GEOLOGIC MAP OF THE PONDEROSA 7.5-MINUTE QUADRANGLE, SANDOVAL COUNTY, NEW MEXICO

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Quaternary Sedimentary Rocks

Frankel and Pazzaglia (2002) present a separate and more detailed map of Quaternary deposits. In general, the Quaternary units on this map are simplified compared to the Frankel and Pazzaglia (2002) map. Readers seeking more detailed Quaternary information are referred there.

Qal Alluvium - Holocene: Predominantly gravel, sand, silt, and clay underlying modern drainage channels and floodplains. Interfingers with colluvium toward drainage side-slopes. Locally contains small amounts of alluvial fan, colluvium and other Quaternary lithotypes. Generally <3m thick.

Qfy Alluvial fan - Holocene: Active alluvial fans composed primarily of cobble and boulders with matrix of sand, silt and clay. Poorly stratified. 1 - 10 m thick. One is dated at 1660 ± 70 radiocarbon years BP (Beta # 85445; Formento-Trigilio, 1997).

Qe Upland alluvium, colluvium, and eolian deposits, undivided: Holocene to upper Pleistocene (?): Poorly sorted alluvial gravel, sand, and silt interbedded with fine-grained, well-sorted eolian sand and silt. May be locally interbedded with El Cajete ash (Qec). Commonly found in flat, broad areas adjacent to major drainages on the flat tops of ridges and divides where other alluvial units are not mapped. Generally <10 m thick.

Qc Colluvium, talus and related hillslope deposits: Undivided hillslope deposits consisting of locally derived pebbly to boulder size clasts with or without finer matrix. May be clast or matrix supported. In general, mapped only where underlying bedrock contacts were obscured. Extensively subdivided by Frankel and Pazzaglia, 2002. Generally 1-50m thick.

Qcbt Bandelier Tuff colluvium and related hillslope deposits - middle Pleistocene to Holocene (?): Hillslope colluvial deposits composed of pebble to boulder size clasts of Bandelier Tuff derived from mesa cap rocks. Poorly sorted and poorly stratified. Matrix and clast supported. Significant accumulations found in Cañon de San Diego, Cañon de la Canada, San Juan Canyon, and Paliza Canyon. Generally from ~ 5 - 50 m thick.

Qls Landslide deposit - middle Pleistocene to Holocene: Undivided landslide deposits composed of locally derived, cohesive blocks of Triassic, Miocene, and Permian bedrock, and Bandelier Tuff. The Zia Formation is a common component of slides on the west side of Borrego Mesa; these slides commonly have reworked El Cajete pumice on the top surface. Generally associated with a head scarp in their source area. Varies in thickness from ~ 5 - 50 m.

Qlsy Landslide deposit - late Pleistocene: Two landslide deposits just northeast and east of Ponderosa *overlie* what appears to be El Cajete pumice. The pumice, which has not been dated at these localities, contains biotite, a mineral commonly found in El Cajete pumice. Thus, the landslides are likely to be younger than 60 ka. The El Cajete pumice at UTM coordinates 13S 351329 3950183 (NAD27) on National Forest land, which is about 0.6 m thick, is a primary fall deposit because it is weakly stratified. In an exposure just to the south, the El Cajete Pumice is underlain by organic material (charcoal?) and is overlain by a fine-grained, ash fall. The material in this slide is different than the debris in the other landslides in the area because it contains Triassic Chinle at the base, overlain by Jurassic Entrada Sandstone, Jurassic Todilto gypsum, and rounded gravel of uncertain origin that includes Proterozoic granite and quartzite clasts. A second landslide exposure, with Chinle mudstone sliding over El Cajete pumice, which in turn rests on Chinle mudstone, is at 13S 350758 3948958 (NAD 27) on private land.

Qrsa Andesite rockslide deposit - middle Pleistocene to Holocene:
Rockslide composed of cobble to house size clasts of andesite. Generally related to a prominent head scarp along the west side of Borrego Mesa. Poorly stratified. Generally 5 - >50 m thick.

Qt_n Terrace deposits - middle Pleistocene to Holocene: Alluvial silt, sand, cobble, and boulder deposits of volcanic, granitic, and sandstone provenance overlying distinct straths and underlying discrete treads related to the large modern drainages of the Jemez River and Vallecito Creek. Commonly exhibits a coarse, fine, coarse alternating Pleistocene stratigraphy.

