First-day road log, from Red River to Questa, Costilla, Valle Vidal, Cimarron and Philmont

Paul W. Bauer, Charles L. Pillmore, Mawer, Christopher, K., Steve Hayden, Spencer G. Lucas, Jeff Meyer, Gerald K. Czmanske, Jeffrey A. Grambling, James M. Barker, S. M. Cather, James Walker, and Jon Nathan. Young

1990, pp. 1-43. https://doi.org/10.56577/FFC-41.1

in:

Tectonic Development of the Southern Sangre de Cristo Mountains, New Mexico, Bauer, P. W.; Lucas, S. G.; Mawer, C. K.; McIntosh, W. C.; [eds.], New Mexico Geological Society 41st Annual Fall Field Conference Guidebook, 450 p. https://doi.org/10.56577/FFC-41

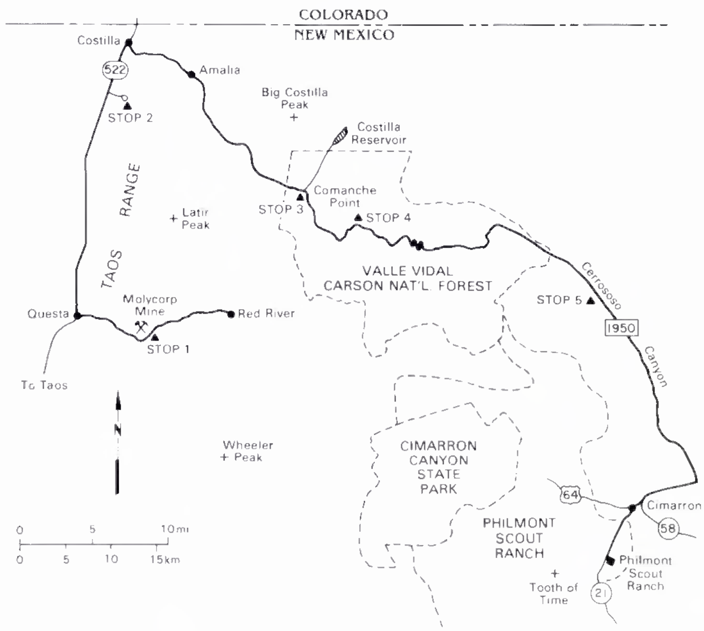
This page is intentionally left blank to maintain order of facing pages.

FIRST-DAY ROAD LOG, FROM RED RIVER TO QUESTA, COSTILLA, VALLE VIDAL, CIMARRON AND PHILMONT

PAUL W. BAUER, CHARLES L. PILLMORE, CHRISTOPHER K. MAWER, STEVE HAYDEN, SPENCER G. LUCAS, JEFF MEYER, GERALD K. CZAMANSKE, JEFFREY A. GRAMBLING, JAMES M. BARKER, S. M. CATHER, JAMES WALKER and JON NATHAN YOUNG

THURSDAY, SEPTEMBER 13, 1990

Assembly point: Parking lot of Lifts West, Red River, New Mexico.
Departure time: 8:00 a.m.
Distance: 110 mi
Stops: 5



SUMMARY

Day 1 begins at the west end of the town of Red River. We begin the tour by driving westward toward Questa along the southern structural margin of the Tertiary Questa caldera (25.7 ± 0.1 Ma). Along the Red River valley, from Red River to Questa, various structural levels of the Questa caldera are well exposed. The major focus is on structural relations along the caldera margin, including mineralized Tertiary volcanic rocks and the Molycorp mining and milling operations. At Stop 1, near the Molycorp mine, we discuss new ideas concerning the role of low-angle normal faulting in the structural and mineralogical evolution of this complex volcanic terrain. From Questa we drive northward, parallel to the faults that separate the Rio Grande rift from the Sangre de Cristo Mountains. Stop 2, at the Urraca Ranch along the western flank of the Taos Range, provides an opportunity to discuss neotectonics, examine the scarp of a recently active fault and view a cross section of the Questa caldera.

At Costilla, we drive eastward, along Costilla Creek, through well-exposed Tertiary rocks of the Latir volcanic field that are complicated by rift-related graben structures. At Comanche Point we stop to examine a 25 Ma biotite rhyolite that was intruded along a fault zone separating Proterozoic from Tertiary rocks. At Stop 3 we will also discuss complexly deformed Early Proterozoic metamorphic rocks that are juxtaposed along tectonometamorphic boundaries. Portions of the section of the road log from Red River to Comanche Point were modified from the 1984 NMGS Guidebook road log by Lipman and Reed (1984).

From Comanche Point, we travel along Comanche Creek through a faulted terrain of mixed Precambrian and Tertiary volcanic rocks, and Santa Fe Group sediments. Stop 4 provides an overview of Laramide thrusting in the Valle Vidal, and a spectacular vista of the Wheeler Peak area to the south. As we continue eastward, we pass through a section of Mesozoic rock that has been intruded by impressive vertical Tertiary rhyolite dikes near the Rock Wall. We then descend onto the flat-lying strata of the Park Plateau and proceed southeastward through well-exposed Cretaceous stratigraphy to Stop 5 in Cerrososo Canyon where we examine the Trinidad Sandstone and discuss the evolution of the Raton basin and coal-bed methane. At the foot of Cerrososo Canyon we join US-64 to Cimarron. Along the final leg of Day 1 we travel from the historic town of Cimarron to lodgings at Philmont Scout Ranch where nearby complex laccoliths have intruded Cretaceous strata.

Red River is a mountain resort nestled in the Sangre de Cristo Mountains on the north bank of the Red River. At 8750 ft in elevation, Red River is the highest town in New Mexico. This area was first prospected by miners from Elizabethtown around 1869–1870. The town gets its name from the Taos Indian name for the river "pee ho ghay po" which means red river creek. The original townsite was laid out by the Mallette brothers in 1894 (Fig. 1.1).

FIGURE 1.1. View northward of Red River in about 1896 shows the original town as platted by the Mallette brothers. Photo courtesy of Mrs. Winifred Hamilton.

Gold, silver and copper mines were in operation in Red River until 1925. The most productive mines were located in Bitter Creek, Goose Creek and Pioneer, Mallette and upper Red River Canyons. Supplemental Log 2 tours the old prospects and mines in Pioneer Canyon, south of Red River. Molybdenum (originally thought to be graphite) was discovered in the lower Red River Canyon in 1901. In 1905, Red River boasted 3000 residents, 15 saloons, four hotels, two newspapers, a hospital and a sawmill. Mining difficulties early in the 1900's turned the community into a ghost town. Around 1930, Red River was advertised as a "mountain playground" to tourists wishing to escape the dustbowl. Since then, the tourist industry has grown, and Red River is now a thriving year-round mountain resort. Much of the flavor of the pioneer days in Red River is captured in a marvelous book by Winifred Oldham Hamilton (Fig. 1.2) titled *Wagon Days in Red River* (1984).

The first-day road log begins at the west end of Red River just after the last building on the right under the "Adios Amigos" sign.

Mileage

0.0 Volcanic rocks in roadcuts to the right along the big curve on the west end of town are quartz-latite intrusions (Lipman and Reed, 1989). These quartz latites are part of an intrusive complex in the Red River area that is interpreted to have underlain a precaldera volcanic center (Lipman, 1988). The volcanic center was intermediate in composition and preceded formation of the Questa caldera by 0.5–3 Ma. The creek bottom and low hills to the south on the far side of the village are colluvium. **0.35**

0.35 Roadcut on right exposes more quartz latite. High slopes to the left contain Tertiary andesites and latites. **0.05**

0.4 Entrance to Red River cemetery on the right. From here until approximately mile 8.0 the highway will follow the broad structural boundary of the southern margin of the Questa caldera. This boundary is an approximately

FIGURE 1.2. Mrs. Winifred Oldham Hamilton of Red River was born in 1901 in Raton. From 1921 to 1931 Winnie taught school in Sugarite, where she met her husband Walter Hamilton who moved to Sugarite to play soccer for the company. In 1931 they moved to Boulder City for construction of Hoover Dam. When the dam was completed in 1935 they returned to New Mexico to manage Tall Pines Resort in Red River, which was owned by the Oldham brothers. The tenth edition of Winnie's book *Wagon Days in Red River* has recently been printed, and she is currently working on a second book in her home at Tall Pines. Photo by P. W. Bauer.

1–2 km wide structural zone defined by: (1) locally preserved ring-fault segments; (2) local E-trending ring-dikes; and (3) megabreccia block zonation in the intra-caldera Amalia Tuff that indicates derivation from a region near the present Red River drainage. **0.2**

0.6 Outcrop of Tertiary quartz latite on the right. **0.15**

0.75 Potassium feldspar-bearing quartz latite dike on right is interpreted to be part of the precaldera volcanic-intrusive center located near Red River. **0.15**

0.9 On the right are alluvial and mudflow deposits representing the debris apron from the Hottentot alteration scar to the north. Deposits from the Hottentot and other scars merge together in this area to form a continuous debris apron for the next mile. This apron forced the Red River drainage to the south side of the canyon and acted as a barrier to the river, resulting in upstream stagnation and formation of the broad valley at the Red River town site. **0.15**

1.05 Official Scenic Historic marker on left reads:

A spectacular drive through Carson National Forest, joining U.S. Highway 64 at Eagle Nest Lake. This popular summer playground offers excellent stream and lake fishing. Guest ranches, hotels and tourist courts serve the visitor. Wheeler Peak to the southeast rises 13,160 feet.

0.05

1.1 Hills to the left are part of the precaldera quartz-latite, volcanic-intrusive center. On the right and ahead, at the higher elevations, is Tertiary andesite that forms the floor to the 25.7 Ma Questa caldera (for this and other age determinations see Czamanske et al., this guidebook). Moly mine waste dumps are now visible in the foreground at 11:00. **0.3**

1.4 Entrance to Junebug Campground on the left (Carson National Forest). Altered rocks on both sides of road are mainly caldera-floor andesite cut by extensive semi-concordant sills and laccoliths of quartz latite. Alteration scars (Fig. 1.3) are visible for the next several miles where high slope angles develop in regions of tectonic preparation and pyritization (see Meyer and Leonardson, this guidebook). Slope oversteepening leads to initial landsliding and continued mass movement processes. Mudflows and alluvial deposits from these scars form the debris aprons that impede the flow of the Red River drainage. Recurrent mudflows during torrential summer rains have caused closure of the highway, and resulted in a motorist fatality in 1982. **0.4**

FIGURE 1.3. Aerial view westward down the Red River valley to the Rio Grande rift. Light-colored areas in foreground are naturally occurring alteration scars. Molycorp open pit mine and mine dumps in left center. Dark hills in the distance are volcanoes of the Taos plateau volcanic field. Photo by P. W. Bauer.

1.8 Entrance to Red River Water Reclamation Plant on right. The plant rests on the debris apron of the Straight Creek alteration scar. **0.3**

2.1 Elephant Rock Campground on left (Carson National Forest). Elephant Rock, a local landmark on the ridge crest to the north, consists of a large quartz-latite megabreccia block within the caldera fill. **0.4**

2.5 Fawn Lakes Campground on right. Quartz latite crops out on the far side of the creek to the left and gray andesite and quartz latite crop out to the right and on the slope ahead. Quartz latite intrusion crosses the road here and is in roadcut to the right. **0.35**

2.85 Milepost 9 on left. **0.2**

3.05 Road bends right; note recently gullied channel in debris apron material on right. **0.35**

3.4 Andesite crops out to the right of the road, across the creek to the left, and ahead to the right. Rib on right is composed of altered Proterozoic quartz monzonite plus minor Proterozoic schist and amphibolite, Mississippian(?) diabase and Tertiary intermediate to rhyolitic intrusive rocks. Complex structural relations of the pre-Tertiary units with early Tertiary sediments and caldera-floor andesites led previous authors to interpret these rocks as slump blocks along the south wall of the Questa caldera (Pillmore et al., 1983). Subsequent detailed mapping (J. Meyer, unpubl., 1990) has led to a reinterpretation of this structural complexity as resulting from postcaldera, ENE-directed extensional faulting.

West-tilted packages of Proterozoic-Tertiary rock lie in low-angle fault slices with upper-plate transport to the ENE. Exposures to the right of the highway between here and the Molycorp mill (mile 4.6) contain complex, low-angle, fault-bounded slices of 90° west-tilted Proterozoic quartz monzonite, early Tertiary sedimentary rocks and caldera-floor andesites. The low-angle fault structures are believed to have initiated at high angles, and to have subsequently rotated to low angles by post-caldera extension.

Rocks along the low-angle fault zones were subsequently altered by hydrothermal fluids related to molybdenum mineralization, and intruded by rhyolite porphyry dikes. Some of these dikes are exposed in the regions east of the Molycorp mill (right side of highway) above and to the east of roadcuts for the open-pit access road. Light-colored, E-trending dikes located east of the pit access road are examples of these younger rhyolite porphyry dikes. They can be seen by looking up-canyon from the mill-yard area to outcrops located north of the highway at approximately mile 4.1. **0.4**

3.8 Sharp bend in road. At bend, bare brown knob on right is an exposure of Precambrian quartz monzonite that stratigraphically underlies 70–90° west-tilted Tertiary rocks, and is probably west-tilted as well. **0.05**

3.85 Milepost 8. **0.15**

4.0 Roadcut on right in dark-colored colluvium of volcanic rock. **0.1**

4.1 At 12:00, road ahead accesses Molycorp open-pit mine. Recent age dating indicates that the coarse molybdenite ore mined here was formed some 400,000 years after solidification of the Sulphur Gulch pluton. The large orange dump truck was used in the open-pit mine; a diesel engine powers electric motors in each wheel. Only a few of these trucks still remain at the mine-site. **0.3**

4.4 The fenced area on right is now a Molycorp boneyard (storage area), but was the former townsite of Moly. See paper by Schilling (this guidebook) for a glimpse of life here in the early 1950's. **0.2**

4.6 Molycorp mill entrance on the right (Fig. 1.4). To the east of the plant, Precambrian through Tertiary rocks are cut by low-angle faults. Rock above and west of the mill is the late Oligocene (24.65 ± 0.1 Ma) Sulphur Gulch pluton (formerly known as the Moly mine pluton).

The meadow in the mill-site area was formed by blockage of the Red River drainage by a debris apron from the former Sulphur Gulch. Sulphur Gulch, at 1:00, has subsequently been filled with terraced mine waste from the open-pit mine.

The tall interconnected towers support a conveyor belt that carries ore from underground block-caving operations up to the primary crusher located at the top of the ridge. The entrance to the underground mine, where the conveyor emerges from underground, is to the west. After the ore is crushed in the primary crusher, it is processed downhill through secondary and tertiary crushers (storage tanks and buildings along the hillside) before entering the mill at the base of the hill. For more information on mining and milling here, see Supplemental Log 1. **0.05**

4.65 Low buildings to the right are assay labs. **0.35**

5.0 On the right, at the west end of the mill property, the tops of large corrugated portal pipes are visible at 3:30. These pipes mark the top of the 7000-ft conveyor belt (decline) that brings ore from the underground mine to the mill area. **0.1**

5.1 Crossing eastern margin of the Sulphur Gulch pluton. This pluton connects in subsurface with the Bear Canyon (formerly known as Log Cabin) pluton to the west (mile 8.3) and probably connects in subsurface with the Red River intrusive complex, north of the Red River townsite. **0.1**

5.2 Road is now paralleling 14-inch-diameter, rubber-lined steel pipes that carry mill tailings 9 mi from the Molycorp mill to tailings ponds near Questa. To the right are waste dumps from the open-pit mine. These dumps fill the former mouth of Sulphur Gulch.

During times of clear weather and low runoff, water in the Red River between here and Questa is typically an opaline, pale blue color. This coloration appears to be due to very fine-grained suspended particles of white aluminum compounds, clay and/or silica. Resident aquatic insects are unable to live under these conditions (Lynch et al., 1988). Fish along this stretch of river have nothing to eat and must either migrate or starve.

Between 1966 and 1981, slurry was released into the river by at least 72 breaks in the Molycorp tailings pipeline (Lynch et al., 1988, p. 20). In the Red River, concentrations of Mo, Mn, Zn, Na, K, Ca, Mg, Ni, Sn and sulfate have been significantly greater downstream from the mill than from upstream reaches (Faith, 1974; U.S. Geological Survey, 1979; Garn, 1985). Because elevated levels of trace metal contaminants in aquatic insects decrease at a slower rate than levels in the river itself, such insects are useful bioindicators of episodic discharges such as tailings spills (Lynch et al., 1988). **0.4**

5.6 South of the highway the forested hills and high mountain ahead are composed of the Proterozoic monzonite of Columbine Creek (Lipman and Reed, 1989), with lesser amounts of Proterozoic amphibolite. An E-trending swarm of dikes and small stocks of Tertiary rhyolite porphyry intrude Precambrian units in the middle to lower portions of the slopes. **0.2**

5.8 Some of these rhyolite porphyry dikes cross below the road here. The dikes are nearly vertical and strike approximately E-W. Yellowish to light tan dike rock is visible in outcrop on the slope to the right. **0.1**

5.9 Tertiary volcanic rocks in roadcut on right are highly sheared and altered. **0.05**

5.95 Ahead are old Molycorp mine buildings. At road level, to the right, is timbered portal (now collapsed) of the tunnel that went a mile into the mountain to connect with over 35 miles of old underground mine workings. See paper by Schilling (this volume) for a description of mine workings. About 250 ft above the road is a 50-ft-thick dike of pre-Mississippian diabase that crosscuts the quartz monzonite. **0.25**

6.2 At 4:00 is dump from the Molycorp open-pit mine. On a rib within the waste dump, Precambrian quartz mon-

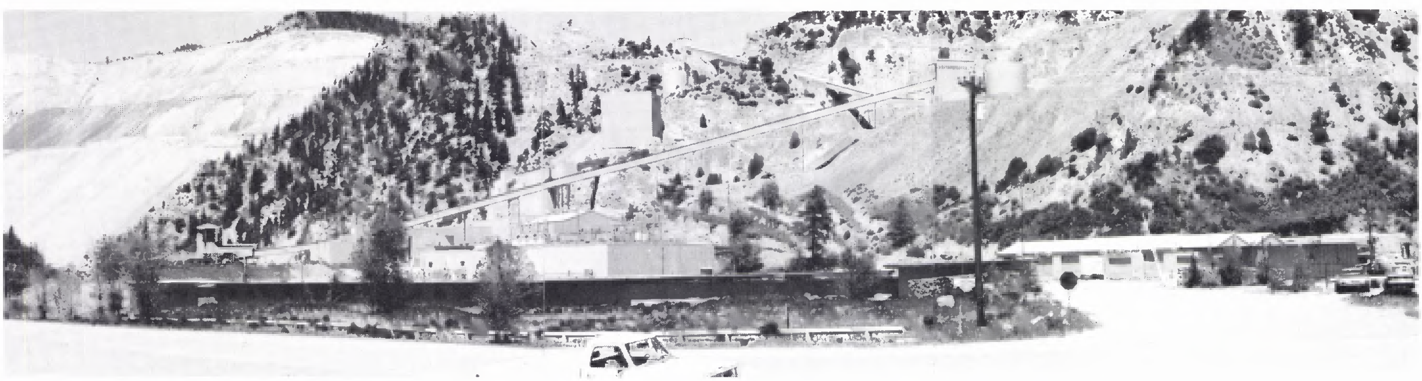


FIGURE 1.4. Molycorp millsite near Questa. Conveyor system transports ore from the top of the decline, on the left, to the primary crusher (large building at top of hill). Mine dumps on left are from the original open pit mine. Photo by P. W. Bauer.

zonite extends up to the highest trees. Immediately above the Precambrian rocks is a low-angle, faulted wedge of early Tertiary sedimentary rock overlain, in low-angle fault contact, by caldera-floor andesites. The structural setting here is similar to that east of the mill, and will be discussed in more detail at Stop 1. **0.2**

6.4 Tailings pipelines cross beneath road. For the next 0.2 mi, at road level, are more vertical dikes of rhyolite porphyry emplaced in the Precambrian quartz monzonite of Columbine Creek. **0.1**

6.5 Gray Precambrian quartz monzonite is well exposed in roadcut at curve. At 12:00 on skyline is concrete headframe of the Goat Hill underground molybdenum mine. **0.1**

6.6 Cross small bridge over Red River. Columbine Creek joins the Red River on the left. Columbine Creek Campground (Carson National Forest) entrance is also to the left.

Cottonwood Park on right. High cliffs across Red River Canyon to the right contain a swarm of Tertiary dikes that cut Proterozoic quartz-monzonite gneiss. Vertical dikes of rhyolite porphyry, as much as 65–100 ft thick, stand as great E-trending fins. Dark band $^{2}/_{3}$ of way up to right skyline is a dike of pre-Mississippian diabase that is unsheared, but has been thermally metamorphosed by Tertiary igneous activity.

To the southeast is medium- to coarse-grained, strongly foliated biotite-quartz monzonite. Well-developed, near-vertical foliation trends about N70°E and lineation plunges 10°W. This rock, called the quartz monzonite of Columbine Creek, is part of an extensive body that makes up much of the Precambrian terrain on the south wall of the caldera. It has a U-Pb zircon isotopic age of about 1730 Ma (Bowring et al., 1984). Part-way up the outcrop, quartz monzonite is cut by a $^{1}/_{3}$–$^{3}/_{4}$-inch dike of Tertiary andesite. The meadowland to the west of Cottonwood Park was formed by blockage of the Red River drainage by a debris apron at mile 7.7. **0.15**

6.75 **Bear left** on dirt road that follows tailings pipelines. Note: this is Molycorp property, and permission is needed to leave the highway. If you choose to continue on highway, you will pick up the road log again at mileage 7.6. **0.15**

6.9 **Bear left** at fork in road. **0.1**

7.0 **Bear right** at fork in road away from pipelines. **0.1**

7.1 **STOP 1,** park near old boxcar on right. To the north, the lower bold outcrops consist of Precambrian quartz monzonite that contains E-trending, near-vertical foliation, and Oligocene dikes that are parallel to the Precambrian foliation trend. The highest outcrops on the hillside show packages of 90° west-tilted Precambrian and Tertiary rocks bounded by low-angle extensional faults that have top-to-the-east displacements. These low-angle faults are believed to have initiated at high angles, and to subsequently have been rotated to low angles in domino-style during extreme ENE-directed extension. Low-angle fault zones strongly influenced the emplacement of Oligocene dikes and tended to channel molybdenum-related hydrothermal fluids. Structural relationships in the bold outcrops to the north are described in more detail in the following minipaper by J. Meyer.

STRUCTURAL CONTROLS OF THE QUESTA MOLYBDENUM DISTRICT, NORTHERN NEW MEXICO

Jeff Meyer

Geological Sciences, University of California at Santa Barbara, Santa Barbara, California 93106

The Questa molybdenum mining district in northern New Mexico has been sporadically active since 1923 and is currently producing 13,000–16,000 tons/day of ore at approximately 0.3% MoS_2. Ore deposits at Questa occur above the apex of highly evolved plutons (e.g., Climax and Henderson: Wallace et al., 1968, 1978) but differ significantly from "Climax-type" model deposits in that mineralization is strongly structurally controlled. In Questa, the deposits are aligned along a 070° trend.

Earlier workers in the district noted the ENE alignment of ore bodies, alteration zones and dikes, as well as the abundance of volcanic rocks between the ENE-trending Red River and Cabresto Creek drainages (Fig. 1.5; Schilling, 1956; Ishihara, 1967; Carpenter, 1968; Clark, 1968; Clark and Read, 1972). These authors proposed the existence of a structural feature termed the Red River trench (Carpenter, 1968) or Red River graben (Schilling, 1956; Ishihara, 1967; Clark, 1968; Clark and Read, 1972), with the Red River and Cabresto Creek drainages being the southern and northern fault boundaries of this ENE-trending graben, respectively.

Regional mapping by Lipman and others of the U.S. Geological Survey (Lipman and Reed, 1989) has led to vast improvements in understanding of the volcanic stratigraphy, geochronology and structural evolution of the district (Lipman, 1983, 1988; Lipman et al., 1986). This work recognized the Questa caldera, with its linear southern boundary that approximately coincides with the Red River drainage between the town of Red River and the Rio Grande rift-front near Questa. Recognition that the Questa mining district spatially coincides with the southern caldera margin led to recent interpretations that caldera margin faults were the primary control for later intrusion, molybdenum mineralization and alteration in the district (Leonardson et al., 1983; Lipman, 1983; Lipman and Reed, 1989).

Mapping by the author and others has redefined the southern structural boundary of the Questa caldera, and has led to interpretations that de-emphasize the influence of caldera-bounding faults on later events. In the redefined scenario, an E-W- to ENE-trending Precambrian structural zone is the primary control on the location and orientation of such Tertiary features as the southern caldera wall, postcaldera plutonism, mineralization and alteration and modern drainage development. The Precambrian structural grain was most influential at lower structural levels. At higher levels in the crust, low-angle faults resulting from postcaldera extension were the primary control on diking and mineralization.

The Questa mining district is underlain by Precambrian basement of stratigraphically lower metaigneous rocks in the southern half of the map area (Fig. 1.5) and stratigraphically higher metasedimentary rocks in the northern half. Metaigneous basement consists of mafic schists, felsic schists and metaquartz monzonite intrusions that are variably foliated; foliations show 060°–100° strikes and vertical to near-vertical dips. This local ENE foliation trend is in contrast to the variable, but commonly NE-trending, foliation of Precambrian units in the majority of the Sangre de Cristo range (Lipman and Reed, 1989). Local mylonite and cataclasite zones parallel this ENE-trending foliation (G. Kirchner, unpubl. report for Molycorp Inc., 1983), suggesting that significant translations were responsible for the north-to-south juxtaposition of the metasedimentary and metaigneous units.

Precambrian rock units were definitely juxtaposed by Eocene times, when locally derived, continental red-bed sediments were shed from Laramide highlands located immediately to the east (Lipman, 1983). These Precambrian-derived sediments overlie both northern and southern Precambrian terrains, and strongly reflect their local source regions. Northern exposures contain high proportions of metasedimentary clasts, and southern exposures have an almost completely metaigneous provenance.

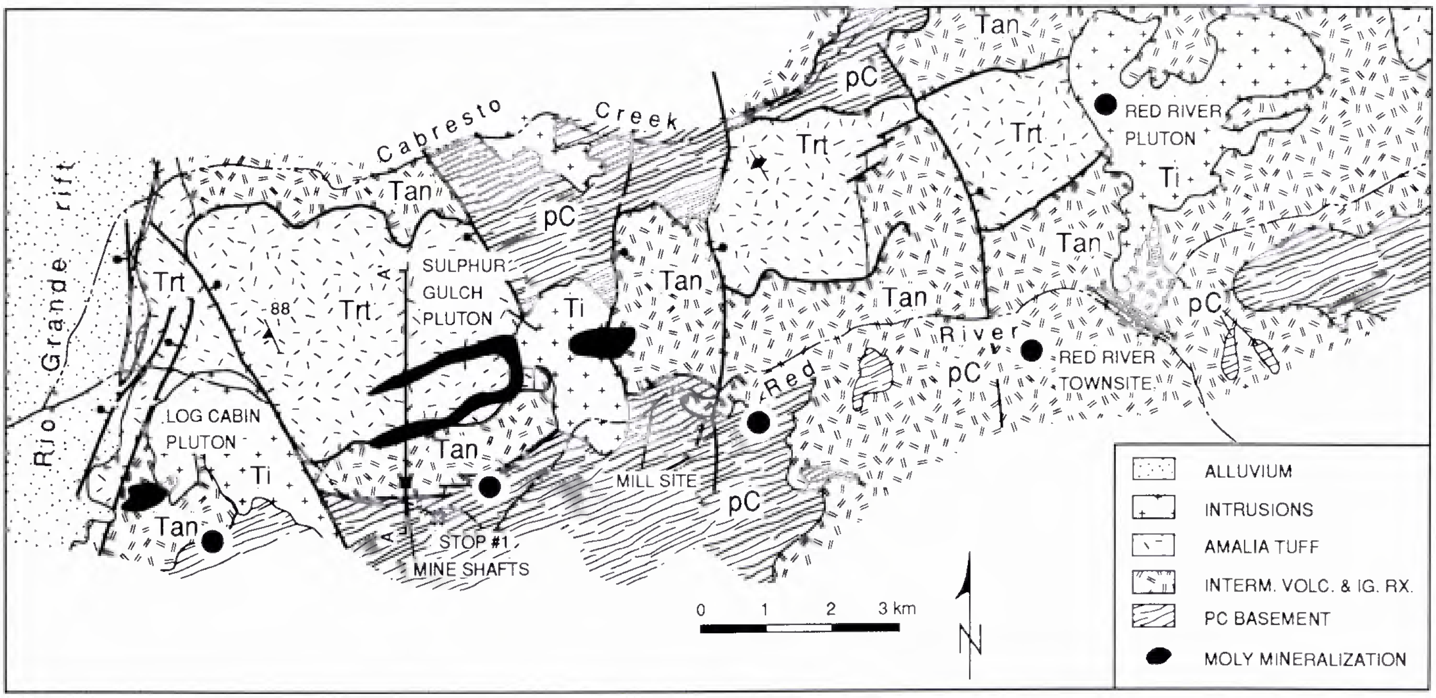


FIGURE 1.5. Generalized geologic map of the Questa mining district demonstrating the abundance of low-angle faults (sinuous contacts in heavy lines) and indicating the approximate location of the southern structural margin of the Questa caldera (large dots). Precambrian foliation in the southern portion of the district trends E-W to ENE (approximately parallel to the direction of patterning). The locations of field trip Stop 1 and Fig. 1.17 (cross section A-A') are indicated.

Eocene sediments are overlain by the Oligocene Latir volcanic field, composed of intermediate-composition volcanic and intrusive units, which in turn is overlain by the Questa caldera-related Amalia Tuff and associated intrusions (Ta and Tr of Fig. 1.5). The caldera floor and intracaldera units have a total thickness of 4–5 km in the southern caldera area, where tilting has exposed the entire Tertiary stratigraphy.

The southern structural boundary of the caldera is a linear, 1–2 km wide zone coinciding with the modern Red River drainage (Fig. 1.5), and defined by: (1) locally preserved, high-angle, down-to-the-north fault segments; (2) local high-angle, E-W- to ENE-striking dikes that are chemically similar to the peralkaline Amalia Tuff; and (3) zonations in the megabreccia block stratigraphy in the intracaldera Amalia Tuff that indicate near-source derivation from a region near the present Red River drainage. This boundary is parallel to the Precambrian structural grain and it is likely that the linear nature of the southern caldera boundary is controlled by this grain.

Although the southern boundary is well defined by structural and facies evidence, no topographic expression of the caldera wall was found during the current study. Two fault zones that were earlier interpreted to represent exposures of the inner topographic wall of the caldera (Lipman, 1983) have been remapped, and these zones are now interpreted by the author to be low-angle fault zones related to post-caldera tilting (compare interpretation of Lipman, 1983, fig. 8, to interpretation of upper faults in Fig. 1.6 of this paper).

