Map Unit Properties Table: Bandelier National Monument

These 54 units were mapped within Bandelier National Monument. A full list and descriptions of all 251 units in the GRI GIS data set for the monument are included in the GRI ancillary map information document (band_geology.pdf). Bold text in the table highlights sections in the report. Rocks of the Jemez Mountains volcanic field are divided into two major groups: Keres and Tewa. Rocks of the Santa Fe Group filled the Rio Grande rift. Rocks of the Cerros del Rio volcanic field are peripheral to the Jemez Mountains volcanic field. The units in this table are ordered chronologically and, in some instances, vary from the order provided in the GRI GIS data and band_geology.pdf, which are grouped by formation name and/or geomorphologic type.

Age	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
QUATERNARY (Holocene to Pleistocene)	Alluvium (Qal)	River-deposited gravel, sand, and silt in modern drainages. Beds generally less than 0.5 m (2 ft) thick, with maximum thickness exceeding 15 m (50 ft).	**Rio Grande Rift**—modern alluvium is not considered part of the Santa Fe Group. **Paleontological Resources**—in situ fossils (e.g., charcoal) occur in Holocene deposits in Frijoles Canyon. Ages range from 2,230 ± 250 to 4,160 ± 40 radiocarbon years before present (BP), or 1,929–2,496 to 4,152–4,297 calendar years BP (as computed using Stuiver et al. 2015).	**Fires, Fluvial Geomorphology, and Slope Movements**—**Qal** includes sediment transported during post-fire flooding. Also includes gravel in stream channels, which if removed during post-fire flooding may induce rapid stream incision.	**Landscape Evolution**—primarily represents modern-day alluvium in present-day stream channels but may be as old as El Cajete pyroclastic beds (**Qvec**; 60,000–50,000 years ago).
QUATERNARY (Holocene to Pleistocene)	Alluvial fan deposits (Qfa)	Coarse to fine river-deposited gravel and sand, silt, and clay; some fan deposits are difficult to distinguish from older alluvial fans. Thickness 2–20 m (7–70 ft).	**El Cajete Pyroclastic Beds**—**Qfa** includes some El Cajete pyroclastic beds (**Qvec**).	**Fires, Fluvial Geomorphology, and Slope Movements**—**Qfa** includes both streamflow and debris-flow deposits, which increase following a fire.	**Landscape Evolution**—Middle Pleistocene to Holocene age is assigned based on a relatively low topographic position in the landscape.
QUATERNARY (Holocene to Pleistocene)	Alluvial deposit, beds of sand (Qa5)	River-deposited sand and pebbly sand, and thin beds of silty sand. Cross- to planar-bedded. Beds generally <0.5 m (2 ft) thick. Base not exposed.	**El Cajete Pyroclastic Beds**—**Qa5** is younger than El Cajete pyroclastic beds (**Qvec;** 60,000–50,000 years ago). **Paleontological Resources**—likely to contain fossils, though none reported within Bandelier National Monument to date.	None reported.	**Landscape Evolution**—**Qa5** deposited by ancestral Rio Grande. Exposed beneath narrow terraces 3–10 m (10–30 ft) above the modern Rio Grande.
QUATERNARY (Holocene to Pleistocene)	Alluvial and eolian deposit (Qpa)	Consists of yellowish brown, pebbly, and silty-clayey sand. Mostly 1–2 m (3–7 ft) thick, with a possible maximum thickness of 8 m (26 ft). ***Note***: Although grouped with alluvial (river/channelized) and eolian (windblown) deposits in the GRI GIS data set, the unit was deposited by sheetwash (overland flow). It was originally mapped as sheetwash deposits by Dethier et al. (2011) and sheetflood deposits and minor eolian sediment by Konig and Read (2010) within the monument.	**Bandelier Tuff**—**Qpa** contains reworked pumice from Otowi Member of the Bandelier Tuff (**Qbo**). **Cerros del Rio Volcanic Rocks**—most deposits of **Qpa** include primary and reworked basaltic colluvium (e.g., **QTcrv**). **El Cajete Pyroclastic Beds**—most deposits include primary and reworked El Cajete pyroclastic beds (**Qvec**). **Paleontological Resources**—likely to contain fossils, though none reported within Bandelier National Monument to date.	**Fires, Fluvial Geomorphology, and Slope Movements**—deposited by sheetflooding (overland flow), which is common following a fire.	**Landscape Evolution**—Holocene age indicates ongoing processes (eolian, fluvial, and sheetwash).

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Age	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
QUATERNARY (Holocene to Pleistocene)	Landslides (Qls)	Gravity-deposited, poorly sorted debris. Thickness varies considerably depending on the size and nature of the landslide.	**Rio Grande Rift**—failures mainly occurred along steeply dipping planes rooted in the Santa Fe Group, and in hydromagmatic deposits and other altered volcanic rock. Slide material commonly overlies rocks of the Santa Fe Group. **Cerros del Rio Volcanic Field**—**Qls** commonly mantled by basaltic colluvium composed of Cerros del Rio volcanic rocks (**Qcrv**). **El Cajete Pyroclastic Beds**—older slides may be overlain by El Cajete pyroclastic beds (**Qvec**; 60,000–50,000 years ago).	**Fires, Fluvial Geomorphology, and Slope Movements**—depending on lithology and drainage-basin morphology, debris flows may be produced following a fire. **Cliff Retreat and Rockfall**—cliff retreat in Bandelier National Monument occurs as a result of deep-seated landslides. **Cochiti Dam and Reservoir**—holding of water beyond "temporary" time frames and lake drawdown reactivates landslides.	**Rio Grande Rift, Peripheral Volcanism, Jemez Mountains Volcanic Field,** and **Landscape Evolution**—morphology and inclusion of Tshirege Member of the Bandelier Tuff (**Qbt**) in some **Qls** deposits suggests that they were active in early Pleistocene time, but many stabilized in middle to late Pleistocene time.