Qt_7 Terrace deposits – Holocene: Red to tan, fine-grained silt and sand alluvial fill with locally well-rounded cobbles. Treads are up to ~ 3 m above modern drainages. Strath is ~ 1 - 2 m above active channel. Age of deposit along the Jemez River is 3160 ± 60 radiocarbon years (LLNL # 24692; Formento-Trigilio, 1997) and 4530 ± 40 radiocarbon years (Beta # 160851) along Vallecito Creek. ~ 1 - 5 m thick. Qt_6 of Formento-Triglio (1997).

Qt_6 Terrace deposits – Holocene: Fine grained, red to tan alluvial silt and sand alluvial fill. Strath is < 8 m above active channel. Qt_5 of Formento-Trigilio (1997). ~ 1 - 5 m thick.

Qt_5 Terrace deposits - late Pleistocene: Coarse grained gravel and and boulder material interbedded with pebbly sand. Clasts are composed of 24% Bandelier Tuff, 20% Tertiary volcanics, 14% Banco Bonito (~ 60 ka) in the Jemez River valley (Reneau et al., 1996, Formento-Trigilio, 1997). Qt_{4a} of Formento-Trigilio (1997). Strath is ~ 10 m above active channel. ~ 8 - 10 m thick.

Qt_4 Terrace deposits - middle to late Pleistocene: Alluvial sands and gravels composed of 34% Bandelier Tuff, 20% Madera Limestone, and 13% Precambrian granite with lesser amounts of Permian sandstone and Tertiary volcanics in the Jemez River valley. Locally cemented by calcium carbonate. A late Pleistocene/early Holocene soil is developed in an eolian deposit on the terrace tread that buries a Bk soil horizon with Stage II carbonate development. ~ 9 m thick. Highly variable strath topography ranging from 4 to 36 meters above active channel (Formento-Trigilio, 1997).

Qt_3 Terrace deposits - late to middle Pleistocene: Coarse, stratified, sandy gravel deposit composed of 41% Bandelier Tuff, 17% Madera Limestone, 17% Precambrian granite and lesser amounts of Permo-Triassic sandstone in the Jemez River valley. Strath exhibits up to 1 m of relief and ranges from 30 to 63 m above modern channel. ~ 10 m in thickness. An Ochric A soil horizon overlies a Bk soil horizon with Stage II - III carbonate development beneath the tread. (Formento-Trigilio, 1997).

Qt_2 Terrace deposits - middle Pleistocene: Coarse-grained sand and gravel interbedded with fine-grained, cross-bedded, sand and silt. Deposit is ~13 m thick. Gravels are composed of 32% Bandelier Tuff, 17% Madera Limestone, 19% Precambrian granite and lesser amounts of Permo-Triassic sandstones in the Jemez River valley. Strath is characterized by up to 1 m of relief and ranges from 61 to 84 m above active channel. Tread exhibits an incomplete K soil horizon with Stage III+ carbonate development. (Formento-Trigilio, 1997).

Qt_1 Terrace deposit - middle Pleistocene: Coarse sand and gravel interbedded with fine-grained silt and sand. Deposit is ~ 14 m thick Gravels are composed of 27% Madera Limestone, 27% Bandelier Tuff, and 23% Precambrian granite with lesser amounts of Tertiary volcanics, quartzite, and chert in the Jemez River valley. Locally cemented by calcium carbonate. Reworked Lava Creek B ash (640 ka; Dethier, 2001) is locally present in fine-grained layers. Tread exhibits an incomplete K soil horizon with Stage III+ carbonate development. Strath ranges from 83 – 100 m above modern channel (Formento-Trigilio, 1997).

Qp_n Pediment deposits - early to late Pleistocene: Alluvial deposits of various clast compositions relating to source in ephemeral tributary drainages. Generally composed of cobble to boulder size clasts. Deposits are of variable thickness and have straths of variable topography that is often obscured by colluvium derived from the pediment deposit. Treads of deposits are relatively flat and grade back towards mesas.

Qp_5 Pediment deposit - middle to late Pleistocene: Piedmont alluvial deposits found on relatively flat treads grading back towards mesas. Composed of cobble to boulder size clasts of Triassic bedrock and basalt from Borrego Mesa as a function of source area and drainage. Deposit is ~5 - 10 m thick. Correlative with Qt_5 terrace elevations.

