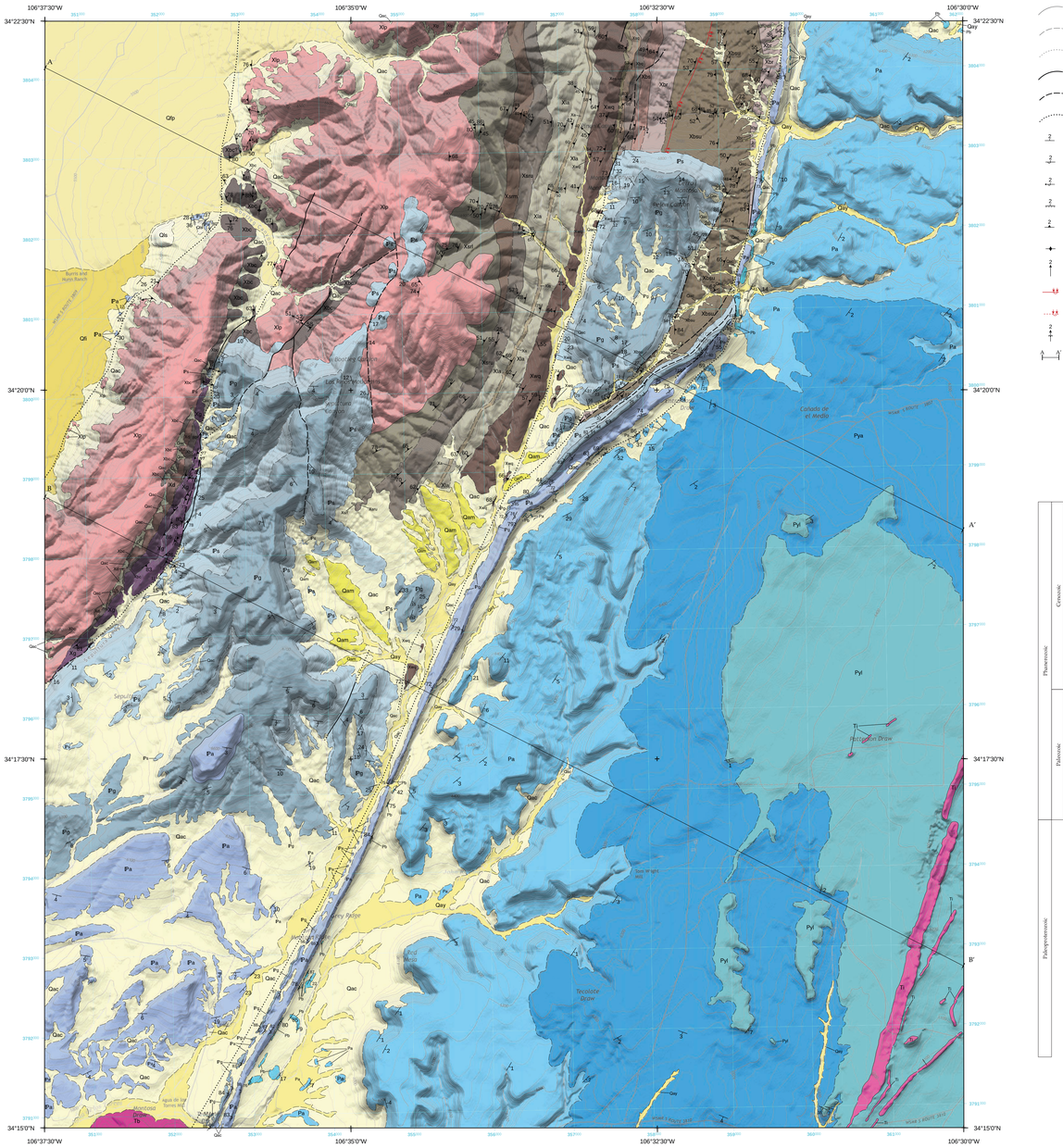

Base map from U.S. Geological Survey 1952, from photographs taken 1947, field checked in 1952.
1927 North American datum. Polyconic projection. Reprojected to UTM projection NAD 27 zone 13.
1000-meter Universal Transverse Mercator grid, zone 13, shown in blue.

