Geologic Road Log
Cumbres and Toltec Scenic Railroad

A Regional Setting
Our journey between Antonito and Chama today takes us from the San Luis Basin, across
the Tusas Mountains, and into the San Juan 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 Antonito-Chama 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

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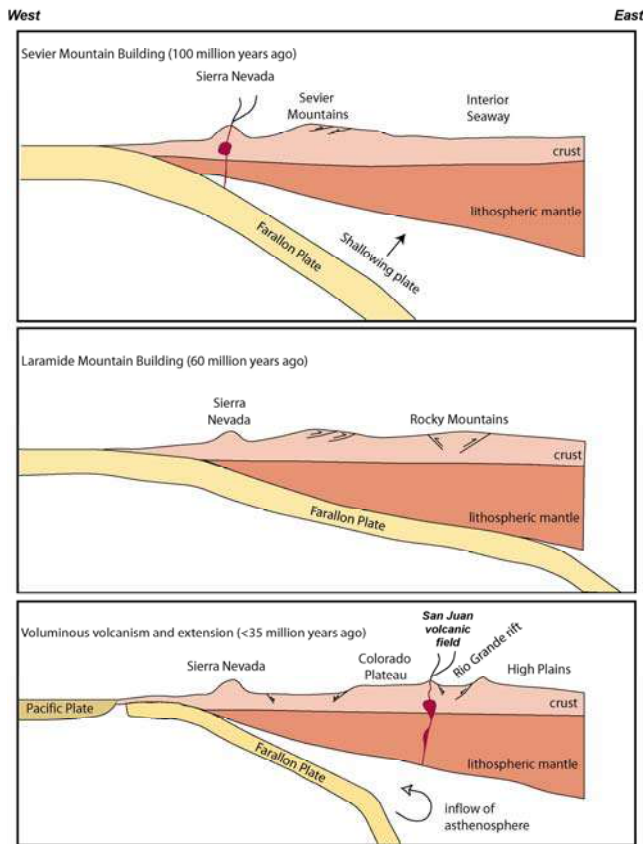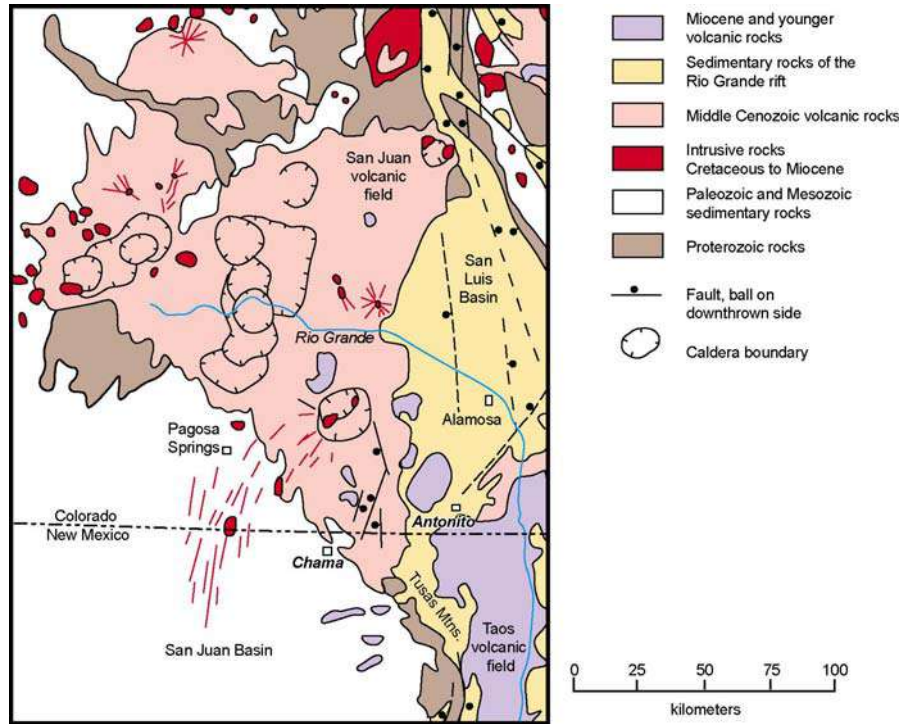

