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

REPORT

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Topographic Setting

The Ponderosa 7.5 minute quadrangle is in the southwestern Jemez Mountains of north-central New Mexico. One of the most notable topographic features in the quadrangle, Cañon de San Diego, was formed by the incision of the south-southwest flowing Jemez River through Pleistocene Bandelier Tuff and Permian redbeds. New Mexico State Highway 4 provides ready access to scenic Cañon de San Diego. Virgin Canyon to the west of Cañon de San Diego is equally scenic, but it is relatively inaccessible. New Mexico Highway 110/Forest Road 10 passes through the village of Ponderosa in the east-central portion of the area. Borrego Mesa is a prominent lava-capped mesa in the southeastern part of the quadrangle. Vallecito Creek flows southward through Paliza Canyon and the broad valley to the west of Borrego Mesa; this creek has cut a steep-sided canyon through resistant sandstone of the Shinarump Formation near the southern edge of quadrangle. San Juan Canyon and Cañon de la Cañada are two N-S trending canyons in the center of the quadrangle that provide important windows into the geologic history of this area.

Regional Geologic Setting

The quadrangle straddles the western margin of the Rio Grande rift, a late Oligocene-Holocene, northerly-striking extensional feature that bisects the state of New Mexico, and is on the southwestern flank of the 15 Ma to 40 ka Jemez volcanic field. The Jemez volcanic field lies at the intersection of the rift and a NE-trending alignment of < 10 Ma volcanism known as the Jemez lineament (Aldrich et al., 1986). The < 1.61 Ma Bandelier Tuff of the Jemez volcanic field caps mesas across the northern half of the quadrangle. Older Jemez volcanic field basaltic, dacitic, and rhyolitic rocks cap Borrego Mesa in the southeastern corner of the area. Paleozoic sedimentary rocks are exposed across the western third of the area, Mesozoic rocks are predominant in the middle, and Cenozoic rift-fill sediments are present in the southeastern corner and along the southern edge of the quadrangle. The overall pattern of decreasing age toward the southeast is, in part, the result of hundreds of meters of down-to-the-southeast displacement across three northeast- to north-striking, rift-related normal fault systems, including, from west to east, the Jemez fault zone, the Cat Mesa fault zone, and the Jose fault zone.

The southeastern flank of the broad Sierra Nacimiento Laramide highland lies within the quadrangle. The Permian to Triassic rocks in the southwestern part of the quadrangle dip about 7° to the south on the southern flank of the Laramide high. Compressive Laramide deformation started in this area about 75 Ma, with activity peaking about 50-55 Ma (Cather, 2004; Pazzaglia and Kelley, 1998). Northerly to northeast-striking monoclines (see cross-section A-A') and folds that likely formed during Laramide deformation are present in Cañon de la Cañada and in Paliza Canyon.

Previous Work

Wood and Northrop (1946), Smith et al. (1970), and Kelley (1977) produced regional-scale geologic maps that include the Ponderosa quadrangle. Kelley (1977) applied the name Jose fault to the prominent fault in the southeastern Ponderosa quadrangle. Renick (1931) described rift-fill sediments and volcanic rocks exposed along the Jemez River. Terraces along the Jemez River were mapped and discussed by Rogers et al. (1996), Formento-Trigilio (1997), and Formento-Trigilio and Pazzaglia (1998).

Important new observations made during the course of this study include (1) delineation of a late Oligocene to early Miocene depocenter adjacent to the Jemez fault zone that is filled with Oligocene dacitic to andesitic cobbles and boulders from an unknown middle Cenozoic volcanic source (2) identification of at least two episodes of landsliding near the village of Ponderosa; (3) identification of an incipient landslide in Cañon de San Diego and (4) recognition of fossil hydrothermal deposits along the Cat Mesa and Jose fault zones.