The entire volcanic stratigraphy north of the Red River drainage and west of the town of Red River was tilted 90° to the west during a period of rapid extension. Tilting followed the 25–26 Ma caldera collapse but pre-dated the intrusion of 24–25 Ma batholith-scale plutons related to molybdenum mineralization (Hagstrum and Lipman, 1986; Johnson et al., 1989; K. Foland, oral commun., 1990). Exposures, such as shown in Figure 1.6 (immediately north of field trip Stop 1), indicate domino-style relationships with younger-on-older offsets on low-angle dip-slip faults that have top-to-the-east displacements as great as 1 km. These low-angle fault planes are interpreted to have initiated at high angles, near 90° to bedding, and to have been rotated to low angles in domino fashion during 200–300% of ENE-directed extension. Low-angle faulting is largely confined to upper crustal levels above postcaldera plutons (e.g., Fig. 1.7, north of the Red River).

Tilting was immediately followed by the emplacement of 24–25 Ma intrusive phases including rhyolite dikes, batholith-scale plutons and associated molybdenum mineralization and related alteration. Igneous emplacement was controlled by the Precambrian structural grain at lower structural levels and by extension-related, low-angle faults at higher levels in the crust. In Figure 1.5 note that the Log Cabin, Sulphur

FIGURE 1.6. Aerial view looking ENE of the underground mine shaft (lower left), field trip Stop 1 (bottom), cliffs to the north of Stop 1, dumps from the open pit mine, and the ENE-trending Red River drainage. The hillside north of Stop 1 shows low-angle, top-to-the-east, extensional structures that are believed to have been initiated at high angles and tilted to low angles in domino fashion. Intervening stratigraphy consisting of Precambrian basement (p€), Eocene sediments (Ts), and overlying andesite (Ta) has been tilted 90° to the west. At deeper structural levels, postcaldera dikes strike E-W and dip near 90°, parallel to the Precambrian foliation of this portion of the district.

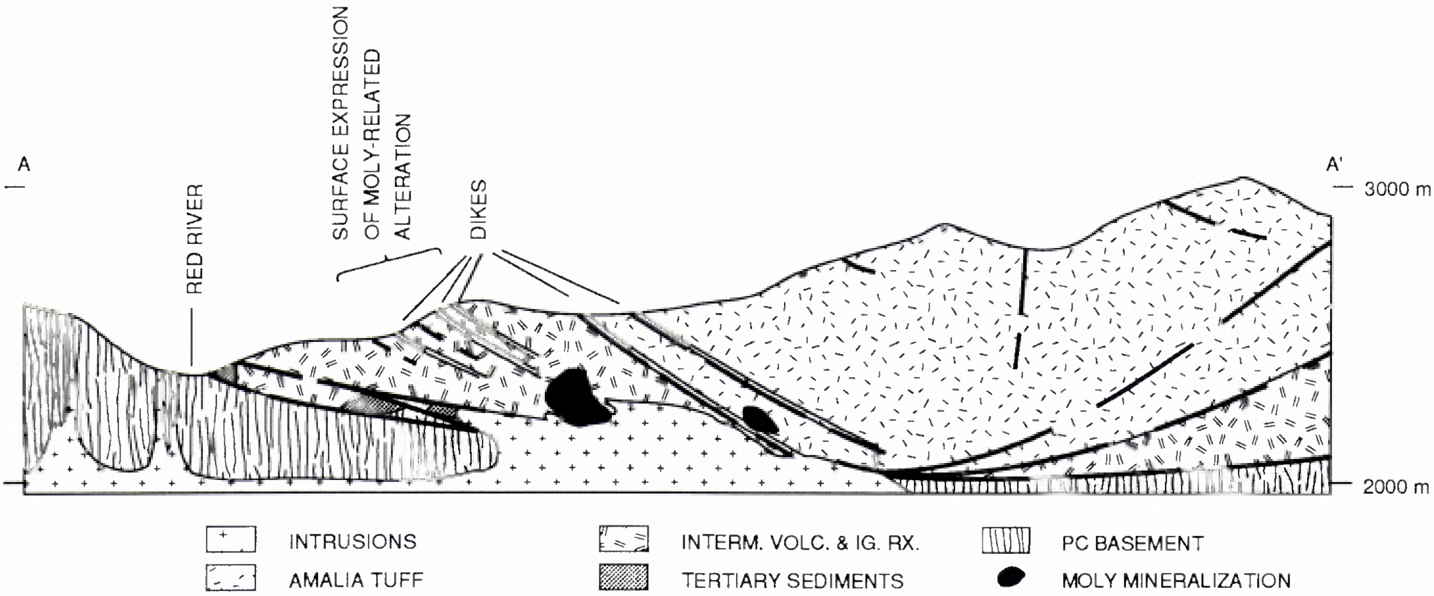


FIGURE 1.7. Generalized cross section A-A' (Fig. 1.15), looking west. Note the significant influence of low-angle faults (heavy lines) on molybdenum mineralization, alteration, and rhyolite porphyry diking at high structural levels. Aplite that is interpreted to be the source of this mineralization is located to the north of, and below, the southernmost mineralized zone. Surface alteration related to molybdenum mineralization is 500–1000 m south of the southern mineralized zones. At lower structural levels, in the southern portion of the cross section, rhyolite porphyry dikes parallel the high-angle, E-W-striking foliation in the Precambrian basement.

Gulch and Red River plutons and molybdenum mineralization are aligned parallel to the ENE Precambrian grain. Many associated lower-level rhyolite dikes (Fig. 1.7, south of Red River) are also parallel to the Precambrian foliation.

At higher crustal levels, low-angle faults significantly influenced the location of rhyolite porphyry diking and channelized molybdenum-related hydrothermal fluids (Fig. 1.7, north of Red River). The outcrops immediately north of Stop 1 exhibit a striking example of the influence of low-angle faulting on molybdenum mineralization. Here, a gently north-dipping low-angle fault zone (Fig. 1.6) can be traced in the subsurface into molybdenum mineralization, of the southwest ore zone (Figs. 1.5, 1.7). Molybdenum mineralization, molybdenum-related alteration and syn- to post-mineral diking parallel this north-dipping fault zone and a characteristic quartz-sericite-green sericite-specular hematite alteration assemblage related to molybdenum mineralization is exposed in the fault zone (Fig. 1.7). One would normally expect alteration from a porphyry-type ore body to be located immediately above the ore body, as at Climax, but at Questa the low-angle faults have channelized the altering fluids and offset the surface exposure of this alteration pattern by as much as 1000 m to the south.

Late Miocene to present uplift of the Sangre de Cristo Mountains has exposed the region. Two major drainages from this uplift are Cabresto Creek and Red River. Both of these drainages flow WSW, which suggested to earlier workers that preferential erosion was occurring along faults that were the northern and southern boundaries of an ENE-trending graben (Schilling, 1956; Ishihara, 1967; Carpenter, 1968; Clark, 1968; Clark and Read, 1972). However, detailed mapping by the author and others has found no indication of throughgoing faults along the course of the drainages, nor evidence of significant offsets in either the volcanic or the Precambrian stratigraphy. Local E-W- to ENE-trending joint sets have been noted, however, and are probably responsible for the parallel orientation of these drainages.

The southern structural wall of the Questa caldera is a linear zone 1–2 km wide and approximately parallel to the course of the Red River for about 15 km. Evidence for its location includes linear ring-dikes, fragmented normal fault exposures, and facies changes in the intracaldera stratigraphy consistent with a near-caldera wall locality. Exposures previously believed to represent block slumpage on the topographic wall of the caldera are actually exposures of low-angle fault zones that post-date caldera formation.

A Precambrian structural zone is proposed as the primary structural control on the district, with many Tertiary events being preferentially located along this Precambrian zone of weakness. Evidence for the zone includes an anomalous E-W- to ENE-trending foliation relative to a more regional NE foliation trend, local mylonite zones paralleling this foliation, and a juxtaposition of Precambrian rock types.

This Precambrian structural weakness exerted profound controls at lower structural levels of the district, and is believed to have: (1) helped to localize the southern caldera wall and caused it to be linear; (2) localized subsequent pluton and dike emplacement along an ENE linear trend; (3) controlled the distribution of molybdenum mineralization (largely through 2); and (4) probably controlled the ENE-trending direction of the Cabresto Creek and Red River drainages. At higher structural levels, low-angle fault zones related to extreme postcaldera extension have strongly influenced higher-level Tertiary diking, and strongly channelized molybdenum mineralizing and mineralization-related hydrothermal fluids.

Continue westward down dirt access road. **0.1**

7.2 Old pipes in meadow to right. **0.1**

7.3 Rejoin pipeline road. **0.1**

7.4 Headframe and tops of buildings at the Goat Hill mine are visible to the right. **0.15**

7.55 Cross narrow steel bridge over the Red River. No passing on the bridge! **0.05**

7.6 **Rejoin highway** and **continue westward.** Pipeline crosses under road. On the right and for the next 0.5 mi, Quaternary deposits are exposed in roadcuts. **0.1**

7.7 Roadcut to right shows a stack of debris flows in a debris apron that continues down to about mile 8.1. The sources of this apron are the multiple alteration scars in Goat Hill Gulch, to the north. **0.1**

7.8 Trellised tailings pipeline on the right. **0.1**

7.9 Gully cuts debris flow on right. At 3:00 an alteration scar is visible on hillside. **0.2**

8.1 Paved mine site entrance to the right. Rocks to the right of the road uphill are a megabreccia facies of the Amalia Tuff of Lipman and Reed (1989). **0.15**

8.25 Goat Hill Campground on the left. High cliffs at 10:00 are part of the Bear Canyon pluton (24.1 ± 0.1 Ma according to Czamanske et al., this guidebook). **0.05**

8.3 Second mine entrance road on the right. Roadcuts along Molycorp tailings pipeline display altered megabreccia blocks of andesite intruded by coarsely porphyritic quartz-latite to rhyolite-porphyry dikes. At the westernmost exposure, indurated but weakly welded Amalia Tuff containing lithic fragments, in contact with andesite, constitutes the matrix of the caldera-collapse megabreccia. The tuff tends to be more highly welded away from andesitic blocks, which acted as local heat sinks.

The Bear Canyon pluton forms the resistant cliffs to the left. From here the road turns to the northwest and transects more-interior portions of the caldera. **0.6**

8.9 Pipeline road on right heads into the mouth of Capulin Canyon. The Bear Canyon pluton is to the left. Since Stop 1 we have been climbing obliquely through structurally higher west-tilted blocks that are bounded by low-angle fault zones. Because the motion of these blocks is top-to-the-east, each time we cross over a major low-angle fault zone into a structurally higher block, a higher stratigraphic level is encountered. This effect combined with the fact that we are traveling west through a west-tilted section has allowed us to pass through over 4 km of section in only 2.5 km of travel. The stratigraphy we have traversed consists of Precambrian basement, early Tertiary sedimentary rock, caldera-floor andesite, megabreccia facies of the Amalia Tuff and finally, at approximately mile 9.0, densely welded Amalia Tuff. **0.05**

8.95 Bear Canyon is on the left. At 11:00 is the contact between the cliff-forming Bear Canyon pluton and the less resistant Amalia Tuff.

Mouth of Capulin Canyon on the right. South-facing slopes to the north of the canyon mouth are very densely welded, granophyrically devitrified Amalia Tuff of the caldera interior. Outcrops to the south and east blocks are close to the southern structural margin of the caldera. Close inspection of tuffs in this area reveals N20°–30°W trends and near-vertical dips. **0.3**

9.25 The canyon narrows between major cliffs of the Bear Canyon pluton. Pipeline road returns to highway on the right. **0.1**

9.35 Tailings pipeline crosses below highway. **0.45**

9.8 Milepost 2. Tailings pipelines depart highway for settling ponds west of Questa. **0.1**

9.9 Guadalupe Mountain is visible at 11:00. Road has passed through the Bear Canyon pluton. Now flanking the highway is Tertiary andesite that displays considerable variation in color. Small outcrops of Amalia Tuff are present locally. **0.25**

10.15 Questa District Forest Service Ranger Station of the Carson National Forest on left. Somewhere close ahead, the highway crosses the buried range-bounding fault zone. Roadcuts on right expose andesitic megabreccia blocks of caldera fill underlying and interleaved with welded tuff. **0.4**

10.55 Road to a small fishing lake on the left. **0.05**

10.6 Questa village limit sign on the right. The high, flat ridges ahead are mainly old alluvial fan deposits. The Red River and Cabresto Creek have become entrenched in these old fans. The valley bottoms contain Quaternary alluvium or latest Holocene deposits. **0.2**

10.8 Milepost 1. **0.65**

11.45 **Questa Post Office** on right. Massive ridge at 4:00, between the Red River and Cabresto Creek, consists of vertically dipping intracaldera welded tuff. **0.15**

11.6 Road up Cabresto Creek on right. **0.25**

11.85 **Junction** of NM-522 and NM-38 in center of Questa. **Turn right** (north) onto NM-522. Questa was originally named San Antonio del Rio Grande. It was renamed Questa in 1883 when the post office opened. The origin of Questa is probably a corruption of the Spanish word "cuesta" (slope or grade). **0.35**

12.2 **Optional stop. Bear right just past Fire Department.** This spot offers a commanding view of the Taos Range and the southern margin of the Questa caldera where it is dissected by the Rio Grande rift and two major E-trending canyons (Red River to the south and Cabresto Creek to the north).

Facing east, several major features are visible. The high mountain at 1:30 is Flag Mountain (11,942 ft), consisting of Precambrian quartz monzonite with inclusions of Precambrian felsic volcanic rock up to 2500 ft across. The north shoulder of Flag Mountain, at 1:00, is part of an E-trending alignment of Tertiary granitic to aplitic ring intrusions along the southern margin of the caldera, which extend approximately 16 km up Red River canyon. The conspicuous switchback roads on the west face of Flag Mountain provided access to drill pads that were used by Molycorp to block out a large, low-grade molybdenum deposit near the crest of the north ridge. This deposit is marginally economic and is not being developed due to the occurrence of higher-grade ore at Goat Hill.

Looking up Red River Canyon, the prominent hill with an encircling road near its top is Goat Hill. Approximately beneath this hill is the site of the new Molycorp underground mine (Leonardson et al., 1983). Goat Hill consists mainly of intracaldera welded tuff and interlayered megabreccia slump blocks of precaldera lava flows. At the crest of Goat Hill is an E-NE-trending dike of altered, coarsely porphyritic rhyolite, which crudely represents part of the ring-intrusion complex along the southern margin of the caldera. In the distance, to the right of Goat Hill above treeline, is the flank of Gold Hill (11,622 ft). Gold Hill consists of a complex succession of mafic/felsic layered gneiss, part of the Gold Hill Complex (Bauer and Williams, 1989) interpreted to represent metamorphosed and deformed volcaniclastic rocks interlayered with flows, tuffs and sedimentary rocks (Reed, 1984). In 1895, gold was discovered in Gold Hill. By 1897, 200 people lived in nearby Amizette (Fig. 1.8) where 600 tons of gold, silver, copper and lead ore were mined per day (Sherman and Sherman, 1975). By 1903, all mining in the district had ceased.

At 11:00, the high timbered ridge, between Cabresto Creek and the Red River, consists of densely welded Amalia Tuff, rotated to nearly vertical, with an aggregate thickness measured normal to its foliation of at least 2.5 km. This represents part of the caldera-filling welded

FIGURE 1.8. Amizette, New Mexico, located approximately 13 mi up the Rio Hondo from the Rio Grande, was so christened in honor of the first female resident in camp and wife of pioneer prospector Al Helphenstine. Initially, the claims of Helphenstine and others appeared to hold great promise for precious metals. Helphenstine erected a hotel which was soon followed by the mercantile store of Alex and Gerson Gusdorf seen here. Boom quickly turned to bust when ores were found to be too complex or low in grade to work profitably, and by 1895 Amizette was deserted. A new gold strike on Gold Hill revived the town briefly in 1897, but the more significant discovery of gold and copper on Fraser Mountain led to the establishment of a new settlement at Twining. By 1902, Amizette was a ghost town for the second, and last, time. Photo by B. G. Randall, circa 1894, courtesy of Las Quince Letras.

tuff. Rotation of this block occurred after caldera collapse, within an approximately 1 million year time period between Amalia Tuff deposition and emplacement of postcaldera granitic intrusions. This timing is constrained by small intrusions projecting upwards from the underlying batholith, which intrude the 90° rotated tuff but exhibit unrotated paleomagnetic pole positions.

Note large alteration scar in Amalia Tuff at 10:30.

North of Cabresto Creek, at 10:00, Pinabete Peak (11,946 ft) consists of volcanic rocks of the caldera floor that have been uplifted in the resurgent core. The lower slopes are Precambrian rocks of the floor, and (difficult to see) on the north skyline are granitic rocks of a resurgent pluton within the core of the caldera.

Thus, from south to north we see a cross section through a caldera, including the structural caldera wall of Precambrian rock, thick moat-filling welded tuff, and the caldera floor uplifted in a resurgent dome. **Proceed northward on NM-522.**

From here, we follow the eastern margin of the modern Rio Grande rift to Costilla. This route provides long-distance views of the Tertiary volcanic sequence resting on Precambrian rocks both within and outside of the Questa caldera. From the town of Costilla, the route follows the Rio Costilla upstream along a series of Miocene fault blocks, related to early extension of the Rio Grande rift system, that tilt the volcanic sequence to the east and repeat it. **0.5**

12.7 Milepost 21. **0.4**

13.1 Questa Mid-School on left. This is the location of the most extreme Bouguer gravity low within the Rio Grande rift zone. This low probably reflects the downdropped western portion of the Questa caldera. **0.2**

13.3 At 9:00 is an excellent view of the two summits of Guadalupe Mountains, a 4.8 Ma rhyodacitic double volcano of the Taos Plateau volcanic field (Lipman and Mehnert, 1979). The saddle between the summits is the site of the tailings dam that Molycorp hopes to construct to contain mill tailings. **0.6**

13.9 At 11:00 is Ute Mountain, another Pliocene rhyodacitic cone of the Taos plateau volcanic field. **0.6**

14.5 On left is road to the village of Cerro and the BLM Wild and Scenic River Recreation Area (see paper by Heffern, this guidebook, for description of geology of Recreation Area). Recreation area is 8 mi to the west. **1.0**

15.5 On left is second turnoff to Cerro. **0.2**

WILDLIFE AND HABITATS IN NORTHERN NEW MEXICO

Ben Kuykendall

U.S. Forest Service, Taos, New Mexico 87571

Until 200 years ago, wildlife species throughout this region suffered population declines and increases based almost entirely on natural events. The ability of Man to influence their numbers or the habitat they depended upon was minimal. The survival of American Indians was largely dependent on their limited hunting weaponry, which also precluded their eradicating game populations. The effectiveness of their harvesting abilities probably resulted in less mortality than our road kills of today. Natural population cycles resulted from disease and overpopulation, which was subsequently followed by starvation, predation and migration, which left one species on the peak of its cycle while others were diminishing. Instead of a "balance of nature," there was a relatively constant or dependable imbalance. How things change. . . .

Habitats are the key elements for survival of wild animals. What do we really know about them? Due to our short-term frame of reference, habitats that we now consider "pristine" might be virtually unrecognizable compared to what they really were before the rapid expansion of the West. The following are some of the more interesting or significant events that leave us with our current situation, and our challenge for the future.

The most serious problem is loss of habitat. Some of the most appealing towns in the state are in northern New Mexico. Some of the most important winter ranges for large ungulates (hoofed mammals) and other species such as sage grouse have now been occupied by people, their pets and their livestock. The current leader in habitat alteration in our region is "overgrazing." The discovery of seemingly endless rangelands led to their immediate exploitation, and to some degree, permanent transformation.

How much has grazing changed the land and wildlife? The Taos Plain is probably the best example of what the range really looked like in the first century BC (**B**efore **C**ows). The plain probably contained a mosaic of sagebrush and dense native grasslands. The diversity of grasslands and shrub types provided an excellent home for the roaming herds of buffalo and pronghorn. Their patterns of use helped to stimulate and perpetuate this habitat. During the 1880's grazing was practiced on what was thought to be an unlimited supply of forage. However, as the grass understory was removed, the rich upper layer of the soil, most important to the grasses, was left unprotected, and was gradually thinned by erosion. This provided an advantage for the sagebrush, which propagates well in more adverse soil conditions.

Fire also played an important role in controlling the attempts at encroachment by sagebrush. After a fire, grasses were able to reestablish themselves more quickly than sagebrush. With the removal of the grass understory, fire could not carry itself through the sagebrush. Once sagebrush dominates a site, it is difficult to eradicate. I recently evaluated a 5-acre exclosure that had been removed from grazing for 40 years. Surprisingly, the exclosure looked worse than the surrounding grazing land. If we choose to return this range to a more pristine and productive state, Man's original intervention must now be met with more of Man's intervention to change this habitat . . . at least for the near future. The sagebrush must be physically removed (plowed) for re-establishment of native grasses.

Pinyon-juniper stands are another important habitat on the Taos Plain. Pinyon trees cover the volcanoes that dot the west side of the Rio Grande. For some reason, the pinyon-juniper-covered hills don't seem to stimulate the same questions as do the vast expanses of sagebrush. In fact, to most observers, the stands of pinyon represent pristine habitats that need protection. Researchers are only now discovering that this habitat has also been significantly altered by Man. The changes in this vegetation type are probably greater, and have had as much or more effect on wildlife, than those on the sagebrush flats. Recent studies on the growth rings of pitch-preserved logs in the Bandelier National Monument indicate that for hundreds of years, prior to the onset of overgrazing, major fires moved through this habitat every 10–12 years. Surviving pinyons and junipers were large enough to be fire-resistant to the burning shrubs and grasses of the heavy understory. The large distance between trees probably prevented a crown fire. The shrubs and grasses were naturally stimulated by these events, and the result was an open savannah-type habitat with large pinyons and junipers more sparsely distributed among thick grasses and shrubs.

Upon the arrival of large herds of cattle, the periodic fires were terminated because the livestock removed the fuel required for this regular phenomenon. Young pinyons that were normally kept in check were given the opportunity to rapidly increase, and soon the more savannah-like pinyon stands became thick woodlands lacking grasses or shrubs. This habitat alteration worsened as wintering herds of elk and deer competed with livestock for the remaining forage species. There was also another set of unlikely partners in this phenomenon . . . the family of Corvids. Let's look at the role the "jays" played.

Unlike most plants in the Southwest, pinyons do not have much of an ability to distribute their seeds; straight down plus one bounce is about as good as they can do on their own. But they have lots of help. The native jays are the "Johnny Appleseeds" of the Rocky Mountains with respect to pinyons. The three major contributors to the local effort are pinyon jays, scrub jays and Steller's jays. All are effective harvesters of pinyon nuts, and store food in the soil for the winter. They bury nuts in caches of from one to five, planning to return at a later date. Scrub jays generally use woodlands sites, whereas pinyon jays will venture farther into the open sagebrush areas to deposit their future meals. The Steller's jays will often frequent this habitat in the fall and carry his prize to the higher elevations where the uppermost-established stands of pinyon trees exist.

Jays are much more effective at planting seeds than one might imagine. Some species have been observed to carry as many as 60 nuts at once in their crop; but more commonly around 20. If one jay takes ten minutes to collect, select sites for and cache 20 nuts and he does this for 8 hours a day for 2 months, he will plant 57,600 pinyon trees per year. Most of these trees are single nut caches in virtually perfectly prepared seed beds. Jays, however, are not only good at planting seeds, they have an uncanny ability to remember where they did it. Research in Colorado has shown about an 80% success rate at relocation and cache retrieval. This still leaves 11,500 nuts in the ground, planted by one bird. Let's be conservative and say that he was only about half that busy, and planted 5000 nuts that were not found by ground squirrels. If 25% of those germinated, and only 1% became established, our one bird successfully planted 125 trees. It is now easy to understand why we have the dense stands of pinyons with little else as understory.

One additional problem with pinyon stands results from uncontrolled fuelwood harvesting of mature trees. This "high-grading" of the pinyon stands results in the opposite age-ratios, growth-ratios and density-ratios from what would occur under the "natural" scenario.

Activities during the 1800's not only affected habitats; animals themselves were used much as the pastures they grazed. Several game species were extirpated from the state as a result of hunting for meat, or in some cases, just hides. Sometime between the end of the Civil War and the turn of the century, the last of the native elk were killed.

New Mexico's healthy elk herds are the result of reintroduction efforts by sportsmen that began as early as 1910, when 25 elk were shipped from Yellowstone National Park to Vermejo Park. The next year 12 more were released in the Cimarron area. Only 50 more were introduced by the late 1930's, but from 1951 to 1966, 2000 more were shipped to various locations in the state. The healthy herds we have today are due to the fact that they are well managed, better than our deer herds. Quality management simply requires more money, and sometimes tough decisions.

Two of the most impressive elk herds in New Mexico are in view of our road trip. One is on the Valle Vidal where about 1200 to 1500 elk live year-round. Hunting is strictly controlled, and management of wildlife habitat is the highest priority for this area. Much of the Valle Vidal has suffered from adverse management practices in years past, especially timber resources. In some areas entire hillsides were cut, and the timber operators took only what they wanted. The Valle Vidal still has tremendous wildlife values. Of the 1400 special-use stamps sold last year, about 200 were for hunting and 1200 for fishing. Fishing is one of those often overlooked, but significant, economic resources. Fishing returns from public lands in Taos County add about $2 million to the economy yearly. In New Mexico, the annual benefits are estimated at close to $300 million.

To the west is a volcano called San Antonio Mountain. Each winter, elk from hundreds of square miles of the Carson National Forest and private lands move into a relatively small area near San Antonio Mountain that is the most important elk winter range on public lands in the state. The elk population grows from about 100 to over 2000 in late December each year. Depending on the severity of the winter, they usually remain there until at least mid-March. The animals are in a total weight-loss situation and calories are burned up faster than are available from the dormant forage. To these animals, winter range is more than a place that contains feed; thermal cover is a critical winter range element. On a cold night, it may be 10° warmer under a stand of dense conifer trees than in the open. Thermal loss from the earth is reduced if branch cover is dense enough. As an example of thermal cover effectiveness, if the open range temperature is –2°F and the wind is blowing at 20 mph, the resulting chill factor is about –40°F. Within the trees there is no wind, so effective temperature is back up to –2°F, and the thermal cover factor brings the temperature up to 8°F. If 200 elk are also under those trees, a micro-climate from their body heat could bring the temperature up another ten or more degrees. The presence of quality thermal cover can therefore result in an effective difference of over 50° warmer night-time conditions for the herd. Thermal cover is the most limiting factor in the San Antonio Mountain winter range. Currently, 3 perlite mines, 2 scoria mines, the associated haul roads, private cabin developments and US-285 bisect the winter range.

I recently spent 6 hours on the side of a scoria-covered vent just south of San Antonio Mountain with a representative from a mining company. We discussed the elements of survival necessary for his company and the public's elk. The issues were complicated. To make a long story short, once we understood each other's dilemma, we worked more as a team to find a solution. The alternative was probably a winner-take-all situation. Considering the public support for management of the elk winter range, and political support for the company, it could have gone either way. I didn't want to chance losing an isolated stand of trees on a site so harsh it might have taken 400 years for them to become established, and he didn't want to test the political winds. Therefore . . . a compromise was made. If we would have chosen not to work together, there would have probably been one winner, and an alienated loser. Instead we had respect and understanding for the other's point of view.

Perhaps the greatest need involving resource management on the national scene is progressive mineral resource legislation. The 1872 Mining Law will continue to fuel the flames of non-cooperation in the future. The 118-year-old legislation does not provide a tool for interdisciplinary management of our natural resources. Instead, it sets up the "winner-take-all" scenario, and fuels bitter battles instead of intelligent decisions.

There will be cases where the compromise scenario is not an option. The challenge is then even greater. The decisions become tougher.

Education and understanding have to grow to the point where a combatant relationship is not the result of the decision. Knowledge and wisdom must also be at the core of resource management decisions. Emotion over loss of jobs or loss of habitat can no longer be the primary decision-making factor. I recently heard on the news that 100,000 species became extinct in the 1980's. To slow down this catastrophe we will have to start making decisions based on extended time periods, at least 200–400 years in the future, as opposed to 10–20 years, or even 1–10 years.

The upper reaches of the Rio Grande gorge provide one of the richest wildlife habitats I have ever worked with. The vertical basalt walls provide nesting places for numerous cavity nesters and ledges for birds of prey. One of the region's hottest news stories this year involved this, and much of the surrounding area. A two-year sting operation was mounted to attack the historical poaching situation. From September 1986 until July 1987, an undercover officer, based in Woodland Park, Colorado, operated a fur route in the valley, and gathered information on illegal activities. In 1987, he was moved to Fort Garland where he set up a shop as a taxidermist and custom meat processor. He remained there until April 1988, whereupon he moved his operation to Costilla, New Mexico.

On 6 March 1989, at 6:30 a.m., 274 officers from all state and federal jurisdictions served 46 felony arrest warrants and 20 search warrants, issued 27 citations, and seized 18 vehicles from defendants in an area encompassing towns from Denver to Phoenix. Including both state and federal operations, a total of 66 people were arrested. Wildlife in the southeast corridor of the San Luis valley of Colorado and northern New Mexico was being taken illegally, in great numbers, and in many instances the meat, antlers and hides were being sold for money, drugs, liquor or other goods or services. The agent purchased or traded for 96 big-game animals weighing approximately 15,000 pounds over a two-year period, while having knowledge of an additional 547 elk, 2006 deer and 92 eagles that had been illegally taken and were moving in commerce in the area. One hundred and eight defendants had committed over 850 wildlife violations. To date, throughout the legal system, charges of racism, entrapment, creation of a market and outrageous government conduct have been leveled in reaction to the sting operation. Walls of opposing attitudes are now higher than ever.

No matter how difficult the scenario, there needs to be someone to meet the challenge. Geologists, wildlife biologists and other resource managers have perhaps the greatest of challenges: how can we develop a team approach to meet the needs of a growing nation and not consume or pollute it at the same time?

15.7 Milepost 24 and New Mexico Port of Entry on right. At about 9:00, across the gorge, is the shield-shaped volcano Cerro de la Olla, a 2.3 Ma andesitic cone of the Taos plateau volcanic field.

To the right, along the mountain front north of Cabresto Canyon, is a low hill composed of Tertiary andesite porphyry, dacite porphyry, rhyolite, Amalia Tuff and the rhyolite of Cordova Creek (Lipman and Reed, 1989). One of four small, postcaldera, resurgent granitic plutons, the Canada Pinabete Pluton, crops out along the range front between 1:30 and 2:30 (Lipman and Reed, 1989). **0.4**

16.1 At 8:30, the dark angular hill between Guadalupe Mountain and Cerro de la Olla is Cerro Chiflo, a 10 Ma quartz latite cone. On the skyline in the far distance is the Brazos uplift. **0.6**

16.7 Milepost 25. **0.9**

17.6 Road on left goes to the community of Buena Vista. **1.0**

18.6 Road to community of El Rito on right. **0.1**

18.7 Milepost 27. The slopes south of El Rito consist of Proterozoic biotite-muscovite schist, and much of the rock to the north along the base of the mountain front is mapped as a mixed unit of felsic gneiss and amphibolite (Lipman and Reed, 1989).