Figure 2. Schematic cross-section of the western United States showing the changes in the geometry of the Farallon Plate through time. The North American plate is composed of continental crust (light pink) and lithospheric mantle (dark pink). Together, the crust and the lithospheric mantle form the rigid 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).

amount of magmatism dramatically decreased because the shallow subduction angle 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
Between Antonito and mile marker 305 (see Figure 3 for an example of a mile marker), 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.

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. As the train leaves the Tusas Mountains and descends into Chama (mile markers 331 to 345) 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.

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 280 to 297 are on Geologic Map 1.

280   Antonito.

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

284   Cisneros Basalt on mesa to the right.

286   Tuffaceous sandstone in the Los Pinos Formation. The Los Pinos Formation 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.

287   Road cut is in older Hinsdale Formation basalt. Basalts of the Hinsdale Formation were erupted from local volcanic centers and are interbedded with the Los Pinos Formation (Lipman and Mehnert, 1975).

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

289   Road cut is in Cisneros Basalt. The 5-million-year-old Los Mogotes volcano to the northwest is the source of the Cisneros flow. This is one of the younger basalts in the Hinsdale Formation.

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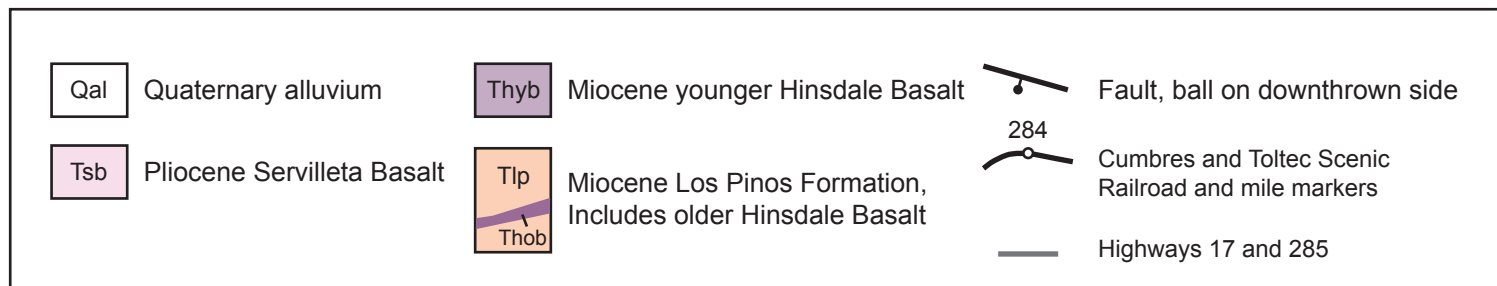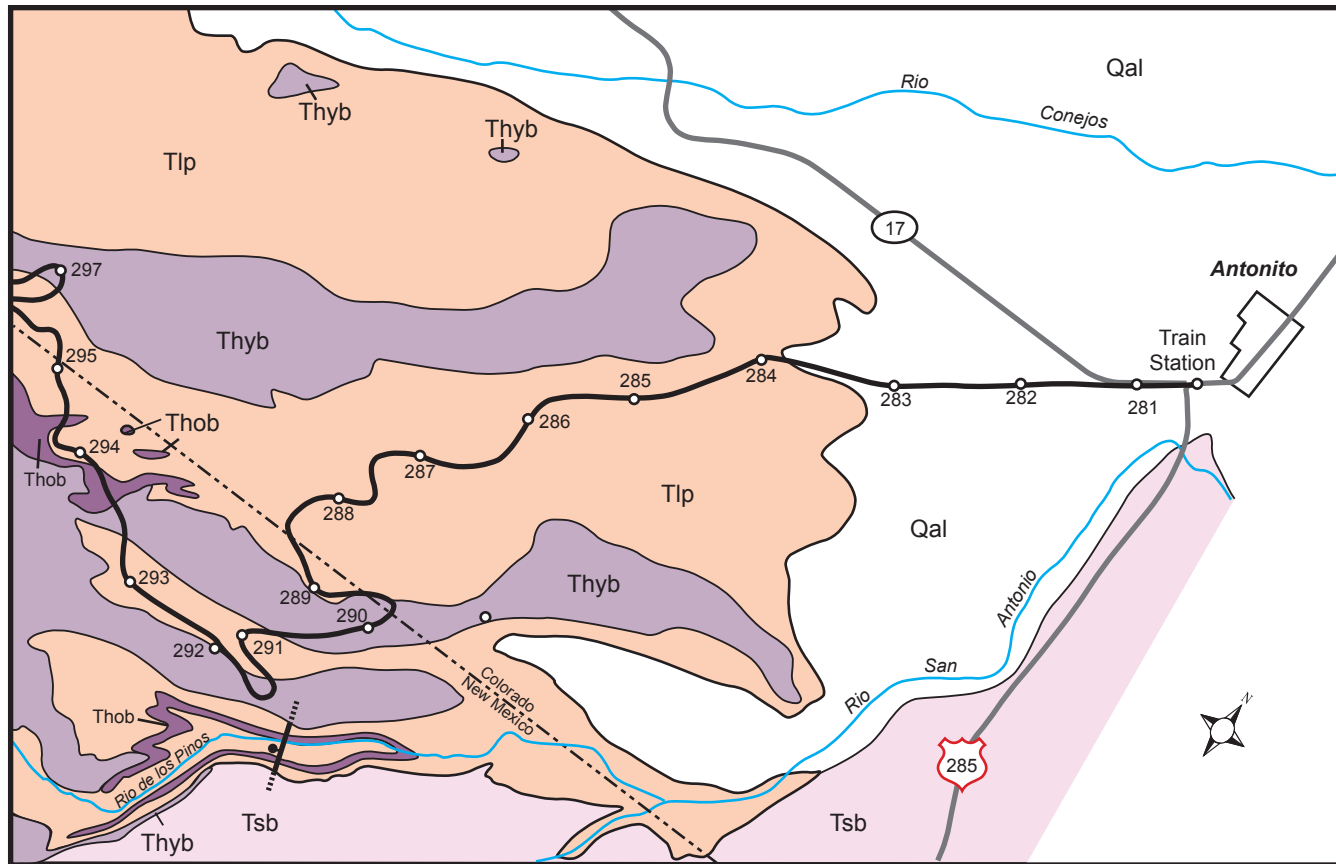

Distant view of Los Mogotes volcano north of the railroad.

291   Lava tank. Good views of Los Pinos Formation sediments, Hinsdale Formation basalt flows, and the Cisneros Basalt.

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

Map 1

Qal

Rio Conejos

Thyb

Tlp

Thyb

17

Antonito

297

295

Thob

294

Train Station

285

284

286

283

282

281

Thob

287

288

Tlp

Qal

293

Thyb

289

290

291

292

Colorado
New Mexico

San

Antonio

Rio

Thob

Rio de los Pinos

285

Thyb

Tsb

Tsb

N

| 0 | 1 | 2 | 3 | 4 | 5 miles |

Qal	Quaternary alluvium		Thyb	Miocene younger Hinsdale Basalt			Fault, ball on downthrown side
Tsb	Pliocene Servilleta Basalt		Tlp / Thob	Miocene Los Pinos Formation, Includes older Hinsdale Basalt		284	Cumbres and Toltec Scenic Railroad and mile markers
							Highways 17 and 285

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

296   Road cuts in Cisneros Basalt and Los Pinos Formation.

297   Cisneros Basalt on top of Los Pinos Formation.

298   The Cisneros Basalt is exposed on the right.

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. Volcaniclastic conglomerate and sandstone of the Los Pinos Formation is exposed here.

