

## **Geologic Road Log Cumbres and Toltec Scenic Railroad**

### **A Regional Setting**

Our journey between Chama and Antonito today takes us from the San Juan Basin, across the Tusas Mountains, and into the San Luis Basin (Figure 1). The San Juan Basin on the Colorado Plateau is an important oil-producing basin that formed during compressional deformation 75 to 55 million years ago. This compressional event, known as the Laramide mountain building event, affected entire the western United States (Figure 2), creating large basins and mountain ranges. The Tusas Mountains also formed during Laramide deformation and are part of the southern Rocky Mountains. Ancient rocks that are 1.4 to 1.7 billion years old were brought toward the surface along faults and were exposed by erosion between 75 and 55 million years ago.

The Tusas Mountain highland and the San Juan Basin were then partially covered by lava flows and ash-flow tuffs derived from cataclysmic eruptions of 38 to 19 million-year-old volcanoes in the San Juan Mountains to the north (Figure 2). Andesitic stratovolcanoes dominated the landscape during the early history of the volcanic field. Later, several violent caldera-forming eruptions in the San Juan Mountains blanketed large portions of southwestern Colorado and north-central New Mexico with rhyolitic ash-flow tuff (Figure 1). Younger volcanic debris eroded from the volcanoes later lapped onto the northeast margin of the Tusas Mountains.

As the volcanoes in the San Juan Mountains eroded, this part of New Mexico and Colorado was stretched by east-west extension, causing eruption of basalts and the formation of deep sediment-filled basins (Figure 2). This extensional feature, known as the Rio Grande rift, started forming in this area about 26 million years ago. The youngest rift-related basaltic volcanism in this region (1 to 5 million years old, Appelt, 1998) is in the Taos Plateau volcanic field just south of Antonito.

### **What triggered mountain building and volcanic activity in this area?**

The mountains and the remnants of long-dormant volcanoes that we will see today can be explained in terms of plate tectonics. According to one hypothesis, the geologic story of the Chama-Antonito area actually began nearly 100 million years ago and hundreds of miles to the west, when a plate, known as the Farallon Plate, was subducted eastward under the western edge of the North American Plate (Figure 2). This plate, which was between the Pacific and the North American plates, has largely been consumed by subduction during the last 100 million years. Originally, the Farallon Plate was subducted beneath North America at a fairly steep angle, giving rise to the plutons preserved in the roots of the Sierra Nevada in California (top panel of Figure 2). Mountain building and magmatism migrated eastward and arrived in southwestern Colorado and northwestern New Mexico approximately 75 million years ago. This eastward migration is thought to have been caused by flattening of the subduction angle of the Farallon plate, initiated either by an increase in the rate of subduction or by subduction of a buoyant oceanic plateau. Between about 70 and 40 million years ago, the amount of magmatism dramatically decreased because the shallow subduction angle

Figure 1. Large-scale geologic features in northwestern New Mexico and southwestern Colorado. Modified from Lipman (2006).