Quadrangle Location

1:24,000

1 0.5 0 1 Miles

1 0.5 0 1 Kilometers

CONTOUR INTERVAL 20 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

New Mexico Bureau of Geology and Mineral Resources
Open-file Geologic Map 238

Mapping of this quadrangle was funded by a matching-funds grant from the STATEMAP program of the National Cooperative Geologic Mapping Act (Award Number: G13AC00186), administered by the U. S. Geological Survey, and by the New Mexico Bureau of Geology and Mineral Resources, (L. Greer Price, *Director and State Geologist*, Dr. J. Michael Timmons, *Geologic Mapping Program Manager*).

Geologic Map of the Cerro Montoso 7.5-Minute Quadrangle, Socorro County, New Mexico

June 2014

by

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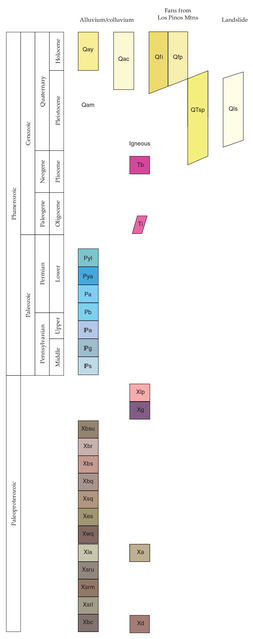
This and other STATEMAP quadrangles are available for free download in both PDF and ArcGIS formats at:

http://geoinfo.nmt.edu

Explanation of Map Symbols

- Contact-Identity and existance certain, location accurate.
- Contact-Identity and existance certail, location approximate.
- Contact-Identity and existance certain, location concealed.
- Fault-Identity and existance certain, location accurate.
- Fault-Identity and existance certain, location approximate.
- Fault-Identity and existance certain, location concealed.
- Inclined bedding-Showing strike and dip.
- Overturned bedding-Showing strike and dip.
- Overturned bedding, where top direction of beds is known from local features-Showing strike and dip.
- Inclined graded bedding-Showing strike and dip.
- Inclined metamorphic or tectonic foliation-Showing strike and dip.
- Vertical metamorphic or tectonic foliation-Showing strike.
- Inclined lineation or linear structure-Showing trend and plunge.
- Overturned syncline-Identity and existance certain, location accurate. Beds on one limb are overturned, arrows show dip direction of limbs.
- Overturned syncline-Identity and existance certain, location concealed. Beds on one limb are overturned, arrows show dip direction of limbs.
- Inclined symmetric minor fold hinge-Showing trend and plunge.
- Cross section line.

Correlation of Map Units



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.

Map Unit Descriptions

Alluvial and colluvial deposits

Qay **Undivided modern channel deposits and valley-bottom alluvium (Holocene)**—Channel deposits are poorly to moderately sorted, unconsolidated sand and gravel with local accumulations of cobbles and small boulders, and lesser amounts of silt and clay, commonly exhibiting waning-flow bedforms such as ripples, dunes, and longitudinal bars. Valley-bottom deposits are poorly to moderately consolidated clay, silt and pebbly sand with accumulations of clast- and matrix-supported gravel, cobbles and small boulders in buried channels, and are inset against older alluvial deposits included in map unit **Qac**. Incipient soils are poorly expressed in these deposits. Modern drainages are commonly incised into finer-grained valley-bottom deposits with vertical cuts up to 5 m deep or more, but not all valley-floor areas are incised. Channel deposits are generally discontinuous and thin, ranging from less than 1 m to more than 2 m thick. Small unmapped areas of exposed bedrock in scoured reaches are locally present. Valley-bottom alluvium ranges from 1 to at least 5 m thick.

