First-day road log, from Lordsburg to Ruth Mine (Lordsburg district) to Twelve Mile Hill to Rock House Canyon (Pyramid Mountains) to Burgett's Greenhouses (Animas Valley) to Steins (Peloncillo Mountains)

V. T. McLemore, W. C. McIntosh, and J. W. Hawley

2000, pp. 1-16. https://doi.org/10.56577/FFC-51.1

in:

Southwest Passage: A trip through the Phanerozoic, Lawton, T. F.; McMillan, N. J.; McLemore, V. T.; [eds.], New Mexico Geological Society 51 st Annual Fall Field Conference Guidebook, 282 p. https://doi.org/10.56577/FFC-51

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

FIRST-DAY ROAD LOG, FROM LORDSBURG TO RUTH MINE (LORDSBURG DISTRICT) TO TWELVE MILE HILL TO ROCK HOUSE CANYON (PYRAMID MOUNTAINS) TO BURGETT'S GREENHOUSES (ANIMAS VALLEY) TO STEINS (PELONCILLO MOUNTAINS), NEW MEXICO

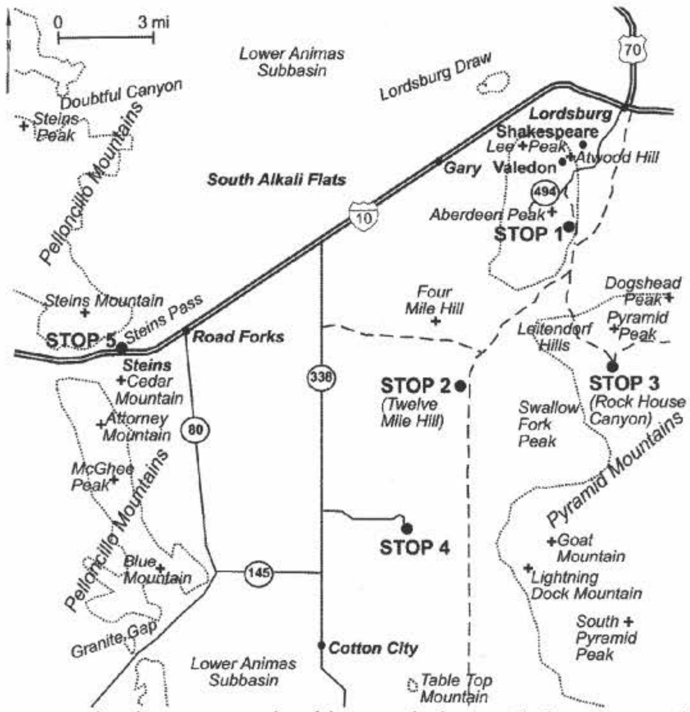
VIRGINIA T. McLEMORE, WILLIAM C. McINTOSH, and JOHN W. HAWLEY

THURSDAY, OCTOBER 19, 2000

Assembly point:	Holiday Inn Express, Lordsburg.
Departure time:	7:30 a.m.
Distance:	78.6 mi
Stops:	5 stops

Summary

The first day of the field conference in the Pyramid Mountains examines the difference in magmatic style between the Laramide and mid-Tertiary igneous rocks in southwestern New Mexico. Composite andesite volcanoes with associated intermediate silicic plutons, dikes, and sills dominate the Laramide systems. Large calderas, which erupted rhyolite ignimbrites (ash-flow tuffs) and lavas that are locally interbedded with andesite flows, characterize the mid-Tertiary systems. Stop 1 will be at the Ruth mine, a Laramide polymetallic vein deposit in the Lordsburg district where we will examine the style of mineralization and alteration, and also examine the intrusive relationships of a dacite dike in andesite. We will proceed along the Animas Road to Twelve Mile Hill at Stop 2 where we will have an overview of mid-Tertiary volcanism and caldera activity in Hidalgo County and examine a sequence of ash-flow tuffs erupted from three different calderas. Lunch at Stop 3 will be in Rock House Canyon, where we will have the unique opportunity to enjoy one of the hidden canyons of the Pyramid Mountains and examine more ash-flow tuffs near the northern margin of the Muir caldera. After lunch, we will travel to the Burgett Floral Greenhouses for Stop 4 and observe geothermal resources in action. The tour route between stops 4 and 5 crosses the lower fan delta of ancestral Animas Creek and the floor of pluvial Lake Animas, with its shorelines and Holocene playa-lake features. The first day will end at Stop 5 at the historic town of Steins (pronounced Steens), on the edge of the Steins caldera, for a barbecue dinner.



Mileage

0.0 Holiday Inn Express. **Proceed south (left)** on Main Street (NM-494).

Lordsburg (elevation 4246 ft) was built at a former stop on the Butterfield Overland Stage route as a water and supply station along the Southern Pacific Railroad in 1880. Motel Drive was part of the stage route before Lordsburg became a town. There are three versions of how the town was named (Julyan, 1996). The name may have been derived from the surname of an engineer in charge of the construction crew or from the surname of a man who owned several restaurants along the railroad. The third version is that the name was derived from a Tucson banking and wholesale distribution company named Lord and Williams, owned in part by Charles H. Lord. When freight handlers at the railroad camp in New Mexico unloaded freight from the company, they simply called out "Lord's". Soon the camp became known as Lordsburg. Lordsburg probably grew in size as a result of its proximity to Shakespeare and the Lordsburg mining district as well as the railroad (Hill, 1963). Lordsburg became the county seat of newly established Hidalgo County in 1919. Hidalgo County was formed from the southwestern part of Grant County. By 1927, Lordsburg had the first airfield in New Mexico and both Amelia Earhart and Charles Lindbergh landed here. It is said by local townspeople that the streets of Lordsburg are paved with gold and silver; material used to construct the roads in Lordsburg came from the mine waste piles in the Lordsburg district. Today, Lordsburg is a center for commerce along I-10 and US-70, and for farming, ranching, and the railroad. Average annual precipitation is 10.9 in. and average mean temperature is 61ºF, with large diurnal temperature changes being common (typically approximately 66ºF). **0.2**

0.2 Junction with Buena Vista Road on the left. Keep straight on NM-494. **0.1**

0.3 Junction with Caches St. on the right. Keep straight on NM-494. **0.6**

0.9 Road to Lordsburg water tower and city maintenance yard. Keep straight on NM-494. Hill consists of porphyritic olivine-andesite flows of Animas Road (Thorman and Drewes, 1978a). A sample of this andesite was dated as 66.3 ± 0.4 Ma ($^{40}Ar/^{39}Ar$, whole rock, Lord 17, see McLemore et al., this road log). **0.1**

