

PRELIMINARY GEOLOGIC MAP OF THE CARRIZOZO AREA, LINCOLN COUNTY, NM

BY

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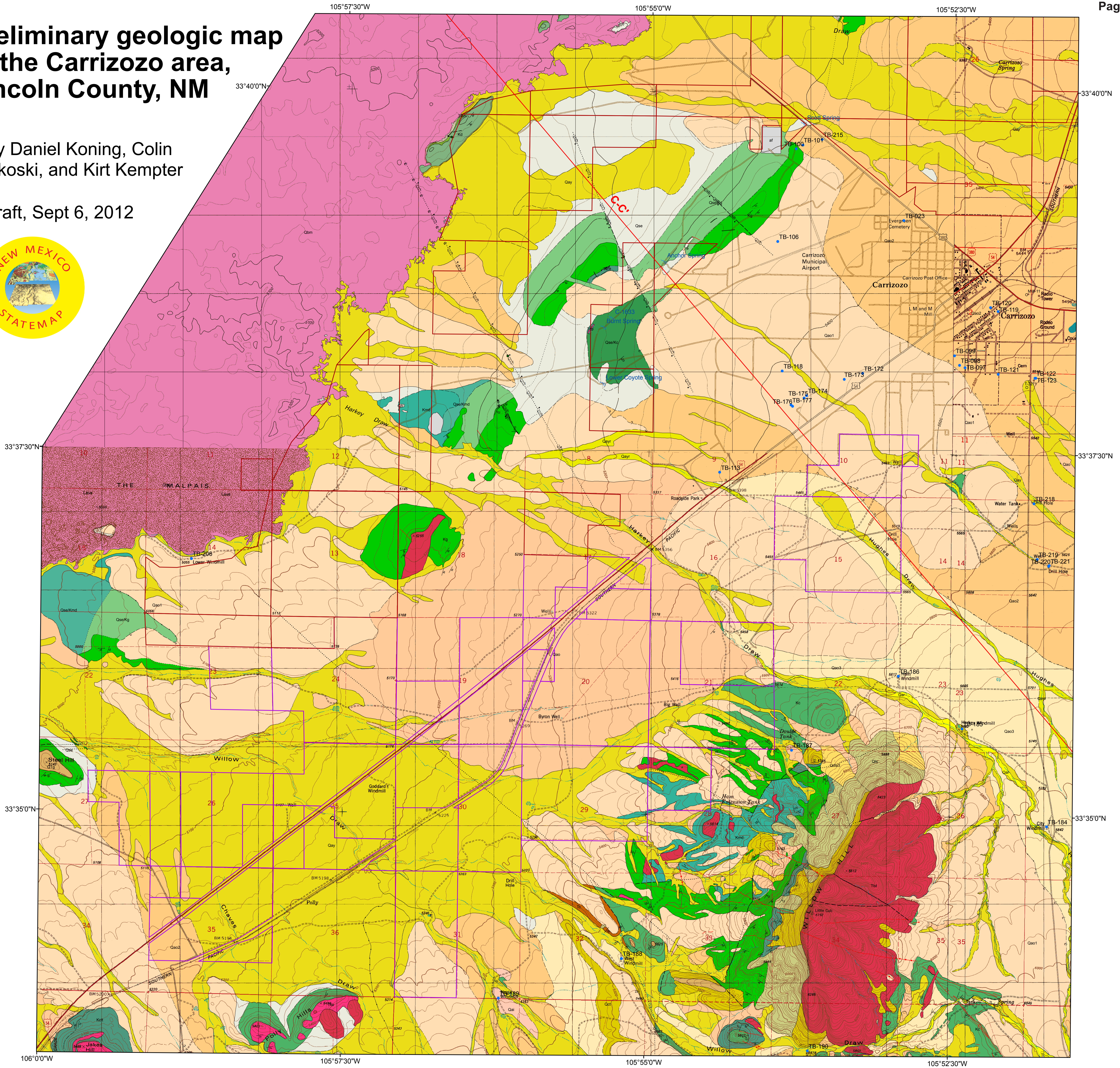
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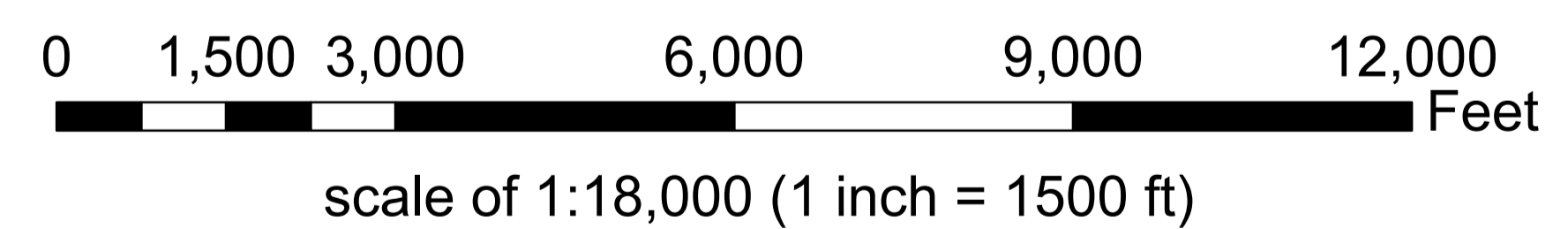
Preliminary geologic map of the Carrizozo area, Lincoln County, NM