Qac **Undivided colluvium and alluvium (Holocene to Upper Pleistocene)**—Colluvial deposits include poorly consolidated, poorly sorted and stratified, fine- to coarse-grained, clast- and matrix-supported deposits derived from a variety of mass-movement hillslope processes, including debris flow, shallow slump, and creep, and overlie, interfinger, and grade into alluvial deposits that include undivided inset terraces along larger drainages at low to intermediate levels above modern channels. Soils are essentially lacking in younger deposits and exhibit stage I-II pedogenic carbonate horizons in older deposits. Clasts are typically rounded to subangular pebbles and cobbles reworked from proximal and distal bedrock sources and older Quaternary units. Colluvium on hillslopes contains a large proportion of locally derived bedrock clast types, whereas terrace alluvium commonly includes a large proportion of clasts transported from upstream areas. Thickness of **Qac** is variable, ranging from less than 1 m to at least 5 m.

Qam **Alluvial deposits underlying abandoned interfluvial ridges and highs (Upper (?) to Middle Pleistocene)**—Moderately consolidated clay, silt, sand and gravel at intermediate levels between lower and upper Montosa wells, largely in the area to the west of Montosa Draw. Gravels are commonly concentrated on the surface of the deposit; cobbles and scattered boulders are present. Associated soils exhibit Stage III pedogenic carbonate development. Lower flanks of **Qam** highs are commonly colluviated and are truncated and inset by younger **Qac**/**Qay** alluvium. Deposits are probably less than 10 m thick.

Qls **Landslide (Pleistocene)**—Two relatively large landslides comprised of granite derived from the west face of the Los Pinos Mountains are mapped as such to the southwest of the mouth of Bootleg Canyon. The larger of the two landslides appears to represent a large, relatively intact block of granite that may have rotated backward as it moved down the steep mountain front. Field relations suggest that the smaller landslide lies on top of Pennsylvanian-age rocks that are present immediately to the west of the mountain-front normal fault. The larger landslide block may rest on Pennsylvanian rocks as well.

Alluvial aprons and fans from the Los Pinos Mountains

Qfp **Undivided alluvium deposited on the fan debouching from the Los Pinos Mountains at Bootleg Canyon (Holocene to Upper Pleistocene)**—Poorly to moderately sorted, unconsolidated pebble to cobble alluvium and fine- to coarse-grained sand with local accumulations of cobbles and small boulders in longitudinal bars; silt and clay in longitudinal areas of low slope. Includes both active broad shallow channels and interchannel areas. Younger deposits lack soils, while interchannel highs exhibit incipient soils. Higher interfluves exhibit stage I-II pedogenic carbonate horizons. Deposits range from 1 m to at least 7 m thick and may be considerably thicker away from the mountain front.

Qfi **Undivided interfan alluvial aprons from small drainages along the Los Pinos Mountain front (Holocene to Upper Pleistocene)**—Poorly to moderately sorted, unconsolidated pebble to cobble alluvium, fine- to coarse-grained sand with local accumulations of cobbles and small boulders; silt and clay in areas of low slope. Unit is overlain by younger **Qfp** and **Qac** deposits and interfingers with older deposits. Thickness and degree of pedogenic carbonate development similar to **Qfp**.

Santa Fe Group

QTsp **Sierra Ladrones Formation, piedmont deposits (upper Santa Fe Group, Middle Pleistocene to Pliocene?)**—Shown on cross section A-A′; description based on observations from exposures along Palo Duro Canyon west of "five points", a short distance west of the map area. Unconsolidated to moderately consolidated, uncemented to cemented, mudstone and sandstone with moderately sorted, tabular sandstone and scattered, irregular pebbly sandstone and conglomeratic sandstone lenses. Beds commonly form upward-fining sequences with a basal conglomerate that fines upward into sand and mud that is locally capped by calcic paleosols. May include older Neogene deposits toward the base of the unit. Scattered exposures on divides between Palo Duro and Cibola Canyons to the southwest suggest that deposits assignable to the Popatosa Formation (Miocene) are minor this close to the mountain front. The well-driller's log from the water well at Nunn Ranch suggests that **QTsp** overlies Permian bedrock (lower Yeso Gp.) at a depth of ~45 m at that locality.

Neogene

Tb **Basalt flow of Black Mesa (Pliocene)**—Light- to dark-gray olivine basalt. According to Weber (1963), the basalt is light-gray with a slightly trachytic texture in the center of the flow, and grades outward to dark-gray and finer grained near the margins. Apparently originated from two or three vents in proximity to the Montosa fault zone (Weber, 1963; Lueth et al., 2008, p. 60-61). A K-Ar age of 3.5 +/- 0.2 Ma was reported by Bachman and Menhert (1978). Only a small outcrop of the flow is present on the southern edge of the map area, where its base is covered by deposits of map unit Qay.