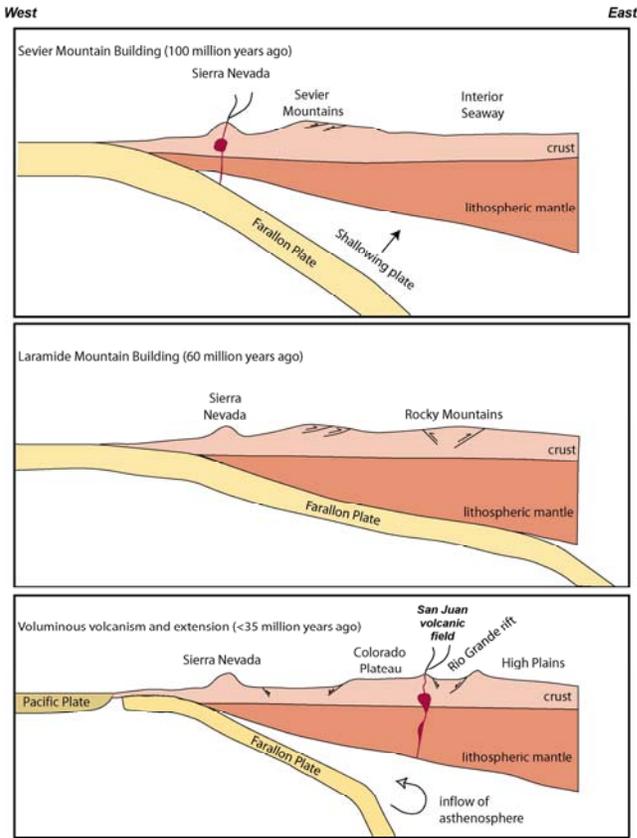
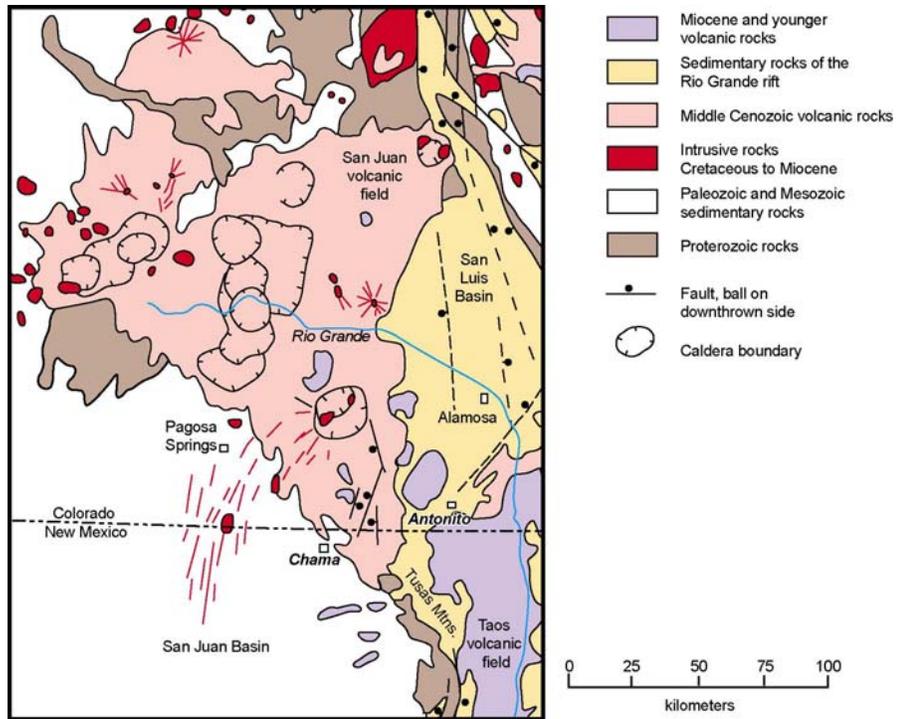


Figure 2. Schematic cross-section of the western United States showing the changes in the geometry of the Farallon Plate through time. The North American plate is composed of continental crust (light pink) and lithospheric mantle (dark pink). Together, the crust and the lithospheric mantle form the rigid outer layer of our planet. The base of the lithosphere (asthenosphere) is marked by the temperature where the mantle exhibits ductile (plastic) flow. Modified from Humphreys et al. (2003).

prevented dewatering of the slab and melting of the overlying mantle. Compression of the crust associated with low-angle subduction led to the formation of the Rocky Mountains during the Laramide mountain building event (middle panel of Figure 2).

Between 45 and 35 million years ago, subduction of the Farallon Plate slowed and the angle of subduction started to increase. This area was still under mild compression as the early andesite stratovolcanoes in the San Juan volcanic field began to erupt. As the subducting plate continued to roll back or sink down into the mantle, hot asthenosphere came in contact with lithospheric mantle that had been enriched by fluids during the subduction process. As a consequence, the conditions were right for explosive and voluminous volcanism. Shortly thereafter, extension led to the formation of the Rio Grande rift (bottom panel of Figure 2).

### **Overview of Geologic Features Visible from the Train**

As the train leaves Chama and climbs up onto the Tusas Mountains (mile markers 345 to 331; see Figure 3 for an example of a mile marker) we will see rocks deformed by Laramide mountain building and red sediments eroded from the Tusas Mountains into the San Juan Basin during the waning stages of Laramide deformation. We will also see good examples of deposits left by glaciers that covered this area during the most recent episode of Ice Age glaciation.



Figure 3. An example of one of the mile markers along the route.

Once we are on top of the Tusas Mountains, the landscape will be dominated by lava flows and ash flow tuffs erupted from volcanic centers located tens of miles to the north in the San Juan volcanic field. Ash flow tuffs are the product of particularly violent eruptions associated with caldera collapse, where the roof of a vigorously erupting magma chamber collapses into the chamber. Sediment shed from the volcanoes by stream action and landslides is interbedded with the lavas and tuffs. Some of these sediments are eroded into interesting spires near Phantom Curve at mile marker 312.5.

A highlight of the trip will be the Toltec Gorge near milepost 316, where the Rio de los Pinos has carved a deep canyon through the soft volcanic rocks into the hard ancient rocks that form the core of the Tusas

Mountains. Between mile marker 305 and Antonito, the rocks in the vicinity of the tracks are basalt flows and sediments full of volcanic detritus that were deposited in the western part of the San Luis Basin,

one of the basins of the Rio Grande rift.