A cross section through the interior of the Questa caldera is exposed to the east. The high areas consist of caldera-floor stratigraphy resurgently uplifted within the core of the caldera. The highest peaks, such as Virsylvia Peak (12,594 ft) at 3:00, Venado Peak (12,734 ft), Cabresto Peak (12,444 ft) at 3:30 and Pinabete Peak (11,946 ft) at 4:00, are mostly capped by precaldera quartz latitic and andesitic lava flows, locally underlain by volcaniclastic sediments, resting on Precambrian rocks in the middle timbered slopes. The Precambrian sequence inside the caldera contains complexly folded sillimanite-grade quartzite and pelitic schist. The wooded slopes of Pinabete Peak are underlain by quartzite that forms white outcrops and talus slopes. Just visible on the upper southwestern slopes of Venado Peak are outcrops of the resurgent Virgin Canyon pluton (24.65 ± 0.1 Ma), which also crops out on the northeastern ridge of Cabresto Peak. Peralkaline porphyry that crops out along the northern margins of the Virgin Canyon and Canada Pinabete plutons is interpreted to represent unerupted portions of the Amalia Tuff magma.

The large cliffs in the range-front canyon at 3:00 are formed by granite of the Rito del Medio pluton (25.5 ± 0.3 Ma according to Czamanske et al., this guidebook), also interpreted to represent resurgent magma within the caldera. The next canyon to the north is Jaracito Canyon, which marks the approximate position of the northern structural boundary of the caldera where it is intersected by the mountain front. At this lower level of exposure, the north caldera margin is marked by a large ring dike of peralkaline granite porphyry, similar to the peralkaline porphyry found at the northern margins of the Virgin Canyon and Canada Pinabete plutons. Light-colored rocks on the ridge just north of Jaracito Canyon are outcrops of this ring dike. The trend of the Precambrian units is about north-south and dips are steep, indicating that vertical slip along the north caldera wall is not large.

In the large canyon at 2:00 is West Latir Creek. Cliffs on the mountain front between Latir Creek and Jaracito Canyon are thick Precambrian pegmatites intruding gneissic granodiorite. Although the caldera wall swings into the upper part of West Latir Creek from Jaracito Canyon, both sides of lower West Latir Creek Canyon are Precambrian rocks outside the caldera.

To the southwest, coming into view behind Guadalupe Mountain, are three major volcanoes of the Taos Plateau volcanic field. Clockwise from Guadalupe Mountain these are Cerro Chiflo, a 10.3 Ma quartz latite lava dome whose slightly jagged summit is just visible; Cerro Montoso, whose gentle slopes are Pliocene olivine andesite; and Cerro de la Olla, a 2.3 Ma andesitic cone. Silbrico operated the Uniperl perlite mine until 1987 near Brushy Mountain north of Cerro Montoso. This deposit (22 Ma) is older than those at No Agua (see minipaper by J. M. Barker) and consists of vitrophyric perlite breccia. Additional perlite reserves are located 500 m (1640 ft) south of the mine at the northern foot of Cerro Montoso (Weber and Austin, 1982). At 9:30, in the distance, the large rhyodacitic volcano is 3.2 Ma San Antonio Mountain

(K-Ar ages from Lipman and Mehnert, 1975). **1.0**

19.7 Milepost 28. **1.95**

21.65 Sunshine Valley turnoff on left. Low, irregular volcano between Cerro del Aire and San Antonio Mountain are the No Agua rhyolite domes (approximately 3.9–4.8 Ma). On the north side in morning light, the obvious quarry scars are perlite mines. At 9:00, in the foreground, is a sand and gravel quarry. **0.05**

ECONOMIC GEOLOGY OF NO AGUA PEAKS

James M. Barker

New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico 87801

No Agua Peaks consists of four erosional remnants of two endogenous rhyolitic domes and associated coulees. The domes, which now are exposed over an area of 6.5 km² (4 mi²) represent at least two extrusive episodes at approximately 4.2 Ma (I. T. Friedman, oral commun., *in* Whitson, 1982). These rocks were included in the middle Tertiary Cordito Member of the Los Pinos Formation by Butler (1946). Schilling (1960) inferred a Pliocene-Pleistocene age for the extrusives. Lipman et al. (1970) reported a Pliocene age based on a fission-track age of 4.8 Ma on obsidian and a potassium-argon age of 3.9 Ma (Pliocene) on obsidian (Lipman and Mehnert, 1979). Preservation of volcanic glass is rare over geologic time so nearly all perlite deposits are Tertiary in age (less than 60 Ma) and most are less than 10 Ma.

The four hills of the No Agua perlite domes overlie basalt flows and interflow sands and gravels of the Jarita Basalt Member (Weber and Austin, 1982). A drill hole near No Agua penetrated about 24 m (80 ft) of gravel, 114 m (380 ft) of perlite, 54 m (180 ft) of basalt and 138 m (460 ft) of the Esquibel Member of the Los Pinos Formation, before penetrating crystalline, quartzitic basement (Naert, 1974).

Differential cooling in the domes and later alteration caused textural and compositional layering ranging from an inner dense felsite to an outer perlitic glass (Whitson, 1982). This layering is concentric and wraps underneath the dome at its margins yielding a repetition and inversion of the various layers at the dome margins (line A-A′ on Fig. 1.9).

The perlite domes at No Agua contain a felsic core, interior and exterior glass envelopes and an exterior chill margin. The felsite core is composed of dense, hypocrystalline, massively banded, speculitic felsite. Contacts with surrounding glass are sharp with some interfingering. The inner glass envelope is massive except for vesiculation and flow banding at the margin. It contains partially divitrified classical perlite that is microscopically similar to that of the outer envelope. The outer glass envelope contains vesicular perlite and most of the obsidian (marekanite). Spalling at the extreme margin produces crumble breccia (Fig. 1.9). The low hills to the west (Fig. 1.10) are rhyolitic flows probably from volcanic activity at West Peak (Whitson, 1982).

Perlite as mined at No Agua Peaks is a volcanic glass in which postdepositional hydration of the glass has raised the combined water content from an initial value of 0.20% to the 2–2.9% now present (Whitson, 1982). The general types of commercial perlite are granular

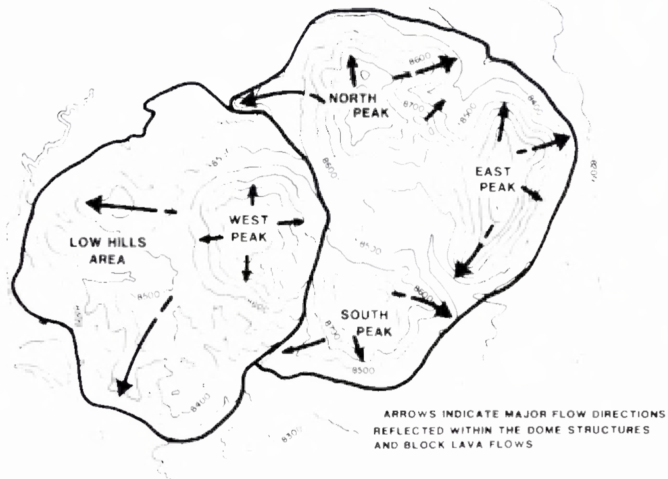


FIGURE 1.10. Topographic features of No Agua Peaks showing at least two separate episodes of volcanism. Area to west is enriched in rubidium and depleted in strontium and barium relative to eastern area (Whitson, 1982). Scale 1 inch = approx. 2.75 miles.

(pumiceous) and classical (onionskin). Granular perlite tends to be relatively uniform in texture and chemical composition over large areas, whereas classical perlite is limited in extent and is more variable in texture and chemistry. Grefco mines pumiceous or "granular" perlite from the West Peak, whereas Manville mines it from the North Peak area (Fig. 1.10). The Grefco deposit and the No Agua domes together are the largest perlite reserves in the world.

Perlite can be expanded, by rapid heating, to a white, very porous, lightweight rock foam with many commercial applications (Barker et al., 1987). Expansion is done commercially by injection of crushed and sized perlite into gas- or oil-fired furnaces at temperatures of 600–800°C (1100–1500°F). The bulk density of expanded perlite ranges from about 1.5 to 11 lbs/ft³ (24–176 kg/m³) compared to an initial bulk density of 139–150 lbs/ft³ (2227–2403 kg/m³). When crude perlite is heated to its softening point it expands or "pops" because combined water flashes into steam. The expanded particle is very light and cools rapidly as it exits the furnace. Expanded perlite is a lightweight, white to light gray, cellular, glassy aggregate that is chemically inert in most environments, has low heat and sound transmission and large surface area. Because of the bulkiness of the expanded product, perlite is commonly shipped sized but unexpanded and is later expanded near where it is to be used. As a result, New Mexico has no major expansion plants within its borders, although a small plant does operate intermittently in Albuquerque and a large plant operates just across the state line near Antonito, Colorado. About one-half to two-thirds of perlite is consumed in construction, predominantly as aggregate in plaster, concrete, insulating board and in thermal insulation. Other major end uses are as a filtration medium and as cryogenic-tank insulation. Lesser amounts are used as soil conditioner, soil substitute, packing material, extender or filler in plastics and as a carrier for chemicals and insecticides.

New Mexico is the leading perlite-producing state, accounting for 87% of domestic production in 1988. The value of New Mexico perlite production was $14.3 million on an output of 458,000 st (415,000 mt) (Anonymous, 1989). Four mines (Fig. 1.11) currently operate in New Mexico: Socorro (Grefco), Grants (U.S. Gypsum) and two at No Agua Peaks (Grefco and Manville).

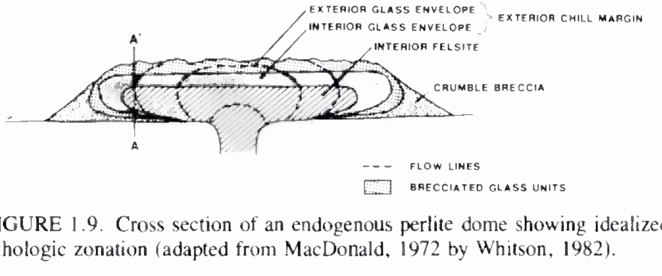


FIGURE 1.9. Cross section of an endogenous perlite dome showing idealized lithologic zonation (adapted from MacDonald, 1972 by Whitson, 1982).

21.7 Milepost 30. In the far distance at 12:00 are the northern Sangre de Cristo Mountains in Colorado (Fig. 1.12), and at 12:30 are the peaks of Sierra Blanca (13,120 ft). At 11:30, in the distance, the irregular, low San Luis

Mine Name	Mine Operator	Capacity (TPY)	County	Startup Date	Deposit Age
El Grande	Grefco	350,000	Taos	1957	3.9-4.8 Ma
No Agua	Manville	350,000	Taos	1951	3.9-4.8 Ma
US Gypsum	US Gypsum	40,000	Cibola	1953	3.3 Ma
Socorro	Grefco	150,000	Socorro	1949	7.4 Ma

FIGURE 1.11. The four active perlite mines in New Mexico for 1989. Note that tpy = tons per year, and that actual production may be less than capacity.

Hills are composed of eroded, faulted, late Oligocene and Miocene lava flows exposed in a horst within the rift. This horst extends southward just west of the position of the present river, almost as far south as Taos, as marked by local erosional exposures of Miocene rocks (Lipman and Mehnert, 1979), and extends all the way to the Picuris Mountains according to gravity data. **2.2**

23.9 Sign on the right for the Urraca Wildlife Area. **0.9**

24.8 Milepost 33. At about 200–300 m to the right of the road is the southernmost surface expression of the N-trending Quaternary fault scarp that is visible between here and Costilla. **1.2**

26.0 **Turn right** at the entrance to the Urraca Wildlife Area and headquarters of the Urraca Ranch. Stop 2 is at the Urraca Ranch, visible ahead at the base of the mountains. Cross cattleguard, pass gate and drive eastward on dirt road. **CLOSE GATE** AFTER PASSAGE. **NO DRIVING OFF ESTABLISHED ROADS. 0.1**

26.1 San Pedro Mesa at 9:00 is capped by 4.3 Ma Servilleta Basalt, offset by about 550 m (1800 ft) along the range-bounding normal fault. The Cedro Canyon Fault scarp extends across the piedmont adjacent to road on right (Fig. 1.13). The most recent movement on this fault appears to have been in latest Pleistocene times (Menges, this guidebook). The fault scarp ranges from 2–14 m in height in mid to upper Pleistocene sediments. At 12:30, an 8–9 m high composite scarp is seen to displace the apex of the Jarosa Canyon fan, the grassy area above and to the right of the ranch house.

In the mountains at 12:00, all rocks up to the skyline are Precambrian rocks outside the caldera, chiefly granite, fine-grained felsic gneiss and amphibolite. Precambrian quartzite caps the ridge at 11:00. Low orange-brown knobs along the mountain front are Precambrian pegmatite. The volcanic sequence is tilted to the east and rests depositionally on Precambrian rocks on the eastern slopes, just out of sight.

In the mountain front north of the Urraca Ranch is a thin, elongate outcrop of the Proterozoic quartz monzonite of Costilla Creek that has intruded mixed felsic gneiss and amphibolite in a complex fashion. **0.7**

FIGURE 1.12. View to the north from mile 21.7. Taos Range to the right. Snow-capped northern Sangre de Cristo Mountains visible in the far center distance. The dark, low, irregular hills on the left skyline are eroded, faulted late Oligocene and Miocene lava flows exposed in a horst within the rift. Photo by C. K. Mawer.

FIGURE 1.13. Fault scarp along the eastern flank of the Rio Grande rift, at mile 30.3, view east. The latest movement along this fault was probably latest Pleistocene (10,000–25,000 yrs ago; Machette and Personius, 1983). Cedro Canyon, in the distance, contains Tertiary volcanic rocks down low and Proterozoic metamorphic rocks higher up. The white cliff on the canyon wall is potassium metasomatized, welded Amalia Tuff. Photo by C. K. Mawer.

26.8 Road crosses small arroyo. At 9:00–10:00 a series of erosional benches is developed about 100 m above the basal junction of the mountain front, at the apices of the main set of basal triangular fault facets. These slopes are composed of resistant Proterozoic gneisses, and contain broad, thick colluvial wedges and debris fans at their bases. **1.0**

27.8 **Pull over and park** in field to either side of road below ranch house. Obey signs, and remember that this is someone's home.

STOP 2. Assemble at junction of road leading south of house. **DO NOT DRIVE ON THIS ROAD.** Stop 2 will examine landforms associated with late Quaternary tectonic activity on the range-bounding fault system. Features include: (1) morphology and stratigraphy of the large, composite fault scarp at the fan head, including an arroyo exposure of the basal colluvial wedge underlying the scarp's wash slope; (2) exposures of a composite soil profile developed on the mid- to late-Pleistocene fan surface above the fault scarp; and (3) a discussion of the general morphology and slope stratigraphy of adjacent bedrock facets, with respect to the relative roles of tectonic activity versus bedrock texture and composition in influencing slope form and processes of development (see Menges, this guidebook, for discussion and figures). After the overview and discussion, we will walk up the dirt road leading south from the ranch house, along the base of the fault scarp at the fan head. We then continue up the road to the upper fan surface, to the soil exposure in the wall of a trash pit. After this stop, return to vehicles, **turn around,** and **retrace route to NM-522. 1.8**

29.6 **Junction** with NM-522. **Turn right** and continue drive northward. PLEASE REMEMBER TO **CLOSE GATE. 0.4**

30.0 Low mesa now visible straight ahead is San Pedro Mesa (also known as Wildhorse Mesa), capped by Servilleta Basalt, consisting of flows of olivine tholeiite which are dated at 4.3 Ma. This is the same lava sequence that is exposed in the Rio Grande gorge, and cross-section interpretations indicate about 1800 ft of subsequent uplift along the mountain-front fault system. Coming into view in front of, and just to the right of, San Pedro Mesa is a beheaded alluvial fan coming out of Cedro Canyon at 2:00. This fan is cut by a late Pleistocene fault scarp. **0.3**

30.3 Low scarp about 200 m east is fault scarp along which the most recent episode of movement was probably latest Pleistocene (10,000–25,000 yrs ago: Machette and Personius, 1983). **1.4**

31.7 The canyon at 3:00 is Cedro Canyon. The lower parts of Cedro Canyon contain a well-exposed section of Tertiary volcanic rocks of the Latir volcanic field, whereas the upper parts expose Proterozoic metamorphic rocks. On the north side of the canyon, the big cliff is welded Amalia Tuff that has been hydrothermally altered by intense potassium metasomatism. Although rocks look fresh in hand sample, some specimens are devoid of Na_2O, and their K_2O content has doubled.

The Amalia Tuff is underlain by precaldera basaltic andesite and andesitic sedimentary rocks, and overlain by tilted, lower Santa Fe Group volcaniclastic sediments that were eroded from the Latir volcanic field. These sediments are in turn overlain unconformably by poorly consolidated gravels of the upper part of the Santa Fe Group. The sequence is capped by Pliocene Servilleta Basalt.

South of Cedro Canyon, the slopes contain andesitic lava flows that interfinger with Precambrian rocks and the thin welded tuff that caps the ridge crest. Light-colored rocks in hills at head of canyon are Proterozoic quartzite that overlies a layered high-grade metamorphic complex. The contact separating quartzite from gneiss is a major Proterozoic ductile shear zone (Grambling et al., 1989). The quartzite preserves peak metamorphic conditions near 520°C, 4 kb, whereas the underlying gneisses preserve granulite-facies mineral assemblages (700–800°C, 8–10 kb) locally retrograded to the amphibolite facies. The same ductile shear zone crops out in scattered exposures south of Cedro Canyon, and is interpreted to crop out 50 km to the southeast in the Cimarron Mountains (see Grambling and Dallmeyer, this guidebook). Preliminary ^{40}Ar/^{39}Ar thermochronology suggests that the shear zone was active at a time near 1400 Ma.

In the farthest distance to the northwest, the low slopes are the southern flanks of the San Juan volcanic field in Colorado, mainly outflow volcanic rocks from the Platoro caldera (Lipman, 1975). The general area of this caldera is marked on days of good visibility by high, snow-covered peaks on the skyline. **3.4**

THE SAN LUIS (EL PLOMO) GOLD DEPOSIT, COSTILLA COUNTY, COLORADO

David M. Jones[1] and Robert G. Benson[2]

[1]Battle Mountain Exploration Company, 2700 E. Executive Drive, Suite 150, Tucson, Arizona 85706; [2]Battle Mountain Gold Company, P.O. Box 310, San Luis, Colorado 81152

The San Luis gold deposit is located in the western foothills of the Sangre de Cristo Mountains, roughly 9 km northeast of the town of San Luis, Costilla County, Colorado (Fig. 1.14). Historically known as the El Plomo or Rito Seco district, the property has undergone sporadic exploration activity since 1890. During 1987–1988 Battle Mountain Exploration Company drilled out the current deposit reserves which consist of 12,149,000 tons of 0.040-ounce-per-ton gold ore. Initial production is scheduled for the fall of 1990. A more detailed account of the deposit geology may be found in Benson and Jones (in press).

The San Luis deposit lies at about 2800 m elevation in the western foothills of the Sangre de Cristo Mountains. Basement lithologies consist of Proterozoic gneisses and weakly foliated granites (Fig. 1.14). Poorly sorted, high-energy sediments of the Tertiary Santa Fe Group partially overlie the deposit and mark the eastern edge of the Neogene San Luis depositional basin.

Gold mineralization at San Luis occurs within silicified and quartz-sericite-pyrite altered rocks along a low-angle fault zone in Proterozoic gneiss. Age dates on alteration and lithologic relations across the fault zone indicate that faulting and mineralization are mid-Tertiary in age.

Precambrian quartz-feldspar-biotite gneiss (1800–1700 Ma; Tweto, 1979) and gneissic granite (1400 Ma; Tweto, 1979) are the dominant basement lithologies at the mine. Biotite gneiss lies in the footwall of, and is the dominant lithology within, the low-angle fault zone (Fig. 1.14). Gneissic granite, locally pegmatitic, is the dominant hanging-wall lithology. Primary metamorphic foliations in both units are obscured by cataclastic deformation related to movement along the low-angle fault zone.

Tertiary lithologies include sedimentary rocks of the Santa Fe Group and volumetrically minor rhyolite and andesite dikes. Santa Fe Group lies in depositional contact with both gneissic granite and the top of

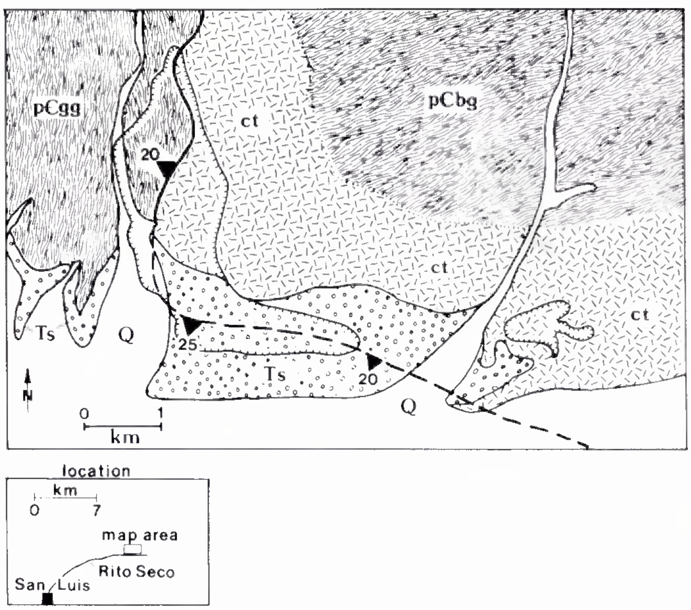


FIGURE 1.14. Location and simplified geologic map of the San Luis deposit. p€bg = Proterozoic biotite gneiss. p€gg = Proterozoic gneissic granite. Ts = Santa Fe Formation. Q = Quaternary alluvium and ferricrete. ct = breccia unit and cataclasite unit, undivided. Dark line with triangles = trace of the low-angle fault as defined by fault clay unit. Finely hachured line = surface projection of >0.0169 ounces per ton gold mineralization in the East and West ore zones.

the low-angle fault zone. Rhyolite dikes are <1–10 m thick, weakly porphyritic and strike roughly north-northwest across the mine area. Sericite concentrates from two altered rhyolite dikes yielded age determinations of 24.0 ± 1.0 and 24.1 ± 1.1 Ma (Krueger Geochron Laboratories). Andesite dikes appear to post-date mineralization and are probably related to flows interbedded with the Santa Fe Group.

The primary structural feature of the San Luis deposit is a low-angle normal fault zone which separates footwall biotite gneiss from hanging-wall gneissic granite (Fig. 1.14). The strike of the fault zone varies from west-northwest in the southern mine area to north in the northern mine area. The fault dips southerly to westerly at roughly 15–25°. Within the fault zone three structural units are recognized. The uppermost is a 2–3 m thick fault clay unit which is interpreted as the principal fault dislocation surface. Except where eroded, the clay unit separates the hanging-wall gneissic granite and Santa Fe Group from footwall biotite gneiss. To date, the clay has not been found to be mineralized or altered.

Immediately beneath the clay unit is a breccia unit which ranges from 0–40 m in thickness, averaging 15–20 m; breccia thickness is generally zero only where it has been eroded away. The breccia consists of subangular to rounded clasts of quartz and feldspar (<1 mm to 10s mm) set in a fine-grained rock flour matrix. Breccia clast size increases with increasing depth from the overlying clay. The breccia is the principal host to gold ore.

Underlying, and gradational into, the breccia unit is a cataclasite unit. The term cataclasite is used here, informally, to describe a rock in which slippage along multiple fractures has caused little rotation or disaggregation of adjacent rock fragments. The gradational nature of the cataclasite with overlying breccia and underling gneiss leads to a somewhat uncertain thickness estimate of 10–40 m for this unit. Cataclasite hosts a minor volume (<10%) of gold ore. Breccia and cataclasite are shown as a single unit in Figure 1.14.

Four alteration assemblages are recognized at San Luis: (1) quartz-specularite veining; (2) silicification; (3) quartz-sericite-pyrite veining and replacement; and (4) chlorite-carbonate veining. Quartz-specularite veins and specularite fracture coatings are dominantly of pre-gold mineralization age and formed throughout the fault zone under oxidizing conditions during cataclasis. Silicification consists of silica veining and replacement in the fault breccia unit. Silicification is most intense at the breccia/clay unit contact and typically is accompanied by finely disseminated pyrite. Quartz-sericite-pyrite alteration is gradational with silicification but is distinct in containing less silica and more abundant sericite and pyrite. In places, breccia is nearly completely replaced with pale green sericite. Pyrite contents range from ~1–>10 volume percent. Silicified/quartz-sericite-pyrite altered areas typically contain trace to minor amounts of the accessory minerals chalcopyrite, molybdenite and fluorite. Silicification and quartz-sericite-pyrite alteration generally overprint quartz-specularite veining. Chlorite-carbonate alteration is ubiquitous and includes minor associated magnetite and clay. Chlorite development appears to be both early and late, while carbonate veining generally crosscuts all other alteration types.

The San Luis gold deposit contains 12,149,000 tons of 0.040 ounces per ton gold ore in two minable zones, the East and West ore zones (Fig. 1.14). The East ore zone contains 1,408,000 tons of 0.049 ounces per ton ore, and the West ore zone contains 10,741,000 tons of 0.039 ounces per ton ore. The breccia hosts greater than 90 volume percent of the ore with the remainder hosted by the cataclasite. Gold is concentrated in silicified and quartz-sericite-pyrite altered tabular bodies which are generally conformable to the morphology of the enclosing fault zone. Ore microscopy studies indicate that gold occurs within and along fractures in pyrite and as discrete particles (all ~20 microns average size). Despite these general relations, gold grades do not correlate directly with either silicification or overall pyrite content. Barren alteration and ore-grade mineralization are locally indistinguishable on the basis of silica and pyrite content.

Gold mineralization and alteration at San Luis overprint cataclastic textures of a pre-existing low-angle normal fault zone. Gold mineralization is inferred to be of the same age as the sericite alteration in the rhyolite dikes (i.e., ~24 Ma). The presence of rhyolite dikes, intense sericite alteration and the accessory minerals chalcopyrite, molybdenite and fluorite, is indicative of a mesothermal mineralizing event. We infer this event to be of at least indirect magmatic origin. To date, however, no direct correlation has been found between mineralization and rhyolite diking.

Several lines of field evidence indicate the fault zone at San Luis is mid-Tertiary in age and extensional in nature. Tertiary sediments and andesite flows, hanging-wall to the fault zone, have been rotated gently to the northeast, indicating normal fault movement. Evidence for normal displacement is also found in directional slickenside and drag features in footwall rocks. Finally, Santa Fe Group lies in depositional contact with the clay unit. If the fault zone was an eroded Laramide thrust structure, the clay unit would have been eroded prior to Santa Fe deposition. Instead, we believe that unroofing of the clay by normal faulting was synchronous with development of Santa Fe Group depositional basins; the clay was preserved through inundation by basin sediments. Similar lithologic relations in other portions of the San Luis basin reveal that the fault zone at San Luis was part of a regional extensional event, synchronous with the Neogene uplift of the Sangre de Cristo Mountains. Although the major period of faulting clearly predates gold mineralization, there is evidence for minor syn- and post-mineralization movement as well. It thus appears that gold deposition was at least in part syn-kinematic. On the basis of its structural setting and the timing of mineralization with respect to faulting, the San Luis deposit is a Colorado analogue of the "detachment"-fault gold deposits of Arizona, California and Nevada.

Our current understanding of the San Luis deposit is, in large part, based upon work conducted in 1987–88 by F. Deakin, V. DeRuyter, S. Johnson, W. Lehman and J. Suthard. However, we accept responsibility for the ideas presented in this paper. We particularly wish to thank Battle Mountain Gold Company and Battle Mountain Exploration Company for their support in this endeavor.

35.1 Entering village of **Costilla.** At 3:00 is Costilla Canyon. In the distance, at 2:00–3:00, the Costilla Mountains are composed entirely of Precambrian rocks. The mesas on both sides of the canyon mouth are capped by Servilleta Basalt which is underlain by Santa Fe Group sediments. **0.1**

35.2 **Junction** of NM-522 and NM-196. **Turn right** onto NM-196 to Amalia. Costilla, which lies 2 mi south of the Colorado border, is Spanish for "rib." The town is named for Costilla Creek, which contains a rib-shaped curve. **0.15**

35.35 Unusual two-story adobe building on left was built in the early 1900's as a school (Fig. 1.15). Vigas are ex-

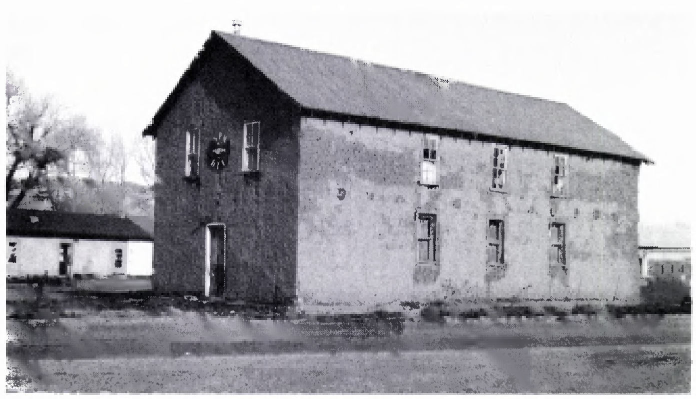


FIGURE 1.15. Two-story adobe building in downtown Costilla was used as a schoolhouse when built in the early 1900's. The second story and pitched roof were probably late additions. More recently, the building has served as a union and dance hall. Photo by C. K. Mawer.

posed at top of first floor, but do not extend beyond the face of the wall. The second story and pitched roof were probably late additions. It was later used as a union dancehall. **0.85**

36.2 Notice unique flat-topped horno (outdoor adobe oven) on right. Although the Spanish introduced this type of beehive oven to the New World, it is mainly the Pueblo Indians who continue to bake in them. **0.9**

37.1 Roadcut exposes Santa Fe Group sediments on right. From here to about mile 42 small patches of Santa Fe Group sediments are visible beneath the basalt in roadcuts. Sediments are mainly fine-grained, reddish mudstone with some well defined calcrete horizons. The Amalia Tuff is sandwiched between underlying precaldera andesitic mudflows and overlying rhyolitic volcaniclastic sediments. **0.2**

37.3 Bridge crosses Costilla Creek. Enter Costilla valley with landslide deposits of Santa Fe Group sedimentary rocks and Servilleta Basalt on both sides of road. **0.3**

37.6 Big Costilla Mountain (12,740 ft) straight ahead is composed chiefly of Precambrian granite. **0.2**

37.8 Reddish-gray mudstone, sandstone and siltstone of axial facies of the Santa Fe Group are exposed in roadcut on left. Axial facies consists of fluvial, floodplain and pond deposits that occupied the valley floor of the Amalia basin, a northeast-tilted half-graben of Miocene age. **0.6**

38.4 End of landslide area. Mesas capped by Servilleta Basalt are underlain by poorly exposed andesitic lavas and interlayered volcaniclastic sediments below the Amalia Tuff that comes down to road level at the bend in road ahead. The slopes across valley to southwest are also Amalia Tuff. **0.1**

38.5 Axial-facies mudstone, sandstone, siltstone and minor conglomerate of Santa Fe Group exposed on the left. **0.5**

39.0 On left is roadcut in greenish basaltic flow interbedded in axial facies of the Santa Fe Group. Fault has truncated east end of outcrop (Fig. 1.16). Whole-rock K/Ar ages for these flows in the Costilla-Amalia area are 15–16 Ma (Lipman and Reed, 1989). **0.3**

39.3 Andesitic sediments exposed in roadcut on left. **0.3**

39.6 On the left is a poorly exposed dark outcrop of basanitic basalt dated by K-Ar whole-rock at about 16 Ma (Lipman and Reed, 1984) that is interlayered with the volcaniclastic sediments. Straight ahead, high hills on left are Proterozoic rocks. The rhyolite of Gonzales Ranch abuts against the bounding fault scarp that trends up the Costilla Valley. **0.2**

FIGURE 1.16. Outcrop in Santa Fe Group at mile 39.0. Roundish-weathering, 2-m-thick, greenish basaltic flow (15–16 Ma) is layered within gently east-dipping Santa Fe Group axial facies. A high-angle fault has truncated the flow on the right side of photo. Photo by C. K. Mawer.