by Daniel Koning, Colin Cikoski, and Kirt Kemper

Draft, Sept 6, 2012



EXPLANATION OF MAP UNITS



Base map from the following U.S. Geological Survey 7.5-minute quadrangles: Carrizozo West, Carrizozo East, Church Mountain, and Cub Mountain.
1927 North American datum, UTM projection -- zone 13N

Geologic symbols

- Strike and dip of bedding. Strike (long line) is the trend of a horizontal line on an inclined bed. Dip (short line) is the maximum slope on an inclined bed and its value is indicated by the number.
- Contact (boundary) separating map units -- Identity and existence is certain, location is accurate.
- Contact (boundary) separating map units -- Identity and existence is certain, location is approximate.
- Contact (boundary) separating map units -- Identity and existence is certain, location is concealed by an overlying map unit (commonly alluvium).
- Laterally gradational contact (boundary) separating map units -- Identity and existence is certain, location is accurate.
- Contact (boundary) separating map units -- Identity and existence is probable, location is accurate.
- Fault -- Identity and existence is certain, location is accurate. Ball and bar denote down-thrown block; arrows denote direction of lateral movement, if any.
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- Dike -- Identity and existence is certain, location is accurate. See Page 2 for illustration of the geometry of a dike.
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Miscellaneous symbols on map

- Bar W Ranch private land holdings
- Kenneth Owens private land holdings
- C-C' Cross section line C-C'
- Well with subsurface geologic data
- Spring

Miscellaneous symbols on cross section

- Well with subsurface geologic data; vertical red line is depth to ground water that was not used in constructing the ground water table. Label denotes well name used in this study (which is not the same as the OSE identification system).
- Ground water table -- dashed where approximate.

Comments to map users

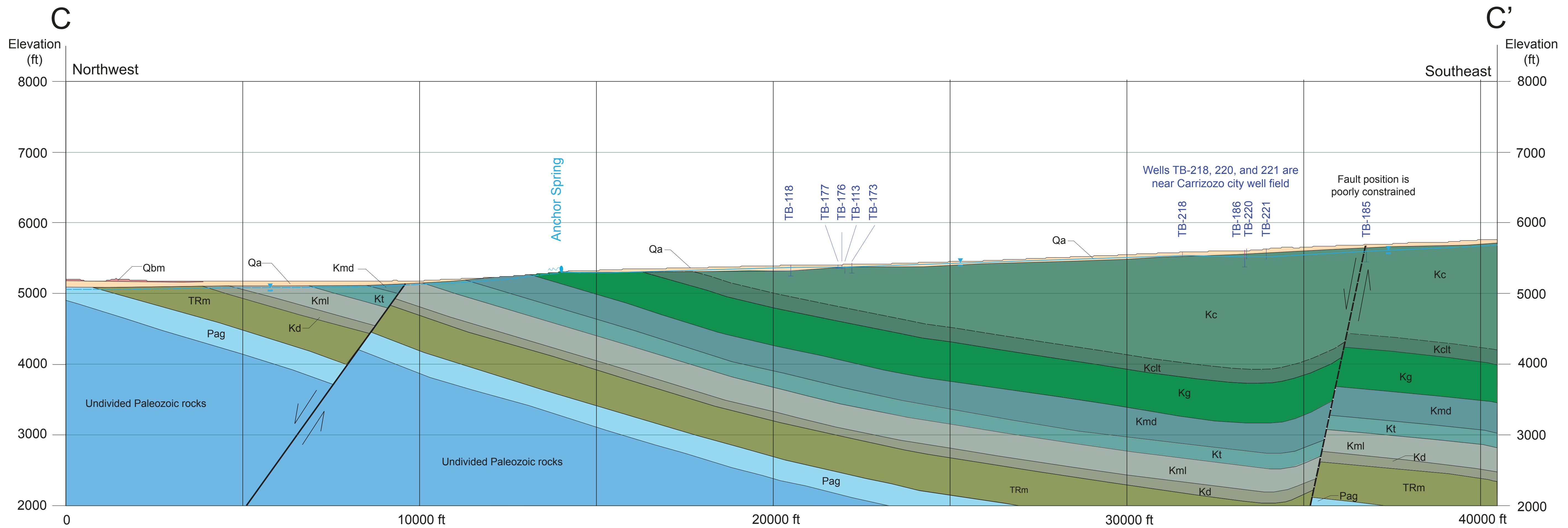
A geologic map displays information on the distribution, nature, orientation, and age relationships of rock and deposits and the occurrence of structural features. Geologic and fault contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic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