1.0 Junction with Shakespeare Road. **Keep left** and pass

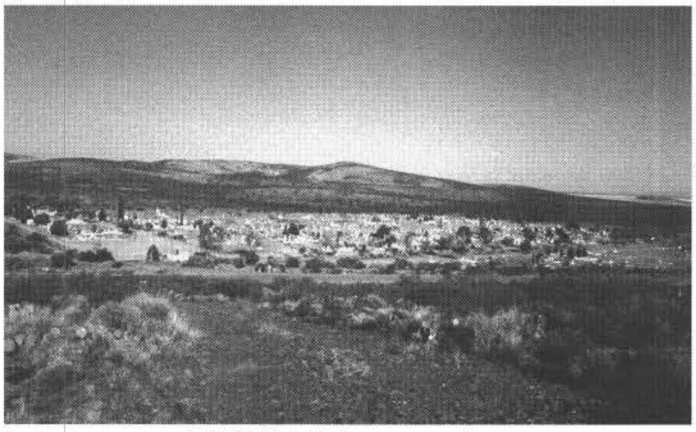
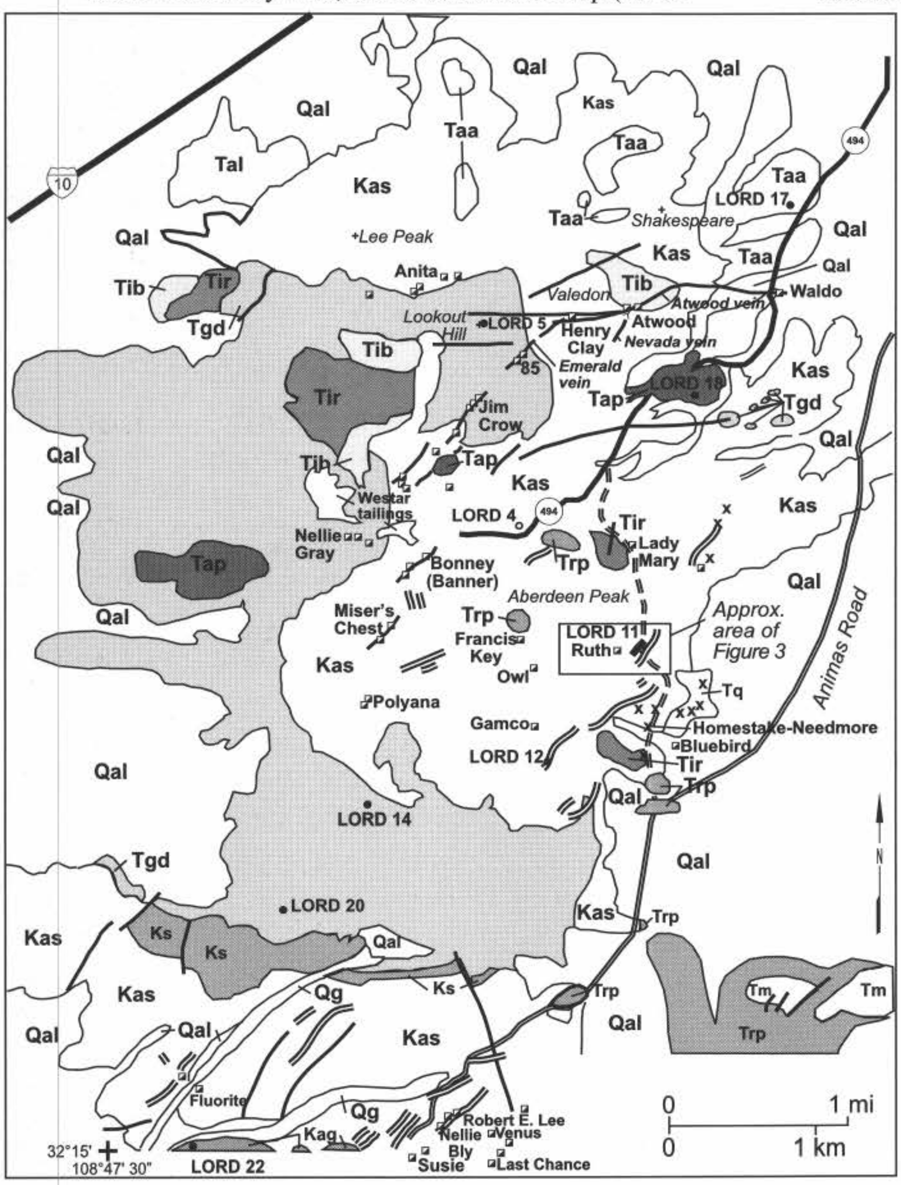


FIGURE 1.1. Shakespeare cemetery.

Shakespeare Cemetery (Fig. 1.1). Entering Lordsburg mining district (Fig. 1.2).

Shakespeare is a National and State Historical Site. In the mid-1800s, the area to become Shakespeare was a watering site for Apache Indians, Spaniards, wagon trains on the way west, and as an alternate stop (called Barney's in 1854–1861) on the Butterfield Overland Stage route. By about 1856, the spring had attracted permanent residents. Confederate followed by Union soldiers passed through on the way west (Hill, 1963). The Butterfield Line failed during the Civil War, and in 1868, a new line, the National Mail and Transportation Co., sent John Evensen and Jack Frost to locate stations. At Mexican Springs, Frost established a mail stop that he named Pyramid Station. Soon thereafter Frost renamed it Grant, after General Ulysses S. Grant. One of the hotels in Shakespeare is known as the Grant House. Grant County, including what is now Hidalgo County, was formed in 1868 from the western part of Doña Ana County. Prospectors came to the area and discovered gold and silver.

In 1869–1870, a townsite was laid out and the name was once again changed, this time to Ralston, after a California banker named W. C. Ralston, who invested in the mines. The town saw many booms and busts. In 1870, about 3000 residents lived in Ralston. However, the mining riches never materialized. Meanwhile a fraudulent diamond scheme (the Great Diamond Hoax)



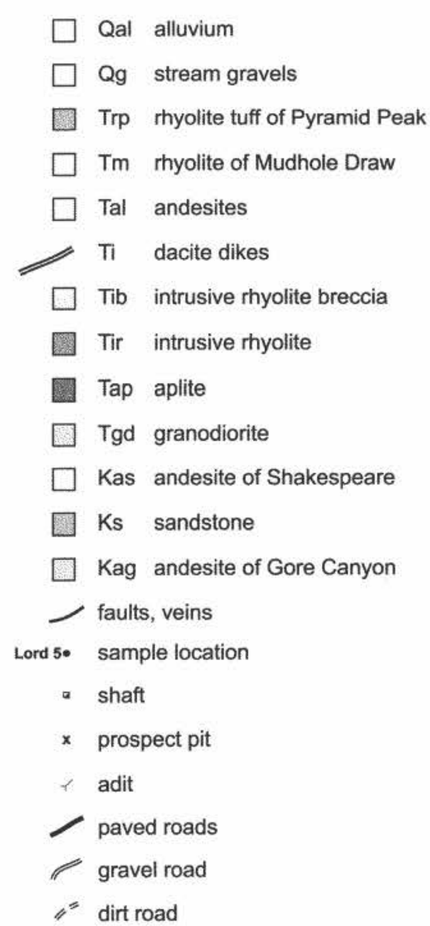


FIGURE 1.2. Simplified geologic map of the northern Lordsburg district, showing mines and sample locations for age determinations (modified from Thorman and Drewes, 1978a).

was attempted and the image of Ralston was tarnished. It was reported that diamonds were found at Lee Peak; other reports claimed that the diamond fields were elsewhere in the United States. People left Ralston as the mines closed (Muir, 1948).

Ralston was renamed Shakespeare about 1879 after the newly formed Shakespeare Mining Co., in order to attract new capital from English investors. The Stratford Hotel, which still stands in Shakespeare today, was built at this time (Muir, 1948). The town once again thrived, only to be hit by another depression in 1880 when the railroad through Lordsburg bypassed Shakespeare. The town continued on, only to decline even more in 1893 when the mines closed after the silver market crashed. The town never had a church, or a newspaper, or any local law enforcement.

Frank and Rita Hill purchased the town in 1935 and began giving tours. It became a National Historic Site in the 1970s. In 1997, a fire started near the blacksmith shop and soon destroyed many of the buildings in Shakespeare. Today, Shakespeare is slowly being rebuilt by Frank and Rita's daughter, Janalloo. The Stratford Hotel, blacksmith shop, and assay buildings have been restored.