39.8 Andesitic sediments under Amalia Tuff in roadcuts on left. **0.2**

40.0 Large, blocky Amalia Tuff outcrops on left. The Amalia Tuff underlies the Santa Fe Group throughout the Amalia basin (see fig. 1 in paper by Cather, this guidebook). **0.1**

40.1 To the left are axial facies sandstones and mudstones intertongued with hanging-wall piedmont conglomerates. Strata dip 24° to 060°, contain abundant volcanic clasts, including basalt, and are overlain by the Servilleta Basalt. Paleocurrent data indicate northwest transport here.

The terraced Costilla Creek valley lies to the right. The view southeast, upriver, is into complexly faulted Precambrian/Tertiary terrain. The low hills at 3:00 are Amalia Tuff with some volcaniclastic conglomerates. The high hills at 3:00 are Ortega Formation-equivalent quartzites overlying granulite-facies sillimanite-K-feldspar gneisses. Straight ahead are Santa Fe Group sedimentary units in the low mesas and Precambrian rocks in the dark hills from 12:30–1:30. The high peaks at 12:00 on the skyline are part of the Culebra Range, just north of Big Costilla Peak. **0.4**

40.5 Mudstones and claystones of axial facies of the Santa Fe Group are exposed in roadcuts. **0.2**

40.7 Junction with dirt roads. Amalia Lumber Co. Inc. sign on left. Entering the village of Amalia. Village cemetery is to the left. Heavily timbered north slopes of mountains on right are underlain by complexly faulted volcanic sequence north of the Questa caldera, and locally by prevolcanic Tertiary sediments and Precambrian rocks. **0.3**

41.0 Welcome to downtown Amalia. Amalia is a Spanish feminine personal name. **0.2**

41.2 The massive peak at 11:00 is Big Costilla Peak (12,740 ft). Santa Fe Group crops out in the roadcuts ahead, along with some Tertiary andesites. The mesa at 8:00–9:00 is capped by Servilleta Basalt flows. The high mountains at 3:00 are Proterozoic felsic gneisses. The lower hills between the road and along the valley at 2:30–3:00 consist of interbedded Tertiary volcanic rocks and Santa Fe Group sediments. **0.1**

41.3 Peak straight ahead above Amalia is vent region of Miocene rhyolite of Gonzales Ranch (Lipman and Reed, 1989). This lava dome is a light-gray, low-silica rhyolite with 10–20% small phenocrysts (plagioclase, sanidine, biotite, hornblende) that erupted from a vent near a buried fault. The vent area contains chaotic breccias with sparse fragments of Proterozoic rock. The 10–12 Ma emplacement of the rhyolite of Gonzales Ranch (K-Ar age from Lipman and Reed, 1989) coincided with eruptions in the Taos plateau volcanic field. **1.5**

42.8 Fire Department on left. **0.1**

42.9 Road crosses over Rio Costilla. **0.1**

43.0 At 9:00 is a good view of the chaotic rhyolite breccia. **0.2**

43.2 On right are more exposures of basanitic basalt interlayered with volcaniclastic sediments. **0.3**

43.5 Sign to Rio Costilla Ski Area. Ridge on right is Amalia Tuff, as are low cliffs across river at 11:00. The road generally goes obliquely down-section through here. Hills ahead on right are composed of andesitic flows. The major fault that bounds the volcanic block lies at the base of the Costilla Mountains to the southeast. **0.1**

43.6 Quality of road surface takes a turn for the worse. **0.3**

43.9 Now entering an area of poorly exposed, complexly layered Tertiary volcanic units on the right. Bold cliffs at 9:00 are composed of Amalia Tuff that is overlain sequentially by: (1) footwall-piedmont conglomerate; (2) axial facies sands with interbedded 15–16 Ma basalt flows; and (3) more footwall-piedmont conglomerates. The presence of agglutinated spatter and scoria (Lipman and Reed, 1989) indicates proximity to a basaltic vent. Average paleoflow direction for the footwall-piedmont facies is west-southwest in this area.

The low ridge behind the outcrop of Amalia Tuff is a sequence of Tertiary volcanic rocks that range from silicic to alkalic basalt and basaltic andesite in composition. There are four of these flows, about 20 m thick, along Costilla Creek which intertongue with conglomeratic facies of the Santa Fe Group on the flanks of a small shield volcano. Intertonguing sequences are as much as 150 m thick in the upper Costilla Valley where eight to ten flows are present. A whole-rock K/Ar isotopic age of 15–16 Ma makes them mid-Miocene (Lipman and Reed, 1989). At about 10:30 in the high distance is Big Costilla Peak. **0.6**

44.5 West side of the mouth of Cordova Canyon along which a northeast-trending fault has dropped Tertiary volcanic rocks to the west down against Precambrian rocks to the east. **0.2**

44.7 Volcaniclastic sandstone interlayered with andesite, dips approximately 40°NE. **0.2**

44.9 Exposures of propylitically altered olivine-augite andesite are typical of this area. **0.3**

45.2 The two pointed hills ahead consist of welded tuff on the lower hill to the west and overlying andesite and basaltic andesite on the high point to the east. **0.2**

45.4 Dirt road, cattleguard and sign for Costilla Park, owned and managed by the Rio Costilla Cooperative Livestock Association. Rocks west of the road, up hill from the colluvium and landslide deposits that line the road, are basaltic lavas. East of the road and underlying it are conglomeratic facies of the Santa Fe Group. Ahead, road passes by a large landslide deposit on the right. **0.2**

45.6 Crossing a major down-to-the-west fault that separates Tertiary volcanic rocks on the west from Precambrian rocks on the east. Outcrops across the creek to the north consist of Proterozoic felsic and mafic gneiss and Tertiary andesite, rhyolitic ash-flow tuff, prevolcanic sedimentary rocks, volcaniclastic breccias, and Amalia Tuff all overlain by Santa Fe Group sediments. **0.3**

45.9 Passing around the end of a landslide. **0.2**

46.1 For the next mile, the road borders mixed Proterozoic felsic schist and mafic gneiss. **1.4**

47.5 Crossing the Rio Costilla and the trace of the main bounding fault of the Amalia half-graben. Proterozoic gneiss and monzonite of the footwall block are exposed in the canyon ahead. **0.2**

47.7 At 12:00, cliffs are composed of Precambrian felsic gneiss. **0.3**

48.0 Passing over cattleguard and entering the Costilla box. Sign reads "Rio Costilla public fishing area." Now in Proterozoic felsic gneiss. **0.3**

48.3 Valley on the left where the small creek joins the Rio Costilla exposes a tectonized contact between felsic gneiss and the quartz monzonite of Costilla Creek. Stream sediments from this drainage yielded uranium values of more than 200 ppm, the highest values sampled during the National Uranium Resource Evaluation study of the Raton 2° sheet (Morgan and Broxton, 1978). One follow-up study suggested that the uranium is contained in shear zones in the granitic rocks (C. S. Goodknight, unpubl., 1983). See accompanying minipaper by McLemore for additional discussion.

The quartz monzonite of Costilla Creek is a well foliated, fine- to medium-grained quartz monzonite gneiss interlayered with medium- to coarse-grained augen gneiss with 1–2 cm potassium feldspar augen. Although these rock types intergrade complexly, locally quartz monzonite gneiss appears to cut augen gneiss. Both are crosscut by slightly discordant boundinaged pegmatites composed of potassium feldspar, plagioclase, quartz and minor biotite.

Foliation trends around N70°E and dips about 35°NW; an extension lineation, defined by elongate augen and biotite streaks, plunges 10° to N50°E. A coarse phase of the augen gneiss from along the creek just ahead (NE corner of Latir Peaks 7.5′ quadrangle) yielded a U-Pb zircon age of 1644 Ma (Bowring et al., 1984). **1.7**

URANIUM IN THE QUARTZ MONZONITE OF COSTILLA CREEK, TAOS COUNTY, NEW MEXICO

Virginia T. McLemore

New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico 87801

Uranium minerals were first reported in pegmatites intruding Proterozoic rocks in the vicinity of Costilla Creek, southeast of Amalia, New Mexico in the early 1950's (Collins, 1954, 1956). Since then several studies have described the uranium mineralization and speculated on the mineral resource potential (Morgan and Broxton, 1978; Reid et al., 1980; Goodknight and Dexter, 1983; Zelenka, 1984), and exploration was carried out in the 1970's and early 1980's by Phillips Petroleum Company and Duval Corporation. To date, no uranium has been produced from this area. This report summarizes the results of studies and a field reconnaissance by the author, and speculates on the mineral resource potential in terms of today's economic market.

Mineralized zones containing anomalously high concentrations of uranium, thorium and rare earth elements occur in Proterozoic pegmatites and quartz monzonite in this area. The quartz monzonite has been referred to as the Costilla massif or Costilla granite by previous workers, but Lipman and Reed (1989) classified the rock as a quartz monzonite based on mineralogic composition. It contains quartz, plagioclase, microcline, biotite, hornblende, and accessory sphene, allanite and zircon (Lipman and Reed, 1989). Lipman and Reed (1989) do not provide modal compositions. Using the geochemical classification of de la Roche et al. (1980) and chemical analyses by Zelenka (1984), the plutonic rock is a granite. Additional geochemical and mineralogic studies are needed to resolve this apparent discrepancy, but for the purposes of this report, the rock will be called the quartz monzonite of

Costilla Creek. Chemically, the granitic rock is similar to high-K and high-Si granites of Proterozoic age from throughout New Mexico (Fig. 1.17; Condie, 1978; Zelenka, 1984). A U-Pb zircon upper-intercept concordia age of 1644 Ma is interpreted as the age of emplacement (Lipman and Reed, 1989). Pegmatites intrude the quartz monzonite, and both intrude a complex Proterozoic terrain of metamorphic sedimentary and igneous rocks (McKinlay, 1956; Lipman and Reed, 1989). The Proterozoic rocks are overlain by Tertiary volcanic and volcaniclastic rocks related to the Questa magmatic system and the Rio Grande rift (Lipman and Reed, 1989). Recent uplift and subsequent erosion of the Tertiary rocks have exposed the Proterozoic rocks and their uranium mineralization.

The quartz monzonite of Costilla Creek contains anomalously high concentrations of uranium relative to average granitic rocks. Samples from the southeastern and south-central portion of the pluton average 33 ppm U with a range of 14–72 ppm; samples from the southwestern portion average 38 ppm (Zelenka, 1984). Granites typically average 4 ppm U (DeVoto, 1978) and most Proterozoic granitic rocks in New Mexico contain less than 10 ppm U (Condie, 1978; McLemore, 1986; McLemore and McKee, 1988 and unpubl., 1990). It has been suggested (Morgan and Broxton, 1978; Reid et al., 1980) that the quartz monzonite of Costilla Creek could constitute a low-grade uranium resource when the price of uranium was around $40 per pound U_3O_8. Although the quartz monzonite is anomalously high in uranium, it is not sufficiently high to provide a viable resource in today's economic market, where the price of uranium is only about $9–10 per pound of U_3O_8.

Pegmatite dikes and pods up to 15 m wide and several hundred meters long intrude the quartz monzonite. Up to 1850 ppm U has been reported from some pegmatites (Zelenka, 1984), but the uranium distribution is localized. Most pegmatites are more radioactive than the quartz monzonite and contain about 100–200 ppm U. Uranium-bearing minerals include thorite, uranothorite, uraninite, secondary uranium minerals and uranium-bearing magnetite. Pegmatite deposits are not of sufficient grade or tonnage to constitute an economic source of uranium.

A third type of uranium mineralization may be more economically promising in the future, but its presence is only inferred as it is not exposed at the surface. Alteration halos enriched in uranium exist along and adjacent to mineralized fractures, which usually cut across foliation in the quartz monzonite (Zelenka, 1984). Uranium concentrations average 200 ppm (Zelenka, 1984). The fracture-filling assemblages consist of smoky quartz, potassium feldspar, plagioclase and magnetite locally. Hematitic alteration that has produced red feldspars is common.

These alteration halos may be indicative of hydrothermal veins of uranium minerals at some unknown depth. Exploration of this type of deposit is difficult in the rugged terrain near Costilla Creek. However, if hydrothermal veins exist, high grades of uranium could occur. This would be an excellent exploration target should the economic conditions of the uranium market improve to justify uranium exploration. High-grade uranium deposits can be developed and produced at low cost, but the exploration costs for locating these deposits are higher than exploration in known uranium districts.

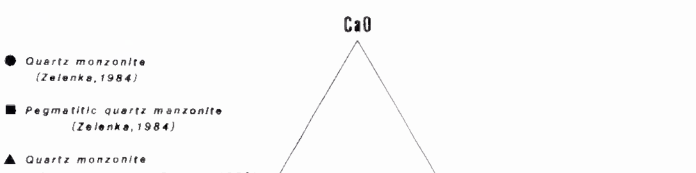


FIGURE 1.17. CaO-Na$_2$O-K$_2$O plot of chemical analyses of the quartz monzonite of Costilla Creek. Data are from Zelenka (1984) and Goodknight and Dexter (1983). Granitic fields are from Condie (1978).

Uraniferous accumulations in the quartz monzonite of Costilla Creek may provide a source for secondary uranium deposits. Uranium could accumulate in weathered quartz monzonite as well as in saprolite and clay zones within the weathered quartz monzonite, such as at the La Cueva deposit (Zelenka, 1984). The La Cueva deposit occurs at the head of La Cueva canyon. Samples from the clay zones contain up to 1500 ppm U (Zelenka, 1984), though the distribution of uranium is discontinuous and sporadic.

These secondary uranium deposits have important implications in this area. Uranium is currently being remobilized and possibly concentrated by supergene or other secondary processes. Surface water samples from the Costilla Creek area are anomalously high in uranium (Morgan and Broxton, 1978; Reid et al., 1980), indicating that groundwater conditions may be leaching uranium from the quartz monzonite, pegmatites and possibly hydrothermal veins. Concentrations of uranium in the basins downstream from the Costilla area may have formed sediment-hosted uranium deposits. However, these types of deposits tend to be low grade and small to medium tonnage and are not viable exploration targets in today's market.

The source of the uranium in the quartz monzonite of Costilla Creek is uncertain. Goodknight and Dexter (1983) suggested that overlying Tertiary volcanic rocks, now eroded, were enriched in uranium. The uranium was leached from the volcanic rocks and remobilized into the quartz monzonite. Zelenka (1984) and the author believe that the quartz monzonite and pegmatites were enriched in uranium during emplacement. Uranium was then leached from the quartz monzonite, remobilized and concentrated to form possible hydrothermal vein deposits and secondary deposits. If this remobilization is occurring today, some of the uranium could be derived from overlying volcanic rocks as suggested by Goodknight and Dexter (1983).

50.0 **Cattleguard.** Road cuts across a dike of dark post-metamorphic but pre-Tertiary biotite-hornblende diorite. Dike is about 25 m wide and is part of a swarm that can be traced for at least 5 km southwest along Costilla Creek. Dike is conspicuous in proper lighting in the lower part of the cliffs on the south side of the creek, but is only poorly exposed on the north side, although excellent samples are found in scree. **0.2**

50.2 Latir Creek and the road to Latir Lakes is on the right. It is 6 miles to Latir Lakes and the Latir Peaks Wilderness area on this four-wheel-drive road. **0.1**

50.3 Diabase dike, 15–20 m thick with chilled margins, cuts gneissic quartz monzonite and pegmatite in outcrop north of road. Dike is part of the same swarm as the diorite dike near the mouth of Latir Creek. **0.1**

50.4 Outcrops of well-foliated, gneissic quartz monzonite with pegmatite lenses on north side of road. Parting along well-developed foliation causes vertical surfaces subparallel to road. Transition from slabby outcrops to smooth slopes ahead marks contact between quartz monzonite and layered mafic-felsic gneiss sequence. **0.5**

50.9 This is the eastern margin of the quartz monzonite of Costilla Creek. The contact is a ductile shear zone, east of which lies mixed felsic schist and mafic gneiss (Lipman and Reed, 1989). Rocks are thinly laminated, muscovite-biotite schists and gneisses with compositional layering parallel to the dominant foliation. Protoliths for much of this unit may have been sedimentary. **0.5**

51.4 Sign for the Costilla Social Club. Valley trends about N30°W, and now parallels a fault zone that separates Tertiary rocks to the south from Precambrian rocks to the north. For several miles quartz latitic intrusions (about 27 Ma) have been emplaced along the fault zone. Ahead on right, light-colored rocks are nonwelded, lithic, rhyolitic ash-flow tuff (tuff of Tetilla Peak), a local prominent marker low in the precaldera section that delineates several fault repetitions on ridge ahead. Rocks overlying the lithic tuff in conspicuous cliffs are andesitic lava flows and interlayered volcaniclastic mudflows between the lithic tuff and the overlying caldera-related Amalia Tuff. North of the road are interbedded Proterozoic felsic gneisses and amphibolites. **0.6**

52.0 Outhouse on the right. **0.2**

52.2 Local bands of dark rock along here are gabbroic dikes according to Lipman and Reed (1989). **0.2**

52.4 **Cattleguard.** Forest Service Road 1950. Entering the part of the Vermejo Land Grant that in 1981 was donated to the federal government by Pennzoil Company and is now being managed by the U.S. Forest Service as the Valle Vidal Unit of the Carson National Forest (Fig. 1.18). The Valle Vidal is 100,000 acres of spectacular scenery, wildlife, timber and geology. The area contains a herd of about 1999 elk, as well as deer, mountain lion, bear, turkey and trout. This cattleguard marks the national forest boundary and also the approximate location of the contact between the interlayered feldspathic gneisses and amphibolites and quartzite. **0.3**

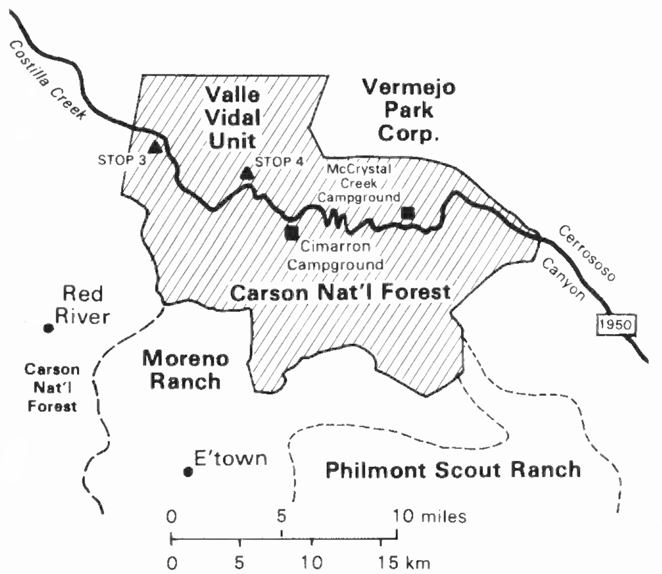


FIGURE 1.18. Map of the Valle Vidal Unit of the Carson National Forest showing road-log Stops 3 and 4, and the two public campgrounds. The Valle Vidal is closed to all visitors during elk calving season, and motorized travel is restricted.

THE CULTURAL RESOURCES OF CARSON NATIONAL FOREST

Jon Nathan Young
Carson National Forest, P.O. Box 558, Taos, New Mexico 87571

Carson National Forest covers over 1.5 million acres of north-central New Mexico, immediately south of the Colorado border. Only a very small percentage of this area has been systematically examined for the presence of cultural resources. Even so, broad, general patterns are beginning to be recognized as more specific details and data are collected, analyzed and collated. We now know, for example, that Man has been using the Forest for at least the last 9000 years. It is almost certain that as we begin to inventory comprehensively the cultural resources of the forest, one of the things we are going to learn is that Man has actually been here closer to 13,000 years. The earliest users of the Forest were hunters of big game animals such as elephants, camels and buffalo. When these animals disappeared from the scene—and disappear they did—Man was forced to find a new way of making a living. No longer could he specialize in harvesting a single aspect of his environment—the very large animals. He was forced to become a generalist and to become increasingly familiar with many more intimate details of his environment. Now he hunted not only deer, but also rabbits and mice. Now he had to know exactly when pinon nuts were ripening, acorns were ready to be collected and cholla buds were edible. We are beginning to find more and more evidence of the hunting and gathering people who were in a period of transition from hunters of big game animals to farmers.

We have much evidence in the Forest of the farmers that the hunters and gatherers were becoming. These later farming people—the Anasazi—are probably the ancestors of today's Pueblo Indians. However, the evidence of the Anasazi is more restricted in areal and geographical distribution than is that of both the hunters and gatherers who preceded them and the historic period people who succeeded them. The reason for this restricted distribution is to be found in the way the Anasazi lived. They were farmers, and about two-thirds of the Carson lies at elevations too high to allow for successful farming—spring frosts arrive too late in the year and fall frosts arrive too early.

In the Fort Burgwin/Pot Creek Pueblo portion of the Forest—south of Ranchos de Taos—are the remains of all sorts of cultural resources left behind by the folks who probably are the direct lineal ancestors of the people at Taos and Picuris Pueblos. Our Jicarilla Ranger District between Chama and Farmington is one large cultural resources site—the entire District! Dotted across the whole area are many hundreds of ruins that once were the villages of the ancestors of various of today's Pueblo Indians. An exciting aspect of the cultural resources of this portion of the Forest is the occurrence of early Navajo materials. When the Navajo first appeared upon the southwestern stage, they were a people with a fairly small collection of material culture items. They had come from a land far to the north—a harsh land of sparse opportunities. When they reached that portion of the Four Corners area which is now the Jicarilla Ranger District, they found settled agriculturalists who are the ancestors of today's Pueblo Indians. From these people, the Navajo learned about agriculture, weaving and sandpainting. Although no Navajo now live in Carson National Forest, the remains of their very early ancestors are there in abundance: small villages of stone-walled houses perched precariously on the tips of tall stone buttes, and pictures painted on sandstone cliff faces. Navajo elders continue to make periodic pilgrimages to this portion of their ancestral homeland.

Man has been using the Carson for at least the past 9000 years, but only for the last 450 years has he been keeping written records of that usage. In 1540, Coronado's Captain Hernando de Alvarado journeyed to Taos. The trail he followed later became El Camino Real, the roadway that linked the colonists at the far outer fringe of northern New Spain with the seat of colonial government in Mexico City. Wooden-wheeled ox carts lumbered up and down this royal roadway between Taos and Durango in the 1700's and early 1800's. At least three long segments of El Camino Real still are readily visible in the Carson Forest area; one is found between the settlements of Cordova and Truchas, another occurs immediately northeast of the settlement of Vadito and the third lies just south of the settlement of Ranchos de Taos. Large portions of these segments appear to be perfectly serviceable at the present time. Indeed, one piece still is—in the vicinity of Picuris Saddle, between Vadito and Ranchos de Taos! Furthermore, long-abandoned Spanish Colonial towns lie on the Carson land, including Casita Vieja, south of El Rito, and the Genizaro settlement of La Cueva, south of La Madera.

Historic-period Anglo cultural resources are especially concentrated in the Questa Ranger District of Carson National Forest. In the Placer Creek and Pioneer Canyon areas near Red River all sorts of remains from the gold mining days of the 1880's and 1890's can be found, including mines, mills, bunkhouses and stores. Exactly the same situation pertains in the Anchor/Midnight portion of the Keystone Mining District, about 5 mi northeast of Red River. In the Valle Vidal Unit of the Questa Ranger District, there are the long-abandoned settlements of Ponil Park and Ring—sawmilling communities connected to Cimarron by the Cimarron and Northwestern Railroad. The heyday of these communities was the early decades of the twentieth century, but tombstones in the Ponil Park cemetery tell us that folks were living and dying there much earlier than that. Only a short distance from Ponil Park are the spectacular multistoried log structures of the Ring Place, a ranching headquarters built in the latter portion of the nineteenth century, and near that are the homesteads of equally early ranching families such as John and Annie McCrystal. Scattered throughout the Ponil Park/McCrystal Creek area are cultural resources pertaining to the use of this very same piece of ground by Apachean people. There are Apachean rock shelters and pictographs at Ponil Park, two hunting blinds near the McCrystal's homestead and several other hunting blinds between the McCrystal's and Ponil Park.

In sum, the cultural resources of Carson National Forest are many and diverse. They form a continuum at least nine millennia in length. They run the gamut from something as small and discrete as a stone knife dropped 9000 years ago by a hunter of big game animals to entire towns with sawmills and railroads and cemeteries. They are an important part of the patrimony and heritage of all of us, and must be treated with respect for future generations.

52.7 Good exposures of intrusive quartz latite. Intrusive quartz latite continues in outcrops ahead south of the creek, with Precambrian quartzite and other metamorphic rocks to the north. **0.1**

52.8 Tertiary diorite cuts fractured Precambrian quartzite and contains 2–3 m blocks of quartzite. This diorite body marks the eastern end of the dike swarm. Outcrops of quartzite for several hundred yards east. Kinematic indicators show near-horizontal slip on a fault plane which dips 80°SE. **0.3**

53.1 Green outcrops on slopes to north are amphibolite layers interlayered with the quartzite sequence. **0.1**

53.2 Fold nose in quartzite visible in outcrops across creek to the south. **0.6**

53.8 A 9-m-long pod of muscovite pegmatite in quartzite-mica-gneiss sequence. **0.3**

54.1 **STOP 3** at junction of Comanche and Costilla Creeks (Forest Service Roads 1950 and 1900). Small outcrop on left side of road is thinly laminated, muscovitic quartzite. The general trend of compositional layering here is fairly consistent with NE trends and gentle to moderate SE dips. Folds with N- or NE-trending axial surfaces are overprinted by folds with NW-plunging hinges. A local fracture cleavage trends NE and dips gently to moderately NW, parallel to axial surfaces of the younger folds. To the east, the quartzite contains a 5–9-m semiconcordant lens of crudely zoned, muscovite-bearing pegmatite.

About 17 m west along the road are large blocks of lustrous muscovite schist with two lineations crossing at about 30°. The schist contains ovoid quartz-muscovite knots as much as 5 cm in diameter, possibly replacements after cordierite. This lithology is interlayered with quartzite on the slopes above.

The prominent knob ahead is Comanche Point, a 25 Ma intrusion of biotite rhyolite (Fig. 1.19). This is part of a laccolith complex, also containing quartz latite, that was emplaced along the bounding fault zone between the volcanic rocks to the south and Precambrian rocks to the north. Note irregular cordwood, columnar-cooling joints in the rhyolite of Comanche Point. High ridge behind Comanche Point is capped by silicic alkalic-basalt flows interlayered with weakly consolidated cobbly conglomerates of the Santa Fe Group.

PROTEROZOIC METAMORPHIC ROCKS NEAR COMANCHE POINT, NEW MEXICO

Jeffrey A. Grambling

Department of Geology, University of New Mexico, Albuquerque, New Mexico 87131

Reed (1984) described metamorphosed Proterozoic rocks in the Taos Range, New Mexico. In order to examine those rocks in greater detail, I began re-mapping parts of Reed's study area at a larger scale in 1985, supplementing the mapping with thin-section and electron-microprobe work. The area treated in this paper, covering approximately 2 km^2, lies along Comanche Creek north of Comanche Point. What follows is a summary of the geology of that region, focusing on the Precambrian rocks.

Precambrian rocks at Comanche Point include metarhyolite, quartzite, schist, amphibolite and minor pegmatite. All are intensely folded, foliated and lineated. They are overlain unconformably by Cenozoic units including volcanic, volcaniclastic, and sedimentary rocks, and unconsolidated alluvial deposits. Figure 1.20 shows the distribution of rocks in the mapped region.

Quartzofeldspathic gneiss is a fine- to medium-grained, tan to orange-weathering rock with quartz, plagioclase, K-feldspar and minor to trace amounts of muscovite and FeTi oxides. Most minerals range in diameter from 0.1 to 0.3 mm, but quartz shows a bimodal size distribution with one population averaging 0.1–0.3 mm and another 1–3 mm. Larger quartz grains typically are rounded, although some are subhedral to euhedral. Many have embayed edges, and some contain 0.1–0.3 mm inclusions filled with numerous, fine-grained crystals of feldspar and mica. The larger quartz grains are interpreted as phenocrysts in a metamorphosed, silicic volcanic rock.

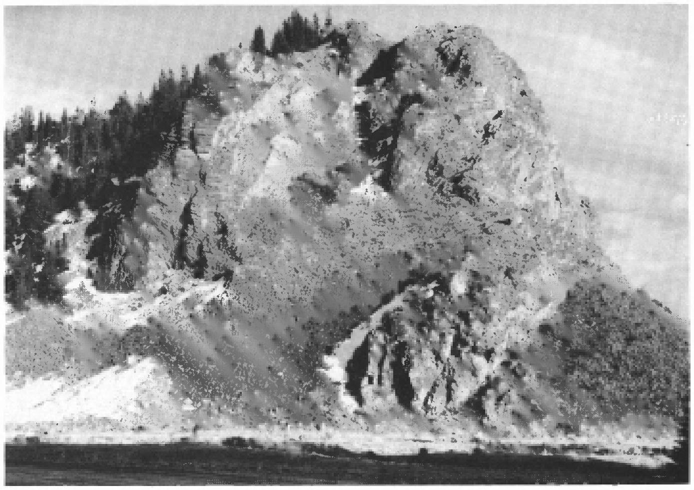


FIGURE 1.19. Comanche Point consists of 25 Ma biotite rhyolite that was intruded along the fault zone that separates Tertiary volcanic rocks to the south from Proterozoic rocks to the north. As shown on this view southeastward, "cordwood"-style columnar jointing is well exposed on the north side. Photo by C. K. Mawer.