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

The map has not been reviewed according to New Mexico Bureau of Geology and Mineral Resources standards. The contents of the report and map should not be considered final and complete until reviewed and published by the New Mexico Bureau of Geology and Mineral Resources. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the State of New Mexico, or the U.S. Government.

Northwest-trending cross section through Anchor Spring, Carrizozo area, NM

Horizontal scale of 1:18,000 (1 inch = 1,500 ft), 2X vertical exaggeration (1 inch = 750 ft)



EXPLANATION OF GEOLOGIC UNITS

Introduction of some geologic terms

Term	Sandstone grain sizes size in millimeters (note that 1 mm is 1.26/32 of an inch)
very coarse	1.00-2.00
coarse	0.50-1.00
medium	0.25-0.50
fine	0.125-0.25
very fine	0.062-0.125

alluvium - Sediment laid down by flowing water, especially in stream or river channels-beds - Layers in sedimentary deposits.
colluvium - Rock and dirt mantling a slope and moving chiefly by gravity.

debris flows - Very muddy water carrying abundant coarse material (more than half of material is sand-size or greater).
conformable - Said of a contact that is gradational and encompassing very little geologic time.
contact - Boundary between rock formations.
eoian - Pertaining to the wind.
igneous - Rock or mineral that solidified from melted or molten material.
matrix - Finer-grained material filling spaces between coarser particles.
paleo - Adjective meaning old or ancient.
sediment - Solid fragments transported and deposited by water, wind or ice (or chemically precipitated from water); generally forms layers (or beds).
sheetflood - Sand, silt, clay, and pebbles that have been moved by a thin sheet of water flowing over a gently sloping surface (usually during a monsoonal rain storm).
slopewash - Soil and rock fragments carried down a slope by gravity assisted by running water that is not confined to channels.
strata - Rock composed of many sedimentary beds stacked on top of each other.
talus - Angular cobbles and boulders covering steep slopes.

Note: Definitions modified from Jackson and Bates (1984)

Young geologic materials (Quaternary Period, 0-2.6 million years old) -- deposited after formation of modern mountains

Volcanic flows

Qbm **Basalt of the Malpais** -- Gray basalt that contains 5% crystals of pyroxene that are 0.5-2.0 mm-long. Groundmass is a mix of plagioclase and pyroxene(?) minerals. Up to 50 ft thick.

Sediment on steep slopes

Qct **Colluvium and talus on hillslopes** -- Sandy gravel that is non-bedded, angular, and very poorly sorted. Gravel consist of cobbles and pebbles with minor boulders. Matrix consists of sand (mostly very fine- to fine-grained) and minor clay-silt. 3-20 ft thick.

Qdsct **Mix of debris flows, slopewash, colluvium, and talus** -- Gravelly sediment on steep slopes inferred to have been deposited by a combination of debris flows, slopewash, or processes associated with colluvium or talus. Gravel is angular and mostly consists of medium to very coarse pebbles and cobbles, but includes minor finer pebbles and boulders. Weakly to non consolidated. 3-30(?) ft. thick

Qls **Landslides** -- Angular cobbles and boulders (minor pebbles) that are non-bedded and very poorly sorted. Matrix is a light brown, very fine- to fine-grained sand with minor medium- to very coarse-grained sand and lesser silt and clay. An erosional lag layer of boulders and cobbles is commonly found on the surface of the unit. Weakly consolidated. Up to 60 m-thick.

