosilite					3.0
Magnetite		1.16	1.16	.77	1.4
Ilmenite	1.06	1.98	.91	1.32	.3
Apatite	.67	1.01	.67	.78	
Calcite			2.30	.77	

1. Amphibole latite, H. B. Wilk, analyst (Elston, 1957, table 7, col. 4).
2. Pyroxene andesite, H. B. Wilk, analyst (Elston, 1957, table 7, col. 3).
3. Amphibole latite, H. B. Wilk, analyst (Elston, 1957, table 7, col. 5). (Norm recalculated.)
4. Average of 1, 2, and 3.
5. Average of 115 analyses of rhyodacite plus rhyodacite obsidian (Nockolds, 1954, p. 1014, col. 4).

The normative orthoclase is generally about three times that of average andesite (6.7 percent), but about one-fourth less than that of average latite (26.1 per-

used it to help me find a specific geologic unit, on the ground. Equally important, it is a way of studying an area where entry is denied. When the authors of the Hillsboro Geologic Map wrote their report on the Map they noted the difficulty they had in gaining access to some areas covered by the map, making "ground truthing" difficult. Google Earth does not solve the "ground truthing" issue; it can help (varies with the unit significantly) but as I noted above, one of the issues that I have faced is that many of the units are very similar in appearance. There may be millions of years of difference in the age of two units, but on the ground you may be struggling with identifying whether some samples have 10% hornblende or 20% hornblende. Such things are beyond my competence as a geologist (which is nil) and my patience.

Jonathan Barnes has provided me with a .kmz file to use as a layer on Google Earth, a layer of the Hillsboro Quadrangle Geologic Map. The image at the lower right is what the area of the Hillsboro Quadrangle looks like with the geologic map overlay.

The detail is even more amazing. East of Hillsboro, NM-152 crosses the Warm Springs Wash and starts uphill; there is a sharp turn at the top of the hill. The

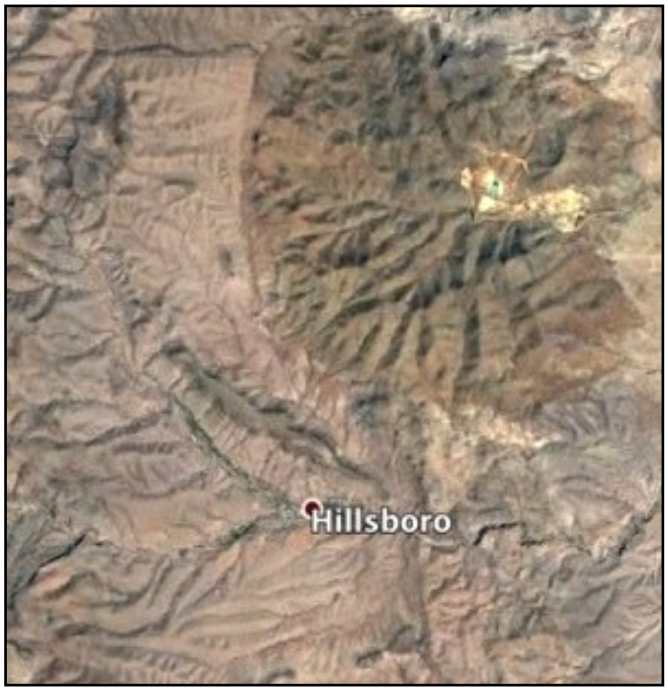






image above is of that area from Google Earth. This happens to be an area which is quite complex geologically. The image below is the same area with the geologic overlay. Note that not only are the geologic units shown but the other information found on the geologic map is shown as well. Dikes, faults (of various depictions), the strike of the unit -- all of it, superimposed over the land form. The overlay comes with the full range of Google Earth tools; for instance, you can change the opacity of the layer.



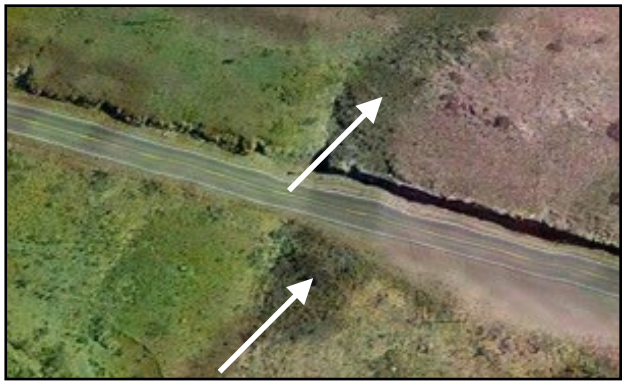
Near the bottom right of the image above, a fault (the dark line running from the bottom of the image upwards at a steep angle) bisects NM-152. The road cut is well known in the area, looking like the image at the upper right, in Street View on Google Earth.

A detail from the geologic map overlay (below the photograph) shows where the fault (the dark line highlighted by white arrows) crosses NM-152.

This tool provides some significant insight into the geology of the area and should be useful in improving the accuracy of the draft geologic map.

The .kmz file is available for your personal use should you wish to explore on your own. Be warned, however, that the file is large (98.7 MB). To download the file, navigate to the geology reference material page on the Black Range website, scroll to the Geological Maps section of the page and click on ".kmz of Hillsboro Geology Map on Google Earth". You may then download the file for your use (you will not see an image, it is a data file). For those of you who are unfamiliar with the .kmz format, it is the file format typically used for GIS applications.





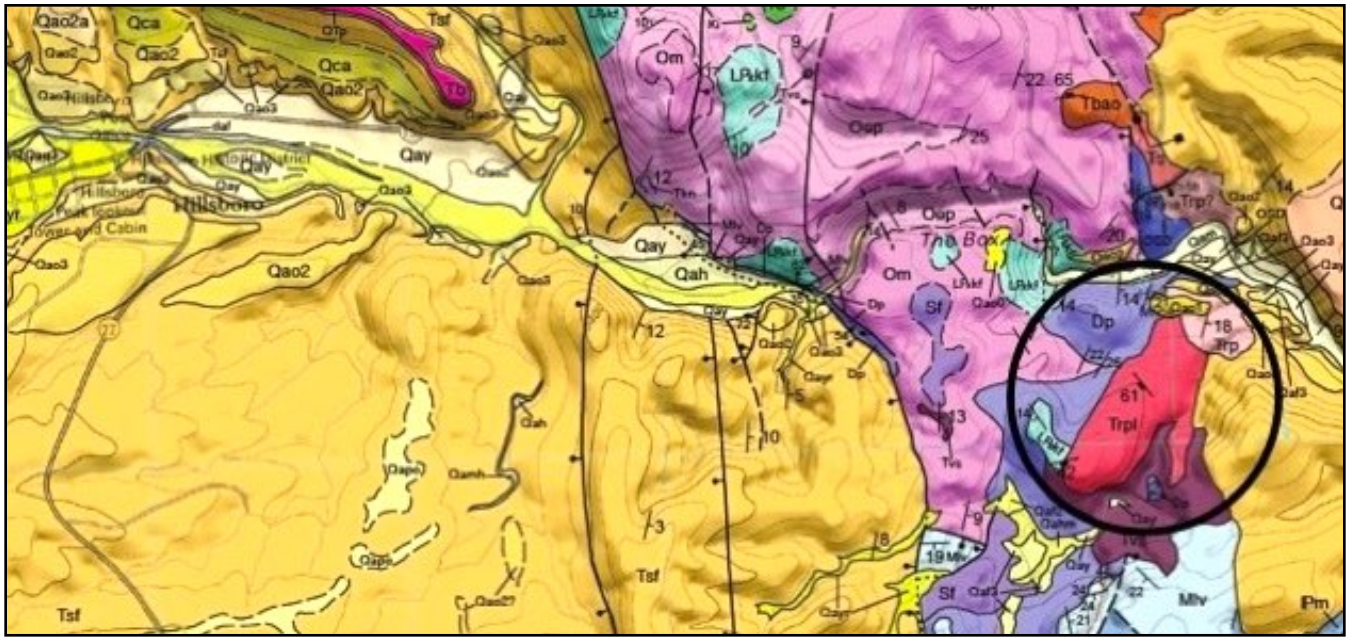
TRPL - ANDESITE FLOWS OF THE RUBIO PEAK FORMATION

The Google Earth image of this geologic unit, with a layer of the Hillsboro Quadrangle Geologic Map, is shown below. This is a fairly large exposure of the unit and easily accessible as you walk from the west into Percha Box.



The Trpl unit is about 36 million years old, dating from the Eocene (in particular, the Priabonian Age). At the end of the Priabonian a major extinction event occurred (the "Grande Coupure", a.k.a. the Eocene-Oligocene extinction event). That event may have been caused by major meteor strikes in Siberia and in what is now the Chesapeake Bay. A word about the link above: it is, of course, a link to a Wikipedia article. In a world of false news and false information, Wikipedia stands as a monument to the truth.

It was during the Eocene that most of the modern mammal orders evolved and arrived in North America. Reptiles (as in snakes as long as a school bus) were also



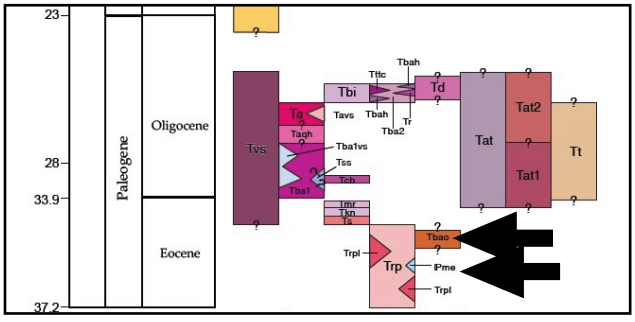
prevalent during this period, although none are known from the area which was to become the Hillsboro Quadrangle.

MAGDALENA GROUP LIMESTONE - LANDSLIDE (IPME)

Among the many interesting events recorded on the Hillsboro Geologic Quadrangle is a major landslide event. In the Trujillo Park Canyon there are the remains of a major landslide. The evidence is a large deposit of Magdalena Group Limestone, and the resulting geologic feature is listed as IPme (the blue area in the Google Earth/Geologic Map detail shown below). Note that the border of the quadrangle runs from near the bottom left corner upward to the right.



IPme **Exotic block of Magdalena Group limestone** – Observed in Trujillo Park Canyon. Transported during major landslide event(s). See IPm description.

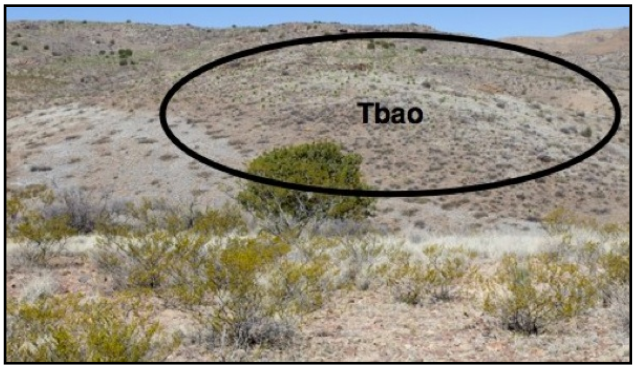


IPm **Magdalena Group (upper to middle Pennsylvanian)** – Pink to brownish-gray, very thin- to thick-bedded, massive, somewhat cherty, sparsely fossiliferous limestone with subordinate siltstone, mudstone, and shale. Fossils include bryozoans, echinoderm fragments, fusulinids, ostracods, and brachiopods. 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.

This entry records the landslide. To review a general discussion of IPm, see page 33 of the report.

TBAO - OLDER BASALTIC ANDESITE FROM THE EOCENE

Most of the central slope in this image is composed of the Tbao geologic unit.

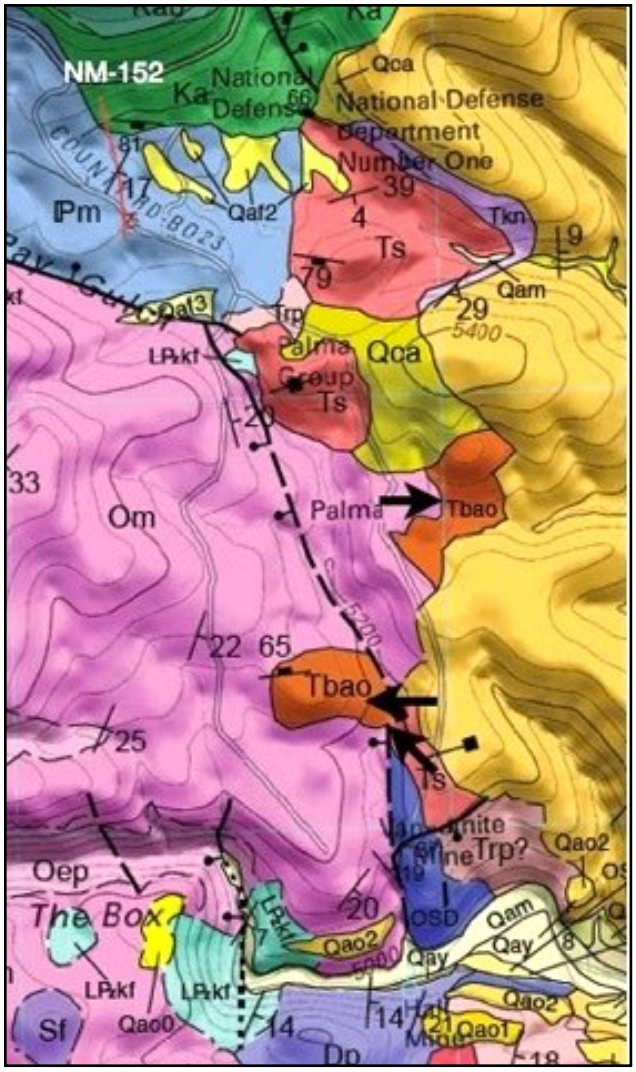


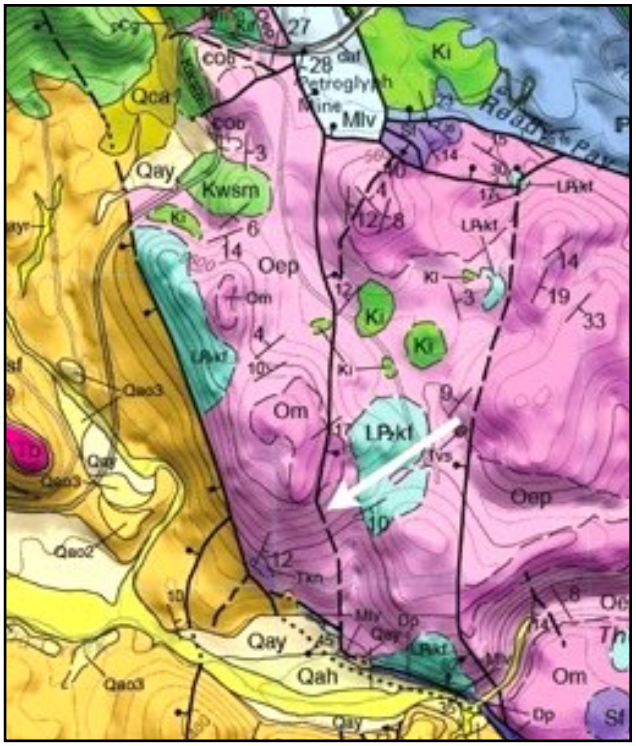
The Hillsboro Quadrangle Geologic Map describes the Tbao Geologic unit as:

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.

The photograph above was taken in Study Area Four (detail at the upper left on the following page). The bottom black arrow indicates where the photograph was taken and the direction of the shot.

The Palma Mine Group mines are located in the area of the two Tbao units found in Study Area Four.







The Tbao geologic unit is not shown in the cross section which is included with the geologic map, nor does the report which accompanies the map describe it in any way other than that above.

In my discussion of the Trpl geologic unit, I mentioned that the Cenozoic saw the evolution of many of the mammalian orders. The definitive work about the mammals of this period is *Late Cretaceous and Cenozoic Mammals of North America* edited by Michael Woodburne. The full range of mammal sizes was found in the Black Range area from the timeframe of this geologic unit. Being molten in origin, this unit does not contain many fossils. See Cenozoic Vertebrates From Sierra County, Southwestern New Mexico by Morgan and Gray for more information about the fauna of this area during this period.

Access to this area is relatively easy via two roads which depart from the access in Ready Pay Gulch, east of Hillsboro.

TVS - VOLCANICLASTIC DEPOSITS (UNDIVIDED) FROM THE OLIGOCENE

The photographs shown in this unit description were taken in Study Area No. 5, at the approximate location of the base of the arrow on the Hillsboro Geologic Quadrangle detail shown to the right. The arrow shows the direction in which the photograph just below the map detail was taken.

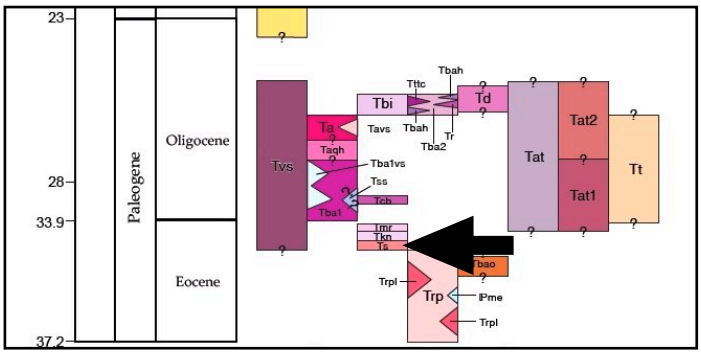
"Undivided" in the description of this unit means that the deposit spans the period indicated (Oligocene and Late Eocene) but is not differentiated into the numerous specific geologic units of the same era. "Undivided" may occur for a number of reasons, including - as is the case here - that the unit has no specific identifying aspects which can be used to differentiate it into more specific subdivisions of the geologic scale. The period spanned is from about 34.5 mya to about 25 mya.

In the photograph at the top left of the next page, the Tvs formation is in the foreground. For those interested in visiting this area, access is gained via the road/trail described as "Vulture Road" in *Volume 2 of Walks in The Black Range*.

Of particular interest to me is the fact that the vulcanism which was typical of the previous 40 million years in this area continued through most of the Oligocene. Bad for fossil hunters, probably good for mineral hunters.

Back to the "undivided" concept for a moment: in the correlation of geologic units time scale the more specifically identified geologic units are indicated to the right of the Tvs unit. The Tvs unit may be composed of any/all of these more specific units. There are very few places where the unit described as Tvs is found at the surface, and they are small. This is an important point





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.

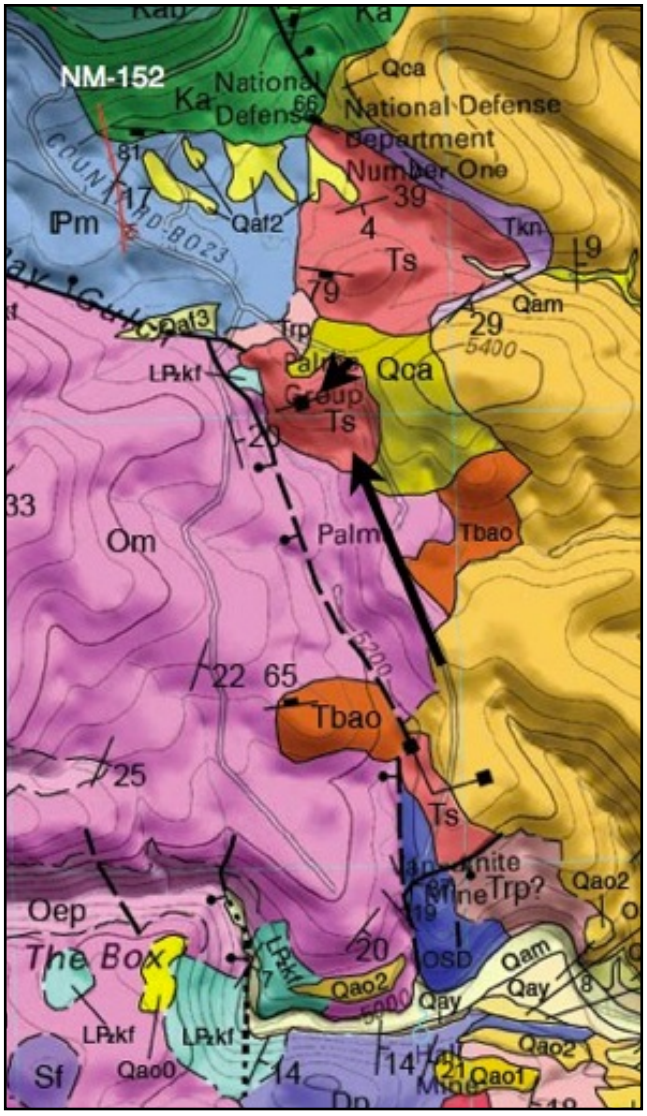
to remember. The "Correlation of Map Units" do not indicate the relative prevalence of particular geologic units.

