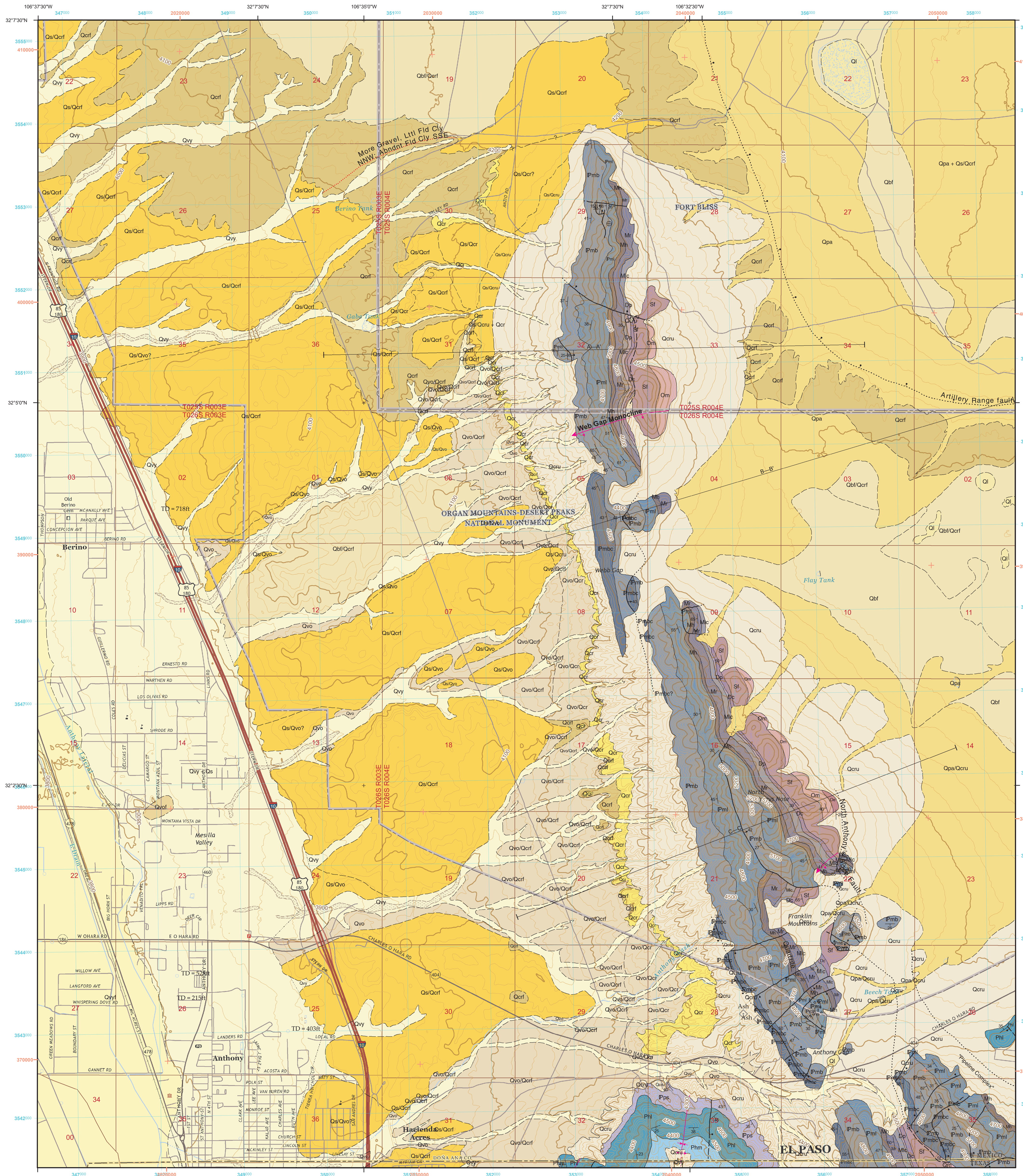
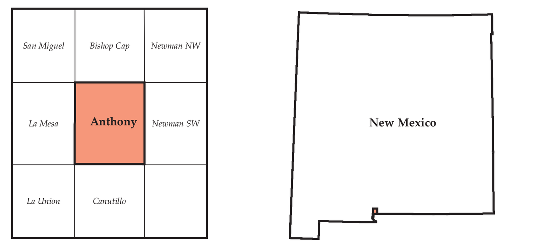
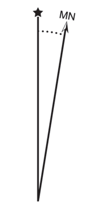


Base map from U.S. Geological Survey 2020.
North American Datum of 1983 (NAD83)
Projection and 1,000-meter grid: Universal Transverse Mercator, Zone 13S/13R, shown in blue.
10,000-foot ticks: New Mexico Coordinate System of 1927 (Central zone), shown in red.

Roads.......... U.S. Census Bureau, 2015–2018
Names.......... GNIS, 1979-2019
Hydrography.......... National Hydrography Dataset, 2001-2018
Contours.......... IFSAR 4.5 m Digital Terrain Model, 2008
Wetlands.......... FWS National Wetlands Inventory, 1984
Public Lands Survery System (PLSS).......... BLM, 2011



Quadrangle Location



Magnetic Declination
July, 1980
11° East
At Map Center

1:24,000

1 0.5 0 1 Mile
1000 0 1000 2000 3000 4000 5000 6000 7000 Feet
1 0.5 0 1 Kilometer

Contour Interval 20 Feet
National Geodetic Vertical Datum 1929

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

[575] 835-5490

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

http://geoinfo.nmt.edu

New Mexico Bureau of Geology and Mineral Resources
Geologic Map 54

Geologic Map of the Anthony 7.5-Minute Quadrangle, Doña Ana County, New Mexico

June 1983

by
Shari A. Kelley and J. Paul Matheny

New Mexico Bureau of Geology and Mineral Resources, 801 Leroy Place, Socorro, NM 87801

Digital layout and cartography by the NMBGMR Map Production Group:
Phil L. Miller, Amy L. Dunn, Ann D. Knight, and Justine L. Nicolette

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 may not be shown due to recent development.

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.