**Geologic Road Log (modified from Burroughs and Butler (1971) to reflect the revised stratigraphic nomenclature of Lipman and Mehnert (1975) and new radiometric age dates)**

*Mile markers 344-334 are on Geologic Map 1.*

345 Chama.

344 Bridge over the Rio Chama.

343 Tracks cross NM Highway 17. Glacial outwash deposits are exposed in the road cuts.

342 Entering a section along the track informally called “the narrows”. More glacial outwash deposits are exposed here.

341 Cretaceous Dakota Sandstone forms cliffs along north side of the Rio Chama. A small fault related to Laramide deformation offsets the Dakota Sandstone down-to-the-north. The roadcuts along NM-17 are Jurassic Morrison Formation covered by landslide debris. The Dakota Sandstone records the alternating rise (shale) and fall (sandstones) of sea level as the shoreline of the Western Interior Seaway moved back and forth across the area~ 98 to 100 million years ago. Rivers flowing toward northeast across a broad, fairly low-gradient muddy floodplain deposited the Morrison Formation about 148 to 150 million years ago.

340.5 Leaving “the narrows.”

340 Lobato siding. An old movie set is located here.

339.8 Lobato trestle over Wolf Creek. The canyon walls to the west are composed of tan Cretaceous Dakota Sandstone overlain by red Eocene Blanco Basin Formation. The Blanco Basin Formation was deposited by west-flowing rivers with headwaters in the Tusas Mountains. The outcrops are partially covered by landslides.



Cretaceous Dakota Sandstone (Kd) and Eocene Blanco Basin Formation (Tbb) north of Chama.

339 Glacial medial moraine deposits in road cuts.

337 NM-17 crosses the railroad. Glacial lateral and recessional moraine deposits and erratic blocks of Conejos Formation volcanic breccia are common in this area.

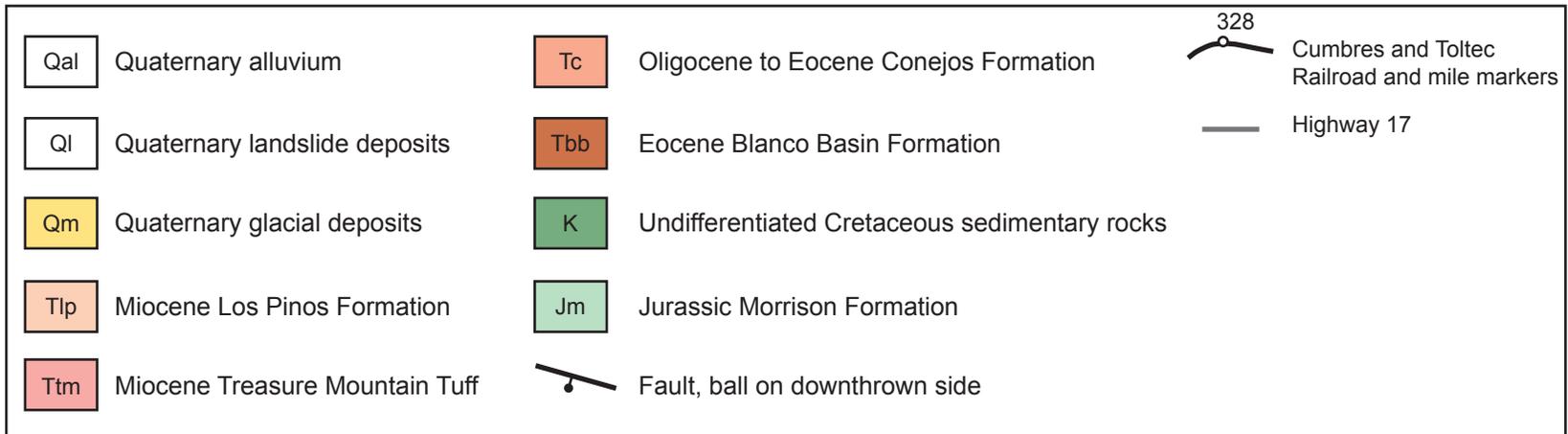
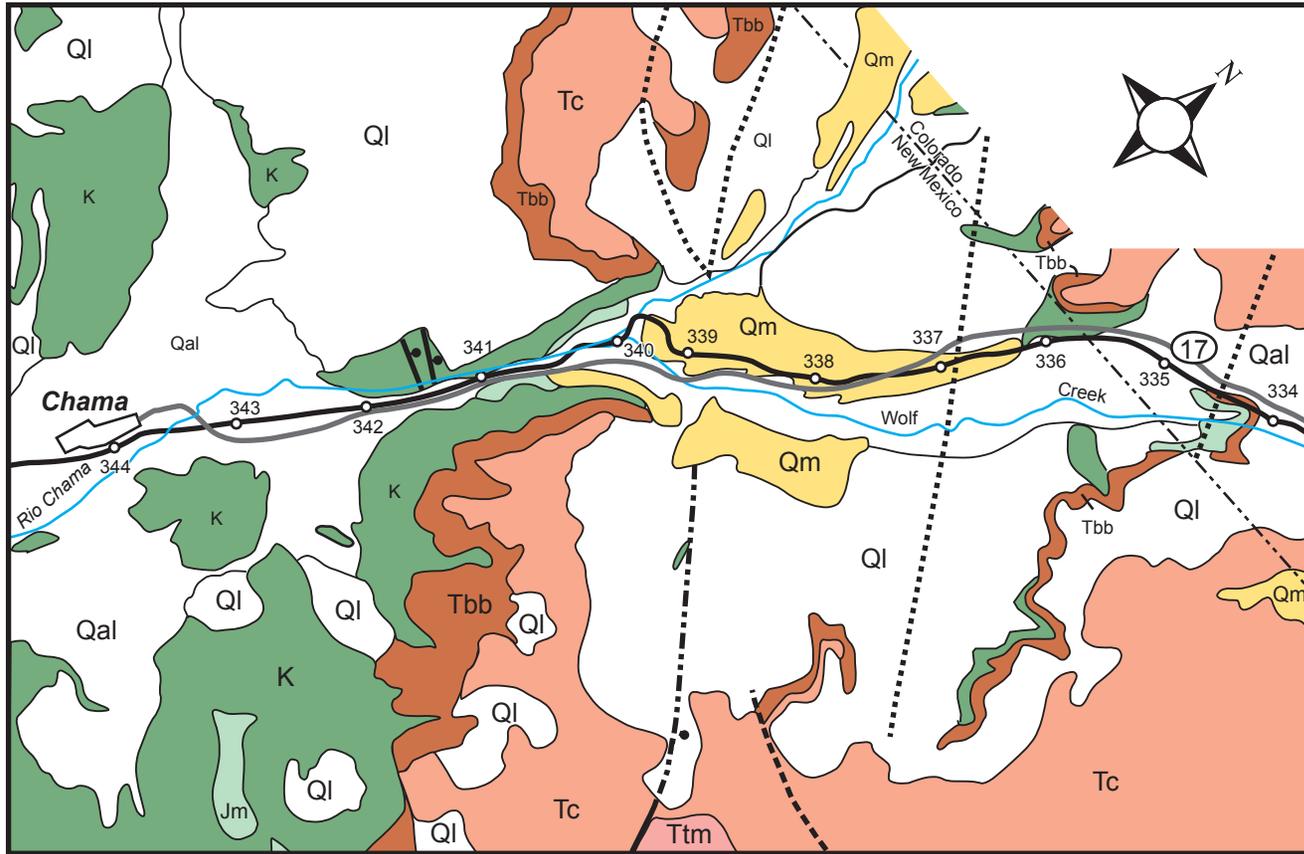
336 Eocene Blanco Basin Formation rests unconformably on Mesozoic sedimentary rocks. Cretaceous Niobrara Formation and Carlile Shale are exposed at track level. The road cuts are in glacial lateral moraine deposits.