Mix of wind-blown sediment and water-laid sediment (alluvium)

Qse **Sheetflood and eolian deposits mantling the surface** -- Pale brown to brown, pebbly-clayey sand that is loose to hard; sand is mostly fine-grained. A component of the fine-grained sediment is likely blown in by wind. About 1-6 ft thick.

Qse/Kc **Sheetflood and eolian deposits mantling the rocks of the Crevasse Canyon Formation** -- See **Qse** description above. About 1-6 ft thick.

Qse/Kg **Sheetflood and eolian deposits mantling the rocks of the Gallups Sandstone** -- See **Qse** description above. About 1-6 ft thick.

Qse/Kmd **Sheetflood and eolian deposits mantling the rocks of the D-Cross Member of the Mancos Shale** -- See **Qse** description above. About 1-6 ft thick.

Sediment deposited by flowing water (alluvium) -- see diagram to right

Qa **Alluvium (cross section only)** -- Sediment laid down by flowing water, especially in stream or river channels, on river floodplains, or on alluvial fans adjacent to a mountain front. Includes all the units listed below.

Qar **Recent alluvium** -- Gravel and sand that lie in active channels or were deposited in historical time. Soil development is very weak to non-existent, and vegetation density is very low. Not saturated for long periods of time. Less than 10 ft thick.

Qayr **Mix of younger and recent alluvium** -- See descriptions of **Qar** and **Qayr** above and below.

Qay **Younger alluvium** -- This unit contains two deposits filling paleo-valleys or paleo-arroyos. The older deposit is volumetrically the greatest and consists of pale brown to brown, very fine- to medium-grained sand and clayey sand. Sand exhibits fining-upward trends and contains sparse pebble lenses. Sediment is non- to weakly bedded. The surface of the older unit is commonly eroded and covered by younger sheetflood deposits. The younger unit fills paleo-arroyos eroded into the older unit and is typically well-bedded and slightly coarser (i.e., less clayey; sand and pebbles are common). The younger unit lacks a notable soil. **Qay** becomes finer-grained to the west, where it consists of clay, silt, and very fine- to fine-grained sand. Not saturated for long periods of time. Unit is commonly 6-15 ft and inset below **Qao3**.

Qai **Intermediate alluvium** -- A clast-supported, sandy gravel (pebbles and cobbles) with a reddish matrix. Away from topographic highs, the sediment becomes progressively sandier and finer-grained. Topsoil of unit exhibits calcium carbonate accumulation. Not saturated for long periods of time. Unit underlies terraces whose surfaces are 5-50 ft above modern streams.

Qao **Older alluvium, undivided** -- Primarily sand and gravel that are divided into three subunits below.

Qao3 **Youngest subunit of older alluvium** -- Sand and gravel deposits that appear to be inset into nearby **Qao2** sediment. The surface of this unit lies as much as 6 m below nearby **Qao2** surfaces. Sand and gravel interfinger with light brown to reddish silty-clayey very fine- to fine-grained sand that is hard. Where not eroded, this unit has a strong calcic horizon at its surface (commonly overlain by a reddish yellow soil horizon with local clay accumulation). Moderately consolidated and 1-40 ft thick.

Qao2 **Intermediate subunit of older alluvium** -- Interbedded sandy gravel, pebbly sand, and sand that is inset into unit **Qao1**. Sand is very pale brown to light yellowish brown and very fine- to very coarse-grained. Base of deposit is commonly not exposed. Thickness is variable due to erosion; generally less than 40 ft thick.

Qao1 **Oldest subunit of older alluvium** -- Sandy gravel near topographic highs that grades westward into intercalated sandy pebbles, pebbly sand, and, and clayey sand. Gravel contains pebbles, subordinate cobbles, and very minor boulders composed of volcanic rocks. Fine sediment is commonly reddish brown. Basal 2-20 ft of unit may be strongly cemented, otherwise it is weakly to moderately consolidated. Up to approximately 50 ft thick.