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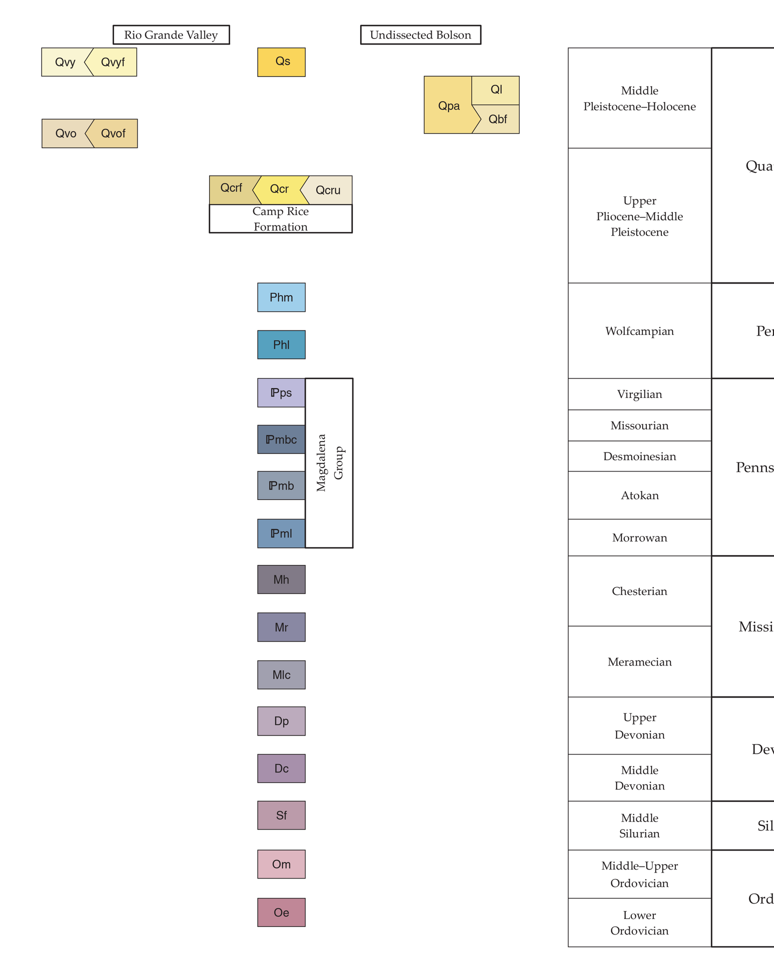
Correlation of Map Units



Explanation of Map Symbols

01.01.01 Contact—Identity and existence are certain. Location is accurate.

01.01.03 Contact—Identity and existence are certain. Location is approximate.

01.01.04 Contact—Identity or existence are questionable. Location is approximate.

01.01.15 Internal contact—Identity and existence are certain. Location is concealed.

01.02.01 Key bed—Identity and existence are certain. Location is accurate.

02.01.01 Fault (generic; vertical, subvertical, or high-angle; or unknown or unspecified orientation or sense of slip)—Identity and existence are certain. Location is accurate.

02.01.03 Fault (generic; vertical, subvertical, or high-angle; or unknown or unspecified orientation or sense of slip)—Identity and existence are certain. Location is approximate.

02.01.07 Fault (generic; vertical, subvertical, or high-angle; or unknown or unspecified orientation or sense of slip)—Identity and existence are certain. Location is concealed.

02.02.01 Normal fault—Identity and existence are certain. Location is accurate. Ball and bar on downthrown block.

02.02.03 Normal fault—Identity and existence are certain. Location is approximate. Ball and bar on downthrown block.

02.02.07 Normal fault—Identity and existence are certain. Location is concealed. Ball and bar on downthrown block.

02.14.04 Fault-breccia zone or zone of broken rock around fault

19.01.23 Metamorphoc facies boundary—Showing approximate boundary between diagnostic mineral assemblages

31.08 Map

05.01.01 Anticline (1st option)—Identity and existence are certain. Location is accurate.

05.01.07 Anticline (1st option)—Identity and existence are certain. Location is concealed.

05.05.01 Syncline (1st option)—Identity and existence are certain. Location is accurate.

05.09.01 Monocline (1st option)—Identity and existence are certain. Location is accurate. Arrow shows direction of dip.

05.09.07 Monocline (1st option)—Identity and existence are certain. Location is concealed. Arrow shows direction of dip.

01.04.12 Key bed—Showing name.

26.01.01 Water well, type

02.11.09 Inclined fault (2nd option)—Showing dip value and direction.

05.10.05 Plunging anticline—Large arrowhead shows direction of plunge.

06.01 Horizontal

06.02 Inclined bedding—Showing strike and dip.

01.01.02 Contact—Identity or existence are questionable. Location is accurate.

02.11.16 Normal fault (in cross section)—Arrows show relative motion.

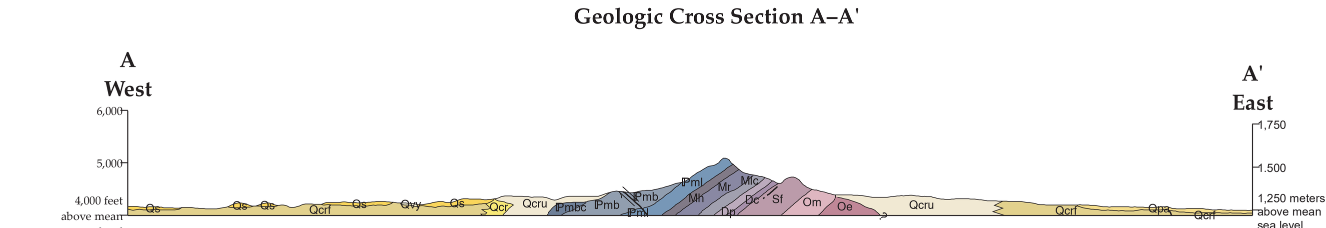
01.01.01 Contact—Identity and existence are certain. Location is accurate.

02.11.16 Normal fault (in cross section)—Arrows show relative motion.

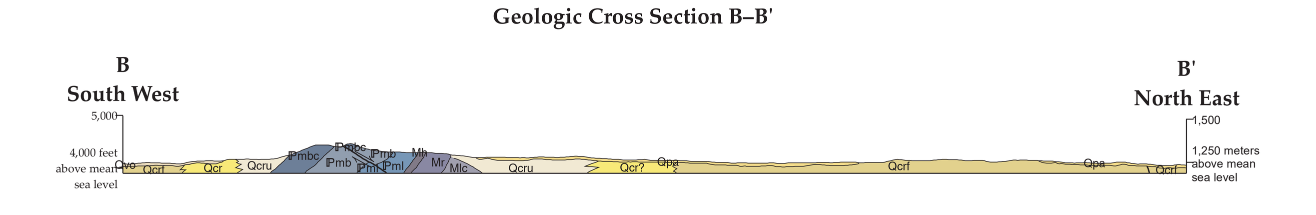
02.11.17 Thrust fault or reverse fault (in cross section)—Arrows show relative motion.

