Base from U.S. Geological Survey:
Caballo, 1980; Polyconic projection, 1927 North American datum
(original base, was reprojected to Transverse Mercator as below).
Apache Gap, provisional edition1985; Transverse Mercator projection, 1927 North American datum.
10,000-foot grid based on New Mexico coordinate system, west zone.
1,000-meter Universal Transverse Mercator grid ticks, zone13, shown in blue.

Geology by William R. Seager and Greg H. Mack, 1990–1998
Drafting and layout by R. J. T. Taylor
Edited by J. C. Love; Cartographic review by Adam Read; Image georeferenced by Lewis Gillard

## UNIT DESCRIPTIONS

### Rio Grande valley

**Qvy** **Younger valley-fill alluvium**–Gravel, sand, silt, and clay deposits of arroyo floors, terraces, and alluvial fans that are graded to or within a few meters of the Rio Grande floodplain; as much as 15 m (49 ft) thick

**Qvyf** **Younger valley-fill fluvial deposits**–Gravel, sand, and clay deposits of the floodplain and river channels of the Rio Grande; as much as 21 m (69 ft) thick

**Qvo** **Older valley-fill alluvium**–Gravel, sand, silt, and clay that comprise at least three generations of terraces or alluvial fans whose surfaces are graded to approximately 24 m (79 ft), 33 m (108 ft), and 50 m (164 ft) above the floodplain of the Rio Grande. Pedogenic carbonate (stage II to stage IV) cements uppermost parts of deposits, especially the higher deposits. The unit interfingers with Qvof and is as much as 30 m (98 ft) thick

**Qvof** **Older valley-fill fluvial deposits**–Sand and cobble gravel with lesser silt and clay deposited by the Rio Grande. Unit interfingers with at least two of the three Qvo units; upper parts of the deposits are cemented by pedogenic carbonate (stage II to stage IV) and crop out as high as 50 m (164 ft) above the modern floodplain; as much as 15 m (49 ft) thick

**Qvou** **Intertonguing Qvo and Qvof**

**Qva** **Undifferentiated Qvy and Qvo**

### Jornada del Muerto and eastern slope of Caballo Mountains

**Qpy** **Younger piedmont-slope alluvium**–Sand, gravel, silt, and clay of modern, shallowly incised drainageways; alluvial fans at the mouths of such drainageways, and broad but thin pediment veneers. Deposits are graded to the surfaces of playas and alluvial flats near the center of the Jornada del Muerto; as much as 6 m (20 ft) thick

**Qpo** **Older piedmont-slope alluvium**–Gravel and gravelly sand deposits of arroyos, alluvial fans, and pediment veneers that are intermediate in geomorphic position between higher Palomas (Qpg) deposits and lower (Qpy) alluvium. At least two generations of Qpo deposits are locally present. Upper part of Qpo deposits is cemented by stage II to stage IV pedogenic carbonate; as much as 7 m (23 ft) thick

**Qpa** **Undifferentiated Qpy and Qpo**

### Caballo Mountains and Red Hills

**Qpg** **Palomas Formation, upper proximal piedmont-slope facies**–Boulder to pebble conglomerate, gravel, sandstone, sand, and mudstone derived from Caballo and Red Hills fault blocks; contains zones of stage III or stage IV pedogenic carbonate as much as 0.8 m (2.6 ft) thick, especially at the top; unit overlies QTpf west of Caballo and Red Hills fault, but above the fault the unit forms a relatively thin (1–20-m-thick) pediment veneer on bedrock; unit is 20 m (66 ft) or more thick near mountain front faults, thinning basinward

**QTpt** **Palomas Formation, transitional facies**–Massive, unbedded, fine- to medium-grained sandstone and mudstone, mapped only locally, that may represent mudflow deposits on distal piedmont slopes adjacent to the ancestral Rio Grande floodplain; as much as 15 m (49 ft) thick