The Shakespeare Cemetery (Fig. 1.1) actually predates Ralston, Shakespeare, and Lordsburg. The first people buried at the site were immigrants who were killed by Apaches in the vicinity of the cemetery. The cemetery is still in use today.

The Lordsburg district is located in the northern part of the Pyramid Mountains and is divided into two subdistricts, the northern Virginia (Ralston, Shakespeare) and southern Pyramid (Leitendorf) subdistricts (Fig. 1.2; McLemore and Elston, this volume). The first mining claims were located in the Pyramid subdistrict in 1870, and some early attempts were made to ship silver ore from the silver-gold-copper vein deposits. It was not until the Southern Pacific Railroad reached Lordsburg in 1880 that mining began in the Virginia subdistrict (Huntington, 1947). The district has seen numerous booms and busts; the last mine closed in 1994. However, Lordsburg Mining Co. produced barren aggregate from the district during the 1990s as part of reclamation of old mine and mill sites. The largest producing mines were on the Bonney and Emerald (Eighty-five) veins. Total production from the district from 1885 to 1994 is estimated as 229,577,000 lbs Cu, 11,000,000 lbs Pb, 4,200,000 lbs Zn, 8,067,741 oz Ag, and 286,275 oz Au (estimated by V. T. McLemore from published references and unpublished NMBMMR file data; McLemore and Elston, this volume). Placer gold has been reported (Johnson, 1972; McLemore, 1994) and 3527 short tons (st) of fluorite were also produced.

The road ahead is in andesite of Shakespeare, which consists of andesite flows and small intrusions, tuff breccia, flow breccia, and epiclastic beds. An andesite flow was dated as 54 ± 2.2 Ma (fission track, zircon, Thorman and Drewes, 1978a). **0.6**

1.6 Waldo (Richins) mine on left. The Waldo mine was developed about 1930 by the Alamo Mining Co. Two shafts are 100 and 500 ft deep. The vein is approximately 800 ft long and consists of predominantly quartz and galena. It follows an east-west fault. A 20–25-short-ton-per-day (stpd) flotation mill was built about 1941. From 1942–1951, the mine yielded 3215 st of ore that averaged 0.37 ppm Au, 48 ppm Ag, 8.2% Pb, 1.0% Zn, and 0.22% Cu.

Atwood mine on right. The Atwood mine is one of the oldest in the district, having been staked in 1870 and developed to 67 m by 1882. In 1930–1931, the Alamo Copper Co. developed the shaft to 700 ft. Development in 1942 by C. N. McIntosh and S. A. McIntosh resulted in deepening the shaft to 800 ft. From 1910 to 1940, the mine yielded 22,069 st of ore containing 1979 oz Au, 92,309 oz Ag, 848,623 lbs Cu, and 55,393 lbs Pb (Huntington, 1947). From 1943 to 1952, a horizontal shoot of enriched ore in the South Atwood vein yielded about 150,000 st of high-silica fluxing ore with 1.94% Cu, 0.62% Pb, 169.7 ppm Ag and 2.2 ppm Au (Huntington, 1947; Storms, 1949) In 1983, Federal Resources, Phelps Dodge Corp., and Westar, Inc. began open pit operations on the North Atwood vein, north of the shaft. Westar obtained full control of the property in the mid-1980s and shipped the ore to a cyanide leach facility west of the Banner mine. The company went bankrupt in 1990 and abandoned the property (White, this road log). The Lordsburg Mining Company operated a decline on the Atwood vein in 1990–1994.

The Henry Clay mine, west of the Atwood claim on the Emerald vein (Fig. 1.2), was developed in the late 1880s and by 1900, it was a principal mine in the district. In 1902, a mill was built to treat the ore, but it failed. In 1930–1931, the Henry Clay mine produced 12,728 st of ore containing 1268 oz Au, 39,615 oz Ag, 503,962 lbs Cu, and 174,521 lbs Pb (Huntington, 1947). **0.2**

1.8 Road (dirt) junction. Keep straight (left). **0.5**

THE LORDSBURG MINING DISTRICT, HIDALGO COUNTY, NEW MEXICO

John L. White

St. Cloud Mining Company, P. O. Box 1670, Truth or Consequences, NM 87901; jwhite@riolink.com

The Lordsburg mining district is located in the northern end of the Pyramid Mountains, 2.5–12 mi southwest of the town of Lordsburg, New Mexico. Mining in the district has been conducted in most of the last 130 yrs for copper, silver and gold, primarily from underground mines. The primary ore mineral is chalcopyrite occurring in steeply dipping quartz veins hosted by Tertiary andesite and granodiorite. Other minerals associated with the mineralization include clays, chlorite, pyrite, calcite, and minor sphalerite, galena, and local specularite, tourmaline, fluorite and barite. Lasky (1938) provided details of geology in the district, Flege (1959), Elston (1965), Clark (1970) and Agezo (1993) also described the mineral deposits.

Lasky (1938) described the early history of the district. The first mining claim was staked in the Lordsburg district in 1870, and intermittent mineral production occurred until 1996. In 1913 the Eighty-five Mining Company developed the Emerald vein and built the adjacent town of Valedon in the north end of the mining district. A flotation mill was constructed and operated for a short period during this time. The "85" mine was purchased by Calumet and Arizona Mining Company in 1920 to provide siliceous smelter flux to the Douglas smelter. Phelps Dodge Mining Co. (PD) acquired the mine in October 1931, and in the same year closed the mine because they already owned alternative flux sources closer to the PD smelter also located in Douglas. During the 1920s the town of Valedon was a thriving community of about 3000 inhabitants. When the "85" mine was closed, the town also was closed down and most equipment was dismantled. At the time of the mine closure, the "85" mine was one of the deepest mines in New Mexico.

In the south end of the district, Banner Mining Company constructed a 300-short-ton-per-day (stpd) flotation mill and began mining on the Bonney vein in 1935. The mill had originally been used in the Mogollon district in Catron County before relocating to Lordsburg. The flotation circuit featured cells without mechanical agitators. The froth was created using forced air from a high-pressure blower. The operation was purchased in 1968 by Federal Resources Corporation, who operated both the Bonney and the "85" mines to depths of 2000 ft until 1975. One thing that Federal accomplished was to drive a tunnel that connected the Bonney and "85" mines at the #1300-ft level. Thus, by the time the mines did close, the underground workings were continuous from the Miser's Chest on the south, through the Bonney, "85" and Henry Clay, to the Atwood in the northeast part of the district, a distance of about 3 mi. Other smaller operations were also active in the district during the life of the mill, producing custom mill feed or custom flux. These include the Superior, Anita, Henry Clay, and Atwood mines. The mill operated nearly continuously during this 40-yr period, and processed approximately 2,500,000 st averaging 2.5% Cu, 1.5 oz per short ton (oz/st) Ag, and 0.03 oz/st Au. The mines and mill ceased operations in 1975 due to low copper prices and high costs of mining at the 2000 ft depths. Copper reserves were not exhausted, and likely continue at depth in the Bonney, "85" and related adjacent mines.

A triventure was formed in 1983 between Federal Resources, PD, and Westar, Inc., to develop an open pit on the North Atwood vein for smelter flux. Westar assumed full control of the operation in the mid-1980s and constructed a cyanide heap-leach facility west of the Banner mill site to treat the material from the North Atwood vein. The heaps and solution ponds were placed on a continuous high-density polyethylene-lined pad (HDPE) with an underlying clay liner and vadose-zone leak-detection system. Gold was recovered using a simple Merrill-Crowe zinc-precipitation process. Lime was added for pH control and cyanide consumption was high due to the partial sulfide nature of the ore being mined. The leach operation produced gold, but not enough to keep Westar from declaring bankruptcy and abandoning the mine.