Qtg **Terrace gravels** -- Sandy gravel underlying terrace surfaces along major streams. Sediment is similar to that of **Qao1** and **Qao2**.

QTg **Very old gravelly sediment** -- High-level sandy gravel whose base is above the bases of nearby **Qao1**. Poorly exposed and less than 30 ft thick.

"Middle aged" geologic materials (Tertiary Period, 27-50 million years old)

Igneous intrusions (lava that cooled and crystallized underground) -- formed in conjunction with Sierra Blanca volcanic activity (Tertiary age)

Tist **Intrusion composed of syenite-trachyte** -- Light-colored, intrusive rocks dominated by the minerals of plagioclase and potassium feldspar. Unit occurs as large, bulbous bodies (stocks), horizontal to gently inclined, tabular shapes (sills), or thin, vertically tabular shapes (dikes). Color ranges from creamy tan to creamy white to light pink to light gray or gray. Orangish swirly pattern is common on weathered surfaces. Grains are typically less than 1 mm long. 1-25% mafic minerals 0.1-0.5 mm long, which locally include the minerals of biotite and pyroxene +/- amphibole. Up to 1% quartz and 1-5% possible sanidine. Large-volume intrusions contain scattered, large grains of feldspar, hornblende and/or pyroxene, and locally biotite. Radiometric dating has returned ages of 28-35 million years. Groundwater flow is confined to fractures; overall, unit is probably less permeable than surrounding sedimentary rocks.

Tita **Intrusion composed of trachyandesite** -- Intrusive rocks containing large grains in a fine-grained groundmass; the unit typically occurs as vertically to horizontally orientated, tabular bodies (i.e., dikes or sills). These rocks are typically light gray to dark gray, locally weathering to reddish brown to brownish gray. The larger grains commonly include the minerals of pyroxene and feldspar, and less commonly hornblende. Feldspar minerals are commonly aligned. Groundmass is composed of feldspar that ranges from 0.1-0.5 mm together with 10-35% pyroxene +/- biotite. Most intrusions are probably 35-37 million years old. Groundwater flow is confined to fractures; overall, unit is probably less permeable than surrounding sedimentary rocks.

Titd **Intrusion composed of trachydacite** -- Light gray to light grayish white to tan, biotite-bearing intrusions. Other minerals include potassium feldspar, plagioclase, and biotite (less commonly, hornblende and quartz). Unit has not been dated. Groundwater flow is confined to fractures; overall, unit is probably less permeable than surrounding sedimentary rocks.

Sedimentary rocks deposited by rivers before Sierra Blanca was formed -- jungle-like paleo-environment and far away from the ocean (Tertiary age)

Ts **Sanders Canyon Formation** -- Interbedded, reddish gray to reddish brown floodplain deposits and light gray, sandy channel-fills. The average sandstone:mudstone ratio is about 30:70 (Cather, 1991) and decreases up-section. The unit appears to be finer-grained west of Cub Mountain than to the southeast. Channel-fills are composed of very fine- to medium-grained (mostly fine-grained) sandstone containing 20% or more volcanic fragments. Floodplain deposits consist of reddish gray to reddish brown claystone and siltstone. Sandstone channel-fills are typically well-cemented by calcium carbonate (Cather, 1991). This unit was deposited 457-37 million years ago by a river sourced partly in volcanic terrain. Lower contact is conformable with the Cub Mountain Formation. Thickness is estimated to be 1500-1900 ft.

Tc **Cub Mountain Formation** -- White to pale yellow to light reddish gray, channel-fill sandstones interbedded with reddish floodplain deposits of mudstone and very fine- to fine-grained sandstone. The slightly coarser texture of the sand (mostly medium-grained), more "pockety" outcrop appearance, and reddish fine-grained sandstone beds serve to distinguish this unit from the underlying Crevasse Canyon Formation. The unit differs from the overlying Sanders Canyon Formation by its general lack of light gray channel-fills and lesser amounts of volcanic detritus in its sand fraction (less than 20%). Locally, there are tongues of Sanders Canyon Formation in the middle to upper part of the Cub Mountain Formation but these were not differentiated on the map. Sandstones are fine- to coarse-grained (mostly medium-grained) and moderately to strongly cemented by calcium carbonate and lesser amounts of clay and quartz (Cather, 1991). Locally, very coarse sand and pebbles are present in the channel-fills and composed of quartz + quartzite, rhyolite, and chert. Floodplain deposits consist of claystone, mudstone, siltstone, and very fine- to fine-grained sandstone. These rocks were laid down by rivers between 55-45 million years ago. 1200-1400 ft thick.