31.08 Map neatline

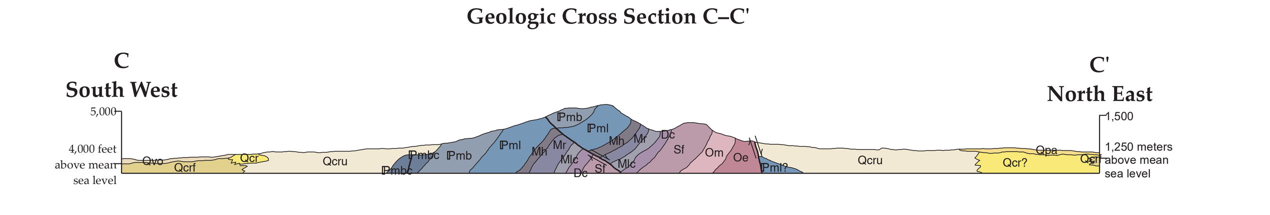
Geologic Cross Section A–A'



Geologic Cross Section B–B'



Geologic Cross Section C–C'



Description of Map Units

01-00-00-00-00 — heading02 — Quaternary — Quaternary —

01-01-00-00-00—map unit—Qs—Quaternary Windblown Sand—Holocene, windblown sand (Qs) forms coppice dunes and relatively thin (0.9–4.5 m; 3–15 ft) veneers of unconsolidated sand on the Camp Rice fluvial facies, older valley-slope deposits, and younger valley-slope deposits (Qcrf, Qvo, and Qvy) adjacent to the modern floodplain. Recent eolian sand, also found in small, coppice dunes next to blowouts in the Hueco Bolson, is derived from reworking of Camp Rice fluvial deposits and/or erosion of modern floodplain sediments.

01-02-00-00-00—heading03—Rio Grande Valley—Rio Grande Valley—The older, valley-fill fluvial facies (Qvof) that intertongues with the Qvo fan deposits is found in a low ridge near the modern floodplain. Other outcrops of this facies are present adjacent to the floodplain, but these outcrops were not included on the map because they are poorly exposed. The sandy to gravelly river deposit contains well-rounded, locally derived pebbles as well as rounded quartz, chert, granite, and basalt pebbles from upstream sources. The deposit is 6–9 m (20–30 ft) thick, and its constructional surface apparently is correlative with the Picacho geomorphic surface (fig. 2). Holocene and latest Pleistocene (< 15,000 yrs) arroyo-fan alluvium (Qvy) is present in modern arroyo bottoms on the west side of the map area. Silty to gravelly, unconsolidated arroyo-channel fill and broad arroyo fans next to the modern Rio Grande floodplain are graded to either the floodplain or Fillmore geomorphic surface (fig. 2), which is 1.5–4.6 m (5–15 ft) above the floodplain. The arroyo alluvium in the northern part of the Anthony quadrangle contains abundant magnetite that was probably reworked from the Camp Rice fluvial facies. The young arroyo-fan alluvium is approximately 1.5–6 m (5–20 ft) thick. The younger (Holocene and latest Pleistocene) valley-fill fluvial facies (Qvyf) that forms the modern floodplain of the Rio Grande is composed of sandy, gravelly, and loamy floodplain and channel deposits less than 15,000 years old that interfinger with the younger arroyo-fan alluvium. The unit is approximately 9–21 m (30–70 ft) thick.

01-02-01-00-00—map unit—Qvy—Quaternary Younger Valley-slope Alluvium—Holocene and latest Pleistocene (< 15,000 yrs) arroyo-fan alluvium (Qvy) is present in modern arroyo bottoms on the west side of the map area. Silty to gravelly, unconsolidated arroyo-channel fill and broad arroyo fans next to the modern Rio Grande floodplain are graded to either the floodplain or Fillmore geomorphic surface (fig. 2), which is 1.5–4.6 m (5–15 ft) above the floodplain. The arroyo alluvium in the northern part of the Anthony quadrangle contains abundant magnetite that was probably reworked from the Camp Rice fluvial facies. The young arroyo-fan alluvium is approximately 1.5–6 m (5–20 ft) thick.

01-02-02-00-00—map unit—Qvyf—Quaternary Younger Valley-fill Fluvial Facies—The younger (Holocene and latest Pleistocene) valley-fill fluvial facies (Qvyf) that forms the modern floodplain of the Rio Grande is composed of sandy, gravelly, and loamy floodplain and channel deposits less than 15,000 yrs old that interfinger with the younger arroyo-fan alluvium. The unit is approximately 9–21 m (30–70 ft) thick.

01-02-03-00-00—map unit—Qvo—Quaternary Older Valley-slope Alluvium—Valley-slope deposits associated with river entrenchment: Older, valley-slope deposits (Qvo) that form terraces along arroyos in the western part of the map area are silty to gravelly, locally derived fan deposits. These deposits are associated with geomorphic surfaces (Tortugas and Picacho, fig. 2) that are graded to late Pleistocene levels of the Rio Grande floodplain. The Qvo deposits and surfaces are inset below the Camp Rice fan deposits (Jornada I surface) but typically are graded to surfaces 15–30 m (49–98 ft) above the present floodplain. A well-developed, petrocalcic soil up to 1 m (3 ft) thick is developed on the surfaces, especially in the southern part of the map area. The Qvo fan deposits are as much as 15 m (49 ft) thick in some places; however, Qvo deposits generally are approximately 6 m (20 ft) thick.

01-02-04-00-00—map unit—Qvof—Quaternary Older Valley-fill Fluvial Facies—The older, valley-fill fluvial facies (Qvof) that intertongues with the Qvo fan deposits is found in a low ridge near the modern floodplain. Other outcrops of this facies are present adjacent to the floodplain, but these outcrops were not included on the map because they are poorly exposed. The sandy to gravelly river deposit contains well-rounded, locally derived pebbles as well as rounded quartz, chert, granite, and basalt pebbles from upstream sources. The deposit is 6–9 m (20–30 ft) thick, and its constructional surface apparently is correlative with the Picacho geomorphic surface (fig. 2).