**QTpf** **Palomas Formation, fluvial and associated facies**–Light-gray, yellow, and pink to tan sand, sandstone, gravel, conglomerate, conglomeratic sandstone, and mudstone representing fluvial-channel and overbank deposits of the ancestral Rio Grande; may include deposits of sand, silt, or loamy sediments deposited on alluvial flats or in eolian environments; tongues of piedmont-slope conglomerate (QTpc) are interbedded locally within the unit; as much as 100 m (328 ft) thick

**QTpc** **Palomas Formation, lower proximal piedmont-slope facies**–Well to moderately cemented, tan to reddish-brown, boulder to cobble-pebble conglomerate and conglomeratic sandstone; derived from Red Hills and Caballo fault blocks; underlies and intertongues laterally with QTpf. Near mountain fronts the unit is gradational upward into Qpg; at least 50 m (164 ft) thick

**QTpu** **Palomas Formation, Qpg and QTpc undifferentiated**–100 m (328 ft) thick

**QTp** **Palomas Formation, distal piedmont-slope facies**–Pink, tan, and gray sandstone, siltstone, and mudstone with thin soil-carbonate horizons and thin to thick (10 m [33 ft]) interbeds of pebble-cobble conglomerate that increase in number and coarseness westward; unit comprises the distal parts of Black Range alluvial fans west of the Rio Grande and represents environments of deposition ranging from arroyo channel and overbank to alluvial flat; intertongues locally with QTpf; at least 90 m (295 ft) thick

**Tb** **Alkali-olivine basalt**–Flows and cinders that underlie and interfinger with the base of QTpc; whole rock K–Ar age is 3.1 ± 0.1 Ma; as much as 10 m (33 ft) thick

**Trvc** **Rincon Valley Formation, conglomerate facies**–Reddish-brown conglomerate and conglomeratic sandstone derived largely from Paleozoic strata; volcanic-clast component increases downsection; strata represent "early rift" alluvial fan and distal piedmont-slope deposits derived from an early stage of uplift of the Caballo Mountains; at least 335 m (1,100 ft) thick

**Thr** **Hayner Ranch Formation**–Light-gray to brown conglomerate, conglomeratic sandstone, and mudstone derived largely from middle Tertiary volcanic rocks; content of Paleozoic clasts increases upward in section; formation represents alluvial-fan and distal piedmont-slope deposits derived from an early stage of uplift of the Caballo Mountains; at least 305 m (1,000 ft) thick

**Tt** **Thurman Formation**–White to light-tan to light-gray, tuffaceous, volcaniclastic sandstone and pink mudstone; bedding ranges from massive, nonsorted to thin and parallel to channel form, the latter filled with tough crossbeds; as much as 508 m (1,666 ft) thick

**Tba** **Dikes**–Dark-gray andesite, andesite-porphyry, and basaltic-andesite dikes, 1–5 m (3–16 ft) thick. $^{40}Ar/^{39}Ar$ age is 26.8 Ma

**Tr** **Dikes**–Gray to cream flow-banded rhyolite dikes 1–3 m (3–10 ft) thick

**Tbt$_T$** **Bell Top Formation, ash-flow tuff 7**–Gray to brownish-gray, fine-grained, vitric ash-flow tuff; approximately 3 m (10 ft) thick

**Tbt$_4$** **Bell Top Formation, ash-flow tuff 6**–Gray to pinkish-gray, moderately welded, crystal-rich ash-flow tuff; approximately 15 m (49 ft) thick where separated from Kneeling Nun Tuff by channel-fill deposits of Tbc; apparently merges with and is indistinguishable from Kneeling Nun Tuff in westernmost outcrops in Apache Valley

**Tbc** **Bell Top Formation, conglomerate member**–Reddish-brown to tan conglomerate and conglomeratic sandstone, pink to tan mudstone, and white tuffaceous sandstone. Boulder and cobble clasts consist predominately of Kneeling Nun Tuff; intermediate-composition volcanic porphyries, and lesser amounts of Paleozoic limestone, the latter two types probably reworked from Love Ranch Formation; Tbt$_4$ is locally interbedded with the conglomerate member, dividing it into upper and lower units; approximately 50 m (164 ft) thick