Older geologic materials (Cretaceous Period, 65 to ~300 million years old)

Sedimentary rocks laid down near the coastline of an ocean that covered the interior of the United States

Kc **Crevasse Canyon Formation** -- Interbedded channel-fill sandstones and floodplain deposits; local coal beds in the floodplain deposits that are up to 1 ft thick. This river-laid sediment differs from the overlying Cub Mountain Formation by its yellowish-greenish floodplain deposits and its slightly finer-grained channel-fill sand. Top contact corresponds with an erosional surface and paleo-soil. Lower contact is conformable with the Gallup Sandstone. The unit coarsens up-section. In the upper half of the Crevasse Canyon Formation (thickness of 820-890 ft), there is a subequal ratio of sandstone to mudstone-rich strata. Sandstone is white to pale yellow, commonly weathering to yellow-orange, and mostly fine- to medium-grained (but coarser in the upper part of the unit, where pebbles also occur). Floodplain sediment consists of mudstone, siltstone, and very fine- to fine-grained sandstone. In the lower half of the Crevasse Canyon Formation (thickness of 920-985 ft), mudstone and shale floodplain deposits dominate and are interbedded with minor sandstone channel-fills. Wells in the Carrizozo area commonly penetrate into this formation, including the city's municipal supply wells, and it appears to provide a suitable aquifer. The lack of fossils inhibits interpretation of a precise age, but it is likely between 88 and 70? million years old. The entire unit is 1800 ft thick.

Kclt **Coal-bearing, transitional base of Crevasse Canyon Formation** -- This unit occupies the lowest 130-230 ft of the Crevasse Canyon Formation and is between 88 and 86 million years old (Hook, 2010). The lower 60-90 ft correlates to the Dilco Member of the Crevasse Canyon Formation and interpreted to have been deposited in a swamp, fluvial, or deltaic environment. It consists of interbedded gray shale and minor yellow sandstone and coal beds. The upper 80-150 ft of this unit is interpreted to have been deposited in a nearshore, lagoonal, and tidal flat depositional environment. Correlated to the Dalton Sandstone, it is composed primarily of sandstone that locally contains marine invertebrate fossils (including oysters). The sandstone beds may serve as local aquifers, but the unit hosts very few springs or seeps.

Kg **Gallup Sandstone** -- White to yellow, fine- to medium-grained sandstone "tongues" interbedded with light gray to gray, marine shale intervals. The sandstone was generally deposited just offshore of an ancient beach (which bounded the ocean depositing the Mancos Shale). Oyster shells are locally abundant. The top bed of the upper sandstone tongue is composed of a distinctive quartz-rich sandstone. Lower contact is conformable with the Mancos Shale. Unit deposited along the retreating shoreline of an ocean 89-88 million years ago (Hook, 2010; Hook and Cobban, 2012). This sandstone hosts several springs west of Carrizozo and is inferred to be an effective aquifer there. However, the unit is much more cemented in the area of Willow Hill, locally being a quartzite, and there it is probably a much poorer aquifer. 500-530 ft thick

Kmd **D-Cross Member of Mancos Shale** -- Dark gray to greenish gray to pale yellow shale, silty shale, siltstone, and claystone. The Mancos Shale erodes readily and as a result it commonly is poorly exposed. Towards top of unit, siltstone and very fine- to fine-grained sandstone become progressively more common. The upper Mancos shale was deposited under a shallow ocean about 89-91 million years ago (Hook and Cobban, 2012). About 340-350 ft thick.

Older geologic materials (65 to ~300 million years old) -- cross-section only

Sedimentary rocks

Kt **Tres Hermanos Formation (Cretaceous Period)** -- A tongue of tan to yellow, very fine- to medium-grained (mostly fine-grained) sandstone within the Mancos Shale. Sandstone is locally interbedded with subordinate yellow shale beds. Unit deposited along the coast during a time that the ancient marine shoreline retreated and then advanced again (about 91 million years ago; Hook and Cobban, 2012). This formation is sandwiched within the Mancos Shale, and no springs or seeps have been observed in this unit. Estimated to be 210-240 ft thick, but unit is poorly exposed in Carrizozo area.