Paleogene

Ti **Igneous intrusions (Oligocene)**—Light- to dark-gray intrusive rocks (dikes) in the southeast corner of the quad. Bates et al. (1947) distinguished phaneritic and aphanitic sills and dikes in the area. Both consist primarily of plagioclase feldspar, with phenocrysts of hornblende or very altered pyroxenes. Mafic phenocrysts and feldspars in phaneritic rocks generally range from approximately 1 to 3 mm. Biotite and magnetite is present in some samples. Bates et al. (1947) identified the phaneritic rocks as hornblende diorite based on thin section petrology of samples just to the east of the quad, and noted that quartz and orthoclase are present in small (< 5%) amounts in that area. Aphanitic rocks were identified texturally as diabases and using the volcanic rock name, are probably basaltic andesite in composition. Mapped where surface exposures are readily apparent on aerial photographs; additional near-surface exposures that are probably present in the area are obscured by the mantle of alluvium/loessal deposits that cover the flat terrain on the east side of the quad. Inferred Oligocene age is based on the widespread distribution of similar intrusions of this age in central New Mexico. Dikes are generally less than 60 m wide, and intrude relatively incompetent, gypsiferous rocks of the Yeso Group that have been locally deformed by the intrusions (see Bates et al., 1947). Thus, the widest (~180 m), N-NE trending intrusion in the map area may reflect lateral spreading from a narrower feeder dike into surrounding, relatively weak Yeso strata.

Permian

Pyl **Yeso Group (Lower Permian)**—Orange, pink, and yellowish sandstone and siltstone; white to gray gypsum; and yellowish-gray dolomite, gray limestone, and gypsiferous silt and fine sand. Subdivided into two formations after Lucas et al. (2005). Unit is generally poorly exposed in the map area, with a thin cover of mixed alluvium and loess that locally exhibits a well-developed calcic soil as seen in borrow-pit exposures.

Los Vallos Formation (includes Joyita, Cañas, and Torres Mbrs)—Interbedded fine-grained, reddish and yellowish sandstone, siltstone, and mudstone, gypsiferous siltstone, gypsum, and gray to yellowish-brown carbonate (limestone and dolomite). Base of unit is mapped at the first laterally continuous carbonate bed above siliciclastic deposits of unit Pya, which is followed upward in succession by several more carbonate beds separated by redbed muds and sand that are commonly gypsiferous. Unit contains increasing amounts of gypsiferous siltstone and bedded gypsum (Cañas Mbr.) upward through the section, commonly culminating in a sequence of siliciclastic redbed sandstone beds (Joyita Member) that mark the regressive stage of the early Leonardian Los Vallos transgressive-regressive cycle. Unit appears to be poorly fossiliferous in the area, containing some macroinvertebrate fragments including brachiopods and gastropods. Approximately 30 m of the lower part of the Los Vallos is present in the map

Pya **Arroyo de Alamillo Formation (equivalent to Mesita Blanca Mbr)**—Pinkish-red, to pale-orange and yellowish to greenish-gray, fine-grained sandstone, siltstone, and mudstone, commonly thinly laminated or ripple laminated. Carbonate beds (dolomite and limestone) and gypsum are present in minor amounts. In better exposures to the west of the map area yellowish and greenish-gray, fine-grained beds containing abundant well preserved casts of hopper-shaped halite crystals are present, suggesting deposition in sabkha or saline mudflat environments at various times. Ichnotossils including invertebrate traces and tetrapod tracks, and poorly preserved plant fossils are beginning to receive some scientific study in the area east of Socorro. Unit appears to gradationally overlie the Abo Formation, and is thought to have been deposited near the beginning of a marine transgression that spread northward into the region during early Leonardian time. Approximately 65 m thick on the Becker SW quadrangle just to the west of the map area (Wilpolt etal., 1946).