In "The First Oligocene Mammal From New Mexico", Spencer Lucas notes that "Oligocene landscapes of New Mexico were dominated by andesite stratovolcanoes and…this pervasive volcanism produced volcanic and volcaniclastic rocks that have been neglected by vertebrate paleontologists, so that, until now no Oligocene vertebrate fossils have been discovered in New Mexico…" He goes on to describe the fossils of the even-toed ungulate, *Montanatylopus matthewi*, which were found in this area (it was a ground dwelling browser). Looking for fossils in volcanic rock is like looking for a needle in a haystack - it takes the right attitude.

TS - SUGARLUMP TUFF

The Hillsboro Quadrangle Geologic Map describes the Ts geologic unit as: "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. 40Ar/39Ar dated at 35.63 ± 0.15 Ma (McIntosh et al., 1991). Maximum thickness 35 m."

The location and direction of the photograph shown on this page are indicated on the map of Study Area 4 at the top right. The photo was taken from the base of the top arrow.

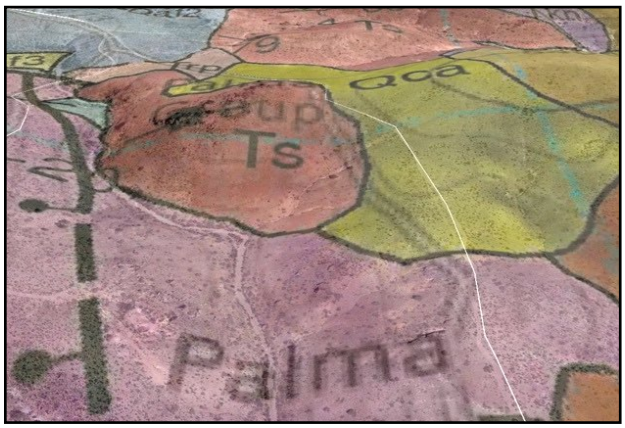


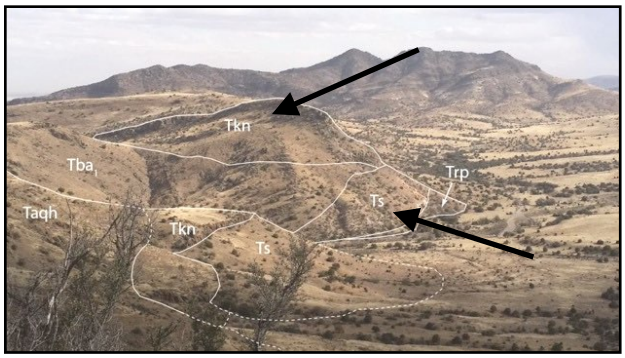


The Sugarlump Tuff geologic unit is not shown in the cross-section which accompanies the Hillsboro Geologic Map.

As can be seen on the Correlation of Map Units chart at the upper left, the Sugarlump Tuff unit is from the late Eocene, dated to about 35.7 million years ago. It is not widespread in the area covered by the Hillsboro Quadrangle and is assumed to be a deposit from a more distant caldera explosion.

The Map/Geologic Overlay at the top of the next page is shown from the perspective of the bottom arrow.





The photo/diagram shown directly above is from the Hillsboro Geologic Report which accompanies the geologic map. The diagram is Figure 8 in the report and is described as: "Figure 8. Volcanic stratigraphy in Trujillo Park Canyon. View is toward the south. McClede Mountain forms the skyline and is comprised of the Mimbres Peak Formation (Tmr), including rhyolite sparingly exposed in the western Hillsboro quadrangle." A Ts unit is shown at the bottom arrow.

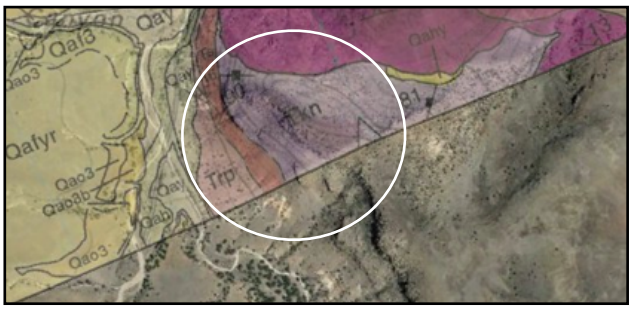
The photograph below was taken of the surface of the Ts unit at the top center of the map detail on the previous page.



TKN - KNELLING NUN TUFF

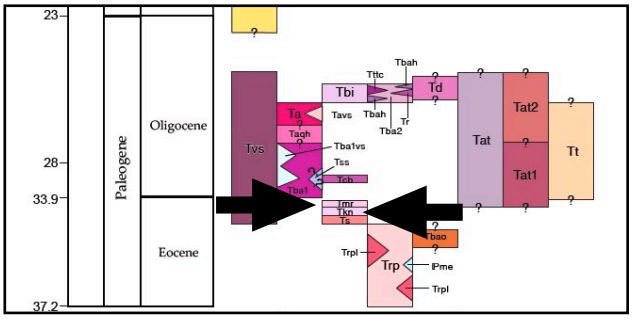
The map at the upper right is the lower left section of the Hillsboro Quadrangle Geologic Map, overlaid on Google Earth. This image shows one of the Tkn exposures in Trujillo Park Canyon (within white circle).

The Knelling Nun Tuff geologic unit is probably the most famous unit within the Hillsboro Quadrangle. Its deposit was dramatic and substantial. The Hillsboro Quadrangle Geologic Map describes the unit as: "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. 40Ar/39Ar dated at 35.34 ± 0.10 Ma (McIntosh et al., 1991). 7-156 m thick."

Let us break that description down a bit and in so doing reinforce some of the points we have made about the "Correlation of Map Units" chart. First of all, the Knelling Nun Tuff deposit dates from the late Eocene. And secondly, the deposition of this geologic unit was a relatively short-lived event. As a result it takes up relatively little space on the chart, just enough to get the letters in. But it is a dramatic feature of our landscape, both within the area covered by the Hillsboro Quadrangle and in much of the Black Range.



Because of the transect which was chosen for the geologic cross section on the geologic map, this unit does not appear in the cross section.

In the photo/diagram which is the second from the top of the left column a Tkn unit is shown at the top arrow.

The Kneeling Nun (Rhyolite) Tuff unit was named by Elston in 1953, for the pinnacle which overlooks the Santa Rita Copper Mine.

The Giant of the Mimbres is associated with the Sugarlump and Kneeling Nun geologic units. See *Early Naturalists of the Black Range*, pp. 53-57.

Some Aspects of the Kneeling Nun Rhyolite Tuff, an excellent paper on this geologic unit, was written/published by David L. Giles in 1965.

In Bulletin 37 - *Geology and Mineral Deposits of Lake Valley Quad*, 1954, Henry L. Jicha, Jr. (pp. 44 - 45) describes Kneeling Nun Rhyolite Tuff:

"The Kneeling Nun rhyolite is named after the prominent rock monument which overlooks the town of Santa Rita and the Chino copper pit. The Kneeling Nun is an isolated column of welded rhyolite tuff which stands a

short distance in front of a high escarpment of the same rock. It is a famous landmark in the Santa Rita area. The Kneeling Nun tuff is characterized by many features which have been described as characteristic of welded tuffs. The latter have been described by numerous authors. The first mention of such rocks was made by Iddings (1899) in his famous monograph on the geology of Yellowstone National Park. Other welded tuffs have been described in Alaska (Fenner, 1923), Idaho (Mansfield and Ross, 1935), California (Gilbert, 1938), Oregon (Moore, 1934), the Lesser Antilles (Anderson and Flett in 1903, La Croix in 1904, and Ferret in 1934), Peru (Fenner, 1948), and New Zealand (Marshall, 1935).

"Paige (1916) originally described the Kneeling Nun as a flow rhyolite. The Kneeling Nun, with its prominently developed columnar structure, is called a welded tuff by the author, because it varies considerably in character from flows of the same rock type. The gently dipping, widespread (tens of square miles) rocks are fragmental, with a glassy groundmass, including some attenuated shards. They lack vesicular or scoriaceous zones, suggesting strongly that they were not flow rocks rendered fluid by high gas content. All of these characteristics point to the probability that the Kneeling Nun is a welded tuff. The rocks may have been formed by a nuée ardente (cloud of hot, particle-laden gases), or possibly by eruption of fragmental material from a vent, without rising high in the air — simply a gaseous particulate flow eruption.

"Megascopically, the rock is pinkish gray to reddish brown, medium-grained, highly porphyritic, with numerous phenocrysts of quartz as much as 3 mm in diameter, less sanidine and plagioclase of similar size, and minor biotite in a fine-grained matrix. The large number of quartz and feldspar crystals give the rock the appearance of a granite porphyry. Quartz and feldspar phenocrysts appear to be somewhat fragmental, some even having the aspect of shards. The rock has marked columnar jointing and, at places, faint horizontal sheeting.

"Microscopically, the rock consists of about one-third phenocrysts and two-thirds cryptocrystalline groundmass. The phenocrysts are large subhedral to anhedral crystals of quartz, oligoclase, sanidine, and some brown biotite. The groundmass surrounding the crystals is translucent and pale brown in color. It contains small spherulites which show radial structure under crossed nicols (pl 5-A). Very tiny particles of magnetite are embedded in the glass, whose refractive index is less than that of balsam. A volumetric Rosiwal analysis gives the following composition:

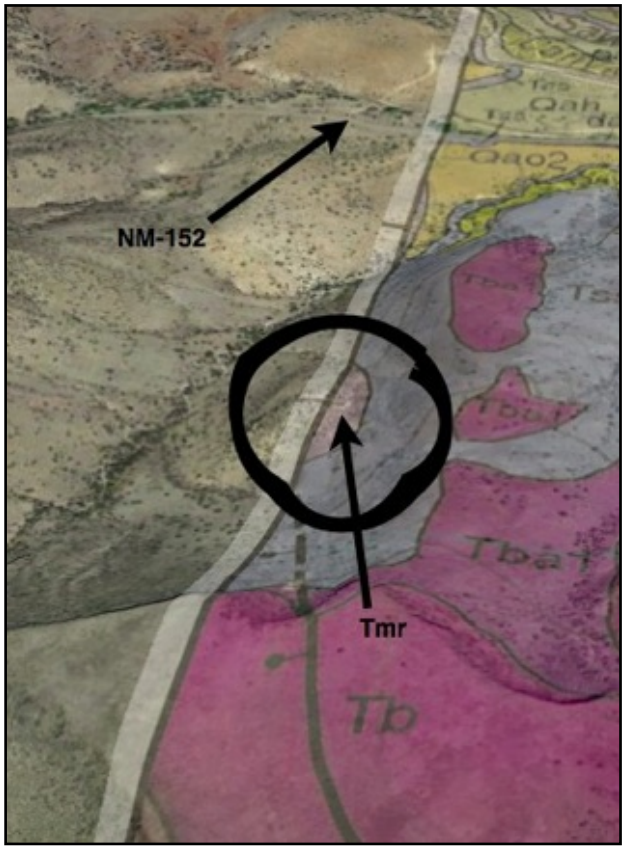
	PERCENT
glassy groundmass	67.5
quartz	21.5
sanidine	7.9
oligoclase	1.6
biotite	1.0
magnetite	0.5
	100.0

The chemical analysis and norm of this rock indicate that it is a rhyolite (tables 4 and 5).

"The Kneeling Nun welded rhyolite tuff generally lies conformably upon quartz latite tuffs of the Sugarlump formation. In Barenda (sic) Valley, directly west of the Lake Valley fault block, and in a separated outcrop about one mile west, the Kneeling Nun formation has a thickness of about 200 feet. To the southwest, near the headwaters of White Rock Creek, the thickness is only 6-10 feet."

TMR - THE MIMBRES PEAK FORMATION OF RHYOLITE

The Tmr geologic formation west of Hillsboro is shown below. This unit is located on the very western edge of the Hillsboro Quadrangle, west of the High Bridge on NM-152 and south of that highway.



The Mimbres Peak Formation of Rhyolite (geologic unit Tmr) is described on the Geologic Map as: "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, porphyriti-caphanitic, brecciated block and ash-flow tuff west of Percha Creek narrows. Phenocrysts there include up to 5% sanidine. May contain spherulites. 40Ar/39Ar dated at 34.32 ±0.11 to 34.22 ± 0.16 Ma (O'Neill et al., 2002). Maximum thickness 52 m. (171 feet)."

At page 18 the report which accompanies the Geologic Map states "The ~34.3 Ma Mimbres Peak Formation rhyolite (Tmr) filled in the ring fractures of the Emory caldera after eruption of the Kneeling Nun."

The Mimbres Peak Formation developed in the Priabonian Age of the Eocene Epoch. As noted earlier in this article, the end of the Eocene is defined by one of the great periods of extinction which the earth periodically has gone through. This extinction is thought to have occurred because of one or more large meteor strikes. The large extinction period which we have entered recently is human caused, home-grown so to speak.

Many of the modern fauna forms evolved during the Eocene.

TAT: TAT1 & TAT2 - LOWER AND UPPER ANDESITE OF TRUJILLO PEAK

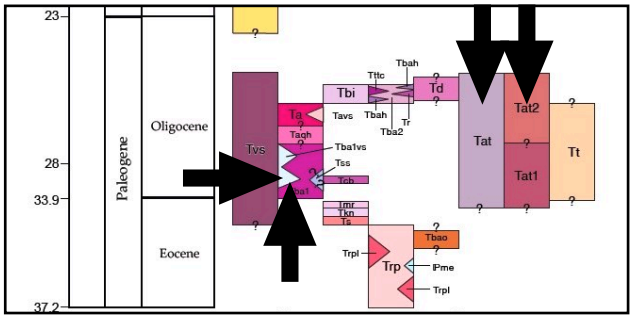
The Hillsboro Quadrangle Geologic Map describes these geologic units as follows:

"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:

Tat1: Lower andesite of Trujillo Peak – Non-vesicular and strongly foliated. Approximately 120 m thick.

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."

These units are most easily found in Trujillo Canyon east of NM-27, south of Hillsboro. The photographs shown here were taken from the location (black arrow) indicated on the detail of the geologic map shown below.





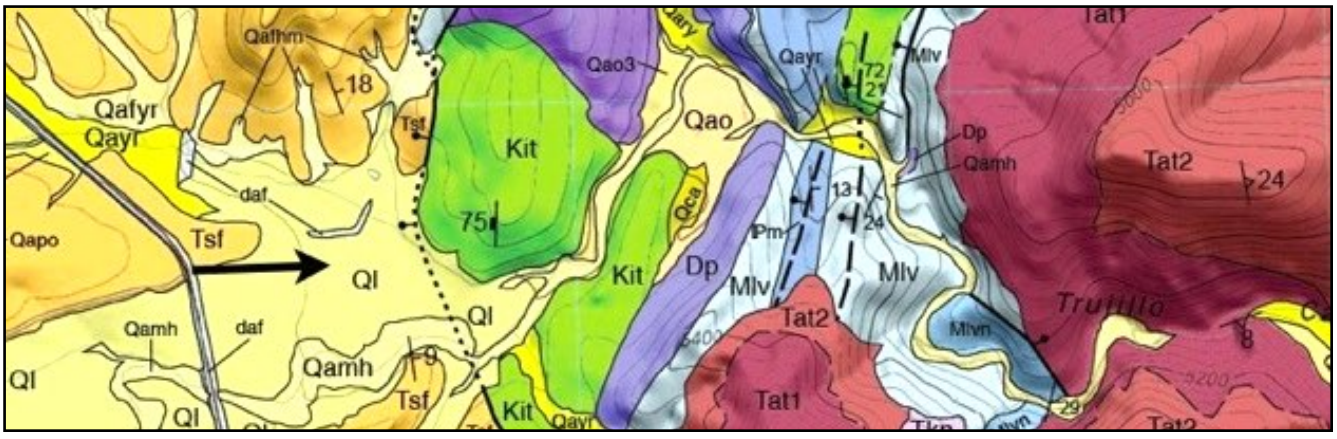
At page 19 of the report which accompanies the Geologic Map, it is stated, as to the andesite deposits of the Oligocene, that "Deposition of the older basaltic andesite was followed by a significant succession of late Oligocene volcanism that resulted in several andesites with variable





phenocryst content (Taqh, Ta, Tba2), and a transition to silicic volcanism forming rhyolite (Tr), dacite (Td), and tuffaceous volcaniclastic sediment found in Tank Canyon (Tttc). The latter unit commonly features reworked ash beds and pumice (Figure 11). Volcaniclastic beds (Tvs) distinct from those of the Rubio Peak Formation are mapped near Percha Creek Box and underlying Pliocene (?) basalt in the western part of the quadrangle. These debris flows typically lack stratigraphic context, but may span the late Eocene to upper Oligocene. Finally, the andesite of Trujillo Peak (Tat) appears distinct from the volcanic units in the western part of the quadrangle, although it may correlate to the middle and upper beds of the younger basaltic andesite (Tba2) based on generally low phenocryst content and variable foliation and vesicularity. These flows lie unconformably above a small exposure of Kneeling Nun Tuff, and O'Neill and others (2002) considered their correlative flows to the south to be middle Oligocene in age."

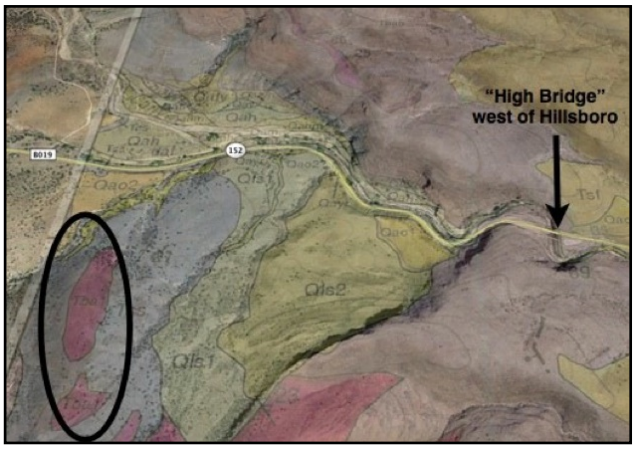
These deposits are from 34 to 25 million years old. The Oligocene is the youngest part of the Paleogene Period. The end of the Oligocene was characterized by a mass extinction.



TBA1 - LOWER TO UPPER ANDESITE & TBA1VS - VOLCANICLASTIC DEBRIS

The Hillsboro Quadrangle Geologic Map describes the Tba1 geologic unit as : "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 (40K/40Ar). Approximately 470 m thick."

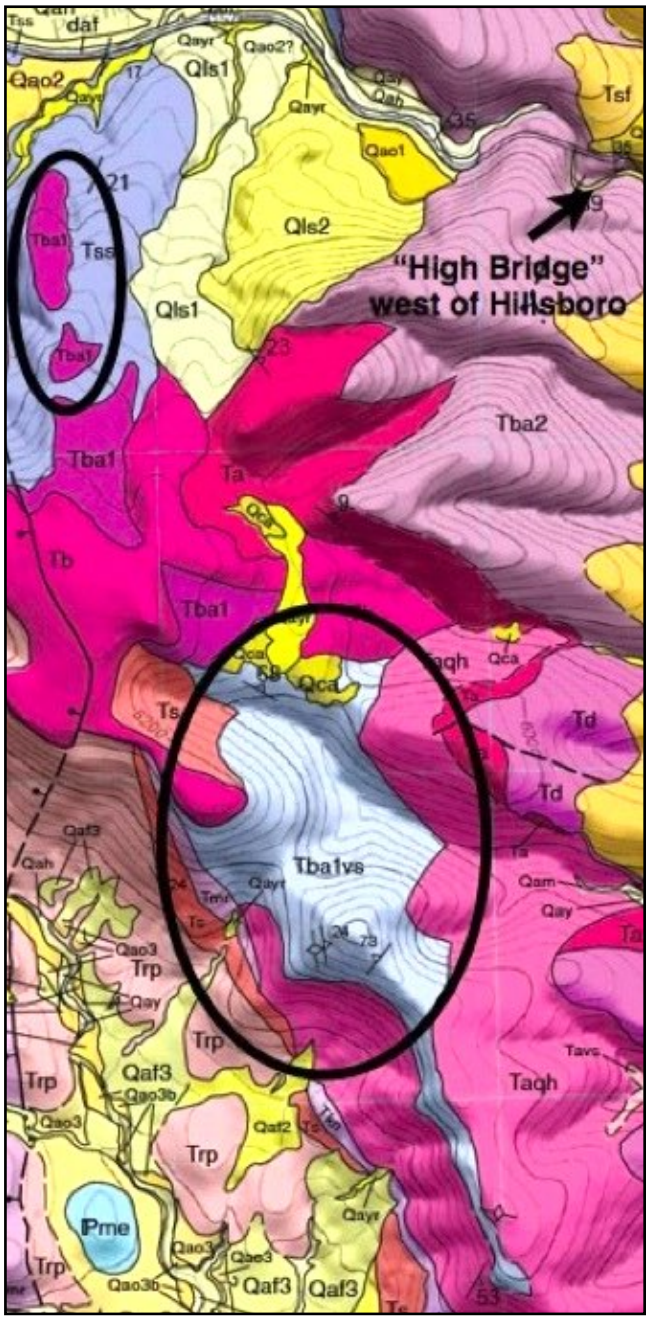
The Hillsboro Quadrangle Geologic Map describes the Tba1vs geologic unit as: "Volcaniclastic debris flows interbedded with basaltic andesite (lower upper Oligocene) – Maroon-brown volcaniclastic conglomerate, in poorly stratified, medium- to very-thick beds. Massive to weakly imbricated. Clasts include 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."