**Tkn** **Kneeling Nun Tuff**–Grayish-pink, crystal- and pumice-rich ash-flow tuff; apparently merges with and is indistinguishable from Tbt$_4$ in westernmost outcrops in Apache Valley; approximately 30 m (98 ft) thick

**Tppl** **Palm Park Formation**–Basal unit of cobble-boulder conglomerate contains a large proportion of porphyritic, intermediate-composition lava or hypabyssal intrusive clasts and lesser amounts of Paleozoic and Precambrian clasts; several such beds totaling 100 m (328 ft) or more are present in adjacent areas, but only the basal few meters are exposed in the Caballo or Apache Gap quadrangles. The rest of the formation consists of tuffaceous, purple, gray, green, and red volcanic mudstone, sandstone, and lahar breccia, mostly intermediate in composition; fresh water algal limestone beds and travertine mounds (Tppl), as much as 30 m (98 ft) thick, are interbedded at the top of the formation; approximately 610 m (2,000 ft) thick

**Tpp**

**Tlr** **Love Ranch Formation**–Reddish-brown to reddish-gray cobble-boulder conglomerate, conglomeratic sandstone, arkosic sandstone, siltstone, and mudstone. Conglomerate clasts include Paleozoic carbonate, Precambrian granite, and intermediate-composition porphyritic rocks of late Cretaceous age. Discontinuous fresh water limestone beds, as much as 15 m (50 ft) thick, are locally present at the base and top of the formation. Total thickness in the map area is approximately 152 m (500 ft), except in the Red Hills area where the formation fills a deep Laramide paleocanyon and is approximately 550 m (1,804 ft) thick

**K** **Undifferentiated Kcl, Kg, Kdc, Kt, Km, Kd**

**Kcl** **Crevasse Canyon Formation, lower member**–Exposed only in adjacent quadrangles but is shown on cross sections; interbedded nonmarine, gray to tan fluvial sandstone, olive-brown crevasse splay sandstone, and brown to olive-brown overbank mudstone and fine sandstone; contains large (> 1 m [> 3 ft]) calcareous, ironrich concretions; approximately 305 m (1,000 ft) thick

**Kg** **Gallup Sandstone**–Massive to crossbedded, cream to gray marine sandstone and minor marine shale, gradational downward into D-Cross Tongue of Mancos; approximately 23 m (108 ft) thick

**Kdc** **D-Cross Tongue of Mancos Shale**–Dark-gray, fissile marine shale with thin interbeds of fossiliferous sandstone and siltstone; 20 m (66 ft) thick

**Kt** **Tres Hermanos Formation**–Brown, fossiliferous, burrowed marine sandstone of the upper **Fite Ranch Member** overlies fluvial brown sandstone and olive-green mudstone of the **Carthage Member** and brown and greenish-brown, fossiliferous, burrowed marine sandstone of the lower **Atarque Member**. Total thickness is approximately 100–106 m (328–348 ft)

**Km** **Mancos Shale**–Thin-bedded to fissile, fine siltstone and shale with at least 5 ash beds, each 6–12 cm (2–5 inches) thick; approximately 120 m (394 ft) thick

**Kd** **Dakota Sandstone**–Upper marine shale and marine, crossbedded quartzose sandstone overlies lower yellow-brown, crossbedded, fluvial, quartzose sandstone. Upper unit grades into overlying Mancos Shale. Thickness ranges from 2 to 44 m (7 to 144 ft) because of relief on the unconformity at the base of the formation