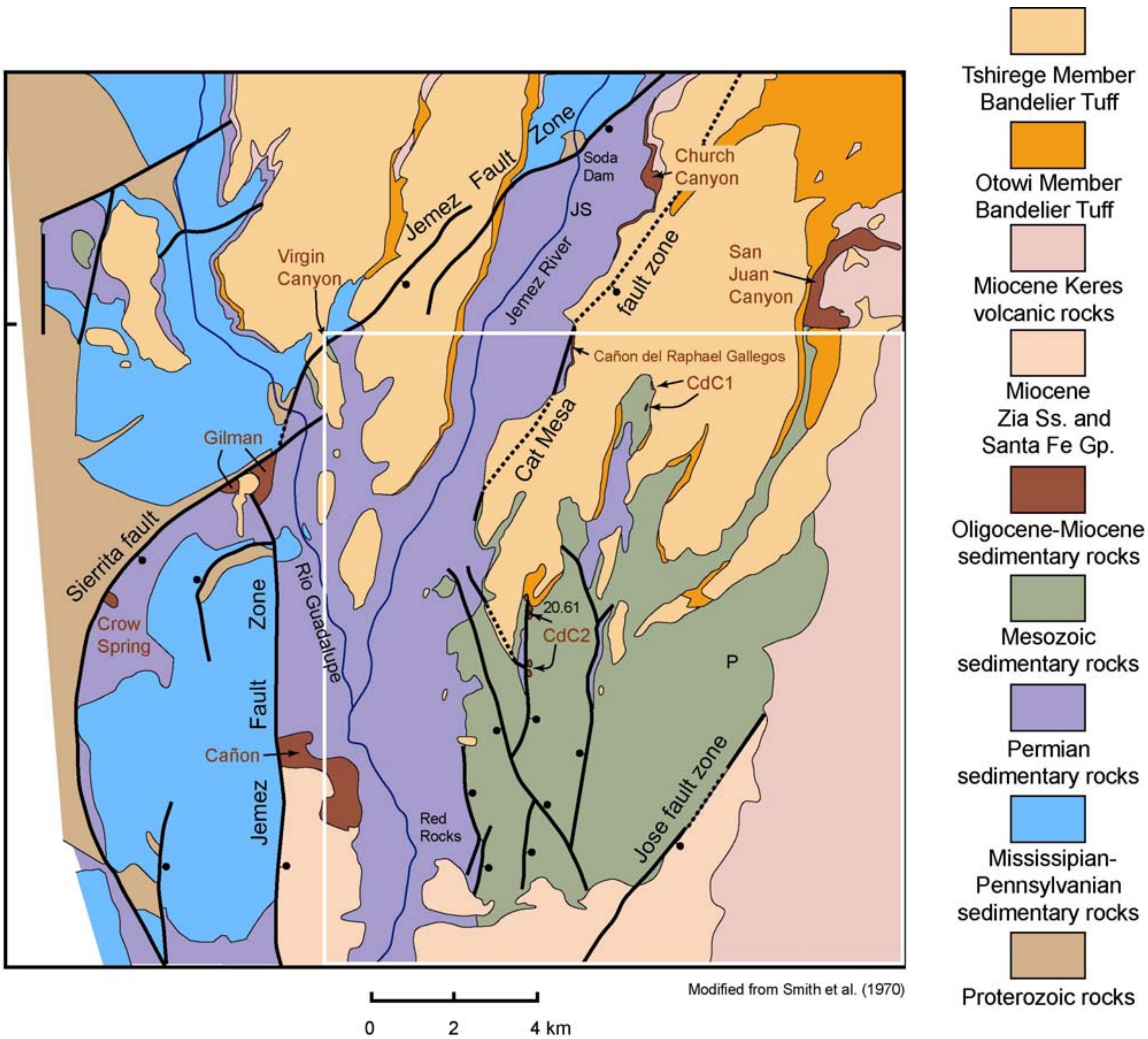


Figure 1. Index map showing the simplified geology, the major structures, and geographic localities discussed in the text. The brown labels and outcrops highlight outcrops of the Abiquiu Formation and Gilman Conglomerate; thick deposits Gilman conglomerate are found only at Cañon, Crow Spring, and Gilman. CdC=Cañon de la Cañada. The white box outlines the Ponderosa quadrangle.

Geologic History

Rocks exposed in the Ponderosa quadrangle contain an rich, but fragmentary geologic record spanning more that 300 million years of Earth's history. This description of the geologic history of this area is modified from Kelley et al. (2007). We use the geological time scale of Gradstein et al. (2005) in our narrative.

Paleozoic

The oldest unit in the area, the Pennsylvanian Sandia Formation (Atokan, ~310 Ma), is in Virgin Canyon north of the Jemez fault zone. The intercalated quartzose sandstone, shale, thin-bedded fossiliferous limestone, and chert of the Sandia Formation is gradationally overlain by fossiliferous limestone, arkosic sandy limestone, and black shale of the Madera Limestone. The limestones and clastic rocks of the Madera Limestone were deposited between latest Atokan (~308 Ma) and late Virgilian (~300 Ma) time along the shore of a shallow ocean that once covered the southern two-thirds of New Mexico during late Pennsylvanian time (Kues and Giles, 2004). The Madera Limestone in Virgin Canyon is at the base of the unit and thus is equivalent to the Gray Mesa Formation of the Madera Group (Kues, 2001; Krainer et al., 2005). The gradational contact between the Madera Limestone and the overlying Abo Formation is not exposed in the Ponderosa quadrangle.

The latest Pennsylvanian to Permian Abo Formation, a red siltstone interbedded with red to white arkosic sandstone, was deposited by a south-flowing river system during the latest Virgilian through Wolfcampian time (~ 280-300 Ma). Lucas et al. (2005a) note 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. The upper Abo Formation is exposed on the Ponderosa quadrangle. Abo Formation sandstone contains pebbles of quartz, quartzite, potassium feldspar, and granite derived in part from the Peñasco highland, site of the modern Sierra Nacimiento, to the west and from the Uncompaghre uplift to the north (Eberth and Miall, 1991). Abo Formation locally contains malachite and azurite in the channel sandstones at the Spanish Queen mine in Cañon de San Diego (McLemore, 1996). These minerals formed when copper-rich fluid moved through the sandstones long after deposition.

The Permian Yeso Group forms orange cliffs in the walls of Virgin Canyon, Cañon de San Diego, and Cañon de la Cañada and is the most conspicuous rock unit in the Red Rocks area on Jemez Pueblo. The contact between the Wolfcampian Abo and the overlying Leonardian Yeso is conformable (Woodward, 1987; Stanesco, 1991). An overall drying trend at ~280 Ma is recorded at the contact between the fluvial Abo and the eolian basal part of the Yeso (Mack and Dinterman, 2002). The Yeso has traditionally been assigned formational status and has been divided into two members in the southwestern Jemez Mountains, the lower Meseta Blanca Member and the upper San Ysidro Member (Wood and Northrop, 1946; Stanesco, 1991). Lucas et al (2005c), following the work of Baars (1962), applied the name De Chelly Sandstone to the Meseta Blanca Member and elevated the Yeso Formation to group status. The De Chelly Sandstone in the vicinity of Red Rocks consists of thin-bedded, cross-bedded, orange sandstone, reddish-orange medium to thick-bedded tabular sandstone with thin shale interbeds, occasional fluvial channel structures, and rare mudcracks, overlain by a distinctive eolian sandstone characterized by meter-scale, tabular-planar, wedge-planar and trough cross-beds that record a paleo-transport direction generally to the south (Stanesco, 1991; Lucas et al., 2005 a,c). The upper sandstone contains a thin discontinuous pedogenic carbonate horizon near the upper contact. The San Ysidro Formation of the Yeso Group 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. Sandstone immediately under the limestone is bleached due to weathering prior to the deposition of the limestone. The limestone exhibits soft-sediment deformation and fills in low spots in the underlying sandstone.

The contact between the upper part of the Yeso Group and the overlying yellow-white Permian

Glorieta Sandstone is gradational. The medium-bedded sandstone of the Glorieta Sanstone is locally cross-bedded. A south to north marine transgression at ~275 Ma is recorded across the contact, as sand-dominated coastal plain and rare carbonate deposits of the San Ysidro Formation gave way to the coastal sand bar deposits of the Glorieta Sandstone (Kues and Giles, 2004).