The image above is a Google Earth image/Geologic Map Overlay of the area west of the High Bridge (west of Hillsboro) near the edge of the Hillsboro Quadrangle Geologic Map. It shows the two sections of Tba1 (see oval) depicted at the upper left on the Geologic Map detail at the right. There are several other exposures of this unit along the western edge of the quadrangle. The top oval on the map detail from the Hillsboro Quadrangle Geologic Map corresponds to the oval in the image above. The bottom oval on the map detail highlights a large exposure of Tba1vs.

The Tba1 unit has been dated to 28.1 million years ago (plus or minus 600,000 years) using 40K/40A dating methodology. (Seager, W.R., Shafiqullah, M., Hawley, J.W., and Marvin, R.F., 1984, "New K-Ar dates from basalts and the evolution of the southern Rio Grande rift", *Geological Society of America Bulletin*, v. 95, no. 1, p. 87–99.) The Tba1vs unit dates from the same period.

Few fossil records have been found in New Mexico from the Oligocene. There are, however, track impressions from the Datil Formation, only one of seven locations where track impressions are found in the western U.S. from this period. Wikipedia has an excellent (short) article on the paleontology of New Mexico.



Edward Cope is closely associated with the mining operations in Lake Valley. He is, of course, known mainly for his extensive work in the field of paleontology. The 66 papers on New Mexican fossils which he published are only a small subset of his total work. In fact, one of his discoveries was the first known Eocene mammal from the southwestern United States, a *Coryphodon*, which weighed between 750 and 1,300 pounds. Cope first described several *Coryphodon* species. (See Early Naturalists of the Black Range, pp. 96-97.)

TSS - LACUSTRINE SEDIMENT AND TCB - CABALLO BLANCO RHYOLITE TUFF

The Geologic Map describes the Tss geologic unit as: "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."

As shown in the detail from the Geologic Map on the previous page, a large unit of Tss is found just south of NM-152, west of Hillsboro, on the western edge of the quadrangle (blue-gray unit at top oval). This geologic unit is also shown in the cross section which is found on the Geologic Map, in proximity to the Tcb unit referenced below. The western end of the cross section is shown to the right; the TSS and Tcb units are highlighted by the oval.

The Geologic Map describes the Tcb unit as: "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. 40K/40Ar dated at 29.8 ± 0.8 Ma (Seager, 1984). Maximum thickness approximately 91 m." In the area of the Hillsboro Quadrangle this geologic unit is found only below ground.

The Tss unit west of the High Bridge, west of Hillsboro, New Mexico, USA, is shown below.

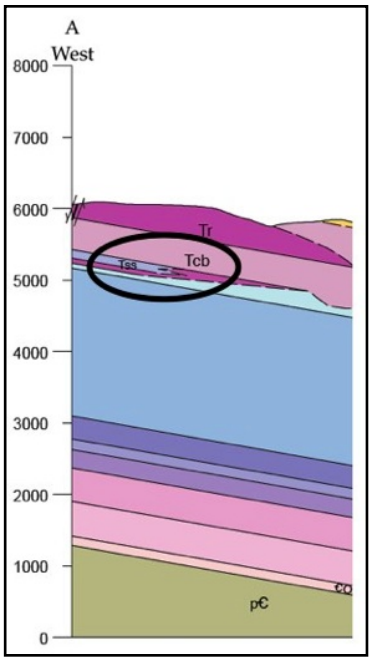


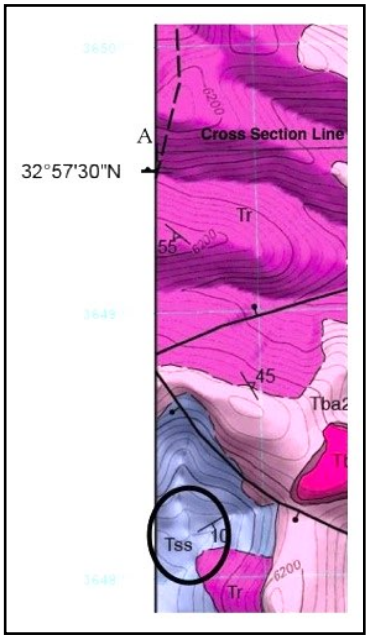
The detail at center right shows the surface area of the cross section detail shown at the upper right. The almost horizontal line near the top is the western end of the Cross Section Line; a label has been added. Note that a Tr unit is on the surface, covering the Tcb and Tss units. However, a Tss unit is shown on the surface to the south of the cross section line.

The report which accompanies the Geologic Map notes that "Lacustrine sediment (Tss) exposed near the Percha Creek narrows (sec. 18, T16S, R7W; sec. 13, T16S, R7.W) overlies (and perhaps interbeds with) the Caballo Blanco Rhyolite Tuff just off the western edge of the quadrangle (Seager, 1986)... The lake in which this sediment was deposited appears to have eventually spilled over one or more constrictions, with fine-grained sandstone and siltstone grading upward into pebbly sandstone and conglomerate signifying a transition to fluvial deposition. The unit also interfingers with older basaltic andesite (Tba1) dated at ~28 Ma (Seager et al., 1984). Elsewhere, lacustrine sediment underlies younger basaltic andesite." (p. 18)

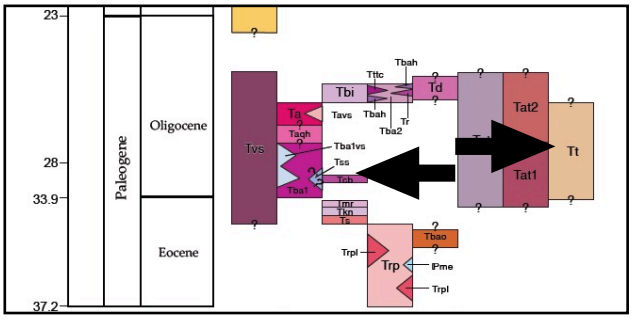
As noted at p. 18 of the report, the Tcb geologic unit is "thought to have erupted from the Twin Sisters caldera ~40 km to the west (McIntosh et al., 1991; Chapin et al., 2004)." (p. 18)

Studies Related to Wilderness Primitive Areas - Black Range, New Mexico - Geological Survey Bulletin 1319-E, Ericksen et al., 1970, p. 33. The Caballo Blanco Rhyolite Tuff member (Tcb) includes the following: "The Caballo Blanco Rhyolite Tuff was named by Elston (1957) from the exposures in the Dwyer quadrangle, southwest of the Black Range. The Caballo Blanco Rhyolite Tuff is extended into the Black Range and adopted as the Caballo Blanco Rhyolite Tuff Member of the Datil Formation. The unit is exposed on the north side of the Mimbres River valley... and consists of white soft pumiceous non-welded or poorly welded rhyolite ash-flow tuff layers... interlayered with tan to pale-red hard strongly welded crystal-rich rhyolite tuff... The principal phenocrysts are sanidine, quartz, and plagioclase. Maximum thickness is about 500 feet. North of the Mimbres valley, rhyolite considered to be equivalent to the Caballo Blanco is exposed in Buckhead Canyon, in the headwaters of Black Canyon, and east of the crest of the Black Range as far north as the North Fork of Palomas Creek... In the Mimbres River drainage, the Caballo Blanco rests on andesite...but northward this andesite evidently pinches out, and the Caballo Blanco rests directly on the Kneeling Nun...In the headwaters of Cooney Canyon, a tributary stream on the north side of the Mimbres valley... the following four units (1 is the basal unit) of the Caballo Blanco can be distinguished:





	Thickness
4. White tuff similar to unit 2	25'-50'
3. Light-red tuff similar to unit 1	100'
2. White to pink soft pumiceous rhyolite tuff	200'
1. Light-red hard cliff-forming crystal-rich rhyolite tuff	200'



Each of these units has the appearance of being a single ash flow cooling unit. Nevertheless, there may be only two cooling units, each consisting of a densely welded zone (units 1 and 3 above) that grades upwards into a poorly welded zone (units 2 and 4)."

TT - THURMAN FORMATION

The Hillsboro Quadrangle Geologic Map defines the Tt unit as: "Thurman Formation (middle to upper Oligocene) – Pebbly to silty sandstone and pebble-cobble conglomerate, in thickly- to medium-laminated, tabular, 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."

The geologic report which accompanies the geologic map provides a more extensive description of the unit: "Thurman Formation (middle to upper Oligocene) – Pebbly to silty sandstone and pebble-cobble conglomerate in thickly laminated to medium, tabular to perhaps lenticular beds. Unit fills in small paleovalley cut into Td, Taqh, and Tba1 in southwestern part of quad, and is weakly consolidated, mostly matrix-supported, and broadly cross-stratified. Pebble lags/lenses are rare. Clasts include moderately well sorted, angular to subrounded pebbles (80-90%) and cobbles (10-20%) of ≤ 55% Kneeling Nun Tuff, ≤ 40% basaltic andesite, and ≤ 5% older andesite. Matrix consists of pale brown (10YR 6/3), well sorted, subrounded to rounded, fine- to medium-grained sand or white (10YR 8/1), well sorted silt to very fine-grained sand. Grains are comprised of 45% feldspar, 35% lithic fragments, and 20% quartz. Silty, very fine-grained sand occurs in laminated beds, typically isolated or occurring in couplets or triplets. Occasional small (≥ 0.5 mm thick) concentrations of iron oxide minerals are found in both pebbly and silty sand beds. Approximately 30 m (98 ft) thick." (p. 35 - See links at Hillsboro Geology Map.)

This geologic unit spans most of the Oligocene. At page 20 of the referenced report it is noted that: "The Thurman Formation (Tt) is exposed only in the southwestern corner of the quadrangle, (ed.: see white oval in detail below) where it consists of sandstone draped on dacite (Td) and quartz-hornblende andesite (Taqh). O'Neill et al. (2002) mapped similar, lenticular bodies of the Thurman Formation to the south. Elsewhere, the dominantly fine-grained deposit contains fallout tephra dated at 27.4 Ma, implying that the Thurman was deposited on a volcaniclastic apron of the Mount Withington caldera some 115 km to the north (McIntosh et al., 1991; Seager and Mack, 2003). Broad cross-stratification and the presence of pebble-rich conglomerate in the exposures near Trujillo Creek indicate deposition by sheetflooding." (See: *Bulletin 1644 - Geologic Investigations in the Lake Valley Area, Sierra County, New Mexico*.)

TAQH, TA, TAVS - TRUJILLO CANYON GEOLOGY

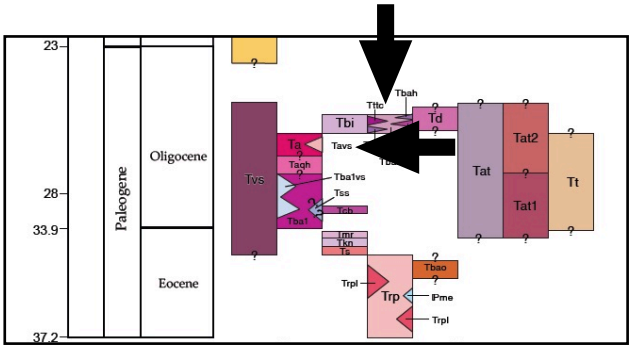
These three geologic units are found in Trujillo Canyon (see the Geologic Map detail below). The Geologic Map describes these units as follows:

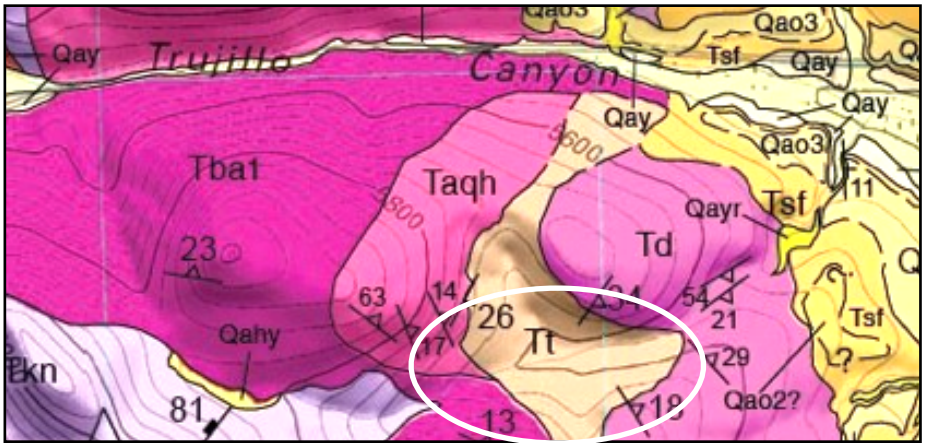
Taqh: "Quartz-hornblende andesitic to dacitic flows and flow breccias (upper Oligocene) – Aphanitic andesite and dacite flows and flow breccias. Phenocrysts include 1-2% total quartz, pyroxene, plagioclase, and altered hornblende. May contain disseminated magnetite. Breccia is clast- to matrix-supported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

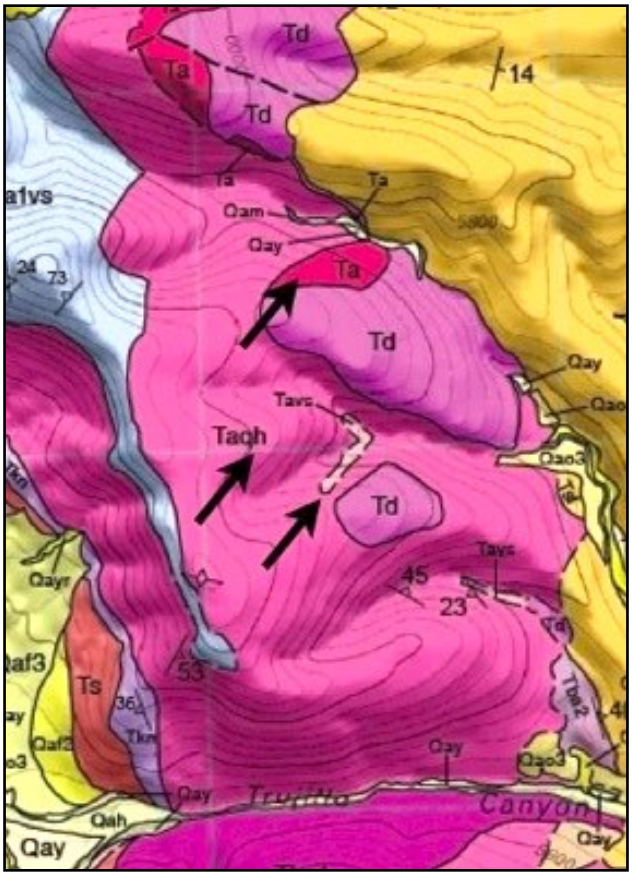
Ta: "Aphanitic trachyandesite (upper Oligocene) – Massive to variably foliated, vesicular, aphanitic to aphanitic-porphyritic, fine-grained trachyandesite. Phenocrysts include < 3% total plagioclase, biotite, hornblende, and pyroxene. May contain small quartz xenocrysts. Vesicles may contain acicular 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." On the Correlation of Map Units chart which accompanies the map these three geologic units are clustered together (see arrow) in the middle (to upper) of the Oligocene.

As noted in the geologic report which accompanies the geologic map, "Deposition of the older basaltic andesite was followed by a significant succession of late Oligocene







volcanism that resulted in several andesites with variable phenocryst content (Taqh, Ta, Tba2)…" (p. 19)

See the discussion of the TT formation, third paragraph on the previous page, for more context.

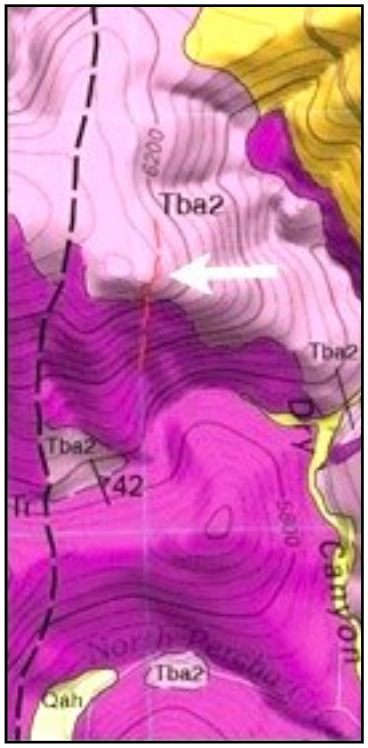
A significant amount of Ta unit rock was incorporated in a large landslide (p. 23 of referenced report): "Landslides are observed at multiple locations and scales in the central and western Hillsboro quadrangle, typically on weak substrate of the Santa Fe Group or Oligocene lacustrine sediment. At least two generations of mass movement are found west of Percha Creek narrows (Figure 10), where a younger, smaller slide (Qls2) rests atop an older slide (Qls1). These deposits feature hummocky surface textures and contain distinct toes and lobes of open-framework gravel. The younger deposit contains a large (≤ 100 m across), detached block of younger basaltic andesite (Ta) near its headscarp, and the older deposit features several blocks of chaotically deformed andesite."

TBI - A MAFIC DIKE

The Tbi geologic unit is described on the Hillsboro Quadrangle Geologic Map as: "Basaltic andesite dike (upper Oligocene) – Mafic dike with a black to dark-gray, phyric matrix and 1-2% phenocrysts of plagioclase, olivine, and pyroxene that appears to be the feeder for one of the younger basaltic-andesite flows."

This unit is only found in the northwest corner of the geologic map and is shown at the arrow on the map detail in the right column.

Wikipedia defines "mafic" as follows: "Mafic is an adjective describing a silicate mineral or igneous rock that is rich in magnesium and iron, and is thus a portmanteau of magnesium and ferric. Most mafic minerals are dark in color, and common rock-forming



mafic minerals include olivine, pyroxene, amphibole, and biotite." As far as volcanic flows/eruptions go, mafic material tends to be less explosive because gases held within the rock are able to escape more easily.

In the photograph at the top of the next page (taken from the area near Empire Peak) the dike is seen at the arrow.