335 Cresco Tank.

334 The road cuts to the left are in Eocene Blanco Basin Formation. Rocks in the ravine to the right are west-dipping red and green shale and sandstone of the Jurassic Morrison Formation. In this area, the Eocene Blanco Basin Formation overlies the Jurassic Morrison Formation. A down-to-the south fault places Cretaceous Dakota Sandstone against green Morrison Formation.



# Map 1



**Mile markers 334 and 314 are on Geologic Map 2.**

332 View of the glacial features in Wolf Creek valley.

331 Windy Point. Altered volcanic breccias of the Conejos Formation are well exposed here. The Conejos Formation is 29 to 33 million years old and originated from andesitic stratovolcanoes to the north (Colucci et al., 1991). A green to blue-green mineral often coats the surface of brecciated fragments and vesicles within the andesitic lava flows of the Conejos Formation. This mineral is most likely celadonite ( $\text{K}(\text{Mg}, \text{Fe}^{2+}, \text{Fe}^{3+}, \text{Al})\text{Si}_4\text{O}_{10}(\text{OH})_2$ ) (Virgil Lueth, personal communication, 2005), a clay mineral of little economic importance that is used as a natural paint pigment. The mineral name is derived from the French word, celadon, which translates to sea-green. This alteration mineral formed when hot water moved through the Conejos Formation, causing iron and magnesium-bearing minerals such as pyroxene and hornblende in the rocks to break down.



Conejos Formation at  
Windy Point.

330.5 Cumbres Pass (elevation 10,015') is the highest railroad pass in the United States. Cumbres is the Spanish word for summit. The pass is on a drainage divide, separating the westerly-flowing Wolf Creek, a tributary of the Rio Chama, from the easterly-flowing Rio de los Pinos, a tributary of the Rio Grande. The railroad traverses Conejos Formation andesitic lavas and volcanic breccias and overlying Treasure Mountain Tuff between this point and Osier at mile 318.5. The contact between the two units can have considerable relief (as much as 300 feet!). The Treasure Mountain Tuff has a black glassy base and a tan upper tuff. The rock unit includes tuffaceous sandstone and conglomerate above the tuff. The Treasure Mountain Tuff erupted from the Platoro Caldera complex 28.5 to 29.5 million years ago (Lipman, 2006).