01-03-00-00-00—heading03—Undissected Bolson—Undissected Bolson—Basin-fill deposits not affected by activity of the Rio Grande: Most of the floor of the Hueco Bolson is covered by late Pleistocene piedmont-slope deposits (Qpo) and younger (Holocene) piedmont-slope, arroyo alluvium (Qpy). We had difficulty distinguishing between Qpo fans and Qpy fans in this area, so we lumped the two units together to form an undifferentiated upper Pleistocene to Holocene piedmont-slope, arroyo-alluvium unit (Qpa). The Qpa deposits are composed of reddish-brown silt and angular, locally derived gravel. Younger alluvium (Qpy) in the Hueco Bolson is found primarily in shallow arroyos and fans at modern arroyo mouths. Shallow drainageways occupied by younger piedmont- slope, arroyo alluvium are usually inset below the constructional surface (Jornada I surface) of the Camp Rice fans. Most of the thin (0.6–3 m; 2–10 ft), unconsolidated, loamy alluvium on Camp Rice fan surfaces east of the mountains probably is older piedmont-slope alluvium (Qpo). The La Mesa geomorphic surface is the basinal extension of the Jornada I piedmont-slope constructional surface (fig. 2). This surface is well developed on the Camp Rice fluvial facies in Fillmore Pass, along the north edge of the quadrangle, and in the Hueco Bolson, just south of the Fort Bliss Military Reservation boundary. Large portions of the La Mesa surface in both Fillmore Pass and Hueco Bolson are covered by late Pleistocene and Holocene, brownish-red, silty basin-floor and toeslope sediments (Qbf). Basin-floor silt and clay also cover the floor of a large depression east of the Artillery Range fault in Hueco Bolson. Undissected basin-floor and toeslope deposits are lithologically similar to the minor toeslope facies of the Camp Rice Formation because both Qbf sediments and Camp Rice toeslope sediments were deposited in the transition zone between central-basin floors and piedmont slopes. The Qbf deposits locally include well-developed soil profiles, which indicates that much of the basin-floor and toeslope sediments probably are correlative with older piedmont-slope alluvium (Qpo). Basin-floor sediments are approximately 1–3 m (3–10 ft) thick. Valley-slope deposits associated with river entrenchment: Older, valley-slope deposits (Qvo) that form terraces along arroyos in the western part of the map area are silty to gravelly, locally derived fan deposits. These deposits are associated with geomorphic surfaces (Tortugas and Picacho, fig. 2) that are graded to late Pleistocene levels of the Rio Grande floodplain. The Qvo deposits and surfaces are inset below the Camp Rice fan deposits (Jornada I surface) but typically are graded to surfaces 15–30 m (49–98 ft) above the present floodplain. A well-developed, petrocalcic soil up to 1 m (3 ft) thick is developed on the surfaces, especially in the southern part of the map area. The Qvo fan deposits are as much as 15 m (49 ft) thick in some places; however, Qvo deposits generally are approximately 6 m (20 ft) thick.

01-03-01-00-00—map unit—Qpa—Quaternary Undifferentiated Piedmont-slope Alluvium—Most of the floor of the Hueco Bolson is covered by late Pleistocene piedmont-slope deposits (Qpo) and younger (Holocene) piedmont-slope, arroyo alluvium (Qpy). We had difficulty distinguishing between Qpo fans and Qpy fans in this area, so we lumped the two units together to form an undifferentiated upper Pleistocene to Holocene piedmont-slope, arroyo-alluvium unit (Qpa). The Qpa deposits are composed of reddish-brown silt and angular, locally derived gravel. Younger alluvium (Qpy) in the Hueco Bolson is found primarily in shallow arroyos and fans at modern arroyo mouths. Shallow drainageways occupied by younger piedmont- slope, arroyo alluvium are usually inset below the constructional surface (Jornada I surface) of the Camp Rice fans. Most of the thin (0.6–3 m; 2–10 ft), unconsolidated, loamy alluvium on Camp Rice fan surfaces east of the mountains probably is older piedmont-slope alluvium (Qpo).

01-03-02-00-00—map unit—Ql—Quaternary Playa-lake Sediments—Holocene ephemeral-lake sediments, brown silt, and clay deposits on floors of modern playa lakes in Hueco Bolson lie unconformably on basin-floor sediments in the northwest portion of the map area. Ephemeral-lake sediments are approximately 1–3 m (3–10 ft) thick.

01-03-03-00-00—map unit—Qbf—Quaternary Basin-floor Sediments—The La Mesa geomorphic surface is the basinal extension of the Jornada I piedmont-slope constructional surface (fig. 2). This surface is well developed on the Camp Rice fluvial facies in Fillmore Pass, along the north edge of the quadrangle, and in the Hueco Bolson, just south of the Fort Bliss Military Reservation boundary. Large portions of the La Mesa surface in both Fillmore Pass and Hueco Bolson are covered by late Pleistocene and Holocene, brownish-red, silty basin-floor and toeslope sediments (Qbf). Basin-floor silt and clay also cover the floor of a large depression east of the Artillery Range fault in Hueco Bolson. Undissected basin-floor and toeslope deposits are lithologically similar to the minor toeslope facies of the Camp Rice Formation because both Qbf sediments and Camp Rice toeslope sediments were deposited in the transition zone between central-basin floors and piedmont slopes. The Qbf deposits locally include well-developed soil profiles, which indicates that much of the basin-floor and toeslope sediments probably are correlative with older piedmont-slope alluvium (Qpo). Basin-floor sediments are approximately 1–3 m (3–10 ft) thick.