**Pyu** **Upper Yeso Formation**–Upper **sandstone–dolomite member** consists of approximately 100 m (328 ft) of interbedded gray limestone, dolomite, and yellow sandstone with local lenses of gypsum. Lower **limestone member** consists of approximately 26 m (85 ft) of medium-bedded, fossiliferous, gray limestone with minor interbeds of yellow sandstone or siltstone

**Pyl** **Lower Yeso Formation**–Upper **red siltstone–dolomite member**, approximately 195 m (640 ft) thick, includes three thin (< 20 m [< 66 ft]) limestone/dolomite units within a sequence of massive gypsum and red siltstone and sandstone beds. Basal **Meseta Blanca Member** consists of approximately 72 m (236 ft) of poorly exposed, brick-red sandstone and siltstone

**Pa** **Abo Formation**–Red fluvial sandstone and siltstone interbedded with gray-ish-red to red overbank shale; approximately 305 m (1,000 ft) thick

**IP** **Undifferentiated IPb, IPn, IPr**

**IPb** **Magdalena Group, Bar B Formation**–Upper 100 m (328 ft) is correlative with Bursum Formation and consists of interbedded red to maroon sandstone and shale, limestone pebble conglomerate, and thin marine, as well as nonmarine, limestone beds. Interbedded gray- to brown-weathering, fossiliferous marine limestone, micrite, and prominent gray shale compose lower 180 m (590 ft). Bar B Formation thickens southward from approximately 281 m (920 ft) in Apache Gap quadrangle to 410 m (1,345 ft) in Alvio quadrangle

**IPn** **Magdalena Group, Nakaye Formation**–Thick-bedded, cliff- or ledge-forming, gray limestone, including many cherty, fossiliferous, and burrowed beds. Green, red, and gray shale beds, generally < 2 m (< 6.5 ft) thick, are interbedded; approximately 200 m (656 ft) thick

**IPr** **Magdalena Group, Red House Formation**–Interbedded gray marine shale, discontinuous brown, channel-shaped sandstones, and thin to medium beds of fossiliferous limestone, some of which contain abundant black chert; thickness ranges from 35 m (115 ft) to approximately 86 m (282 ft)

**Dp** **Percha Shale**–Greenish-gray to black, micaceous shale containing a few thin limestone beds in middle part; generally approximately 46 m (150 ft) thick but was removed by pre-Pennsylvanian erosion across much of the Red Hills area and from Burbank Canyon northward

**Sf** **Fusselman Dolomite**–Brown, cherty dolomite in thick to medium beds, sandy at base; generally 26–30 m (85–98 ft) thick in southern part of area but thins to zero northward as a result of pre-Percha and pre-Pennsylvanian erosion

**Om** **Montoya Dolomite**–Formation is capped by 43 m (141 ft) of light to medium-gray, medium-bedded **Cutter Dolomite Member** followed, in descending order, by 46 m (151 ft) of very cherty, light to dark-gray, fine- to medium-grained **Aleman Dolomite Member**; 21 m (69 ft) of massive, dark-gray, coarse-grained **Upham Dolomite Member**; and approximately 8 m (26 ft) of basal tan to brown, coarse-grained **Cable Canyon Sandstone Member**. Total thickness is approximately 119 m (390 ft), but formation is locally thin or missing due to pre-Pennsylvanian erosion

**Oe** **El Paso Formation**–Upper **McKelligon Canyon Member** is 54 m (177 ft) thick and is largely light colored, fine-grained dolomite. Medial **Jose Member**, approximately 7 m (23 ft) thick, is dark-gray, burrowed and mottled, oolitic limestone. Lower **Hitt Canyon Member** consists of approximately 91 m (298 ft) of medium-bedded, burrowed, mottled limestone, sandy at the base. Total thickness is approximately 152 m (498 ft); thins northward

**€Ob** **Bliss Formation**–Brown to nearly black, hematitic to glauconitic, arkosic sandstone and gray orthoquartzite; dark-brown to greenish-brown siltstone, dolomite, limestone, and shale; and minor dark-maroon, oolitic ironstone; approximately 35 m (115 ft) thick