Federal Resources regained control of the properties in 1990, and later that year entered into the Lordsburg Mining Company (LMC) joint venture. LMC reinitiated siliceous flux operations from small surface open pits and developed the underground North Atwood mine on the down dip extension of the gold reserve drilled out by PD and open pit mined for the heap leach by Westar. The underground mine closed in 1994 and all flux operations discontinued in 1996 due to low metal prices and lack of markets for metal-bearing silica fluxes.

The "85" and Banner mines account for most of the mine production from the district to date. Total metal production for the entire district through the end of 1994 included 4,337,495 st averaging 2.36% Cu, 1.86 oz/st Ag and 0.066 oz/st Au, making this one of the most productive districts in the state.

During the last ten years, LMC has consolidated their ownership of the Banner and "85" mine properties. Also during that period, the mining industry in New Mexico has undergone some radical changes. When LMC began, there was a significant demand for metal-bearing siliceous smelter flux, and LMC proceeded quickly to develop the gold-silica reserves. Through the decade, the smelter requirements for flux changed in favor of barren higher-silica fluxes. LMC phased out the underground operation that produced precious-metal-bearing flux and concentrated on more-siliceous surface fluxes with only minor metal content. This too was phased out by competition from barren higher silica sources located closer to the smelters. Today, all metal- and silica-mining operations are idle at Lordsburg, as are the two smelters that were the largest customers of LMC: El Paso and Playas. LMC presently is producing construction aggregates from two quarries located on the mine properties. Customers include Hidalgo County, the New Mexico State Highway Department, the City of Lordsburg and private building contractors. Through the end of 1999, LMC produced 106,618 st of mineralized flux from underground that averaged 0.63% Cu, 1.71 oz/st Ag and 0.082 oz/st Au; approximately 102,135 st of barren siliceous flux; and approximately 139,578 st of construction aggregate products.

It is important to note that as a result of 120 yrs of mining activity prior to LMC's arrival, abundant old mine disturbances in the Lordsburg mining district have been created. In addition to mine production, LMC has undertaken several projects to try to mitigate such disturbances. These undertakings include backfilling several shafts that represented safety hazards adjacent to NM-494 in cooperation with the AML Bureau, reclamation of the Westar heap leach site that was abandoned by Westar leaving more than 30,000 st of cyanide-bearing heap material, backfilling of hazardous open stopes and shafts in the Atwood Hill area, initiation of in-filling of the Westar pit, and general clean up of old trash, waste and debris throughout the district. Cleaning up 120 yrs worth of mining work is a major undertaking. The work done thus far has addressed items that represent the most serious concerns with respect to safety and the environment. This work was initiated voluntarily before the New Mexico Mining Act was conceived in 1994. LMC hopes to continue such efforts while trying to maintain a balance between the demands of aggregate production, reclamation, mineral exploration, historic preservation, commercial development and government regulations.

2.3 Road (dirt) junction to right. Keep straight and follow bend in road. Atwood mine dump at 2:00. Mine dumps at 11:30. Hill on left consists of aplite, which has an age of 57.25 ± 0.12 Ma (biotite, $^{40}Ar/^{39}Ar$, sample Lord 18, see McLemore et al., this road log). **0.6**

2.9 Graded road to Lordsburg Mining Company, subsidiary of St. Cloud Mining Company, and abandoned town of Valedon. The mining camp of Valedon was established about 1885; in 1913 the railroad built a spur to the town (Julyan, 1996). By 1926, 2000 residents were living in Valedon. A U.S. Post Office was established in 1919, but closed in 1932 after Phelps Dodge Corp. bought and closed the mines.

Be prepared to turn left onto dirt road ahead. 0.2

3.1 Road junction. **Turn left onto dirt road** (before hill). Paved road continues to the Bonney (Banner) and Miser's Chest mines. The Bonney mine was the most productive in the district and was discovered about 1881. Production was minor until 1935 when the Banner Mining Co. acquired the mine. A 200-stpd mill was built, and the mill capacity was increased in 1937 to 400 stpd and in the early 1940s, to 500 stpd. In 1945, the Banner Mining Co. acquired the adjacent Miser's Chest mine, which had been sporadically active since 1881. The Bonney and Miser's Chest mines are at intersections of northeast and east-west faults (Fig. 1.2). The mines closed in October 1957 due to depressed copper prices. Production resumed in May 1959, but Banner Mining Co. ceased operations permanently in December 1966. From 1905 to 1966, more than 2 million st of ore containing >450,000,000 lbs Cu, >2,000,000 oz Ag, and >20,000 oz Au were produced by the Banner Mining Co. In 1967, Federal Resources Corp. acquired the properties and resumed production in 1969 until final closure in January 1975. Federal Resources Corp acquired the Henry Clay mine in 1968–1969 and the Lady Mary mine later. **0.2**

3.3 Cross cattle guard. **0.2**

3.5 Road junction. **Keep right**. Pyramid Peak at 12:00 was named in 1853 by geologist Jules Marcou who worked for the Whipple Pacific Railroad Expedition (Julyan, 1996). The prominent, jagged Dogshead Peak in the distance at 11:00 consists of mid-Tertiary rhyolite tuff of Pyramid Peak of Elston et al. (1983; rhyolitic tuff of Dogshead of Thorman and Drewes, 1978a). Aberdeen Peak at 3:00, which consists of mid-Tertiary rhyolite tuff of Pyramid Peak overlying Cretaceous–Eocene andesite of Shakespeare (Thorman and Drewes, 1978a). The rhyolite tuff of Pyramid Peak is believed to be the same age as the Muir caldera at 35.3 Ma (Elston et al., 1983; McIntosh and Bryan, this volume). **0.1**

3.6 Road junction. **Keep left.** Hill at 3:00 consists of mid-Tertiary rhyolite tuff of Pyramid Peak overlying andesite of Shakespeare (Thorman and Drewes, 1978a). **0.2**

3.8 Road junction. **Keep right.** Road to left to Lady Mary mine. The Lady Mary mine consists of two shafts that developed quartz-galena veins. Production, if any, is unknown. Cross drainage ahead. **0.1**

3.9 Road junction. **Keep left** and cross drainage. **0.2**

4.1 Road junction. **Keep right**. Aberdeen Peak at 3:00. Francis Key mine dumps south of peak. **0.2**

4.3 Cross Aberdeen Draw. Ruth mine on hill to right at 2:00. Purplish-gray andesitic volcanic breccias exposed in arroyo. **0.1**

4.4 **STOP 1**. Overview and examine Eocene andesite, dacite dike, and polymetallic veins at the Ruth mine (Figs. 1.3, 1.4).

The top of the hill at the Ruth shaft is an ideal vantage point for viewing much of Lordsburg basin area between the Pyramid Mountains and Big Burro Mountains to the northeast. This area is traversed by I-10 and the first leg of Day 2 route. The northwest-striking frontal-fault system of the east-tilted Burro uplift juxtaposes Proterozoic metamorphic and igneous rocks of the footwall block with Neogene basin fill (Gila Group) and younger (Quaternary) bolson deposits of the Lordsburg basin (hanging wall block). According to Machette et al. (1998; fault #2094a, b), the youngest fault displacements along the southwestern Burro boundary-fault system are middle–late Pleistocene offsets of pediment-slope deposits along the Gold Hill fault zone.