Pa **Abo Formation (Lower Permian)**—Distinctive monochromatic brick-red mudstone, fine-grained sandstone and siltstone with lesser shale and intraformational conglomerate. Unit contains some greenish- and reddish-gray fine-grained sandstones in addition to the characteristic dark-red deposits, and exhibits greenish-gray reduction spots and mottling in some beds that seems to be ubiquitous in the Abo Formation over much of New Mexico. Unit is interpreted as representing deposition of overbank muds and associated fluvial sands on a widespread lower Permian alluvial plain interrupted by eroded hills remaining from ancestral Rocky Mountain uplifts. Intervals containing nodular non-fossiliferous carbonates are interpreted as representing paleosols. Upper part of unit contains numerous sheet-like sandstone bodies; lower part is predominantly mudstone, with lesser lenticular and cross-bedded, fine-grained sands. Tetrapod tracks and other trace fossils as well as terrestrial plant remains are relatively common and have received increasing scientific attention in recent decades. Approximately 125 thick on the Cerro Montoso quadrangle; unit is considerably thicker (~280 m) to the north at its typelocality near Abo Pass (Needham and Bates, 1942).

Pennsylvanian-Permian

Pb **Bursum Formation (Upper Pennsylvanian to Lower Permian)**—Interstratified red to maroon and greenish-gray mudstone and shale, reddish- to yellowish-brown sandstone, gray fossiliferous limestone, and minor intraformational (limestone-clast) conglomerate beds. Unit represents the transition from dominantly marine (Atrasado Fm) to terrestrial (Abo Fm) depositional environments. Unit is poorly exposed along the east side of Gray Ridge, just east of the Montosa fault. Allen et al. (2013) measured approximately 40 m of Bursum Formation southwest of the map area on the Sierra de la Cruz quadrangle, where Schwagerinid fusulinids midway up in the section suggest a lowermost Wolfcampian (Permian) age for the formation in this area.

Pennsylvanian

IPa **Atrasado Formation (Upper Pennsylvanian)**—Gray, fossiliferous (normal marine), cliff-forming, thin- to thick-bedded limestone and intervening intervals dominated by slope-forming greenish-gray to reddish-brown siliciclastic mudstone, siltstone, and calcareous shale. Crossbedded and planar laminated, silty sandstone to pebbly sandstone, including thick, lenticular channel fills, are common. The stratigraphic nomenclature in current use for the Atrasado Formation in central New Mexico (Nelson et al., 2013a) identifies 8 lithostratigraphic members in the Atrasado Formation, the lower 6 of which are readily identified in the map area. An apparent merging of the upper two limestone-dominated members (Story and Moya) in the area makes precise placement of the contacts between the uppermost members less obvious. About 240 m thick just west of the southwestern part of the quadrangle; unit appears to be thinner (~180 m thick) in places along Gray ridge, but this apparent thinning seems likely to be a result of structural thinning in the immediate vicinity of the Montosa fault zone.

IPg **Gray Mesa Formation (Middle Pennsylvanian)**—Cliff-forming, fossiliferous (normal marine), medium- to thick-bedded cherty limestone and slope-forming siliciclastic deposits consisting of mudstone, shale, and sandstone. The base of the Gray Mesa in parts of the map area consists of two or three intervals dominated by medium to thick bedded, cliff-forming limestone, which are interbedded with and overlain by slope-forming intervals containing a relative abundance of siliciclastic sediment. These basal, mixed carbonate-siliciclastic strata are in turn overlain by a thick sequence of thin- to thick-bedded and massive limestones that form a bold cliff, recognizable throughout the map area where it is present, that pertains to the Whiskey Canyon Member of the formation as delineated elsewhere in central New Mexico (see Nelson et al., 2013b, for a discussion of Gray Mesa Formation lithostratigraphy). The upper part of the Gray Mesa Formation contains limestone beds up to a few meters thick, some of which are intercalated with thin shaley partings, and lesser interbeds of siliciclastic mud and sand. The base of the overlying Atrasado Formation is generally a covered slope containing siliciclastic muds and thick lenticular sandstone beds. More detailed stratigraphic work is needed, but in areas the thick limestone beds near the base of the Gray Mesa appear to be represented laterally by siliciclastic deposits including thick beds of sandstone and pebbly sand, that for mapping purposes could arguably be assigned to the Sandia Formation. Approximately 120 m thick.

