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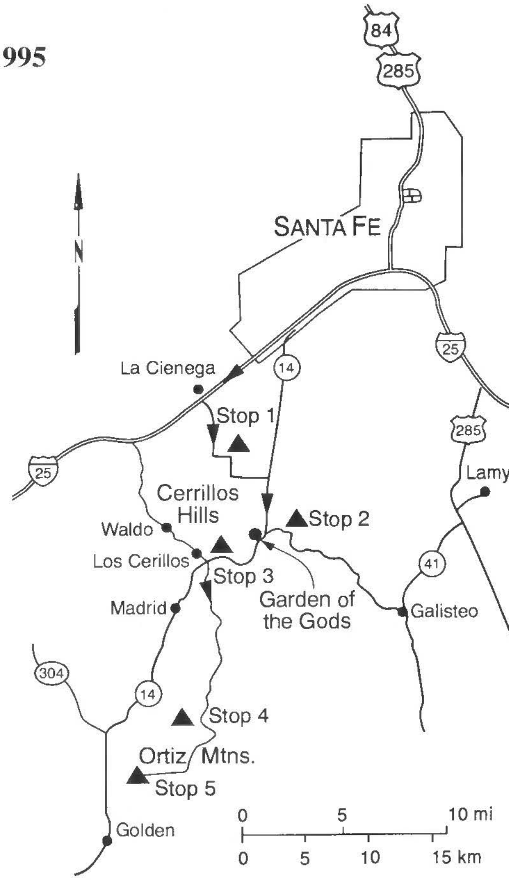
THIRD-DAY ROAD LOG, FROM SANTA FE TO THE CERRILLOS HILLS, CERRILLOS, AND THE ORTIZ MOUNTAINS

PAUL W. BAUER, STEPHEN R. MAYNARD, GARY A. SMITH, DAVID L. GILES, SPENCER G. LUCAS, JAMES M. BARKER, EDWARD W. SMITH and FRANK E. KOTTLOWSKI

SATURDAY, SEPTEMBER 30, 1995



Assembly point: High Mesa Inn parking lot, Cerrillos Rd., Santa Fe.
Departure time: 7:30 a.m.
Distance: 37.5 miles
Stops: 5

Summary

The Day 3 trip takes us southeast from Santa Fe, through the Cerrillos Hills and into the Ortiz Mountains. For the first 6 mi we travel on I-25 over the Pliocene–early Pleistocene Ancha Formation of the uppermost Santa Fe Group. At La Cienega exit we turn southeastward into the Cerrillos Hills, which are composed of pre-rift subvolcanic intrusions of monzonite and related rocks dated at 34-30 Ma that represent the northern end of the San Pedro-Ortiz porphyry belt. The Cerrillos Hills intrusions have domed the pre-middle Oligocene strata, so that average dips on the southeast flank are to the southeast. Farther east along Galisteo Creek toward Galisteo, dips are to the west (as they are in the Tesuque Fm north of I–25 from Santa Fe to west of the I–25–Cerrillos Road junction). This faulted asymmetrical syncline (the Santa Fe embayment, the southeasternmost part of the Española Basin) is truncated to the southeast by the Tijeras–Cañoncito fault system. Although zinc, lead, silver, copper and gold have been mined from the Cerrillos Hills, the district is most prominent for its fine turquoise. At Stop 1 we will visit the Tiffany Mine at Turquoise Hill, from which more than $2,000,000 worth of high-grade gem turquoise was removed in the 1890s.

From the Tiffany Mine, we travel eastward across the Ancha Formation and surface sands and gravels to NM-14 south. Deeply incised arroyos to the west expose the basal Tertiary unit in the area, the Eocene Galisteo Formation of sandstone, mudrock and fresh-water limestone. The Galisteo is conformably overlain by intermediate-volcanic agglomerates, breccias and fanglomerates of the Oligocene Espinaso Formation. The Espinaso is syndepositional with igneous activity of the San Pedro-Ortiz porphyry belt, extending from La Cienega southward to South Mountain, east of the Sandia Mountains. At Stop 2 we visit the studio of famed sculptor Allan Houser, who turned New Mexico alabaster and Italian marble into stunning sculptures.

We continue south through the steeply dipping Galisteo Formation to Stop 3, just east of Cerrillos, where we will discuss the relationship between mid-Tertiary igneous activity, deformation, and sedimentation. The trip continues south from Cerrillos onto a gravel road leading to the gold mines of the Ortiz Mountains. As we climb out of the valley of Galisteo Creek, we pass from the Galisteo Formation to the unconformably overlying Tertiary-Quaternary Tuerto Gravel, a coarse cobble conglomerate that was derived from the Ortiz and San Pedro Mountains. Stop 4 finds us at the inactive Cunningham Hill open pit gold mine in the northeastern Ortiz Mountains. Gold Fields Mining Corporation operated the mine from 1979 to 1987, producing approximately 250,000 oz of gold. Brecciated quartzite derived from the Galisteo Formation adjacent to the volcanic vent of Dolores Gulch is the host rock. We will examine the ore deposit and discuss mine-related environmental concerns and the status of remediation efforts.

From Cunningham Hill the tour continues southwestward through the intruded Cretaceous sedimentary section of the Ortiz Mountains to Stop 5 at Carache Canyon, where LAC Minerals

has identified a mineral resource of one million ounces of gold, mainly in fractured and mineralized sills related to a spectacular collapse breccia.

After returning to NM-14, the caravan disbands.

Mileage

0.0 From intersection of Cerrillos Rd. and I-25 on-ramp, **drive south on I-25**. We are on the Plains surface, the intermediate level of three Pliocene-Pleistocene(?)-age physiographic surfaces (Spiegel and Baldwin, 1963) that developed on the uppermost Santa Fe Group, mapped in this area as Pliocene-Pleistocene Ancha Formation by Baldwin and Kottlowski (in Spiegel and Baldwin, 1963). The Plains surface forms the inter-arroyo divides to the south. To the north is the Airport surface, the lowest surface, which parallels the Santa Fe River. The highest surface, the Divide surface, forms the low skyline north of Santa Fe. All of these surfaces are partly erosional and partly constructional in origin. Old pumice mines in this vicinity were excavated in Jemez Mountains tephra deposits within the upper part of the Ancha Formation. **1.8**

1.8 Exit 276. At 1:00 to 3:00, the series of low hills and mesas is part of the Cerros del Rio volcanic field, one of the largest volcanic fields in the Rio Grande rift (300 km^2). The present platform of flows contains approximately 60 cinder cones, maars, tuff rings and tuff cones (Aubele, 1978) that range in age from 2.8 to less than 1.4 Ma (Doell et al., 1968; Smith et al., 1970; Bachman and Mehnert, 1978). Basalts are the most abundant composition, but rocks range to latite-andesite (Baldridge, 1979; Duncker, 1988). The flows interfinger with the upper beds of the Ancha Formation on the east side of the field.

About 6 mi to the north the Yates Petroleum No. 2 La Mesa Unit oil test was drilled in 1985. Beneath about 40 ft of Ancha beds, the Tesuque Formation is 3926 ft thick, and the underlying late Oligocene–early Miocene Abiquiu Formation/Bishops Lodge strata are 3574 ft thick, above Proterozoic rocks. As noted by Cather (1992), the Abiquiu/Bishops Lodge unit contains a 1950-ft-thick unique basal "La Mesa" sequence of interbedded lacustrine limestones and vitric volcanoclastics, similar to the fresh-water limestones that crop out near La Bajada, about 15 mi southwest of the oil test. Yet, as we will see 7.5 mi to the south, as the field trip route drops off of the Santa Fe plains into the Galisteo Creek valley, horizontal Ancha Fm beds unconformably overlie steeply dipping Espinaso and Galisteo strata. No Tesuque or Abiquiu beds are present and a full Mesozoic–Paleozoic sequence underlies the early Tertiary units. These geologic relationships support Cather's (1992) Eocene Pajarito uplift, postulated local source of the Galisteo Formation, whose southwest-trending southeast edge parallels I–25. This is Cather's (1992) Santa Ana accommodation (Fig. 3.1) zone which projects northeastward toward the Santa Fe River fault zone. **0.7**

2.5 Santa Fe Downs Race Track, on the right, is built on the Airport geomorphic surface. At 11:00 are the Cerrillos Hills. **1.3**

3.8 Milepost 274. At 3:00, on the skyline are the Jemez Mountains. **1.8**

5.6 The cienega (Spanish for marsh) on the right has formed where ground water discharges from a zone in permeable Santa Fe Group deposits which rest on impermeable bed-