Qp_4 Pediment deposit - middle to late Pleistocene: Piedmont alluvial deposits found on relatively flat treads grading back towards mesas. Composed of cobble to boulder size clasts of Triassic bedrock, Bandelier Tuff, and basalt from Borrego Mesa as a function of source area and drainage. Deposit is ~ 5 - 10 m thick. Correlative with Qt_4 terrace elevations.

Qp_3 Pediment deposit - early to middle Pleistocene: Piedmont alluvial deposits found on relatively flat treads grading back towards mesas. Composed of cobble to boulder size clasts of Triassic and Permian bedrock, Bandelier Tuff and basalt derived from Borrego Mesa as a function of source area and drainage. Deposit is ~ 10 - 15 m thick. Correlative with Qt_3 terrace elevations.

Qp_2 Pediment deposit - early to middle Pleistocene: Piedmont alluvial deposits found on relatively flat treads grading back towards mesas. Composed of cobble to boulder size clasts of Tertiary (Miocene) bedrock and basalt derived from Borrego Mesa as a function of source area and drainage. Deposit is ~ 10 - 15 m thick. Correlative with Qt_2 terrace elevations.

Qp_1 Pediment deposit - early to middle Pleistocene: Piedmont alluvial deposits found on relatively flat treads grading back towards mesas. Composed of cobble to boulder size clasts of basalt derived from Borrego Mesa. Deposit is ~ 5 - 10 m thick. Correlative with Qt_1 terrace elevations.

Qp Pediment deposit - early to late Pleistocene: Undivided piedmont alluvium found on relatively flat treads grading back towards mesas. Composed of cobble to boulder size clasts of Bandelier Tuff, Triassic and Permian bedrock, and basalt as a function of source area and drainage. Ranges in thickness from ~ 5 - 15 m.

Qtr Travertine deposit – Middle to late Pleistocene: Light gray irregularly bedded limestone or travertine. One travertine deposit overlies pink to tan fluvial sandstones of uncertain age (Santa Fe Group?) on the south-dipping Glorieta Sandstone surface east-southeast of Red Rocks. Further south, travertine sits on the pediment gravel and is reworked into the base of the Qt_4 terrace gravel. This relationship suggests that the travertine is older than 150,000 ± 50,000 years, the estimated age of the Qt_4 terrace (Formento-Trigilio and Pazzaglia, 1998) and is younger than the pediment gravel. The elevation of the pediment gravel appears to correspond to 400,000 ± 100,000 year Qp2 (Formento-Trigilio and Pazzaglia, 1998). A second, more extensive travertine deposit is located north of Vallecitos Creek and rests on Zia Sandstone. 1-3 m thick.

<u>Quaternary Volcanic and Sedimentary Rocks (Tewa Group)</u>

Qec El Cajete pumice - middle to late Pleistocene. White to tan, moderately sorted, pyroclastic fall deposits of vesicular pumice containing sparse phenocrysts of quartz, biotite, and plagioclase with rare microphenocrysts of hornblende and clinopyroxene; Qec originated north of map area from E1 Cajete crater in southern moat of Valles caldera (Bailey et al., 1969; Smith et al., 1970; Gardner et al., 1986; Self et al., 1988; Wolff and Gardner, 1995); unit dated at about 50 to 60 ka (Toyoda et al., 1995; Reneau et al., 1996). Maximum exposed thickness about 10 m in northeast part of map area, where the unit forms extensive mesa top cover on San Juan Mesa. In the eastern and southeastern parts of the map area, the El Cajete pumice is thin (~ 15 cm) and has been fluvially reworked.

Qbt Upper Bandelier Tuff (Tshirege Member) – early Pleistocene: White to orange to pink welded to non-welded rhyolitic, ash-flow tuff (ignimbrite) containing abundant phenocrysts of sanidine and quartz, rare microphenocrysts of black clinopyroxene and trace microphenocrysts of hypersthene and fayalite; sanidine typically displays blue iridescence; consists of multiple flow units in a compound cooling unit (Smith and Bailey, 1966; Broxton and Reneau, 1995; Gardner et al., 2000). Most exposures are incipiently to poorly welded, although units on San Juan Mesa are locally welded. Locally contains a thin (<2 m) laminated, pumice fall and surge deposit at base of unit (Tsankawi Pumice) that contains roughly 1% of hornblende dacite pumice (Bailey et al., 1969). Locally contains accidental lithic fragments of older country rock entrained during venting and pyroclastic flow, especially on San Juan Mesa, where the white tuff capping the mesa contains 5 to 10% lithic fragments. **Qbt** forms conspicuous orange to tan mesa-capping cliffs; originated from catastrophic eruptions that formed Valles caldera. $^{40}Ar/^{39}Ar$ age is 1.22 ± 0.01 Ma (Izett and Obradovich, 1994; Spell et al., 1996). Maximum observed thickness ~ 140 m.