01-04-00-00-00—heading03—Camp Rice Formation—Camp Rice Formation—Overlying the Paleozoic rocks with pronounced angular unconformity is the Camp Rice Formation (late Tertiary (?) to early Quaternary). Although the Camp Rice was originally described by Strain (1966) in west Texas, Seager and others (1971) were the first to apply Camp Rice terminology to the older Quaternary and latest Tertiary river and piedmont-slope deposits adjacent to the Rio Grande valley in south-central New Mexico. The Camp Rice Formation is primarily a Quaternary unit, but fossil evidence and radiometric dating of interbedded basalt indicate that the basal conglomerate of the formation, at some locations in the Rio Grande valley, is of Pliocene age (John Hawley, personal communication, 1979). Three distinctive facies of the Camp Rice Formation are present in the Anthony quadrangle: 1) a fluvial facies composed of channel sand and floodplain clay that intertongues with, or is overlain by, 2) an eolian facies consisting of loamy sand that in turn intertongues with, 3) a piedmont-slope facies composed of alluvial-fan gravel and sand derived from the Franklin Mountains (fig. 2).

01-04-01-00-00—map unit—Qcrf—Quaternary Fluvial Facies of the Camp Rice Formation—The fluvial facies crops out in arroyo cuts approximately 0.8 km (0.5 mi) west of the current western mountain front, and outcrops extend to the modern floodplain of the Rio Grande. This fluvial facies is also exposed in the Hueco Bolson along the Artillery Range fault scarp and is characterized by well-rounded gravel and gray to buff sand, interbedded with red, floodplain clay. The gravel includes abundant chert, quartz, granite, and basalt pebbles from distant upstream sources as well as rounded silicic volcanics from nearby ranges like the Organ Mountains. The fine- to coarse-grained, locally crossbedded sand is found in either well-defined channels or discontinuous sheets. Stacked paleosols with reddish-brown, slightly leached, root-mottled clay horizons that grade into lighter-colored, carbonate-enriched zones are common in the floodplain clay. The only fossils found so far in the fluvial facies in this area are silicified roots in the paleosols. On the west side of the Mesilla Valley, fossil remains of mastodons, horses (Mammuthus, Equus), and other vertebrates of lrvingtonian age (Hawley and others, 1969) are present in the fluvial facies. Although we were not able to determine the exact thickness of the fluvial unit because the base is not exposed in the Anthony quadrangle, lithologic logs from wells in or near the map area provided some idea of the thickness of the unit (table 1). The fluvial facies is approximately 235–271 m (770–890 ft) thick in Fillmore Pass, more than 218 m (715 ft) thick in the Mesilla Valley near Berino, and more than 331 m (1,085 ft) thick in the Hueco Bolson, just east of the Anthony quadrangle. In the northernmost part of the map area and in the Hueco Bolson, very little floodplain clay is found in the fluvial facies. Approximately 1.6 km (1.0 mi) west of the northwest tip of the Franklin Mountains, floodplain clay forms more than 50% of the exposed fluvial section. At approximately the same latitude on the west side of the Mesilla Valley, between the villages of Chamberino and La Mesa, a similar type of transition in the fluvial fades is observed (S.A. Kelley, unpublished mapping for the southeast Las Cruces 1° x 2° sheet, 1979). Apparently, when the river flowed through Fillmore Gap (Hawley, 1975), a large amount of water flowed into the Hueco Bolson, while less water was transported into the southern Mesilla Bolson. Less water and the proximity of Lake Cabeza de Vaca (Strain, 1966; Hawley, 1975) led to the formation of a relatively stagnant, deltaic environment south and southwest of Fillmore Pass. The deltaic environment was characterized by the development of a meandering-river system (channel sand and gravel and sand sheets) on a broad alluvial flat or floodplain (red clays with paleosols).

01-04-02-00-00—map unit—Qcr—Quaternary Eolian and Piemont Toeslope Facies of the Camp Rice Formation—The eolian facies crops out in a 90–915-m (300–3,000 ft) wide strip, 0.5–0.8 km west of the western edge of the mountain front. A few thin (0.1–1 m thick) layers of piedmont toeslope facies composed of reddish-brown, clayey to silty deposits that represent distal-fan and/or adjacent basin-floor sediments are lumped with the eolian facies for mapping purposes. The eolian facies includes reddish-brown, fine- to medium-grained sand and silt, and a minor amount of polished chert and quartz gravel. Both the eolian facies and the minor, piedmont toeslope facies complexly intertongue with the fluvial and piedmont-slope facies. The only fossils in this facies are silicified roots (root casts) in the paleosols developed on the sand. The eolian facies ranges from 0.3 m (1 ft) thick (sand stringers in the floodplain deposits) to approximately 30 m (100 ft) thick (ancient dunes near Anthony Gap). The Camp Rice eolian dunes formed during the Pleistocene in much the same way that coppice dunes east of the Rio Grande floodplain are forming today. The prevailing westerly wind, after picking up sand from river sediments in the valley, deposited sand against alluvial fans forming next to the Franklin Mountains during the Pleistocene. Eolian sand was concentrated west of Webb Gap and Anthony Gap, where changes in wind direction and velocity caused deposition. Absence of the eolian facies west of a large, plunging syncline on the southern edge of the quadrangle suggests that the ancestral Rio Grande once flowed close to this structure and eroded away the windblown sand.

01-04-03-00-00—map unit—Qcru—Quaternary Undifferentiated Piedmont Toeslope Facies of the Camp Rice Formation—The piedmont-slope facies of the Camp Rice Formation, present on both the east and west flanks of the Franklin Mountains, is divided into two units; 1) a basal, well-lithified, calcium-carbonate-cemented, boulder-to-pebble fanglomerate (Qcrc) overlain by 2) a younger, less-consolidated, sandy and gravelly, alluvial-fan deposit (Qcrp). Gravel in the piedmont-slope facies includes mostly chert, limestone, and dolomite pebbles and boulders derived from the Franklin Mountains. A well-developed petrocalcic horizon averaging 0.3–0.9 m (1–3 ft) thick is generally present just below the constructional surface (Jornada I surface) of the Qcrp fan deposits. Because the contact between the upper and lower gravels is often difficult to locate, particularly in the Hueco Bolson, we mapped the piedmont-slope facies as a single unit (Qcru). The piedmont-slope facies is approximately 5–60 m (16–200 ft) thick. In 1969, John Hawley discovered an ash bed 18 cm (7 in) thick in the upper piedmont-slope (Qcrp) facies in the El Paso Natural Gas pipeline cut near Anthony Gap (SE¼ SW¼ NE¼ sec. 28, T. 26 S., R. 4 E.). The discontinuous bed of impure, white, rhyolitic ash occurs in a layer of light-brown sand containing root casts. Analysis of the ash indicates that its source probably was the Long Valley caldera near Bishop, California (Hawley, 1975), which implies an age of 0.7 m.y. for the upper piedmont-slope facies (Qcrp) in this area. The brown, sandy zone probably is a tongue of the eolian facies within the fan deposits (John Hawley, personal communication, 1979). K-Ar dates of 3–4 m.y. on basalts interbedded with the basal piedmont-slope facies (Qcrc) found elsewhere in the Rio Grande valley imply that, locally, the basal part of the Camp Rice Formation is of late Pliocene age. Unconformably resting on the Camp Rice Formation are middle to late Quaternary valley-slope deposits associated with entrenchment of the Rio Grande on the west side of the mountains and continuing sedimentation in the Hueco Bolson on the east side. We have adopted the same terminology used by Seager and Hawley (1973) and Seager and others (1975) in other portions of the Rio Grande valley to describe units older than the Camp Rice in our area.