Kml **Lower Mancos Shale (Cretaceous Period)** -- Hard, gray, calcareous shale. Lower part of unit includes several bentonite (altered ash) layers. Up-section is an interval of three closely spaced limestone beds separated by < 3 ft of shale. The lower Mancos shale was deposited under a shallow ocean 91-95 million years ago (Hook and Cobban, 2012). Unit probably acts as an aquitard (i.e., acts as a semi-barrier to groundwater flow because of its clayey texture). About 340-350 ft thick, but unit is poorly exposed in the Carrizozo area.

Kd **Dakota Sandstone (Cretaceous Period)** -- Ledge-forming, fine- to coarse-grained, quartz-rich sandstone. Colors range from white to light purplish white. Exposed sandstone tends to develop a strong purplish black-dark brown desert varnish. Unit underlies the main north-south hill at Valley of Fires State Park. Very fine to very coarse pebble-conglomerate beds and very coarse sand locally occur near the base of unit and are composed of rounded quartzite, quartz, chert, and 0.5-1% metarhyolite. Interbeds of light gray siltstone, very fine-grained sandstone, and light to dark gray shale become increasingly common up-section. Unit deposited by rivers along the coastline 95-100? million years ago (Hook and Cobban, 2012). Sandstone beds are well-cemented and groundwater probably flows in fractures. 130-140 ft thick.

*****Time gap in geologic record of about 140 million years*****

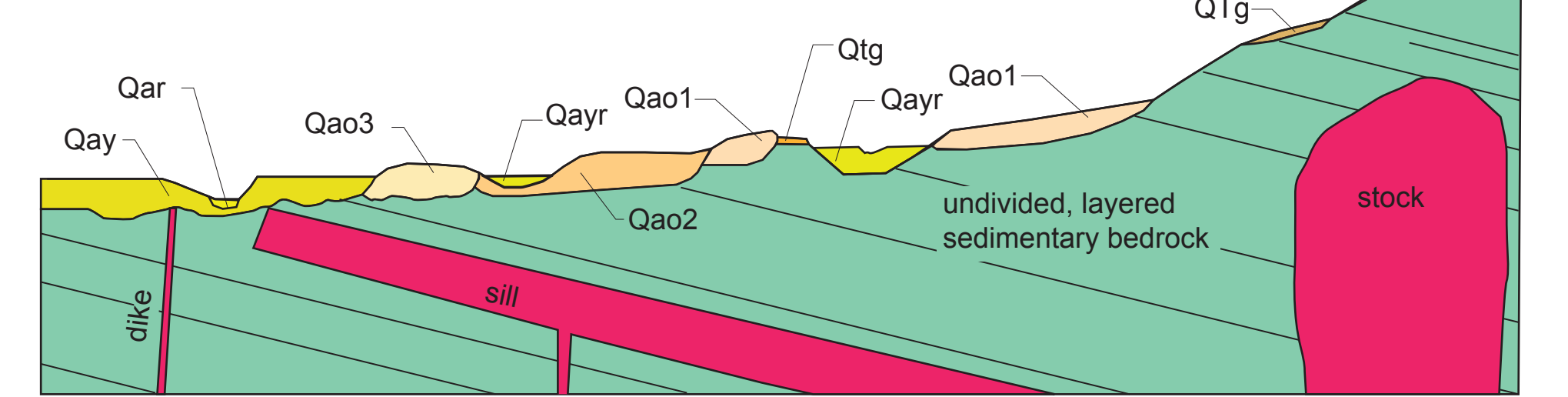
Trm **Moenkopi Formation (Triassic Period)** -- Chocolate brown to reddish brown, interbedded sandstone, pebbly sandstone, and fine-grained floodplain deposits. This unit is poorly exposed in the lower west slope of the main north-south hill at Valley of Fires State Park. Pebbles are composed of quartz, chert, quartzite, limestone, and metarhyolite(?). Sand contains variable amounts of mica. Floodplain deposits are composed of mudstone, siltstone, and very fine- to fine-grained sandstone. Unit deposited by northwestward-flowing rivers about 237-245 million years ago. Cemented and well-consolidated. Probably a poor to moderate aquifer because of cementation and interbedded mudstones. ~450 ft thick.