330 Neff Mountain (elevation 10,880') is capped by Masonic Park Tuff. The 28.2 million-year-old (Lipman and McIntosh, 2008) Masonic Park Tuff probably erupted from the Mount Hope caldera about 50 miles northwest of this point.

325 Los Pinos Tank.



Andesite lava flow in  
Conejos Formation  
near mile marker 322.

320 Cascade Creek Trestle. The valley cuts through volcanic breccia of the Conejos Formation.

319.5 Lava flows of the Conejos Formation and Quaternary rock glaciers.

318.5 Osier. Conejos Formation lava flows and volcanic breccias and overlying Treasure Mountain Tuff are exposed here. The prominent mountain to the north is Osier Mountain (elevation 10,746'). The basalt flow on top of the peak is part of the Hinsdale Formation.

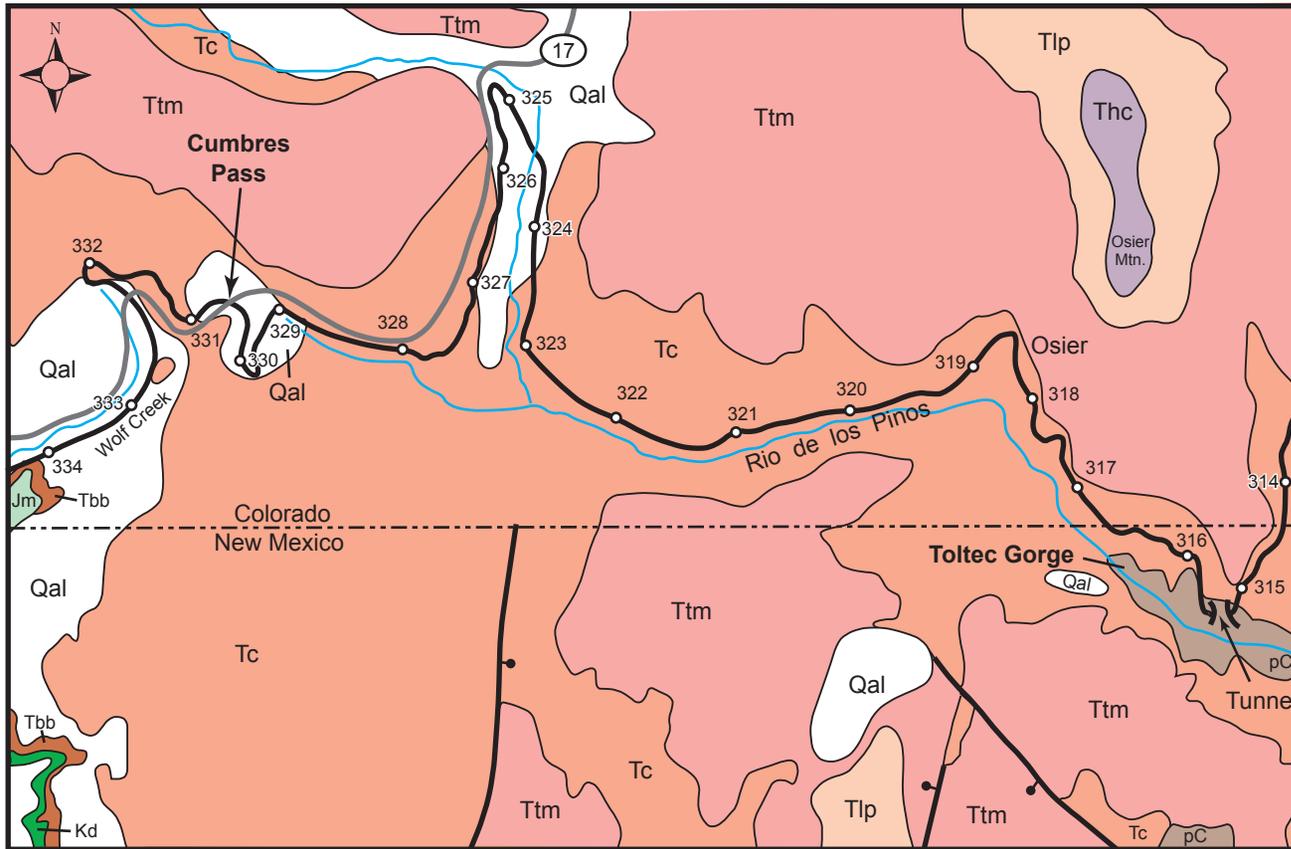
317 Conejos Formation lava flows and volcanic breccias are exposed in the road cuts.