IPs **Sandia Formation (Middle Pennsylvanian)**—Greenish-gray, reddish-brown, and yellowish mudstone to silty sandy shale and calcareous shale, yellowish and reddish-brown, gray, and greenish-gray, planar laminated and crossbedded sandstone to pebble conglomerate, and fossiliferous (normal to restricted marine), gray to brownish-gray limestone and sandy limestone. Terrestrial plant fossils have been known for some time to be present in shales from the Sandia Formation in the area east of Socorro; within the map area hematitic fragments of terrestrial plants are common. The deposits are of mixed terrestrial, marginal marine, and normal marine origin. The base of the Sandia in the area is commonly a pebble to cobble conglomerate containing white quartz clasts. Approximately 70 m to more than 100 m thick, depending in part on where the contact with the overlying Gray Mesa Formation is chosen.

Proterozoic

Xlp **Los Pinos Granite**—Pale-reddish-gray to pink and red, massive, medium- to coarse-grained, microcline + orthoclase + quartz + albite granite in Los Pinos Mountains. Has a distinctive myrmekite texture in some locations. Los Pinos Mountains granite yielded radiometric ages of 1653 to 1658 million years (Karlstrom et al., 2004).

Xq **Granite of Sepultura Canyon**—Medium-reddish-brown to pink, medium- to fine-grained, quartz, biotite, microcline, and minor plagioclase granite located in Sepultura Canyon. This strongly foliated granite and locally granite mylonite, intrudes the Bootleg Canyon sequence but does not appear to come in contact with the Los Pinos granite. The relative deformation of this unit relative to the Los Pinos granite suggests that this granite is older and predates the main deformational events that affect all metasedimentary and metavolcanic units.

Xbsu **Blue Springs Upper Schist**—Green to white, chlorite + muscovite schist. Locally, thin K-feldspar veins cut foliation. The apparent uppermost unit of the Manzano Peak (F2) synclinorium, found east and northeast of the Los Pinos granite (**Xlp**) in the eastern region of the quadrangle. Equivalent to the Metaclastics Series **pCm** of Myers and McKay (1974).

Xbr **Blue Springs Rhyolite**—Black and brown to gray with lenticular quartz-feldspar pink colored stripes within darker layers. Interpreted as a metarhyolite due to the presence of potassium feldspar in the felsic lenses and a geochemical composition close to rhyolite. Equivalent to the part of **pCa**, the argillite of Myers and McKay (1972), Blue Springs Quartzite (bq1) of Bauer (1983). The Blue Springs Rhyolite yielded a U-Pb zircon date of 1601 +4/-3 Ma (Luther et al., 2005; J. Jones, unpublished data).

Xbs **Blue Springs Schist**—Green to white, garnet + chlorite + quartz + muscovite schist. Crenulated with well-preserved garnet.

Xbq **Blue Springs Quartzite Member (of Blue Springs Schist)**—Thinly-bedded, medium-grained quartzites, interbedded with chlorite-muscovite schist and quartz-muscovite schist.

Xsq **Sais Quartzite**—Thinly-bedded, reddish, schistose quartzite. Bedding planes commonly show mica concentrations. Grains range in size from very fine to coarse. Primary structures include preserved cross-bedding.

Xes **Estadio Canyon Schist**—Coarse-grained, staurolite + garnet + biotite schist. Equivalent to the Lower part of the Pine Shadow Springs of Myers and McKay (1972); called the White Ridge schist (ws1) of Bauer (1983).

Xwq **White Ridge Quartzite**—Coarse-grained, impure, orange to gray, thinly-bedded, quartzite. Fairly immature metasedimentary rock with well preserved cross-bedding. The upper part of the unit has a distinctive red, and alusite + muscovite, foliated, schistose layer. Detrital zircons from the Estadio quartzite (correlative to the White Ridge quartzite in the Los Pinos) have a maximum age of ~1630 Ma based on the youngest zircon although the error on these analyses is large (~50 Ma; Luther et al., 2005; J. Jones, unpublished data).