02-00-00-00-00 — heading02 — Permian — Permian —

02-01-00-00-00—map unit—Phm—Permian Middle Member of the Hueco Formation—The Hueco Limestone conformably overlies the Panther Seep Formation in the Franklin Mountains. As defined by recent workers, the Hueco contains only the Permian rocks in Richardson's (1904, 1908, 1909) Hueco Formation. The Hueco is divided into three units (Harbour, 1972), but only the lower member and part of the middle member of the formation are present in the map area. This formation is characterized by limestone cliffs and ledges separated by talus-covered slopes of siltstone and shale and crops out in low, U-shaped hills formed by a plunging syncline west of the main range along the southern edge of the quadrangle. The Hueco consists of fossiliferous, cherty, gray limestone and marly, yellowish-gray siltstone. Although the lithology is not markedly different above or below the siltstone outcrops, the siltstone beds serve as markers between the three members because these beds are laterally continuous. Abundant brachiopods, crinoids, gastropods, corals, and fusulinids in the formation indicate that the lower and middle members of the Hueco are of Wolfcampian age. The lower unit is 200 m (656 ft) thick, and approximately 213 m (699 ft) of the middle member (Harbour, 1972) is exposed in the Anthony quadrangle.

02-02-00-00-00—map unit—Phl—Permian Lower Member of the Hueco Formation—The Hueco Limestone conformably overlies the Panther Seep Formation in the Franklin Mountains. As defined by recent workers, the Hueco contains only the Permian rocks in Richardson's (1904, 1908, 1909) Hueco Formation. The Hueco is divided into three units (Harbour, 1972), but only the lower member and part of the middle member of the formation are present in the map area. This formation is characterized by limestone cliffs and ledges separated by talus-covered slopes of siltstone and shale and crops out in low, U-shaped hills formed by a plunging syncline west of the main range along the southern edge of the quadrangle. The Hueco consists of fossiliferous, cherty, gray limestone and marly, yellowish-gray siltstone. Although the lithology is not markedly different above or below the siltstone outcrops, the siltstone beds serve as markers between the three members because these beds are laterally continuous. Abundant brachiopods, crinoids, gastropods, corals, and fusulinids in the formation indicate that the lower and middle members of the Hueco are of Wolfcampian age. The lower unit is 200 m (656 ft) thick, and approximately 213 m (699 ft) of the middle member (Harbour, 1972) is exposed in the Anthony quadrangle.

03-00-00-00-00 — heading02 — Pennsylvanian — Pennsylvanian —

03-01-00-00-00—heading03—Magdalena Group—Magdalena Group—The Magdalena Group (Pennsylvanian) conformably overlies the Helms. Originally, Richardson (1904, 1908, 1909) described the Magdalena Group as part of the Hueco Formation, which at that time included all rocks between the Silurian and Cretaceous. Nelson (1940) restricted the term "Magdalena Group" to Pennsylvanian rocks in the Franklin Mountains. Harbour (1972) called the Magdalena a formation and divided the formation into four members: the La Tuna, Berino, Bishop Cap, and unnamed transitional members. Because many workers in New Mexico and Texas (Kelley and Silver, 1952; LeMone, 1976) consider the Magdalena to be a group, we have assigned formation status to Harbour's four members. In order of decreasing age, the formations within the Magdalena Group are: the La Tuna, Berino, Bishop Cap, and Panther Seep Formations. Harbour's unnamed transitional members seem to be correlative with the Panther Seep Formation defined by Kottlowski and others (1956) in the San Andres Mountains. The Magdalena Group forms the crest and western dip slope of the northern Franklin Mountains.

03-01-01-00-00—map unit—IPps—Pennsylvanian Panther Seep Formation or Upper Member of the Magdalena Group—Conformably overlying the Bishop Cap is the Panther Seep Formation, named by Kottlowski and others (1956) in the San Andres Mountains. Nelson (1940) and Harbour (1972) assigned the uppermost Pennsylvanian rocks in the quadrangle to an upper, unnamed transitional member of the Magdalena Formation; however, based on lithology and relative position in the section, these rocks appear to be correlative with the Panther Seep Formation in the Organ and San Andres Mountains (LeMone, 1976; Hair, 1976, 1977). The Panther Seep, which generally forms gentle, talus-covered slopes, is well exposed at quarries in a plunging syncline in the southern portion of the map area. This formation is composed of silty, argillaceous limestones, 2–12-m (6.5–39 ft) thick gypsum beds, and silty shale but lacks sufficient fossils to be dated accurately. Fossils in the San Andres Mountains suggest a Virgilian age for most of the formation, although the chert-pebble conglomerate exposed at the base of the Panther Seep in Vinton Canyon may be Missourian (Harbour, 1972), and the uppermost beds may be Wolfcampian (Hair, 1977). Harbour (1972) arbitrarily placed the upper contact of the Panther Seep halfway between the last occurrence of Pennsylvanian fauna and the first appearance of Permian fauna in the section. Hair (1977) redefined the upper contact on the basis of a facies change from basinal sedimentation to shelf sedimentation in this area. We chose to use the contact defined by Hair (1977), because it is easier to recognize in the field.