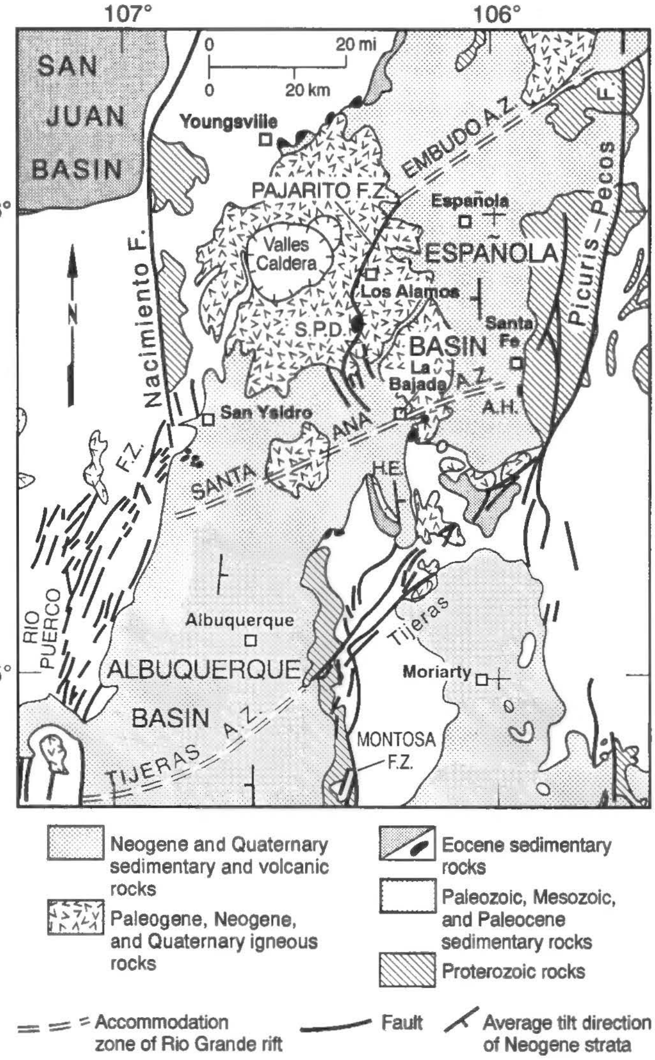


FIGURE 3.1. Simplified geologic map of field conference area showing major structural features. Modified from Cather (1992).

rock shale. Just out of sight to the right is El Rancho de Los Golondrinas (Ranch of the Swallows), a living history museum operated by a charitable trust, that reconstructs Spanish colonial culture. During the 1700s and 1800s, Las Golondrinas was a paraje (overnight stop) on the Camino Real between Mexico City and northern New Mexico. The original ranch buildings are restored, and have been supplemented by other old buildings from northern New Mexico. Also present are operational flour and molasses mills, and blacksmith and wheelwright shops. Self-guided tours of the 200-acre site are available from June through September. **0.3**

5.9 **Take Exit 271, La Cienega.** The hills to the right (northwest) are eroded high-level intrusions and domes of Oligocene monzonite and latite representing the northern extent of the San Pedro-Ortiz porphyry belt. Late Eocene and Oligocene magmatism along this belt included an early phase of calc-alkaline intrusion and volcanism (products are typically hornblende and/or augite phyric) and a later phase of alkaline activity (products are Fe-rich augite and/or biotite phyric) (Erskine and Smith, 1993). The highest point to the right, Cerro Segundo, is an augite monzonite body capped by nephelinite lava of the Cieneguilla limburgite (Sun and Baldwin, 1958). This unusual volcanic unit, and associated olivine basalts, was dated at 25.1±0.7 Ma by Baldridge et al. (1980). Farther south, these volcanic rocks are interbedded with the lowest Santa Fe Group rift-fill sediments, thus establishing the approximate age of the onset of extensional faulting in this part of the Rio Grande valley (Baldridge et al., 1980). Similar flows occur near Bishops Lodge in the lower part of the Tesuque Fm, above the basal Bishops Lodge Member. **0.2**

6.1 **Turn left** across I-25 overpass. The pointed twin-peaked hill at 12:00 is Bonanza Hill, composed of Tertiary intrusives of augite-biotite syenite trachyte porphyry according to the map by Disbrow and Stoll (1957). **0.2**

6.3 **Turn right onto frontage road** towards Los Cerrillos. **0.1**

6.4 The conical hill at 9:00 is known as Cerro de la Cruz (Cavalry Hill, 6468 ft). It is mostly covered by Quaternary colluvium but there are a few small exposures of Tertiary flows and interbedded tuff breccia of the Cieneguilla limburgite. The chemical analysis by Stearns of the limburgite on Sierra de la Cruz includes an SiO_2 content of about 40 wt%. Roadcuts to the right along I-25 are in Santa Fe Group. The fairly low, rounded hills on the 12:00 skyline are remnants of cinder cones related to eruption of the Cuerbio basalt, the basal flows of the Cerros del Rio volcanic field. **0.6**

7.0 **Turn left on Santa Fe County Road 45** towards Bonanza Creek Ranch. **0.5**

7.5 The Bonanza Creek Ranch is at 2:00. To the south on the skyline are the Cerrillos Hills. The highest peak at 3:00 is Cerro Bonanza (also known as Santa Rosa Mountain, 7088 ft.), composed predominantly of Oligocene augite biotite monzonite. Coeval volcanic rocks and volcaniclastic sedimentary rocks of the Espinaso Formation are exposed along the north and east sides of the Cerrillos Hills. The western side of the mountain preserves a Cretaceous through Jurassic sedimentary section. **0.3**

7.8 Entrance to Bonanza Creek Ranch on right. This 16,000-acre working ranch, owned by Glenn Hughes, is the location of one of the state's three major Western movie towns. The first film shot on the ranch was *The Man From Laramie* (1955), starring Jimmy Stewart. More than 50 films have subsequently been shot here. Some recent productions include *Silverado* (1983), part of the TV series *Lonesome Dove*, *Lightning Jack* with Paul Hogan, and the 1994 movie *The Fight Before Christmas*. **0.2**

8.0 Road bends sharply to right; Bonanza Hill to left. Straight ahead, behind the low hills, is the major Western movie town; *Buffalo Girls* was being filmed there as this log was written. **0.5**

8.5 Road climbs onto the top of a surface cut in buff-colored sands and gravels, exposed in roadcuts. **0.7**

9.2 At 9:00 to 10:00 is Turquoise Hill, our destination for Stop 1. **0.5**

9.7 Straight ahead the high peak on the skyline is El Cerro de la Cosena (called Mt. McKenzie on old maps, 6923 ft.) It consists of augite biotite monzonite and Espinaso Formation volcanic rocks. At about 3:00 in the low slopes in the foreground the dark-colored mine dumps mark the location of the Marshall Bonanza Mine, one of numerous lead-zinc mines in the Cerrillos district. Lead and zinc sulfides are typically found in N- to NE-striking veins in fractured Espinaso volcanics and associated intrusions throughout the Cerrillos Hills. **0.4**

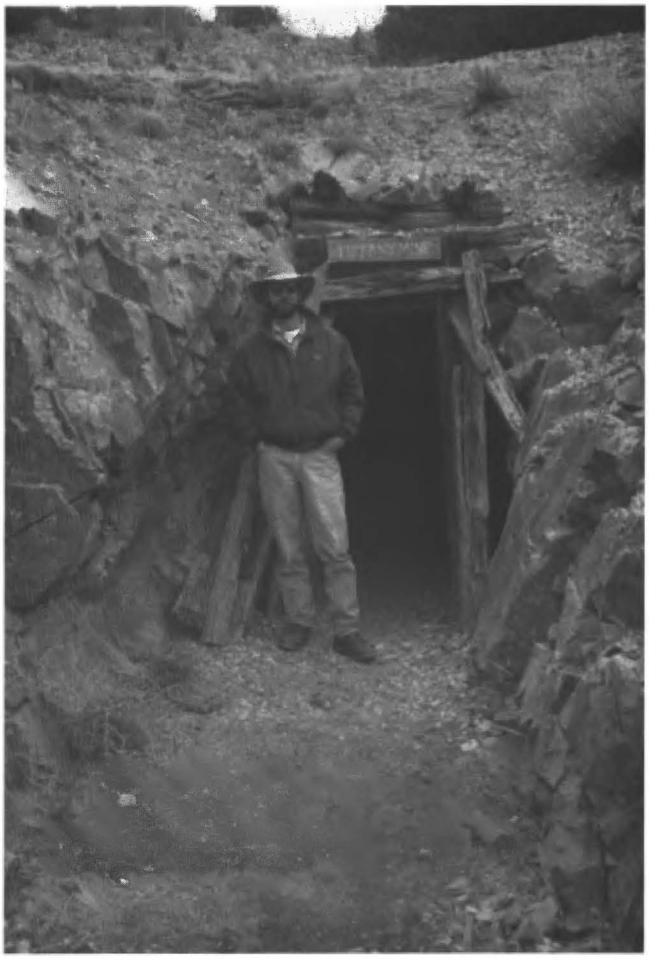


FIGURE 3.2. Entrance to the Tiffany turquoise mine.

10.1 Road turns sharply to left. **0.5**

10.6 Turquoise Hills ahead to left. The main workings of the Tiffany Mine (Fig. 3.2) are about halfway up the farthest right hill. **0.1**

10.7 Milepost 3. At 9:00 are the remains of a building and some old turquoise mine workings. **0.4**

11.1 **STOP 1. Tiffany Mine at Turquoise Hill. Bear left through gate** onto a dirt road that heads northward. This mine is privately owned, and permission must be granted prior to any visits.