Mesozoic

Triassic Moenkopi Formation (early Anisian) unconformably overlies Glorieta Sandstone; at least 26 m.y. of rock record is missing across this unconformity between Permian and Triassic rocks. The Moenkopi Formation is composed of reddish-brown micaceous shale, silty shale, and thin-bedded feldspathic sandstone. The unit is often shaly at the base and sandy at the top. The Moenkopi Formation in the Red Rocks area is unique in that it contains a 1-m thick layer of sandy limestone intercalated with cross-bedded red sandstone; the basal part of the limestone contains abundant unioid pelecypod shells (fossils identified by S.G. Lucas, personal comm., 2005). The Moenkopi Formation was deposited by north- to northwest- flowing rivers sourced in the Mogollon highlands to the south and the Ouachita Mountain belt to the east and southeast at ~245 Ma (Lucas, 2004).

Upper Triassic Chinle Group, a thick interval of brick-red to red siltstone and mudstone and white to tan sandstone, was deposited by rivers flowing from Texas toward Nevada between 205 and 225 Ma (Lucas, 2004; Lucas et al., 2005b). The Chinle Group unconformably overlies the Moenkopi Formation, with an ~20 m.y. hiatus in the rock record between the units. The basal Shinarump Formation (formerly called Agua Zarca Sandstone by Wood and Northrop, 1946) is yellowish brown, medium- to coarse-grained, trough-cross-stratified, conglomeratic quartzose sandstone with well-rounded pebbles of quartz and chert. Petrified wood is common. Shinarump Formation is overlain by < 5-m of red Salitral Formation shale, < 5-m of conglomeratic Poleo Sandstone, and < 5-m of ripple-laminated Mesa Montosa Sandstone. The overlying Petrified Forest Formation of the Chinle Group is exposed near the village of Ponderosa.

Jurassic rocks are exposed east of Vallecito Creek and the village of Ponderosa. Another significant gap in the rock record spanning about 44 million years occurs between the late Triassic rocks and the middle Jurassic rocks. The oldest of the middle Jurassic rocks, the Entrada Sandstone, forms the prominent red and yellow cliffs northeast of the village of Ponderosa. The Entrada Sandstone contains cross-beds that are several meters high, indicating an eolian origin for this unit. The Entrada Sandstone deposits in the Ponderosa quadrangle are part of a vast sand dune field that covered much of the Four Corners region. Paleocurrent indicators show that the Entrada sands were transported by wind blowing toward the south to southwest (Tanner, 1965). The Entrada Sandstone is ~161 to 165 million years old.

The Todilto Formation, which consists of a basal limestone and shale unit (Luciano Mesa Member) and, northeast of Ponderosa, ~25 m of gypsum (Tonque Arroyo Member), was deposited on the Entrada Sandstone. The contact between the Entrada Sandstone and the Luciano Mesa Member of the Todilto Formation is poorly exposed on the quadrangle, but elsewhere in the Jemez Mountains, the contact is relatively flat and quite sharp. Ahmed Benan and Kocurek (2000) speculate that that the Entrada dune field was flooded catastrophically, with very little reworking of the sand dunes. The Todilto Formation was most likely deposited in a salina (Lucas et al., 1985); in other words, in a moderately deep, oxygen-poor, body of saline water that was isolated from the main body of the Jurassic Sundance Sea by a barrier. First, limestone precipitated from the evaporating seawater. Later, as the waters of the salina became more concentrated by evaporation, gypsum precipitated. The Todilto Formation, based on fossil evidence (Lucas et al., 1985), is ~159 million years old.

Younger Jurassic units, the Summerville Formation and the Morrison Formation, are exposed only in slivers along the Jose fault, which makes the geologic history of these particular units in this area difficult to decipher. The Summerville Formation consists of maroon mudstone and pinkish-tan, poorly cemented sandstone likely deposited on an arid coastal plain. The sliver of Morrison Formation in the southeastern part of the quadrangle is pistachio-green to salmon-pink mudstone with a few interbedded tan sandstone beds, characteristic of the Bushy Basin Member. The Morrison Formation was deposited by rivers flowing toward northeast across a broad, fairly low-gradient muddy floodplain that dipped toward the north to northeast away from the developing Mogollon highlands in southwestern New Mexico and southeastern Arizona. Radiometric dating of ash beds ($^{40}Ar/^{39}Ar$ on sanidine; Kowallis et al., 1998) in the Brushy Basin Member in Utah and Colorado yields ages of 148 to 150 million years for this unit.

Oligocene to Miocene structures and rift fill sedimentary rocks

One of the most significant structures in the southwestern Jemez Mountains is the northeast-striking Jemez fault zone, a down-to-the-southeast, rift-related, normal fault that offsets Pennsylvanian-Permian rocks 200-250 m and 1.25 Ma Tshirege Member of the Bandelier Tuff 15 m in Virgin Canyon in the northeastern Ponderosa quadrangle (Figure 1). The stratigraphic offset across the Jemez fault zone decreases dramatically toward the northeast; Abo is juxtaposed against Abo across the fault in the valley of the East Fork of the Jemez River. South and east of the Jemez fault zone, the Cat Mesa fault zone has a more NNE-strike (Figure 1). This fault zone parallels the western edge of Cat Mesa. In the drainage north of Cañon del Raphael Gallegos, Yeso Group is juxtaposed against the upper part of the Abiquiu Formation and the basal part of the Piedra Parada Member of the Zia formation across this fault (Figure 2). Stratigraphic offset of the Permian and Triassic rocks across the Cat Mesa fault zone appears to increase toward the north; the Permian Yeso Formation is displaced ~240 m down to the east where the fault crosses the East Fork of the Jemez River. The fault offsets Paliza Canyon Formation andesite < 10 m in the south wall of the East Fork of the Jemez River and the Bandelier Tuff < 2 m east of Jemez Springs, so the Cat Mesa fault zone is primarily an early rift fault. The Jose fault is a third important NE-striking fault that places Jurassic rocks against upper parts of the Zia Formation. The abundant slivers of Jurassic caught in the fault zone may indicate a strike-slip component, but no slickenlines were observed along the fault. This fault appears to control the location of vents in the older Jemez volcanic field, but the fault does not