316 The craggy cliffs in the Rio de Los Pinos valley to the right are composed of 1.6 to 1.7 billion year old Proterozoic metamorphic rocks.

315 Toltec Gorge. The Proterozoic rocks in the tunnel and in the Rio de Los Pinos valley are gneiss, schist, and amphibolite intruded by granite and dikes of aplite and pegmatite. The older unit is an intermediate composition intrusive rock known as granodiorite that was emplaced at depths of 10 to 15 km in the middle crust about 1.7 billion years ago. This rock was deformed during southward growth and assembly of the North American continent during Proterozoic time, and the igneous rock was converted to a gneissic metamorphic rock. Later, a second plutonic body with a more granitic composition intruded the older granodiorite gneiss about 1.4 billion years ago. The younger intrusion does not have a gneissic fabric, which suggests that the crust was not under compression at the time of emplacement. The Proterozoic rocks were uplifted and eroded during later deformational episodes to form the core of younger mountain ranges. One mountain range formed about 310 to 270 million years ago during Ancestral Rocky Mountain deformation. After a long period of quiescence, erosion, and minor deposition, the area was elevated once again during Laramide compressional deformation about 75 to 55 million years ago.

314 Outcrops of Conejos Formation and Treasure Mountain Tuff.

# Map 2



 Qal	Quaternary alluvium	 Tbb	Eocene Blanco Basin Formation	 328	Cumbres and Toltec Railroad and mile markers
 Thc	Miocene Cisneros Basalt	 Kd	Cretaceous Dakota Sandstone		Highway 17
 Tlp	Miocene Los Pinos Formation	 Jm	Jurassic Morrison Formation		Fault, ball on downthrown side
 Ttm	Miocene Treasure Mountain Tuff	 pC	Proterozoic metamorphic and plutonic rocks		
 Tc	Oligocene to Eocene Conejos Formation				

***Mile markers 314 to 294 are on Geologic Map 3***



313 Calico Cut on the left exposes altered Conejos Formation volcanic breccia.

312 Phantom Curve. Note the impressive spires of Conejos Formation volcanic breccia, lava flows, and sandstones and conglomerates composed of eroded volcanic detritus.

311 Mud Tunnel is in a debris flow deposit in the Conejos Formation.

309 Cliffs of Conejos Formation volcanic breccia.

308 Outcrops of Conejos Formation flow breccia, lava flows, and volcanoclastic sediments.

307 Road cuts are in Treasure Mountain Tuff. The Conejos Formation is exposed in the cliffs below the roadbed.

306 Sublette. Good exposures of the Treasure Mountain Tuff and associated tuffaceous sedimentary deposits.

305 Outcrops of Masonic Park Tuff on Treasure Mountain Tuff. The low hills to the left are in Los Pinos Formation.

304 Roadcut in Masonic Park Tuff displaying a classic nonwelded base and a welded top. Tuffaceous sandstone and conglomerate of the Treasure Mountain Tuff lies below the Masonic Park Tuff.

303 The road is in Los Pinos Formation. Here the unit is made of debris eroded from nearby volcanic centers. Boulders in the conglomerate are black, gray, and red andesite to andesite porphyry. Rhyolite tuff is common near the base of this unit; the amount of rhyolite decreases upsection.

299 Big Horn Peak to the south is capped by an older Hinsdale Formation basalt flow, which is interbedded with sediments of the Los Pinos Formation. Volcanoclastic conglomerate and sandstone of the Los Pinos Formation is exposed here.

298 One of the younger flows in the Hinsdale Formation (called the Cisneros Basalt by Burroughs and Butler, 1971) is exposed on the left.