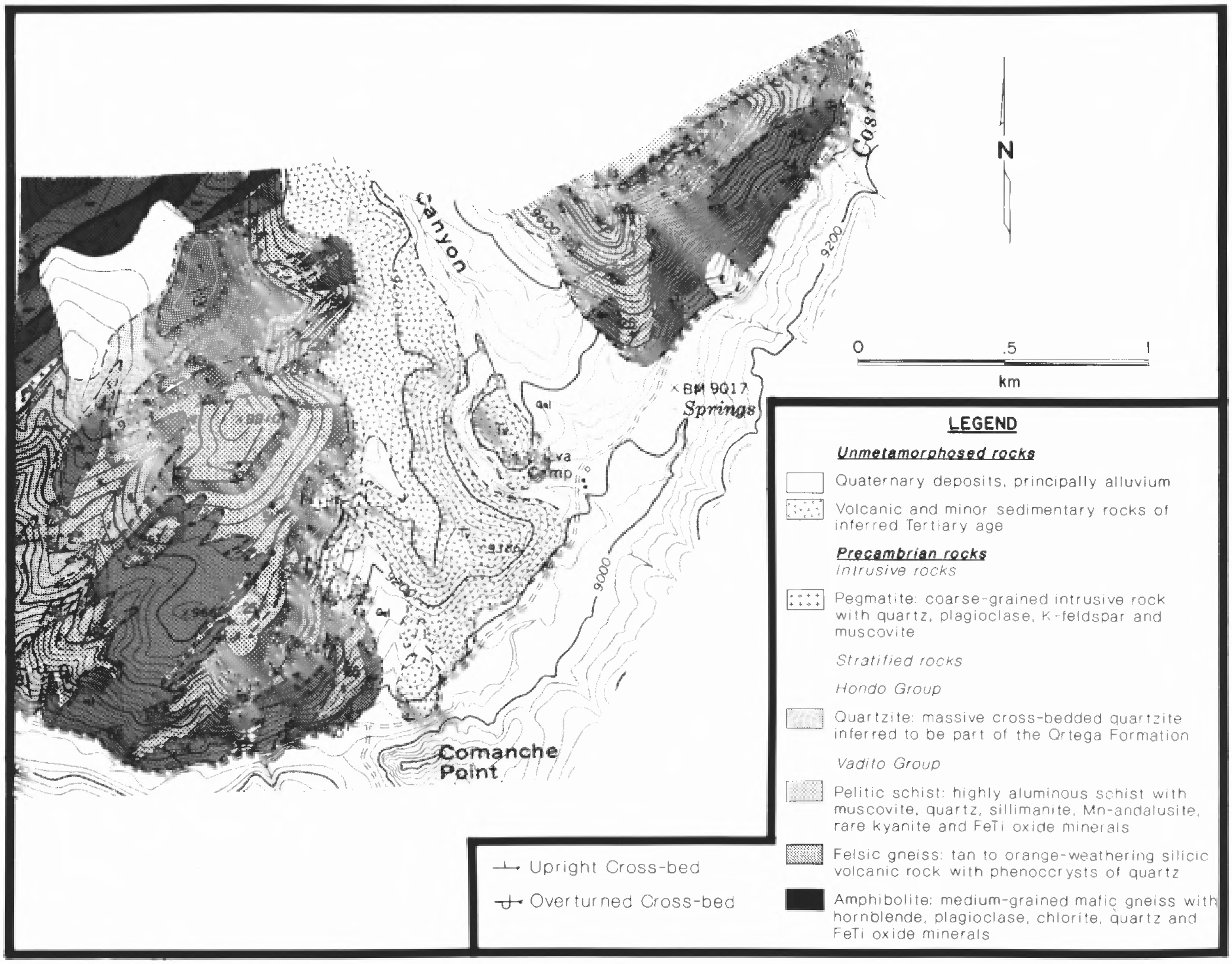


FIGURE 1.20. Geologic map of Proterozoic rocks in exposures north of Comanche Point, New Mexico. Mapped in 1985.

Quartzite forms large, isolated outcrops scattered across the study area. Hematite, rutile, muscovite and aluminum silicates are common accessory phases. Aluminum silicates include both kyanite and sillimanite, rarely accompanied by the green, manganiferous variety of andalusite known as viridine. Quartzite commonly preserves crossbeds in which the foresets and topsets are outlined by hematite and aluminum silicate.

Schist contains muscovite, quartz and one or more polymorphs of Al_2SiO_5. Manganiferous andalusite and sillimanite are the most common polymorphs, although kyanite is found locally. Hematite and rutile are abundant accessory phases.

Amphibolite typically appears as float or alluvium. It contains hornblende, plagioclase, chlorite, quartz and minor FeTi oxides. Most grains average 2–3 mm in size, but hornblende locally forms porphyroblasts up to 2 cm long. Amphibolite presumably originated as basalt. Pegmatite, rare at Comanche Point, can be found within map units of quartzofeldspathic gneiss. The simple pegmatites contain quartz, plagioclase, K-feldspar and muscovite.

These Proterozoic supracrustal rocks crop out in a consistent sequence across the mapped area (Fig. 1.20): amphibolite, quartzofeldspathic (felsic) gneiss, schist and then quartzite. Crossbeds in quartzite typically face away from the schist, indicating that the quartzite lies stratigraphically above schist and the other rocks lie below it.

Manganiferous andalusite, common in schist at Comanche Point, is a rare mineral found in only about 50 locations worldwide. Over half of these are in northern New Mexico, in a unique stratigraphic position immediately below the base of a thick Proterozoic quartzite, the Ortega Formation (Grambling and Williams, 1985; Bauer and Williams, 1989). The presence of manganiferous andalusite along the contact between schist and quartzite at Comanche Point suggests that the same layer crops out there, which in turn indicates that the quartzite at Comanche Point is part of the Ortega Formation. The viridine schist at Comanche Point, as well as the other occurrences of schist with manganese andalusite in New Mexico, are interpreted to represent a single, widespread, metamorphosed laterite deposit (Grambling and Williams, 1985). This interpretation is consistent with the abundance of rutile and hematite, inferred to be residual products of deep weathering, in the schist. Viridine found in massive quarzite may have been derived from sedimentary reworking of the lateritic unit.

Metamorphic grade at Comanche Point can be defined by aluminum silicate minerals and FeTi oxides if mineral compositions are known. Such compositions were obtained for three samples using the JEOL 733 electron microprobe at the Department of Geology, University of New Mexico. Each sample contained andalusite, sillimanite, hematite and quartz, but none contained kyanite. In all samples, hematite was virtually pure Fe_2O_3. Grambling and Williams (1985) demonstrated how to obtain precise estimates of metamorphic pressures and temperatures for the given assemblage, based upon the aluminum silicate triple point of Holdaway (1971). Their method gives results summarized in Figure 1.21. For sample 85-223, in which andalusite and sillimanite have variable composition, calculated P-T conditions fell in the range 3.4–3.8 kb, 528–575°C. In two other samples, andalusite and sillimanite

	85-223				85-223A		85-226A	
	Spot 1		Spot 2					
	Sil	And	Sil	And	Sil	And	Sil	And
Fe_2O_3	1.37	3.08	0.96	2.32	1.30	2.38	0.74	2.43
Mn_2O_3	0.03	1.24	0.00	1.40	0.02	0.13	0.02	2.24
TiO_2	0.00	0.06	0.00	0.00	0.01	0.00	0.00	0.01
Al_2O_3	62.12	59.84	61.21	60.56	63.84	63.10	62.80	60.71
SiO_2	36.15	36.41	36.19	35.10	36.66	36.52	36.83	36.07
Total	99.67	100.62	98.36	99.38	101.83	102.13	100.41	101.46
Fe^{3+}	0.028	0.063	0.020	0.048	0.026	0.048	0.015	0.050
Mn^{3+}	0.001	0.026	0.000	0.029	0.000	0.003	0.000	0.046
Ti^{4+}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	1.99	1.92	1.99	1.97	2.00	1.98	1.99	1.94
Si	0.98	0.99	1.00	0.97	0.98	0.97	0.99	0.98
Calculated PT	3.4 kb 575°C		3.8 kb 528°C		4.0 kb 530°C		4.0 kb 532°C	

FIGURE 1.21. Compositions of Al_2SiO_5 minerals at Comanche Point, and calculated metamorphic P-T conditions.

did not have variable composition, and calculated P-T conditions were 4.0 kb, 530°C and 4.0 kb, 532°C. The latter two values probably give the best estimate of metamorphic P-T conditions at Comanche Point, as the first sample records minor chemical disequilibrium.

Nearly identical metamorphic P-T conditions are quite common in the Proterozoic metamorphic terrance of northern and central New Mexico. Grambling et al. (1989) and Grambling and Dallmeyer (this guidebook) have suggested that regional metamorphism at these P-T conditions resulted from a major episode of deep-crustal extensional deformation. Extension and thinning of the lower continental crust transferred heat upward across a major extensional decollement, located at a crustal depth near 15 km, into higher levels of the crust. The 4 kb pressure estimate at Comanche Point equates to a crustal depth near 13 km; thus, the major extensional decollement may lie 2 km below the exposed erosional surface. The decollement is exposed at the surface some 20 km farther west in the Taos Range (Grambling et al., 1989).

Geologic mapping at Comanche Point was supported by the New Mexico Bureau of Mines and Mineral Resources. Analytical expenses were covered by a research grant from the National Science Foundation (EAR-8309503). I thank Frank Kottlowski and Jamie Robertson for their long-term support of field research in the Proterozoic rocks of northern New Mexico and Paul Bauer, Christopher Daniel, Jane Pedrick, Christopher Mawer and Christine White for reviewing this manuscript.

DIFFERENTIATION WITHIN THE TERTIARY COSTILLA RESERVOIR SILL, COMANCHE POINT QUADRANGLE, NORTHERN NEW MEXICO

Stephen M. McDuffie and Bruce D. Marsh

Department of Earth and Planetary Sciences, The Johns Hopkins University, Baltimore, Maryland 21218

Sheet-like igneous bodies such as sills and lava lakes can tell us much about the processes leading to magmatic differentiation. These bodies are reasonable, through small-scale, approximations of magma chambers, and when exposed in their entirety they reveal the chemical and physical diversity achievable within a single cooling unit. The fundamental assumptions are that the body was intruded as a homogeneous melt, and emplacement occurred over a very short period of time. Differentiation processes occur during subsequent cooling and solidification, which occurs as crusts, or solidification fronts, grow inward from the top and bottom of the magma body. Crystal settling is found to be the dominant process leading to differentiation of sheet-like bodies (Congdon and Marsh, 1988; Marsh, 1988). Several factors influence the amount of crystal settling that takes place during the solidification of a body. Most important are viscosity or magma composition; body thickness, which determines cooling rate and time; depth of burial, thus boundary temperature and solidification rate; and the crystallinity of the magma at the time of emplacement. Our chief interest is the role of viscosity in differentiation. Much previous work has gone into characterizing differentiation within basaltic bodies, so a logical progression is the investigation of differentiation within intermediate composition (55–60% SiO_2) magma chambers. The Costilla Reservoir sill has been selected as the focus of this study.

The Costilla Reservoir sill, so named by P. Lipman of the USGS, is described briefly on the Lipman and Reed (1989) map of the Latir Volcanic Field and adjacent areas. It is located in the north-central portion of the Comanche Point 7.5-minute quadrangle. The sill is intermittently exposed along the upper Costilla Valley from Comanche Point to Costilla reservoir, mostly on the east side of the valley; best exposures are found on the west side of the valley about 250 m downstream from Costilla dam and in Blind Canyon, a side canyon off to the east of Costilla Valley 2 km downstream from the dam. The sill is semiconformable within a sequence of volcaniclastics and tuffs. In the stratigraphic sequence of Lipman and Reed's map, the intrusion is associated with volcanic activity of Late Oligocene/Early Miocene age. The upper contact of the sill strikes roughly N15°E, dipping 25°E. A thickness of 220 m was measured at the Blind Canyon sample area.

Samples from various levels within the sill show definite textural, mineralogical and chemical differences, and these variation trends within the vertical transects (one from the reservoir locality and one from Blind Canyon) agree fairly well. The upper and lower chill margins both contain about 20 volume percent phenocrysts in a groundmass of microphenocrysts and glass. Where exposed, both upper and lower contacts are very sharp. The upper chill margin consists of a 3–4 cm thick horizon of dense, fine-grained black rock; its 20 volume percent of phenocrysts consists mostly of plagioclase and clinopyroxene. Below this horizon there is an abrupt change to a more crystalline rock with a gray, andesitic appearance. In contrast, the rock above the lower chill is not visibly different from the chilled rock; it has the same black, fine-grained, basaltic appearance for several meters upward.

Phases present in the Costilla Reservoir sill include plagioclase, clinopyroxene, olivine, iron-titantium oxide, ± orthopyroxene, biotite and basaltic hornblende. Olivine crystals are extremely altered in most samples; their identity is determined in thin section by crystal form and their reddish-brown alteration product. The olivine crystals, often altered to bright orange in hand sample, are conspicuous in most samples collected from the upper 50 m of the sill but much less common between 50 and 125 m depth. There is a gap in exposure between 85 and 110 m depth, and the macroscopic appearance of the rock changes dramatically over this region. The rock above 85 m has an andesitic appearance, with small phenocrysts in a light gray groundmass. In contrast, nearly all the rock below 110 m has small phenocrysts in a dark gray to black groundmass, giving the block a basaltic look. Pending more detailed petrographic work, this upper versus lower classification is based on macroscopic appearance only. The weathered olivine crystals are common once again below 125 m depth, though not conspicuous in hand sample, perhaps due to the darker color of the rock. Plagioclase and clinopyroxene, the largest phenocrysts present, rarely exceed 5 mm length anywhere in the sill. The groundmass is coarser-grained toward the center of the body. This is to be expected since crystallization rates decrease as the solidification fronts advance less quickly during their inward propagation. Rock containing glass in the groundmass is found only within 5 m of a contact, but not all rock this close to a contact contains glass. No samples have the equigranular texture found in many plutonic rocks; even near the center of the sill the groundmass is quite fine-grained and all samples are porphyritic. Most of the sill is of a texture transitional between the classic intrusive and extrusive textures. Another notable feature in the sill are the abundant xenoliths, sometimes up to 10 cm across. None have been closely analyzed as of yet, but many appear to have a gneissic character.

Preliminary chemical data (Fig. 1.22) shows no distinct trends through the body. One can broadly say that the interior is enriched in SiO_2 and Na_2O relative to the margins, and the interior is depleted in FeO and

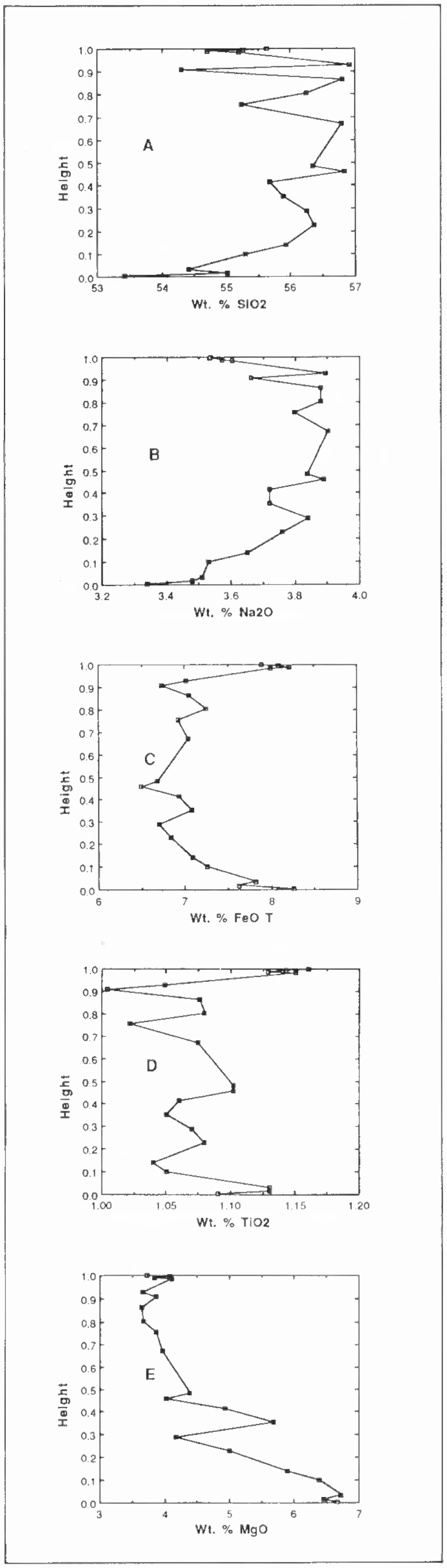


FIGURE 1.22. Chemical profiles of the Costilla Reservoir sill as determined from the Blind Canyon transect. A through E display the weight percentages of SiO_2, Na_2O, FeO (total), TiO_2 and MgO against stratigraphic level in the sill. Height is normalized to 220 m, the thickness of the Blind Canyon section.

TiO_2. For a closed system with material transport in the vertical direction only, one would expect to see S-shaped profiles of elements that are associated with the settling phases. For example, olivine settling would cause depletion of MgO in the upper portions of the body and concentration in the lower regions. Mass balance dictates that the average MgO content across the body remains equal to the value at the chill margins. Differentiation within the Costilla Reservoir sill does not appear to have been a straightforward process, as one can gather from chemical profiles. Taking the chill margin compositions to be representative of the entire body at the time of emplacement, there is a mass-balance problem with some elements. The average SiO_2 and Na_2O contents across the sill are greater than the border values, whereas the FeO and TiO_2 averages are less. There appears to be a net enrichment of SiO_2 and Na_2O, and a corresponding depletion of FeO and TiO_2, in the center of the body. Lateral transport of material during solidification, possibly due to an original nonhorizontal orientation while crystallizing, may be one explanation for this. The sill currently dips 25°, and so this explanation may not be unreasonable. In addition, an uneven distribution of phenocrysts upon emplacement could account for the apparent mass balance problem. More mysterious than the profiles of SiO_2, Na_2O, FeO and TiO_2 is the MgO profile. The upper and lower chill margins differ significantly, and there is a steady increase in MgO with depth. This disparity between upper and lower MgO contents is strong grounds for reevaluation of the single, homogeneous injection assumption.

A transect of samples from several hundred meters down dip from the Blind Canyon section might elucidate the differentiation processes that took place in this sill. Such exposures do not exist; other approaches must be taken to gain understanding of the emplacement, crystallization and differentiation history of this body. Mineral composition data from microprobe analyses should be quite useful, as will melting experiments to determine the phase equilibria.

Bear right along Comanche Creek on Forest Service Road 1950. A fault to the east of Comanche Point exposes more micaceous quartzite. The road turns south up Comanche Creek toward Shuree Ponds in the Valle Vidal. The left fork leads up Costilla Creek to Costilla reservoir. Lipman and Reed (1984) published a supplemental road log from Comanche Point to Costilla Reservoir in the 1984 NMGS Guidebook. **0.3**

54.4 Notice the fresh slumping above roadcut just south of the bridge across Comanche Creek. **0.1**

54.5 On the right is Tertiary rhyolite of Comanche Point. **0.1**

54.6 From 8:00–9:00, spectacular columnar jointing on Comanche Point is visible. **0.2**

54.8 Tertiary andesite visible in roadcuts on the right. Across the road is andesite and Santa Fe Group gravels derived from andesite. **0.1**

54.9 On the left are Proterozoic felsic metavolcanic rocks. Along both sides of the road is a gravel ridge that Lipman and Reed (1989) called possible morainal deposits. Fresh exposures along this new roadcut show gravels with graded bedding and imbricated clasts (Fig. 1.23). These features suggest that these sediments were deposited in an alluvial environment. Up the hill on the right are Tertiary volcaniclastic rocks. **0.1**

55.0 Along the right side of the road is a small outcrop of either the quartz monzonite of Costilla Creek or felsic gneiss. Where a paleoerosion surface has cut into bedrock on the curve ahead, bedded gravels lie on top of Precambrian. Note slump with undisturbed upper grassy surface. **1.7**

56.7 Road is now passing well-exposed Proterozoic meta-

FIGURE 1.23. Layered sand and gravel deposit displays coarse grading and imbricated clasts, suggesting an alluvial depositional environment. Mile 54.9, east of Comanche Point. Photo by C. K. Mawer.

volcanic rocks both in roadcut on the right and in outcrop on the left. **0.5**

57.2 To the left, on the far side of Comanche Creek, is the fault contact between Proterozoic metavolcanic rocks and Tertiary andesites.

Restricted access Forest Service road at old corral leads up to area mapped by McKinlay (1956) as a small fenster that exposes rocks of the Sangre de Cristo Formation in the valley bottoms of Little Costilla and Spring Wagon Creeks, surrounded by Proterozoic granitic and Tertiary volcanic rocks. This same area was mapped in more detail by Lipman and Reed (1989) as down-dropped blocks of Sangre de Cristo surrounded by normal faults rather than a thrust fenster (Fig. 1.24). The thrust fault interpretation is reasonable because 2 mi to the east Proterozoic rocks are thrust over Sangre de Cristo and younger rocks and a shallow-dipping warped thrust plate could possibly be present. However, the actual geometries of fault traces, as indicated by admittedly sparse field outcrop evidence, are much more supportive of the normal fault interpretation. But this interpretation is not without question because it, too, requires a fortuitous set of circumstances: the presence of Sangre de Cristo rocks in depositional contact with Proterozoic rocks at just the right distance above the area of outcrop at the precise time of faulting. A simpler interpretation would bring Sangre de Cristo rocks up from below the thrust rather than down from above, but that would require

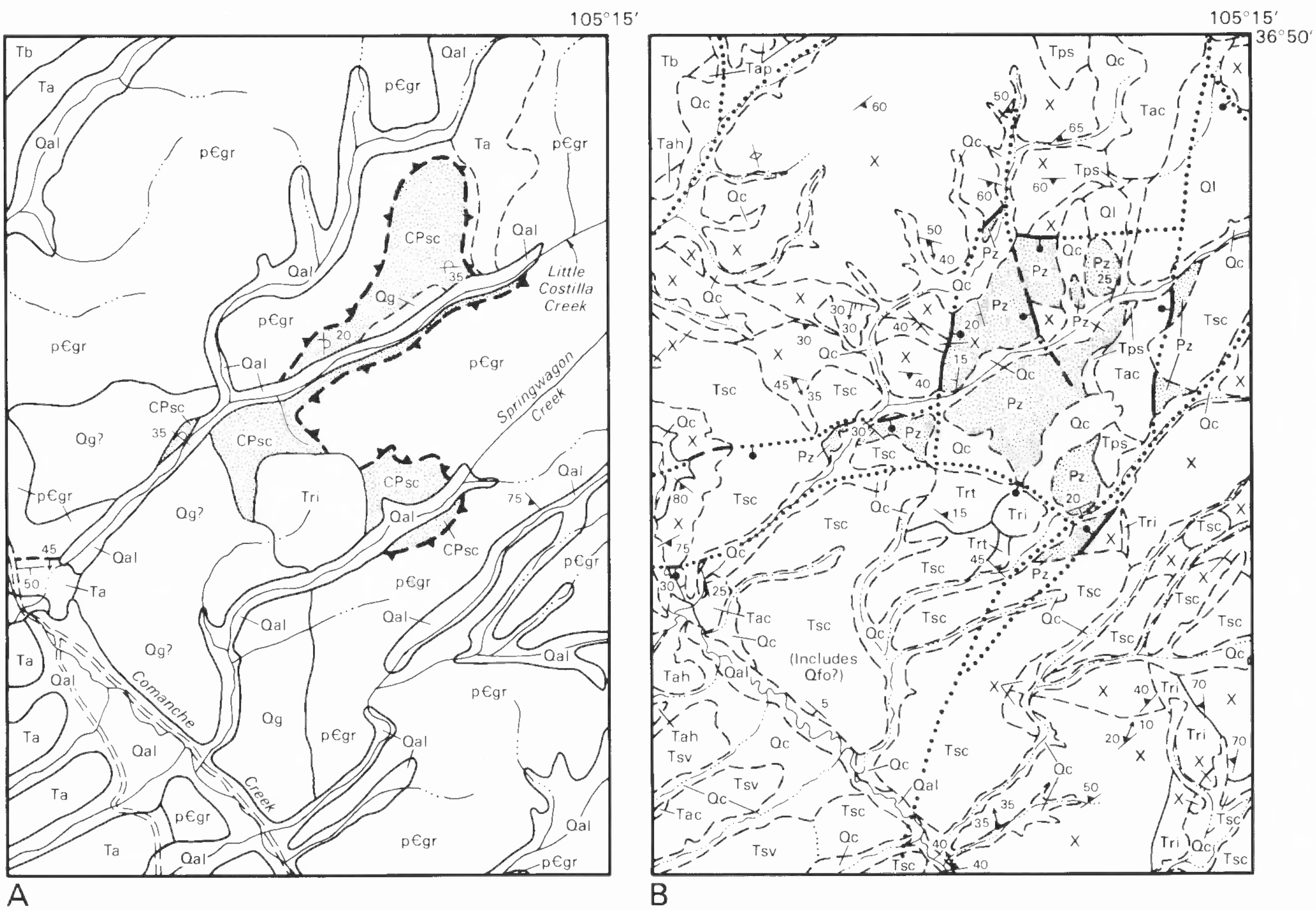


FIGURE 1.24. Two different interpretations of structural relationships in the Springwagon Creek area. A) Thrust faulting. Generalized map by McKinlay (1956) that shows rocks of the Sangre de Cristo Formation exposed in an area bounded by Quaternary colluvium, Tertiary Santa Fe Group gravels, and Tertiary intrusive rocks and nearly surrounded by overthrust Precambrian rocks. B) Normal faulting. The same area, mapped by Lipman and Reed (1989), showing rocks of the Sangre de Cristo Formation surrounded by normal faults. See text for a discussion of these two possibilities.

movement in the opposite direction. The area is beautiful, but outcrops are rare and the geology is complex. The nearest similar exposures of Sangre de Cristo Formation rocks surrounded by Proterozoic rocks are on ridge crests on the east flank of the Sangre de Cristo Mountains about 15 mi to the southwest. **0.3**

57.5 **Cattleguard. 0.4**

57.9 Hills to the left of the road are Santa Fe Group gravels, whereas low hills on the far side of the creek southwest of the road are Tertiary volcaniclastic rocks. **0.6**

58.5 The tributary creek to the right is Gold Creek. The next major creek upstream is La Belle Creek, famed for the now–ghost town of La Belle, located about 1.5 mi west. La Belle boomed as a gold mining camp in 1894 (Fig. 1.25). By July of 1895, La Belle contained over 600 residents, a newspaper, 5 general stores, 4 liveries, 6 saloons, 2 barber shops, 3 hotels, 2 laundries and a jail that was never used (Sherman and Sherman, 1975). The Southern Hotel, painstakingly moved from Catskill, New Mexico, contained 4 stories and 80 rooms. "Black Jack" Tom Ketchum, notorious outlaw and train robber, was always in great demand as a dance partner by the young ladies of La Belle at the frequent dances.

The gold ore proved to be low-grade, and despite the miners' optimism, by the turn of the century La Belle was nearly dead. Reportedly, the majestic Southern Ho-

FIGURE 1.25. La Belle town from the south, summer 1897. The first prospectors to visit the La Belle area arrived in 1866 from St. Louis. Development was slow until 1895 when the population rocketed to 600 residents. The town was named for Mrs. Belle Dixon, wife of one of the early prospectors and investors. The Southern Hotel (probably the large building just to the right of center in photo) was moved in pieces 50 mi from Catskill to La Belle. It is reputed to have been four stories containing 80 rooms. Due to a shortage of patrons the Southern was eventually converted to a livery stable. Because of its remoteness, La Belle was a favorite party town for the train bandits Black Jack Tom Ketchum and his brother Sam. Black Jack's exploits ended at the end of a rope in Clayton; Sam died in the Territorial penitentiary in Santa Fe and is buried under old Highway 85 south of Santa Fe. Ultimately, the rich ore played out, and La Belle was added to the long list of New Mexican ghost towns. Curiously, no people are visible in this 8×10 glass plate photo by O. E. Aultman of Trinidad, Colorado. Courtesy of Colorado Historical Society.

tel was sold for $50 at auction. Sporadic mining and exploration in the area continued through the 1930's, resumed in the 1950's, and again, with the rise in metal prices, in the 1970's.

In the mid-1970's Duval Corporation conducted mineral exploration in the La Belle area and determined that the grade of mineralization is too low for commercial operation. The steeper slopes west of the valley are dotted with hundreds of small dogholes and prospect pits and a few larger shafts and adits cut into the propylitic and argillic alteration facies of andesitic lahars and tuffs and quartz latite tuffs. The altered areas are variously anomalous in Hg, Mo, Pb, Zn and Au and are essentially contiguous with those at the Anchor and Midnight mines two and three miles west of La Belle, respectively, in the Bitter Creek drainage west of the ridge crest. **0.2**

58.7 Road leaves the Comanche Creek drainage and begins climb to the Valle Vidal via Holman Creek. Rugged outcrops visible looking up the valley and on the east side of Holman Creek are Proterozoic quartz monzonite of Costilla Creek that probably form the upper plate of the northern extension of the Blue Lake/Sixmile thrust fault, the surface trace of which is about 2 mi to the east as shown on the geologic map of the Valle Vidal area (Fig. 1.26).

The headwaters of Comanche Creek lie near Costilla Pass, a drainage divide that separates the Comanche Creek–Valle Vidal drainage from the Moreno Valley. At Eagle Nest Lake, Moreno Creek joins the east-flowing Cimarron River, a tributary of the Canadian River. **0.9**

59.6 Crossing contact between quartz monzonite of Costilla Creek and Proterozoic felsic metavolcanic rocks. **1.5**

61.1 **STOP 4. Pull off on right shoulder** at the overlook (Figs. 1.27, 1.28). The broad valley before you is the Valle de Vidal, originally part of the Maxwell Land Grant. The 100,000 acres that constitute the Valle Vidal parcel were later acquired by W. J. Gourley, as part (about one-fourth) of his Vermejo Ranch. The Vermejo Ranch had formerly been the Vermejo Club in the 1930's, a private playground for the rich and famous, including personalities such as Herbert Hoover, Douglas Fairbanks, Mary Pickford and Cecil B. De Mille (see "History of Vermejo Park" by Laurie, 1976). Gourley operated the ranch as a combination guest and working cattle ranch operation. Following Gourley's death in 1973, the ranch was purchased by Pennzoil. The Valle Vidal parcel was then acquired in 1982 by the Forest Service in exchange for a tremendous tax write-off (of a rumored amount nearly twice what Pennzoil originally paid for the entire Vermejo property). Before Pennzoil purchased the property, the National Park Service attempted to acquire the ranch for the advertised price of $26 million, but the appropriations bill was never passed, and the attempt failed. The state of New Mexico also considered purchase, but they, too, were unable to raise the necessary funding.