QUATERNARY (Holocene to Pleistocene)	Colluvium (Qc)	Primarily gravity-deposited, pebbly silty sand to cobbly and boulder rubble with sandy matrix. Thickness generally 4–10 m (10–30 ft), but locally exceeds 25 m (80 ft), for example in White Rock Canyon. Although abundant, **Qc** was mapped only where deposits are extensive or where they cover critical contact of fault relations.	**Bandelier Tuff**—**Qc** occurs at the base of cliffs that are commonly composed of Tshirege Member (**Qbt**). **El Cajete Pyroclastic Beds**—deposits include El Cajete pyroclastic beds (**Qvec**) in many areas.	**Cliff Retreat and Rockfall**—**Qc** includes rockfall, debris flow, slope wash, and poorly sorted alluvium on slopes or at the base of cliffs in wedge-shaped deposits. **Seismic Activity**—seismic shaking may induce rockfall and deposition of **Qc**.	**Landscape Evolution** and **Humans on the Landscape**—Holocene age indicates an ongoing process.
QUATERNARY (Holocene to Pleistocene)	Terrace gravel (Qt)	Gravel deposited in previous stream channels now "perched" as terraces above the modern floodplain. Maximum thickness as much as 15 m (50 ft). Mapped in only a few locations but relatively extensive along major streams such as El Rito de los Frijoles.	None reported.	**Fires, Fluvial Geomorphology, and Slope Movements**—changes in channel geometry following a fire may affect **Qt**.	**Landscape Evolution** and **Humans on the Landscape**—consists of slightly older alluvium that lies along the margins of present streams and basins; now undergoing erosion.
QUATERNARY (Holocene to Pleistocene)	Boulder fields (Qrx)	High-elevation areas covered with boulders as large as 3 m (10 ft) across derived from subjacent rock units. Thickness unknown.	**High-Elevation Features**—**Qrx**, as well as rock glaciers, patterned ground, and felsenmeer occur at high elevations in the monument.	None reported.	**Landscape Evolution**—contemporaneous with landslide deposits (**Qls**) and terrace gravel (**Qt**) but likely predates their occurrence on the landscape. May be associated with Pleistocene (ice age) glaciations.
QUATERNARY (Late Pleistocene)	Alluvial deposit, gravel and sand (Qa4)	River-deposited, well-sorted cobble to boulder gravel, cross-bedded sand, and thin-bedded sand; and river-deposited and windblown silty sand. Thickness probably 4–20 m (13–66 ft).	**Rio Grande Rift**—**Qa4** overlies Santa Fe Group deposits, landslide deposits, or older alluvium. **El Cajete Pyroclastic Beds**—**Qa4** is younger than El Cajete pyroclastic beds (**Qvec**).	**Cochiti Dam and Reservoir**—extensive deposits around Cochiti Dam.	**Landscape Evolution**—**Qa4** consists of ancestral Rio Grande alluvium. Exposed beneath terrace remnants 14–20 m (46–66 ft) above the present-day stream channel.

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Age		Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
QUATERNARY (Late Pleistocene)		Piedmont alluvial deposit, gravel, sand and silty sand (Qp4)	River-deposited, poorly sorted cobble to boulder gravel, sand, and local silty sand. Deposits 0.5–8.0 m (2–26 ft) thick.	**El Cajete Pyroclastic Beds**—**Qp4** is younger than El Cajete pyroclastic beds (**Qvec**).	None reported.	**Landscape Evolution**—**Qp4** makes up piedmont alluvial deposit west of the Rio Grande. Exposed beneath terraces 14–20 m (46–66 ft) above present channels graded to the Rio Grande.
QUATERNARY (Pleistocene)	Tewa Group	Valles Rhyolite El Cajete pyroclastic beds (Qvec)	White to tan, moderately sorted, pyroclastic fall deposits of vesicular rhyolite. Consists of pumice clasts with a maximum diameter of about 15 cm (6 in); clast size diminishes from west to east away from source vent. Maximum exposed thickness varies from 70 m (230 ft) in vent area to scant exposures too thin to map.	**Jemez Mountains Volcanic Field**—emplaced in Valles caldera, following resurgent uplift of the caldera floor. Source was El Cajete crater. **Bandelier Tuff**—**Qvec** is extensively reworked by erosion and collects on east-facing slopes and on benches cut into upper flow unit and/or cooling unit boundaries of Tshirege Member of Bandelier Tuff (**Qbt**). **El Cajete Pyroclastic Beds**—significant time-stratigraphic marker in the area; deposited 60,000–50,000 years ago. Facilitated "dry farming" in the Jemez Mountains.	**Fires, Fluvial Geomorphology, and Slope Movements**—slopes mantled in pumice (**Qvec**) promote flooding. **Volcano Hazards**—future hazards include ash and pumice deposited beyond caldera rim; similar to hazards during deposition of **Qvec**.	**Jemez Mountains Volcanic Field**—originated from El Cajete crater in southern part of Valles caldera. **Landscape Evolution** and **Humans on the Landscape**—forms extensive mesa-top cover in Bandelier National Monument.
QUATERNARY (Pleistocene)	Tewa Group	Valles Rhyolite Older alluvium (Qtoal)	River-deposited gravel, sand, and silt overlying Tshirege Member of Bandelier Tuff (**Qbt**) on the rim and flanks of Valles caldera. Maximum exposed thickness about 6 m (20 ft).	**Jemez Mountains Volcanic Field**—contemporaneous with the most recent volcanism in the volcanic field. Emplaced in Valles caldera, following resurgent uplift of the caldera floor.	None reported.	**Jemez Mountains Volcanic Field**—maximum age of **Qtoal** is at least 1.1 million years. **Landscape Evolution**—largely pre-dates incision of canyons in surrounding plateaus and highlands.