The Lordsburg basin block is interpreted by Hawley et al. (2000, plate 1) as a complex, northeast-tilted half graben with at least one major buried fault zone basinward from and synthetic to the Gold Hill fault zone. Maximum thickness of Neogene and Quaternary basin fill in the Lordsburg structural basin appears to be approximately 2000 ft. This estimate is based on interpretation of gravity and seismic surveys and a few deep drillhole logs (Trauger, 1972; Drewes et al., 1985; Stone and O'Brien, 1990, Heywood, 1992; Klein, 1995). Much of the basin-fill sequence comprises conglomeratic sandstone and mudstone of the Miocene "lower" Gila Group (Gila Conglomerate on most maps and sections). The lower part of this sequence (15–25 Ma) is locally interbedded with and/or intruded by basaltic andesites. Most ground-water production (irrigation, urban, and industrial uses) is from unconsolidated to partly indurated "upper" Gila Group (latest Miocene–early Pleistocene) and overlying bolson deposits that have saturated thicknesses rarely exceeding 650 ft (Kennedy et al., this volume).

At the junction of the arroyo and the road is a porphyritic dacite dike that has intruded an andesite lava flow (Fig. 1.3). The dike is also exposed in the road to the Ruth mine. The locally brecciated andesite is gray–purplish-gray–greenish-gray, porphyritic–fine grained, and consists of plagioclase, biotite, hornblende, and locally olivine. The andesite is locally altered to epidote and chlorite, which indicates temperatures of alteration of 536°F or higher (Reyes, 1990; Simmons et al., 1992). The dacite is light-gray–tan, porphyritic, and consists of plagioclase, K-feldspar, biotite, quartz, and local hornblende, magnetite, sphene, and zircon. The dacite dike is similar in composition to larger stocks that intruded the andesites in the northern Pyramid Mountains. A sample of the dike has a $^{40}Ar/^{39}Ar$ date of 54.53 ± 0.56 Ma (Lord 11, biotite, see McLemore et al., this road log). Several thin quartz veins parallel the dike in the road.

The Ruth mine consists of an adit and an inclined shaft (300 ft deep) that was first developed about 1919 (Fig. 1.4). Development accessed by the shaft amounts

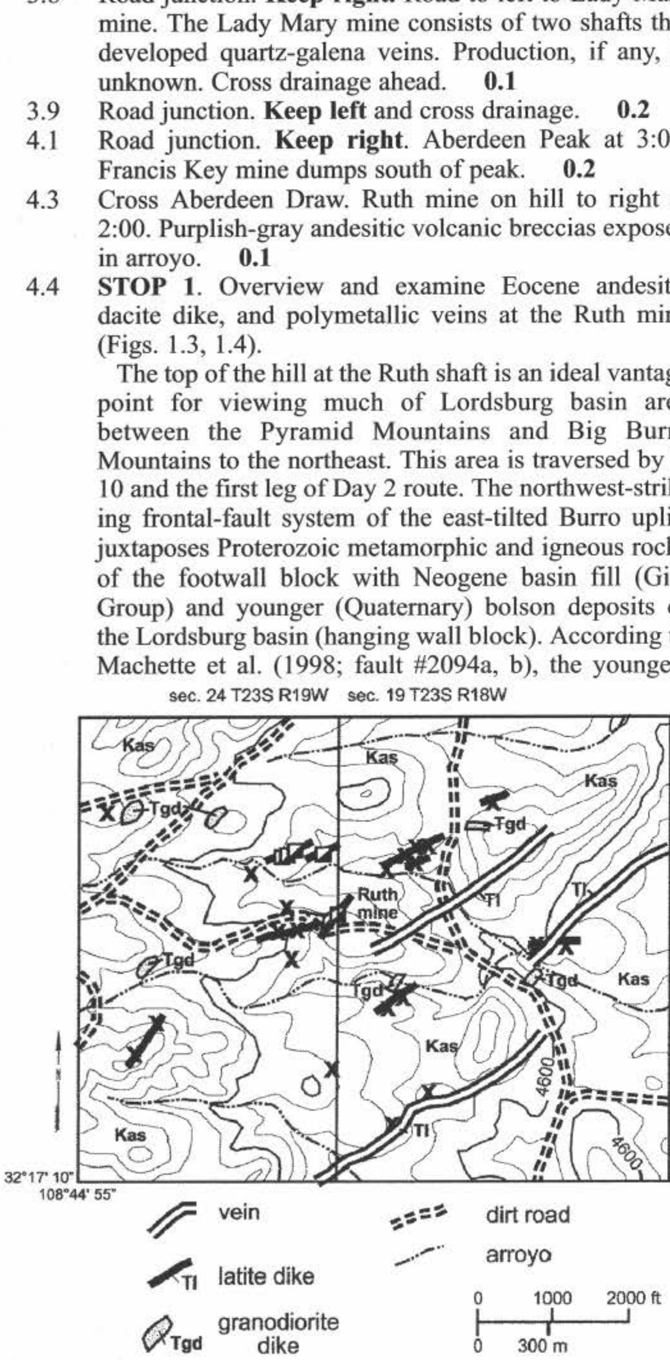


FIGURE 1.3. Geologic map of the Ruth mine area in the Lordsburg district, Hidalgo County (Stop 1).

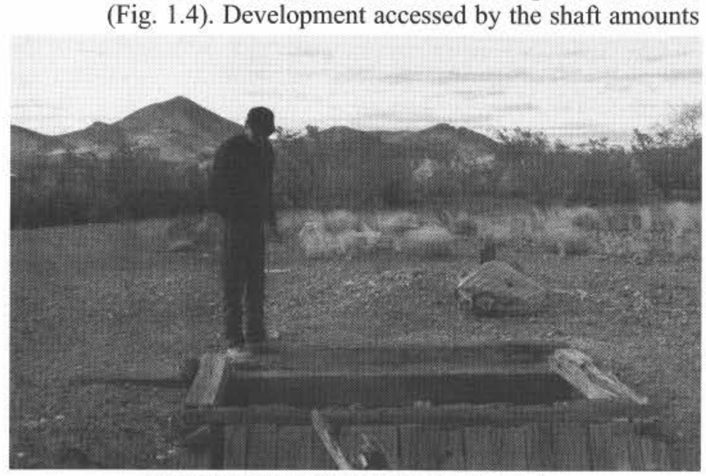


FIGURE 1.4. Top of inclined shaft at Ruth mine.

to nearly 1000 ft of drifts and stopes. The vein is less than 8 ft wide and can be traced intermittently for 2000 ft. The National Zinc Corp. built a small gravity concentrate mill at the mine about 1941. Dump samples containing quartz and rare pyrite and minor amounts of chalcopyrite, bornite, malachite, galena, and sphalerite can be found. Some samples of bladed quartz puesodomorphs after calcite are present, which indicate that boiling occurred during quartz deposition (Simmons et al., 1992). Ore grades were approximately 7% Zn, 3.5% Pb, 0.3% Cu, 34 ppm Ag, and 0.69 ppm Au.

Thorman and Drewes (1978b) believed that the mineralization and the granodiorite are nearly the same age. Several veins cut the granodiorite. A vein east of the Ruth mine is intruded by a dacite dike, indicating that at least some of the veins are younger than the dacite dikes.