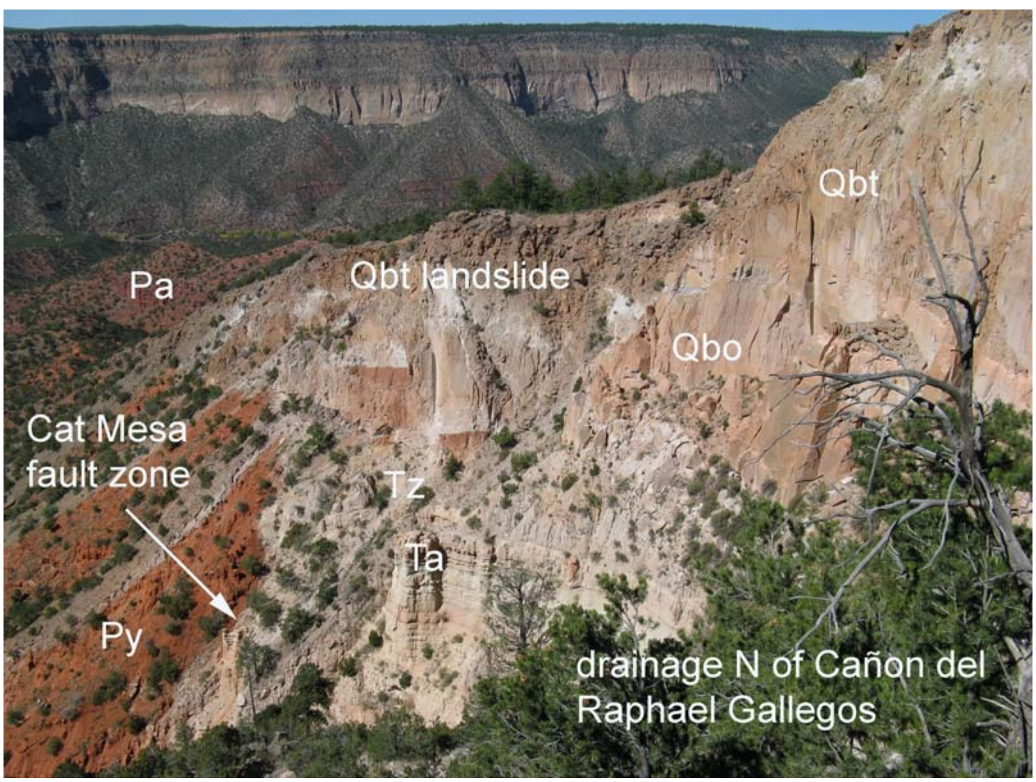
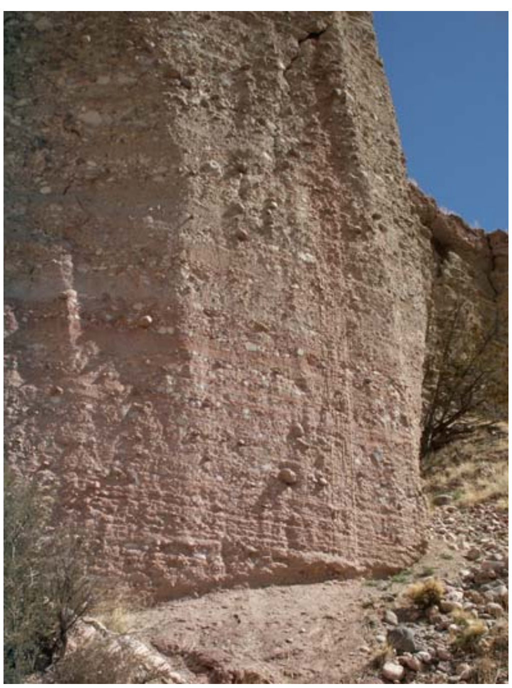


Figure 2. View from the west side of Cat Mesa looking toward Cañon de San Diego and the Cat Mesa fault zone. Pa=Abo, Py=Yeso, Ta =Abiquiu, Tz=Zia, Qbo=Otowi, Qbt=Tshirege.

obviously offset Paliza Canyon Formation or Canovas Canyon lavas. Consequently, like the Cat Mesa fault, the Jose fault may have been most active in middle Miocene time.

Figure 3. Gilman Conglomerate on red Abo Formation sandstone west of Jemez Valley High School. The greenish, volcaniclastic conglomerate is overlain by brown terrace gravel. A closer view of the outcrop is shown below.



Poorly sorted, weakly bedded, greenish-gray volcaniclastic conglomerate crops out in the southwestern corner of the quadrangle west of Jemez Valley High School in the village of Cañon, where it is preserved on the hanging wall of the Jemez fault zone (Figures 1, 3). DuChene (1973) and DuChene et al. (1981) initially described this unit in the vicinity of Gilman, an old logging camp located along the Rio Guadalupe just west of the western edge of the quadrangle. The conglomerate, named the Gilman Conglomerate by Kelley et al. (2009), has a basal 3-to-10-m thick transition zone, a middle section dominated by volcanic clasts, and an upper 10-m-thick transition zone. The transition zones have a pink hue because granules and pebbles of Proterozoic granite, quartz, quartzite and schist are mixed with the volcanic rocks in these intervals. Limestone and sandstone clasts eroded from the nearby Paleozoic section are in the basal deposit. The volcanic clasts include crystal-rich (20-40% phenocrysts) porphyritic dacite with plagioclase, ±hornblende, and ±biotite, crystal-poor (<15% phenocrysts) porphyritic andesite with plagioclase and pyroxene, and fine- to medium- grained equigranular to porphyritic dacitic intrusive rocks. Rare clasts contain quartz as phenocrysts. Two clasts yield groundmass $^{40}Ar/^{39}Ar$ ages of 28.55±0.07 and 28.63±0.10 Ma; two different clasts have biotite $^{40}Ar/^{39}Ar$ ages of 29.38±0.59 and 29.22±0.58 Ma. The rounded clasts are generally < 20 cm in diameter. The volcaniclastic deposit is about 59 m thick in an unnamed drainage on the west side of the Jemez River west of Jemez Valley High School in the village of Cañon and is about 56 m thick near Gilman. The volcaniclastic unit thins dramatically to the north, east, and south of the Gilman-Cañon area and generally is only 0.5 to 1.5 m thick in the canyon walls on the east side of Cañon de San Diego in Cañon del Raphael Gallegos. Paleocurrent direction recorded by imbricated cobbles in the conglomerate near Cañon indicates flow toward north near the base of the deposit and a more easterly component of flow higher up. The transitional interval at Cañon records flow toward the northwest. The volcaniclastic unit typically rests on Permian Yeso Group or Abo Formation and underlies medium-bedded white sandstone assigned to Abiquiu Formation by previous workers (Smith et al., 1970, DuChene, 1973). The source of the 28 to 29 Ma dacitic and andesitic clasts at Gilman is uncertain, but thickness, clast-size, and paleocurrent data suggest a proximal source from the south. A previously unrecognized Oligocene volcanic center may lie beneath the northern Albuquerque basin to the south of the Ponderosa quadrangle.