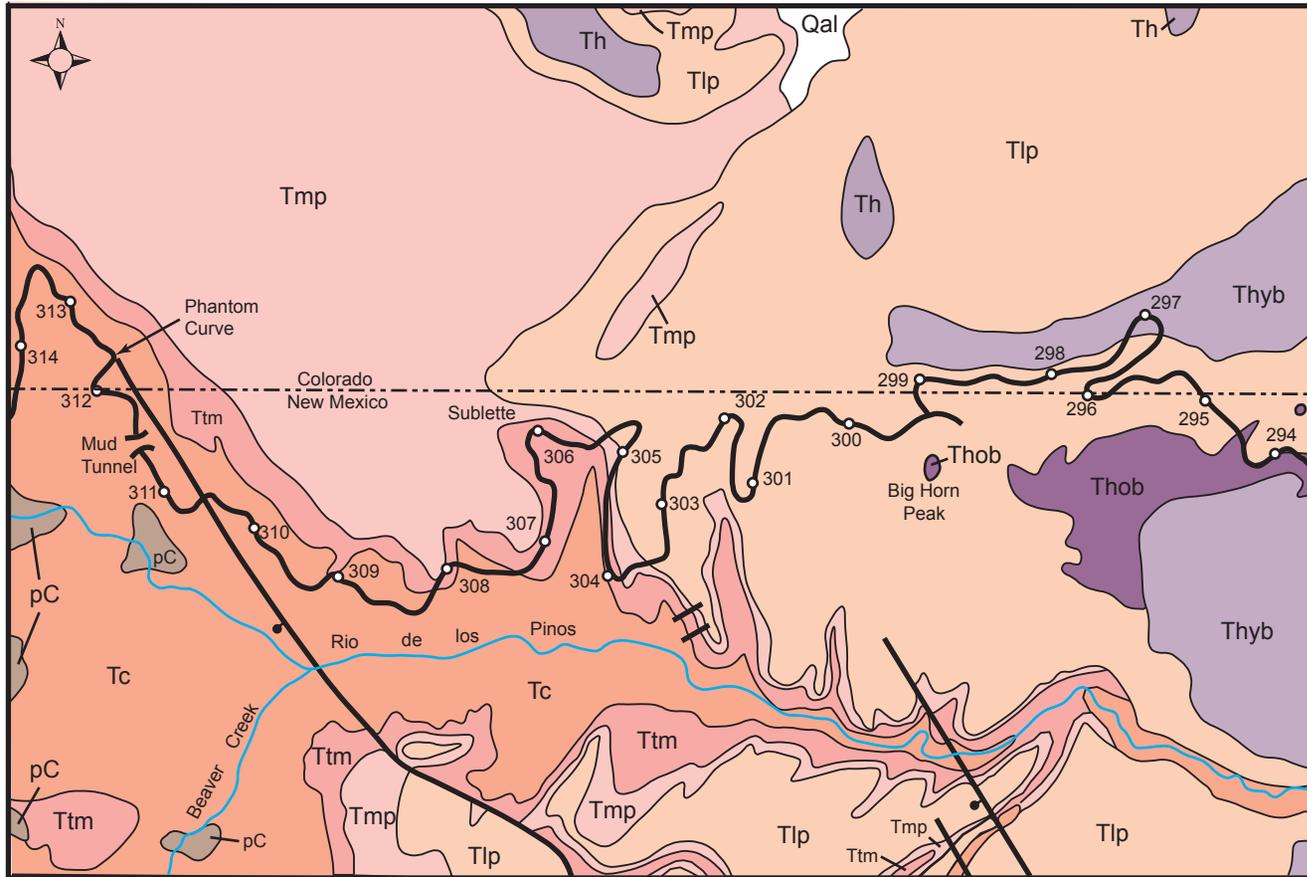
297 Cisneros Basalt on top of Los Pinos Formation.

296 Road cuts in Cisneros Basalt and Los Pinos Formation.

295 An angular unconformity between the east-dipping Los Pinos Formation and the overlying Cisneros Basalt is visible on the mesa to the north.

294 Road cut is in an older basalt flow in the Hinsdale Formation.

# Map 3



	Quaternary alluvium		Miocene Masonic Park Tuff		Cumbres and Toltec Railroad and mile markers
	Miocene younger Hinsdale Basalt		Miocene Treasure Mountain Tuff		Fault, ball on downthrown side
	Miocene Hinsdale Basalt		Oligocene to Eocene Conejos Formation		
	Miocene Los Pinos Formation, Includes older Hinsdale Basalt		Proterozoic metamorphic and plutonic rocks		

*Mile markers 297 to 281 are on Geologic Map 4.*

293 Road cuts are in sedimentary rocks of the Los Pinos Formation, Hinsdale Formation basalt, and Cisneros Basalt.

291 Lava tank. Good views of Los Pinos Formation sediments and basalt flows and the Cisneros Basalt. The 5-million-year-old Los Mogotes volcano 8 miles to the northwest is the source of the Cisneros flow.

Distant view of Los Mogotes volcano north of the railroad.