Turquoise Hill is an isolated, multiple-intrusive laccolithic complex on the very north end of the Cerrillos Hills (Fig. 3.3), the terminus of the San Pedro–Ortiz porphyry belt of north-central New Mexico (Maynard et al., 1991). The exposed complex, approximately 3500x2000 ft in plan view, consists of several varieties of quartz-poor augite monzonite of Oligocene age intruding Cretaceous Mancos Shale and coeval Espinaso volcanics, as in the Cerrillos Hills to the south (Disbrow and Stoll, 1957; Giles, 1991). The encircling host rocks have been domally upturned and contact metamorphosed near the igneous contacts. Aprons of Espinaso volcanics occur on the east and northeast sides of the hill; a small exposure of marbleized Greenhorn limestone member of the Mancos occurs on the north side.

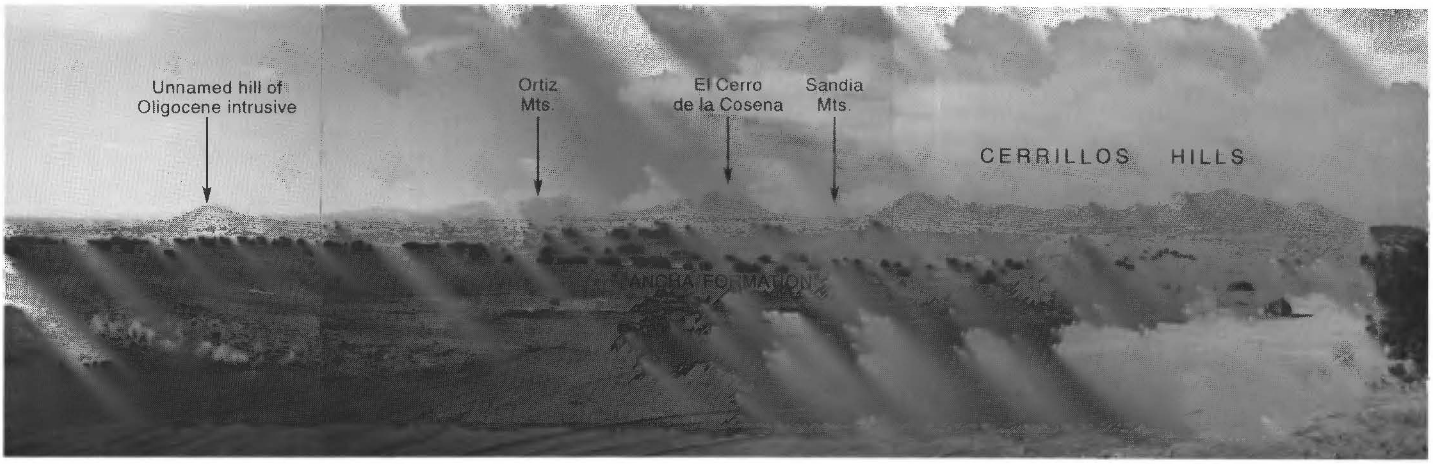


FIGURE 3.3. View southward of the Cerrillos Hills from Stop 1 at the Tiffany Mine.

The core of the Turquoise Hill igneous complex is a late, unaltered and equigranular monzonite stock or plug, around which both igneous and sedimentary rocks have been variably altered and mineralized by copper-bearing hydrothermal solutions. This strongly pyritic halo of mineralization was localized for the most part in NE- and NW-trending fracture zones, particularly where the fractures intersect. Subsequent surficial oxidation has reduced the pyrite and copper sulphides to limonites and supergene turquoise; the thickness of the oxide zone is unknown. In intrusive style and mineralization controls, Turquoise Hill is nearly identical to the porphyry copper deposit of the San Marcos intrusive complex in the southern Cerrillos Hills (Giles, 1991; this volume).

As is typical of deposits in the Cerrillos Hills and elsewhere, the turquoise at Turquoise Hill occurs as nodules and irregular veinlets in fracture zones and fracture intersections (Fig. 3.4). Argillic alteration is more intense adjacent to these fractures than in the surrounding rocks. There was probably some prehistoric mining at this site, but not to the extent as at Chalchihuitl to the south. The most extensive mining was by the American Turquoise Co. (majority stockholder: Tiffanys of New York) from 1890 to about 1905. The usually-quoted production from this operation is $2 million, but this is probably a run-of-mine figure. The value of finished stones on the New York retail market was certainly far greater. At the time, the mine site was the scene of sporadic armed conflict with local Pueblo Indians claiming ancestral heritage to the deposit.

After tour of the mine, continue eastward on the highway towards Cerrillos. **0.2**

TURQUOISE

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The word "turquois" ("turquoise" is an older form of the spelling) is from the French word "Turquie" for Turkey, where the mineral was thought to have originally been mined. Turquoise is a hydrous aluminum phosphate that contains a small amount of copper and occasionally a bit of iron. Its hardness is 5-6; specific gravity, 2.6-2.8. The famous and desirable blue color of the gem is due to the copper, whereas the green color is due to iron. Uniformly colored blue specimens are greatly in demand for fine jewelry, often matched with gold, silver and diamond. Turquoise can range is color from a hard, bright, electric blue to pale blue to pale sea-green. Crystals are very rare, and therefore greatly valued. Spectacular microcrystals are found in quartz and schist near Lynch Station in Campbell County, Virginia. In the southwestern U.S., an unusual occurrence, formed by a network of thin chestnut-brown veinlets in the turquoise, is greatly admired. This "spider" variety is also notable at Bisbee and Morenci.

FIGURE 3.4. Turquoise mine workings that have followed a large, vertical, veined fracture zone in western part of Turquoise Hill.

The recent high interest in turquoise jewelry made by southwestern Native American Indians is only the latest in a long history of appreciation for this striking mineral. Turquoise was mined on the Sinai peninsula 7000 years ago. After being long abandoned, these rich mines were rediscovered in 1849. Egyptian artists fashioned blue turquoise into grand brooches and pectorals, and created fine ornamental inlays. Neither the Greeks nor the Romans used turquoise, and it wasn't until the middle ages that the fine blue turquoise of Persia was mined. India, Burma and Ceylon supplied no turquoise, although Tibetans used Chinese turquoise widely. During several Chinese dynasties, from 1766 BC to 221 AD, Chinese turquoise was crafted into stunning artistic pieces worn by royalty. In spite of the enormous copper deposits of South America, surprisingly little turquoise was used there, although some fine blue gemstones were inlaid in gold during the Chimu period in Peru.

Turquoise for the inlaid ritual objects of the Aztecs was actually mined in New Mexico and Arizona by local Indian tribes. Evidence for early trading includes neutron activation techniques to "fingerprint" Aztec turquoise with North America sources (Harbottle and Weigand, 1992). They concluded that the major trade came from the Cerrillos area, specifically Mt. Chalchihuitl, and that it was extensive and contributed to a lavish trade in gem, ceremonial and religious art. Aztec artifacts from Alta Vista, Mexico—northwest of Mexico City—a prehistoric site dated at 700 AD, contain turquoise "fingerprinted" from Cerrillos. By inference, turquoise mining at Chalchihuitl extends to nearly 13 centuries ago. And as a footnote on this, the earliest use of turquoise as gem was found in a burial site near Mezcala, Guerro State, Mexico, dated archaeologically at 600 BC. If this turquoise came from the Cerrillos area, as is possible, then that mining date is pushed back to nearly 26 centuries. Clearly, the oldest mining in North America. Mount Chalchihuitl, here in the Cerrillos Hills, was the largest open pit mine of any metal or mineral in North America when the Spanish arrived in 1535. Turquoise is also found in Colorado, Nevada, California, France, Germany and Russia.

CERRILLOS MINING DISTRICT

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The Cerrillos mining district is about 30 mi^2 in area and encompasses the Cerrillos Hills (or more properly, Los Cerrillos) southwest of Santa Fe, New Mexico. The district is not necessarily notable for the monetary value of past production; it is truly distinguished, however, in the rich history of turquoise, silver, lead and copper mining that dates back to at least 700 AD, and probably beyond. The turquoise deposits at Mt. Chalchihuitl ("turquoise" in the Aztec dialect Nahuatl) have been widely cited as being the most extensive prehistoric mining operations in North America. Various lines of archeological and chemical evidence (e.g., Pepper, 1905; Pogue, 1915; Warren and Mathieu, 1985; Goodman and Levine, 1990; Harbottle and Weigand, 1992) point to extensive mining and trade of Cerrillos turquoise across the continent for over 13 centuries. Combined open pit/underground mining at Chalchihuitl (Fig. 3.5) probably ceased around 1700; prior to then the Indians had excavated an estimated 15,000 tons of rock using stone tools. Pre-fracturing of the host rock was by the bonfire/water-dousing technique—the water being either snow melt or via bucket brigade from the Galisteo River 3 mi distant (when flowing).

Artifacts from several prehistoric mines in Los Cerrillos (e.g., Mina del Tiro and Bethsheba mines) indicate that Indians were also mining copper oxides for pigment and lead for pottery glaze at about the same time. In Spanish Colonial and Mexican time, from around 1700 to 1849, various vein deposits in Los Cerrillos were mined intermittently for silver (bullion), lead (musket balls) and copper (armorplate and utensils) (Simmons, this volume). As opposed to the Old and New Placer districts of the Ortiz and San Pedro Mountains to the south along the Tijeras–Cañoncito fault zone, the Cerrillos district has never produced a significant amount of gold. Nevertheless, in 1973 the state of New Mexico placed the district proper on the State Register of Cultural Properties and recommended it to the National Register of Historic Places (Schroeder, 1979).