Qog$_2$ Old fluvial gravel – early Pleistocene. *Not shown on map, but exposed in cliff walls in Virgin Canyon and Cañon de San Diego east and west of Virgin Mesa.* Fluvial gravel and sandstone deposits underlying air fall Tsankawi pumice of the Tshirege member of the Bandelier Tuff and overlying the Otowi member of the Bandelier Tuff. At southern tip of Mesa de Guadalupe, this gravel lies beneath the upper member of the Bandelier Tuff and contains rounded pieces of Qbo. The clasts are composed predominantly of Paliza Canyon andesite and basalt (80%) and Abo, Yeso and Glorieta sandstones (20%). Ranges in thickness from ~ 1 – 6 m. Stratigraphically equivalent to the Cerro Toledo Interval epiclastic sediment and tephra deposits on the Pajarito Plateau (Broxton and Reneau, 1995).

Qbo Lower Bandelier Tuff (Otowi Member) – early Pleistocene: White to pale pink, generally poorly welded rhyolitic ash-flow tuff containing abundant phenocrysts of sanidine and quartz, and sparse mafic phenocrysts; sanidine may display a blue iridescence. Contains abundant accidental lithic fragments; consists of multiple flow units in a compound cooling unit. The stratified pumice fall and surge deposit at base of unit (Guaje Pumice) is generally not found in this area. Qbo discontinuously fills in rugged topography on a pre Toledo caldera age volcanic surface and can form spectacular tent rocks; upper surface quite undulatory due to erosion. Very difficult to distinguish from upper Bandelier Tuff in hand samples; best distinguished by poorer degree of welding, greater tendency to form slopes instead of cliffs, more abundant lithic fragments, less abundant iridescent sanidine, and stratigraphic position beneath the Tsankawi Pumice. On Cat Mesa, the characteristic lithic-rich tuff is overlain by a more welded, pink, lithic-free tuff. Originated from catastrophic eruptions that formed Toledo caldera; $^{40}Ar/^{39}Ar$ ages 1.61± 0.01 to 1.62±0.04 Ma (Izett and Obradovich, 1994; Spell et al., 1996); maximum exposed thickness about 100 m.

Qog$_2$ Fluvial gravel and sandstone – early Pleistocene. *Not shown on map, but exposed in cliff walls of Cañon de San Diego east of Virgin Mesa.* Tan fluvial sandstone and gravel deposit between the Otowi member of the Bandelier Tuff and the San Diego Canyon Tuff. Gravel composed of imbricated Paliza Canyon andesite boulders and pebbles. Maximum of 4 m thick.

Qsd San Diego Canyon Tuff – early Pleistocene: *Not shown on map, but exposed in cliff walls in Cañon de San Diego east of Virgin Mesa down to the southern end of Virgin Mesa.* Gray to white, nonwelded to poorly welded ash flow tuff containing phenocrysts of quartz and sanadine with trace pyroxene and magnetite. The deposit consists of two units (Tuberville and Self, 1988). The lower unit (A) is nonwelded and is comprised of abundant lithic fragments. The lithic fragments are dominantly basalt and andesite from the underlying Paliza Canyon Formation, with minor Proterozoic plutonic and metamorphic components (Tuberville and Self, 1988). The maximum clast size is 25 cm (Tuberville and Self, 1988). The upper unit (B) is nonwelded to slightly welded and contains large pumice clasts characterized by vesicles with high aspect ratios. A third unit not previously recognized is present near the northern boundary of the quadrangle on the west wall of Cañon de San Diego. Locally, the units are separated by fluvial gravels and mudstones. The tuff is underlain by the Paliza Canyon debris avalanche in the northern part of the area and by the Qtog to the south tip of Virgin Mesa. Spell et al. (1990) determined $^{40}Ar/^{39}Ar$ ages of 1.79 ± 0.04 Ma for the lower unit and 1.78 ± 0.07 Ma for the upper unit. Locally, debris flows or fluvial gravels (**Qsg**) occur between the units, but the sedimentary packages are too thin (< 2 m) and too discontinuous to show on the map. One of the best exposures of fluvial gravel between the units is near the northern edge of the quadrangle on the west side of Cañon de San Diego. Thickness ranges from 2 to 20 m.