**p-Cg** **Caballo granite**–Red, coarse- to fine-grained microcline granite containing widely scattered and small red syenite (p€Cg) plutons

**p-Cgpm** **Caballo granite, pegmatite facies**–White to light-gray pegmatite at northern margin of Caballo granite; grades into main body of Caballo granite. Pegmatites are in form of semi-concordant sheets, as well as discordant, irregular bodies, both of which complexly intrude amphibolite and other metamorphic wall rock of the batholith

**p-Cn** **Northern granite**–Heterogeneous assemblage of 1) pink to gray, coarse-grained granite; 2) gray, coarse-grained, porphyritic granite or granodiorite that may be Longbottom granodiorite; 3) brown, massive, granular granite with thin lenticular schistose zones; 4) small (100–300 m [328–984 ft]) bodies of red granite; 5) numerous small (< 1 m [< 3 ft]) to large (> 100 m [> 328 ft]) xenoliths and/or irregular septa (ft) of amphibolite with lesser gneiss and schist. Unit is primarily granite and granite gneiss, apparently with mutually gradational contacts. Amphibolite, schist, and gneiss have sharp, crosscutting contacts with enclosing granitic rocks. None of the units were mapped in detail

**p-Cgd** **Granite dikes**–Pink to lightbrown, medium-grained granite dikes as much as 15 m (50 ft) wide that trend northnorthwest; cut metamorphic rocks as well as Longbottom granodiorite

**p-Cg** **Longbottom granodiorite**–Medium- to dark-gray, coarse-grained granodiorite containing abundant and conspicuous phenocrysts of microcline and plagioclase as much as 3 cm (1.5 inches) long. Contains many angular xenoliths of metamorphic rocks, is locally flow foliated at the margins, and has complexly intruded metamorphic foliation in wall rock

**p-Cd** **Diorite**–Dark- to medium-gray, medium-grained diorite or gabbro in small bodies adjacent to Longbottom granodiorite and at deepest levels of exposure of the "northern granite"

**p-Cs** **Syenite**–Small bodies of red, coarse-grained syenite mapped north of Longbottom Canyon. Other similar but unmapped plutons in the Caballo granite, especially in the Red Hills, may be of late Cambrian age

**p-Cm** **Metamorphic rocks**–Interlayered amphibolite schist and gneiss, biotite schist, mica schist, quartz-feldspar-mica schist, and brown quartz-feldspar gneiss; strongly foliated and isoclinally folded; complexly intruded by marginal pegmatites of Caballo granite, as well as by Longbottom granodiorite

**p-Ca** **Amphibolite**–Black amphibolite schist and gneiss and biotite schist; forms many conspicuous lenses, at least some of which are boudins, as well as thick to thin, somewhat continuous layers within the metamorphic sequence between Burbank and Longbottom Canyons; weakly to strongly foliated; contains local lenses and pods of both concordant and discordant quartz

**p-Cgn** **Brown gneiss**–Brown- to tan- to reddish-brown-weathering quartz-feldspar-biotite gneiss containing minor amounts of interlayered pelitic schist and amphibolite; distinct coarse-grained, foliated texture