QUATERNARY (Pleistocene)	Tewa Group	Valles Rhyolite Young Rabbit Mountain debris-flow deposits (Qrd2)	**Qrd2** consists of two debris-flow deposits overlying Tshirege Member of Bandelier Tuff (**Qbt**) immediately south of Rabbit Mountain. Resembles **Qrd1** (see description below) except that the matrix is not as ash rich. Maximum exposed thickness about 60 m (200 ft).	**Jemez Mountains Volcanic Field**—contemporaneous with the most recent volcanism in the volcanic field. Emplaced in Valles caldera, following resurgent uplift of the caldera floor.	None reported.	**Jemez Mountains Volcanic Field**—**Qrd2** is younger than about 1.25 million years ago, when Young Rabbit Mountain dome formed.
QUATERNARY (Pleistocene)	Tewa Group	Bandelier Tuff Tshirege Member (Qbt)	White to orange to pink welded to nonwelded rhyolitic ash-flow tuff. Consists of ash fall ("pyroclastic fall") and multiple pyroclastic flows ("ash flows") in a compound cooling unit. Maximum observed thickness within caldera more than 900 m (2,950 ft).	**Jemez Mountains Volcanic Field**—represents one of two caldera-forming eruptions in the central part of the volcanic field. Eruption of **Qbt** resulted in the formation of Valles caldera, which largely obliterated Toledo caldera. **Bandelier Tuff**—the most famous rock unit in the Jemez Mountains volcanic field, and possibly the most famous ash-flow tuff in the world. **Features in Bandelier Tuff**—**Qbt** contains cavates, and weathered to form tent rocks. Trails eroded into **Qbt**. **Paleontological Resources**—ash deposits likely to contain fossils, though none reported within Bandelier National Monument to date. Cavates in **Qbt** may contain packrat middens (*Neotoma* spp.).	**Cliff Retreat and Rockfall**—erosion of **Qbt** tends to form cliffs. Rockfall from cliffs is the most common type of slope movement in Bandelier National Monument. **Cavate Deterioration**—cavates primarily impacted through small-scale spalling and granular erosion of Bandelier Tuff, and to a lesser extent from large-scale rockfall.	**Jemez Mountains Volcanic Field**—**Qbt** erupted 1.25 ± 0.01 million years ago (^{40}Ar/^{39}Ar age). **Humans on the Landscape**—ancestral Puebloans hollowed out cavates for storage and habitation.

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QUATERNARY (Pleistocene)	Tewa Group	Cerro Toledo Formation Pueblo Canyon Member (Qcpc)	Colluvial deposit of reworked pumice and angular blocks of Otowi Member of Bandelier Tuff (**Qbo**) in middle Frijoles Canyon; two thin deposits of primarily Tschicoma Formation–derived gravels in upper Frijoles Canyon and northwest of Rendija Peak. Maximum thickness about 4 m (13 ft).	**Jemez Mountains Volcanic Field**—consists of domes, flows, and pyroclastic deposits of Toledo caldera, and pyroclastic and contemporaneous volcaniclastic units between the two members of Bandelier Tuff (**Qbo** and **Qbt**).	**Cliff Retreat and Rockfall** and **Cavate Deterioration**—where exposed at the base of Tshirege cliffs in Frijoles Canyon, **Qcpc** facilitates cliff retreat, which negatively impacts archeological sites.	**Jemez Mountains Volcanic Field**—**Qcpc** deposited between the two cataclysmic explosions of Bandelier Tuff in the central part of the volcanic field.
QUATERNARY (Pleistocene)	Tewa Group	Cerro Toledo Formation Valle Toledo Member, Old Rabbit Mountain debris-flow deposits (Qrd1)	Debris flows formed by multiple failures of the Rabbit Mountain dome during growth. Outcrops display sintered ashy matrix, suggesting formation as pyroclastic flows. Forms southeast-trending hummocky tongue 5 km (3 mi) long and 3 km (2 mi) wide. Maximum exposed thickness about 40 m (130 ft).	**Jemez Mountains Volcanic Field**—deposited between the two cataclysmic explosions of Bandelier Tuff in the central part of the volcanic field. Formed in Toledo caldera during eruption of Rabbit Mountain (lava dome). **Lithic Resources**—**Qrd1** contains abundant obsidian blocks that are a known source of artifacts.	None reported.	**Jemez Mountains Volcanic Field**—**Qrd1** deposited between lower and upper Bandelier Tuffs during the Cerro Toledo interval. **Human on the Landscape**—**Qrd1** contains obsidian used for making tools.
QUATERNARY (Pleistocene)	Tewa Group	Cerro Toledo Formation Valle Toledo Member, Rabbit Mountain rhyolite (Qcrm)	Makes up Rabbit Mountain (lava dome) and thick flows and flow breccias of rhyolitic composition. Maximum exposed thickness about 410 m (1,345 ft).	**Jemez Mountains Volcanic Field**—deposited between the two cataclysmic explosions of Bandelier Tuff in the central part of the volcanic field. Vent for **Qcrm** collapsed before or during formation of Valles caldera. **Lithic Resources**—**Qcrm** contains obsidian and is a known source of artifacts.	None reported.	**Jemez Mountains Volcanic Field**—**Qcrm** deposited between Otowi and Tshirege members of Bandelier Tuff. Potassium/argon (K/Ar) ages of 1.43 million ± 0.04 million and 1.54 ± 0.06 million years ago. **Human on the Landscape**—**Qcrm** contains obsidian used for making tools.