303   The roadcut is in Los Pinos Formation.

304   Roadcut in Masonic Park Tuff displaying a classic nonwelded base and a welded top. 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. The Treasure Mountain Tuff lies below the Masonic Park Tuff. 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).

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

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

307   Road cuts are in Treasure Mountain Tuff. Andesitic debris flows, flow breccia, lava flows, and volcaniclastic sediments of the Conejos Formation is exposed in the cliffs below the roadbed. The Conejos Formation is 29 to 33 million years old and originated from andesitic stratovolcanoes to the north (Colucci et al., 1991).

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

309   Cliffs of Conejos Formation volcanic breccia.
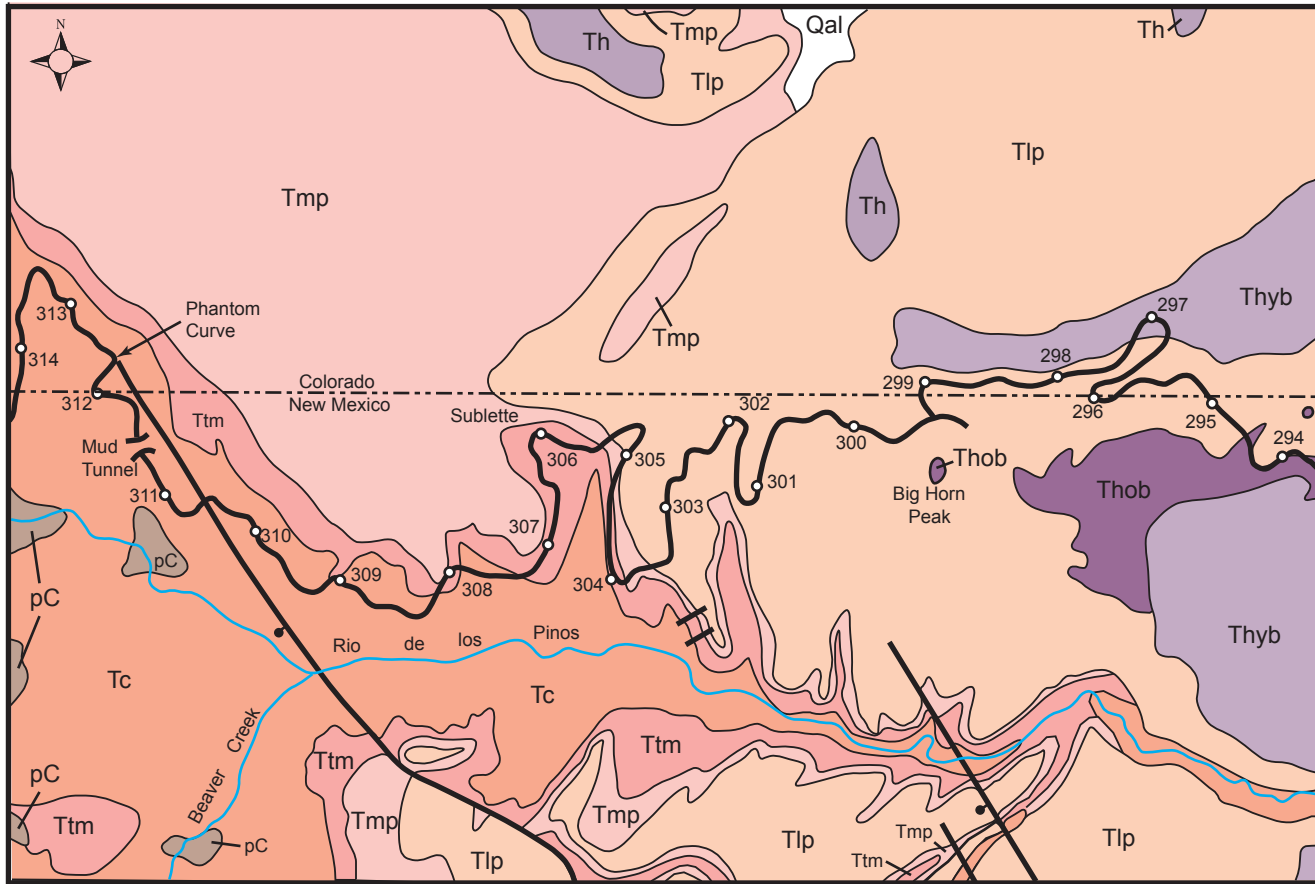

311   Mud Tunnel is in a debris flow deposit in the Conejos Formation.