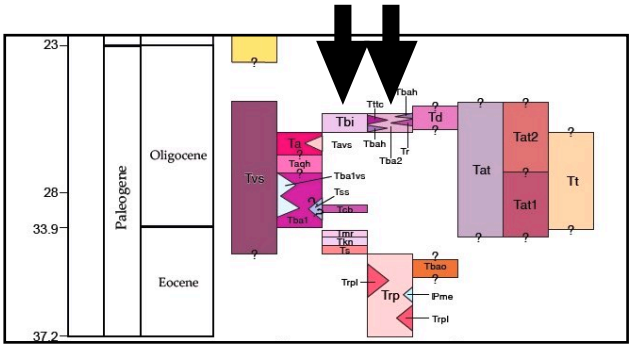
TBAH, TBA2 & TR - HIGH BRIDGE GEOLOGY

The Hillsboro Quadrangle Geologic Map describes these units as follows:

"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;

"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; and

"Tr: Rhyolite (upper Oligocene) – Porphyritic rhyolite flows that are variably massive to flow banded. In the





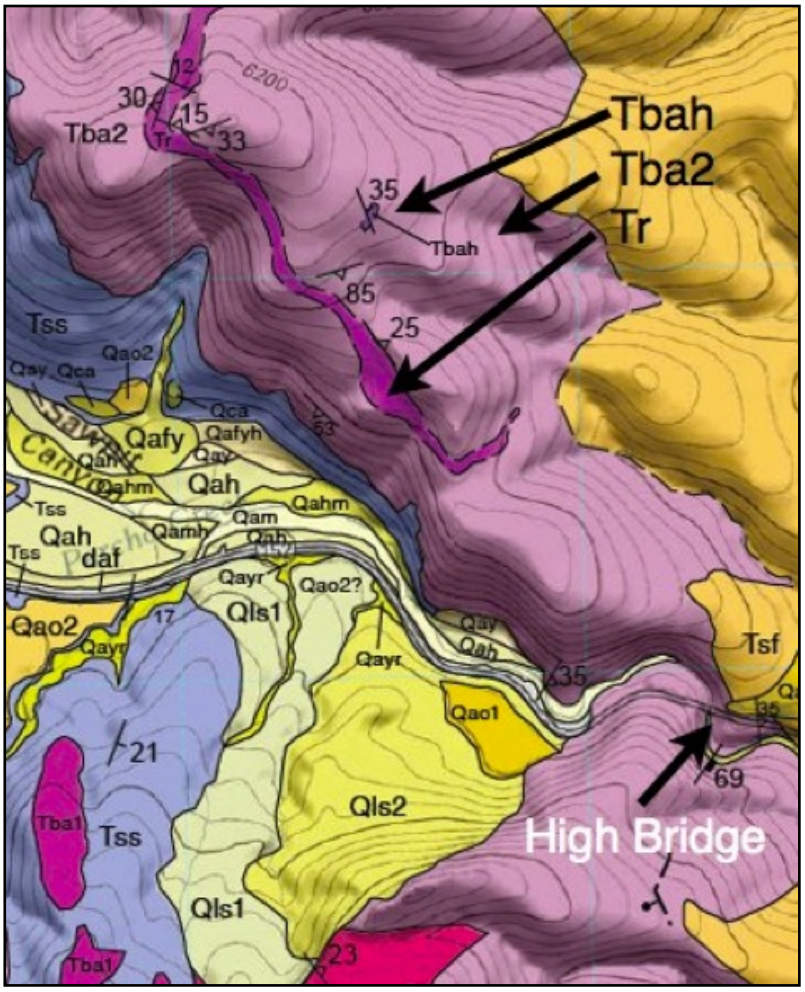
thicker parts of the section, the flows are more crystal rich (15-25%) and pink at the top, and more crystal poor (3-10%) and gray near the base. Block and ash deposits near the base are common. Phenocrysts include sanidine, quartz, biotite, and hornblende. The rhyolite flow unit is intercalated with 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."

These geologic units are found close to the High Bridge on NM-152 west of Hillsboro, New Mexico. When you stand on the old bridge the Tba2 geologic unit is all around you.

The western edge of the cross-section on the geologic map is north of the high bridge area. At the western edge of the map both the Tba2 and Tr units come to the surface and are shown in cross-section. The Tcb label at the western end of the cross-section is a bit misleading. It refers to the geologic unit represented just below the label.

All of these units are about 25 million years old.

The Hillsboro Report which accompanies the map notes (p. 19) that: "Deposition of the older basaltic andesite was followed by a significant succession of late Oligocene volcanism that resulted in several andesites with variable phenocryst content (Taqh, Ta, Tba2), and a transition to silicic volcanism forming rhyolite (Tr)..."



On a more "practical" level the Tba2 unit is a nice andesite basalt. It is cohesive and not prone to a lot of shattering, has good texture and typically has sharp edges, and has some large cracks. The location of this unit at the high bridge makes this an outstanding bouldering area for those prone to rock climbing.



The video High Water at Hillsboro Sep 12, 2014 shows a debris flow coursing through the narrows at the high bridge (shown in the photograph above).

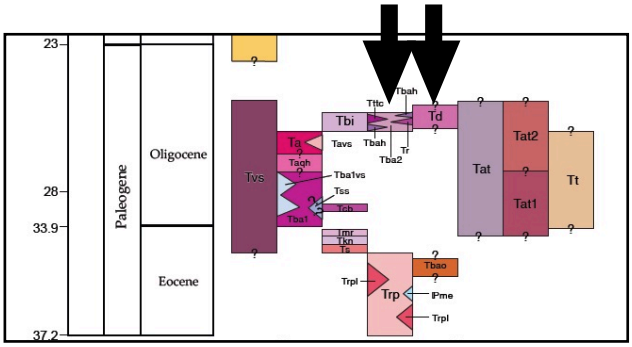
The description of the Tbah unit (above) uses the term "hydromagmatic". The first known use of the word was in 1942. This term, also magnetohydrodynamics, refers to the interaction which occurs between electrically conducting fluids and magnetic fields. Molten rock (like basalt and andesite when they are flowing and being deposited) is subject to the magnetic field. When it solidifies it reflects the Earth's magnetic field at the time when the rock hardened. Such rock has been used to study the changes in the Earth's magnetic field and the location of the magnetic poles.

TTTC TUFF AND TD DACITE

We end our coverage of the geologic units from the Oligocene with the Tttc and Td units. The Hillsboro Quadrangle Geologic Map describes these units as:

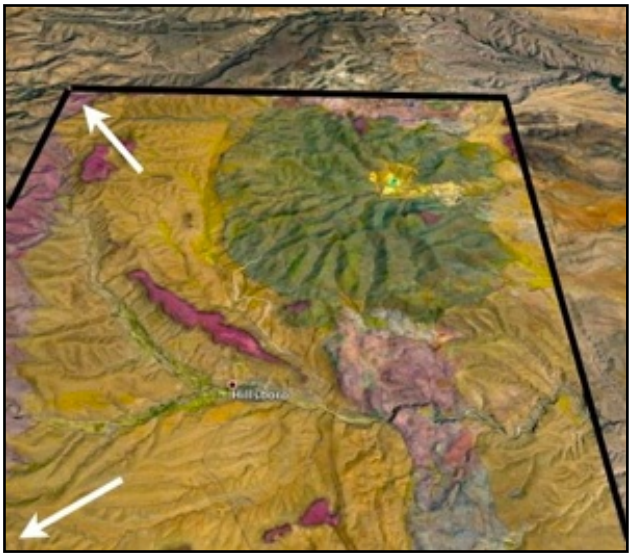
Tttc: "Tuffaceous volcaniclastic sediment of Tank Canyon (upper Oligocene) – Laminated, tabular beds of weakly sorted volcaniclastic conglomerate with minor volumes of laminated fine-grained ash beds, ignimbrites, and fluvial conglomerate and sandstone. Laminated, hyper-concentrated deposits are interbedded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

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 mono-lithologic clasts with 10-15% total phenocrysts of sanidine, biotite, hornblende, quartz, and zoned potassium feldspar. Maximum thickness is 35 m."



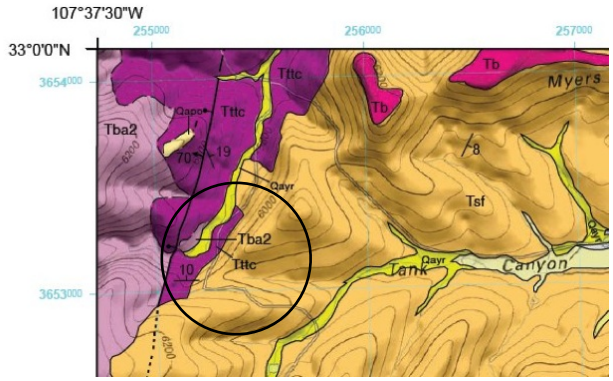
Note that there is a break in the timeline between these units and the next (Tsf). This discontinuity was fairly short in duration, being only a million years or so.

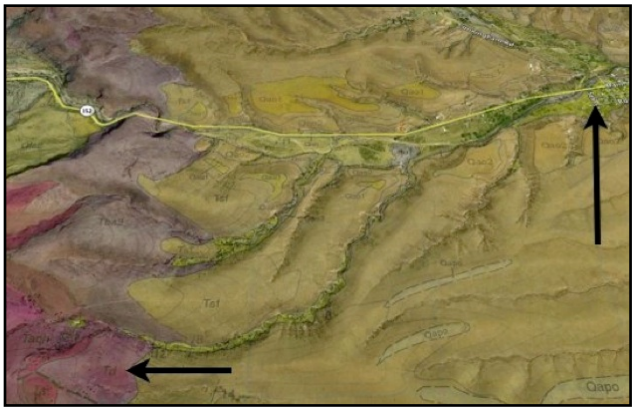
The image below is of the Hillsboro Quadrangle Geologic Map overlay of Google Earth. It shows the approximate locations of outcrops of these two units. The Tttc unit is found only in the northwest corner of the quadrangle (upper left arrow) while a Td unit is found southwest of Hillsboro (lower left arrow).



The image at the top left of the next page is a detail of the northwest corner of the geologic map. It shows the location of the Tttc units which are found in this quadrangle. They are at the head of Tank Canyon (Study Area 2), west of Myers Mesa.

The second image from the top in the left column of the next page is a Google Earth image with the Hillsboro Quadrangle Geologic Map overlay. It shows the location of Hillsboro (right arrow [pointing up]) and the nearest unit of Td, west of the town.





The walk titled "Mesa Walk South of Hillsboro" (Volume 2 of Walks In The Black Range) crosses the mesa country from Hillsboro to this unit, which is shown on the left of the photograph below. What I remember most about this walk was that the Td location was a bear to walk through; there were many fairly large cobbles which made walking up the hill tenuous.



TSF - THE SANTA FE GROUP

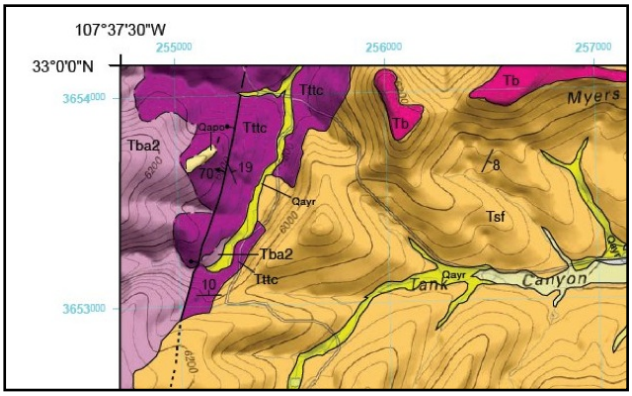
The Santa Fe Group of rock (Tsf) is one of the dominant landforms within the boundaries of the Hillsboro Quadrangle. The geologic map of the Hillsboro Quadrangle describes Tsf as:

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.

The Hillsboro Report which accompanies the Hillsboro Quadrangle Geologic Map (Map) has an extensive description of the Santa Fe Group: "The Santa Fe Group (Tsf) in the study area is likely correlative to the Hayner Ranch Formation, the lowermost unit of the Santa Fe Group in the Palomas and Rincon basins to the east and southeast, respectively. Although the upper Miocene-lower Pliocene Rincon Valley Formation is known to contain basin-margin fanglomerates (Hawley et al., 1969; Seager et al., 1971), we suggest that the Santa Fe Group gravels exposed in the Hillsboro quadrangle were deposited in an early rift basin (i.e. the Animas graben) bound by the Berrenda fault. This fault offsets Eocene volcanic and volcaniclastic rocks in the region, and would have generated sufficient accommodation space for early rift-margin alluvial fan deposits."

In the photograph directly below, Tsf is in the foreground and Kab above. The photograph was taken east of Warm Springs and northwest of the Rattlesnake placers in Study Area 3, from UTM 260522.44 E by 3647361.02 N.

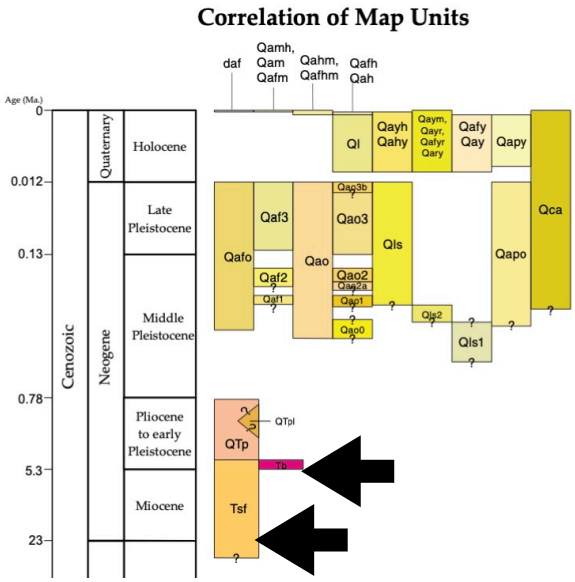




The detail of the upper left of the Geologic Map (above) shows how dominant the Santa Fe Group can be as a land form in much of the quadrangle.

The report notes: "The most common lithologies of the Santa Fe Group in the Hillsboro quadrangle are pebbly sand/sandstone beds and pebble-cobble gravel/ conglomerate. The matrix-supported, typically massive nature of these beds suggests proximal deposition on large alluvial fans emanating from the west. Deposition was mostly via debris flows, but occasional cross-stratified beds with lenticular bodies of pebble-cobble gravel represent local inter- or extra-channel deposits. Paleocurrent determined from clast imbrication is generally eastward in older Santa Fe Group beds, but may be toward the south in younger beds. This shift could be due to drainage reorganization in coalescing fans, or alternatively, a response to faulting and attendant drainage capture on the Berrenda fault zone, temporarily focusing flow into the subsiding Animas graben. The Santa Fe Group is generally finer-grained in

the eastern part of the Hillsboro quadrangle, representing a transition to medial fan facies, and commonly silicified in and around fault zones. Although only ~200 m of Santa Fe Group gravels are exposed at the surface, the eastern boundary of the Animas graben along Copper Flat may preserve a thickness of up to ~500 m."



The Santa Fe group is the only Miocene era rock in the Map area, and the unit spans the entire Miocene. The Miocene is the fourth epoch of the Tertiary Period and dates from 23 million to 5.33 million years before present. "Things" were beginning to look more like today than they had ever before (to paraphrase Eisenhower).

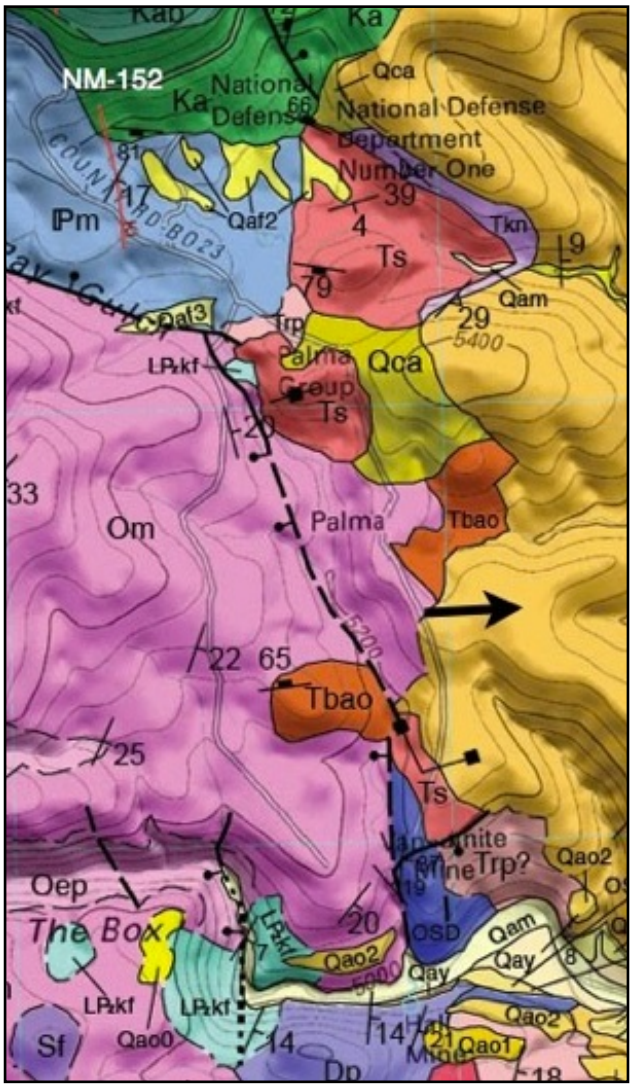
During the Miocene, New Mexico (in general) was home to four-tusked "elephants", giant beavers, three toed horses, and rhinoceroses.

The Santa Fe group is found throughout the Black Range (being especially prevalent around Winston, for instance).

The photograph below was taken in Study Area Four, at the location of the arrow on the Map detail to the right. The Tsf unit is in the foreground and takes up most of the photograph.



The fossils of an elephant-like creature, *Gomphotherium obscurum*, have been discovered from the Miocene in New Mexico. The first fossil record of this species dates from 23 million years ago (13 mya in some sources) and



the last fossil record dates from 4.9 mya, placing this species firmly in the Miocene. It is the four-tusked elephant referred to above.

TB - BASALT FLOWS FROM THE LOWER PLIOCENE

The Tb geologic unit (see description from the Map below) is one of the easiest to observe in the area of the Hillsboro Quadrangle. That is due, in part, to the fact that it is a fairly young geologic unit, dating from the Lower Pliocene, or about 4.2 million years ago. The photograph at the top of the next page is of Tb cap rock east of the Warm Springs Wash.

The map describes the Tb unit as:

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.

The report which accompanies the Map notes (p. 22) that: "Pliocene basalt (Tb) is found at several locations in the Hillsboro quadrangle, and several other mesa-capping flows are postulated to be Pliocene in age based on their landscape position and mineralogic character. In Warm Springs Canyon, a basalt flow overlying undeformed gravels of the Palomas Formation and slightly tilted Santa Fe Group fanglomerate was dated by

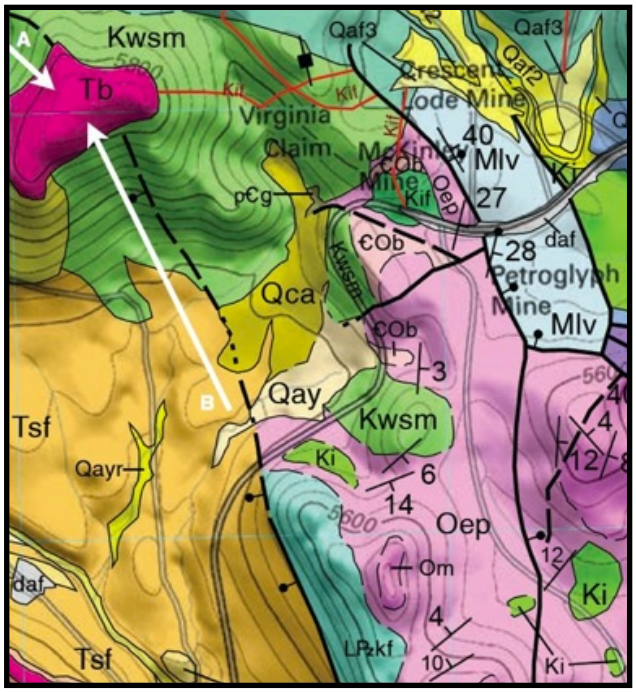


Seager and others (1984) at ~4.2 Ma (Table 1). They also dated basalt flows just east of the quadrangle at ~4.5 Ma; these flows were presumably sourced from the Vulcan vent found in the northeast corner of the quadrangle. Red cinder deposits at the base of the basalt flow on Black Peak are ~1 m thick on the south side of the exposure and 10 m thick on the north side, suggesting a local vent and lava that flowed toward the northeast, filling a paleovalley with a floor that is only 24 m above modern stream grade".

The map detail at the right indicates the direction from which the photographs were taken of this Tb formation. The image above was taken from angle "A", image at the top left of the next page from angle "B".

The photograph at the bottom of the next page was taken at the summit of the hill (Tb unit shown to the right). The rock below is Tb basalt.



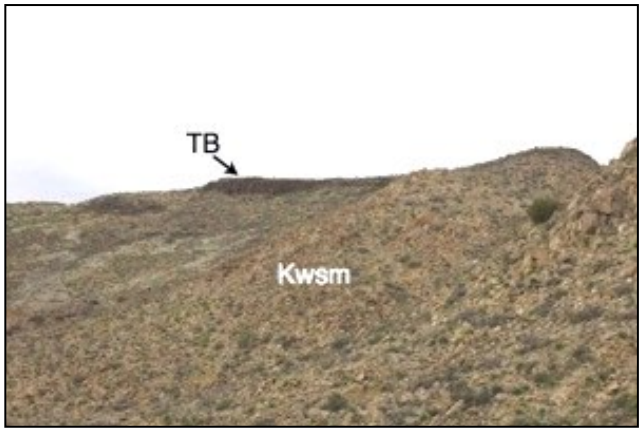


THE HILLSBORO QUADRANGLE: THE REST

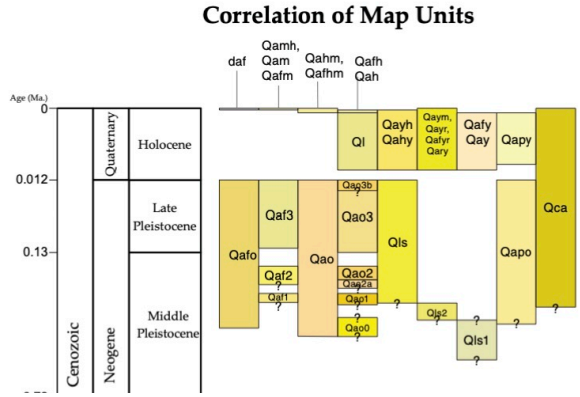
I will make no attempt to describe the geologic history which occurred within the area of the Hillsboro Quadrangle during the last million years, instead deferring to the Hillsboro Quadrangle Geologic Report section on this period (see below). Suffice to say that it was mostly a period of alluvial depositions of various scales and types.