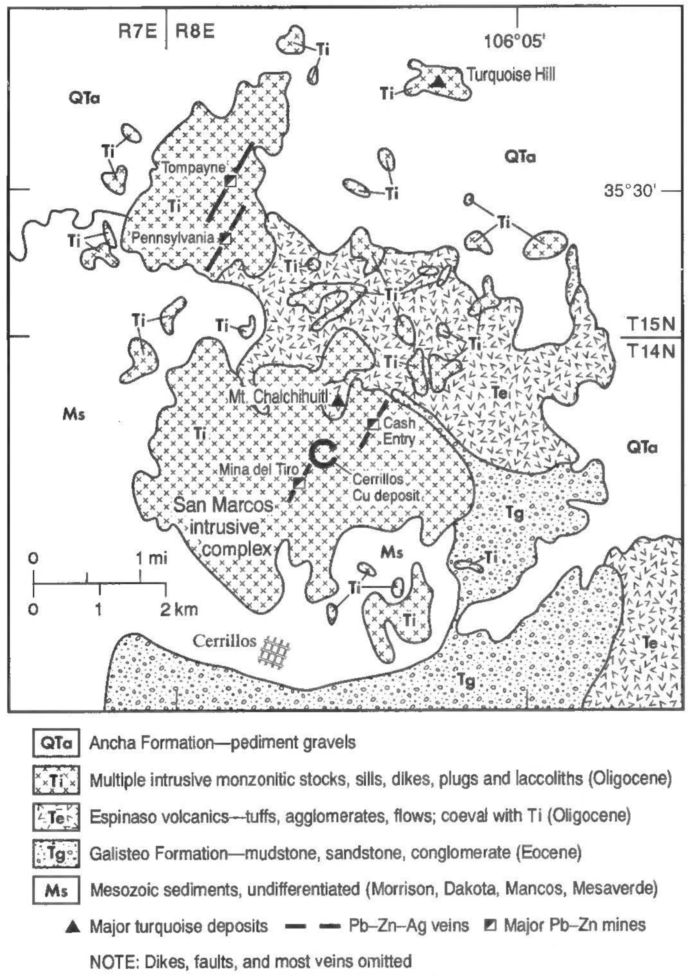

FIGURE 3.5. Generalized geologic map of Cerrillos mining district, showing principal mines.

During the Territorial period, discovery by Colorado miners of new lead-zinc-silver lodes in 1879 led to a boom that lasted several years before subsiding to sporadic production from a handful of mines until the early 1950s (Elston, 1967). In 1959, Bear Creek Mining Company, then a subsidiary of Kennecott Copper Corporation, discovered and explored a small, low-grade porphyry copper deposit in the southern part of the district (Fig. 3.5). This deposit was then extensively studied by Occidental Mineral Corporation in the mid-1970s as a possible in-situ heap leach operation (Wargo, 1964; Akright, 1979; Giles, 1991).

In brief, Los Cerrillos is underlain by a multiple intrusive complex of laccoliths, dikes, sills and stocks of Oligocene age intruding upper Mesozoic and Eocene sedimentary strata. The igneous rocks range from syenite to diorite, with monzonitic varieties predominating (Disbrow and Stoll, 1957). The domed host rocks include extensive aprons of volcaniclastic Espinaso Formation that are the extrusive equivalents of the plutonic rocks (Kautz et al., 1981; Smith et al., 1991). Skirts of the Espinaso and Cretaceous Mancos Shale separate two main intrusive lobes—the Bonanza lobe on the north, of which Turquoise Hill is an outlier, and the San Marcos intrusive center on the south, which hosts the Cerrillos porphyry copper deposit and the Chalchihuitl turquoise (Fig. 3.5).

The copper porphyry body is hosted in an annular stockwork zone surrounding an unaltered equigranular monzonite plug—similar to the copper zone at Turquoise Hill. The deposit displays most of the mineralization and alteration zoning patterns that are typical of porphyry systems elsewhere such as concentric potassic-phyllic-argillic-propylitic halos and coincident high copper/potassic and high pyrite/propylitic zones. Not typical, however, particularly in the southwest U.S., are the high chalcopyrite/pyrite ratios, very low MoS_2 content, high magnetite, significant gold, and apparent lack of a spatial zoning scheme for lead and zinc. The goethitic oxide cap is 100–400 ft thick and there is no supergene chalcocite blanket. At a 0.2% cutoff, the deposit contains around 10 million tons at 0.3% total Cu. Given current metal prices, plus environmental and regulative factors, the deposit is uneconomic.

The vein-type lead-zinc-silver lodes postdate the porphyry copper mineralization and are localized along a NNE fracture pattern throughout the district. The veins occur as lenses and crustifications in shoots that partially fill shear zones and faults. In general, primary ores consist of sphalerite and argentiferous galena, with lesser chalcopyrite and some weird sulphosalts (e.g. bournonite), in a gangue of quartz, ankerite and barite. Most production was obtained from 12 mines, chiefly the Cash Entry, Tom Payne and Pennsylvania (Fig. 3.5). The Cash Entry was the site of a platinum promotion a few years back. The "ore" was a magnetite-epidote tactite (probably contact-metamorphosed Greenhorn Member of the Mancos Shale) from somewhere in the district; it was brought to the mine site and treated by an enigmatic and mysterious metallurgical process to produce Pt-group metals. This alchemic exercise came to a sudden and tragic end around 1970, following significant financial investment in the enterprise.

Turquoise occurrences are scattered throughout the district in patches of strongly argillized and weakly tourmalinized monzonite and Espinaso volcanics. These bleached zones, most or all of which are pockmarked with prospect pits, reflect initially high hydrothermal pyrite content, perhaps up to 10%. The turquoise occurs as nodules in open spaces and as irregular veinlets with little continuity. Within an individual deposit the color can range from sky-blue to apple-green, including sporadic cream-colored variscite ($AlPO_4\ 2H_2O$). The three deposits in the district that had sustained production of high quality material were Chalchihuitl and Turquoise Hill, and the Blue Bell mine southeast of the Cash Entry, which was worked from 1900–1925.

11.3 Road bends sharply to right. Straight ahead in the distance are the Sangre de Cristo Mountains and Santa Fe. **0.7**

12.0 Middle Hill, on right, consists of Oligocene augite biotite trachyte porphyry. **0.3**

12.3 From 12:00 to 1:00 on the skyline are the San Pedro and Ortiz Mountains. Residue and waste dumps of the Cunningham Hill operation are visible on northern slope of Ortiz Mountains. **0.1**

12.4 Road bends sharply to left. **0.3**

12.7 Road to right leads to another of the state's major Western movie sets, the J.W. Eaves Movie Ranch (Fig. 3.6), which includes a railroad. The modern era of New Mexico filmmaking began in 1968 when J.W. Eaves built a complete western town here for the Henry Fonda and James Stewart film *The Cheyenne Social Club*. The long list of films since then includes John Wayne's *The Cowboys*, *Easy Rider*, *Billy Jack*, *Young Guns*, and the recently released *Wyatt Earp* starring Kevin Costner. The Eaves location is also leased for music videos, commercials, photographic ads, and private wild west parties. Adjacent to the J.W. Eaves Ranch is a Mexican village set, complete with twin-towered adobe church. **0.2**

FIGURE 3.6. Eaves movie ranch.

12.9 To right is Picture Rock, composed of augite biotite monzonite porphyry. Old maps label it Rocky Butte, but it is commonly called Lone Butte. **0.3**

13.2 The drainage on right, Gallina Arroyo, exposes Galisteo Formation and Espinaso Formation. In this area the Galisteo dips 60° to 70° westward. **0.5**

13.7 Junction with NM-14, **turn right toward Cerrillos**. **0.3**

14.0 Off to the right in the middle distance are the adobe-colored twin bell towers of the Mexican movie set mission, and just to the south are wooden, false-fronted buildings of the J.W. Eaves Western movie town. **1.0**

15.0 Milepost 37. Here in Arroyo Coyote are exposures of Espinosa Formation. As we climb out of the canyon we see roadcuts in Quaternary-Tertiary alluvial deposits. **1.4**

16.4 Roadcuts in Ancha Formation. **0.2**

16.6 **Turn left** onto Santa Fe County Road 42. This dirt road can become muddy and slippery after a rain. We are driving across Plio-Pleistocene sand and gravel deposits. **1.5**

18.1 **Bear left** on Haozous Road. **0.1**

18.2 **Stay left** on Haozous Road. Ahead on the left is the studio and workshop of Allan Houser, the famous sculptor and painter who died in August of 1994 at the age of 81. We have special permission to visit the workshop today. At any other time, please do not disturb the artists. **0.1**

18.3 **STOP 2. Allan Houser Gallery.**

In September 1994, the nation lost the famous artist, Allan Houser (Fig. 3.7), known as the patriarch of native sculptors. Houser's works of sculptural art range from representative works to totally abstract works in steel, bronze and stone. Of particular interest to the geologist was his widespread use of a variety of sculpture stone. From the Roswell area he carved the pink to white alabaster produced from the Permian Seven Rivers Formation. From Belen he obtained multicolored travertine. However, the majority of his carving stone was obtained from other states and included the Indiana limestone, Vermont and Tennessee marble, and Virginia steatite (soapstone).