Return to vehicles and continue south along dirt road. **0.1**

$^{40}Ar/^{39}Ar$ GEOCHRONOLOGY OF IGNEOUS ROCKS IN THE LORDSBURG DISTRICT, NORTHERN PYRAMID MOUNTAINS, HIDALGO COUNTY, NEW MEXICO

Virgina T. McLemore, Lisa Peters, and Matt T. Heizler

New Mexico Bureau of Mines and Mineral Resources, New Mexico Institute of Mining & Technology, Socorro, NM, 87801; ginger@gis.nmt.edu

The Lordsburg mining district is one of the few districts in New Mexico that contain Laramide polymetallic veins without any known porphyry copper deposits (North and McLemore, 1986; McLemore, *in press a*). Exploration for porphyry-copper deposits in the district has occurred during the last 30–40 yrs because of the similarity in alteration and style of polymetallic veins in the district to porphyry copper deposits elsewhere in southwestern United States. The purpose of this report is to present preliminary results of new $^{40}Ar/^{39}Ar$ geochronologic data and to summarize the regional significance of the age determinations. Lasky (1938) and Flege (1959) provided an extensive geologic report of the district. Thorman and Drewes (1978a) remapped the district and provided a description of the geology and some age determinations based on fission-track analyses.

Host rocks in the district consist of Lower Cretaceous andesite to basalt flows at least 600 m thick, which were intruded by plugs of basalt and rhyolite breccias (Thorman and Drewes, 1978a). The volcanic rocks have been intruded by a granodiorite porphyry stock (Fig. 1.2; Thorman and Drewes, 1978a; Elston et al., 1983) and dikes and plugs of related granodiorite porphyry and aplite. Plugs and dikes of dacite cut the granodiorite. Mineral deposits in the district are polymetallic, fissure-filling veins in fault and fracture zones that transect the contact zone of the granodiorite porphyry stock (Thorman and Drewes, 1978a; McLemore and Elston, this volume). The veins are older than the dacite dikes, because at least one dike intruded a vein near the Ruth mine (Fig. 1.3).

Several samples of igneous rocks were collected in the Lordsburg district for $^{40}Ar/^{39}Ar$ dating (Table 1.1). Sample locations are shown in Figure 1.2. From these rocks we report age spectral analyses for 6 biotites, one groundmass concentrate, and a plagioclase. The spectra were obtained by incremental heating in either a double-vacuum resistance or CO_2 laser furnace. Analytical methods for argon extraction and mass spectrometry are summarized in McLemore et al. (1999a), and the isotopic results are summarized in Table 1.1. Biotite age spectra yield two overall forms (Fig. 1.5a–c). Four of the samples have flat age spectra and yield ages between ~57.3 and 58.8 Ma, whereas two samples (Lord 11, 12) have age gradients ranging from ~20 to 63–67 Ma (Fig. 1.5). Typical 2σ uncertainties for the weighted mean ages given by the flat spectra range from ~0.2 to 0.6%. Bulk K/Ca values range from ~6 to 32 for the biotites and do not correspond to the form of age spectra (Fig. 1.5). The radiogenic yields for the samples with severe age gradients are significantly lower than for the samples with flat spectra, and the release of ^{39}Ar occurred at much lower temperatures for these samples relative to the well-behaved samples (Fig. 1.5c).

The groundmass concentrates from Lord 17 yield very disturbed age spectra (Fig. 1.5d). The majority of the age spectra yields relatively precise ages ranging between 57 and 66 Ma with radiogenic yields as high as 95% (Fig. 1.5d). The final part of the age spectrum displays a drop in apparent age, K/Ca, and radiogenic yield (Fig. 1.5d).

The age spectrum for Lord 22 plagioclase is characterized by initially very old ages that drop to a minimum of ~54 Ma followed by a rise to ~67 Ma (Fig. 1.5e). K/Ca values display minor variability and are ~0.2 or more for most of the spectrum. Radiogenic yields are somewhat undulatory, with initial heating steps giving the lowest values. An isochron diagram for the first four heating steps is shown for Lord 22 plagioclase (Fig. 1.5f). Steps B–D define a linear array with intercepts giving an isochron age of 54.7 ± 1.4 Ma and a trapped initial $^{40}Ar/^{36}Ar$ composition of 352.0 ± 4.6. Step "A" contains only 0.4% of the total ^{39}Ar released, falls above the regression line for steps B–D, probably contains a mixture of atmospheric argon and the trapped argon associated with steps B–D, and therefore was not used in the isochron analysis. Apparent ages calculated for steps B–D using the trapped $^{40}Ar/^{36}Ar$ value of 352 rather than the atmospheric value of 295.5 (cf. Heizler and Harrison, 1988) are shown as solid boxes in Figure 1.5e. These apparent ages are similar to the apparent ages for increments E–I and a weighted mean age of 54.99 ± 0.89 Ma is calculated for the combined steps of B–I (Fig. 1.5e). An age of 67.97 ± 0.57 Ma is calculated for the final two heating steps (Fig. 1.5e).

The flat age spectra obtained for biotites from Lord 5, 14, 18, and 20 are interpreted as chronologically meaningful plateau ages. The plateau ages for Lord 5, 14, and 18 are analytically indistinguishable and indicate a pulse of igneous activity at ~57.4 Ma. The plateau age of 58.81 ± 0.10 Ma for Lord 20 biotite is analytically older than the other well-behaved biotite samples. The granodiorite from which Lord 20 was sampled is mapped as the same granodiorite from which Lord 14 biotite was collected; however, based on the $^{40}Ar/^{39}Ar$ ages these appear to be two distinct units.

Samples Lord 11 and 12 are from dacite dikes, which intruded the granodiorite (Lord 14). These samples yield disturbed age spectra with gradients ranging from ~20 to 67 Ma. Because biotite is hydrous, age-spectral analysis generally does not yield the spatial argon distribution due to structural breakdown in the ultra-high vacuum furnace used to degas the biotite (e.g., McDougall and Harrison, 1999). If the age gradients from Lord 11 and 12 were meaningful, the maximum age (i.e., 67 Ma) could be interpreted as the minimum age for the sample, and the 20 Ma ages could be interpreted as the time of argon loss. However, these dacite dikes cut the ~57 Ma granodiorite and therefore the old ages in the Lord 11 and 12 spectra are not geologically sensible. Apparent-age gradients and overall age spectrum complexity can be caused by recoil of ^{39}Ar into alteration phases such as chlorite, which degas in the laboratory at low temperature relative to the biotite (Lo and Onstott, 1989). Lord 11 and 12 biotite have significantly lower (~50%) ^{39}Ar concentrations compared to the well-behaved biotites, indicating that their bulk K content is much lower. This observation supports the notion that Lord 11 and 12 biotites are altered and thus the age gradients are interpreted to be an artifact of ^{39}Ar recoil. Lo and Onstott (1989) argued that the total-gas ages of chloritized biotites yielded meaningful argon closure ages. The total-gas ages are 54.53 ± 0.56 and 41.9 ± 1.1 Ma for Lord 11 and 12, respectively. The total gas age from Lord 11 is within uncertainty of the zircon fission-track age reported by Thorman and Drewes (1978a), and may indicate that the 54.53 ± 0.56 Ma total gas age is an accurate intrusion age.

Lord 17 groundmass does not provide a precise age determination because there is too much discordance in the age spectrum to yield a weighted mean

TABLE 1.1. Summary of age determinations in the northern Lordsburg district.