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

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

Map 2

Legend:

Qal	Quaternary alluvium
Thyb	Miocene younger Hinsdale Basalt
Th	Miocene Hinsdale Basalt
Tlp / Thob	Miocene Los Pinos Formation, Includes older Hinsdale Basalt
Tmp	Miocene Masonic Park Tuff
Ttm	Miocene Treasure Mountain Tuff
Tc	Oligocene to Eocene Conejos Formation
pC	Proterozoic metamorphic and plutonic rocks

312 — Cumbres and Toltec Railroad and mile markers

— Fault, ball on downthrown side

Scale: 0 1 2 3 4 5 miles

Mile markers 314 and 334 are on Geologic Map 3.
314   Outcrops of Conejos Formation and Treasure Mountain Tuff.

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.

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

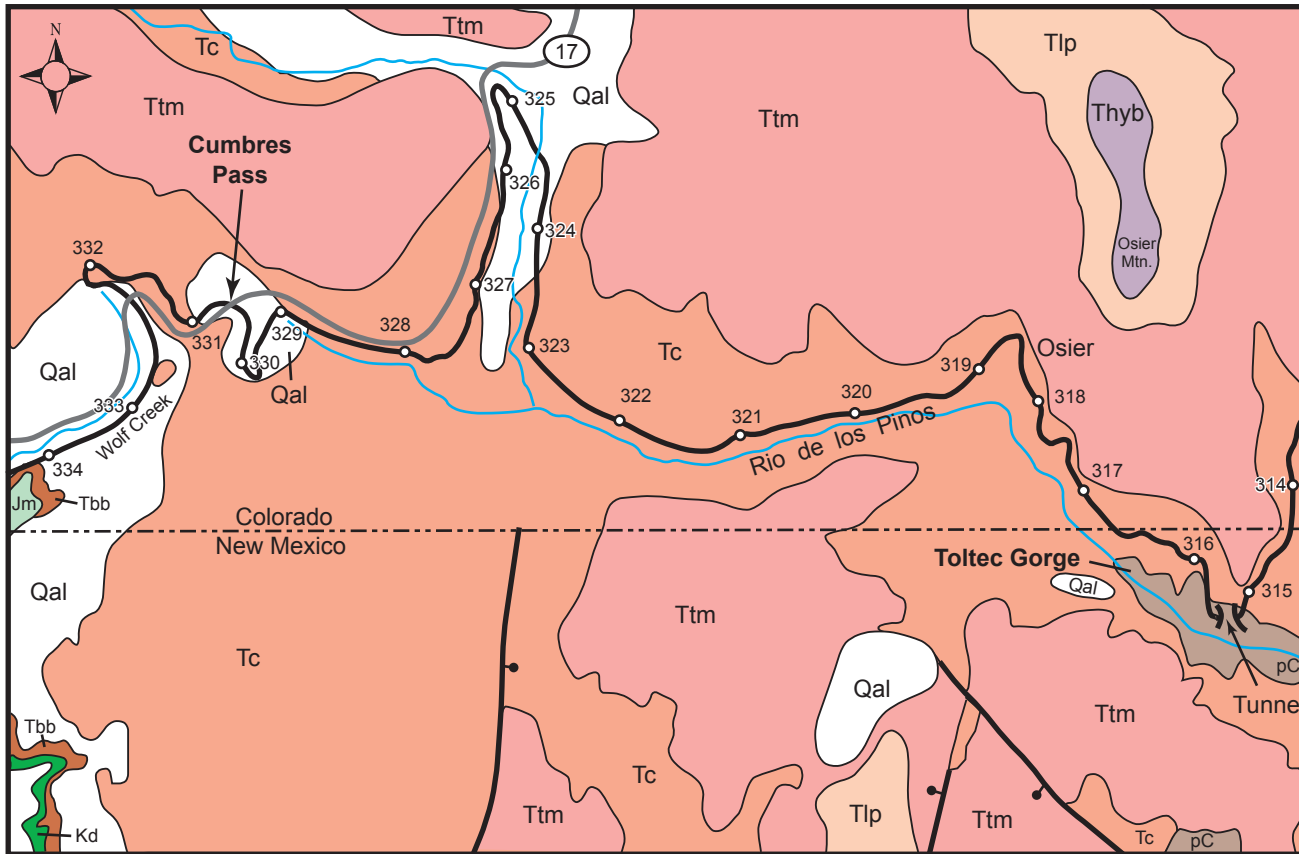317   Conejos Formation lava flows and volcanic breccias are exposed in the road cuts.