The Abiquiu Formation in the southwestern Jemez Mountains is a white to tan, medium-grained, tabular bedded sandstone that is interbedded with thin (0.1-0.3 m) fine-grained ash-fall deposits. A few thin-bedded and laminated calcareous siltstones are in this unit. The upper Oligocene to lower Miocene Abiquiu Formation, which covers a broad region of north-central New Mexico, was deposited by southward-flowing sandy braided streams. Clasts from the Latir volcanic field northeast of Taos are common in the Abiquiu Formation in the northern and southeastern Jemez Mountains, but are absent in the southwestern Jemez Mountains. 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, within the age range of the 18 to 27 Ma Abiquiu Formation in the northern Jemez Mountains near Cerro Pedernal (Tedford et al., 1993; Smith et al., 2002). This unit is 50 to 62 m thick in the Cañon-Gilman area. Although thick deposits of Pedernal chert are not present in the southwestern Jemez Mountains, rare lenses of chert were observed in the Abiquiu Formation in Cañon del Raphael Gallegos. A carbonate-cemented sandstone is locally preserved at the base of the Abiquiu Formation at several localities in the east wall of Cañon de San Diego.

The northern edge of a basin preserving the 16 to 19 Ma Zia Formation laps onto south-dipping Permian rocks in the vicinity of Jemez Pueblo. A white, poorly cemented, cross-bedded sandstone with well-rounded sand grains conformably overlies the Abiquiu Formation in an unnamed drainage west of Jemez Valley High School and in Cañon del Raphael Gallegos. This sandstone correlates to the Piedra Parada Member of the Miocene Zia Formation (Tedford and Barghoorn, 1999; Connell et al., 2007). The Piedra Parada Member is eolian, deposited by winds blowing from the west (Gawne, 1981). The Chamisa Mesa Member overlies the Piedra Parada Member near the base of Borrego Mesa, but the exposures are poor. This member is characterized by tabular to cross-bedded sandstones with root casts with a few interbedded red siltstone beds, indicative of a fluvial system flowing through a dune field. The 16 to 9 Ma Cerro Conejo Formation, which consists of tabular to crossbedded sandstone with ripple marks and root casts intercalated with thin to medium bedded red mudtone, lies above the Zia Formation and marks the transition from primarily eolian deposition to mainly fluvial deposition (Connell et al., 2001). A gravel with pebbles and cobbles of intermediate composition volcanic rocks and Proterozoic granite, quartz and quartzite is present about 10 m below the oldest basalt flow on Borrego Mesa. This fluvial deposit, likely derived from the basement-cored Sierra Nacimiento to the west, may be a unique facies in the Cerro Conejo Formation or part of the younger Navajo Draw Member of the Arroyo Ojito Formation.

Miocene volcanic rocks

Some of the oldest rocks in the Jemez volcanic field are exposed on Borrego Mesa. Basalt flows interbedded with volcaniclastic sediments belonging to the Paliza Canyon Formation and rhyolitic tuffs and tephra deposits of the Canovas Canyon Formation are preserved here. The Chamisa Mesa basalt (Smith et al.,1970) is the oldest flow on Borrego Mesa. This basalt, which is a 5 to 10 m thick stack of flows, contains sparse phenocrysts of plagioclase and olivine. The uppermost flow on Borrego Mesa contains abundant olivine and small phenocrysts of plagioclase and has a distinct red speckled appearance on weathered surfaces. This basalt likely correlates to the trachybasalt of Bodega Butte to the southwest (Chamberlin and McIntosh, 2007). $^{40}Ar/^{39}Ar$ ages of ~9.9 Ma have been determined for the oldest basalt and ages of ~9.1 Ma have been determined for the olivine basalt (Chamberlin et al., 1999; Kempter et al., 2003; Chamberlin and McIntosh, 2007; this report). A third basalt is present below the basalt of Bodega Butte along the east-central edge of the quadrangle. This basalt is characterized by abundant plagioclase phenocrysts.

A plug of dacite that grades to rhyolite is a prominent landmark on Borrego Mesa east of the village of Ponderosa (Figure 4). The main part of the 9.4 Ma plug is composed of dacitic lava with phenocrysts of hornblende and biotite. Toward the east, the lava forms a flow with a glassy base resting on volcaniclastic sediments; small phenocrysts of quartz are visible in the lava along the eastern margin of the exposure. This plug/flow complex is considered to be part of the Canovas Canyon Formation (Smith et al., 1970). The dacite is intruded by an andesitic dike with phenocrysts of plagioclase and pyroxene. All of these intrusive bodies are located along the Jose fault zone. Sediments that are likely part of the Cerro Conejo Formation located just north-northwest of the plug contain gravels composed exclusively of dacite from the plug and reworked pumice likely associated with the eruption of the plug/flow complex. These gravels were mapped as Canovas Canyon sedimentary deposits to emphasize their local origin.