Allan's father was a member of the Chiricahua Apache band that surrendered with Geronimo in 1886. Subsequently, the Apaches were imprisoned for 27 years. Allan was born in 1914, after their release on a small farm outside Fort Sill, Oklahoma. He was the first Chiricahua child born in freedom. Houser came to Santa Fe in the 1930s and received formal training in drawing and painting. He is self-taught as a sculptor.

International collections that have acquired Houser's works include the Pompidou Museum, Paris; the National Portrait Gallery and the National Museum of the American Indian, Smithsonian Institution, Washington, D.C.; the Dablem Museum, Berlin; and the State Capitol of Oklahoma. In a career that spanned more than six decades, Houser has earned the highest possible awards and honors. In addition to the National Medal of Arts awarded by President Bush in 1992, Houser received two Guggenheim

FIGURE 3.7. Allan Houser among his stone sculptures.

fellowships, an honorary Ph.D. in Fine Arts from the University of Maine, the American Indian Lifetime Achievement award, and the prestigious Palmes Academique from the French Government.

A list of the localities and their stone he commonly used are as follows: New Mexico alabaster—Roswell area; New Mexico travertine/marble; Utah alabaster; Colorado alabaster; Indiana limestone; Vermont marble; Tennessee black marble; Tennessee pink marble; Steatite talc—Virginia; Portuguese marble; Carrara marble; Italian gray marble; African Wonder Stone—black talc.

Turn around and retrace route to NM-14. **1.8**

20.1 **Turn left** at intersection with NM-14. **0.5**

20.6 Milepost 35. View of Glorieta Mesa on skyline at 10:00. Outcrop of Ancha Formation sand and gravel on right. Begin descent to Galisteo Creek. **0.5**

21.1 At top of hill on left is a dramatic right-angle angular unconformity between the steeply tilted Galisteo Formation and flat-lying Santa Fe Group. **0.1**

21.2 On right is the "Garden of the Gods" pulloff. The "Garden of the Gods" was long known to locals as "ambush rock" because this is where bandits hid and attacked prospectors and miners taking silver and gold from the Cerrillos mining district to Santa Fe by wagon for assay. Spectacular exposures of vertical and near-vertical Galisteo Formation are on the right. These exposures are near the middle of the Galisteo Formation, which is about 3280 ft thick here (Lucas, 1982). Fragmentary bones of brontotheres found just east of the highway indicate a late Eocene (Duchesnean) age. At this locality the Galisteo consists of pebbly sandstone, cobble conglomerate and mudstone. On the left, beyond the red and tan sandstone cuestas of Galisteo Formation, the middle-ground ridge is composed of brown and gray outcrops of upper Eocene-Oligocene Espinaso Formation. The nearly vertical dips of the Galisteo Formation along the road diminish to about 25°E on the east side of the road and the Galisteo grades upward into the Espinaso Formation, which dips only 5-10°E. **0.8**

22.0 At 11:00, in the Ortiz Mountains, are visible several features. On the right, is the large, light-colored old waste dump from the Cunningham Hill open-pit gold mine. This material has been recontoured and revegetated as part of an environmental restoration program by LAC Minerals. The two smaller, white piles to the left are mill tailings from Gold Fields Mining Company's cyanide leach operation. The flat, gently E-dipping pediment surface just below the mill tailings is called the Tuerto gravel surface. In the middle distance, across Galisteo Creek, is a second, lower geomorphic surface called the Ortiz surface. **0.5**

22.5 Roadcuts through exposures of SW-dipping Galisteo Formation. **0.1**

22.6 Milepost 33. **0.2**

22.8 **STOP 3. Turn off to the right** into the large pullout the Highway Dept. is using to store gravel.

Galisteo and Espinaso Formations. To the northeast the lower part of the type section of the Galisteo Formation is exposed. Here, Galisteo dips steeply (30° to 75°) to the SE and is locally vertical to slightly overturned. Nearly horizontal strata of the Pliocene-Pleistocene Ancha Formation overlie lower Galisteo strata, creating a visually impressive angular unconformity (Fig. 3.8).

Views to the north and northwest from this vantage point illustrate the deformation of Cretaceous and Eocene rocks that was caused by intrusion of magma now represented by the Cerrillos Hills (Fig. 3.8). Tan and red sandstone with associated red mudstone are fluvial strata of the Eocene Galisteo Formation; an outcrop of lithic subarkose may be examined at the east end of the pullout. Buff sandstones interbedded with gray to black carbonaceous shale are coastal-plain facies of the Upper Cretaceous Menefee Formation; an overturned sequence of these strata is exposed in the roadcut to the west near the crest of the hill. The highest hill visible to the northwest from here is hornblende latite porphyry associated with the early calc-alkaline phase of magmatism in the Cerrillos Hills. Stearns (1953b) envisioned this intrusion to be a laccolith because Cretaceous rocks exposed farther west dip at a modest angle below the intrusion, whereas the overlying strata, seen here, have been tilted to a high angle. Dips within Galisteo strata diminish to the east and the lithic subarkose and related mudstone grade upward into coarse-grained volcaniclastic strata of the Espinaso Formation, underlying the ridges along the north side of Galisteo Creek as visible in the background to the east of here (described by Smith et al., 1991). Basal Espinaso strata contain clasts of Galisteo Formation mudstone as much as 3.3 ft across, apparently eroded from the domal uplift above the laccolith. The intruding magma deformed the near-surface sedimentary strata and eventually ruptured through to the surface to produce viscous, crystal-rich porphyry extrusions from which breccias were shed eastward to form the Espinaso Formation (Smith et al., 1991; Erskine and Smith, 1993). It may be that the near-surface intrusions were endogenous volcanic domes that broke through, with concomitant deformation of country rock, in a fashion similar to the better-studied Sutter Buttes in the Sacramento Valley of northern California (Williams and Curtis, 1977).

Some uncertainty has existed about the age of strata assigned to the lower part of the Galisteo Formation by Stearns (1953b), Disbrow and Stoll (1957), Bachman (1976) and Lucas (1982), among others. Early Eocene (Wasatchian) fossil mammals are present in the Galisteo Formation 1210–1390 ft above its base as picked by these workers (Lucas, 1982). The traditional view has been to regard the underlying nearly 1300 ft of strata as also of early Eocene age, reflecting sedimentation due to a sharp pulse of Laramide tectonism at the beginning of Eocene

FIGURE 3.8. Photo mosaic to the north from Stop 3.

time (Chapin and Cather, 1981; Smith et al., 1985; Lucas and Williamson, 1993).

The pioneer geologist Ferdinand Vandeveer Hayden visited this area right after the Civil War and coined the term "Galisteo sand group" for strata now called Galisteo Formation (Hayden, 1869). The type section of the Galisteo Formation exposed here is about 3280 ft thick over a nearly 2 mi west-east traverse (Stearns, 1953b; Lucas, 1982). About 1.25 mi east of here the upper part of the formation produces late Eocene (Duchesnean) fossil mammals (Lucas, 1982, 1992).

Magnetostratigraphy of the upper part of the Galisteo Formation east of here indicates a pattern of short normal-long reversal-short normal over the Duchesnean fossil-mammal-bearing interval of the formation. Correlation of this pattern with chrons 18N1–17r–C17N1 is best supported by mammalian biochronology and indicates an age of about 38 Ma for the Duchesnean interval of the Galisteo Formation (Prothero and Lucas, in press). **0.2**

23.0 Roadcuts through Galisteo Formation. **0.2**

23.2 Roadcuts through overturned Menefee Formation of the Mesaverde Group. Mesaverde strata in this area mostly belong to the Crevasse Canyon Formation of Coniacian-Santonian age. Total thickness of these coal-bearing clastics is nearly 985 ft here (Bachman, 1976a). All the coal mined in the Madrid and Hagan areas to the south of here came from the Crevasse Canyon Formation. Strata of the Mancos Shale in the Los Cerrillos area include the Graneros, Greenhorn, Juana Lopez and Niobrara members (Bachman, 1975). They are as much as 2300 ft thick, very fossiliferous and range in age from Cenomanian to Coniacian (Late Cretaceous). **0.3**