As I wrap up this discussion of the geologic units found within the Hillsboro Quadrangle, it might be a good time to summarize what I have learned about the process.





Not the geology, the process. First of all, all of those "Q" deposits make it difficult to discern differences in the landscape and thus distinguish between the various geologic units. In a real sense the geology of this area is readily apparent on a grand scale - capstones along ridges, the flows of molten rock associated with the Copper Flat area, and some of the major faults. Secondly, the history of this area (especially the mining history) is told in the geology. To know the mining history of this area, know the geology first, and all of those holes in the ground will begin to make sense. And thirdly, the approach I used in this work was useful, but perhaps not the most useful of approaches. I am still working out the details of this last point in my mind. I have ideas about how to tell the story better, but for the most part they are beyond my technical expertise to accomplish, both in the substance of the story and in the method of telling the story. This is aggravated by the fact that much of what that history is, especially in detail rather than general statement, is not known or is suspected only from various geologic models.







Geologists, and geologic maps, distinguish large areas of human created change as Daf - like the "unit" shown above.

With that we end our survey of the geology of the Hillsboro Quadrangle. It goes without saying that this effort would not have been possible had it not been for the previous efforts of the individuals involved in creating the Geologic Map and Geologic Report referenced repeatedly above.

THE HILLSBORO MINING DISTRICT

Knowledge of the mining activity in an area can be very useful in working out the geology, and vice versa.

OVERVIEW

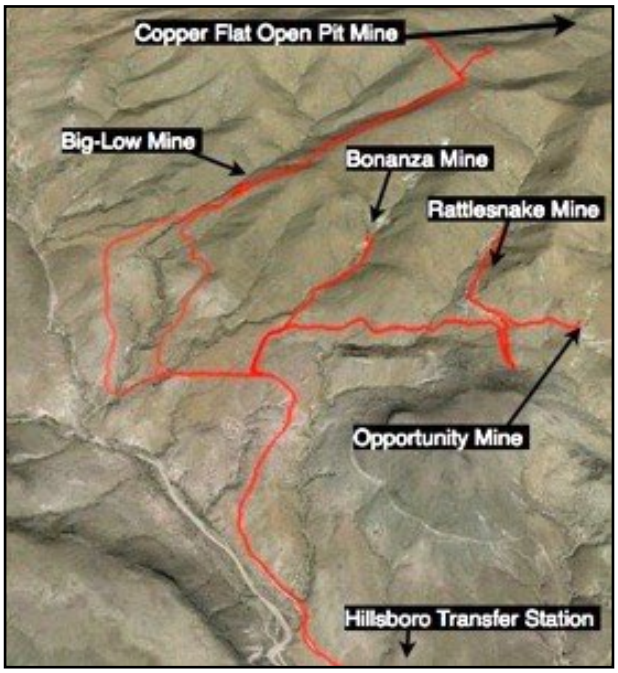
As part of the effort to understand the mining and the geology of this area, we have recorded several mine videos. They may be viewed here:

- Mines of the Hillsboro Mining District - Volume 1 (includes the Bonanza, Rattlesnake, Big-Low, and Opportunity;
- Mines of the Hillsboro Mining District - Volume 2 (includes the Big-Low and Garfield/Butler Group of Mines);
- Mines of the Hillsboro Mining District - Volume 3 (includes the Garfield/Butler Group and the Wicks Mine Shaft);
- A Trip to Andrews (Mines of the Hillsboro Mining District - Volume 4);
- The Bonanza Mine;
- The Garfield, Butler and Jackpot Mines;
- The Bigelow Mine;
- Wick's Mine;
- Mines of Upper Ready Pay Gulch;
- The Stowaway and McKinley Mines;
- The Rattlesnake and Opportunity Mines;
- Mines at Andrews; and
- Mining the Black Range.

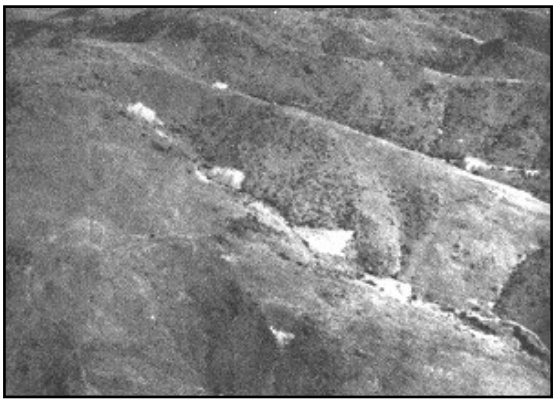
Mine names were fluid in the Hillsboro Mining District. Sometimes the names changed because of an ownership change. Sometimes they changed because of a misunderstanding of what the name meant. For instance, the Big-Low is also known as the Bigelow and the Big-Lo. (The name is apparently a hyphenation of the first part of the original owners' names, so Big-Low is most likely the correct name.) The Rattlesnake is also known as the Snake Mine but may also be referred to by the major shafts of the mine, the Bobtail and Eureka.

Some mines were small claims worked by one person, others were major operations with substantial infra-structure. The workings were mostly under the ground. The Bonanza had three tunnels; the lengths of two are known. One was 3,500' long and another was 2,000' long. The nature of the veins that the miners followed varied, sometimes significantly within the same tunnel. For instance, in one of the Bonanza tunnels the vein was a fracture zone 2-8' wide in one spot and a shear zone 80' wide in another. The nature of the mineralization varied within a tunnel as well.

And they were close together. For instance, *The Geology and Ore Deposits of Sierra County, New Mexico, Bulletin 10* (by George Townsend Harley) describes the location of the Bonanza as "in the arroyo east of the



Garfield-Butler and Bigelow groups and west of the arroyo in which the Rattlesnake vein is located" (p. 148). These mines are a short walk apart. An aerial view of the Bonanza (below) prior to 1934; seen just over the ridge to the upper right (in the next wash) is the Rattlesnake.



And there was money to be made, sometimes. An indication of how things were going at a mine was the building of a mill on site to process the ore. A mill was constructed at the Bonanza in 1904, initially with 10 stamps - later increased to 20. In 1932 the mill was remodeled. The cost of the remodeled mill was between $25,000 and $30,000 (1932 dollars). It is fairly easy to adjust monetary value from 1932 to present using inflation as an adjustment. The remodel would have cost roughly a half a million dollars (based on an initial figure of $30,000) if built today. Maybe; this type of adjustment does not take into consideration the differences between 1932 and the present in wages, building practices, availability of material, all sorts of things. Costs associated with environmental and worker protection were virtually non-existent at that time.



W. H. Bucher, who was the vice-president of the Sierra County Bank in Hillsboro, which handled the ore shipments from the Bonanza, said the value of those shipments was in the range of $700,000. The source document I am working from does not define "dollars" in this case. All sorts of games get played with valuation, often centered around the definition of dollar. For instance, $700,000 does not sound like that much when we look at it as "current dollars" but it represents a substantial sum for production between 1877 and 1931. We can say that with certainty. But what were the economics? Some of it is easy to figure out. Beyond that, it gets a bit more complicated and subject to all sorts of bias. Simply applying inflationary adjustments to that figure does not produce the value of the production in "current dollars". Variability in the production distribution (what was produced year to year) will result in different "current dollar" figures. The price of gold was fixed for all of the production period. It is now driven by market demand, not by a fixed rate or by inherent value (value created by use). Today, the price of gold is driven primarily by the assumption that it is valuable, by perception. So how do you go about determining how rich the mining was in Hillsboro? Pick from the menu of valuation techniques and someone will be able to tear your assumptions and analysis apart. I'm not going there. Mining in Hillsboro was enough to form the economic basis of a small town in the outback of New Mexico, that is clear, and it was enough to generate small fortunes of investment from people "back east".

What was all that wealth buying? If you were a miner, not a mine owner, it wasn't buying you much. Your wages were small, the hours were long, and the work was dangerous. If you were a miner, at least in the early days, you were most likely Mexican or Chinese, because you worked for smaller wages. It was a life, but for many it was a very hard life.

Signs of danger are everywhere. Cave-ins occurred with some frequency. For instance, the tunnel at the Bonanza Mine caved in about a hundred feet from the entrance, opening a way to the surface (photo center right). Loose rock is held in place by bolts and wire, some of which have eroded out (see the photo at the top of the Eureka Tunnel [adit]). Rock fall, short of cave-ins, was a frequent cause of death in mines.



Mines and shafts are dangerous places. You should not approach or enter them.

As we continue to fill out the mining section of the Black Range website we hope to tell the story of individual mines, of individual miners, of individual investors. The Tales of Lake Valley is a start in that direction. And there is a wealth of other information in stories like "Played Out in Minneapolis: The Rise? and Fall? of a Hillsboro Mining Venture" by Mark B. Thompson, III from Volume 7, No. 1 of *Guajalotes, Zopilotes, y Paisanos,* a story about investors. Joe Diel's survey of claims in the Hillsboro area at "Hillsboro and Las Animas Mining Districts", from Vol. 6, No. 4 of *Guajalotes, Zopilotes, y Paisanos* is very informative. And our interview with Federico Antonio Chavez Luna, who was born in Hillsboro in 1919 and worked at the Bigelow mine in the 1930s, is full of local color.

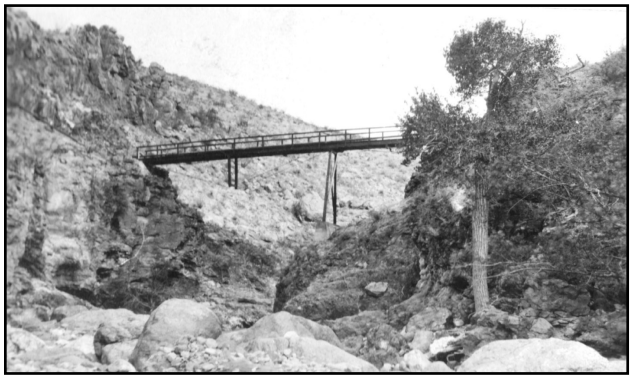
WATER

And what made everything tick? Water. Sometimes there was too much. Journals and newspapers of the late 1800s and early 1900s are full of "dewatering" stories.

Sometimes there was too little. Real mining efforts and mine scams both had to prove they had access to water to be successful.



Above: Water pipe fitting found east of Hillsboro - Photograph taken on April 15, 2015. It may have been associated with the water pipe bridge built in about 1900, pictured below.



Not all of the mining that was done in the Hillsboro Mining District was of the hard rock variety (shafts and adits dug into the earth). There was a significant amount of placer and dredge work which was done east of Hillsboro. To be very effective, such mining requires significant amounts of water. The New Mexico Directory and Gazetteer (1882) (referred to below as "The Gazetteer") contains the following description of the water situation on page 54:

HILLSBORO.—In this district are located the most extensive placer deposits found in the southern part of the Territory. For some time great difficulty was experienced in working them on account of the scarcity of water, but this draw back has been removed by a pipe line, by which is brought an inexhaustible supply from Percha Creek, nine miles distant. Besides the placers found at Hillsboro, a number of gold quartz and galena leads have been discovered, many of which are being extensively worked.

The Hillsboro Hydraulic Mining Company and the Dona Ana Mining Company —two strong corporations—are doing much towards developing the resources of the district.

The property of the Hillsboro Mining Company consists of 300 placer claims, all of which yield two dollars in gold to the yard from the surface. The company is now building a reservoir on the north branch of Percha creek of a capacity of 7,000,000,000 gallons of water, and laying pipe from the reservoir to the claims, a distance of nine miles. It became necessary in laying the pipe to run a tunnel through a hill 1,500 feet, which tunnel is now completed. The stock of this company cannot be bought, although offers have been made for shares far above the par value of the same. Mr. Fuller, the superintendent of the company, is a gentleman thoroughly acquainted in placer mining.

The property of the Dona Ana Mining Company consists of four mines and a ten-stamp mill, located about one mile north of Hillsboro, in Cold Spring gulch. The company's mines all show large veins of gold quartz. There is an abundance of high grade ores on the dumps awaiting reduction.

The Snake mine, recently purchased by the Dona Ana Company, is now down over one hundred feet and shows up six feet of mineral which it is thought will mill run well. Besides this, contracts have been let on several other claims, all of which are claimed as good leads. The men in charge of the work seem to have taken hold of it in the right way and will work to get out all there is there.

The above companies are employing about two hundred and fifty men, and with private claims now being worked, there is afforded steady employment for about three hundred men in this camp.

The "water problem" was purported to be solved in this case by running a nine-mile pipeline from North Percha Creek where a reservoir capable of impounding seven billion (7,000,000,000) gallons of water was being built. The pipeline was to run through a tunnel 1,500' long in its transit to the mining operations. (See the March 2, 1883 edition of the Black Range newspaper for more information.)

G. M. Fuller, the Superintendent of the Hillsboro Hydraulic Mining Company, reported the condition of six miles of pipe (8", 9", and 12") on March 8, 1885, and noted that "It is contemplated by this company to extend the pipe line some six miles this coming season..." He further noted that during the fall of 1884 "our reservoir broke loose and it became necessary to relay over a mile of the twelve-inch pipe." (Reference: Facts About Pipe, by Edmund Cogswell Converse, National Tube Works, 3rd Ed., 1895, p. 62)

"Dry-Land Gold-Saving Machines" from the Hillsboro Placer Mining District, are pictured on the next page (from "*The Geology and Ore Deposits of Sierra County, New Mexico*" by George T. Harley, NM State Bureau of Mines and Mineral Resources, Plate IX, found between pages 166 and 167). In the bottom photograph, a row of rock mounds extends off to the right (material which has been dredged and processed), still a common sight in areas around Hillsboro.

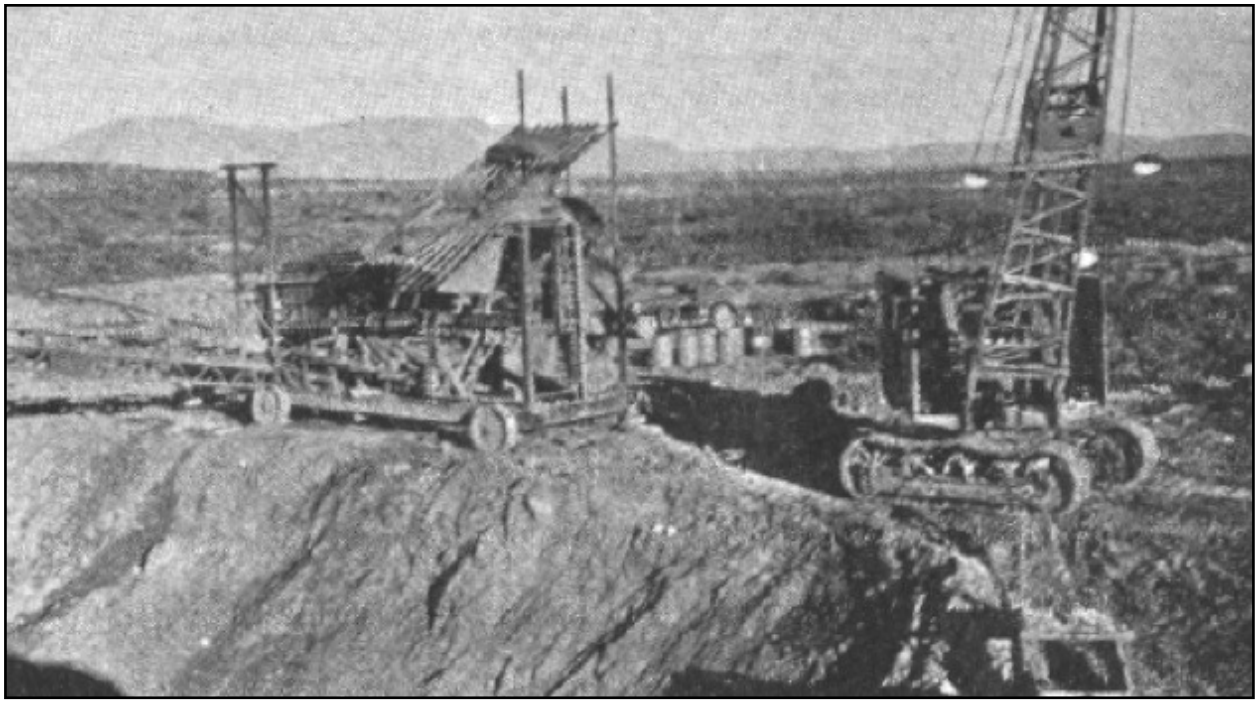
Harley (see above) reported that the Animas Consolidated Mines Company supplied its operations from one well which produced 23 gallons a minute and that the Placer Syndicate Mining Company had constructed a 4,000,000 gallon reservoir between Dutch and Grayback Gulches (p. 168). He goes on to say that "The water supply in this district is a serious problem, as wells to a depth of 85 feet are pumping less than 100 gallons of water per minute, and it is questionable if a large underground supply is available. The water in the Rio Percha is said to be available in part, but its utilization would involve pumping against a 600-foot head for a distance of over 4 miles."

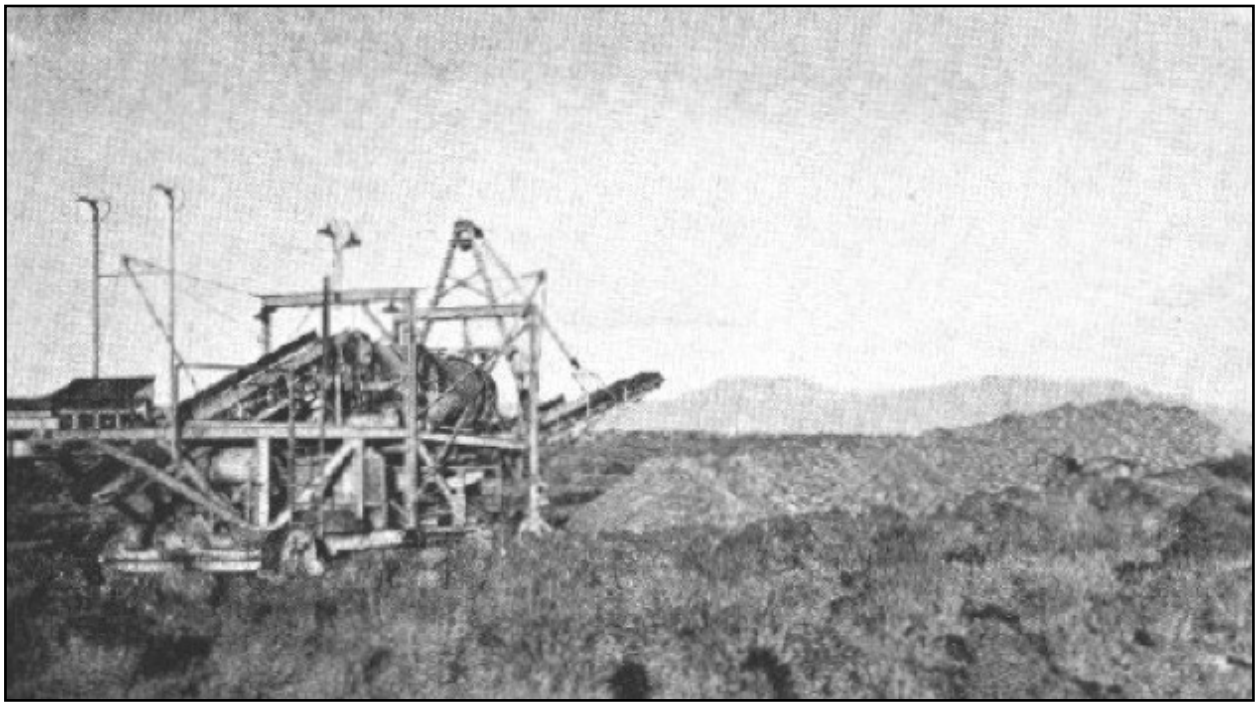
On October 21, 1892, Ellis Clark, General Manager of The Silver Mining Company of Lake Valley, reported that the pipe at their leaching mill "has given perfect satisfaction". (Reference: Facts About Pipe, by Edmund Cogswell Converse, National Tube Works, 3rd Ed., 1895, p. 67)

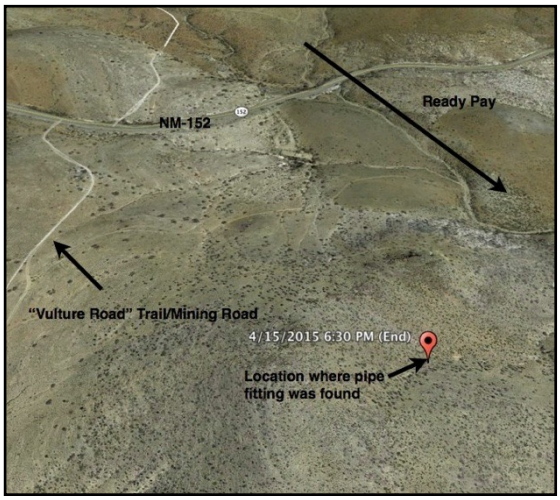
When the mines gave out, the pipe was not necessarily abandoned. Converse reports that "an hydraulic mining company in New Mexico that had several miles of Converse Joint Pipe in use; the mines giving out, the pipe was taken up, after having done seven or eight years' service, and resold at prices which netted about 80 per cent of the original cost." (Reference: Facts About Pipe, by Edmund Cogswell Converse, National Tube Works, 3rd Ed., 1895, p. 435) Although the hydraulic mining company is not named, the facts match well with the Hillsboro operations and may explain why so little evidence exists of their use/presence.