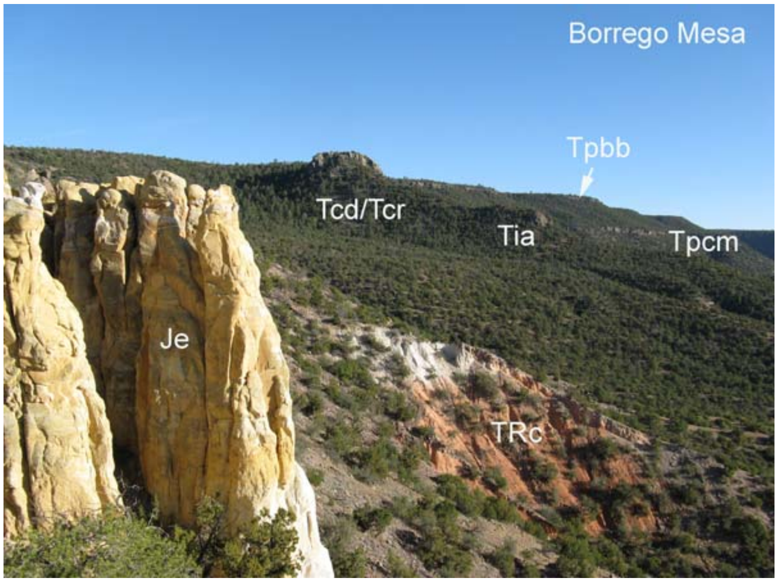


Figure 4. View of the dacite/rhyolite plug (Tcd/Tcr) and Borrego Mesa looking south. TRc=Chinle Group; Je = Entrada Sandstone; Tia = andesite intrusive, Tpcm = basalt of Chamisa Mesa; Tpbb=trachybasalt of Bodega Butte.

The youngest Paliza Canyon Formaton lava flow in the Ponderosa quadrangle is a dacite erupted from a vent located just east of the map boundary (Gardner et al., 1986). The vent lies on the projection of the Jose fault.

Pliocene sedimentary units

Thin (<2 m), discontinuous outcrops of a breccia containing blocks of Paliza Canyon andesite overlain by a sandy debris flow deposit are exposed on the east side of Virgin Mesa in Cañon de San Diego near the north edge of the quadrangle. These are the southernmost exposures of a large debris avalanche likely derived from the flanks of a Paliza Canyon andesite volcano that has since collapsed into the Toledo-Valles caldera complex north of the quadrangle. Kelley et al. (2003; 2007) speculate that this deposit is Pliocene (1.8 to <4.2 Ma) in age, based on the clast content of the debris flow near the village of Jemez Springs to the north of the quadrangle.

Thin deposits (<12 m) of fluvial gravel and sandstone overlie Permian, Triassic, or Pliocene (?) debris avalanche deposits and underlie the 1.85 Ma San Diego Canyon Tuff or the 1.61 and 1.25 Ma Bandelier Tuff in Virgin Canyon, Cañon de San Diego, Cañon de la Cañada, San Juan Canyon, and Paliza Canyon (Figure 5). Pebble to boulder clasts in the fluvial deposits are generally sub-rounded to well-rounded Paliza Canyon Formation volcanic rocks with few granite, Permian sandstone, Permian conglomerates, and rare Pedernal chert supported in a silt to sand matrix. Paleocurrents based on pebble imbrications indicate that a southerly flowing drainage network was present in the southwestern Jemez Mountains prior to the caldera eruptions (Scholle and Kelley, 2003; Appendix 1). These deposits are, in part, stratigraphically equivalent to the Cochiti Formation in the southeastern Jemez Mountains (Smith and Lavine, 1996).

Table 1. $^{40}Ar/^{39}Ar$ ages for samples from the Ponderosa quadrangle

Sample	Description	Location (NAD27; 13S)	Age (Ma)		2σ
01-PON-11a	lowest basalt, Borrego Mesa	352106 3948213	9.39	±	0.31
01-PON-12	lowest basalt, Borrego Mesa	352062 3948125	9.45	±	0.22
01-PON-1	Canovas Canyon Rhyolite plug	352107 3948321	9.47	±	0.13
01-PON-2	Canovas Canyon Rhyolite plug	352107 3948321	9.49	±	0.18
01-PON-4	Canovas Canyon Rhyolite tephra	352174 3948143	9.80	±	0.51