318.5   Osier. Conejos Formation lava flows and volcanic breccias and overlying Treasure Mountain Tuff are exposed here. The railroad traverses Conejos Formation andesitic lavas and volcanic breccias and overlying Treasure Mountain Tuff between this point mile 330.5. The contact between the two units can have considerable relief (as much as 300 feet!). 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.

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

Andesite lava flow in Conejos Formation near mile marker 322.

Map 3

Map showing geological formations with locations including Cumbres Pass, Wolf Creek, Osier Mtn., Rio de los Pinos, Toltec Gorge, Tunnel, and the Colorado/New Mexico border. Mile markers 314–334 along the Cumbres and Toltec Railroad.

0 1 2 3 4 5 miles

Legend

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

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

325   Los Pinos Tank.

330   Neff Mountain (elevation 10,880') is capped by Masonic Park Tuff.

330.5   Cumbres Pass (elevation10,015') is the highest railroad pass in the United States. Cumbres is the Spanish work 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.

Conejos Formation at Windy Point.

331   Windy Point. Altered volcanic breccias of the Conejos Formation are well exposed here.   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 ($K(Mg, Fe^{2+})(Fe^{3+}, Al)Si_4O_{10}(OH)_2$) (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.

332   View of the glacial features in Wolf Creek valley.

Blanco Basin Fm. near mile marker 334

Mile markers 334 to 344 are on Geologic Map 4.

334   The road cuts to the right are in Eocene Blanco Basin Formation. Rocks in the ravine to the left 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.

335   Cresco Tank.

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.

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.

339   Glacial medial moraine deposits in road cuts.

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

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.