23.5 Exposed on the cliffs ahead is a Tertiary intrusion in the Mancos Shale. **0.4**

23.9 Crossing over railroad tracks. **0.1**

HISTORY AND ENGINEERING ASPECTS OF GALISTEO DAM AND RESERVOIR, SANTA FE COUNTY, NEW MEXICO

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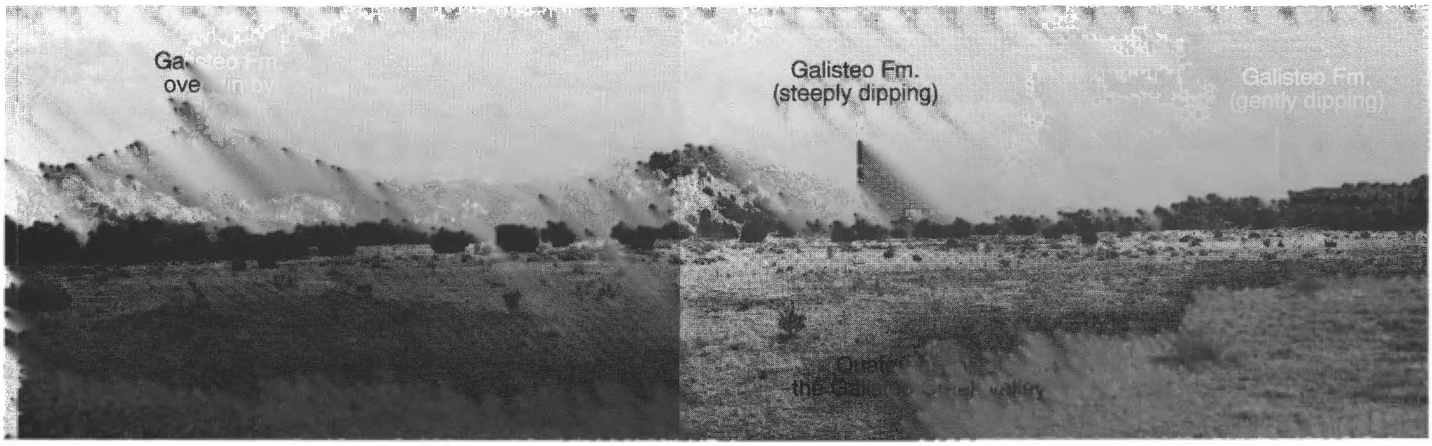
Galisteo Dam and Reservoir, located on Galisteo Creek about 12 mi above its confluence with the Rio Grande, was authorized by the 1960 Flood Control Act for flood control and sediment detention, but does not impound a permanent pool. Access to the dam is 4.6 miles eastward from I-25 to the south end of the dam embankment and a locked maintenance road gate. Vehicle entrance is restricted, but a visitors center and picnic area are nearby on an unrestricted spur road to the right of the locked gate.

Actual construction on the dam, by List and Clark Construction Company of Overland Park, Kansas, began March 24, 1967, and ended September, 1970. The dam is a rolled earth-fill structure 2820 ft long with a maximum height of 158 ft above streambed, a crest width of 20 ft, base width of 2600 ft and a compacted fill volume of 9.33 million yd^3. The outlet works, located on a bedrock-excavated bench in the right abutment, includes an inlet channel, an ungated intake structure (one of only two such in the state operated by the Corps, the other being Santa Rosa Dam, completed in 1980), a 10-ft-diameter conduit, a flip bucket (for energy dissipation) and an outlet channel. The ungated outlet works allows Galisteo Creek to flow naturally during times of low rainfall, but provides a uniform discharge during high rainfall or flash flood events. The spillway, 1070 ft long by 250 ft wide, is an uncontrolled, rock-cut trapezoidal channel located in sandstones and shales of the Morrison and Dakota/Mancos Fms in the right abutment. Bedding flattens eastward from 14°-16° in the middle of the spillway to 10°-12° a few hundred feet upstream. A pinned-on concrete wall, 21 ft high and 492 ft long, was built throughout the shale zone on the south side of the spillway for slope protection. Two minor faults (±8 ft) were noted in the north abutment area, but grouting was not required. As structures are buried in soil, seismic stability was not considered in the design. Valley alluvium, made up of discontinuous lenses of sand, gravel, clay, and silty clay, is approximately 80 ft thick. Leakage along the base of the dam is minimized by a low permeability clay-rich "blanket" extending upstream from the foot of the embankment.

Elevation of the dam embankment is 5639 ft, allowing for a maximum pool elevation of 5634 ft above sea level. At maximum pool height, the reservoir has a surface area of 2920 acres with a capacity of 153,400 acre-ft and storage allocations for 10,200 acre-ft of sediment below the spillway crest. The spillway (elev. 5608 ft) has a capacity of 90,000 cfs at maximum pool height. Drainage area behind the dam is 596 mi^2. The maximum pool of record was July 22, 1971, when a pool elevation of 5517 ft was recorded, corresponding to 2870 acre-ft of water.

The instrumentation system consists of foundation and embankment piezometers, foundation settlement gauges, tiltmeters (slope indicators) and surface settlement and horizontal movement points.

The dam is managed by the U.S. Army Corps of Engineers, Albuquerque District. Periodic inspections are carried out, usually as a joint effort by the Albuquerque and Cochiti districts of the Corps, and the State Engineer, whereas inspection and annual maintenance of the reservoir gauges are included in the U.S.G.S. Cooperative Stream Gaging Program. The dam was inspected in 1992, with the next inspection scheduled for 1997. Thanks to Dwayne Lillard, P.E. and Richard Barnitz, P.E. of the Albuquerque District, U.S. Army Corps of Engineers, for much of this information.



24.0 Entering Cerrillos (5658 ft). Supplemental log 3 begins here and proceeds westward through the ghost town of Waldo to I-25, south of Santa Fe; geologic features include intrusions in the Cerrillos Hills and sedimentological and paleontological aspects of the Cretaceous Mancos Shale. This former coal-mining town was built by the Santa Fe Railroad in 1879. When its population peaked in the 1880s, the town contained 21 saloons and four hotels. **Continue south** on NM-14. **0.4**

24.4 Crossing over arroyo. **0.1**

24.5 **Turn left** onto County Road 55, also known as Gold Mine Road, which goes to the old Gold Fields mine at Cunningham Hill in the Ortiz Mountains. The first part of the road is the narrowest part; it is serviceable for heavy mine equipment from here to the mine. For the next mile we travel through the Galisteo Formation, locally visible along arroyo walls. Locally, in the arroyos, the erosion-cut surface between the Galisteo Formation and the overlying Tuerto gravel is visible. **1.1**

25.6 Road emerges onto the top of the mesa on the type Ortiz erosion surface of Bryan (1938) and the conoplain landform of Ogilvie (1908). **0.3**

25.9 At 1:30 are the Ortiz Mountains. The main mass of the Ortiz Mountains consists of augite monzonite, dated at approximately 29 Ma. The small, conical brown hill in the middle distance at 2:30-3:00 is composed of tailings from an old coal mining operation in Madrid. **1.0**

26.9 Stay left at fork in road. **1.3**

28.2 We are now on the Ortiz Mine Grant. The mine grant was deeded to Francisco Ortiz in 1832 by the Mexican Government. Surface and mineral rights of the area were originally approximately 100 mi^2, centered in the Ortiz Mountains. The surface and minerals were separated in 1948. The mineral rights continue to be held by private interests, and the surface rights by ranchers. **0.4**

28.6 At 12:00 is the recontoured and planted waste rock pile from the old Gold Fields Cunningham Hills mine. The waste rock pile was identified as having an acid rock drainage problem in 1991 and several steps have been taken to mitigate the waste drainage problem. We will visit the waste pile at Stop 4. **1.5**

30.1 Locked gate of the Dolores Ranch. Ahead is private property; permission from the landholders is required for access. **0.1**

30.2 On right is a view up Dolores Gulch. The low depression is underlain by the Dolores vent breccia, inferred to be one of the sources for the Espinaso volcanics. **0.5**

30.7 This is probably Galisteo Formation sandstone intruded by andesite porphyry. **0.2**

30.9 At 3:00, the abandoned Dolores Ranch is located near the middle of the Dolores vent breccia (Fig. 3.9). On the far hillside lies the Florencio quartzite-hosted gold prospect. Large green water tank on ridge is potable water supply from a 600 ft well near the open pit.

MINING HISTORY OF THE CUNNINGHAM DEPOSIT AND ORTIZ MINE GRANT, SANTA FE COUNTY, NEW MEXICO

Homer E. Milford

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The majority of colonists who founded New Mexico in 1598 came from the silver mining town of Zacatecas, Mexico and had experience in silver mining rather than gold mining. By 1601, there were several silver mines in the Cerrillos Hills, 10 mi north of the Ortiz Mountains, and also mines south of the Ortiz near the San Pedro Mountains (Hammond and Agapito, 1953, p. 829). Though no record of Spanish mining in the Ortiz Mountains is known, it occurred all around the Ortiz Mountains. Two smelter sites southwest of the Ortiz were dated

FIGURE 3.9. Photo of Dolores Canyon from mine road at mile 30.9. The old town of Dolores was the site of New Mexico's first railroad in 1868, a gravity tram line that connected the Ortiz mine with the stamp mill at Dolores. The roads on the far hillside mark the location of the Florencio quartzite-hosted gold prospect.

between 1650 and 1700, and this year is the 300th Anniversary of Governor Vargas's founding of "Real de los Cerrillos," a mining camp which served the Cerrillos silver mines. News of the Ortiz gold rush was published in 1828, two decades before the California gold rush and the first gold rush in the western U.S. In 1832, wealthy individuals began to purchase small lode mines in the Ortiz Mountains, and also to apply for official Mexican lode mining grants. In 1833, two local merchants, Jose Francisco Ortiz and Ignacio Cano bought the Santa Rosalia mine and applied for a mine grant (SANM I, SG 43). Their mine grant, later called the Ortiz Mine Grant, was the first grant recognized by the U.S. Government in the area. Lode production was small during the Mexican period. Through 1979, the vast majority of gold was produced by placer mining. Total production for the area prior to 1900 is estimated at 100,000 oz, mainly produced during the Mexican period from placer deposits. Less than 2000 oz of gold were mined between 1900 and 1979. From 1979 to 1987, Goldfields Corporation extracted approximately 250,000 oz from the Cunningham deposit.