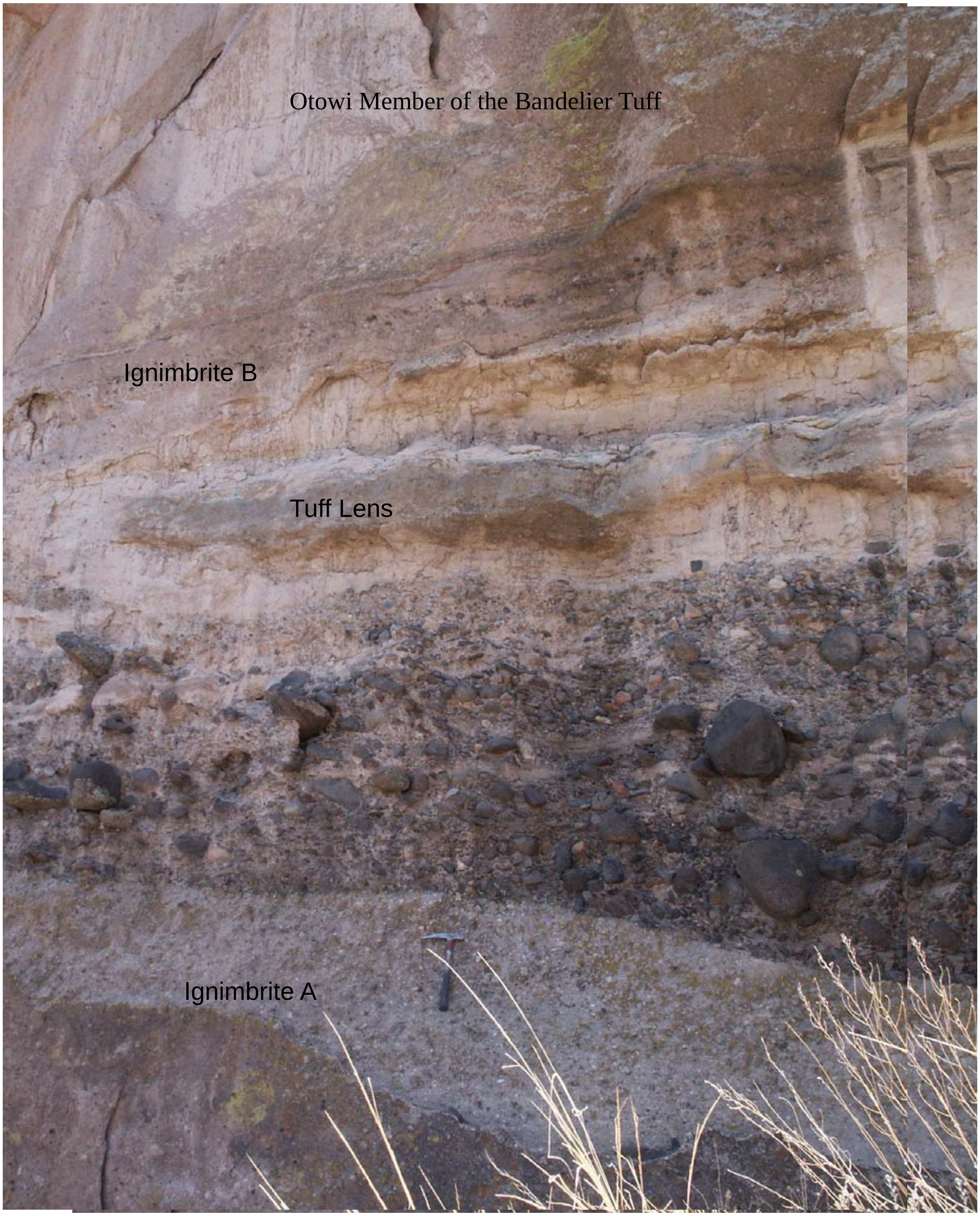


Figure 5. Fluvial gravels between Ignimbrite A and Ignimbrite B of the San Diego Canyon tuff, north end of Ponderosa 7. 5’ quadrangle, west side of Cañon de San Diego. The origin and affinity of the lens of tuff within the sandy interval is uncertain. Photograph by Steve Scholle.

Latest Pliocene to Quaternary volcanic and volcaniclastic deposits

San Diego Canyon tuff is a nonwelded to poorly welded ash flow tuff that is exposed only on the west side of Cañon de San Diego between the north edge of the quadrangle and the south end of Virgin Mesa. The source of the small-volume 1.85 Ma San Diego Canyon tuff (Spell et al., 1996) has been obscured by younger caldera-forming eruptions. This tuff is characterized by phenocrysts of quartz and sanidine with trace pyroxene and magnetite. The tuff consists of two (Tuberville and Self, 1988), or possibly three (fig. _) units. The San Diego Canyon tuff obviously filled an active stream channel in the northern Ponderosa quadrangle positioned slightly west of modern Cañon de San Diego because gravel is interbedded with the two (or three) ignimbrite flows. Fluvial deposition was re-established after the eruption of the San Diego Canyon tuff.

The landscape of the Jemez Mountains changed dramatically with the collapse of the Toledo caldera and the eruption of the Otowi Member of the Bandelier Tuff at 1.61 Ma (Izett and Obradovich, 1994; Spell et al., 1996). During the early stages of the eruption, the plinian tephra, the Guaje Pumice Bed, was blown toward the east and northeast (Self et al., 1986) and is not preserved or is very thin (<20 cm) in the Ponderosa quadrangle. The ignimbrite from the eruption blanketed the country side, filling in valleys and overtopping ridges. The Otowi Member is generally thicker on the west side of Cañon de San Diego compared to the east side, filling in the paleovalley that preserves the older San Diego Canyon tuff. The Otowi Member is typically a white to pale pink, generally poorly welded rhyolitic ash-flow tuff containing phenocrysts of sanidine and quartz, and abundant lithic fragments.

During the ~400 k.y. between eruptions, west to southwest-trending drainages developed on top of the Otowi Member and in a few places, fluvial gravel is preserved between the members of the Bandelier Tuff. Those gravels are found on Mesa de Guadalupe, on Virgin Mesa, and in Cañon del Raphael Gallegos on the Ponderosa quadrangle (Scholle and Kelley, 2003).

Formation of the Valles caldera at 1.25 Ma (Phillips, 2004) led to the deposition of the plinian Tsankawi Pumice Bed, which averages 1-1.5 m thick, but locally can be up to 3 m thick, in the southwestern Jemez Mountains. Paleovalleys cut on the Otowi Member were filled by the ignimbrites of the Tshirege Member. The cooling unit stratigraphy for the Tshirege Member that has been developed for the Pajarito Plateau (e.g., Broxton and Reneau, 1995) appears to be present in the walls of Cañon de San Diego, although more work is need to confirm the correlations. The conspicuous dark gray band in Cañon de San Diego in the Tshirege Member cliffs corresponds to unit 2 of Broxton and Reneau (1995), although the unit is more strongly welded here compared to the Pajarito Plateau. Lithic fragments are relatively rare in the Tshirege Member in general, but outcrops of unit 3 on the mesas above Cañon de San Diego can have fragment abundances of 5-10% (e.g., Smith and Bailey, 1966).

The youngest volcanic units in the Jemez volcanic field were erupted from the El Cajete crater along the southwest ring fracture zone of the Valles caldera. The 50-60 ka El Cajete pumice (Wolff and Gardner, 1995) covers San Juan Mesa in the northeastern corner of the quadrangle and is preserved in pockets on Cat Mesa (not mapped) and on the east side of the quadrangle.