The Valle de Vidal, now called the Valle Vidal and shortened by the local people to "Vividal," was the setting for Frank O'Rourke's novel *The Last Ride,* a story about rounding up wild horses in this valley in the early part of the century and herding them down for breaking at Horse Ranch on the confluence of the Vermejo River and Gachupin Canyon, about 20 mi east of here.

The Valle Vidal is part of the north-south linear graben system that includes the Mora and Moreno valleys to the south and Costilla valley to the north. The broad openness of the valley probably results from normal block faulting and perhaps partly from erosion of the nonresistant, altered, sheared and broken quartz monzonite that constitutes the upper plate of a thrust fault, here called the Little Costilla thrust, probably the northern extension of the Blue Mountain/Sixmile thrust of Clark and Read (1972) and Lipman and Reed (1989). The thrust is mapped as a steep- to low-angle fault zone that has been traced south into the Costilla Pass quadrangle by Clark and Read and mapped to the south in the Eagle Nest quadrangle and the Wheeler Peak area by Lipman and Reed. The thrust can be followed north along the east front of the Sangre de Cristo Mountains for several miles, into Colorado. It is the major compressional tectonic feature in the region. The thrust fault is not visible where mapped along the east side of the valley, but it appears as a line of springs and vegetation, as shown in the photograph (Fig. 1.29).

The line of springs marks a young (probably Quaternary) normal fault scarp that is probably coincident with the Little Costilla thrust fault. Reactivation of the thrust as a normal fault related to Rio Grande rift extension is likely. To the south the fault passes east of the conical hill at the south end of the valley and extends nearly 20 mi toward Wheeler Peak on the distant skyline. At the south end of the valley, Proterozoic rocks are faulted against conglomeratic sandstone beds of the Poison Canyon Formation (Tertiary and Cretaceous). As the fault is traced back to the north, succeedingly older beds appear. The Trinidad Sandstone (Cretaceous) caps the third peak along the ridge, but its contact with the Proterozoic rocks of the upper plate is covered by colluvium.

The geologic map (Fig. 1.26) shows the thrust trace, the manner of faulting at the north end of the valley where it crosses our route a short distance ahead of this stop, and its expression to the north on Little Costilla Peak. The tree-covered ridge to the northeast of here is a hogback comprised of Mesozoic rocks of the Dockum Group (Chinle Formation), Exeter (Entrada) Sandstone, Morrison Formation, Dakota Sandstone and Purgatoire Formation. One who assumes that this ridge is a typical Dakota hogback would be in error. The ridge crest is supported by overturned to vertical sandstone beds of the Morrison Formation—the sandstones of the Dakota Group crop out midslope, well below the crest, for about 5 mi. Past that point the Dakota becomes more resistant and forms the crest of a rugged hogback ridge that continues for more than 20 mi to Stonewall, Colorado, where it forms a prominent vertical wall. A stratigraphic section measured at the notch, about 1.5 mi north, includes rocks of the Dakota Sandstone, Purgatoire, Morrison and Ralston Creek? Formations, and the Exeter (Entrada) Sandstone and the upper part of the Dockum Group. The notch section is the southernmost exposure of these rocks in this region. A better section of these

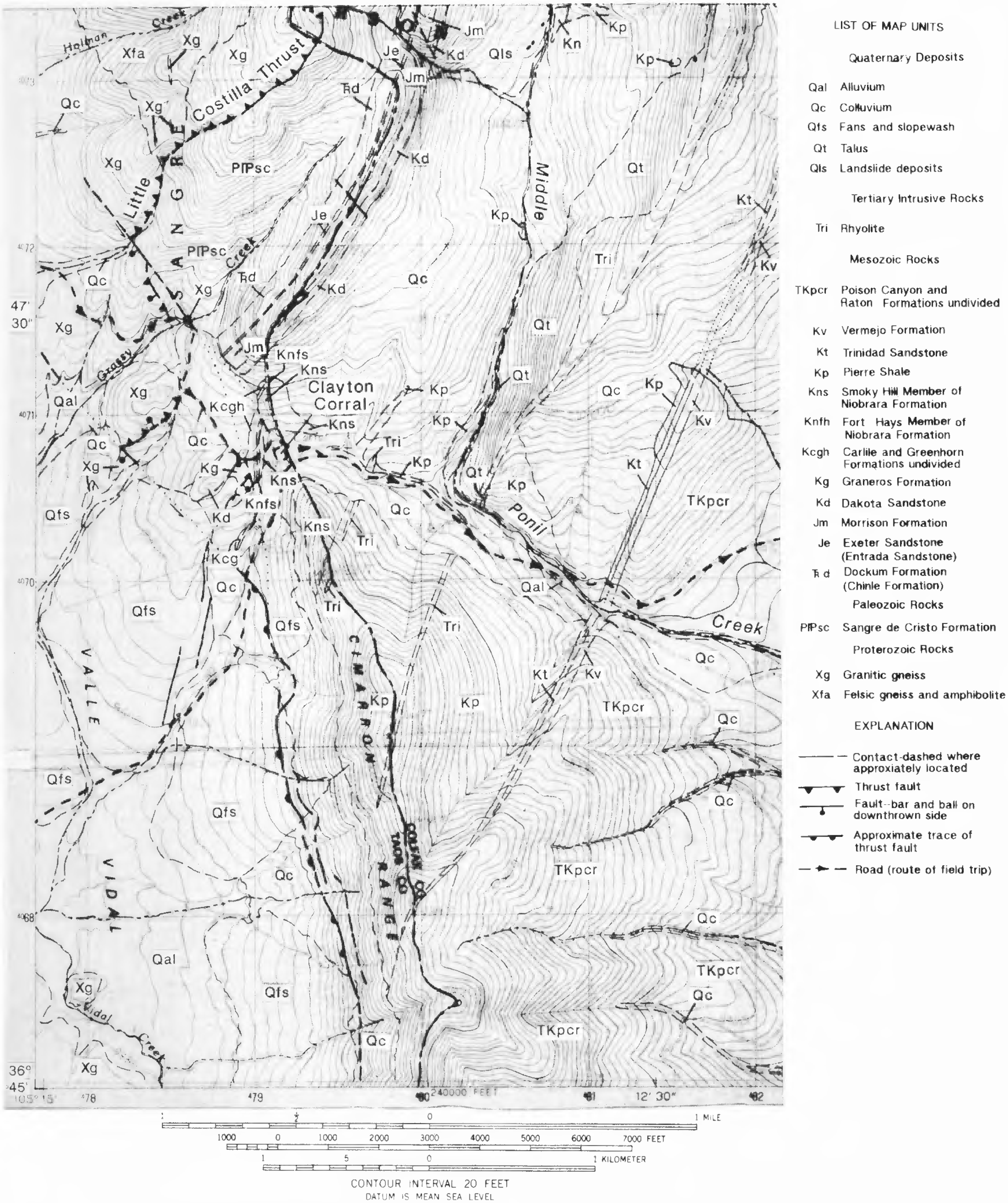


FIGURE 1.26. Geologic map of the Valle Vidal area, Colfax and Taos Counties, New Mexico, by Jim Walker, Consultant, Tucson, Arizona, and C. L. Pillmore, U.S. Geological Survey, Denver, Colorado.

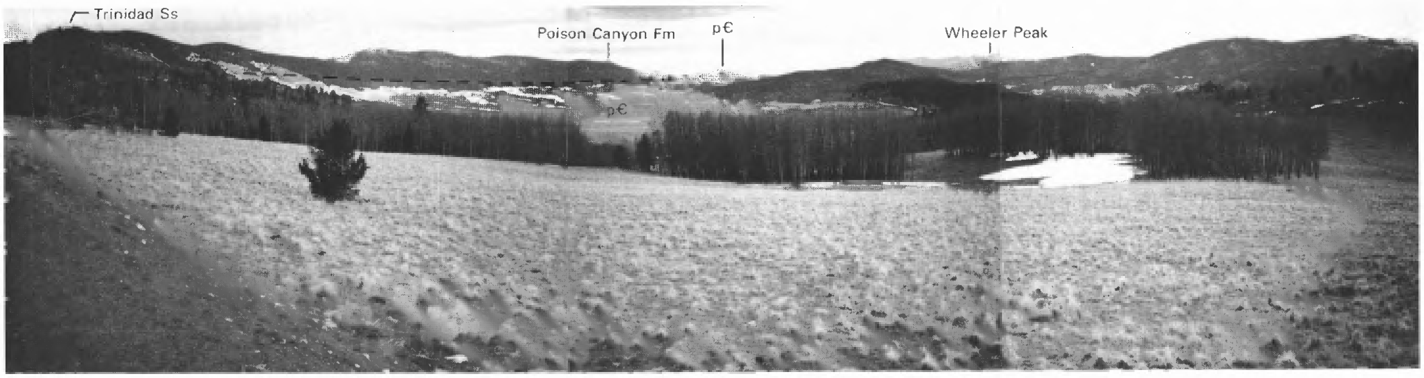


FIGURE 1.27. Panoramic view to the south across the Valle Vidal from Stop 4. The trace of the Little Costilla thrust fault is shown by dashed line along the east side of the valley. The fault passes to the left of the small conical hill in the middle of the photograph, where Precambrian rocks are faulted against conglomerates of the Poison Canyon Formation (Late Cretaceous and Paleocene). Photo by C. K. Mawer.

rocks, 11 mi north in Ricardo Creek, is described in the New Mexico Geological Society Guidebook 27 (Pillmore, 1976, pp. 45–47). The next exposure to the south is in Urraca Creek on the Philmont Scout Ranch. The Upper Cretaceous marine rocks in the Valle Vidal are poorly exposed and generally covered by landslide or talus debris and colluvium, but the pre–Pierre Shale marine rocks are well exposed about 10 mi north of here at Gold Creek and are described in a section measured by Pillmore and Eicher (1976, pp. 171–176). **Continue drive eastward. 0.4**

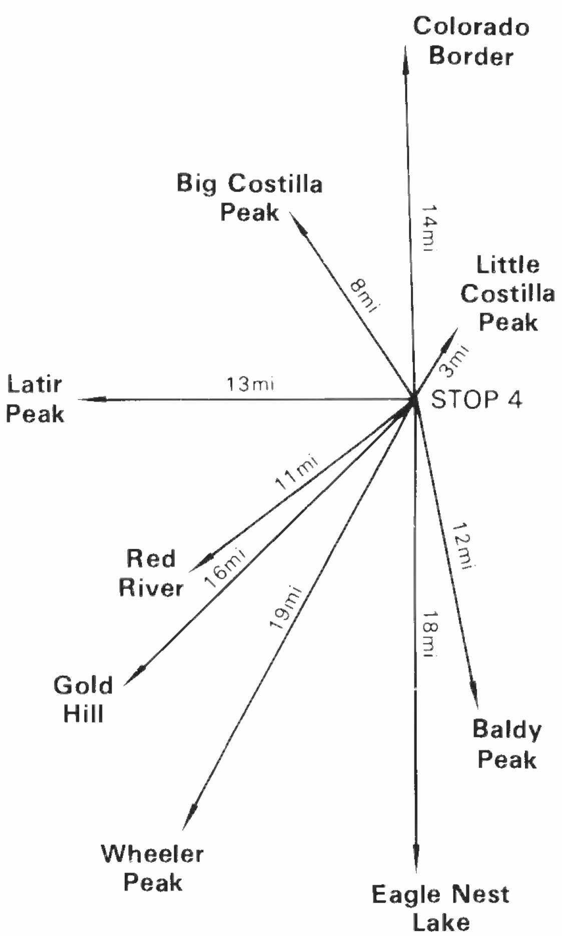


FIGURE 1.28. Panoramic mileages from Stop 4.

61.5 We are now close to the fault trace of the Blue Lake thrust. Deformed Proterozoic (probably granitic) rocks with mafic dikes are exposed in a quarry on the hill to the left. Just ahead, in the drainage, is the trace of the thrust fault, unfortunately covered by red colluvium and fan deposits probably derived from the Pennsylvanian and Permian Sangre de Cristo Formation. The Sangre de Cristo Formation consists of pinkish gray to dark reddish brown and very dark red, fine-grained to conglomeratic, poorly sorted micaceous subarkosic sandstone, mostly of presumed Wolfcampian (Early Permian) age (based on its probable equivalence to the Abo and Cutler Formations of adjoining regions). **0.2**

61.7 At about 8:00, high on the hill, are overturned Jurassic Exeter (Entrada) Sandstone and Triassic Dockum Group. The roadcut exposes colluvium washed down from these rocks. **0.1**

61.8 The red dirt in the roadcut to the left is probably derived from rocks of the Dockum Group. **0.4**

FIGURE 1.29. View across the Valle Vidal to the east. The dark lines of vegetation and minor breaks in slope on the east side of the valley represent a young (Quaternary?) scarp of a normal fault that probably is an expression of reactivation along the covered Little Costilla thrust fault. The Shuree Lakes are in the meadow in the center left of the photograph, and Beatty Lakes are in the right center. The far distance is across the Park Plateau. Photo by Jim Walker.

62.2 The hill to the right at about 2:30 is composed of Cretaceous Dakota Sandstone. J. Walker (unpubl. mapping) mapped a fault extending to the south that repeats the Dakota. The high ridge ahead at 12:00 is the Ash Mountain rhyolite dike.

The rhyolite dike of Ash Mountain forms a prominent ridge that extends north about 7 mi from the Valle Vidal area. It is mostly a vertical tabular body about 200 ft thick, but locally it thickens to about 500 ft. It forms a sheer wall many places along the west side of the dike (Fig. 1.30) but the east side is totally covered by talus and rock stream deposits. Ash Mountain is aptly named because when viewed from the east and north, the northern end of the dike forms a peak 10,972 ft in elevation and resembles a huge pile of ashes (Fig. 1.31), even though it consists entirely of large blocks of hard, resistant rhyolite. The rock resembles quartzite on its fracture surface but it is easily distinguished in river and terrace gravels by its distinctive grayish-yellow to grayish-orange color. The rock is a rhyolite porphyry with phenocrysts of quartz and feldspar, and its chemical composition is (weight percent): SiO_2, 75.1; Al_2O_3, 14.0; Fe_2O_5, 0.15; FeO, 0.2; MgO, 0.1; CaO, 0.47; Na_2O, 4.9; K_2O, 4.1; H_2O^+, 0.37; P_2O_5, 0.13; MnO, 0.19; and CO_2, 0.11.

Attempts at dating the rhyolite by fission track methods failed because of the metamict nature of the zircon. It almost certainly falls into the 23–26 Ma group of rocks associated with the Latir volcanic field. Clasts of the rhyolite will be visible along the route ahead and at mile 71.2 where the gravel that armors the McCrystal pediment surface is exposed. **0.1**

62.3 Gray shale with bentonites on left is Upper Cretaceous Carlile Shale above bedded limestones of the Bridge Creek Member of the Greenhorn Formation. The Greenhorn here is mostly medium light gray to light olive gray fossiliferous limestone, shale and bentonite that are overturned, dipping 44° westward. It contains abundant fossils of the inoceramid bivalve *Mytiloides mytiloides* (Fig. 1.32), characteristic of the *Mammites nodosoides* ammonite zone of early Turonian (Late Cretaceous) age (Hattin, 1987). **0.4**

FIGURE 1.30. Photograph showing the near-vertical west wall of Ash Mountain dike and a rock stream at the base of the talus slope. Photo by C. L. Pillmore.

FIGURE 1.31. View north across McCrystal Creek notch, along Ash Mountain dike to Ash Mountain in the distance. At this point, the dike is probably several hundred feet wide, but the margins are covered with talus. Photo by C. L. Pillmore.

62.7 On the left, overturned baked shale beds of the Smoky Hill Member of the Cretaceous Niobrara Formation dip 55° to the SW. **0.1**

62.8 **Cattleguard;** roadcut on left in pale olive to olive black shale/hornfels of the lower part of the Pierre Shale (Late Cretaceous). Among the trees on the left is a gray and dark yellowish orange limestone concretion. A rhyolite dike that resembles Ash Mountain dike cuts shale beds at road level. **0.4**

63.2 Approximate trace of a thick dike of the rhyolite of Ash Mountain. The rhyolite dike extends 7 mi north from here, is as wide as 500 ft, and forms a major high topographic ridge. The distinctive yellowish and orangish-gray clasts from this dike are resistant to weathering and they make up the armored gravel that caps pediment and terraces to the east. These clasts have been found several miles downstream in terraces of the Vermejo River. Here, where the dike crosses the valley, it appears no more resistant to weathering than the country rock,

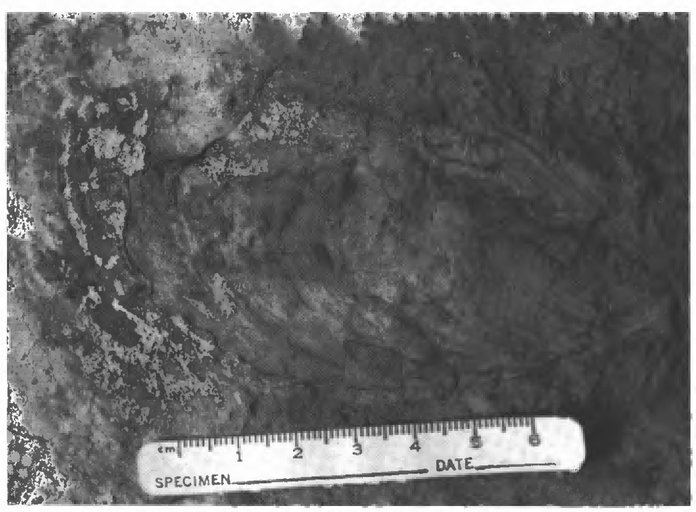


FIGURE 1.32. *Mytiloides mytiloides* from the Bridge Creek Member of the Greenhorn Formation is a characteristic index fossil of the Greenhorn across its outcrop extent from Kansas to Deming, New Mexico. Bar scale is in cm. Photo by S. G. Lucas.

but to the north this dike forms prominent ridges. **0.2**

63.4 The road to the right leads to a quarry in the Pierre Shale, used by the Forest Service to obtain rock for resurfacing this road. **0.2**

63.6 Road to the right leads to the Cimarron Campground, the middle fork of Ponil Creek and ultimately back to this road (Forest Road 1950) east of the Rock Wall at the Beatty Lakes turnoff. In the valley at about 9:00 the ruins of the old Shuree cow camp are visible. Audrey (Chase) Brewer, who was born and raised at Chase Ranch, about 23 mi downstream from here, remembers coming to this cow camp with her father in a springwagon buggy about the time of World War I. **0.1**

63.7 Road crosses Middle Fork Ponil Creek. Roadcut on left exposes steeply dipping beds of Pierre Shale that contain fragments of large coarse-ribbed inoceramids, large concretions and numerous thin bentonite beds.

We are now on the western margin of the Raton basin as defined by the outcrop of the Trinidad Sandstone. This Laramide basin is about 85 mi long (N-S), as much as 50 mi wide (E-W) and strongly asymmetric. It has steeply dipping to overturned beds on its western limb (here) and a gently dipping eastern limb that merges with the Sierra Grande and Apishapa (southeastern Colorado) arches (Fig. 1.33). There are about 15,000 ft of structural relief between the Raton basin and the Sangre de Cristo uplift. As much as 10,000 ft of sedimentary rocks, ranging in age from Mississippian (or older?) to Paleocene, fill the Raton basin (Roberts et al., 1976). **0.1**

63.8 Small quarry in the Trinidad Sandstone at the bend in the road. Sandstone contains *Ophiomorpha* trace fossils. Sandstone beds of the Trinidad and the basal part of the Raton Formation bracket the Vermejo Formation and form a double ridge that parallels the Ash Mountain dike and extends up the hill to the left for about a mile before being covered by talus debris from the dike. The same units form the ridge to the south across the valley. The

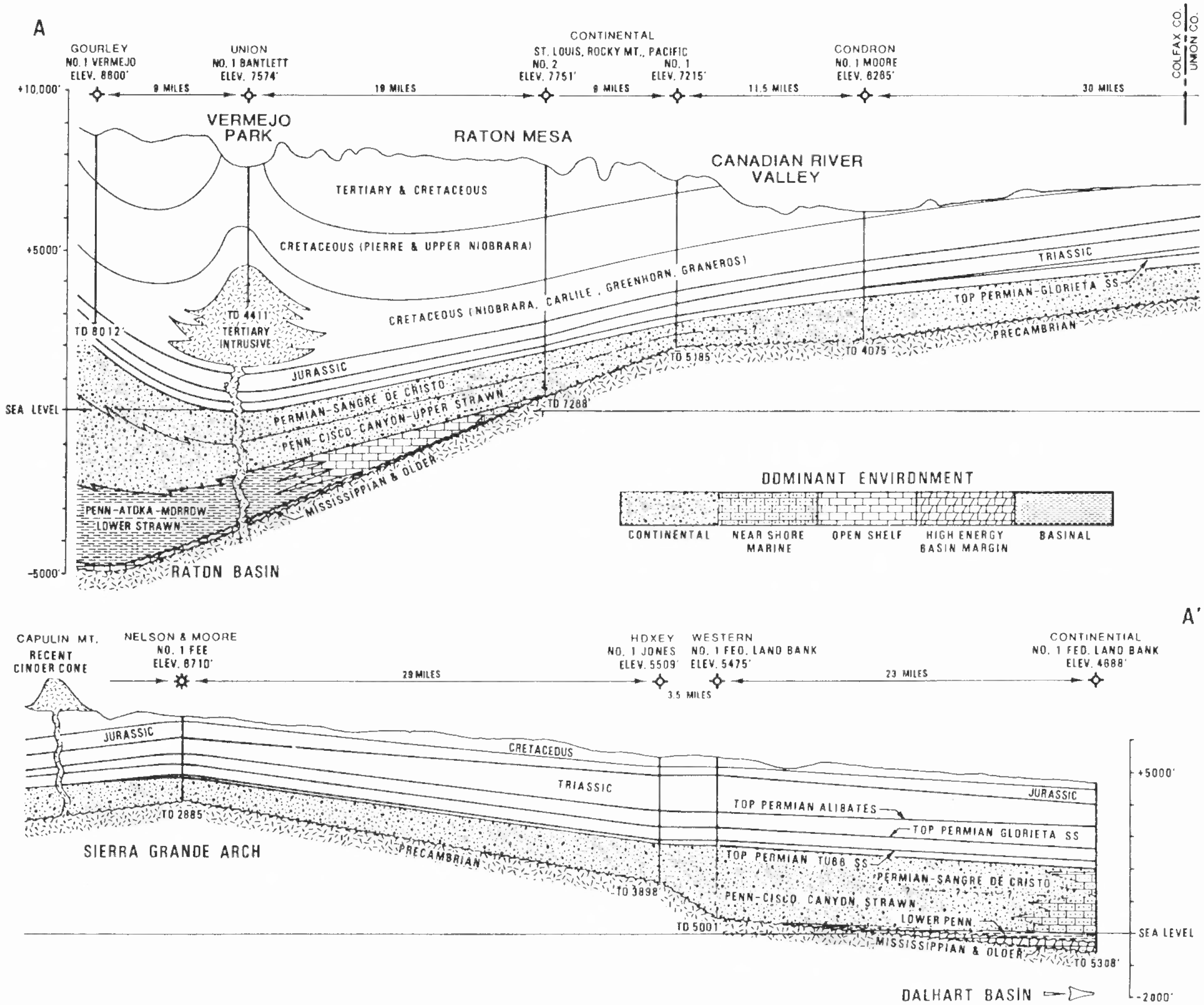


FIGURE 1.33. Regional east-west cross section through the Raton basin, Sierra Grande arch, and into the Dalhart basin. Taken from Roberts et al. (1976) in the NMGS Guidebook 27.

trace of the Trinidad Sandstone marks the western margin of the Raton coal field, but in this area of sparse exposures, no coal beds have been found, only carbonaceous siltstones and shales. **0.1**

63.9 Roadcut exposes beds of conglomerate, sandstone and siltstone of the Raton and Poison Canyon Formations undivided. **0.7**

64.6 Junction with road on right to Shuree Ponds. **Optional stop. Turn right** and **park** in the parking lot north of the pond. The high peak to the south is Baldy Mountain (12,441 ft). The ridge to the east of here is called the Rock Wall. It is one of several dacitic dikes intruded radially from Baldy Mountain. Here it intrudes the Poison Canyon Formation.

One of the previous owners of the Valle Vidal was W. J. Gourley, who purchased the area in 1948. Soon after the purchase, he built Shuree Lodge as a hunting lodge. The lodge sleeps about 40 comfortably. The Forest Service presently uses the lodge on a limited basis as crew quarters.

Retrace route to the road. Turn right onto Forest Road 1950 to continue trip eastward. **1.1**

65.7 **Windy Gap cattleguard.** Road crosses the Rock Wall (Windy Gap) dacite dike. Begin descent down the east side of the Rock Wall into the Raton basin. **0.7**

66.4 The ridges to the south are extensions of the Rock Wall dike and a second, and less-resistant third, dike to the east that are nearly parallel. Sandstone beds of Poison Canyon–type lithology that weather to distinctive grayish orange to dark yellowish orange soils are exposed along the roadcuts. The southern switchbacks on this descending part of the route afford a grand view out to the east over the Park Plateau supported by sandstones of the Poison Canyon Formation in the foreground, and mostly by rocks of the Raton Formation in the distance. The broad wooded flat in the bottom of the valley to the east is the McCrystal pediment surface that is armored by gravel composed of rhyolite clasts of the Ash Mountain dike. Just south of east are the wind-formed depressions of the Beatty Lakes, perhaps similar in origin to Adams and Bartlett lake basins that sit atop a high gravel-covered mesa 9 mi to the north (Pillmore, 1976, pp. 121–124). If it is a clear day, you should be able to see the Tooth of Time about 25 mi south-southeast near the headquarters of the Philmont Scout Ranch, our destination for this evening. **1.0**

67.4 At second switchback. On the left, the Rock Wall forms the ridge above road level. **0.9**

68.3 Larger channel sandstones are becoming more prevalent in the Poison Canyon Formation along this roadcut. The sand bodies are 160–245 ft wide and up to 10 ft thick in mudstones. They are simple to multistoried with gravel lags on each bounding surface, and show trough cross-bedding with some evidence of lateral accretion deposits and interbedded organics. **0.6**

68.9 In the foreground, on the hill directly ahead, is the Rock Wall. The higher hill behind, Ash Mountain ridge, is composed of rhyolite, and the highest hill in the background is Little Costilla Peak (12,585 ft), composed of Proterozoic rocks in the upper plate of the Little Costilla thrust. **2.1**

71.0 Road to the right goes to Beatty Lakes. **0.1**

71.1 **Cattleguard.** The road is on a pediment surface armored with dense clasts of rhyolite from Ash Mountain. **0.2**

71.3 On right is road to the Ring Place. Timothy Ring was a rancher who, along with his neighbor John McCrystal, pioneered cattle ranching in northern New Mexico. In 1890, Ring purchased 320 acres of the Valle Vidal, and began construction of a magnificent, massive, log home which forms the architectural centerpiece of the Ring Place (Fig. 1.34). When completed, the house had four bedrooms on the first floor and six more on the second. Seven reasons for the large number of rooms were most certainly the seven daughters born to Catherine Ring. After Timothy died and his family sold out in 1906, the Ring Place went to various owners until donated to the Forest Service in 1981. The buildings have stood vacant for many years, and in 1987–1988 Forest Service personnel (mainly archaeologists from New Mexico and Arizona) performed stabilization and restoration. The house was jacked up, 50 timbers were replaced, and both the house and the barn were reroofed. Although the Ring sisters have not been home for a long time, the magnificent house their father built still stands. **0.1**

71.4 The small quarry on the left in the roadcut exposes the gravel comprised of rhyolite clasts from Ash Mountain, that armors the McCrystal pediment cut on Poison Canyon Formation. The gravel is only a thin veneer on the pediment surface (Fig. 1.35). **0.3**

71.7 McCrystal Creek Campground entrance. From here to Stop 4, on the left and back a little into the trees, you might see the remains of a high 10-wire fence that once enclosed an area of about 1 mi^2 and was called the elk trap. When W. J. Gourley of Fort Worth, Texas, bought the Vermejo Ranch in 1948, the once-prevalent elk were only rarely seen. In order to build an elk herd to meet his plans for a prestigious hunting resort, Gourley imported elk from Yellowstone Park and placed them in this trap, and another smaller trap about 10 mi north, so that they could become accustomed to the region and wouldn't wander from the ranch. The elk flourished and were released, the herd grew, and Vermejo Ranch became the private hunting reserve for the rich and privileged that Gourley had envisaged. The Shuree lodge is one of three rustic, yet luxurious, lodges (in addition to the accommodations at Vermejo Park) that he developed for his guests. Pennzoil still owns the remaining 380,000 acres of the original Vermejo Ranch, and in 1989 also purchased the area that joins the ranch to the east, formerly owned by Kaiser Steel Corporation. Thus, the Vermejo Ranch now covers nearly 700,000 acres, more than 1000 mi^2, and the elk herd on it is probably the largest "privately owned" herd in the country. The ranch is also a popular fishing resort, and hunts for deer, bear and turkey are also held each year. What is the cost of such entertainment? If you have to ask, you probably can't afford it. The ranchland and National Forest land adjacent to the Vermejo Ranch have benefited greatly from the development of the Vermejo elk herd. **0.2**

71.9 **Cattleguard. 0.8**

72.7 Road crosses North Ponil Creek. **Optional stop. Park on right shoulder.** Look about 0.5 mi downstream of the north side of the valley to see the rugged ridge formed by another of the radiating dacite dikes. This

FIGURE 1.34. The Ring Place in 1921. Timothy Ring began construction of this massive log structure in 1890. The house contains four bedrooms on the first floor and six on the second—adequate to accommodate his seven daughters. The cowboys, from left, are Shorty Murry the ranch foreman, Mason Chase of the Chase Ranch in Cimarron, unknown, unknown, Willie Dunn and his brother Walter Dunn. During 1987–1988 the building was renovated by Forest Service personnel. Photo printed from a copy negative owned by Mrs. Marilyn Decker of Raton. Courtesy of J. N. Young, U.S. Forest Service, Taos, NM.

one extends for several miles from Baldy Mountain, but it dies out a short distance north of the stream valley.

McCrystal Creek joins North Ponil Creek a short distance west of the road. McCrystal Creek heads in a beautiful little valley nestled between Little Costilla Peak and Ash Mountain, both of which are visible to the west. Little Costilla is capped by Proterozoic rocks thrust over Sangre de Cristo Formation (Permian-Pennsylvanian). The Little Costilla thrust fault is nearly flat-lying at about timberline around the north side of the peak (Fig. 1.36). The rhyolite of Ash Mountain forms the dominant ridge in front of Little Costilla Peak. McCrystal Creek flows through the notch in the ridge. There used to be beaver dams 5–6 mi upstream from here, but the beaver left when it got dry in the early 1960's. According to Audrey (Chase) Brewer, when her family would come by wagon to visit the McCrystal family many years ago, this little stream produced all of the native cutthroat trout they could eat.