QTog Old fluvial gravel– late Pliocene(?). Alluvial to fluvial gravel and sandstone deposits underlying the San Diego Canyon Tuff or the Bandelier Tuff. Clasts are generally sub-rounded to well rounded, and are pebble to boulder size. Clasts are in a silt to sand size matrix or are clast supported. Occasional fining upwards sequences are present. Gravel clasts composed predominantly of Paliza Canyon volcanics with occasional granite, sandstone, conglomerates, and rare Pedernal chert. The sandstones locally contain abundant pumice clasts that are likely derived from the lower unit of the San Diego Canyon Tuff. Well exposed both west and east of Virgin Mesa. These deposits could be equivalent to gravels of the Quaternary/Tertiary Cochiti Formation (Smith and Lavine, 1996), which contains predominantly rounded, volcanic clasts. Varies in thickness from ~ 1 – 12 m.

Keres Group Volcanic Rocks (Miocene)

Tpa Paliza Canyon andesitic lavas: Dark gray, dense lava containing a few percent plagioclase phenoscrysts and sparse but distinctive acicular hornblende phenocrysts . Lava forms mesa cap and small knobs on northern extent of Borrego Mesa on this map and several of the large coherent masses mapped as rock slide deposits on the mesa slopes. A few small exposures are present beneath Qtog near the northern edge of the quadrangle on the west side of Cañon de San Diego.

Tpv Paliza Canyon volcaniclastic gravel: Volcaniclastic sediments interbedded with and overlying the volcanic rocks of Borrego Mesa. Consist of tan to brown sandstones, and conglomerates. Often contain abundant clasts of a volcanic rocks, mostly mafic to intermediate. Some rhyolite and obsidian pebbles and cobbles are locally present as are thin pumice and ash beds. 0-70m.

Tcc **Rhyolite intrusion and flows:** Small plug of rhyolite to dacite composition. Dominant lithology is pink to reddish brown rhyolitic rock containing biotite, feldspar, and quartz phenocrysts. Chilled glassy margin present at some intrusive contacts. $^{40}Ar/^{39}Ar$ ages of 9.37± 0.16 and 9.41 ± 0.24 Ma were determined for the intrusion and glassy margin, respectively. The rhyolite interfingers with a darker, more biotite- and hornblende-rich, quartz-free dacite (**Tcd**), and sediments composed of dacitic material (**Tds**), which were mapped separately when exposures were large enough.

Tct **Canovas Canyon ignimbrite and tephra:** White to pink pyroclastic flow and ash fall deposits. Thin beds of pumice interlayered in volcaniclastic conglomerates and sandstones of the Santa Fe Group and with Paliza Canyon basalt on the west side of Borrego Mesa.

Tpb **Basalt of Borrego Mesa:** Basaltic lavas. Two intervals mapped on Borrego Mesa. Lower is fine-grained virtually phenocryst free basalt locally with well developed interstitial texture. 5-10m thick. Upper contain abundant 5 mm tabular plagioclase phenocrysts giving a distinctive platy texture and forms the mesa cap over much of the part of Borrego included in this study. Two basalt flows low in the sequence yield $^{40}Ar/^{39}Ar$ ages of 9.44± 0.45 and 9.37 ± 0.28 Ma. Thickness probably 5-10 m.

Tertiary Sedimentary Rocks

Tsfa **Arroyo Ojito Formation of the Santa Fe Group**: Tan sandstone and volcaniclastic fluvial gravel derived from the Nacimiento and southern Jemez Mountains.

Tz **Zia Formation undivided:** white to tan, poorly cemented sandstones with locally preserved cross-bedding and minor interbedded red to green silts and silty sands. Zia Formation is an eolianite derived from sources to the west.

Tau **Upper member of the Abiquiu Formation:** White to tan, medium-grained sandstone that is alternately well-cemented and poorly cemented with interlayered ash fall deposits. A biotite-rich ash bed from the upper Abiquiu Formation in Cañon de la Cañada yields a $^{40}Ar/^{39}Ar$ age of 20.61 ± 0.07 Ma, younger than the 23 to 25 Ma determined for equivalent strata to the north near Cerro Pedernal (Smith et al., 2002).