Landslides

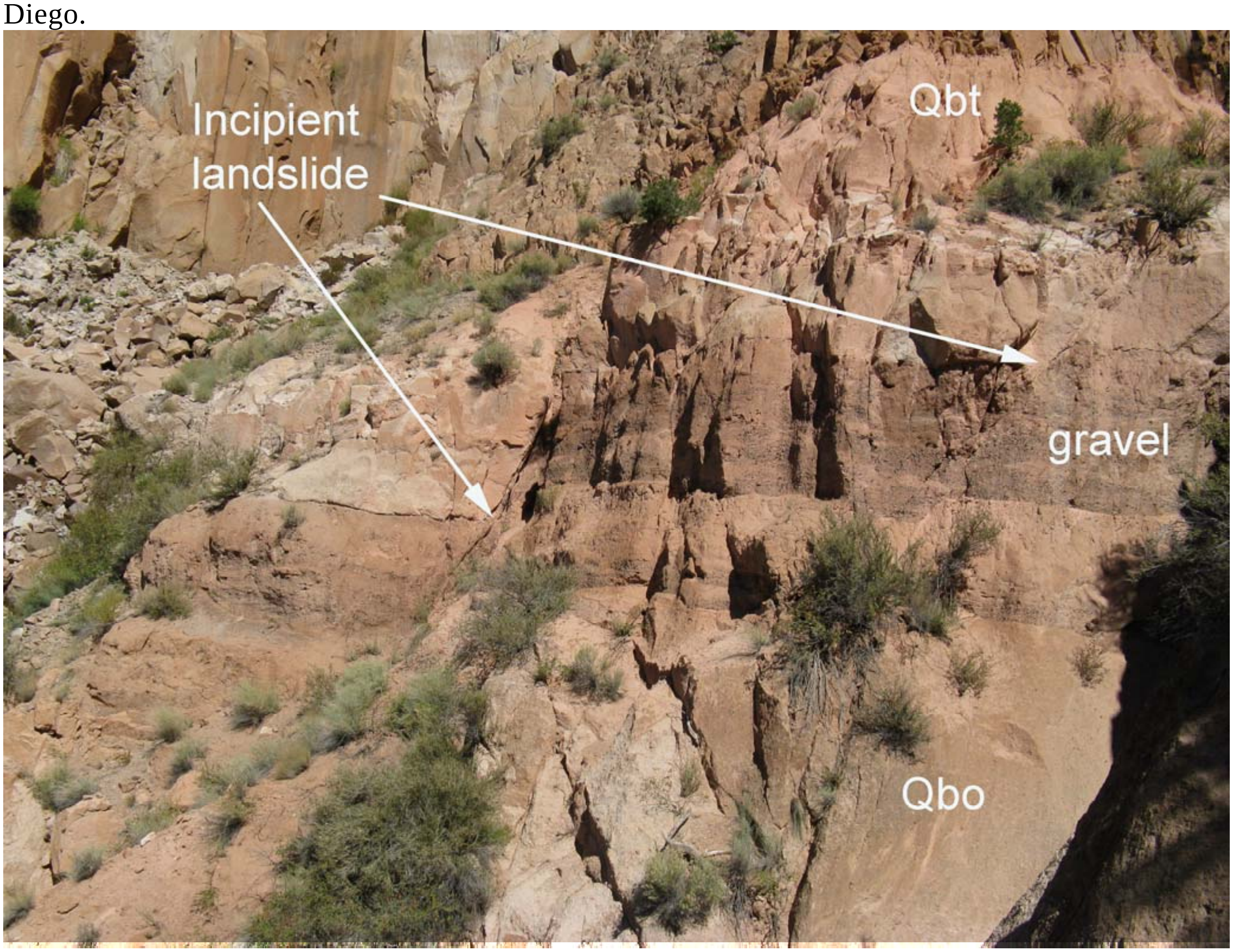
Ponderosa

Much of the area west of Borrego Mesa, including the village of Ponderosa, is underlain by red mudstone of the Triassic Chinle Group. The current configuration of the landscape, with a topographically significant mesa adjacent to a valley underlain by slippery-when-saturated Chinle Group mudstone, has led to the development of large, 2 km wide, landslides that have moved at least 2.5 km from their origin on Borrego Mesa westward toward the village of Ponderosa. Several generations of landslides occur in this area. Most of the landslides consist of rubble of white to tan Zia Formation or Santa Fe Group sandstone near the toe of the slide and rotated blocks of basalt flows near the head of the slide. In places, the basal sandstone rubble is held together with opaline cement. Other landslides northeast of town are composed primarily of andesitic debris. Most of the slides are older than 50-60 ka because El Cajete pumice is found on the surface of many of the landslides. However, two landslide deposits just northeast of Ponderosa sit on 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, these landslide deposits are likely to be younger than 50,000 years old.

An excellent exposure of a young landslide is located at UTM coordinates 13S 351329 3950183 (NAD27) on National Forest land. The material in this younger slide is different than the debris in the other local landslides because it contains Triassic Chinle mudstone, Jurassic Entrada Sandstone, Jurassic Todilto gypsum, and rounded gravel that includes Proterozoic granite and quartzite clasts from the Cerro Conejo Formation(?). Outcrops of Jurassic Entrada and Todilto formations are present upslope of this location. The El Cajete pumice beneath the landslide deposit is a weakly stratified primary fall tephra that is ~0.6 m thick. Here, the El Cajete pumice is underlain by organic material and is overlain by a fine-grained, air fall tuff.

Cañon de San Diego

Landslide and rock fall deposits are common in the rugged terrain of Cañon de San Diego. A prominent landslide composed of Bandelier Tuff covers the down-to-the-east Cat Mesa fault zone near the eastern rim of Cañon de San Diego near the northern edge of the quadrangle (Figure 2). The Otowi Member, the Tshirege Member, and gravels between the tuffs are exposed in cliffs to the east of the landslide. Rocks in this cliff are fractured and there is down-to-the-west offset across some of the fractures that is suggestive of recent mass wasting. Landslide and rockfall potential is high in Cañon de San Diego.



Fossil Hydrothermal Deposits

Travertine and opaline deposits are associated and with a set of N to NW-striking faults between the Jose and Cat Mesa fault zones and with with the Jose fault zone on the Ponderosa quadrangle (Figure 1). A flat-lying travertine deposit remnant located on the Pueblo of Jemez just east of Red Rocks overlies pink to tan fluvial Santa Fe Group(?) sandstones that rest on a south-dipping Glorieta Sandstone surface. This deposit is between north-striking fault strands. Further south, a correlative travertine sits on pediment gravel and is reworked into the base of the Qt4 terrace gravel. This relationship suggests that the travertine is older than 150,000 ± 50,000 years, the estimated age of the Qt4 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); thus the travertine is ~150 to ~400 ka. A second travertine deposit that appears related to the NW-striking faults is located east of Red Rocks and north of Vallecito Creek on Pueblo of Jemez land. This extensive travertine sits on Zia Sandstone with a basal elevation of 6200 feet (1890 m), perhaps correlative to a Qp1 surface. Consequently, this travertine may be older than 640 ka.

As briefly mentioned above, landslide and colluvial deposits composed of Zia Formation sandstone sitting on Chinle Group mudstone in the vicinity of the projection of the Jose fault east of Ponderosa are commonly cemented by opaline material, especially near the base of the Quaternary units. A small, banded travertine deposit east of Ponderosa may be related to this same fossil hydrothermal system.

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