FIGURE 1.35. Gravel comprising clasts of rhyolite of Ash Mountain on McCrystal pediment surface cut into arkosic sandstones of the Poison Canyon Formation at mile 71.4. Black dog for scale. Photo by C. L. Pillmore.

The broad valley to the west contained the elk trap. For many years after releasing the elk, Mr. Gourley kept a small herd of buffalo within the enclosure. Under Pennzoil's ownership, the buffalo herd has been allowed to expand, and now nearly 50 animals graze freely in the upper reaches of Van Bremmer Canyon, across the ridge to the north. The crest of this ridge appears beveled at an angle to bedding in the Poison Canyon Formation, which would indicate the presence of an erosional (pediment) surface; yet, no gravel caps the surface (Fig.

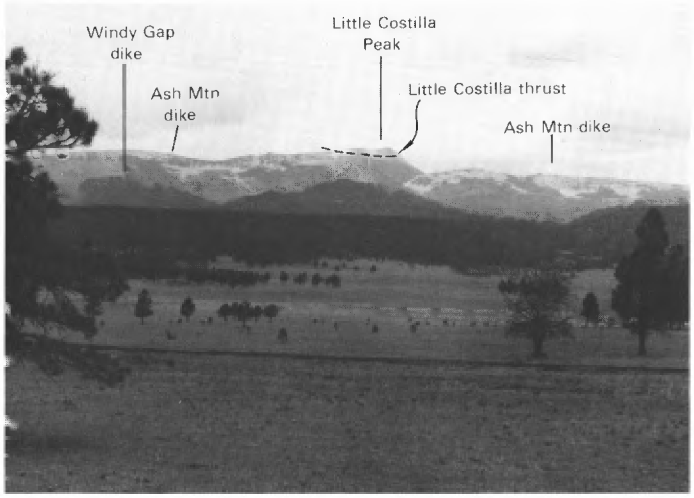


FIGURE 1.36. View west from optional stop at mile 72.7, across Whiteman Vega to Little Costilla Peak and Ash Mountain dike. The dark, tree-covered, flat-surfaced ridge in the foreground is the McCrystal pediment. Buffalo are grazing in the elk trap. Photo by C. L. Pillmore.

1.37). The prominent scarp that crosses the valley from southeast to northwest is formed by the edge of the McCrystal pediment, covered by gravel composed principally of rhyolite washed down from the Ash Mountain dike. The valley that extends to the northwest from here is Whiteman Vega. It was excavated by McCrystal Creek when the creek began downcutting its old pediment-covered valley floor through the easily eroded friable channel sandstones and clayey sandstone interbeds of the Poison Canyon Formation. The pediment surface, which is considered equivalent to the San Miguel surface (Pillmore and Scott, 1976) is about 400 ft above the valley floor at the upper part, but only about 200 ft above the creek level at the lower part; the gradient of the pediment exceeds the gradient of the stream.

North Ponil Creek, to the south, leads to the ghost town of Ponil Park, an abandoned sawmilling community that flourished during the early part of the century (Fig. 1.38). Tombstones date from as early as 1880, and

FIGURE 1.37. View northwest across Whiteman Vega from optional stop at mile 72.7 on McCrystal Creek. Note the planar surface cut at an angle to the bedding of Poison Canyon Sandstones. No gravel is present on this surface. Photo by C. L. Pillmore.

FIGURE 1.38. Ponil Park, 22 mi northwest of Cimarron, came into existence during 1907 when the Cimarron and Northwestern Railway, a wholly owned subsidiary of the Continental Tie and Lumber Company, extended its tracks into the parent's timber holdings along North Ponil Creek. Sawmills were constructed at Ponil Park and at Ring a few miles farther up the line. Ultimately, as the timber became exhausted, trackage was pulled back so that by 1 May 1921 when the above photo of Mill #2 was taken, Ponil Park was again the railhead. Permission to abandon the line back to South Ponil Creek at a point called "The Forks" was received 29 August 1923 and Ponil Park became history soon after. Courtesy of J. N. Young, U.S. Forest Service, Taos, NM.

a post office existed in 1879. When the narrow gauge railroad arrived from Cimarron in 1908, Ponil Park boomed, and every commercial pine tree for miles was harvested. When the railroad was discontinued in 1923, Ponil was abandoned, and only decaying log cabins remain today.

From here, the route continues for 2 mi up Hart Canyon and about 4 mi down Lookout Canyon through rocks of the Poison Canyon Formation. Thick, cavernous, massive, gently dipping channel sandstones form prominent outcrops near the road and ledges and cliffs on the hillsides. The valleys are typically broad, open and grass-covered. **0.4**

73.1 Although the amount of organic matter and small coal seams in the Poison Canyon Formation increase as we drive eastward, they are still too minor for this rock to be considered as Raton Formation. **0.2**

73.3 The hills of Poison Canyon Formation on either side of the road are capped by large channel sandstones that are several feet thick, many yards wide, and tend to form ridges. **1.4**

74.7 Windmill. Still in Poison Canyon Formation channel sandstones. **0.4**

75.1 Road sign. US-64 is 23 mi ahead. **0.2**

75.3 Turnoff to Cerrososo entrance of Vermejo ranch. Locked gate. **2.6**

77.9 Windmill on left. **2.4**

80.3 **Cattleguard** at the junction of Lookout and Cerrososo Canyons marks the east boundary of the Valle Vidal Unit of the Carson National Forest. From here to US-64 the road follows Cerrososo Canyon and crosses restricted-access land of the Vermejo Ranch. **2.0**

82.3 Passing the ranch buildings of the Van Houten camp. Below here the soil color changes from the yellows and oranges of the Poison Canyon Formation, through a transition zone about 100 ft thick, to the gray tones of the Raton Formation. Some carbonaceous shale and thin coal beds are present in this zone and at the top of the Raton Formation. The contact is generally placed above the highest coal bed. **0.9**

83.2 Coal seam about 3 ft thick in the cut on the left side of the road is the uppermost coal bed in the Raton Formation. **0.5**

83.7 The thick white sandstones at road level are channel deposits in the upper coal zone of the Raton Formation. The Raton Formation is divided into: (1) a lower coal zone that includes the basal conglomeratic sandstone and consists of mudstone, sandstone and thin coal beds; (2) a barren series that consists mostly of stacked channel sandstones with few coal and carbonaceous shale beds; and (3) an upper coal zone that east of here contains most of the coal beds of commercial thickness in the Raton coal field (Fig. 1.39). **5.9**

89.6 Sign: "US-64 11 mi." **0.7**

90.3 Note soil horizons developed on alluvium in the arroyo. **1.3**

91.6 Sandstone in the bottom of the arroyo from 10:00–11:00 is probably close to the top of the barren zone of the Raton Formation. **1.8**

93.4 Road passes through massive sandstones of the barren zone of the Raton Formation. **1.3**

94.7 Stream meander off to the right of the road exposes a zone of mudstone and carbonaceous shale with two coal beds about 10 ft apart (Fig. 1.40). This sequence is near the top of the lower coal zone of the Raton Formation and probably contains the Tertiary-Cretaceous boundary, but detailed pollen work has not been done on these coals and the iridium-rich boundary claystone layer has not been found. A friable sandstone unconformably

AGE		FORMATION	GENERAL DESCRIPTION	APPROXIMATE THICKNESS (ft)	(m)
TERTIARY	PALEOCENE	POISON CANYON FORMATION	Sandstone, roarse to conglomeratic, beds 5 ft (1.5 m) to more than 50 ft (15 m) thick, interbeds of soft yellow-weathering cloyey oandstone; thickens to west at expense of underlying rocks.	500+	(150+)
		RATON FORMATION	Sandstone, very fine grained to fine grained, with interbeds of claystone, siltstone, and coal; commercial coal beds in uppec part. Lower few fect coneIomeratic; intertongues with Poison Canyon to the west. Generally sharp erosional contact with underlying Vermejo Formation.	0-2,000	(0-610)
CRETACEOUS	LATE CRETACEOUS	VERMEJO FORMATION	Sandstone, very fine gcained to medium erained, interbedded with mudstone, carbonaceous shale, and coal; extensive thick coalo top and bottom.	0- 380	(0-115)
		TRINIOAD SANDSTONE	Sandstone, very fine grsined to medium gcained; contains casts af *Ophiomorpha* sp.	0- 130	(0- 40)
		PIERRE SHALE	Black shale, Iimestone contretions, silty in uppec part; grades up to sandstone.	2,500+	(760+)
		NIOBRARA FORMATION	Limestone and calcareous shale; consists of the Smoky Nill and Fort Hays Limestone Members.	500+	(150+)
		CARLILE FORMATION	Black shalc, gray calcareous shale, and calcarenite; ronsists of the upper black shale unit, and Juana Lopez, Blue Hill Shale, and Faicport Members.	250	(76)
		GREENHORN FORMATION	Limestone and calcareous shale. Consists of the Bridge Creek Limestone Membec and the Hartland and Lincoln Members.	130	(39)
		GRANEROS SHALE	Black shale and shaiy limestone.	110	(33)
	EARLY CRETACEOUS	DAKOTA SANDSTONE	Quartzitic sandstane.	145	(44)
		PURGATOIRE FORMATION	Dark-gray silty shale of the Glencaicn Shale Member equivalent and conglomeratic sanostonea, about 50 ft (15 m) thick, that consist of granules and pebbles af pink and gray chert as lacge as 1 in. (2.5 cm) in diameter.	70	(21)
JURASSIC	LATE JURASSIC	MORRISON AND RALSTON CREEK(?) FORMATIONS	Red and green claystone, limestone, and sandstone with gypsiferous siltstane and claystone contsining jaspec.	200- 300	(60- 90)
		ENTRABA SANDSTONE	Fine-grained sandstone; cheet granules at base.	70- 95	(21- 30)
TRIASSIC	LATE TRIASSIC	JOHNSON GAP AND CHINLE FORMATIONS	Beds of limestone pebble canglomecate, siltstone, and asndstane of the Johnson Gap in upper two-thicds af unit. Red to grsyish-purple siltstones and sandstones; white conglomeratic sandstone of the Chinle in lower part.	198	(58)
PENNSYLVANIAN-PERMIAN		SANGRE DE CRISTU FORMATION	Red and gray conglamerate and sandstone.	1,000+	(305+)
PRECAMBRIAN			Gnelos, schist, quartzite, and grsnite.		

FIGURE 1.39. Generalized stratigraphic column for the Raton basin.

FIGURE 1.40. Carbonaceous shale and coal zone at the top of the lower coal zone of the Raton Formation. This zone probably contains the K-T boundary, but the K-T boundary clay has not been found here. Photo by C. L. Pillmore.

overlies mudstones at top of cut ±12–15 ft above upper coal. **0.2**

94.9 Stacked channel sandstones on either side of road represent base of barren series. **0.4**

95.3 Approximate base of Raton Formation; ledge on the east side of valley is formed by basal conglomerate. **0.2**

95.5 Road starts to climb. Landslides obscure slopes on east side of canyon. **0.1**

95.6 Roadcut exposes sandstones and mudstones of lower coal zone of the Raton Formation. **0.4**

96.0 Top of hill. Just over the crest look across the canyon (Fig. 1.40). Grayish red and brownish and yellowish-orange cliffs of the barren zone of the Raton Formation cap the ridge with landslide-covered slopes of the lower coal zone beneath. Ledges of Raton conglomerate visible at base of slope. The conglomerate unconformably overlies the coal-bearing, slope-forming Vermejo Formation. Coal bed in the Vermejo visible at bottom of canyon beneath Raton conglomerate if you look closely. Grayish ledges of the Trinidad Sandstone visible in valley bottom about 1 mi downstream. **0.3**

96.3 Driving along landslide and talus-covered lower coal zone of the Raton. Good view back up the canyon of the section we've been driving through. **0.2**

96.5 Road levels out and entire section from barren zone to Trinidad is visible across and down the canyon. **0.3**

96.8 View across valley—gray cliffs of the Trinidad Sandstone in bottom of canyon overlain by slopes of the Vermejo Formation—basal Raton conglomerate at about road level in lower midslope with ledges and cliffs of the barren zone composing the upper third of the slope and capping the ridge. **0.7**

97.5 Bottom of the hill. Old adobe cabin ruin on left. **Turn left** off road through gate (if permitted), and park on flat for **STOP 5.** Exposure of top of Pierre Shale in stream bank across valley. **Walk** 0.4 mi up road to junction with Bat Canyon to see excellent exposures of the Trinidad Sandstone with *Diplocraterion* and *Ophiomorpha* and other trace fossils.

From this stop, we are nearly surrounded by the units that we have been driving through (Fig. 1.41). Capping

FIGURE 1.41. View across Cerrososo Canyon from Stop 5 showing: Kt = Trinidad Sandstone; Kv = Vermejo Formation; Krlc = Raton Formation conglomerate; Krl = lower coal zone of the Raton Formation; and Trub = barren zone of the Raton Formation. Photo by C. L. Pillmore.

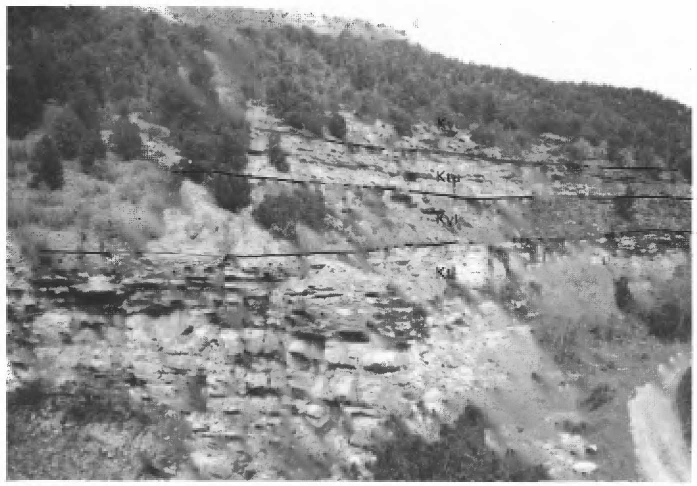


FIGURE 1.42. View showing the double Trinidad Sandstone near Stop 5. The lower (Ktl) and upper (Ktu) parts of the Trinidad Sandstone are separated by the lower tongue (Kvl) of the Vermejo Formation. The upper part of the Vermejo Formation (Kvu) overlies the Trinidad. Photo by C. L. Pillmore.

the mesas are the thick, stacked, channel sandstones of the barren zone of the Raton Formation. The slope beneath is formed by the lower coal zone of the Raton and the Vermejo Formation, separated by the minor ledge-forming basal Raton sandstone that is locally conglomeratic. The cliff-forming Trinidad Sandstone is generally prominent and traceable for miles. It is underlain by the Pierre Shale, which contributes to large landslides caused by oversteepening of slopes beneath the Trinidad cliffs. This stratigraphic sequence is nearly continuously exposed along the margin of the Raton coal field for nearly 40 mi, from Cimarron to Raton.

At this location the Trinidad consists of an upper and a lower sandstone (Fig. 1.42), as observed by Wanek (1963). According to Haynes and Flores (written commun., 1988), in this region the Trinidad Sandstone consists of an eastward-pinching lower unit and a westward-pinching upper unit separated by an eastward-pinching tongue of the Vermejo Formation. The lower Trinidad consists of coarsening-upward, bioturbated, hummocky, planar and trough-crossbedded sandstone in the lower part, and rooted, parallel and ripple-laminated sandstone in the upper part. These deposits represent a regressive wave-influenced, barred beach-shoreface complex. Siltstone, mudstone, carbonaceous shale and coal beds of the overlying eastward-pinching tongue of the Vermejo Formation represent back-beach swamp and estuarine environments.

The upper unit of the Trinidad Sandstone has an erosional base and coarsens upward. It consists of multiple scoured bodies of trough and planar-crossbedded and convolutely bedded sandstone. The lower sandstone bodies of this unit are bioturbated and contain Toredo bored wood. The upper unit of the Trinidad Sandstone records a transgressive (backstepping) pulse that resulted in tidal inlet and estuarine environments. The upper Trinidad Sandstone pinches out westward into sandstone, siltstone, mudstone, carbonaceous shale and coal beds of the Vermejo Formation. Locally, the top of the lower unit is a bioturbidite of *Diplocraterion* trace fossils. *Diplocraterion* resembles a ladder formed by U-shaped tubes as long as 3–4 ft with spreite linking the tubes, as described in Pillmore and Mayberry (1976, p. 192).

As we continue on, the hillsides west of the gate are covered by landslide debris with ledges of Trinidad Sandstone cropping out. **0.9**

98.4 Broad terrace flats at the mouth of Cerrososo Canyon were sites of Indian encampments. Landslides cover the Pierre Shale across the valley to the east. **2.7**

101.1 **Junction** with US-64. **Turn right** to Cimarron. After turn, at 1:30, note section from Pierre Shale up through basal Raton Formation. **0.4**

101.5 Milepost 314. **0.7**

102.2 Low hill at 3:00 rising from slopewash plain at the foot of the mountain front is composed of dikes of hard gray aphanitic syneite that intrudes Pierre Shale. **1.3**

103.5 Milepost 312. Vista. To the south, the flat-topped mesas on the skyline include Gonzalitos Mesa at 8:30, Horse Thief Gap at 9:00, Rayado Mesa from 9:00–9:30 and Ortega Mesa from 9:30–10:00. From 10:00–11:00 is Tooth of Time Ridge; at 11:00 is the town of Cimarron, from 11:00–12:30 is the Cimarron Range; at 12:00 is Antelope Mesa; at about 2:00 is Ponil Creek Canyon; and from 2:00–3:00 is Indian Head. Indian Head consists of high prominent cliffs formed of thick, stacked channels of the barren series of the Raton Formation.

Landslides locally obscure the Cretaceous Vermejo Formation, Trinidad Sandstone and underlying Pierre Shale slopes. The thin blocky ledge at midslope, beneath the sandstone cliffs, is the basal conglomerate of the Raton Formation. The gray sandstone ledges below form the Trinidad Sandstone.

The Ocate volcanic field, located principally in Mora County to the south and east, formed between 8.0 and 0.8 Ma in five eruptive pulses (Nielsen and Dungan, 1985; O'Neill and Mehnert, 1988). Five main rock types are present—alkali olivine basalt, transitional olivine basalt, xenocrystic basaltic andesite, olivine andesite and dacite—and constitute more than 20 mi^3 of igneous rock.

Wagon Mound and Las Mesas de Conjelon to the east, probably the most familiar features of the Ocate volcanic field, mark an east-trending fissure system dated at 5.9 Ma. Maxon Crater, 7 mi south of Wagon Mound, is a large basaltic shield volcano within the field. At about 1.4 Ma, lava flowed from this crater to the east, down the canyon carved by the Mora River, a short distance beyond the confluence of the Mora and Canadian Rivers. See paper by O'Neill and Mehnert (this guidebook) for more information. **0.7**

104.2 Roadcut is in the Pierre Shale. Glenn Scott collected *Exitiloceras jenneyi* and *Baculites rugosus* at this locality. The Santa Fe Trail crossed the location of the present highway at this point and continued south across Ponil Creek into Cimarron.

In the Cimarron area, three well-defined gravel-capped pediment levels rise above the alluvial terraces and flood plains of the Cimarron River and Urraca and Rayado Creeks to the south (Fig. 1.43). These pediments were first studied by Smith and Ray (1943) and have recently been mapped by Scott (1986) and Scott and Pillmore (1989), who had adopted the terminology of Levings (1951). Levings originally identified and named three pediments (surfaces) near Trinidad, Colorado, on the north side of Raton and Barilla Mesas. From highest to lowest they are: the San Miguel, Beshoar and Barilla surfaces. He applied these names to similar pediments in the Raton area on the south side of the mesas. Later, Pillmore and Scott (1976) correlated these pediments with other Tertiary(?) and Quaternary surfaces farther north along the eastern front of the Rocky Mountains and they extended their correlations to the Cimarron and Moreno Valley areas. Figure 1.44 shows their correlations and the approximate height of the surfaces above modern stream levels. **0.3**

104.5 Road to right up Ponil Creek crosses private land, mostly of the Chase Ranch and Philmont Scout Ranch. The Chase Ranch, along with Maxwell's house in Cimarron, was where Governor Lew Wallace wrote the last chapters of *Ben Hur*. Gravels on top of the Barilla pediment surface cap the low mesa across Ponil Creek to the west. A road log to the North Ponil–Philmont Cretaceous–Tertiary boundary site is included as Supplemental Road Log 4 (from Pillmore et al., 1988); however, it is on private property of the Philmont Scout Ranch and not open to the public. Ahead is the Cimarron Range of the Sangre de Cristo Mountains (Fig. 1.45). **0.2**

104.7 Crossing bridge over Ponil Creek. In 1846, General Kearny and his Army of Occupation made a night camp near here when the U.S. claimed the Province of New Mexico. **0.1**

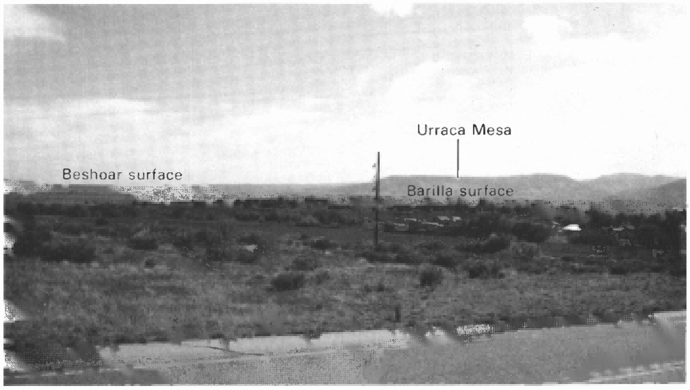


FIGURE 1.43. View south across Ponil Creek at mile 104.2 showing pediment surfaces of the Cimarron area. Ranch buildings of the Vermejo Ranch's WS headquarters are in the foreground. Photo by C. L. Pillmore.

104.8 WS Ranch, Cimarron headquarters of the Vermejo Ranch on the left. The WS Ranch, established as an English company in 1899, specializes in Hereford cattle, as do most ranches in this area. **0.3**

105.1 **Cimarron** village limit (Figs. 1.46, 1.47) Several low terraces and remnants of the various pediment levels are visible from here. General Slough and his Colorado Volunteers camped here in 1862 on their march to Fort Union to save the fort from the advancing Confederate Army which had taken Santa Fe. **0.1**

105.2 Lumberyard on left. **0.1**

105.3 Official Scenic Historic Marker reads:

Cimarron, population 888, elevation 6,427 feet. This village on the Mountain Branch of the Santa Fe Trail was settled around 1844. In 1857 it became the home of Lucien B. Maxwell, and headquarters for the famous Maxwell Land Grant of almost 2,000,000 acres. An agency for Utes and Jicarilla Apaches was located here from 1862 to 1876.

0.5

105.8 **Junction** with NM-58 in Cimarron. **Continue straight.** Town plaza is on the right. **0.4**

106.2 Four Official Scenic Historic Markers read:

Santa Fe Trail. Opened by William Becknell in 1821, the Santa Fe Trail became the major trade route to Santa Fe from Missouri River towns. The two main branches, the Cimarron Cutoff and the Mountain Branch, joined at Watrous. Travel over the trail ceased with the coming of the railroad in 1879.

Santa Fe Trail. The difficulty of bringing caravans over rocky and mountainous Raton Pass kept most wagon traffic on the Cimarron Cutoff of the Santa Fe Trail until the 1840's. Afterwards, the Mountain Branch, which here approaches Raton Pass, became more popular with traders, immigrants, goldseekers, and government supply trains.

Colfax County war. For twenty years after the 1869 sale of the Maxwell Land Grant, homesteaders, ranchers, and miners fought the new owners for control of this enormous region. The resulting murders and general breakdown of law and order led to the removal from office in 1878, of Territorial Governor Samuel B. Axtell.

Black Jack's hideout. In Turkey Creek Canyon near here, the outlaw gang of Thomas "Black Jack" Ketchum had one of its hideouts. After a train robbery in July 1899, a posse surprised

NEW MEXICO				COLORADO				
Vermejo Park area (this report)	Cimarron area (Smith and Ray, 1943)	Moreno Valley (Ray and Smith, 1941)	Raton area (modified from Levings, 1951)	Trinidad area (Levings, 1951)	Pueblo area (Scott, 1969)	Air Force Academy site, Colorado Springs (Varnes and Scott, 1967)	Kessler quadrangle, near Denver (Scott, 1963)	Eldorado Springs quadrangle, north of Denver (Wells, 1967)
				HIGH GROUP				
Ash Mountain	--?-- Mid-Tertiary	Mills Divide	Raton Mesa	---	---	---	---	High-level alluvium
State Line (Park Plateau surface)	--?-- Urraca Stage	Broad Valley --?-- Stage	---	---	Nussbaum 320-360 ft (97-110 m)	---	---	Pre-Rocky Flats 450 ft (135 m)
				LOW GROUP				
Adams-Bartlett	Cimarroncito	Pediment 1	San Miguel	San Miguel	Rocky Flats	Lehman Ridge	Rocky Flats	Rocky Flats
350-400 ft (107-120 m)	250 ft (75 m)	140-150 ft[1] (42-45 m)	240-260 ft (73-79 m)	340 ft (140 m)	250-260 ft (76-79 m)	400 ft (120 m)	3 50 ft (107 m)	350 ft (107 m)
Intermediate	Philmont	Pediment 2	Beshoar	Beshoar	Verdos	Douglass Mesa	Verdos	Verdos
120-200 ft (37-60 m)	100 ft (30 m)	60-75 ft[1] (18-23 m)	100-200 ft (30-37 m)	260 ft (79 m)	200-220 ft (61-67 m)	250 ft (76 m)	250 ft (76 m)	250 ft (76 m)
Lowest	Rayado	Pediment 3	Barilla	Barilla	Slocum	Pine Valley	Slocum	Slocom
50-80 ft (15-24 m)	45 ft (14 m)	20-40 ft[1] (6-12 m)	40-80 ft (12-24 m)	100 ft (30 m)	110-120 ft (34-37 m)	100 ft (30 m)	100 ft (30 m)	100 ft (30 m)

[1]Spot checks of these elevations on recent (1963) U.S. Geological Survey 7 1/2-minute topographic quadrangle maps (Red River Pass and Eagle Nest, New Mexico) indicate that Ray and Smith's measurements were conservative; some of our measurements are nearly twice those reported by them.

FIGURE 1.44. Correlation of Tertiary(?) and Quaternary surfaces along the eastern front of the Rocky Mountains. Modified from Scott (1963, p. 53). Leaders (--) indicate no correlative surface. Questioned leaders (-?-) indicate uncertain correlations. Figures roughly indicate elevations of each surface above modern streams.

the gang at the hideout. The outlaws scattered after a bloody battle, and the Ketchum gang was broken up.

0.2

106.4 **Junction** with NM-21. **Turn left** toward Philmont Scout Ranch. **0.2**

106.6 Crossing over the Cimarron River. **0.2**

106.8 Historic St. James Hotel on left. **Turn right** on road to the old Aztec Grist Mill museum. **Park near museum.**

The small park on the right, between the houses and the mill, is Lambert Park, owned by the CS Ranch. The CS Ranch, established by Charles Springer and now operated by his descendants, has bred some of the finest race horses in the country, and its excellent quarter horses are from stock imported from England in 1882. The three-story mill (Fig. 1.48) was built by Lucien Maxwell in 1864. From 1870 to 1878, the mill served as headquarters of the Indian Agency. Until his death in 1971, Fred Lambert, famous lawman and son of Henry Lambert, acted as curator of the mill museum. **Continue south** toward Philmont. **0.1**

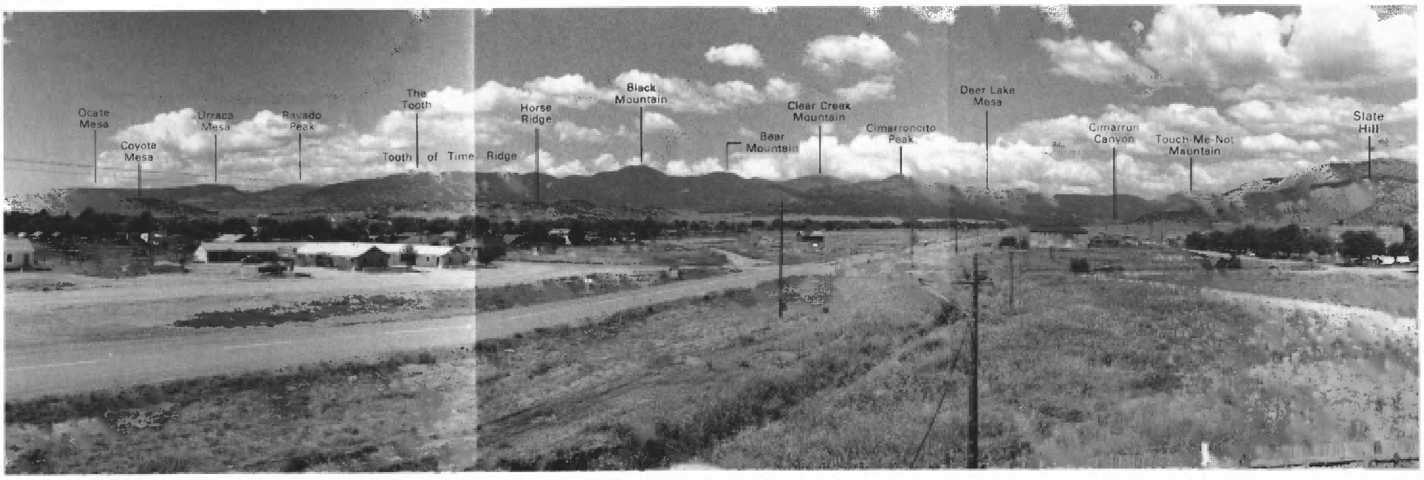


FIGURE 1.45. Photo mosaic of view westward from Cimarron showing major geographic features. This photograph was originally published in USGS Professional Paper 505 by Robinson et al. (1964). Courtesy of U.S. Geological Survey.

FIGURE 1.46. A photograph of the old Maxwell House, Cimarron, taken between 1909–1913. The residence had at least 39 rooms and was built in 1857–1858. It was the stopover point for most of the travelers along the Santa Fe Trail until the St. James Hotel was built in 1872 on an adjacent lot. Maxwell's house was purchased in the early 1920's by Mrs. Charles Springer with the intention of preserving it as an historical building. However, in the early morning of 22 April 1924 fire gutted the Maxwell mansion. Suspiciously, the magnificent Cimarron home of Charles Springer was also destroyed by fire the same morning. Many citizens of Cimarron still believe that both fires were the result of arson by parties unknown. Photo courtesy of Museum of New Mexico. Neg. no. 14621.

CIMARRON

C. K. Mawer and Deborah Rhue

Department of Geology, University of New Mexico, Albuquerque, New Mexico 87131

Last night after taps, about nine o'clock, as three of the colored soldiers belonging to the detachment under Capt. Moore stationed at this place were entering Lambert's saloon they were fired upon by a party of cowboys name unknown and killed instantly. From what we can gather from the bartender there was no provocation whatever. No arrests have been made, but the guilty parties are being searched for.