03-01-02-00-00—map unit—IPmbc—Pennsylvanian Bishop Cap Formation of the Magdalena Group—The Bishop Cap Formation is exposed in a few small, talus-covered ridges along the west edge of the mountain front. This formation consists primarily of shale that weathers to a puffy, yellow clay and contains a few medium-bedded, fossiliferous, dark-gray micrite layers. Algae, gastropods, pelecypods, corals, brachiopods, and fusulinids within the formation indicate that the Bishop Cap is of middle Desmoinesian age (Harbour, 1972). A complete section of the Bishop Cap is not exposed in the quadrangle, but Harbour (1972), using the base of a shale unit as the basal contact of the Bishop Cap, measured 194 m (636 ft) of the formation at Vinton Canyon. El Foul (1976) measured 180 m (590 ft) of Bishop Cap at the same locality in Vinton Canyon. El Foul used the base of the massive limestone discussed by Allouani (1976) as the basal contact of the Bishop Cap

03-01-03-00-00—map unit—IPmb—Pennsylvanian Berino Formation of the Magdalena Group—The Berino Formation, which forms the yellowish-brown and gray, ledgy outcrops on the western dip slope of the Franklin Mountains, is composed of beds of gray limestone (0.5–6 m; 1.6–19 ft thick) alternating with layers of carbonaceous, brown shale (0.5–8 m; 1.6–26 ft thick). Both lithologies are present in approximately equal proportions. This formation is partially equivalent to both the Atoka and Desmoines Series of the Midcontinent (Harbour, 1972; Allouani, 1976). Dominant fossils in the Berino include mollusks, brachiopods, corals, bryozoa, and fusulinids. Thickness of the Berino in the map area is approximately 160 m (530 ft); however, the contact between the Berino and the overlying Bishop Cap Formation is arbitrary, so this thickness may be in error by ± 5 m (± 16 ft) compared to other sections of the Berino measured in the Franklin Mountains. Allouani (1976) measured 154 m (505 ft) of Berino Formation at Vinton Canyon. We could not positively identify the massive limestone unit used by Allouani to define the top of the Berino at Vinton Canyon in our measured sections north of Anthony Gap, so we chose a distinctive, algal limestone bed as the approximate contact between the Berino and the Bishop Cap. Beds found within 3 m (10 ft) above and below this marker were sufficiently different to suggest an important change in depositional environment. Specifically, strata above the algal bed contain thicker shale units, pseudomorphs of hematite after pyrite, and a fauna characterized by abundant algae, gastropods, and pelecypods

03-01-04-00-00—map unit—IPml—Pennsylvanian La Tuna Formation of the Magdalena Group—The La Tuna Formation, which forms imposing, gray-weathering, (100–130 ft) high cliffs on the east side of the range, is a cherty, gray, crystalline limestone that is massively bedded at its base. Because the number of shale interbeds in the La Tuna increases upward in the stratigraphic sequence, the top of the formation is more thinly bedded. The La Tuna is equivalent to Morrowan rocks in the Midcontinent {Harbour, 1972; Lane, 1974) and contains abundant silicified corals, brachiopods, crinoids, mollusks, bryozoans, and some petrified wood. The La Tuna, which thins to the south, is approximately 107 m (350 ft) thick at the north end of the range and 85 m (280 ft) thick south of Anthony Gap. Because the La Tuna grades vertically into the Berino Formation, the contact between the two is somewhat arbitrary. We placed the contact at the base of the first major (3–5 m) shale break, which corresponds to the basal Berino contact defined by Allouani (1976) in Vinton Canyon.

04-00-00-00-00 — heading02 — Mississippian — Mississippian —

04-01-00-00-00—map unit—Mh—Mississippian Helms Formation—The upper member of the Rancheria grades into the overlying Helms Formation. The Helms, named by Beede (1920) and more clearly defined by Laudon and Bowsher (1949), forms greenish-gray slopes below the Pennsylvanian limestone cliffs along most of the east flank of the Franklin Mountains. This formation is composed of calcareous, gray shale, fossiliferous, olive-green micrite, and some oolitic, olive-green micrite. A 6 m thick red quartzite lens containing a Lepidodendron impression (Harbour, 1972) crops out at the top or the Helms, south of North Anthony's Nose. Fossils found in the Helms Formation (Chesterian) include brachiopods, gastropods, ostracods, crinoids, and bryozoa. The Helms is approximately 30 m (100 ft) thick in the Anthony quadrangle.

04-02-00-00-00—map unit—Mr—Mississippian Rancheria Formation—The Rancheria Formation, also named by Laudon and Bowsher (1949), apparently lies conformably on the Las Cruces. The Rancheria crops out in orange-brown to light-gray slopes with few cliffs or ledges along the east face of the range. This formation is divided into three unnamed members: a lower member composed of cherty, black micrite with some siltstone and shale; a middle member characterized by chert-free black micrite that weathers to a light-gray band; and an upper member composed of cherty, sandy, black micrite. The lower member includes a 3 m (10 ft) thick basal bed of crossbedded, crinoidal limestone. The Rancheria, which was assigned a Meramecian age by Laudon and Bowsher (1949), contains abundant crinoid debris, bryozoa, brachiopods, and gastropods. The crinoidal bed near the base of the Rancheria at Vinton Canyon yields a few conodonts that also indicate a Meramecian age (Lane, 1974). The lower, middle, and upper members of the Rancheria are 45, 11, and 61 m (150, 35, and 200 ft) thick, respectively.

04-03-00-00-00—map unit—Mlc—Mississippian Las Cruces Formation—The Las Cruces Limestone (Mississippian), named by Laudon and Bowsher (1949) for exposures in Vinton Canyon, 3.5 km (2.1 mi) south of the New Mexico-Texas state line, unconformably overlies Devonian rocks. The Las Cruces forms distinctive, light-gray, evenly bedded (0.3–0.6-m-thick beds), ledgy cliffs along the east side of the Franklin Mountains. In general, the Las Cruces is a dense, brittle, primarily chert-free micrite. Small chert lenses and thin (0.5–1.0 cm), bioturbated, sandy layers are interbedded with limestone in the upper 4 m (13 ft) of the section, north of Webb Gap. Small chert lenses are more common throughout the Las Cruces section, south of Webb Gap. Although the Las Cruces contains very few fossils, Laudon and Bowsher (1949) considered the formation to be of Meramecian age on the basis of a few ostracod valves and lithologic resemblance to the overlying Rancheria Formation. Conodonts found in the Las Cruces at Vinton Canyon indicate that the formation is of late Osage lo early Meramecian age (Lane, 1974). The Las Cruces is approximately 27 m (90 ft) thick throughout the area.