Sample	$^{40}Ar/^{39}Ar$ (NMBMMR)	Fission track ages (Ma, zircon, Thorman and Drewes, 1978a)	Lithologic unit (Thorman and Drewes, 1978a)
Lord 11 (biotite)	54.53 ± 0.56 (total gas age)	52.7 ± 2.7	Dacite porphyry dikes (Tl)
Lord 12 (biotite)	41.9 ± 1.1 (total gas age)		Dacite porphyry dikes (Tl)
Lord 18 (biotite)	57.25 ± 0.12		Aplite (Tap)
Lord 5 (biotite)	57.31 ± 0.30	58.5 ± 2.0	Granodiorite (Tgd)
Lord 14 (biotite)	57.58 ± 0.36		Granodiorite (Tgd)
Lord 20 (biotite)	58.81 ± 0.10		Granodiorite (Tgd)
Lord 17 (groundmass)	66.3 ± 0.4	54.9 ± 2.7	Andesite flows of Animas Road (Taa)
Lord 22 (plagioclase)	67.94 ± 0.57 (high-temperature plateau age)	67.3 ± 7.1	Andesite of Gore Canyon (Kag)

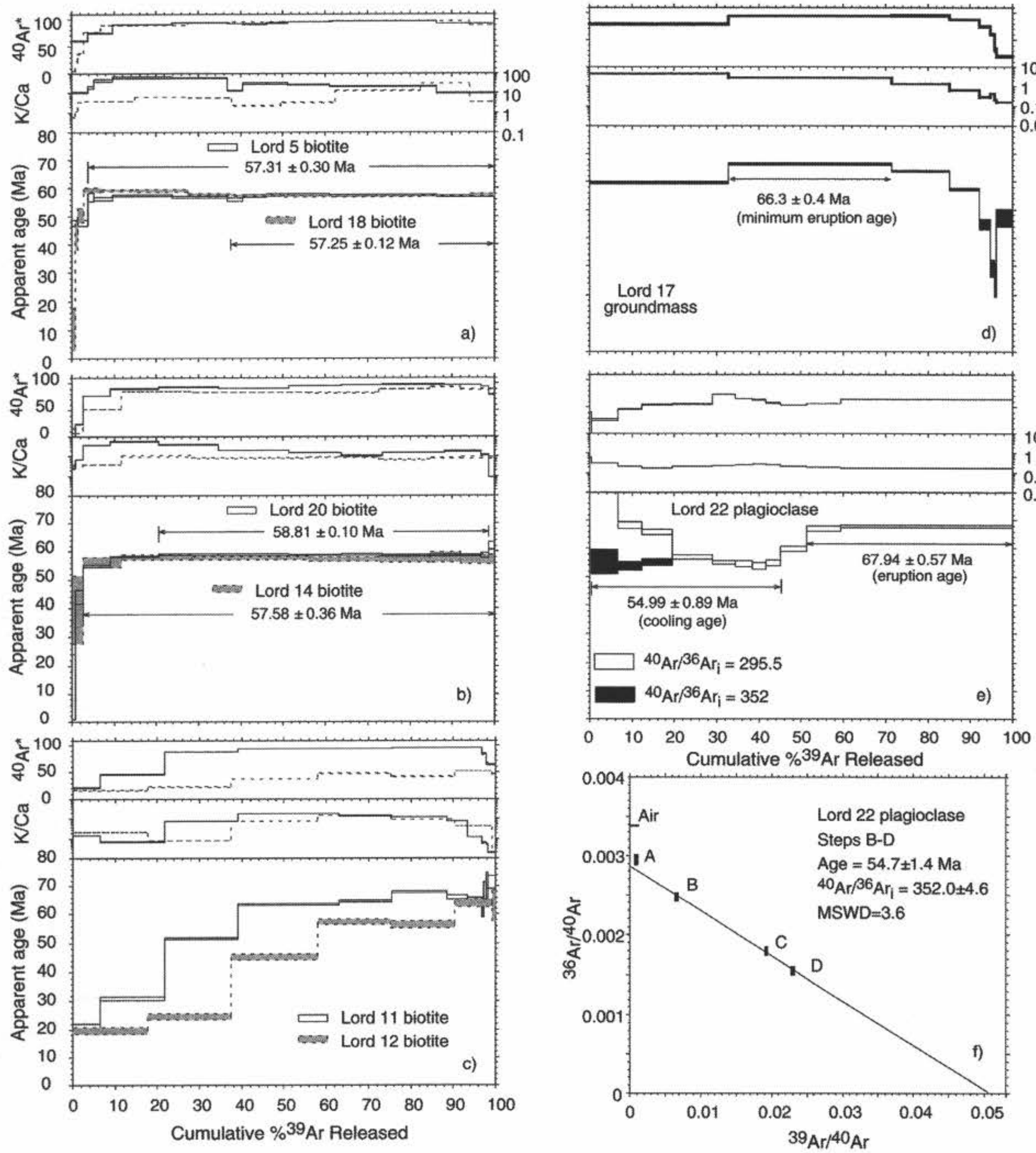


FIGURE 1.5. Age spectra, K/Ca, and radiogeneic yield diagrams (**a–e**) for biotite, groundmass and plagioclase from igneous rocks in the Lordsburg district. Biotites from the granodiorite (**a, b**) yield plateau age spectra and have precise ages, whereas dacite dikes, which intruded the granodiorite (**c**), are complex and of limited geochronological use. The groundmass sample (**d**) has a complex age spectrum, however its oldest step is 66.3 Ma and indicates a Cretaceous age for this rock. The plagioclase spectrum has two plateau segments. The high-temperature step ages are interpreted to record an eruptive age at ~68 Ma and the low-temperature steps record a cooling age at ~55 Ma. Isochron diagram (**f**) for the initial heating steps of the plagioclase indicate excess argon contamination and an age of ~55 Ma.

plateau age. The oldest step is 66.33 Ma and may be a minimum age for the andesite, provided this step does not contain excess argon or was not affected by ^{39}Ar recoil. If Lord 17 is at least 66 Ma, then the zircon fission-track age of 54.9 ± 2.7 Ma is either a cooling age, a partial-annealing age, or a reset age. Alternatively, the argon-age spectrum does not record an accurate age and the zircon fission-track age represents the true age of this sample.

The complexity of the Lord 22-plagioclase spectrum may be related to a combination of partial argon loss and excess argon contamination. The overall saddle-shape spectrum is often interpreted to be caused by excess argon contamination of the early and late heating steps (Lanphere and Dalrymple, 1976) with the minimum ages representing a maximum age for the sample. Two observations suggest that this standard interpretation is not applicable in this case: (1) the isochron of the initial steps reveals an age similar to the apparent ages in the saddle of the spectrum; (2) the high-temperature steps yield ages indistinguishable to the zircon fission-track age of 67.3 ± 7.1 Ma. A possible interpretation is that Lord 22 plagioclase is ~67 Ma and underwent partial argon loss at ~55 Ma (Fig. 5e). Argon loss could be related to heating and subsequent cooling of the area following the pulse of igneous activity at ~57 Ma. Little is known about the argon retentivity of plagioclases; however, it is expected that plagioclase would behave like K-feldspar. Initial heating steps of K-feldspar age spectra often have argon closure temperatures significantly less than 200°C (Lovera et al., 1989), and thus it may be possible to partially reset the argon clock in plagioclase without resetting the zircon fission-track system, which has a track annealing temperature of about 240°C (Hurford, 1986).