QUATERNARY (Pleistocene)	Tewa Group	Cerro Toledo Formation Valle Toledo Member (Qct)	Consist of rhyolitic pyroclastic fall deposits usually less than 2 m (7 ft) thick. Maximum exposed thickness about 20 m (70 ft) but exceeds 30 m (100 ft) in several wells drilled on the Pajarito Plateau.	**Jemez Mountains Volcanic Field**—**Qct** deposited between the two cataclysmic explosions of Bandelier Tuff in the central part of the volcanic field. Tuffaceous layers are part of the Cerro Toledo rhyolite originating from sources in Toledo caldera. **Lithic Resources**—obsidian phase is completely aphyric ("fine grained") and a known source of artifacts.	None reported.	**Jemez Mountains Volcanic Field**—**Qct** deposited between lower and upper Bandelier Tuffs during the Cerro Toledo interval. Ages of tuffaceous units and source domes range from 1.64 million to 1.21 million years ago. **Human on the Landscape**—used obsidian for making tools.
QUATERNARY (Pleistocene)	Tewa Group	Bandelier Tuff Otowi Member (Qbo)	Poorly to densely welded rhyolitic ash-flow tuff. Very difficult to distinguish from **Qbt** 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 and/or Cerro Toledo Formation. Maximum exposed thickness about 120 m (390 ft).	**Jemez Mountains Volcanic Field**—represents one of two caldera-forming eruptions in the central part of the volcanic field. Eruption of **Qbo** resulted in the formation of Toledo caldera. Discontinuously fills in rugged topography on a pre–Toledo caldera age volcanic surface; upper surface undulatory due to erosion. **Bandelier Tuff**—**Qbo** is part of the most famous rock unit in the Jemez Mountains volcanic field, and possibly the most famous ash-flow tuff in the world. **Features in Bandelier Tuff**—contains tent rocks. **Paleontological Resources**—ash deposits likely to contain fossils, though none reported within Bandelier National Monument to date.	**Cliff Retreat and Rockfall**—**Qbo** has greater tendency to form slopes than Tshirege Member (**Qbt**).	**Jemez Mountains Volcanic Field**—Erupted 1.61 ± 0.01 to 1.62 ± 0.04 million years ago ($^{40}Ar/^{39}Ar$ ages).

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Age	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
QUATERNARY (Middle? Pleistocene)	Alluvial deposit, boulder gravel and cross-bedded sand (Qa3)	River-deposited, well-sorted cobble to poorly sorted boulder gravel, cross-bedded sand, and thin-bedded sand, preserved at mouths of tributaries and in an extensive deposit near Alamo Canyon that contain angular boulders as large as 3.5 m (11 ft). Thickness 4–15 m (13–49 ft).	**Jemez Mountains Volcanic Field**—**Qa3** consists of clasts of predominantly axial river lithologies but locally rich in andesitic and dacitic rocks derived from volcanic terrane to the west. **Rio Grande Rift**—**Qa3** overlies and truncates rocks of the Santa Fe Group, landslide deposits, older alluvium, or hydromagmatic deposits. **El Cajete Pyroclastic Beds**—extensive deposits on both sides of Rio Grande near the mouth of Alamo Canyon are overlain by El Cajete pyroclastic beds (**Qvec**).	None reported.	**Landscape Evolution**—**Qa3** is composed of ancestral Rio Grande alluvium. Exposed beneath terrace remnants 25–45 m (80–150 ft) above the Rio Grande.
QUATERNARY (Middle? Pleistocene)	Piedmont alluvial deposit, poorly sorted gravel and sand (Qp3)	Poorly sorted cobble to boulder gravel and sand at the base of mountain slopes. Thickness 0.5–8.0 m (2–26 ft).	**El Cajete Pyroclastic Beds**—**Qp3** is older than El Cajete pyroclastic beds (**Qvec**).	None reported.	**Rio Grande Rift** and **Jemez Mountains Volcanic Field**—**Qp3** locally overlies Cochiti Formation (**QTc**), Otowi Member of Bandelier Tuff (**Qbo**), or Santa Fe Group deposits. **Landscape Evolution**—piedmont alluvial deposits west and east of the Rio Grande. Exposed beneath terraces 25–40 m (80–130) above present channels.
QUATERNARY (Middle? Pleistocene)	Alluvial deposit, cobble and boulder gravel (Qa2)	River-deposited, well-sorted cobble to boulder gravel. Boulders as large as 3 m (10 ft) across. Thickness generally 10–30 m (30–100 ft).	**El Cajete Pyroclastic Beds**—**Qa2** is older than El Cajete pyroclastic beds (**Qvec**). **Paleontological Resources**—amino-acid ratios from gastropods in the upper 5 m (16 ft) of **Qa2** suggest a local age of 300,000 to 250,000 years ago.	None reported.	**Landscape Evolution**—**Qa2** is composed of Rio Grande alluvium. Exposed beneath terrace remnants approximately 50 to 70 m (160 to 230 ft) above the present Rio Grande channel.
QUATERNARY (Middle? Pleistocene)	Piedmont alluvial deposit, gravel, silt and massive sand (Qp2)	Poorly sorted cobble to boulder gravel and massive sand and local silt beds.	**El Cajete Pyroclastic Beds**—**Qp2** is older than El Cajete pyroclastic beds (**Qvec**).	None reported.	**Rio Grande Rift** and **Jemez Mountains Volcanic Field**—**Qp2** locally overlies Cochiti Formation (**QTc**), Otowi Member of Bandelier Tuff (**Qbo**), or Santa Fe Group deposits. **Landscape Evolution**—**Qp2** was deposited west and east of the Rio Grande. Exposed beneath terrace remnants 45–60 m (150–200 ft) above present channels.
QUATERNARY (Early Pleistocene)	Andesite of Cochiti Volcano, lower unit (Qcl)	Reddish brown to medium gray andesite. Maximum exposed thickness is 350 m (1,150 ft).	**Cerros del Rio Volcanic Field**—**Qcl** consists of lava flows and oxidized cinder and spatter erupted from Cochiti volcano in the Cerros del Rio volcanic field.	**Seismic Activity**—Cochiti volcano deposits post-date down-to-west offset along the Cochiti fault, whose footwall scarp formed a topographic barrier to eastward deposition of lava flows.	**Peripheral Volcanism**—**Qcl** is part of the Cerros del Rio volcanic field. Erupted 1.7 million–1.5 million years ago.