John Greiner signed a contract in 1853 to deliver, to a group of investors, the title to the two Mexican Mine Grants in the Ortiz Mountains. By 1854, Abraham Rencher, a North Carolina politician, was the largest stockholder of the group. Rencher was appointed Territorial Governor of New Mexico (1857-1861) but before he arrived in New Mexico, the mine had been leased to Eugene Leitensdorfer or his family-controlled company, the Carondelet Company. In 1857, the Carondelet Company shipped a stamp mill and steam engine to New Mexico. However, by late 1857, the company was in financial trouble (Elder and Weber, in press).

On February 1, 1858, the New Mexico legislature passed a law incorporating the "New Mexico Mining Company" as the first New Mexico corporation. The law gave Rencher total authority, and within two weeks he bought the Carondelet Company stamp mill (Elder and Weber, in press, Kingsbury to Webb, 2/14/1858). It was the first stamp mill in both New Mexico and the Rocky Mountains. A Confederate soldier, whose unit stopped at Dolores in 1862, described a tour of the stamp mill and its operation and made the only known drawing of the mill (Aberts, 1984, p. 73). The Ortiz Mine Grant of 69,458 acres was approved by Congress on March 1, 1861.

After the Civil War, the New Mexico Mining Company raised money for mine development and construction of a larger stamp mill at Dolores. In 1868, New Mexico's first railroad was built (Fig. 3.10). The 1.5-mi-long railroad, or gravity tram line, connected the Ortiz Mine to the new mill in Dolores (NMMC, 1868).

In 1879, Steven B. Elkins and Jerome B. Chaffee gained control of the New Mexico Mining Company. In 1899, a 99-year lease for the entire grant, not previously leased to others, was sold to the Galisteo Company, owned by the Hoyt brothers of New York City. The Hoyts believed that large placer deposits still existed on the grant, and that Thomas Edison had developed a dry placer mill that would make large scale placer mining profitable. However, Edison's engineers could not locate enough paying placer ground to justify building a large dry placer mill, and Edison abandoned the project. The Hoyts retained the Ortiz Mine Grant until 1943, when it was sold to a local livestock association, which in turn sold it to Mrs. George Potter in 1946. The Potters sold off the surface,

FIGURE 3.10. The Ortiz is the oldest lode mine in the Old Placers Mining District, having been discovered in 1833 and worked more or less continuously through 1870. Several attempts to work the deposit thereafter, the last during the 1930s, yielded only modest returns. The first reduction mill was built at Dolores and was connected to the mine by New Mexico's very first "railway"—a half-mile tramway constructed of iron scraps laid upon wooden beams, the remains of which may still be seen if one knows where to look. The second mill was built upon the site of the first. The third and final mill, shown above in this March 1901 view, was constructed at the mine site and contained 10 stamps, two Huntington mills, and three vanners. Little remains of this historic site today. NMBMMR Photo collection, #1680, courtesy of Robert Shantz.

but retained the mineral rights. Potter took in a partner, and formed the Ortiz Mines Company of Missouri to manage the leasing of the mineral rights. Goldfields Corporation obtained a mineral lease to 36,000 acres in the 1970s and started developing an open pit mine on the Cunningham Deposit.

The Cunningham Deposit had been worked sporadically since the 1830s, and probably was the"Mina del Compromiso" mine referred to as east of the Ortiz Mine. It was worked intermittently during the Mexican and U.S. Territorial periods. The Cunningham deposit was a large diffuse ore body and even the prominent mining engineer of the 19th Century, Rossiter W. Raymond, was frustrated by the difficulty in telling high grade from low grade ore. Raymond made an unusual concession for a 19th Century U.S. miner in recognizing that only the local native New Mexican miners were skilled enough to distinguish good ore from bad in the Cunningham deposit (Raymond, 1874, p. 316-317). Steven B. Elkins had a high opinion of the Cunningham deposit, and in the 1890s took a 99-year lease on it. Elkins formed the Sandia Mining Company and sent his brother to manage the mine. The mine was unprofitable, and the Hoyts acquired the property in the early 1900s. No mining is recorded at Cunningham from about 1902 until 1979 when Goldfields began operations. Goldfields' closure in 1986 proved to be the last mining on the grant, except for exploratory work that began in the late 1980s when LAC Minerals Corporation purchased the mineral lease and brought in a potential partner, Pegasus Gold Corporation. Pegasus conducted exploration and mapped two deposits on the south side of the Ortiz Mountains before abandoning the project in the fall of 1993. LAC Minerals was purchased by Barrick Resources in 1994. Barrick hopes to permit two open pit mines on the south side of the Ortiz Mountains in Lukas and Carache Canyons.

The prominent role of the Ortiz Mine Grant in New Mexico and U.S. history has never been recognized by the general public. The Grant is in the heart of the "Oldest Mining District in the United States" and is the location of the "First Western Gold Rush". It was also the site of the first stamp mill in the Rocky Mountains, and the first railroad in New Mexico. The grant provided the funds that made the Santa Fe Trail trade economically significant, and spurred U.S. interest in acquiring the Southwest. Five years hence will mark the 400th anniversary of European mining in southern Santa Fe County. **0.2**

31.1 Gate to Gold Field mine. **0.2**

31.3 Vista to the left, north-northeast. The Sangre de Cristo Mountains form the background for Santa Fe. In the foreground, beyond the chain link fence, is an area known as Cunningham Mesa where the Cunningham placers were worked in the 19th century. The most notable miner was Thomas Edison, who invented an electro-winnowing plant for working dry placers, which is said to have failed miserably. Most of the 100,000 oz of placer gold production in the Ortiz Mountains came from this area. To the NNW are the lower Cerrillos Hills. The Jemez Mountains are to the WNW. At about 10:00, in the middle far distance near the town of Galisteo, is a prominent dike that is part of a family of dikes that radiates from the Ortiz Mountains. Mesa de los Cobreros at 11:00 is underlain by sills presumed to be part of the Ortiz laccolithic complex. **0.2**

31.5 On the left is the maintenance shop for the old Gold Field's Cunningham Hill mine. On the right is the pregnant solution pond and the foundation for the recovery plant for the old mine. At 1:00-2:00, at about 100 yards, is the asphalt-lined leach pad from the mining operation. **0.1**

31.6 On the left is the residue pile, or spent ore pile, from the Cunningham Hill mine. At 12:30, on the hill in the near distance, is the open-pit mine. **0.2**

31.8 On the right is the final stage crusher for the three-stage crushing plant. **0.3**

32.1 Western end of mill. This is the beginning of the crushing process circuit. The view down to the east is of remains of the crushing equipment and the leach pad. A gantry spread the crushed ore out on the surface of the pad, where cyanide solution was sprinkled over the ore. The metal-rich leachate was then collected and gold was electroplated on stainless steel sheets in the recovery plant. What remained of the old milling operation was being salvaged and removed as this log was being written (Fig. 3.11). The rock walls to the north are Galisteo Formation. The Galisteo here is atypical because contact metamorphism has changed the sandstone to quartzite. **0.1**

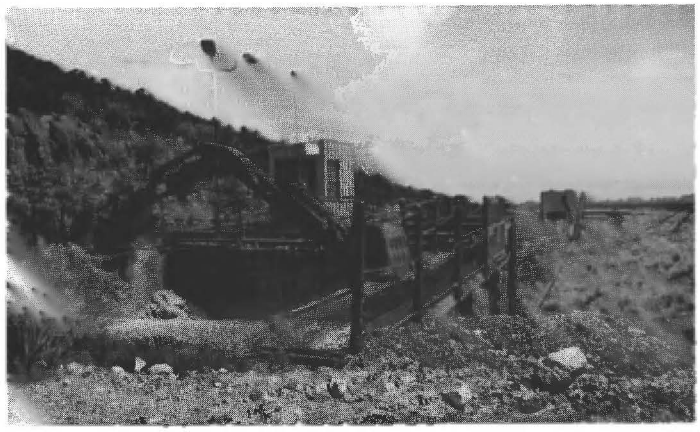

FIGURE 3.11. The Gold Fields crusher at the Cunningham Hill mine. The conveyor in the background moved crushed ore to the leach pad in the distance. Most of this equipment was being salvaged in early 1995 as the road log was being produced.

32.2 **STOP 4. Park near the open-pit mine.**

Cunningham Hill open pit mine. We are at the eastern side of the Cunningham Hill pit (Fig. 3.12). This mine was operated from 1979 to 1987 by Gold Fields Mining Company. It produced approximately 250,000 oz of gold from 5 million tons of ore, grading .055 oz/ton. The scattered chunks of breccia are typical of the ore. Notice the specularite-pyrite gangue assemblage in the breccia fill. The gold was microscopic, but was not bound up in sulfides, and was therefore easily leached, with recoveries of greater than 90%.