Xa **Abajo Lithic Arenite**—Composed of a variety of metasedimentary rocks including meta-pelite, meta-arkose and impure quartzite. Contains thin layers of chlorite schist, quartzite and metarhyolite. Massive quartzite domains are locally dominant. Also includes garnet-staurolite schist, which may be related to the intrusion of gabbro dikes (now amphibolites). A 5-10 meter wide amphibolite layer (**Xa**) is interbedded within the Abajo Lithic Arenite.

Xa This relatively fine grained unit typically contains hornblende, epidote, and biotite. Relic pillow features are also preserved within this unit suggesting this was a basalt that flowed and is interbeded within the lithic arenites.

Interbedded Proterozoic

Xasu **Sevilleta Metarhyolite, Upper member**—Brown to pink, finely-banded sericitic metarhyolite with fine-grained quartzo-feldspatic matrix, minor biotite aligned in foliation, ± carbonate;; 0.5-3.5 mm feldspar and quartz crystals with sphene and epidote inclusions, and rare sertization K-Feldpar in tails of porphyroclasts. Porphyoclasts in Upper member appear much more rounded than other members.

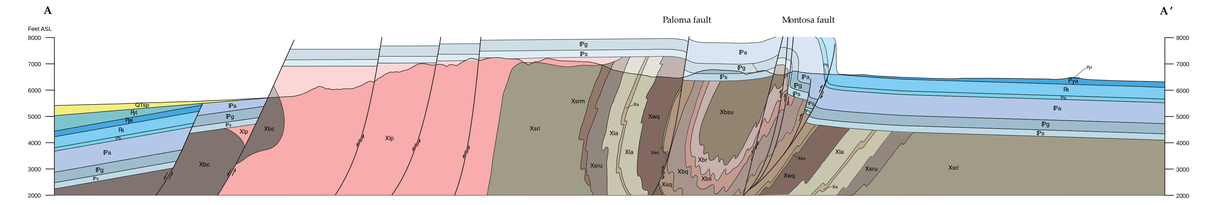
Xarm **Sevilleta Metarhyolite, middle member**—Dark-gray to black, felsic, meta-igneous rocks with 0.5 to 2 mm quartz and feldspar phenocrysts. Texture ranges from thin, well developed compositional banding to massive. Quartz veins, pegmatite and massive schistose units and up to 3 cm long flattened lapilli are present locally and generally parallel foliation.

Xarl **Sevilleta Metarhyolite, Lower member**—Medium-gray to black, dense, finely-banded metarhyolite with minor white mica, oxides, epidote and biotite; speckled with 1.0-2.5 mm white feldspar crystals that have been sericitized.

Xbc **Bootleg Canyon sequence**—Interbedded layers of coarse-grained amphibolite, pelitic schists, quartzites and "layered" schists described previously by Shastri (1992). Coarse-grained amphibolite is black-and-white to greenish-grey to black depending on the mineral content, which is typically hornblende, epidote, biotite, chlorite and actinolite with similar accessory minerals as the finer-grained unit and appears similar to that found in **Xla**. Light-green to beige pelitic schist layers contain garnet, biotite, ± chlorite, muscovite, plagioclase, quartz, Fe-Ti oxides, ± K-feldspar, and ± tourmaline. Greenish (epidotized?) quartzite layers are thinly-bedded, micaceous and contain fine-grained, epidote-rich 0.5-2 cm-scale pods of calc-alkaline material. The layered schist is an interbedded mafic and granitic schist, suggesting that amphibolite supracrustal rocks were complexly intruded by granite (Shastri, 1992). Located with Sepultura Canyon, and proximal to the Los Pinos Granite (**Xd**) is an amphibolitic unit that is in intrusive contact with the Bootleg Canyon sequence.

Xd This amphibolite exhibits a variety intrusive features including cross-cutting relationships with the Bootleg Canyon sequence and mingled magma textures (Figure X). This unit is composed of hornblend, biotite and may also include pyroxene. Plagioclase feldspar and very minor quartz are also observed. Mingled magmatic textures indicate that this unit represents a metamorphosed gabbro and diorite suite.

Geologic Cross Sections A—A′



Geologic Cross Sections B—B′