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QUATERNARY and TERTIARY (Lower Pleistocene to upper Pliocene)	Cerros del Rio volcanic rocks (QTcrv)	Basalt, basaltic andesite, andesite, and dacite. Silica content ranges from 48%–65% (mostly 48%–60%). Phreatomagmatic deposits (pale brown to very pale brown silty sand with 3%–20% pebbles) and lapilli (black and in very thin, planar to wavy, even beds or laminations) generally underlie the package of flows. Thickness of the volcanic pile ranges from a few meters along the eastern margin to 100–240 m (330–790 ft) in the central part of the Caja del Rio plateau.	**Cerros del Rio Volcanic Field**—lava flows and associated phreatomagmatic deposits. Primarily cap the Caja del Rio plateau. Central-vent volcanoes typify the eruptive centers in this field, and range from low-relief shields to steep-sided, breached cinder cones. **Lithic Resources**—dacitic lavas (>63% SiO_2) are related to late-stage dome growth and eruption of viscous, blocky lava flows as much as 50 m (160 ft) thick in the Cerros del Rio volcanic field. Ancient people utilized a dacite quarry in this material at the mouth of Alamo Canyon in Bandelier National Monument.	**Cochiti Dam and Reservoir**—dam constructed on three extinct volcanoes of Santa Ana Mesa, which are contemporaneous with Cerros del Rio volcanoes.	**Peripheral Volcanism**—erupted from the Cerros del Rio vents. Age of the volcanic rocks ranges from 2.7 million to 1.0 million years ago, with most 2.7 million–2.2 million years ago. **Humans on the Landscape**—**QTcrv** contains dacite used for making tools.
TERTIARY (Pliocene)	Mafic lava flows (Tclf)	Basaltic rock in undivided unit of flows, dikes, and associated cinder deposits. Flows massive to sheeted, generally showing broad columnar joints. May contain abundant xenocrysts of rocks from beneath the Pajarito Plateau that were transported upward during a volcanic eruption. Maximum exposed thickness about 40 m (130 ft).	**Cerros del Rio Volcanic Field**—**Tclf** erupted in the Cerros del Rio volcanic field.	None reported.	**Peripheral Volcanism**—age range from 2.8 million to 2.3 million years ago ($^{40}Ar/^{39}Ar$ ages).
TERTIARY (Pliocene)	Benmorite (Tcba)	Basaltic rock in thick lava flow exposed in upper walls of lower Frijoles Canyon and adjacent White Rock Canyon. Locally contorted and flow banded within upper two-thirds of flow. Lower part of flow generally massive and cut by widely spaced columnar joints. Maximum exposed thickness about 70 m (230 ft).	**Cerros del Rio Volcanic Field**—**Tcba** erupted in the Cerros del Rio volcanic field.	None reported.	**Peripheral Volcanism**—**Tcba** erupted 2.75 ± 0.08 million years ago ($^{40}Ar/^{39}Ar$ age).
TERTIARY (Pliocene)	Cinder deposit (Tcbc)	Basaltic rock in scoria, bombs, and associated thin lavas from partially exposed cone in eastern wall of Frijoles Canyon just upstream of Upper Frijoles Falls. Maximum exposed thickness about 25 m (82 ft).	**Cerros del Rio Volcanic Field**—**Tcbc** erupted in the Cerros del Rio volcanic field.	None reported.	**Peripheral Volcanism**—relations with other Cerros del Rio rocks uncertain.
TERTIARY (Pliocene)	Mafic hydromagmatic deposits (Tcbm)	Layered hydromagmatic (maar) deposits, consisting of cinders, ash, and decomposed glass with pebble- to boulder-sized fragments of rocks from beneath the Pajarito Plateau that were brought to the surface during volcanism. Magmatic component is primarily basalt. Contains numerous interbedded, mafic lava flows too thin or discontinuous to map. Maximum exposed thickness about 150 m (490 ft).	**Cerros del Rio Volcanic Field**—**Tcbm** is the result of magma–water interactions in the Cerros del Rio volcanic field.	None reported.	**Rio Grande Rift**—**Tcbm** contains beds and lenses of ancestral Rio Grande gravels. **Peripheral Volcanism**—formed by interaction of mafic magmas with shallow groundwater or surface water about 2.78 ± 0.04 million years ago ($^{40}Ar/^{39}Ar$ age).
TERTIARY (Pliocene)	Basalt of La Bajada Rim (Tb)	Medium- to dark-gray basalt (48%–50% silica). Maximum exposed thickness 40 m (130 ft).	**Cerros del Rio Volcanic Field**—likely erupted from buried and/or eroded volcanic centers overlain by the andesite of Cochiti Volcano, upper unit (**Qcu**).	**Seismic Activity**—exposed principally along topographic rim of the La Bajada fault escarpment (southeastern part of Bandelier National Monument). Lava flows occur locally to the west of the La Bajada fault escarpment in the hanging wall of the fault.	**Peripheral Volcanism**—**Tb** erupted 2.57 ± 0.02 million years ago ($^{40}Ar/^{39}Ar$ age). **Humans on the Landscape**—**Tb** contains basalt used for making tools.

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Age	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
TERTIARY (Pliocene)	Hydromagmatic deposits (Tbhm)	Basaltic tuff and cinders, and thin (<10 m [30 ft]), interlayered basaltic flows. Ash fall beds, 0.3–3.0 m (1–10 ft) thick, composed mainly of ash and lapilli containing sparse bombs of accidental and basaltic fragments. Surge beds are planar and cross-bedded, locally rippled, coarse silt to pebbly sand, generally 0.1–0.4 m (0.3–1.3 ft) thick. Flowage deposits mainly matrix-rich pebble to boulder gravel in discontinuous beds 1–4 m (3–13 ft) thick. Locally sheared, slumped, or brecciated.	**Rio Grande Rift**—includes accidental fragments of the Santa Fe Group. **Cerros del Rio Volcanic Field**—**Tbhm** deposited as bedded to massive fall, surge, and flow deposits.	None reported.	**Rio Grande Rift**—**Tbhm** is contemporaneous with paleochannel deposits of the Rio Grande (river). **Peripheral Volcanism**—**Tbhm** is older than approximately 2.5 million years; maximum age not closely constrained.