It is likely that mining operations ran pipelines to any number of mines. Evidence is scarce and often circumstantial. For instance, the pipe fitting shown at the top of this page was found at the location shown at the bottom of the following page, in a wash running down the side of a good sized hill. What was it doing there? It is unlikely that this fitting is part of a pipeline to the placer operations, more likely it was to a shaft or adit mine, but which.... when.... why....

The employment level of these operations, estimated at about 300, is generally consistent with the estimate for Doña Ana County. The Gazetteer estimated that at that time "from fifteen hundred to two thousand reside in the mountains and on the plains engaged in agricultural







pursuits, stock-raising, and mining" throughout the county (p. 46), further, that the "census of 1880 gives Doña Ana county a population of 7,612. The present population of the county is about 10,000; of these over 8,000 are native born and speak the Spanish language." (And that the "majority of the prisoners…in jail…are English speaking persons who are not natives of the Territory.")

At page 57, the Gazetteer notes:

HILLSBOROUGH.—The town of Hillsborough derives its importance chiefly from the mines in the vicinity. The population is now about five hundred, mainly American, and is being rapidly swelled by miners and prospectors. There are several business houses located here which do a large trade with the surrounding camps, among the most important of which are, Perrault & Galles and S. M. Blun. As soon as the stamp mill of the Dona Ana Mining Company is started up the ore now on the dumps can be reduced to bullion, and this will do much towards building up the town. Hillsborough will always be a place of some note among the mining centers of the county.

Water made the placer operations much more efficient, and the companies which ran those operations went to extraordinary lengths to assure water was available. However, there is little current evidence of this part of our mining history.

The Role of Water in the Rattlesnake and Opportunity Mine Groups

"Moody's Manual of Railroads and Corporation Securities" (1906) describes the Rattlesnake and Opportunity Mine operations of the Sierra Consolidated Gold Mining Company. It notes: "The company is proceeding with development work, and purposes erecting a stamp mill and plant in connection with the Rattlesnake Group, capable of treating 200 tons of ore daily, and a pumping plant of sufficient capacity to furnish water to treat at least 500 tons of ore daily." The company's prospectus (p. 5) notes that "It will also erect a pumping plant at the source of water supply which it owns and lay a pipe line of sufficient capacity to furnish water to treat at least 500 tons of ore daily."

Sierra Consolidated was incorporated in West Virginia on December 1, 1902 (for a term of 50 years) with a place of business listed as Hillsboro and a capitalization of $3,000,000. When the term of the corporation expired, the state of New Mexico simply listed it as delinquent - along with page after page of mining and milling companies of that era. In The Ore Deposits of New Mexico, Waldemar Lindgren et al. note that "The Snake Mine, once actively worked but idle for many years, became the property of the Sierra Consolidated Gold Mine Company, which began operations on it in 1906, but soon closed down." (Professional Paper 68 of the United States Geological Survey, Washington, 1910, p. 210.) Sierra Consolidated acquired the properties from Henry M. Porter of Denver ("Report of the Director of the Mint Upon the Production of the Precious Metals in the United States During the Calendar Year 1902", Washington, GPO, 1903, p. 175.)

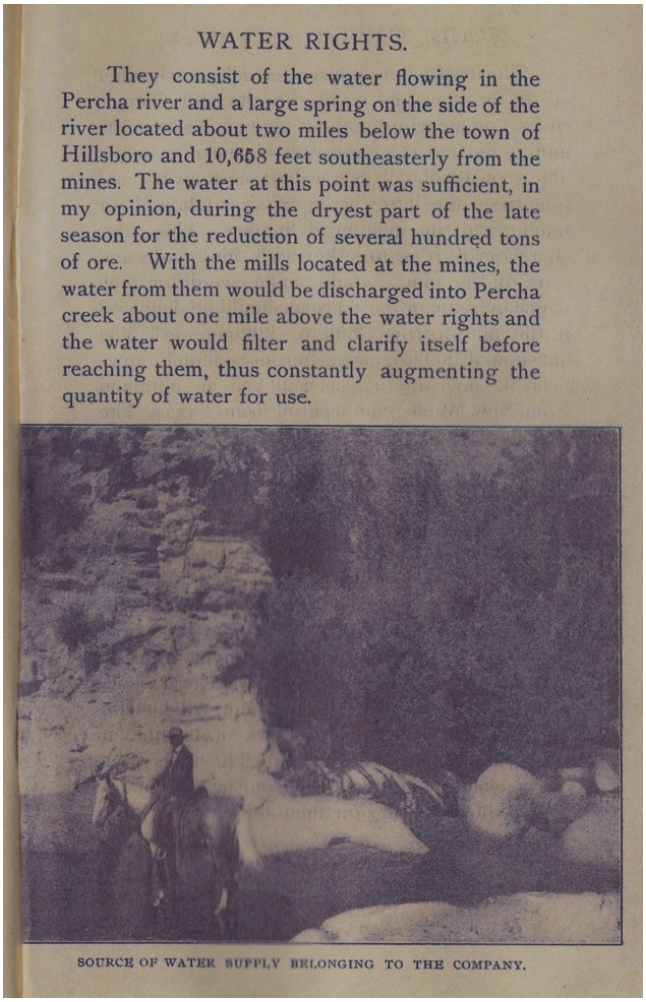
The prospectus of the Sierra Consolidated Gold Mining Company includes a report by a mining engineer named William M. Farish. At page 39 (image upper right) of the prospectus, Mr. Farish discussed where the water needed for the mining operation was to be obtained.

Water was to be pumped (by "a pumping plant") from "Percha River" to the mines. Polluted water was to be returned to the Percha a mile above the pumping plant so that it could "clarify itself" and be re-pumped to the mines. The pollution of the ground water by this process would have been significant.

Farish notes at the end of his report, p. 40 of the prospectus, that "The mines give every evidence of permanency and lasting quality of ore, thus insuring for them long life and prosperity."

The "Report of the Director of the Mint Upon the Production of the Precious Metals in the United States During the Calendar Year 1902", Washington, GPO, 1903, p. 175 states that "The principal gold camp of Sierra County is Hillsboro, in the Las Animas mining district. Both placer and lode gold are mined in considerable quantities at Hillsboro. The Mexican element work the placers, while the lode mining is being done by Americans."

What was happening at the Sierra Consolidated properties during its lifetime? Or more particularly what was being reported? See "Played Out In Minneapolis: The Rise? and Fall? of a Hillsboro Mining Venture" by Mark Thompson in the February 2014 issue of *Guajalotes, Zopilotes, y Paisanos* - Newsletter of the Hillsboro Historical Society, for one possible scenario. Bad business decisions or fraud? Much of the mining money of the west was made from investors responding



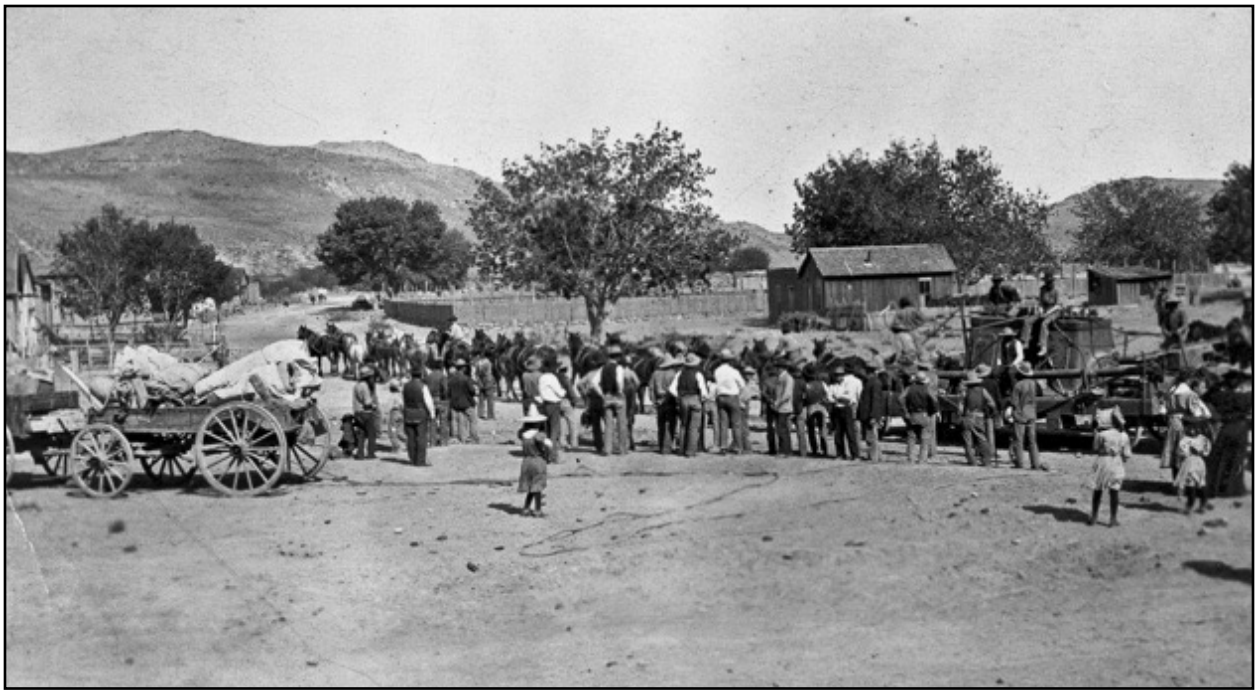
WATER RIGHTS.

They consist of the water flowing in the Percha river and a large spring on the side of the river located about two miles below the town of Hillsboro and 10,658 feet southeasterly from the mines. The water at this point was sufficient, in my opinion, during the dryest part of the late season for the reduction of several hundred tons of ore. With the mills located at the mines, the water from them would be discharged into Percha creek about one mile above the water rights and the water would filter and clarify itself before reaching them, thus constantly augmenting the quantity of water for use.

SOURCE OF WATER SUPPLY BELONGING TO THE COMPANY.

to such a prospectus. Ferreting out the real from the fraud was often very difficult. At roughly the same time that the Sierra Consolidated Gold Mining Company was circulating its prospectus, "the postoffice department lately issued a fraud order against the Hillsboro Consolidated Mines Co., alleging that the company purchased a defunct mine in the Hillsboro camp for $9,950, capitalized the company for $2,000,000 and sold a large amount of stock, the money from which went into the pockets of the promoters rather than into the development of the property." (*The Mining Reporter*, Volume 56, page 411, October 31, 1907.)

At this time Sierra Consolidated was "retimbering the three-compartment shafts on its Snake and Opportunity groups and is making a number of other improvements. A traction line is to be built from Hillsboro to Osceola and a large milling plant is to be erected." (*The Mining Reporter*, Volume 53, page 121, February 1, 1906.) Two weeks later (February 15, 1906, Volume 53, p. 181) *The Mining Reporter* noted that "A traction engine and cars have been delivered at this company's (Sierra Consolidated) property and will be used on the road which will be built either from Lake Valley or Osceola to Hillsboro. The company is preparing to unwater its Snake mine and to erect a hoist on the main shaft of the Opportunity. It is also reported that the company will, as soon as possible, erect a fifty-stamp mill." Three months later *The Mining Reporter* was reporting that "Work on the traction road from Osceola to Hillsboro will commence soon and will probably be concluded before the rainy season sets in." (Volume 53, May 17, 1906, p. 501) A few months later, February 21, 1907, *The Mining Reporter* (Volume 55, p. 192) was reporting that "according to local reports, this district is more active



than it has been in years. The most extensively operating companies are the Sierra Consolidated Gold Mining Co. and the Empire Gold Mining & Milling Co."

The photograph above is provided courtesy of the New Mexico State University Library, Archives and Special Collections Department. It is from the Mildred Elizabeth Fulghum Rea Papers, 1880-1921, Ms0054. Used with permission. It documents the delivery of heavy mining equipment in Hillsboro during this period. Mildred Elizabeth Fulghum Rea described this photograph as: "An Exciting Event in Hillsboro, about 1906 or 1907 I believe. One of the mines near Hillsboro - if I remember right, it was the Snake - purchased some very heavy equipment. It came to Lake Valley by rail, from there was hauled to the mine by a 24 horse team, brought in from outside Sierra County. Shown here passing thru Hillsboro between "Happy Flat" (the lower, Mexican portion) and the upstream (largely "American") part of town. A sad happening as they pulled out of Lake Valley, on the road then existing which went west past the mill and over a steep rise before turning north. Two of their best lead horses were somehow crowded off the road and fell into a shallow shaft just left of the road. They had to be killed."

In the March 26, 1908 issue, p. 328, of *Mining American* (Vol. 57) it is reported that "E. S. Neal, receiver of the Sierra Cons. Gold M. Co., has headquarters at Hillsboro, NM" and that (May 14, 1908, p. 478) "leasers are profitably operating on the Snake and Opportunity Mines, with occasional shipments of high-grade ore." In Vol. 61 (March 3, 1910), p. 213, of *Mining American* it is noted that "The Statehood Mines Co., which took over the late Sierra Consolidated at receiver's sale, will unwater the old workings and rumor has it that shortly after this work is done actual operations on the property are to begin."

***The Engineering and Mining Journal*, Vol. 101, p. 500, March 11, 1916, reported that "John M. Sully and associates, of the Chino Copper Co., have taken an option on the Snake and Opportunity mines. Consideration, $75,000. Force of workmen has been set to work unwatering and retimbering the main shaft. New shaft is being sunk on Snake, from which crosscuts will be extended to tap veins. This mine formerly produced several million dollars in gold and copper." A week later, (March 18) it was reported a "Big Diesel engine being put in shape for operation...hiring skilled labor and engineers...preparatory to beginning unwatering" (ibid. p. 540). And on April 22, "Diesel engine now in operation. Station at 300-ft. level Opportunity mine being retimbered." (ibid. p. 754)**

The Mines Handbook, by Walter Weed, Vol. 14, 1920, p. 1258, reported that the "Sierra Consolidated Mining Co. (is) out of business. Property taken over by Statehood Mines Co., both of which companies were reported into bankruptcy through incompetent management and spectacular get-rich-quick financing. Mine now operated by the Snake and Opportunity Mines Co." and the following about the Snake and Opportunity Mines Co.:

SNAKE AND OPPORTUNITY MINES CO. NEW MEXICO

Address: 50 Broad St., New York City, N. Y. **Mine office:** Hillsboro, N. Mex.

Officers: H. L. Carr, pres.; E. F. Carlson, v. p.; E. L. Kerstetter, sec.-treas.; N. C. Sheridan, mgr.

Inc. June, 1919, in Delaware. **Cap.**, $1,000,000; $1 par; 800,000 shares outstanding. Company is controlled by the Mines Holding and Operating Corporation of New York, through ownership of 450,000 shares of stock together with an option on 200,000 additional shares.

Property: 28 claims, 5 patented, about 400 acres, near Hillsboro, Sierra county, formerly owned by the Sierra Consolidated Mining Co. and later by Statehood Mines Co., both of which companies were reported forced into bankruptcy through incompetent management. Property contains 3 gold bearing fissure veins in andesite.

Development: by 3 shafts, 570', 458' and 240' deep. Company reports 170,000 tons of low grade ore, assaying $5-$10 per ton, broken in the stopes, having been left by former operators as filling.

Equipment: 50-h. p. gasoline hoist, compressor, 100-gal. pump and oil engines.

Reported that property produced over $2,000,000 gross, previous to 1901. Present company expects to ship in 1920.

A history of mining in the American West, seen through the shafts of some Hillsboro mines.

THE MINES AND WHAT THEY MINED

Mines and mining districts are ill defined. Geographic coverage and names have varied over time. In general, the mines listed here are to the east and northeast of the village of Hillsboro, New Mexico.

The following is a listing of the mines of the Hillsboro Mining District, the minerals that were taken from the mines, pages dedicated to specific mines, and links to other material about the mines (e.g. entries in the *Black*

Range newspaper). Many of the mines are covered in greater detail in the *Second Edition of Walks In the Black Range*.

THE MINES

85 MINE - Acanthite, Calcite, Chalcopyrite, and Gold

BARKING FROG - SEE: MACY MINE

BIG CHIEF MINE IN PERCHA CREEK - Calcite, Kentrolite, Quartz, Vanadinite, Wad, and Wulfenite

BIGELOW GROUP (a.k.a. BIG-LO AND BIG LOW)
VIDEO: Mines of the Hillsboro Mining District - Volume One
VIDEO: Mines of the Hillsboro Mining District - Volume Two
VIDEO: Bigelow
Specific information about this Mine is available in the Second Edition of *Walks In the Black Range*. Vol. 1
Bornite, Chalcopyrite, Gold, Lead, Quartz, and Zinc

BLACK PEAK MINE
Specific information about the Black Peak Mine is available in the Second Edition of *Walks In the Black Range*.

BOBBEE DE CLAIM - SEE MACY MINE

BOBTAIL SHAFT - SEE: RATTLESNAKE MINE

BONANZA - Acanthite, Calcite, Chalcocite, Chalcopyrite, Galena, Gold, Limonite, Pyrite, Quartz, and Sphalerite
VIDEO: Mines of the Hillsboro Mining District - Volume One
Specific information about the Bonanza Mine is available in the Second Edition of *Walks In the Black Range*.

BRAEUER GROUP - SEE: FREIDBERG MINE

BUETECKE TUNNEL - SEE: COPPER FLAT

BUTLER - SEE GARFIELD-BUTLER

CABALLERO GROUP - SEE: SHERMAN VEIN/MINE & MCKINLEY MINE

CHANCE MINE (CINA MAHONEY GROUP) - Bornite, Chalcanthite, Chalcocite, Limonite, Pyrite, and Quartz were mined at this site.
Specific information about this mine at The Diggings.

CINA MAHONEY GROUP - SEE: CHANCE MINE

CINCINNATI NO. 1 AND NO. 2 - SEE: NORTH PERCHA MINING CO.

COPPER FLAT (BUETECKE TUNNEL, HOMESTAKE MINE, STERNBERG SHAFT, & TRIPP MINE) - Azurite, Calcite, Chalcocite, Chalcopyrite, Copper, Chalcotrichite, Cuprite, Malachite, Molybdenite, Pyrite, Quartz, and Tenorite
Mine mentioned in the March 23, 1883, issue of the *Black Range* newspaper (The Homestake Claim).

COPPER FLAT CLAIMS - Chalcopyrite, Gold, Pyrite, Quartz, and Tetradymite

EL ORO SHAFT (a.k.a. THE GOLDEN RULE)
Specific information about the El Oro Mine is available in the Second Edition of *Walks In the Black Range*.
Andrews - site of the El Oro Mine.
Photographs from Andrews and the El Oro Mine.
VIDEO: A Trip to Andrews.

EMPIRE MINE

EUREKA SHAFT - SEE: RATTLESNAKE MINE

FREIDBERG MINE OF THE BRAEUER GROUP

FULLERTON PROPERTY - LEWELLYN TUNNEL

GARFIELD-BUTLER GROUP - Azurite, Chalcanthite, Chalcocite, Chalcopyrite, Galena, Goslarite, Limonite, Malachite, Pyrite, Quartz, and Sphalerite.
VIDEO: An Interview With Federico Antonio Chavez Luna
VIDEO: Mines of the Hillsboro Mining District - Volume Two
Covered in greater detail in the Second Edition of *Walks In the Black Range*.



Hall Mine Hillsboro Mining District South side of Percha Box, Sierra County



Eureka Tunnel (Adit) Rattlesnake Mine Complex



Gold from the Bigelow Mine - Mineral Museum - New Mexico Institute of Mining and Technology, Socorro, New Mexico



El Oro Shaft, Andrews.