05-00-00-00-00 — heading02 — Devonian — Devonian —

05-01-00-00-00—map unit—Dp—Devonian Percha Shale—Conformably overlying the Canutillo Formation is the Percha Shale, a fissile, black shale, distinguished mainly by its stratigraphic position between thick limestone or dolomite units. This shale was correlated by Laudon and Bowsher (1949) with the Percha Shale of southwest New Mexico. Like the Canutillo, the Percha forms a talus-covered slope on the east face of the northern Franklin Mountains. The Percha pinches out just north of North Anthony's Nose and appears to be absent between North Anthony's Nose and Anthony Gap. A relatively thin (12–15 m; 39–49 ft) Percha section crops out in the mountains south of Anthony Gap. The exact age and correlation of the Percha in this area are uncertain, because no fossils have been found in this shale. The average thickness of the Percha in the Franklin Mountains north of North Anthony's Nose is approximately 18–21 m (60–70 ft).

05-02-00-00-00—map unit—Dc—Devonian Canutillo Formation—The Canutillo Formation overlies the Fusselman with slight angular discordance caused by minor erosion following tilting of the Fusselman and older rocks. Nelson (1940) included all Devonian rocks in the Franklin Mountains in the Canutillo Formation; however, Laudon and Bowsher (1949) later realized that the upper part of Nelson's Canutillo Formation is actually correlative with the Percha Shale farther north. As a result, the name "Canutillo Formation" is applied to only the lower portion of Nelson's Canutillo Formation. The Canutillo crops out in talus-covered slopes along the eastern escarpment of the range, except at the north end of the Franklin Mountains. The lower two-thirds of the formation is primarily lenses of chert and marl; the upper third consists of interbedded , dark-gray shale and siltstone. Because the Canutillo is composed of incompetent strata, small, local, disharmonic folds are common within the formation. The only significant fossils found in the Canutillo Formation (late Middle Devonian) are brachiopods and conodonts (Harbour, 1972). This formation thins northward from at least 30 m (97 ft) at North Anthony 's Nose (Harbour, 1972) to approximately 15 m (49 ft) near Webb Gap.

06-00-00-00-00 — heading02 — Silurian — Silurian —

06-01-00-00-00—map unit—Sf—Silurian Fusselman Dolomite—The Fusselman Dolomite (Silurian), which was defined by Richardson (1908), disconformably overlies the Montoya Dolomite. Rugged, complexly jointed, light-gray cliffs formed by the Fusselman crop out along the entire east side of the northern Franklin Mountains, except at the extreme northern end. The Fusselman is a pure, thick-bedded, light-gray dolomite with minor amounts of chert and limestone. Richardson (1909) and Pray (1958) both assigned a Middle Silurian age to the Fusselman on the basis of brachiopods, corals, and gastropods found within the formation. Erosion prior to the Middle Devonian caused the formation to thin from 185 m (607 ft) in the southern part of the area to 150 m (492 ft) at the north end of the Franklin Mountains (Harbour, 1972). Silicified zones containing barite, fluorite, and limonite mineralization are common in the Fusselman near its unconformable upper contact with the Canutillo Formation. Mineralizing fluids probably migrated upward through extensive fractures in the Fusselman and spread laterally along the unconformity upon encountering the impermeable Canutillo Formation aud Percha Shale.

07-00-00-00-00 — heading02 — Ordovician — Ordovician —

07-01-00-00-00—map unit—Om—Ordivician Montoya Dolomite—The El Paso Limestone unconformably underlies the Montoya Dolomite, which was differentiated from the El Paso by Richardson (1908). Although many workers in southern New Mexico (Kelley and Silver, 1952; Pray, 1958; Kottlowski, 1975) divide the Montoya into the Upham, Aleman, and Cutter Formations, Harbour (1972) considers the Upham, Aleman, and Cutter to be members within the Montoya Dolomite. For mapping purposes, we have chosen to follow Harbour's definition of the Montoya Dolomite. A fourth member of the Montoya, the Cable Canyon Sandstone Member, is absent in the Franklin Mountains, but is present at the base of the formation in the mountains farther north. The Montoya weathers to a gray to light-gray, ledgy slope along the east front of the northern Franklin Mountains. The lowermost unit of the Montoya, the Upham Dolomite Member, is a medium-grained, gray dolomite that weathers gray to dark gray. Above the Upham is the Aleman Dolomite Member, a fine-grained, dark-gray dolomite with conspicuous, abundant lenses and nodules of medium- to light-gray chert. Overlying the Aleman is the Cutter Dolomite Member, a fine-grained, dark-gray dolomite that weathers to light gray. The Upham Member (Middle Ordovician) and the Aleman and Cutter Members (Upper Ordovician) (Kottlowski and others, 1956: Howe, 1959) contain a few brachiopods, corals, and gastropods and abundant, dolomitized fossil debris. Thickness of the Montoya ranges from 116 m (380 ft), at a point 4.8 km (3 .0 mi) south of the New Mexico-Texas state line (Harbour, 1972), to 130 m (426 ft) at Bishop Cap (Kramer, 1970). The Upham, Aleman, and Cutter Members of the Montoya are 27 m (89 ft), 44 m (144 ft), and 52 m (170 ft) thick, respectively (Harbour, 1972); total thickness of the Montoya Dolomite in this area is 123 m (403 ft).

07-02-00-00-00—map unit—Oe—Ordivician El Paso Limestone—The El Paso Limestone (Lower Ordovician) is the oldest rock unit exposed in the northern Franklin Mountains. This formation, originally named by Richardson (1904) from exposures in the Franklin and Hueco Mountains, has been divided into three unnamed members by Harbour (1972). Only a portion of Harbour's upper dolomite and sandy limestone member is found in the Anthony quadrangle in a poorly-exposed outcrop just east of North Anthony's Nose. The outcrop consists of approximately 30 m (98 ft) of gray, cherty dolomite that weathers to light tan. The most common fossils in the El Paso Limestone (Lower Ordovician) are snails, brachiopods, trilobites, and conodonts (Harbour, 1972). Because the El Paso thins northward due to post-depositional, pre-Montoya erosion (Harbour, 1972), the outcrop exposed in the Anthony quadrangle is far below the depositional top of the El Paso section. The El Paso is approximately 369 m (1,210 ft) thick farther south in the Franklin Mountains (Harbour, 1972).