TERTIARY (Pliocene)	Andesite of Sanchez Canyon (Tas)	Medium gray to reddish brown andesite (56% silica). Consists of lava flows and associated near vent pyroclastic deposits. Lava flows are discontinuous and variable in thickness from 1.5 m (5 ft) to tens of meters thick, depending on local underlying paleotopography. Locally includes oxidized andesitic scoria, breccia, spatter, and spatter agglutinate interbedded with lava flows. Maximum thickness is 100 m (330 ft).	**Cerros del Rio Volcanic Field**—exposed along the Rio Grande principally between Bland Canyon on the south and Capulin Canyon on the north (southeast corner of Bandelier National Monument).	None reported.	**Peripheral Volcanism**—**Tas** erupted in the Cerros del Rio volcanic field.
TERTIARY (Pliocene)	Andesite and basaltic andesite, undivided (Taba)	Undifferentiated deposits of andesite and basaltic andesite lava flows and associated breccias; some interbedded pyroclastic and/or hydromagmatic deposits. Maximum exposed thickness 130 m (430 ft).	**Cerros del Rio Volcanic Rocks**—**Taba** erupted in the Cerros del Rio volcanic field.	None reported.	**Rio Grande Rift**—**Taba** is contemporaneous with paleochannel deposits of the Rio Grande (river). **Peripheral Volcanism**—**Taba** emplaced about 3 million years ago.
QUATERNARY and TERTIARY (Lower Pleistocene and Pliocene)	Santa Fe Group Axial channel facies (QTsfa)	Slightly lithified pebble to cobble gravel rich in rounded clasts, arkosic sand, and thin beds of silty sand. Coarse units are 0.5–3.0 m (2–10 ft) thick, massive to cross-bedded, and locally planar-bedded. Gravel generally >70% quartzite, granite, and other resistant rocks from northern New Mexico; andesitic and dacitic rocks from the Jemez Mountains common locally; vesicular basalt uncommon. Matrix quartzose or arkosic. Thickness 5 to >70 m (16 to >230 ft).	**Rio Grande Rift**—**QTsfa** is part of the Santa Fe Group. Lies beneath landslide deposits, Pliocene basalt, or hydromagmatic deposits at most exposures. Fills channels in and locally interbedded with Cochiti Formation (**QTc**) of the Keres Group. **Paleontological Resources**—likely to contain fossils, though none reported within Bandelier National Monument to date.	None reported.	**Rio Grande Rift**—**QTsfa** filled in developing Española basin.

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Age	Map Unit (Symbol)		Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
QUATERNARY and TERTIARY (Lower Pleistocene to lower Pliocene)	Keres Group	Puye Formation ancestral Rio Grande facies (QTpt)	Slightly lithified pebble to cobble gravel (with abundant clasts of Proterozoic quartzite and granite), sand, and thin beds of silty sand. Thickness 5–45 m (16–150 ft).	**Jemez Mountains Volcanic Field**—extensive volcanogenic alluvial fan complex shed eastward from volcanic domes and flows of the Tschicoma Formation (e.g., **Ttpm**, **Ttcg**, and **Ttsd**). Displays considerable lateral variation, consisting of complex, intertonguing mixtures of streamflow, sheet flow, debris flow, block and ash flow, pumice fall, and ignimbrite deposits. **Rio Grande Rift**—**Qtpt** is generally found west of the modern Rio Grande. East of the Rio Grande, it is exposed at one outcrop south of the mouth of Cañada Ancha. **Qtpt** interfingers with the Puye Formation fanglomerate and underlies the fanglomerate in upper White Rock Canyon. The Puye Formation pre-dates overlying Cerros del Rio volcanic rocks (2.2 million–2.7 million years ago). **Paleontological Resources**—likely to contain fossils, though none reported within Bandelier National Monument to date.	None reported.	**Rio Grande Rift**—**QTpt** deposited by the ancestral Rio Grande during the Pliocene Epoch. Contemporaneous with the Tschicoma Formation. **QTpt** lies beneath landslide deposits, Pliocene alluvium, or phreatomagmatic deposits at most exposures, indicating an age of 5.3 million to 2.7 million years ago.
QUATERNARY and TERTIARY (Lower Pleistocene to Miocene)	Keres Group	Cochiti Formation (QTc)	Thick sequence of volcanic gravel and sand (alluvial fans) derived from penecontemporaneous erosion of volcanic units of the Keres Group. Consists of weakly lithified pebble to cobble gravel, massive to planar-bedded sand, thin (<0.3 m [1 ft]) beds of rhyolitic tephra and pumiceous alluvium, beds of fine sand and silt, and silt-rich debris flows containing volcanic clasts. Maximum exposed thickness about 450 m (1,480 ft).	**Jemez Mountains Volcanic Field**—**QTc** consists of volcaniclastic material shed from domes of Bearhead Rhyolite (**Tbh**), primarily as lahars, block and ash flows, and other debris flows that accumulated in small basins and topographic lows between volcanoes. Locally contains hyperconcentrated flow and fluvial deposits, cinder deposits, and pyroclastic fall deposits. **Rio Grande Rift**—**QTc** generally thickens to the south, east, and north into the developing basin of the Rio Grande rift, forming coalesced but eroded alluvial fans.	None reported.	**Rio Grande Rift** and **Jemez Mountains Volcanic Field**—much stratigraphic confusion with **QTc**, but deposited during Keres volcanism (approximately 13 million–6 million years ago).