*****Time gap in geologic record of about 125 million years*****

Pag **Artesia Group, Grayburg Formation (cross section only)** -- Very fine- to fine-grained sandstone and silty to clayey very fine- to fine-grained sandstone; subordinate siltstone and shale. Colors range from orange to red to light red to reddish brown (most to least common). Unit deposited about 260-267 million years ago near an ancient coastline in a relatively dry environment. Orangish color, fine texture, and quartz-rich composition serve to differentiate this unit from the overlying Moenkopi Formation. Cemented and well consolidated. Probably a relatively poor aquifer because of fine grain size and cementation. About 310-350 ft thick

Pag **Undivided Paleozoic rocks (cross section only)** -- Limestone, dolomite, and anhydrite (San Andres Formation) underlain by an interval of sandstone + siltstone + limestone (Yeso, Abo, and Bursum Formations) underlain by an interval dominated by limestone (including the Madera Group). Although the limestone and dolomite probably transmit groundwater well, the presence of anhydrite can result in poor groundwater quality.

Schematic profile illustrating spatial relations of the young (Quaternary) geologic units and geometry of igneous intrusions



Summary of Geology and Hydrogeologic inferences

Note: Hydrogeologic inferences presented below are based largely on field observations. A study is underway by the N.M. Bureau of Geology and Mineral Resources that will more rigorously test and quantify the nature of aquifers, groundwater flow paths, and the influences of various formations on groundwater chemistry. Consequently, these hydrogeologic inferences should be treated as preliminary and subject to change.

The Carrizozo area is mostly underlain by alluvium consisting of sand, gravel, silt, and clay that are less than 2.6 million years old. This alluvium mantles sedimentary bedrock that is 300-70 million years old. Sedimentary layers in the bedrock dip gently to the east towards the north end of the Sacramento Mountains. Fault lines offset these layered rocks, but the exact locations of some of these faults are poorly constrained due to the alluvial cover. During a time of intense volcanic activity, about 37 to 27 million years ago, the sedimentary bedrock was intruded by molten rocks, this produced a variety of igneous geometries that include stocks, sills, and dikes (see diagram above). Because igneous rocks are crystalline, we infer that groundwater flow through them is mainly along cracks and fractures.

The sedimentary bedrock was deposited by water in a variety of environments -- including deep marine, immediately offshore of a beach, and rivers (in general, from oldest to youngest). The Mancos Shale was deposited in a deep marine setting. Its clay-rich composition inhibits groundwater flow and it is widely considered to be a poor to very poor aquifer. Conformably above the Mancos Shale lies the Gallup Sandstone, which was generally deposited immediately offshore of a beach and composed of sandstone. However, interbedded in the near-beach sandstones are deeper-marine shale layers that could act as barriers to groundwater flow within the unit. Accordingly, we postulate that the Gallup Sandstone may not be as productive of an aquifer as the overlying Crevasse Canyon Formation -- unless the two are displaced against one another along fault(s). This fault scenario seems to have occurred west of Carrizozo near Anchor Spring, where the Gallup Sandstone is in fault-juxtaposition against the Crevasse Canyon Formation and ground water is flowing out of the Gallup Sandstone. Northeast of Anchor Spring lie a series of aligned seeps that terminate at a northwest-trending dike (illustrating how a dike can act as a groundwater barrier). The Gallup Sandstone is more indurated in the Willow Hill area than at Carrizozo and this likely reduces the permeability of the formation there. The Crevasse Canyon Formation was deposited by rivers. Springs discharge from this formation in the map area (e.g., Bloom Spring and Lower Coyote Spring) and to the south (e.g., Milagro Spring and Jake Spring northeast of Oscura). Evidently, sandstone channel-fills in much of the Crevasse Canyon Formation (especially the mid-upper part) are suitably connected so that they can transmit groundwater. Although younger in age, the Cub Mountain and Sanders Canyon Formations were also deposited by rivers and locally host springs and seeps. In a practical sense, the Crevasse Canyon, Cub Mountain, and Sanders Canyon Formation may function as a single aquifer in which groundwater flows primarily in channel-fill sandstones (the mudstone-rich floodplain deposits being less transmissive). Based on inspection of well records, in some areas the basal part of the geologically young alluvium (unit Qa in the cross section) is saturated and screened by many wells in the Carrizozo area. The spatial distribution of this saturated alluvium may be controlled by upwelling of groundwater from underlying sedimentary bedrock of the Crevasse Canyon Formation.