FIGURE 3.12. Open pit mine showing heterogeneous, fractured host rock for gold mineralization. View northwest. The darkest outcrops are the volcanic breccia of the Dolores vent. Scheelite is found on the upper level of the mine on the western side.

Looking across the pit to the right, notice the crudely bedded nature of the altered and intruded Galisteo Formation (Fig. 3.13). Across the pit, the gray outcrops and some of the greenish-brown outcrops are the volcanic breccia of the Dolores vent. Scheelite is found here; and in fact, the deposit was first drilled in the 1950s as part of a tungsten exploration program. Scheelite occurred on the upper level of the mine on the western side. Boulders on the upper part of the wall contain some good scheelite crystals.

Beyond the southern wall lies the Golden fault strand of the Tijeras-Cañoncito fault system. Most of the mines and prospects in the Ortiz Mountains lie on or within a few hundred feet of the Golden fault (see Maynard, this volume). Up the valley, the low hill in the middle distance is quartz latite porphyry that intrudes the volcanic vent. The intrusion forms the barren core of a small porphyry copper-gold resource in Cunningham Gulch.

Gold had been known at Cunningham Hill since the mid-19th century (Raymond, 1874), though systematic drilling and tunneling of the deposit did not begin until the late 1940s and 1950s. Some of the impetus for the mid-20th century exploration came from interest in the tungsten resource in the upper part of the deposit. In the 1970s, exploration efforts by Gold Fields Mining Corporation delineated a resource of 6 million short tons with an average grade of 0.055 oz of gold per ton.

FIGURE 3.13. Flat-lying, crudely bedded, highly fractured, altered and intruded Galisteo Formation exposed in the high wall to the north of the parking area. Prospectors for scale.

Gold Fields decided to develop the gold resource at Cunningham Hill in 1978 and stripping of overburden began in 1979 (Nicholson, 1979). The company was producing gold by the time of the all-time high gold price of more than $850/oz in February, 1980. Mining continued until 1986 and the last gold was recovered from the leached ore in 1987. About 70-75% of the contained gold, or 250,000 oz, was recovered from Cunningham Hill ore.

After the ore was blasted and trucked out of the mine, gold was recovered through a process of crushing of the ore, cyanide leaching, and electroplating (Hickson, 1981). Because gold in the Cunningham Hill ore was free, that is, not bound in sulfide minerals, both sulfide and oxidized ore could be subjected to the same extraction process. Cunningham Hill ore was reduced to 3/8 in. size in three stages: (1) a jaw crusher first crushed the ore to 5 1/2 in; (2) a set of two cone crushers further reduced the ore to 3/8 in; and (3) another cone unit caught the oversize portion from stage 2 and brought it to the 3/8 in. size required for the leaching process. Conveyors carried the 5 1/2 in. ore from the primary crusher to a stockpile at the secondary crusher, allowing the crushers to work independently. The system was designed to process an average of 3000 short tons per day.

A moving gantry stacked the crushed ore onto an asphalt leach pad (Fig. 3.14). The pad consisted of eight 200x160 ft sections separated by curbs. Each section had a load of 18,750 short tons of ore that was leached for an average of 10 weeks. After leaching, the spent ore was removed to a residue pile south of the pad. A sodium cyanide (NaCN) solution was sprinkled on the ore. The concentration of cyanide ranged from 0.05 to 1.5 ppm, depending on the sulfide content of the ore. A lime solution was sprayed on the ore piles to maintain a pH of 10.2. The pregnant (gold-bearing) solution ran into a series of drains and into a recovery plant at the east end of the asphalt pad.

The pregnant solution passed through a series of tanks containing activated carbon, which adsorbed gold from the pregnant solution. The gold-bearing carbon was put in desorption vessels where it was subjected to a sodium hydroxide, ethanol, and cyanide solution that stripped the gold from the carbon. The gold-laden stripping solution was run through electrolytic cells, where the gold was plated onto stainless steel wool. The gold was then replated as foil onto steel plates in a second electrolytic process. The foil, which consisted of 83% Au, was scraped off. The reactivated carbon was recycled and shipped to a refining plant.

Walk north on the access road around the open pit, towards the reclaimed mine dump. Pegasus Mining and LAC Minerals have carried out a program designed to reclaim the waste rock and residue piles and to control acid-rock drainage into Dolores Gulch (Fig. 3.15).

Return to the parking area, and drive back to the maintenance shop where we **turn right through gate** onto the road leading to Cunningham Mesa and Carache Canyon. **0.8**

33.0 **Bear right** after going through the gate. **0.3**

33.3 Ahead is the toe of the residue, or spent ore, pile from the Cunningham Hill Mine. **0.7**

FIGURE 3.14. Aerial view of Gold Fields Cunningham Hill mill and mine in early 1980s. Photography and flying by Paul Logsdon.

34.0 Locked gate. Entering the Lone Mountain Ranch with the eponymous hill at 10:00. **2.4**

36.4 Driving on Tuerto gravel surface on the southeast flank of the Ortiz Mountains. At 12:00 is Buckeye Hill, and off to the left are the San Pedro Mountains, also in the Ortiz porphyry belt. Sedimentary rocks in the San Pedro Mountains range from Triassic Chinle and Santa Rosa on the eastern side, down to Pennsylvanian rocks on the western side. The high peaks of the San Pedros, including the highest, Oro Quay Peak at 9:30, are composed of augite monzonite, similar to the central intrusion of the Ortiz Mountains. Skarn mineralization in Pennsylvanian limestones of the San Pedro Mountains was exploited for copper and gold by several mining companies, culminating in the 1970s by Goldfield Corporation (a different company than the Gold Fields Mining Company in the Ortiz Mountains). A considerable garnet resource still exists in the San Pedro Mountains at the San Pedro mine. A windmill ahead at 11:00. **0.5**

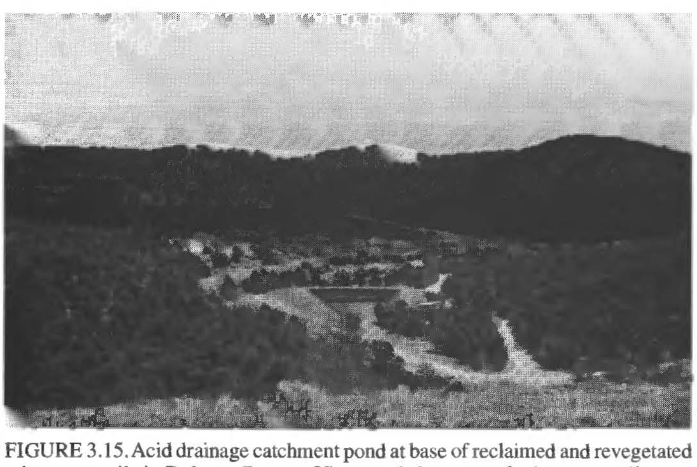

FIGURE 3.15. Acid drainage catchment pond at base of reclaimed and revegetated mine waste pile in Dolores Canyon. View north from top of mine waste pile.

36.9 Road ascends a steep slope that is underlain by alluvium and Tuerto gravel. This fan deposit was derived from Carache Canyon and drainages east of Carache Canyon. **0.5**

37.4 Arriving at the junction of East Carache Road and Carache Canyon Road. **Park in large graveled lot. 0.1**

37.5 **STOP 5. Carache Canyon exploration adit.** Dump of the Carache Canyon exploration adit. On the right is the adit that is driven into the Galisteo Formation within the Ortiz graben (Fig. 3.16). As of April 1995 the adit had advanced 1700 ft and has been on hold for the last three years. From the south end of the dump is a view of the San Pedro Mountains, and in the right background, to the south-southwest, are the Monte Largo Hills. The Monte Largo Hills are a horst block of Proterozoic rock along the Tijeras-Cañoncito fault system. Farther off to the right, behind Buckeye Hill, are the southeastern slopes of the Sandia Mountains, where Pennsylvanian rocks form the eastern dip slope of the Sandia uplift.

Walk west past the trailer for tour of the Carache Canyon breccia pipe and mineral deposit. **Take hairpin right turn** going back up Carache Canyon. Outcrops of massively bedded Galisteo Formation sandstone to the right. The Galisteo here is within the Ortiz graben. Core drilling

FIGURE 3.16. Carache Canyon exploration decline and stacks of ventilation ductwork.

has shown that approximately 1000 ft of sandstone lies below us.

On the right is a vent raise for the Carache exploration decline. The depth to the decline is about 300 ft. We are on the Golden fault, along which has intruded a dike of latite andesite porphyry. The Golden fault is a north-bounding fault of the Ortiz graben. Ahead, where the canyon splits, is the upper part of Carache Canyon where LAC Minerals has explored mineralization associated with the collapse breccia pipe. Numerous drill roads, reclaimed and unreclaimed, have been cut in the Carache Canyon area to support nearly 200,000 ft of core and reverse circulation drilling.

Continue up the road towards the surface of the Carache Canyon collapse breccia pipe. See paper by Schutz (this volume) for description of geology at this stop.

End of Third-day Road Log. Return to NM-14.