TERTIARY (Pliocene)	Keres Group	Tschicoma Formation Pajarito Mountain dacite (Ttpm)	Consists of voluminous domes (e.g., Tschicoma and Polvadera peaks) and flows of dacite. Maximum exposed thickness about 365 m (1,200 ft).	**Jemez Mountains Volcanic Field**—**Ttpm** erupted from vents mostly in the northern part of the volcanic field. Source was Pajarito Mountain. **Lithic Resources**—**Ttpm** is too porphyritic for making tools and projectile points.	None reported.	**Jemez Mountains Volcanic Field**—^{40}Ar/^{39}Ar ages on geographically separated samples range from 3.09 million to 2.93 million years ago.
TERTIARY (Pliocene)	Keres Group	Tschicoma Formation Cerro Grande dacite (Ttcg)	Consists of extensive dome and flow complex of dacite. Maximum exposed thickness about 750 m (2,460 ft).	**Jemez Mountains Volcanic Field**—**Ttcg** erupted from vents mostly in the northern part of the volcanic field. Source was Cerro Grande. **Lithic Resources**—**Ttcg** is too porphyritic for making tools and projectile points.	None reported.	**Jemez Mountains Volcanic Field**—erupted from 3.35 million to 2.88 million years ago, as estimated from ages on widely separated samples.

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Age	Map Unit (Symbol)		Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
TERTIARY (Pliocene)	Keres Group	Tschicoma Formation Sawyer Dome dacite (Ttsd)	Consists of dome and flow complex of dacite. Maximum exposed thickness is 245 m (800 ft).	**Jemez Mountains Volcanic Field**—erupted from vents mostly in the northern part of the volcanic field. **Lithic Resources—Ttsd** is too porphyritic for making tools and projectile points.	None reported.	**Jemez Mountains Volcanic Field—Ttsd** erupted 3.44 ± 0.30 million years ago ($^{40}Ar/^{39}Ar$ age).
TERTIARY (Pliocene to Miocene)	Keres Group	Bearhead Rhyolite (Tbh)	Consists of domes, shallow intrusions (e.g., dikes and plugs), flows, and pyroclastic rocks of rhyolitic composition. Some domes (e.g., Bearhead Peak) are quite voluminous. Locally shows pervasive hydrothermal alteration. Maximum observed thickness about 100 m (330 ft).	**Jemez Mountains Volcanic Field—Tbh** erupted from vents in the southern part of the volcanic field.	None reported.	**Jemez Mountains Volcanic Field—Tbh** erupted between 7.83 million to 4.81 million years ago, as estimated from $^{40}Ar/^{39}Ar$ ages on widely separated samples.
TERTIARY (Miocene)	Keres Group	Bearhead Rhyolite Peralta Tuff Member (Tkpt)	White to tan, lithic-rich, ash fall tuff. Includes major sequences of pyroclastic rocks consisting of fall, flow, surge, and hydromagmatic surge deposits that were erupted from different vents. Sources for all tuff units unknown. Fills in rugged volcanic topography on earlier Keres Group rocks. Maximum observed thickness about 170 m (560 ft).	**Jemez Mountains Volcanic Field—Tkpt** erupted from vents in the southern part of the volcanic field.	None reported.	**Jemez Mountains Volcanic Field—Tkpt** erupted 6.81 ± 0.15 million years ago (K-Ar age of lowermost tuff bed at Peralta Canyon type locality).
TERTIARY (Pliocene to Miocene)	Santa Fe Group, undivided (Tsf)		White to tan to very pale green feldspathic sandstone, as well as siltstone and conglomerate. Maximum observed thickness 200 m (660 ft).	**Rio Grande Rift—Tsf** was deposited by the ancestral Rio Grande (river) in the Rio Grande rift as Earth's crust pulled apart. **Paleontological Resources**—likely to contain fossils, though none reported within Bandelier National Monument to date.	None reported.	**Rio Grande Rift—Tsf** deposited in the rift.
TERTIARY (Miocene)	Keres Group	Paliza Canyon Formation Porphyritic dacite tuff (Tpdt)	White pumice, ash, crystals, and lithic fragments commonly found in volcaniclastic deposits of the Paliza Canyon Formation. Consists of pyroclastic fall deposits. Beds are not laterally extensive and pinch out due to erosion. May show reverse or graded bedding. Maximum exposed thickness about 40 m (130 ft).	**Jemez Mountains Volcanic Field—Tpdt** erupted from vents in the southern part of the volcanic field. **Lithic Resources—Tpdt** consists of dacite.	None reported.	**Jemez Mountains Volcanic Field**—erupted 8.20 ± 0.29 million years ago (K-Ar age of altered tuff). **Humans on the Landscape—Tpdt** contains dacite used for making tools.
TERTIARY (Miocene)	Keres Group	Paliza Canyon Formation Porphyritic hornblende dacite (Tphd)	Gray to pink porphyritic dacite. Consists of domes, flows, and minor intrusive rocks. Flows massive to sheeted; may contain flow breccia. Eroded flows cap the summits of Las Conchas, Los Griegos, and other hills south of Valles caldera. Maximum exposed thickness is 75 m (250 ft).	**Jemez Mountains Volcanic Field—Tphd** erupted from vents in the southern part of the volcanic field. **Lithic Resources—Tphd** consists of dacite.	None reported.	**Jemez Mountains Volcanic Field**—erupted 8.53 ± 0.63 million years ago ($^{40}Ar/^{39}Ar$ age from Los Griegos). **Humans on the Landscape—Tphd** contains dacite used for making tools.
TERTIARY (Miocene)	Keres Group	Paliza Canyon Formation Porphyritic andesite (Tppa)	Gray to black coarse porphyritic andesite. Consists of domes and flows. Flows generally sheeted with minor flow breccia. Maximum observed thickness about 150 m (490 ft).	**Jemez Mountains Volcanic Field—Tppa** erupted from vents in the southern part of the volcanic field.	None reported.	**Jemez Mountains Volcanic Field**—erupted 8.69 ± 0.38 million years ago (K-Ar age).