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

340.5   Entering a section along the track informally called "the narrows."

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.
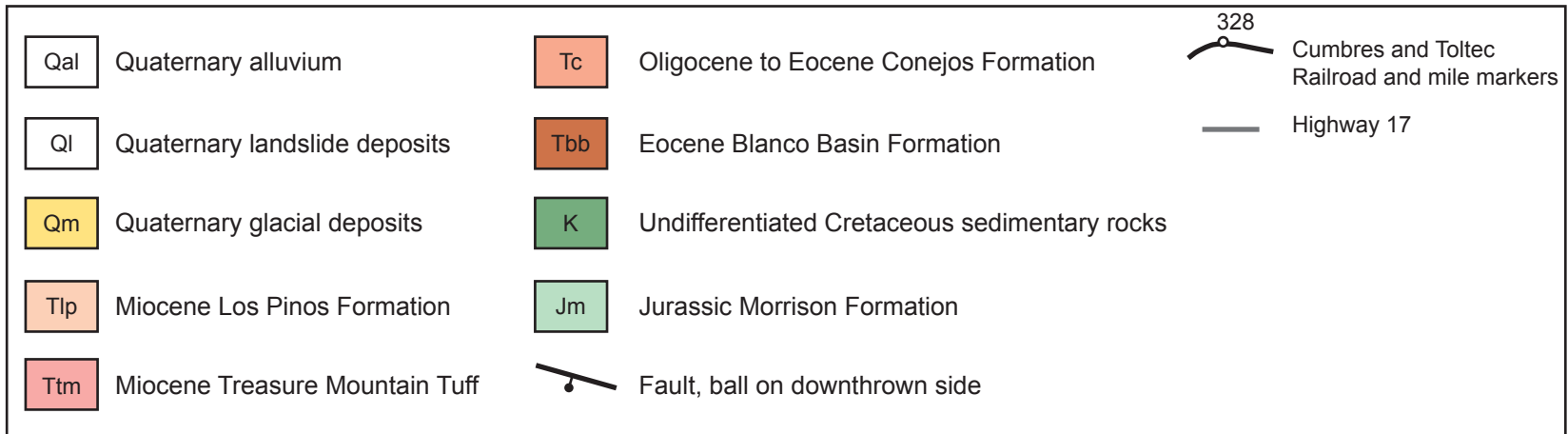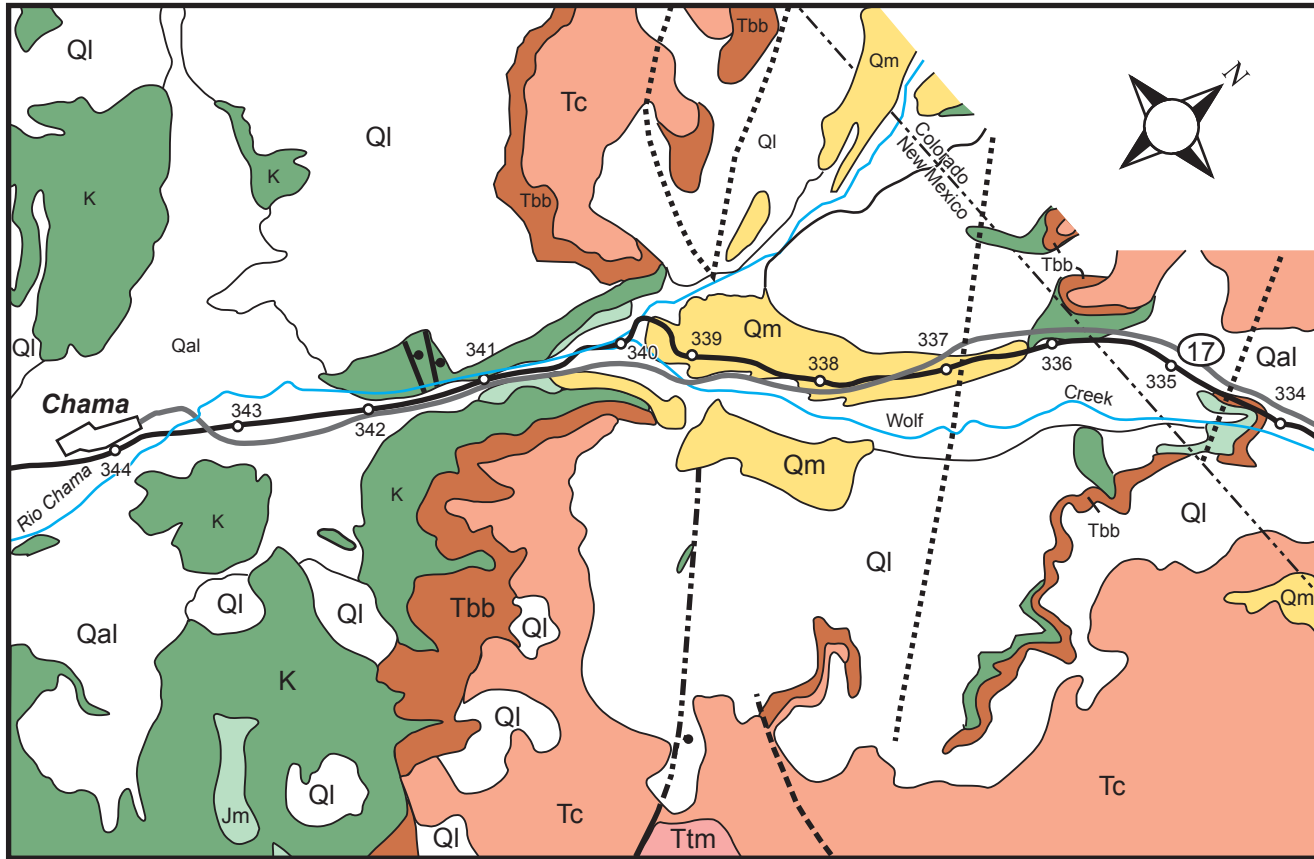
342   Leaving "the narrows." More glacial outwash deposits are exposed here.