GOLD DUST PLACERS - Gold

GOLDEN RULE MINE (SEE EL ORO)

GOLD STAR - SEE: READY PAY VEIN/MINE

HALL MINE - Vanadium ores (unspecified) were mined at the site.
Information about the mine on The Diggings.

HILLSBORO HYDRAULIC COMPANY
This company was mentioned in the March 2, 1883 and May 9, 1884 issues of the *Black Range* newspaper.

HOMESTAKE MINE - SEE: COPPER FLAT

J. C. MACY CLAIM - SEE: MACY MINE

JACKPOT MINE
Specific information about the Jackpot Mine is available in the Second Edition of *Walks In the Black Range*.

LEWELLYN TUNNEL - SEE: FULLERTON PROPERTY

LITTLE JEWESS PROPERTY

LUXEMBURG PLACERS - These Gold Placers are east of Copper Flat

MCKINLEY VEIN (AKA CABALLERO MINE OR CABALLERO CLAIMS)
VIDEO: Stowaway and McKinley Mines
Argentite, Calcite, Chalcopyrite, Gold, Copper, Quartz, and Silver
Specific information about the McKinley Mine is available in the Second Edition of *Walks In the Black Range*.

MACY MINE (AKA PERCHA MINE, VANADINITE MINE, J. C. MACY CLAIM, BARKING FROG, BOBBEE DE CLAIM) - Arsenatian, Calcite, Cerussite, Descloizite, Fluorite, Galena, Heulandite, Melanotekite, Mimetite, Quartz, Vanadinite, and Wulfenite
Additional information at: mindat.org

MARY (MAMIE) RICHMOND MINE - Calcite, Chalcopyrite, Galena, Gold, Limonite, Pyrite, and Sphalerite

MINERS DREAM MINE - SEE: PETROGLYPH MINE

MOGUL CLAIM - SEE: SWEETWATER CLAIM

MORNING GLORY MINE - Gold, Copper, and Silver
Information about this mine in Western Mining History.

NATIONAL DEFENSE MINE GROUP (NATIONAL DEFENSE MINES 1-11, TITTMAN MINE GROUP) - Wad

NORTH PERCHA MINING CO. (CINCINNATI NO. 1 AND NO. 2) OLD KELLY
Articles in The Black Range newspaper, issues of August 24, 1883 and May 16, 1884.

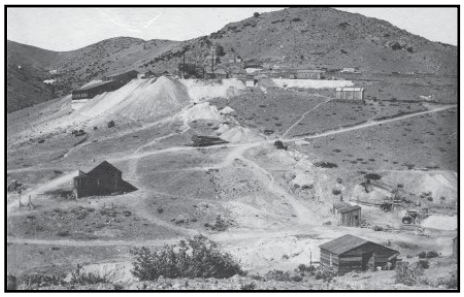
OPPORTUNITY MINE
VIDEO: Mines of the Hillsboro Mining District - Volume One
VIDEO: Rattlesnake and Opportunity Mines
Specific information about the Opportunity Mine is available in the Second Edition of *Walks In the Black Range*.

PALMA GROUP - Calderónite, Pyrolusite, and Wad
Information about this mine at mindat.org.

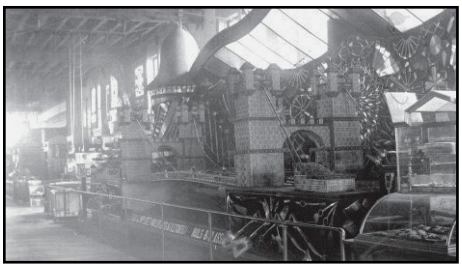
PERCHA MINE - SEE: MACY MINE

PETALUMA GROUP

PETROGLYPH MINE (AKA MINERS DREAM MINE) - Anglesite, Aragonite, Arsenatian, Baryte, Calcite, Cerussite, Descloizite, Goethite, Hemimorphite, Melanotekite, Mimetite, Mottramite, Quartz, Vanadinite, Wad, Willemite, and Wulfenite
Information about the Petroglyph Mine on mindat.org.



Rattlesnake Mine Complex, east of Hillsboro.



Stamp Mill at the Rattlesnake Complex.



Mamie Richmond Mine, NE of Hillsboro ~1890



Smelter site in Hillsboro ~1900.



Macy Mine, Hillsboro Mining District, North side of Percha Box, Sierra County, NM

RATTLESNAKE MINE (AKA SNAKE MINE) - BOBTAIL SHAFT, EUREKA SHAFT, AND SNAKE SHAFT
VIDEO: Mines of the Hillsboro Mining District - Volume One
VIDEO: Rattlesnake and Opportunity Mines
Specific information about these mines is available in the Second Edition of *Walks In the Black Range*.
The Bobtail was mentioned in the March 2, 1883, July 7, 1883, and September 21, 1883 issues of the *Black Range* newspaper.

READY PAY GROUP - SEE: READY PAY VEIN/MINE

READY PAY VEIN/MINE
VIDEO: Mines of Upper Ready Pay Gulch
Argentite, Bornite, Gold, Chalcopyrite, Copper, and Silver.
Specific information about the Ready Pay Mine is available in the Second Edition of *Walks In the Black Range*.

REPUBLIC CLAIM

REX MINE (AKA SMUGGLER MINE) - Arsenatian, Heulandite, Kentrolite, Melanotekite, Mordenite, and Vanadinite.
Information about this mine on the mindat.org site.

SCANDIA - SEE: READY PAY VEIN/MINE

SHERMAN GROUP - SEE: SHERMAN VEIN/MINE

SHERMAN VEIN/MINE - Argentite, Gold, Chalcopyrite, Copper, and Silver.
Specific information about the Sherman Mine is available in the Second Edition of *Walks In the Black Range*.

SMUGGLER MINE - SEE: REX MINE

SNAKE GULCH PLACERS - Gold

SNAKE SHAFT - SEE: RATTLESNAKE MINE

SOUTH PERCHA CLAIM - SEE: SWEETWATER CLAIM

STERNBERG SHAFT - SEE: COPPER FLAT

STONEWALL JACKSON
The Stonewall Jackson was mentioned in the August 31, 1883, issue of the *Black Range* newspaper.

STOWAWAY MINE
VIDEO: Stowaway and McKinley Mines
Specific information about the Stowaway Mine is available in the Second Edition of *Walks In the Black Range*.

SWEETWATER CLAIM (AKA MOGUL CLAIM, SOUTH PERCHA CLAIM)

TRIPP MINE - SEE: COPPER FLAT

TROJAN MINE IN PERCHA CREEK - Cryptomelane.

UNICORN - SEE: READY PAY VEIN/MINE

VANADINITE MINE - SEE: MACY MINE

VIRGINIA LODE - Cerussite, Ilmenite, Vanadinite, and Wulfenite
Specific information about the Virginia Claim is available in the Second Edition of *Walks In the Black Range*.

WARM SPRINGS CANYON - Pseudobrookite.
Information on Warm Springs Canyon at mindat.org.

WICKS GULCH PLACERS - Gold

WICKS VEIN
VIDEO: Wick's Mine
Specific information about the Wick's Mine is available in the Second Edition of *Walks In the Black Range*.

WISCONSIN CLAIM - Chrysocolla

YORK CLAIM - Minium



National Defense Mine Complex, east of Hillsboro.



National Defense Mine Complex, east of Hillsboro.



Palma Mine Group, Lower Ready Pay Gulch, east of Hillsboro



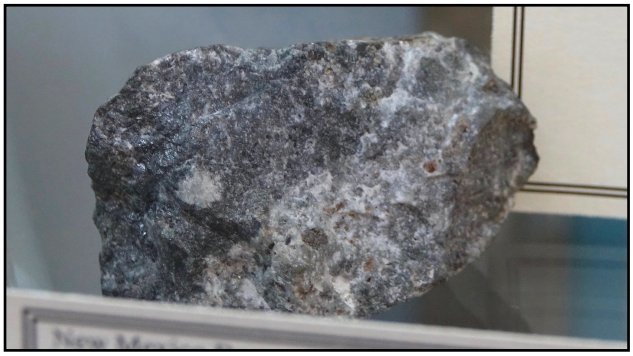
Petroglyph Mine site, east of Hillsboro

ROCKS AND MINERALS

The following specimens were mined in the Black Range, not necessarily within the Hillsboro Mining District or the area of the Hillsboro Quadrangle. Unless otherwise indicated, the specimens are housed at the Mineral Museum on the campus of the New Mexico Institute of Mining and Technology, Socorro, New Mexico.



Amethyst (quartz variety SiO_2) - Royal Castle Claim, Mule Creek, Grant County



Argentite (Ag_2S) - Hillsboro Mining District, Sierra County



Barite ($BaSO_4$) Crystals - From the Day Tunnel of the Pelican Mine, Hermosa Mining District, Sierra County



Biotite ($K(Mg, Fe)_3AlSi_3O_{10}(F, OH)_2$), Chalcopyrite ($CuFeS_2$), Quartz ($CuFeS_2$) - Copper Flat Mine, Hillsboro Mining District Sierra County



Calcite ($CaCo_3$) - Macy Mine, Hillsboro Mining District, Sierra County

If you are prowling around mine sites in the Black Range or walking down washes, calcite, $CaCO_3$, will be one of the most common minerals you will come across.

As minerals go, calcite is a wimp. It is not very hard (3 on the Mohs scale) and it reacts with almost anything acidic. It has a distinctive, perfectly rhombohedral, cleavage. More than 800 different crystal forms have been described for this mineral. Clear specimens will refract light and have a strong double refraction. Its chemical composition shows it to be a carbonate (in Dana, an Anhydrous Normal Carbonate).

Although I often think of calcite as clear or white, that is not always accurate. It can also be pink, red, purple, blue, yellow brown, orange, green, gray, or black.

Calcite will often form coatings on other minerals, as on the vanadinite specimen shown below.



Calcite ($CaCO_3$) on Vanadinite - Hillsboro Mining District, Sierra County

Calcite is found at many mines in the Hillsboro Mining District, including: 85 Mine - Bonanza Mine - Copper Flat (Sternberg Shaft) - Big Chief Mine in Percha Creek - Macy Mine - Mary (Mamie) Richmond Mine - Petroglyph Mine.



Calcite ($CaCO_3$) plus Quartz (SiO_2) - Black Knife Mine, Cuchillo Negro Mining District, Sierra County



Black Knife Mine, Cuchillo Negro Mining District, Sierra County



Chalcopyrite, Biotite, Quartz ($CuFeS_2$) - Copper Flat Mine, Hillsboro Mining District, Sierra County



Bottom of Previous Page: Chlorargyrite (AgCl - Silver Chloride) - Palomas Mine, Hermosa Mining District, Sierra County.

Chlorargyrite is a common silver ore in the Black Range. As a mineral, it was first described in 1875.



Chlorargyrite (AgCl) - Caroline Mine, Lake Valley Mining District, Sierra County



Chlorargyrite & Silver (AgCl & Ag) - Bridal Chamber, Lake Valley Mining District, Sierra County

The specimen shown at the upper right is of roughly the same composition and from the same location as the specimen directly above.

The chlorargyrite (AgCl) specimen shown at center right is also from the Bridal Chamber.

Native copper (Cu), like that from the Copper Flat Mine, Hillsboro Mining District, Sierra County, shown at the bottom right, is truly a thing of beauty.







Copper ore includes minerals like azurite and malachite, something everyone is taught in beginning geology - perhaps because nice specimens of each pop with either blue or green. Both are found here.

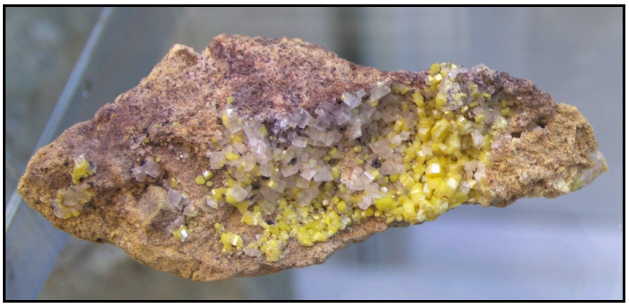
mindat.org has an excellent description of copper the mineral. Copper (as azurite) is shown in the specimen at the top left on the following page, from the Copper Rose Mine, Santa Rita District, Grant County.











Cryptomelane ($K(Mn_4{+}7Mn_3{+})O_{16}$) - Lake Valley Mining District, Sierra County

Specimen at upper right: Cuproskiodowskite ($Cu(UO_2)2(SiO_3OH)_2 \cdot 6H_2O$) - Iron Mountain Mining District, Sierra County

Two specimens at the middle right: Endlichite ($PB_5(VO_4)_3Cl$), is a variety of vanadinite. The middle specimen from the Sierra Grande Mine, Lake Valley Mining District, Sierra County. The lower right specimen from the Macy (Vanadinite) Mine, Hillsboro Mining District, Sierra County.

In Volume 2, Number 4 (October 2019) of this journal we described the discovery of this mineral by Dr. Frederic Miller Endlich who was the Superintendent of the Sierra Mines at Lake Valley when he discovered it. See "To Be Known as a Variety".

Fluorite (See specimens on the next page)

When I think of the minerals of the Black Range, I think of three: gold, silver, and fluorite (a.k.a. fluorspar - a term generally used when the material is an industrial or chemical commodity). The first two I think of as garish and overpriced. The source of needless destruction throughout the world, the symbol of greed and pain, and the source of our tendency to place value on things of only nominal use. The price of gold and silver are purely in the heads of the people who have them or want them. In themselves, they have limited particular value. When civilizations fail and food is short, try buying some wheat with your gold certificate. Driving this point home is the following quote from "*Mineral-Resource Assessment of Luna County, New Mexico*" by McLemore et al., September 2001 - p. 15 "On October 6, 1942, the U.S. War Department closed all gold and silver mines in the U. S. Only base metals and other strategic minerals such as tin, tungsten, manganese, beryllium, fluorite, and iron were mined...war ended...as did the ban on gold and silver mining."

(The latin word, fluere, is the basis for the name fluorite, and means "to flow", a reference to fluorite's use as a flux in smelting.)

Fluorite has utility and a fluorite crystal is a thing of beauty, without the intervention of humankind. CaF2 is its chemical composition, it is one of the halide minerals, and it represents a hardness of 4 on the Mohs scale. It was mined rather extensively along Fluorite Ridge, Pony Hills, in the extreme southwest of "the Black Range". See "Fluorite Ridge" for an extensive discussion about the mineral and its mining in the Fluorite Ridge area.

Both the words fluorescence (coined by George Stokes in 1859) and fluorine are derived from the word fluorite. The element fluorine is very reactive, forming compounds with almost all of the other elements (including some of the "noble gases"). Its crystalline structure is typically either cubic (if formed in neutral solutions at less than 350° C , when the solution is not supersaturated) or as octahedrons (when there is more acidity and saturation, at higher temperatures). Impurities of various kinds can cause other crystal shapes. Fluorite is colorless, but impurities change its hue to many beautiful shades, mostly greens and blues, but also reddish hues.

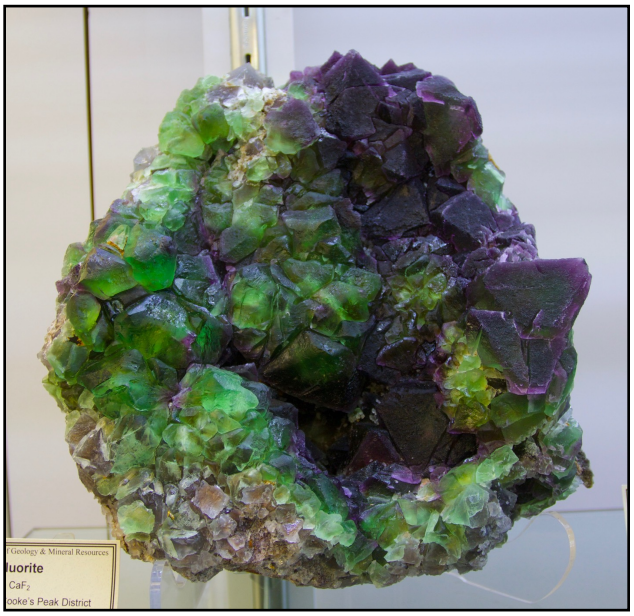
Because fluorite forms in hydrothermal veins, of which there are many in the Black Range, it is fairly common here. It is often associated with calcite, quartz, and galena.

My first experience with fluorite was on a collecting trip as part of a mineralogy course as a sophomore in college. We were digging in a nice vein in southern California when I found a fluorite crystal about half the size of my fist. I gave the crystal to the college but kept the image in my mind.

In the Hillsboro Quadrangle, fluorite was found at the Macy Mine.



Fluorite/Calcite - Fluorite Ridge, Luna County



Fluorite (CaF_2) - From the Surprise #1 Mine, Cooke's Peak Mining District, Sierra County



Fluorite (CaF_2) - From Cooke's Peak, Cooke's Peak Mining District, Sierra County

Following Page

Top Left: Fluorite (CaF_2) - From the Gratten Mine, Cooke's Peak District, Luna County

Bottom Left: Fluorite (CaF_2) - From the Surprise # 1 Mine, Cooke's Peak Mining District, Sierra County

Top Right: Fluorite (CaF_2) - From the Surprise # 1 Mine, Cooke's Peak Mining District, Sierra County

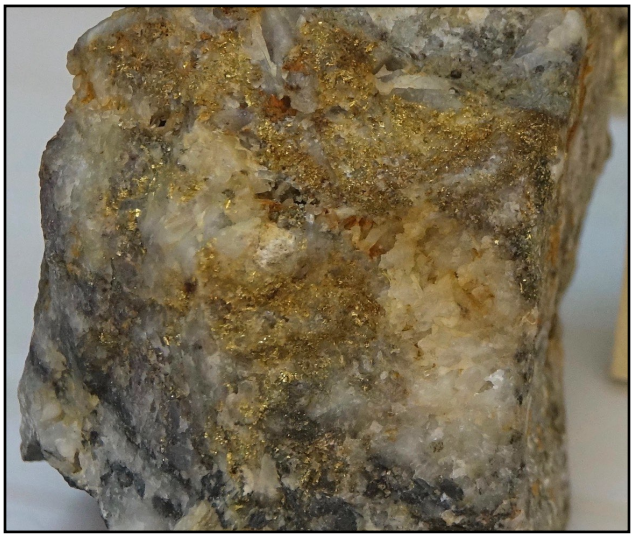
Center Right: Fluorite (CaF_2) - From the Surprise # 1 Mine, Cooke's Peak Mining District, Sierra County











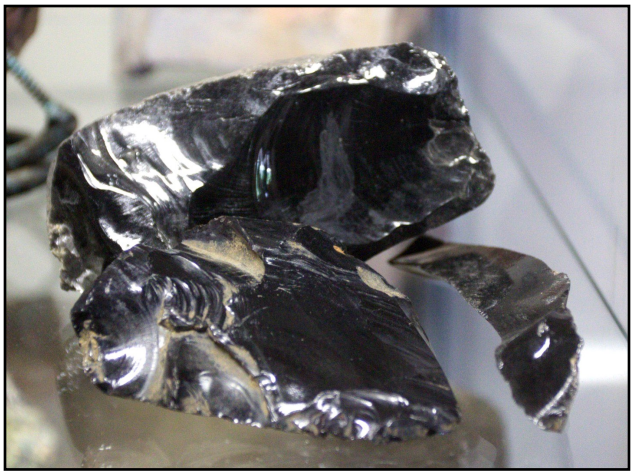
Gold from the Bigelow Mine, Hillsboro Mining District, Sierra County



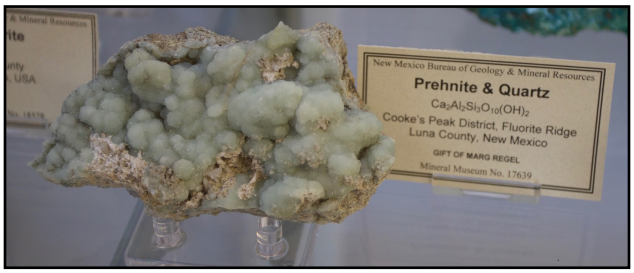
Kentrolite ($Pb_2Mn_3+2(Si_2O_7)O_2$) - From Hillsboro Mining District, Sierra County



Malachite ($Cu_2CO_3(OH)_2$) - Specimen at the Mimbres Cultural Heritage Site, San Lorenzo, NM