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Age	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
TERTIARY (Miocene)	Keres Group Paliza Canyon Formation Two-pyroxene andesite, undivided (Tpa)	Consists of domes, flows, flow breccia, spatter deposits, and scoria of andesite. Maximum exposed thickness about 150 m (490 ft).	**Jemez Mountains Volcanic Field—Tpa** erupted from multiple, widely scattered vents in the southern part of the volcanic field.	None reported.	**Jemez Mountains Volcanic Field**—erupted from 9.4 million to 8.2 million years ago ($^{40}Ar/^{39}Ar$ ages).
TERTIARY (Miocene)	Keres Group Canovas Canyon Rhyolite (Tcct)	White to pink tuffs, consisting of several distinct deposits, including lowermost unit of pink, lithic-rich tuff containing abundant fragments of flow banded rhyolite (informally named the "pink tuff"). Consists of as ash-fall and ash-flow tuffs. Maximum exposed thickness about 10 m (30 ft).	**Jemez Mountains Volcanic Field—Tcct** erupted from vents in the southern part of the volcanic field.	None reported.	**Jemez Mountains Volcanic Field**—erupted about 10 million years ago.
TERTIARY (Late Miocene)	Basalt flows and cinders (Tsfb)	Black alkali basalt and basanite (category of basaltic volcanic rocks). Consists of thin discontinuous flows, pillow basalt, and palagonite tuff. Maximum observed thickness about 5 m (16 ft).	**Rio Grande Rift—Tsfb** represents basaltic volcanism associated with formation of the Rio Grande rift. Interbedded with Santa Fe Group deposits	None reported.	**Rio Grande Rift**—part of minor basaltic volcanism that erupted into sediments of the Santa Fe Group 16.5 ± 1.4 million years ago (K-Ar age).
TERTIARY (Miocene)	Chamita Formation Lower Vallito Member (Tscv)	Buff colored, strongly to weakly cemented fine to coarse grained sandstone. Locally cross-bedded to planar laminated, otherwise massive. Contains two light gray to white chert beds in the lower 100 m (330 ft). Thickness about 250 m (820 ft).	**Rio Grande Rift**—Tesuque and Chamita formations are part of the Santa Fe Group. **Tscv** was deposited by the ancestral Rio Grande (river) in the Rio Grande rift. **Paleontological Resources**—likely to contain fossils, though none reported within Bandelier National Monument to date.	None reported.	**Rio Grande Rift—Tscv** was deposited by the ancestral Rio Grande (river) in the Rio Grande rift as Earth's crust pulled apart.
TERTIARY (Miocene)	Tesuque Formation Chama-El Rito Member (Tstc)	Orange to pinkish quartz-rich sandstone with a few thin lenses of volcanic pebbles derived from volcanic fields to the north (Latir). Dominated by a sandy bed load. At least 200 m (660 ft) thick.	**Rio Grande Rift**—Tesuque and Chamita formations are part of the Santa Fe Group. **Tstc** was deposited by the ancestral Rio Grande (river) in the Rio Grande rift. **Paleontological Resources**—likely to contain fossils, though none reported within Bandelier National Monument to date.	None reported.	**Rio Grande Rift**—deposited in the rift by a south-flowing (from the San Luis Basin) ancestral Rio Grande (river).
TERTIARY (Miocene)	Olivine andesite (Tpoa)	Black to gray slightly porphyritic andesite. Flows massive to sheeted, commonly with vesicular flow tops. Maximum observed thickness about 70 m (230 ft).	**Rio Grande Rift**—domes, flows, and minor red cinder deposits associated with the formation of the Rio Grande rift.	None reported.	**Rio Grande Rift**—basaltic volcanism in the Rio Grande rift. Ages of various flows unknown.
TERTIARY (Miocene to upper Oligocene)	Tesuque Formation Basalt flow (Tstb)	Exposures of flow and pillow-palagonite tuff east of St. Peter's Dome of black alkali basalt. Thickness about 3 m (10 ft).	**Rio Grande Rift**—Tesuque and Chamita formations are part of the Santa Fe Group. **Tstb** represents basaltic volcanism in sediments of the Santa Fe Group. **Paleontological Resources**—likely to contain fossils, though none reported within Bandelier National Monument to date.	None reported.	**Rio Grande Rift**—deposited in the rift between 25.48 ± 0.84 million and 20.83 ± 0.63 million years ago, as estimated from interbedded basalt lava ($^{40}Ar/^{39}Ar$ ages).

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Age	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
TERTIARY (Miocene to upper Oligocene)	Volcaniclastic sediments (Tstv)	Black alkali basalt. Exposures of flow and pillow palagonite tuff. Thickness about 3 m (10 ft).	**Rio Grande Rift**—**Tstv** represents basaltic volcanism associated with formation of the Rio Grande rift.	None reported.	**Rio Grande Rift**—**Tstv** is interbedded with Santa Fe Group deposits between 25.48 ± 0.84 million and 20.83 ± 0.63 million years ago ($^{40}Ar/^{39}Ar$ ages).
PALEOGENE (Eocene)	Galisteo Formation (Tgs)	Orange to tan to brick red beds of well-indurated sandstone, siltstone, arkose, and conglomerate. Maximum observed thickness about 200 m (660 ft). Base of unit not exposed.	**Paleontological Resources**—likely to contain fossils, though none reported within Bandelier National Monument to date.	**Seismic Activity**—**Tgs** is exposed on rotated fault block with beds dipping steeply west.	**Tgs** predates development of the **Jemez Mountains volcanic field** and formation of the **Rio Grande rift**. Deposited by rivers in a broad, deep inland basin, 56 million–33 million years ago.