The Daily New Mexican, March 25, 1876, p. 1.

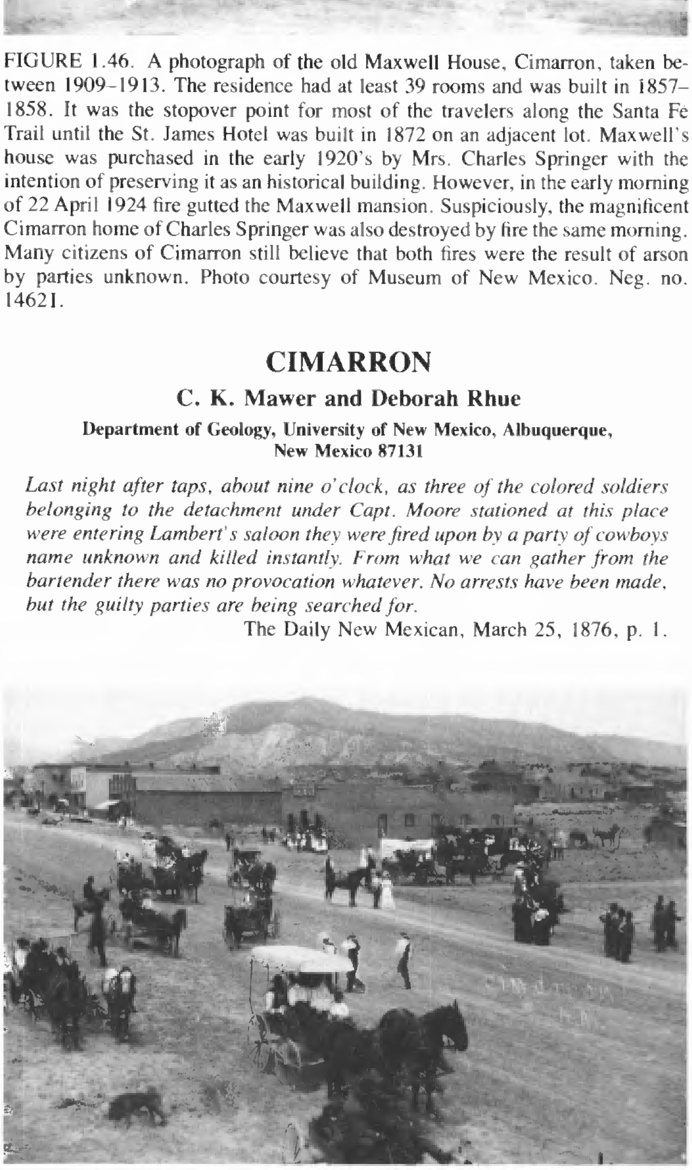


FIGURE 1.47. While "Old Glory" and several of its smaller brethren flap vigorously in the breeze, and the ladies are turned out dressed in their best finery, a crowd gathers at the Antlers Hotel in this pre-automobile era view of Old Cimarron, circa 1910. The actual occasion has been lost to memory, but the phaetons, surries, dog carts and buckboards may well be maneuvering for a Fourth of July parade. In the background, the white, barren Slate Hills contain a well-exposed section of Cretaceous strata. Courtesy of Museum of New Mexico. Neg. no. 147399.

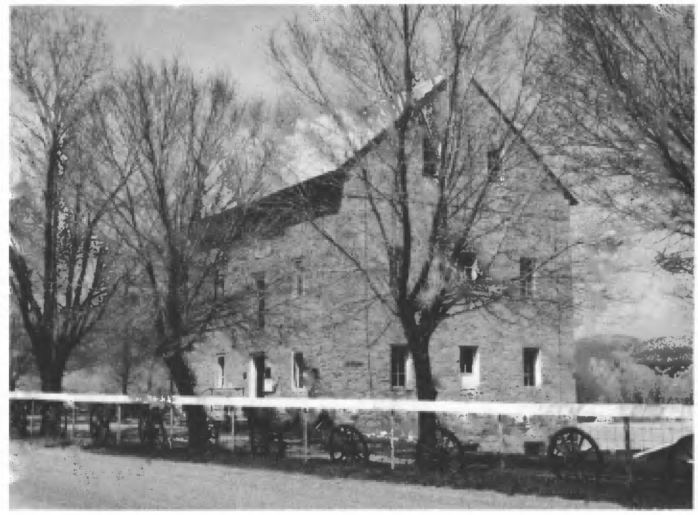


FIGURE 1.48. Old Aztec grist mill built in 1864 by Lucien B. Maxwell served as headquarters for the Indian Agency from 1870–1878. In 1870, Maxwell's daughter Virginia was surreptitiously married to U.S. Army Captain A. S. B. Keyes on the third floor of the mill. When the outraged Maxwell learned of the marriage several weeks later, he went so far as to threaten to challenge the Methodist missionary who married them, Rev. Thomas Harwood, to a duel. The mill is now used as a museum. Photo by C. K. Mawer.

Early on a cool Saturday morning in late March 1876, Henri Lambert finished cleaning the floor of his saloon and quietly shook his head. More death caused by those damned drunken gun-toting bullies! Where would it all lead, and when would it end? Lambert bent to lift the bucket of red-tinged water, and walked out into the sun. Cimarron was still; a few cattle called softly in the distance.

Henri Lambert, born in Nantes, France, in 1838, had led an eventful life even before building his adobe saloon in Cimarron (Fig. 1.49). A sailor turned cook, Lambert had arrived in America in 1860. His culinary skills became well-known and in 1862, at the beginning of the American Civil War, he was hired by General Ulysses S. Grant as Grant's personal cook. Before the year was out, Henri Lambert was invited to the White House, where he became chef for President Abraham Lincoln. The excitement of this position rapidly dwindled, and Lambert traveled to New Mexico in 1863 during the Maxwell Land Grant gold rush, where he soon realized that more riches were to be had wielding a frying pan than a gold pan. He first built the small, wooden E'town Hotel in Elizabethtown, and when the gold rush waned, Lambert moved to Cimarron. There he built a larger adobe hotel, the St. James, which quickly became a favorite frontier meeting place. Cimarron was a perfect break-point for journeys on the Mountain Branch of the Santa Fe Trail, and became a major trading center as treaties were made with the Ute and Apache Indians. Business for Lambert was very good, and he soon became a wealthy man.

Cimarron was perhaps too aptly named. Literally translated, the Spanish word means wild person or untamed animal, and for several decades it seemed that Cimarron's inhabitants and visitors did their best to live up to this description. Henri Lambert, once a sailor, now with his future linked to the Wild West, was no stranger to violence, and yet he was forced eventually to post a sign on the wall of the St. James saloon, in a futile bid to diminish the mayhem within it. His sign read:

GENTS WILL PLEASE LEAVE
THEIR SIX-GUNS
BEHIND THE BAR WHILE
IN TOWN!

This Will Lessen The
Customary Collections
For Burials

The 'seventies and 'eighties were by far the most colorful period in Cimarron's history. In one ten-year interval then, twenty-six recorded

FIGURE 1.49. Henry Lambert, founder of the E'town Hotel and the much celebrated St. James Hotel in Cimarron. As a young man in France, Lambert enlised in the Navy as a cook and was assigned to the first submarine built by the French government. His bold spirit took him on adventures such as cook with a circus troupe, head chef in the White House for President Lincoln, buffalo hunter with Kit Carson, and gold miner, before settling into life at the St. James in Cimarron. Lambert died on 24 January 1913 at the age of 75. Courtesy of Philmont Scout Ranch.

killings took place in the hotel saloon. Cimarron was so flamboyantly lawless that it developed a reputation across the entire frontier, almost from the instant of its birth, for gunplay, violence and death (Fig. 1.50). Just a few short years after its settlement, the village boasted four hotels, fifteen saloons, a post office and a newspaper, and anyone looking for trouble of any type could find it, night or day. The St. James, Cimarron's "social center," at various times hosted many of the frontier's most famous cowboys, worst badmen and hottest tempers. The list of visitors to the hotel is very long, and names that appear define the style and substance of the West in those years: Kit Carson, the famous scout, mountain man and Indian fighter; Sheriff Pat Garrett, and Billy the Kid Bonney, whose lives would intersect fatally a few short years in the future; Clay Allison, handsome and hard-eyed, with a black-powder temper and a powerful thirst which fueled it, and never beaten in a gun fight; David Crockett, nephew of the famous frontiersman, and his gun-slinging pal Gus Heffron; Buffalo Bill Cody, who organized his Wild West Show there, and Annie Oakley, who starred in it; and many others, including, of course, Lucien Bonaparte Maxwell.

Burly, mustachioed, cigar-chewing Maxwell was the son of a prosperous Missouri trader (Fig. 1.51). He had spent his early life in Missouri and Illinois and, like his friend Kit Carson, ran away from home to go West, to join in the excitement and potential of the largely unknown frontier lands. He joined Colonel John C. Fremont's first Western expedition as a hunter, becoming a dead shot and a skilled woodsman in the process. Maxwell married the beautiful Luz Beaubien, daughter of wealthy French-Canadian landowner Carlos Beaubien, in Taos in 1844, and after almost a decade of managing Beaubien's ranch at Rayado, decided to strike out on his own. After first building a house at Rayado, Maxwell quickly realized that Cimarron, 12 mi north, was not only safer but had far greater trading potential. The palatial house that Maxwell built in Cimarron in 1857 was a wonder of the frontier, three stories high, reputed to contain over 50 rooms and covering a city block. In 1858, Maxwell acquired a large tract of the original Beaubien and Miranda Grant from his father-in-law. Maxwell's property and wealth continued to grow, and it was natural that a village would grow around his holdings in Cimarron. He became the village's first postmaster in 1861. In 1864, Maxwell built the imposing three-story stone grist mill which stands today (Fig. 1.48), a six-gun shot from the St. James. Maxwell had several thousand acres of land under cultivation, employed over 500 workers and ran many thousands of cattle and sheep on his ranges around Cimarron; by 1868, Maxwell's annual income was around $50,000 and he was one of the wealthiest men in New Mexico. Eccentric, demanding, occasionally ruthless and yet known for his generosity, Maxwell's relationship with Cimarron ended in 1870, when he sold most of his holdings to a group of investors for $1,350,000. He moved to Fort Sumner, and spent his remaining days there, occasionally staring into the distance toward his beloved northern New Mexico high country, and thinking about past days.

Major expansion of the frontier lands followed the introduction of the western railroads. The first train of the St. Louis, Rocky Mountain and Pacific Railway Company reached Cimarron on 10 December 1906, to the great delight of local merchants. Goods could be exported and imported far more cheaply, even though the prices of these goods sold locally did not seem to greatly diminish. The train continued west through Cimarron Canyon to Ute Park, allowing easy shipping to the eastern markets of cattle, fruit, ore and timber. Vast timber resources north of Cimarron, along Ponil Creek and its tributaries, led to the formation of a second rail group, the Cimarron and Northwestern Railway Company, in early 1907. The enormous local timber reserves, and the service boom occasioned by two working railroads, brought great prosperity to Cimarron in the earliest twentieth century and caused a major surge in construction, including the building of one of the finest water systems in New Mexico.

But large timber is a rapidly depleted and non-renewable resource at the scale of human lives. By about 1930, all accessible big timber had been removed, and the valleys were bare. The C&N company soon ceased to exist, and by the early 1940's the Rocky Mountain line also abandoned its tracks. The economy of Cimarron received a body blow from which it never recovered.

Untamed in its adolescence, old Cimarron rests quietly today. The traveler on U.S. Highway 64, less than impressed by Cimarron and searching no farther, misses much, for there are really two Cimarrons. Old Cimarron hides beneath stately elm and cottonwood trees south of the river on N.M. Highway 21, less than a mile and more than one hundred years from the new. Here, the St. James Hotel still stands, complete with bullet holes in the pressed-tin dining room ceiling, mute testimony to its eventful past life. Squint just a little, and you will see Henri Lambert, dapper little Henri with his pointed black moustache and white apron, standing behind the saloon bar and smiling. Maxwell's mansion has long since disappeared; his grist mill, looking as if built just last week, is now owned by the CS Ranch of Cimarron and has been converted to a museum which houses a large, eclectic collection of frontier relics. The original Cimarron cemetery has many notable residents, and to read the inscriptions on their tombstones is to experience with startling immediacy the history of the West. The old village plaza lies vacant, weed-covered and neglected in the cool mountain air, with its unused water-well still visible. Several plaqued historic sites exist nearby. Stand in the plaza, and imagine: soon, you will see mounted cowboys ride along the adjacent dusty streets, and hear, above the soft lowing of Maxwell's cattle, an occasional gunshot. (Sources used for this paper include Pearce [1965]; Looney [1968)]; Murphy [1976]; and Bullock [1981].)

Two noted desperados, Crockett and Heffron, who have long been a terror to this community and who were implicated in the killing of three colored soldiers at the St. James Hotel last spring have been "running the town"

FIGURE 1.50. Cimarron, New Mexico, settled as early as 1841, was a convenient stopover point along the Taos branch of the Santa Fe Trail. As such it became an oasis for many of the West's most famous (and infamous) characters. Thanks to its lawless reputation, Cimarron needed all the help it could muster to attract new people and capital. Thus, the above view, said to be a turn-of-the-century press release by the Chamber of Commerce, presents a cross section of Cimarron's elite maintaining law and order. This photo, actually taken in the courtyard of the old St. James Hotel in 1904, includes Henry Lambert (far left, with bird) and his son Fred Lambert who was an artist, writer and lawman (in white shirt). Courtesy of Philmont Scout Ranch.

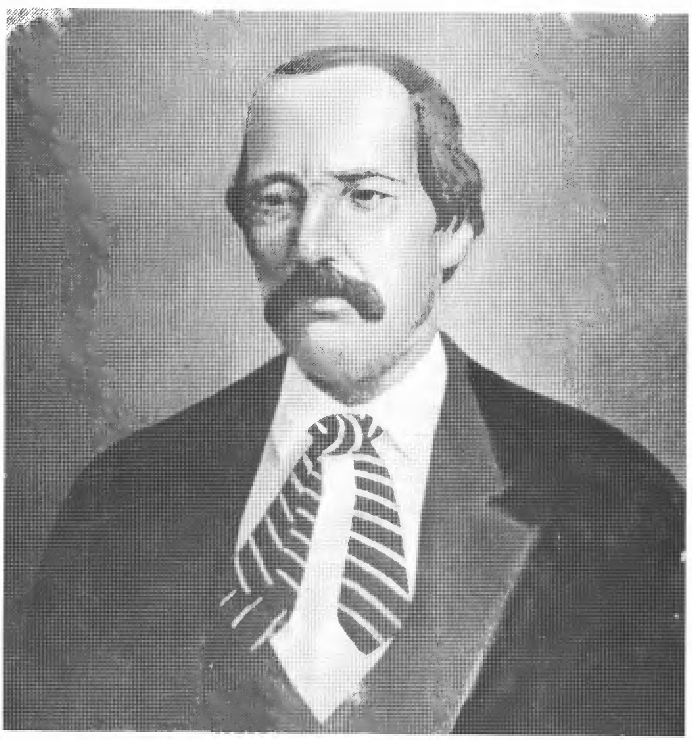


FIGURE 1.51. Lucien B. Maxwell, owner of the largest private land grant in the country from 1858 to 1871. Courtesy of Philmont Scout Ranch.

for the past week, poking six-shooters and shotguns in the faces of whom they meet. Last evening Sheriff Rinehart and two others started to arrest these fellows, armed with double-barrel shotguns. The sheriff's posse went out in the western part of town in the neighborhood of Schwenk's barn and found Crockett and Heffron on horseback, starting for the Urac, and were halted just opposite the barn well and told to surrender. Instead of throwing away their arms, Crockett and Heffron at once placed themselves on the defensive, when the sheriff's party fired one volley, and as the horsemen started off toward the river on a run let loose the other barrels of the guns. Crockett was found dead on the other side of the river, a few hundred yards off and Heffron was arrested having been shot in the wrist and in the head. No one has many tears to shed over the living or the dead, as they have been a terror here for the past week and often previously. Things will now take a change for the better as there are plenty here now who say they will stand up for Sheriff Rinehart in enforcing the law against all evil doers.

The Daily New Mexican, October 4, 1876, p. 1.

106.9 The ridge ahead is composed of Quaternary sand and gravel stream terraces. **0.2**

107.1 Cemetery and landfill on right. The high mountain ridge ahead is Tooth of Time Ridge, a Tertiary double laccolith in Carlile Shale, Fort Hays Limestone and Niobrara Formation. **0.1**

107.2 Lowhills are capped by the Beshoar and Barela pediment gravels overlying Pierre Shale. At 2:30 is a remnant of the high San Miguel pediment. **0.2**

107.4 Milepost 1. Official Scenic Historic Marker reads:

Philmont Scout Ranch. Oklahoma Oilman Waite Phillips gave this 127,000 acre property to the Boy Scouts of America in 1938 and 1941. The first National Boy Scout Camp ever established, Philmont now hosts young men from all over the world. Kit Carson, Lucien B. Maxwell, and Dick Wootten were important in the history of the area. **0.1**

107.5 Entering Philmont Boy Scouts of America property. **0.7**

108.2 Crossing the younger, lower Barela pediment surface. A higher-level Beshoar pediment remnant is visible to the right at about 2:30. **0.4**

108.6 High mesa on skyline at 12:00 is Urraca Mesa, composed of Pierre Shale and Niobrara Formation capped by Pliocene?-Pleistocene? basalts. As is common in many such settings, the basalt-capped mesa is surrounded by recent landslide deposits. We are driving on Pierre Shale covered locally with terrace gravels. The Pierre Shale underlies much of the low flats in this area. **0.4**

109.0 At 1:30–2:00, Tooth of Time Ridge contains a prominent bare peak known as the Tooth of Time (Fig. 1.52). The Tooth is a weathered exposure of dacite porphyry of the double laccolith, and is the unofficial emblem of the Philmont Boy Scouts. Tooth of Time Ridge is separated from the mountains to the west by the down-to-the-east, high-angle Shaefers Pass fault. The fault juxtaposes Cretaceous sedimentary rocks against the laccoliths. Much of the high country to the west is underlain by a swarm of similar laccoliths. Mountain peaks appear to be the crests (thickest parts) of the largest laccolithic intrusions (Robinson et al., 1964). Many of the laccoliths are multistoried, and can therefore be called Christmas-tree laccoliths. Although the feeder dikes are not exposed here at Philmont, Robinson et al. (1964) suspected that the laccoliths were fed from the sides, similar to those in the Henry Mountains of Utah. In the Philmont region, magmatism and faulting appear to have overlapped in time and in space. **0.2**

109.2 Large mesas on the left and a smaller one ahead on the right are capped by syenite sills intruded into Pierre Shale. **0.2**

109.4 Begin descent into Quaternary alluvial valley of Cimarroncito Creek where the Philmont Ranch headquarters is located. **0.45**

109.85 On the left is a residential area for Philmont employees. **0.15**

110.0 Road on left to Philmont administration area. The hill on the right is capped by high-level gravel of Tertiary age (Pliocene?) overlying a remnant of a syenite sill that caps a ridge of Pierre Shale. The gravel lies at 300–400 ft elevation above nearby major streams, and is largely composed of Proterozoic igneous and metamorphic boulders up to 2 ft in diameter, but also contains some basalt boulders as large as 5 ft (1.5 m) in diameter. **0.3**

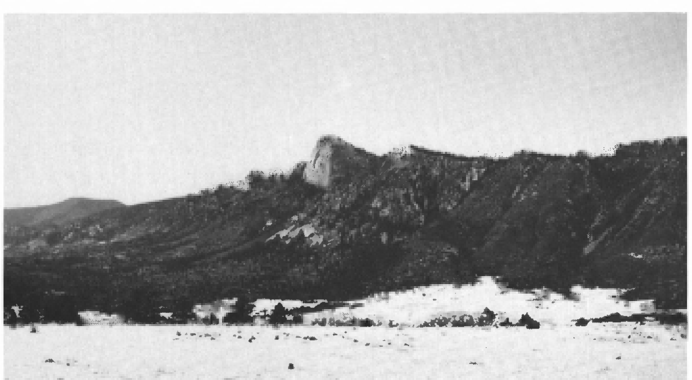


FIGURE 1.52. Tooth of Time Ridge showing prominent, weathered dacite porphyry exposure of the Tooth. View to the northwest. Photo by P. W. Bauer.

110.3 Philmont Training Center on left. **Turn left** into Training Center and **proceed to parking area** behind (east of) the building complex. The magnificent Villa Philmonte, built by Waite Phillips, stands to the right.

End of First-Day Road Log.

A RANCH FOR BOY SCOUTS: WAITE PHILLIPS AND PHILMONT

Stephen Zimmer
Philmont Scout Ranch, Cimarron, New Mexico 87714

"That ranch represents an ideal of my youth. . . . And [it] has meant a lot to my son and his pals. Now I want to make it available to other boys. . . ." With these words, quoted in the *Tulsa Daily World* on 19 December 1941, Oklahoma oilman Waite Phillips made public the gift of 127,395 acres of his Philmont Ranch near Cimarron, New Mexico, to the members of the Boy Scouts of America.

At the time, the Philmont was one of the best-developed ranch properties along the front range of the Rockies. Carved out of the Maxwell Land Grant, the ranch ran 3000 head of commercial and registered Hereford cows and 9000 head of Corriedale sheep. Its thoroughbred and part-thoroughbred mares and stallions were recognized all over the West for the quality of the colts they produced. Its irrigated acres, sown with alfalfa, oats and barley, supplied feed for its livestock, while the ranch's orchards annually produced thousands of boxes of apples.

The ranch was also Phillips' private resort for his family and friends. The mountain back country comprising the western part of the ranch was linked by an elaborate network of horseback trails that provided access to four different hunting and fishing lodges.

The Philmont Ranch represented a dream come true for Phillips who was born on a small farm near Conway, Iowa, on 19 January 1883. With his identical twin brother, Wiate, Phillips left home at 16 for an undetermined destination in the Rocky Mountains. For the next three years, the Phillips twins traveled through the northern Rockies working as laborers at various mining, timber and railroad camps. Waite Phillips wrote later that these years, spent living and working in the mountains as a young man, were responsible for his inspiration to give the Philmont Ranch to the Boy Scouts.

In the summer of 1902, Wiate became seriously ill with a ruptured appendix in Spokane, Washington. He died there at age 19, and Waite returned to Iowa with his brother's body. Back in Iowa, Phillips enrolled in the business department of Western Normal College in Shenandoah. Upon graduation in the summer of 1903, he took a job with the Hawkeye Coal Company in Knoxville and later became a salesman for the Rex Coal and Mining Company of Creston. During this period, his older brothers, Frank and L. E., moved to the Indian Territory where they invested in the oil business. Phillips followed his brothers to their Bartlesville headquarters in the spring of 1906, where he worked in their oil exploration and production business until the summer of 1914. At that time, the two older brothers decided to liquidate the assets of their oil enterprises in order to devote their full energies to banking interests. Waite followed suit by selling his minor interest in the business and purchasing an oil marketing firm in Arkansas, headquartered in Fayetteville. After a year, he sold the company and returned to Oklahoma. Establishing headquarters at Okmulgee, Phillips successfully developed a number of extensive oil-producing properties and soon expanded his operation to include refining, transportation and marketing.

Frank and L. E. Phillips, in liquidating their various oil assets in 1914, were compelled to retain certain oil and gas leases they held on Osage Indian land. These properties proved to be so valuable after further exploration that the brothers again entered the oil business in 1917 and established the Phillips Petroleum Company. Waite, on the other hand, remained on his own and moved his headquarters to Tulsa in 1918. Four years later, he integrated his holdings into the Waite Phillips Company, and served as its president and general manager.

In the spring of 1925, Phillips sold the capital stock of the Waite Phillips Company to Blair and Company, a Wall Street investment firm, for $25 million cash. The sale freed him to pursue his banking and real estate investments, most importantly the Philmont Ranch in New Mexico.

From the time he had spent in the northern Rockies as a young man, Phillips had wanted to own a mountain cow ranch. As his oil investments profited, he looked more into ranch property. His first ranch near Denver, bought in 1920, was called the Highland. Evidently not pleased with its recreational possibilities, he continued to search for a ranch with more mountainous acreage.

South of Cimarron, New Mexico, along the mountain branch of the Santa Fe Trail, Phillips learned of the proposed sale of George Webster's Urraca Ranch in the spring of 1922. He dispatched his Denver ranch manager, Gene Hayward, to Cimarron to investigate and, as a result of Hayward's report, Phillips purchased almost 44,000 acres of the Urraca for more than $150,000. Early in the spring of the next year, he acquired an additional 30,000 acres from Webster for nearly one-quarter million dollars.

The Urraca Ranch, with its choice grazing and farming along the Sangre de Cristo Mountains, provided an excellent foundation property from which Phillips was able to expand his holdings. As contiguous property became available, he purchased it, and by 1933, he had put almost 300,000 acres within one fence.

Phillips initially named the ranch Hawkeye, in recognition of his native state of Iowa, but in 1925 he renamed it Philmont, a name derived from his own name and the Spanish word for mountain, "monte."

Of first importance was a residence on the ranch for him and his family. In the summer of 1925, Phillips and his wife Genevieve (Fig. 1.53), accompanied by Kansas City architect, Edward B. Delk, embarked on a Mediterranean cruise with the express purpose of gathering architectural ideas for homes at Philmont and in Tulsa. Construction on both houses began in the spring of 1926. The Phillipses returned to the Mediterranean that summer and acquired the majority of furnishings that eventually went into both mansions.

The 22-room Philmont mansion was known as the Villa Philmonte (Fig. 1.54). It was home to the Phillips family each summer, roughly from June 1 to October 1, where they hosted friends and business acquaintances who were invited to the ranch to rest and relax in the pleasant summer climate.

No aspect of the ranch's operation escaped his attention. He was especially concerned with the welfare of his employees. On the average, the ranch employed 50 people including 10 cowboys, 15 sheepherders, 20 farmers, plus maintenance and office personnel. Each employee with a family was supplied a house, milk cow, garden seed, poultry stock, beef and pork. In a letter to his ranch manager in May of 1936, Phillips stated that the ranch furnished "to its employees as nearly as possible, what they would receive if they owned or leased a small place of their own."

Perhaps the greatest contribution Phillips made to the success of the ranch's cattle operation was his plan for the management of the cow herd and its efficient utilization of the available range grass. This plan involved developing springs and using cross fences and strategic salt distributions in pastures in order to entice cattle to graze inaccessible parts of the ranch. In addition, he instructed cow and sheep employees to kill grass-eating gophers, and he had them dig loco weed each spring as it began to grow and threaten livestock.

He used the beaver found on the ranch to help improve range conditions. He had employees live-trap beaver that resided along streams running through winter calving pastures which destroyed much of the

FIGURE 1.53. Painting of Waite and Genevieve Phillips that hangs in the Villa Philmonte. Courtesy of Philmont Scout Ranch.

FIGURE 1.54. Waite Phillips' ranch house, the Villa Philmonte. This house was made a part of his gift to the Boy Scouts of America in 1941. It now serves as a memorial to his generosity to the Scouting movement. Courtesy of Philmont Scout Ranch.

cover important in sheltering cows during calving season. These beaver were transported to mountain parks where they felled aspen, thus creating better growing conditions for grass. Also, their dams caused siltation areas in the parks that eventually grassed over.

The Philmont's horse breeding program was renowned for the variety, quality and versatility of the foals it produced. Standing at the ranch were Thoroughbred, Steeldust (Quarter Horse) and Percheron sires. Depending on what broodmares they were crossed on, these stallions sired colts capable of either working cows, playing polo, serving as cavalry mounts or pulling wagons and farm equipment.

Waite Phillips was an advocate of Andrew Carnegie's "Gospel of Wealth." He strongly believed it to be the responsibility of those who acquired riches to share them with others. "Real philanthropy," he once wrote, "consists of helping others, outside our own family circle, from whom no thanks is expected or required." Throughout the Depression, Phillips aided a number of individuals and organizations who had suffered economic hardships. Moreover, as the Depression drew to a close, he developed plans to dispose of much of his property and real estate. In late September of 1938 he gave his Tulsa estate, Philbrook, to the Southwest Art Association to serve as an art museum for the city of Tulsa.

Turning next to Philmont, he and his family decided to deed 35,857 acres of the north part of the ranch to the Boy Scouts of America. Phillips was impressed with the character-building and citizenship-training goals of the scouting programs, fulfilled through an active program of camping and hiking in the outdoors. He felt the Philmont Ranch property he offered the Scouts a perfect setting for them to pursue their program.

The National Council of the BSA accepted the gift and after a thorough evaluation of the property and its resources, they established a camp named Philturn Rockymountain Scoutcamp. Philturn was derived from Phillips' name and the BSA slogan, "Do a good turn daily."

After its initial season of 1939, Philturn developed and expanded its program and, as a result, saw a substantial increase in participation the following two years. Phillips took great interest in the development and participation at Philturn. He frequently drove by car or rode on horseback to the camp to observe the Scouts in their activities.

Evidently pleased with what he saw, he again contacted BSA officials after the 1941 camping season to discuss with them the possibility of a further gift. The talks resulted in Phillips' decision to give the Scouts the entire headquarters of the ranch, including the Villa, plus an additional 91,538 acres of the mountainous part of the ranch.

With the additional property, the Boy Scouts changed the name of the operation to Philmont Scout Ranch. The ranch has since hosted more than one-half million Boy Scout and Explorer campers from the United States and foreign countries. Phillips' gift was subsequently augmented in 1963 with 10,098 acres made possible through the generosity of Scouter Norton Clapp that brought the total ranch area to 137,493 acres. Philmont today is the world's largest camping operation in terms of both total area and attendance.

The Scouts and Explorers that come to Philmont each summer participate in a wide variety of outdoor experiences, many of which are unique to the ranch's western setting. Most outfit for twelve-day backpacking treks through the ranch's wilderness backcountry called High Adventure Expeditions. These groups select from more than 20 different itineraries that take them to various staff camps offering programs in rock climbing, rifle shooting, burro packing, fly fishing and archaeology. In addition, some camps present programs drawn from the area's rich historical heritage such as gold mining, lumbering, fur trapping and cattle ranching. Annually, Philmont welcomes an average of 15,000 campers and their leaders on High Adventure Expeditions.

Other campers see the Philmont backcountry entirely from horseback. In the Cavalcade program, participants learn the elements of horsemanship and packing by way of an eight-day ride through some of the ranch's most scenic country. The experience is for most a once-in-a-lifetime opportunity requiring each to saddle, feed and care for their own mounts.

The ranch maintains a remuda of 250 saddle horses that are not only ridden by the Cavalcaders, but also by hikers that visit Beaubien, Ponil and Clark's Fork camps. In keeping with Waite Phillips' desire that the property remain a working cow ranch, Philmont also runs a herd of 200 Hereford cows.

Philmont stands today as a monument to Waite Phillips and his farsighted generosity. His love of ranch life and the outdoors, coupled with his desire to help young people, has created a unique camping area for American Scouts unequaled in the world.