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

344   Bridge over the Rio Chama.

345   Chama.

Map 4

Qal	Quaternary alluvium	Tc	Oligocene to Eocene Conejos Formation
Ql	Quaternary landslide deposits	Tbb	Eocene Blanco Basin Formation
Qm	Quaternary glacial deposits	K	Undifferentiated Cretaceous sedimentary rocks
Tlp	Miocene Los Pinos Formation	Jm	Jurassic Morrison Formation
Ttm	Miocene Treasure Mountain Tuff		Fault, ball on downthrown side

328 — Cumbres and Toltec Railroad and mile markers

Highway 17

Scale: 0 1 2 3 4 5 miles

References

Appelt, R. M. (1998) ^{40}Ar/^{39}Ar geochronology and volcanic evolution of the Taos Plateau volcanic field, northern New Mexico and southern Colorado: Unpublished M.S. thesis, New Mexico Institute of Mining and Technology, 149 pp.

Burroughs, R. L. and Butler, A. P. (1971) Third Day Rail Log: Antonito, Colorado, to Chama, New Mexico, *in* James, H. L., ed., Guidebook of the San Luis Basin, Colorado: New Mexico Geological Society, pp. 41 – 67.

Colucci, M.T., Dungan, M.A., Ferguson, K.M., Lipman, P.W., and Moorbath, S. (1991) Precaldera lavas of the southeast San Juan Volcanic field: Parent magmas and crustal interactions: Journal of Geophysical Research, v. 96, p. 13,413-13.434.

Humphreys, E., Hessler, E., Dueker, K., Farmer, C., Erslev, E., and Atwater, T. (2003) How Laramide-age hydration of North American lithosphere by the Farallon slab controlled subsequent activity in the western United States: International Geology Review, v. 45, p. 575–595.

Lipman, P.W. (2006) Geologic map of the central San Juan Cluster, southwestern Colorado: U.S. Geological Survey Map I-2799.

Lipman, P. W. and McIntosh, W. C. (2008) Eruptive and noneruptive calderas, northeastern San Juan Mountains, Colorado: Where did the ignimbrites come from?: Geological Society of America Bulletin, v. 120, p. 771 – 795.

Lipman, P.W., and Mehnert, H.H. (1975) Late Cenozoic basaltic volcanism and development of the Rio Grande depression in the southern Rocky Mountains: Geological Society of America Memoir 144, p. 119-154.