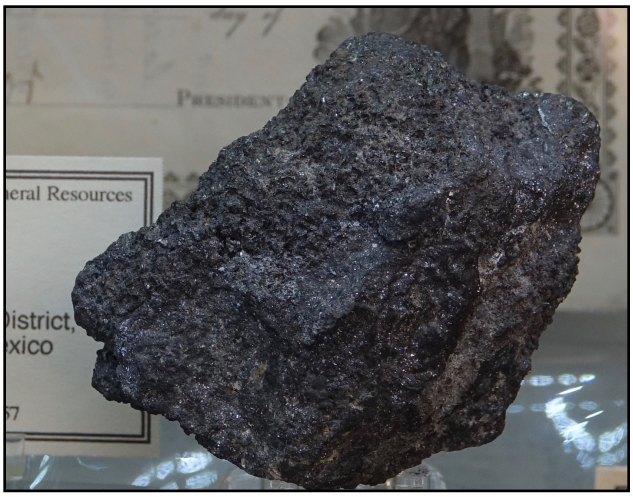
Obsidian - Probably not mined in the Black Range but used by the Mimbres people. Specimen at Mimbres Cultural Heritage Site, San Lorenzo, NM



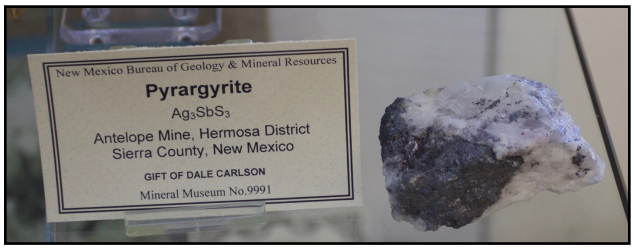
Prehnite & Quartz ($Ca_2Al_2Si_3O_{10}(OH)_2$) - From Cooke's Peak Mining District, Fluorite Ridge, Luna County



Pyrargyrite (Ag_3SbS_3) - Gypsy Mine, Lady Franklin Camp, Kingston Mining District, Sierra County



Pyrargyrite (Ag_3SbS_3) - From the Pelican Mine, Hermosa Mining District, Sierra County



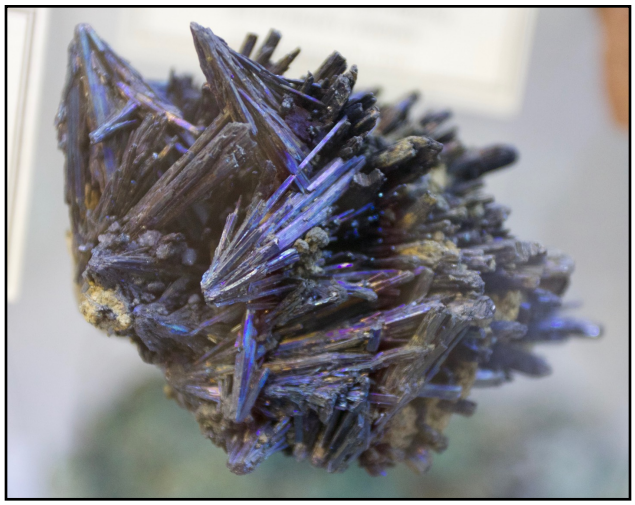
Pyrargyrite (Ag_3SbS_3) - From the Antelope Mine, Hermosa Mining District, Sierra County



Pyrite (FeS_2) - From the Brush Heap Mine, Kingston Mining District, Sierra County



Pyrite (FeS_2) - Specimen at the Mimbres Cultural Heritage Site, San Lorenzo, NM





Pyrolusite

Pyrolusite is a common ore of manganese (manganese dioxide - MnO_2). Crystals of this mineral are rare. It has a hardness of only 2 when in its massive form, otherwise it has a hardness of 6 to 6.5. It has a specific gravity of 4.4 to 5.06.

In the Hillsboro Mining District it was mined at the Palma complex of mines.

Bottom Left and Right Column: Specimens from the Lake Valley Mining District, Sierra County





Pyrolusite (possibly Ramsdellite Mn_4O_2) - Lake Valley Mining District, Sierra County



Quartz (SiO_2) - Sawpit Gulch, Kingston Mining District, Sierra County

Quartz

See other mineral entries for quartz as part of a matrix or some other combination.

Quartz, SiO_2, meant a lot to the miners of the Black Range. Where there was quartz there were likely to be all sorts of goodies: gold, silver, lead.... Quartz is found in many geologic settings and is a component of many rock types (granite, for instance). You may, or may not, know it as κρύσταλλος, the name given it by Theophrastus in about 325 BCE.

Quartz comes in a number of varieties, often with descriptors relating to color created by "impurities". Within a particular variety, there can be a significant color gradient, both in hue and intensity. The amethyst specimen pictured earlier in the specimen listing is an excellent example of quartz color. But when we say a significant color gradient, we mean it, from clear to.... See, for example, the specimen of quartz and calcite on page 81 from the Black Knife Mine of the Cuchillo Negro District in Sierra County. The white material is calcite. There are more variety names given to quartz than to any other mineral. Chalcedony is a variety of quartz but is often treated in "the trade" as if it were a distinct mineral, for instance.

What I often tell beginning birdwatchers is that they should really learn the common birds - really learn them. Then when something different shows up they will recognize it as different from the very beginning - and pay attention. Quartz is like that; learn quartz and you can dispense with a lot of rock. It is a hard rock (Mohs scale of 7) and has a specific gravity of 2.7. With practice you can recognize the specific gravity of a pure specimen quickly.

A partial listing of mines where quartz was found in the Hillsboro Mining District includes Big Chief Mine in Percha Creek, Bonanza Mine, Chance Mine, Copper Flat (Sternberg Shaft), Copper Flat Claims, Garfield Butler Group, Macy Mine, and the Petroglyph Mine.



Silver (Ag) + Chlorargyrite (AgCl) - Bridal Chamber, Lake Valley Mining District, Sierra County



Silver (Ag) - From Palomas Chief Mine, Hermosa Mining District, Sierra County



Silver (Ag) - From the Grey Eagle Mine, Tierra Blanca Mining District, Sierra County



Silver (Ag) - From the Grey Eagle Mine, Tierra Blanca Mining District, Sierra County



Vanadinite $PB_5(VO_4)Cl$ - Hillsboro Mining District

Most people like nice pure samples; with rock that is problematic for three reasons: 1) minerals and rocks are often in a matrix; 2) the particular sample of interest is often mixed in with other minerals (a bit different from the matrix issue); and 3) because these are chemical creatures there may be various impurities (or variations) in the chemical composition of the specimen. I deal with "clines" all the time in studying avian speciation but had never really thought about it from a "rock and mineral" perspective until now.

Vanadinite is in the apatite group of minerals which includes the mineral mimetite. An intermediate mineral type between vanadinite and mimetite is vanadinite var. endlichite (which is shown earlier). Vanadinite contains the vanadate radical VO_4; when it is replaced with an arsenate radical (AsO_4) the mineral is mimetite. Endlichite, $Pb_5([V,As]O_4)_3Cl$, is often considered to be an arsenic-rich form of vanadinite. To make things worse, if the chemical composition includes a phosphate radical $Pb_5(PO_4)_3Cl$, the mineral is pyromorphite.

The Big Chief Mine in Percha Creek, the Macy Mine, the Petroglyph Mine, the Rex Mine, and the Virginia Lode in the Hillsboro Mining District were all sources of vanadinite.

Following Page- Top Left: This vanadinite $PB_5(VO_4)Cl$ specimen came from the Petroglyph Mine in the Hillsboro Mining District.

Following Page - Center Left: Wad. To quote Wikipedia - "Wad is an old mining term for any black manganese oxide or hydroxide mineral-rich rock in the oxidized zone of various ore deposits. Typically closely associated with various iron oxides. Specific mineral varieties include pyrolusite, lithiophorite, nsutite, takanelite and vernadite." This specimen is from the National Defense Mine complex in the Hillsboro Mining District.







Wulfenite ($PbMoO_4$)

Wulfenite is a lead molybdate mineral which is often found in granular masses. If you are a chemistry buff, it is the "molybdate" description which will raise your interest. Molybdenum is a very flexible element and oxidizes in several different forms. In fact it is not found in a pure state naturally on Earth but rather is always found in one of its oxidized forms.

In my entry on vanadinite I referred to the "clinal" nature of many chemical compositions. The term in mineralogy is "series". As in "Wulfenite forms a series with the rarer mineral stolzite, which contains tungsten in place of the molybdenum."

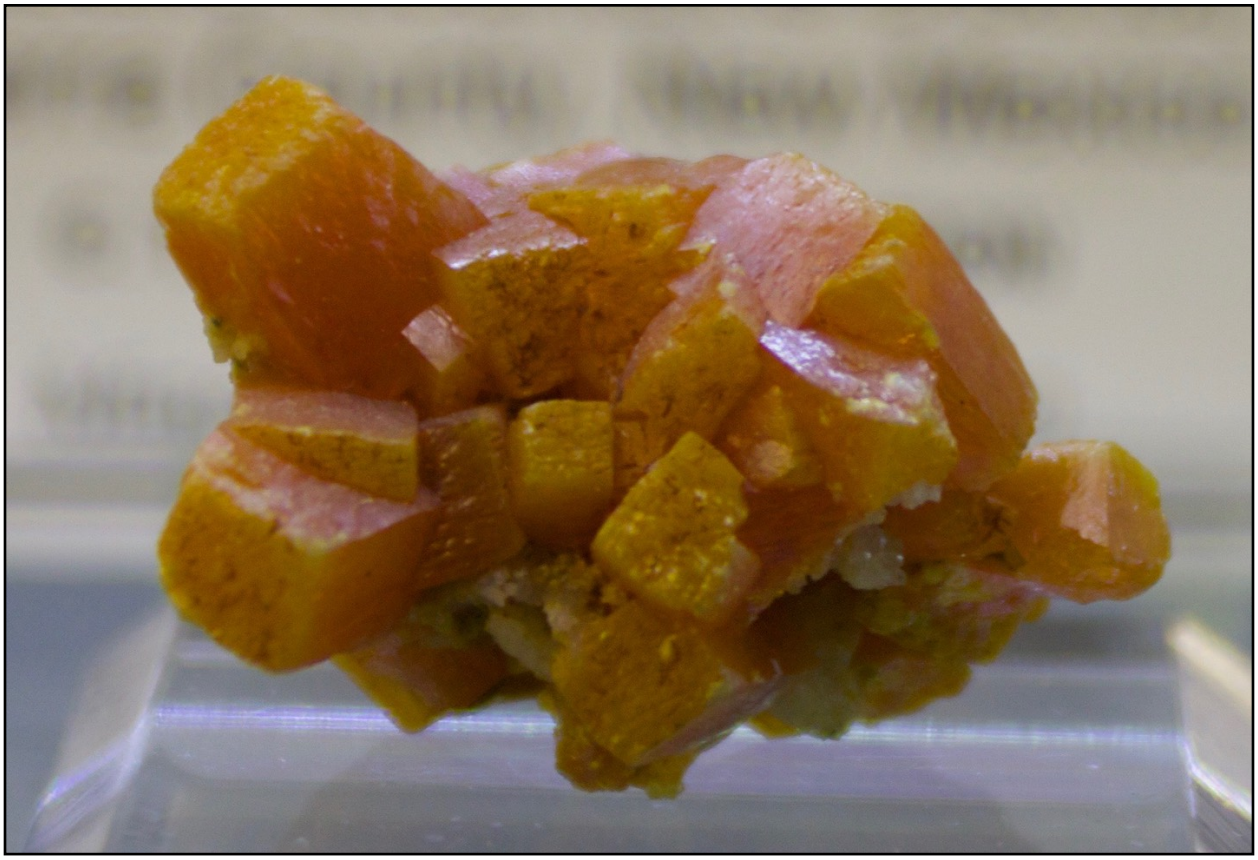
The wulfenite specimen shown at the lower left is from the Petroglyph Mine, Hillsboro Mining District. It is prized because of its beautiful crystal structure. It is only a minor ore of lead and molybdenum.

Many minerals were not named until the 1700s and 1800s. Wulfenite received its current name in 1845, for instance. (Its original name - given in 1772 - was "plumbum spatosum flavo-rubrum ex Annaberg, Austria".

In the Hillsboro Mining District, wulfenite was found at the Big Chief Mine in Percha Creek, at the Macy Mine, the Petroglyph Mine, and at the Virginia Lode.



Wulfenite ($PbMoO_4$) - Macy (Vanadinite) Mine, Hillsboro Mining District, Sierra County



Wulfenite ($PbMoO_4$) - Sierra County

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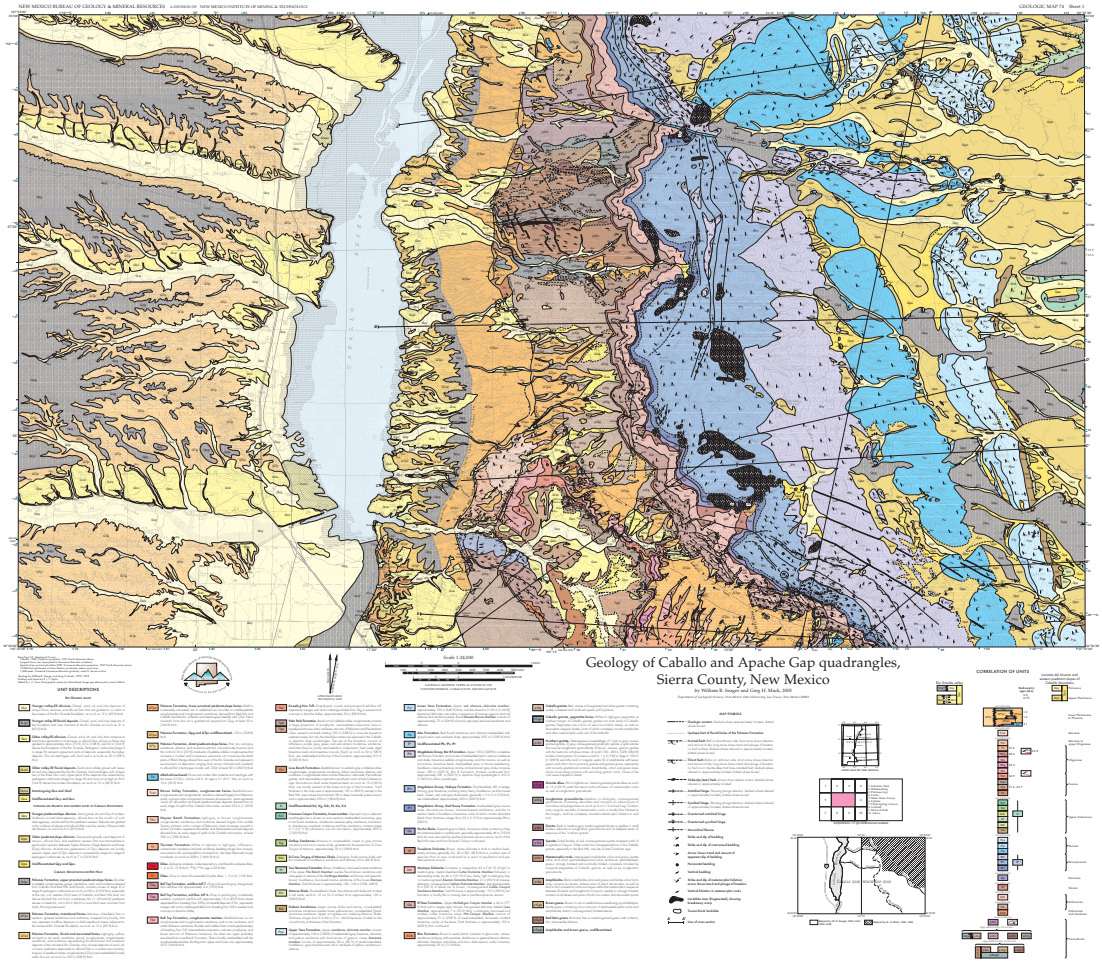
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Second Edition
The Odonata of Doña Ana County and the Black Range
Volume Two - Damselflies

The Black Range Website published this volume at the beginning of September 2025. It is available as a free download in two file sizes:

Compressed (52 MB)
Uncompressed (350 MB)

This volume and Volume One are also available at the Odonata page on the Black Range Website.

The Native Plant Society of New Mexico's annual conference will be held in Las Cruces.

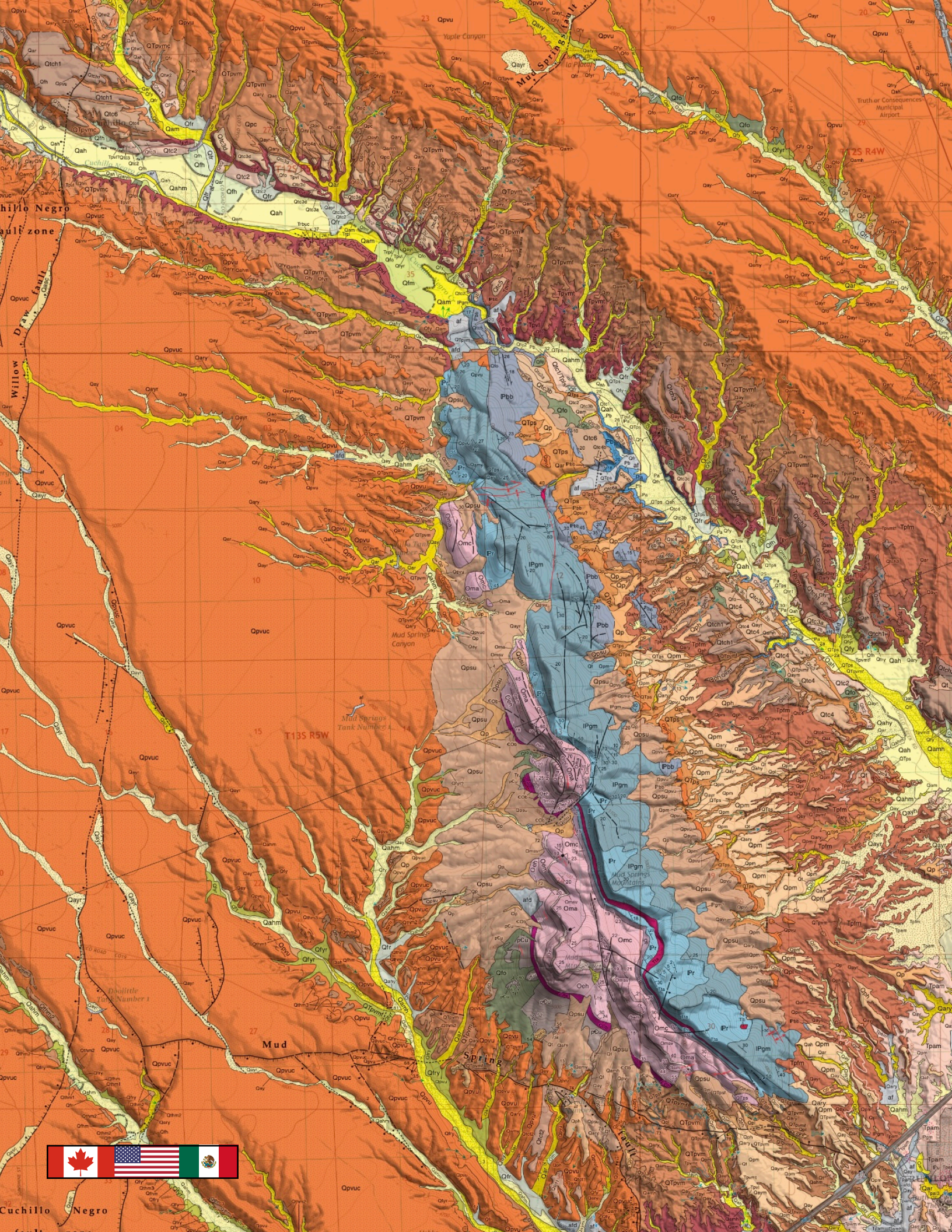
October 2-5, 2025

Follow this link for details.

Erratum: Volume 8, Number 3, Page 47 - The images at the the bottom left and in the right column (and the narrative which refers to them as Penstemon barbatus torreyi) is incorrect. These images and the bit of narrative which refers to them are Penstemon lanceolatus (ramosus). Good news for us because it expands the date range (17 May 2020 and August 2021) for this uncommon species in our area. Bad news for the editor who apologizes. Many thanks to Elliot Gordon who spotted the error.

Contact the Editor: Bob Barnes
(rabarnes@blackrange.org) or
Associate Editor Emeritus - Harley Shaw
Copy and Associate Editor - Rebecca Hallgarth
The Black Range Naturalist is a
"Not For Revenue" Journal
Previous issues are available for download at this link
(www.blackrange.org/the-black-range-naturalist/)

Unattributed material is contributed by the editor.


Mud Spring S. fault
Truth or Consequences Municipal Airport
T12S R4W
Cuchillo Negro fault zone
Draw fault
Willow
Mud Springs Canyon
Mud Springs Tank Number 1
T13S R5W
Mud Spring fault
Cuchillo Negro