Tav **Volcaniclastic member of the Abiquiu Formation:** Greenish gray, matrix-supported, pebble to cobble conglomerate. This debris flow deposit contains cobbles of volcanic rocks, granites, quartz and sedimentary rocks. Precambrian material is concentrated at the base and at the top of the unit. Most of the clasts are intermediate volcanics from an uncertain source, contain phenocrysts of plagioclase and pyroxene, and are <15 cm in diameter. A few clasts have hornblende and rare clasts contain quartz as phenocrysts. The basal volcaniclastic unit of the Abiquiu Formation in the southwestern Jemez Mountains is ~60 m thick west of Cañon, and is ~40 m thick at Gilman. The basal unit thins abruptly to the north and east and is generally represented by fluvial and debris flow deposits <1 m thick that contain only Proterozoic granitoid and Oligocene (?) volcanic clasts and local 1 m thick limestone beds. Preliminary analysis of paleocurrent direction recorded by imbricated cobbles in the basal volcaniclastic unit near Cañon indicates flow toward the northwest. The paleocurrent data and the decrease in thickness toward the north suggest a source to the south (Kelley and Connell, 2004).

Jurassic Sedimentary Rocks

Jurassic beds crop out only on the steep slopes of Borrego Mesa where they are largely buried by mass wastage deposits of various types. Exposures are discontinuous and poor. The situation is further complicated by structural disruption.

Jm **Morrison Formation:** yellowish to tan, iron-stained subarkosic to arkosic sandstones. Occurs only as small discontinuous outcrops along fault zone west of Borrego Mesa.

Js **Summerville Formation:** gray, maroon or red siltstones and silty mudstones. Occurs only as small discontinuous outcrops along fault zone west of Borrego Mesa

Jt **Todilto Formation:** Brown to gray laminated, fetid limestones and overlying white gypsum. In some places the gypsum member has been eroded away.

Je **Entrada Sandstone:** White to yellow to tan, fine- to medium-grained, well-sorted, well-rounded, cross-bedded quartzose sandstone. Base not exposed. Locally mapped with the overlying Todilto Formation (Jet).

Triassic Sedimentary Rocks

TRc **Petrified Forest Formation (Chinle Group):** Principally red mudstones with minor thin, tan thin-bedded, ripple-laminated to cross-laminated micaceous sandstones. Locally the mudstones may be black, purple, dark blue, especially near the lower contact. Interbedded sandstones are particularly common and persistent in the approximate stratigraphic position of the Poleo Formation. These sandstones are particularly thick and persistent in two locations in Canon de Canada (approximately 39°49.5' and 39°55.4') and were mapped as (**TRcs**).

TRaz **Agua Zarca Formation (Chinle Group):** White to brown, medium- to coarse-grained quartzose sandstones. The sandstones are usually strongly cross stratified, often in trough geometries, and they are usually well cemented, making the unit a consistent ridge former. Coarse conglomerate beds, up to several feet thick, containing siliceous pebbles and cobbles up to 15 cm, are common near the base. Clasts are predominantly white, gray, or red quartzite, sedimentary rip-up clasts and petrified wood. Conglomerates often cemented with dark brown ferruginous material. Upper contact is mapped at upward increase in shale content. This increase is often abrupt and the lower shale is often purple, black or dark blue, suggestive of Salitral Formation. In other places the contact is less abrupt perhaps because of the presence of thin-bedded, ripple- and cross-laminated sandstones in the overlying Chinle Formation.

TRm   Moenkopi Formation: Dark chocolate brown to reddish brown micaceous shale, silty shale and thin-bedded feldspathic sandstone. Proportion of shale and sandstone vary laterally and in sand rich areas sandstones are medium bedded. Sandstones are locally reddish and resemble the upper sands of the underlying Yeso Formation. Overlain in sharp contact by the contrasting light-colored sands of the Agua Zarca Formation. The Moenkopi Formation is composed primarily of red siltstone interbedded with thin (0.3 to 1 ft. [0.1 to 0.3 m]) yellow (on weathered surface) sandstone. The Moenkopi Formation in the Red Rocks area is unique in that it contains an approximately 1 m thick layer of fossiliferous sandy limestone. Poorly preserved pelecypod fossils are concentrated near the base of the limestone. In most exposures of the Moenkopi Formation on the ridge east of Red Rocks, the limestone is the topmost unit; however at one locality (13 S 345037 3945145), the limestone is capped by a cross-bedded red sandstone. Thickness varies laterally perhaps due to erosion of upper beds beneath the Agua Zarca Formation.