290 Exposures of sandstone and conglomerate of the Los Pinos Formation.

289 Road cut is in Cisneros Basalt.

288 Road cut is in older Hinsdale Formation basalt and sandstone of the Los Pinos Formation.

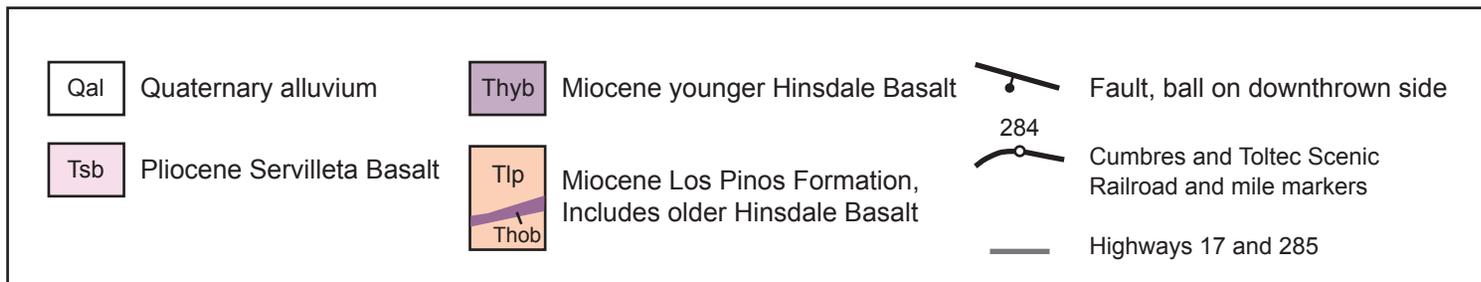
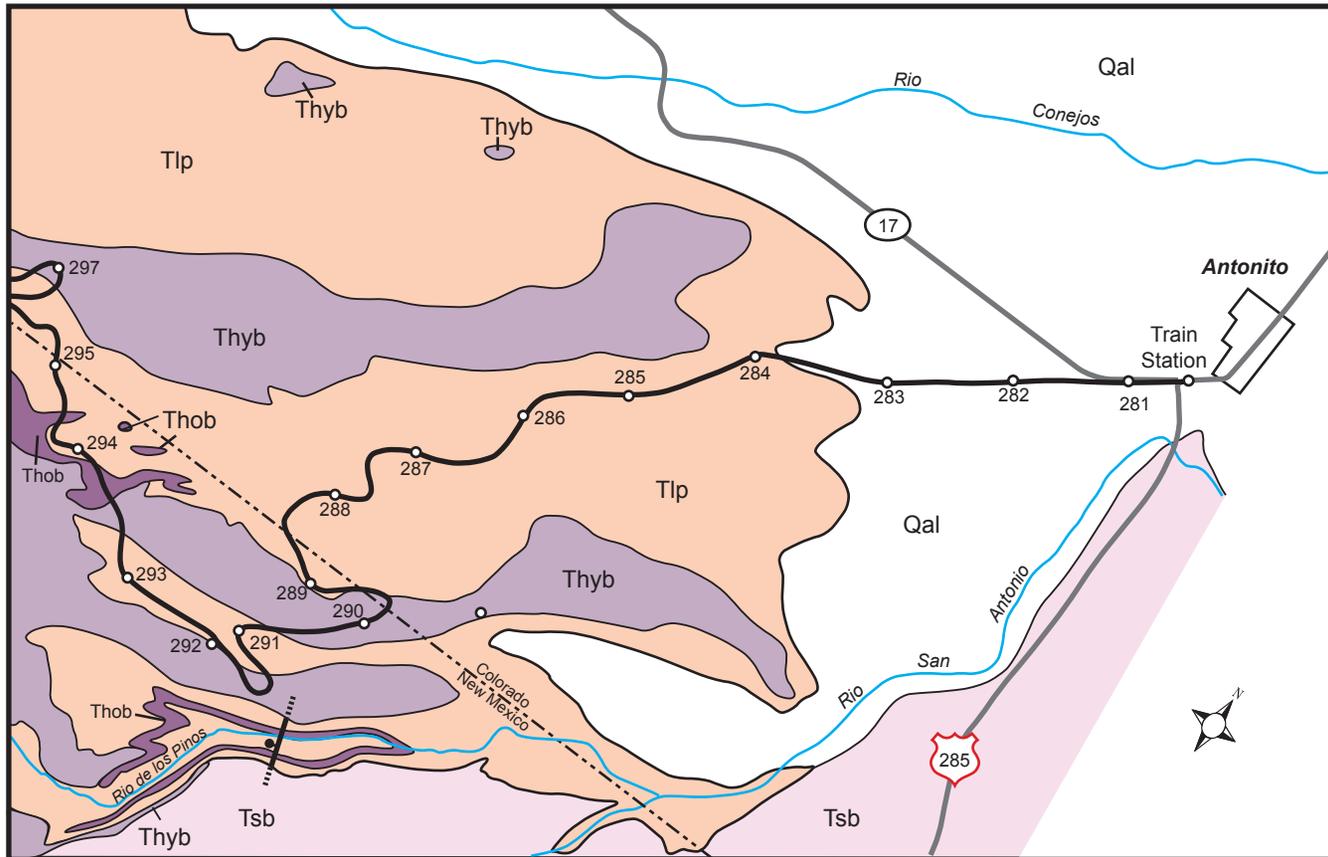
287 Road cut is in older Hinsdale Formation basalt.

286 Tuffaceous sandstone in the Los Pinos Formation.

284 Cisneros Basalt on mesa to the left.

282 Roadbed is on the alluvial fan of the Conejos River.

280 Antonito.



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