**p-Cgd** **Red felsic gneiss**–Brick-red, fine- to medium-grained gneiss with indistinct, thin, laminae-like foliation

**p-Cagn** **Amphibolite and brown gneiss, undifferentiated**

### MAP SYMBOLS

- Geologic contact–Dashed where approximately located, dotted where buried
- Upslope limit of fluvial facies of the Palomas Formation
- Normal fault–Ball on downthrown side; short arrow shows direction and amount of dip; long arrow shows trend and plunge of lineation on fault surface; dashed where inferred or approximately located, dotted where buried
- Thrust fault–Barbs on upthrown side; short arrow shows direction and amount of dip, long arrow shows trend and plunge of lineation on fault or on rhyolite dikes that have invaded fault; dashed where inferred or approximately located, dotted where buried
- Strike-slip (tear) fault–Arrows show relative motion; dashed where inferred or approximately located
- Anticlinal hinge–Showing plunge direction; dashed where inferred or approximately located, dotted where buried
- Synclinal hinge–Showing plunge direction; dashed where inferred or approximately located, dotted where buried
- Overturned anticlinal hinge
- Overturned synclinal hinge
- Monoclinal flexure
- Strike and dip of bedding
- Strike and dip of overturned bedding
- Arrow shows trend and amount of apparent dip of bedding
- Horizontal bedding
- Vertical bedding
- Strike and dip of metamorphic foliation; arrow shows trend and plunge of lineation
- Vertical foliation in metamorphic rocks
- Landslide mass (fragmented), showing breakaway scarp
- Toreva block landslide
- A–A' Line of cross section

INDEX MAP OF NEW MEXICO

1. Saladone Tank
2. Williamsburg
3. Palomas Gap
4. Cutter
5. Skute Stone Arroyo
6. Upham
7. Clark Spring Canyon
8. Garfield
9. McLeod Tank
10. Alivio

ADJOINING 7.5' QUADRANGLE NAMES

Mapped by W. H. Seager 1990–1991; 1996–1998

Mapped by G. H. Mack, 1996–1998

Scale 1:24,000

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 KILOMETER

1 MILE

NATIONAL GEODETIC VERTICAL DATUM OF 1929
CONTOUR INTERVAL: CABALLO 20 FT, APACHE GAP 40 FT

APPROXIMATE MEAN DECLINATION, 2005

# Geology of Caballo and Apache Gap quadrangles, Sierra County, New Mexico

by William R. Seager and Greg H. Mack, 2005
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## CORRELATION OF UNITS

| Rio Grande valley | | Jornada del Muerto and eastern piedmont slopes of Caballo Mountains | Radiometric ages (Ma) | |
|---|---|---|---|---|
| Qvyf, Qvy | Qvy | Qpy, Qpa, Qpo | | Holocene |
| Qvof, Qvou, Qvo | Qvo | Qpo | 0.6–0.75 | Upper Pleistocene |
| unconformity | | | | |
| QTpf, QTpc, QTpt | QTp | | 1.3–3.1 | Lower Pleistocene to Pliocene |
| Tb | | | 3.1 | |
| unconformity | | | | |
| Trvc | | | | Miocene |
| Thr | | | | Miocene to upper Oligocene |
| Tt | | | 27.4–28.6 | |
| Tbt$_T$, Tbc | | | 26.8 | Tbt$_T$ |
| Tbt$_4$ | | | 33.6 | |
| Tbc | | | 34.9 | Tr |
| Tkn | | | | |
| Tppl, Tpp | | | 51.5–36.7 | Oligocene |
| Tlr | | | | Eocene |
| unconformity | | | | |
| Kcl | | | | |
| Kg | | | | |
| Kdc | | | | K |
| Kt | | | | Upper Cretaceous |
| Km | | | | |
| Kd | | | | |
| unconformity | | | | |
| Pyu | | | | |
| Pyl | | | | Permian |
| Pa | | | | |
| IPb | | | | IP |
| IPn | | | | Pennsylvanian |
| IPr | | | | |
| unconformity | | | | |
| Dp | | | | Devonian |
| unconformity | | | | |
| Sf | | | | Silurian |
| unconformity | | | | |
| Om | | | | Ordovician |
| unconformity | | | | |
| Oe | | | | Ordovician and Cambrian |
| €Ob | | | | |
| nonconformity | | | | |
| p-Cs | | | | Precambrian |
| p-Cgd | | | | |
| age relationship not known | | | | |
| p-Cgpm, p-Cg | | | | |
| p-Cm | | | | |
| p-Cd | | | | |
| p-Cgn | | | | |
| p-Cagn | | | | |
| p-Cgnf | | | | |