<u>Permian Sedimentary Rocks</u>

Pg   Glorieta Sandstone: White to red, medium-bedded quartz arenite. Bedding varies from massive to planar to cross stratified. Sandstones are typically well sorted. Feldspathic red sandstones and some shale interbedded in subordinate amounts.

Py   Yeso Formation: Red orange to dark red, fine to medium grained, quartzose sandstone. The Yeso Formation has traditionally been divided into two members in the southwestern Jemez Mountain region, the lower Meseta Blanca member and the upper San Ysidro member (Wood and Northrop, 1946; Stanesco, 1991; Mack and Dinterman, 2002). In the Red Rocks area on Jemez Pueblo, the basal part of the Meseta Blanca member consists of thinly bedded, orange sandstone that is cross-bedded with low angle to subhorizontal stratification. The basal unit pinches out north of Red Rocks. This unit is overlain by a reddish-orange, medium to thick-bedded tabular sandstone with thin shale interbeds, occasional fluvial channel structures, and rare mudcracks. This package of tabular sandstone thickens to the north of Red Rocks. The upper part of the Meseta Blanca member is characterized by a distinctive eolian sandstonewith meter-scale, tabular-planar, wedge-planar and trough cross-beds that record a paleo-transport direction generally to the south (Stanesco, 1991). This sandstone contains a thin (0.1 to 0.3 m thick), discontinuous pedogenic carbonate horizon that is present in the cliffs just the contact with the San Ysidro member.   The San Ysidro member of the Yeso Formation is primarily medium-bedded, tabular sandstone that is orange red near the base and red near the top. A continuous (1 to 2 m thick) limestone bed is present near the top of the unit. The sandstone under the limestone is altered and bleached due to weathering of the sandstone prior to the deposition of the limestone. The limestone exhibits soft-sediment deformation and fills in low spots in the underlying sandstone. The contact of the Yeso Formation with the overlying Glorieta Sandstone mapped at the transition to predominantly medium to course grained, white quartzose sandstone. The Yeso

Formation is 170 m thick in Cañon de San Diego (Stanesco, 1991) and is 156 m at Red Rocks.

Pa Abo Formation: Red to dark red, medium- and thin-bedded arkose or feldspathic, medium- to coarse-grained, fluvial channel sandstones, intraformational conglomerates, and fine-grained overbank deposit mudstones and shales. Green reduction spots and layers are common. The sandstones are cross-stratified (typically trough and wedge-planar geometries) and the finer grained rocks commonly have ripple cross-laminations. Mud-chip clasts and plant debris are common. Base is not exposed in map area. Upper contact with Yeso Formation mapped at abrupt change from medium-grained to coarse-grained arkosic sandstones to fine- to medium-grained quartzose sandstones. The contact between the Abo Formation and the overlying Yeso Formation is usually conformable (Woodward, 1987; Stanesco, 1991), but a local angular unconformity is present in the vicinity of a northwest-trending fault near the northern boundary of Jemez Pueblo in the Red Rocks area. Spencer Lucas (personal communication, 2004) measured 492 ft (150 m) of Abo Formation, (base not exposed, but measured up to the Yeso Formation) south of Jemez Springs on the Ponderosa 7.5' quadrangle. Although this section is incomplete, Lucas notes that the basal portion of the Abo Formation is dominated by mudstones and that channel sands become thicker and more abundant in the upper part of the formation. This trend has also been noted in central and west-central New Mexico.

Pennsylvanian Sedimentary Rocks

lPm Madera Formation: Light-gray, fossiliferous limestone, white to buff quartzose sandstones, course-grained arkose, light-gray shale with subordinate arkosic limestone. Overlies Sandia Formation. Upper contact not observed in this map area.

lPs Sandia Formation: Fine- to coarse-grained, white to tan, quartzose sandstones interbedded with brown, red, green or gray shale and thin-bedded fossiliferous limestone. Minor arkosic sandstones also present. Base not exposed in this map area. Contact with overlying Madera Formation mapped at abrupt increase in proportion of limestone beds.

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