The age results may record three chronologically discrete events in the region. The ~67 Ma andesites in the Lordsburg district are younger than the Hidalgo

Formation in the Little Hatchet Mountains where a hornblende andesite at the base of the section is 71.44 ± 0.19 Ma ($^{40}Ar/^{39}Ar$, hornblende; Lawton et al., 1993). It is possible that the Lordsburg andesites may correlate to the upper Hidalgo Formation or alternatively, they represent a separate volcanic event. Laramide intrusions of this older time interval in southwestern New Mexico include the Piños Altos stock (74.4 Ma, K/Ar, McDowell, 1971), Twin Peaks monzonite porphyry in the Burro Mountains (72.5 Ma, K/Ar, Hedlund, 1980), Georgetown dikes (71 Ma, $^{40}Ar/^{39}Ar$, McLemore, 1998), and Hillsboro volcanic/intrusive complex (75 Ma, $^{40}Ar/^{39}Ar$, McLemore et al., 1999b).

The second pulse is the 57.3–58.8 Ma-intrusion of the granodiorite and associated rocks (Table 1.1). The third age grouping recorded by the zircon fission-track data, the total gas age from Lord 11 biotite, and the young part of Lord 22 plagioclase ~54 Ma (Table 1.1). This time may represent a discrete pulse of igneous activity or a time of cooling below ~200–250°C in the area.

The polymetallic veins are 57–54 Ma, since they cut the granodiorite and are intruded by the dacite dikes. The ages of the veins and associated granodiorite in the Lordsburg district are also similar to the ages of the Santa Rita (58.3 Ma, $^{40}Ar/^{39}Ar$, unpubl. data, Phelps Dodge Corp.), Tyrone (54.5 Ma, $^{40}Ar/^{39}Ar$, unpubl. data, Phelps Dodge Corp.), Hanover-Fierro (57.6 Ma, $^{40}Ar/^{39}Ar$, McLemore et al., 1996a), and Lone Mountain (51.5 Ma, K/Ar, [unpubl. report, P. B. Hubbard and P. G. Dunn, 1983]) porphyry copper deposits (see McLemore, Supplemental Road Log 2, this volume, fig. S.2.1). Thus, the 51–58 Ma intrusive event responsible for porphyry copper deposits did extend into the northern Pyramid Mountains, although a porphyry copper deposit has yet to be discovered.

4.5 Road junction. **Keep right**. **0.3**

4.8 After crossing the arroyo, **keep left** at the road junction. Homestake-Needmore mine on right, which produced some lead ore. **0.1**

4.9 Road junction. **Keep straight (left)**. **0.2**

5.1 Cross drainage. Outcrops of west-tilted and fractured "lower" Gila Group conglomerate of late Miocene age in drainage. Thorman and Drewes (1978a) mapped this unit as rhyolitic tuff of Dogshead. **0.1**

5.2 Junction with Animas Road (graded). Continue south on Animas Road. **0.4**

5.6 Ranch house. **0.1**

5.7 Cross cattle guard. **0.3**

6.0 Road junction. **Keep straight**. Hills at 3:00 consist of andesite. Pyramid Peak at 11:00. **0.6**

6.6 Road junction. **Keep left**. **0.5**

7.1 Top of small hill with dacite porphyry dikes cutting andesite. Robert E. Lee mine at 12:00 (Fig. 1.2). The Robert E. Lee mine is one of numerous mines that comprise the South Pyramid (or Leitendorf) subdistrict of the Lordsburg district (McLemore and Elston, this volume). Eugene Leitendorfer dug water wells in the area about 1852 and the site became a watering stop for travelers to California (Julyan, 1996). A small community, Leitendorf, grew around the wells. Silver was discovered in the area in the early 1880s and a mining camp, Pyramid, grew. Pyramid had a U.S. Post Office in 1882–1884 and in 1891–1897 (Julyan, 1996). By the late 1890s, both communities were nearly abandoned with the closure of the mines due to the dramatic drop in silver price.

The Robert E. Lee mine was developed in 1885. Several shafts and pits developed the veins at the mine. A mill operated at the mine from 1894 to 1898 (Jones, 1907). Total production is unknown, but unpublished reports (NMBMMR file data) indicate that from 1885 to 1907, $93,000 worth of silver and copper was produced. The mine also operated in the early 1900s. **0.4**

7.5 Road junction. **Keep right**. **0.1**

7.6 Road junction. **Keep right**. **0.6**

8.2 Road junction. **Keep right**. Campbell prospect pits at 1:00. The Peloncillo Mountains form the western skyline with Chiricahua Mountains behind them. **0.1**

8.3 Road junction. Keep right. Cliffs at 9:00 are mid-Tertiary rhyolite tuff of Pyramid Peak. **0.7**

9.0 Cross cattle guard. Four Mile Hill at 2:00 consists of Tuff 1 and latite of Uhl Well of Elston et al. (1983). **0.5**

9.5 Road junction. Keep straight. Four Mile Hill at 2:00. **0.5**

10.0 Road junction. **Continue straight (left)** on old Animas Road (dirt). Twelve Mile Hill at 1:00. **1.3**

11.3 **STOP 2. Twelve Mile Hill**. The purposes of this stop are: (1) to examine a series of regional Oligocene ignimbrites (ash-flow tuffs), (2) to have an overview of their source cauldrons, and (3) to consider modern and ancient playa systems in the Animas Valley.

The Boot Heel area of New Mexico is part of an extensive belt of large, late Eocene/Oligocene silicic volcanic fields that extended from the Sierra Madre Occidental of Mexico to the San Juan volcanic field of Colorado. The Boot Heel volcanic field includes at least nine large cauldrons (eroded calderas), each of which erupted catastrophically, producing voluminous ignimbrites which ponded within the calderas and also flowed outward to form extensive regional ignimbrite outflow sheets (Fig. 1.6, Table 1.2; Elston, 1984; Bryan, 1995; McIntosh and Bryan, this volume). In addition to the rhyolitic ignimbrites, the Boot Heel volcanic field includes numerous basaltic-andesite to rhyolite lavas and local pyroclastic units.

Between the road and the ridge top of Twelve Mile Hill are several prominent outcrop ridges of dark-brown, densely welded, outflow-facies ignimbrites (Fig. 1.7). An additional low ridge of buff-colored,

TABLE 1.2. Calderas in southern Hidalgo County modified from Elston (1984). Minimum volume from Bryan (1995). Age of calderas by $^{40}Ar/^{39}Ar$ from McIntosh and Bryan (this volume). Elston et al. (1983), Erb (1979), and Peterson (1976) proposed four additional calderas (Rodeo, Cowboy Rim, San Luis, Apache); but volcanic and structural evidence do not support the presence of these calderas (McIntosh and Bryan, this volume).

Caldera	Mountain Range	Ignimbrite	Age Ma	volume (km^3)	Reference
Turkey Creek	Chiricahua Mountains	Rhyolite Canyon Tuff	26.8	580	1
Portal	Chiricahua and Peloncillo Mountains	Tuff of Horseshoe Canyon	27.6	120	2
Steins	Peloncillo Mountains	Tuff of Steins	34.4	100	3
Clanton Draw?	Peloncillo Mountains	Park Tuff	27.4	?	4
Geronimo Trail	Peloncillo Mountains	Gillespie Tuff	32.7	550	5
Muir	Pyramid Mountains	tuff of Woodhaul Canyon	35.2	50	6
Juniper	Animas Mountains	Oak Creek Tuff	33.5	450	5
Animas Peak	Animas Mountains	tuff of Black Bill Canyon	33.5*	35	5
Tullous	Animas Mountains	Bluff Creek Tuff	35.1	280	5

References: 1 Du Bray and Pallister (1999), 2 Bryan (1988), 3 Richter et al. (1990), 4 McIntyre (1988), 5 Erb (1979), 6 Elston et al. (1983).
*Rounded down to relect well-constrained age of overlying Oak Creek Tuff.

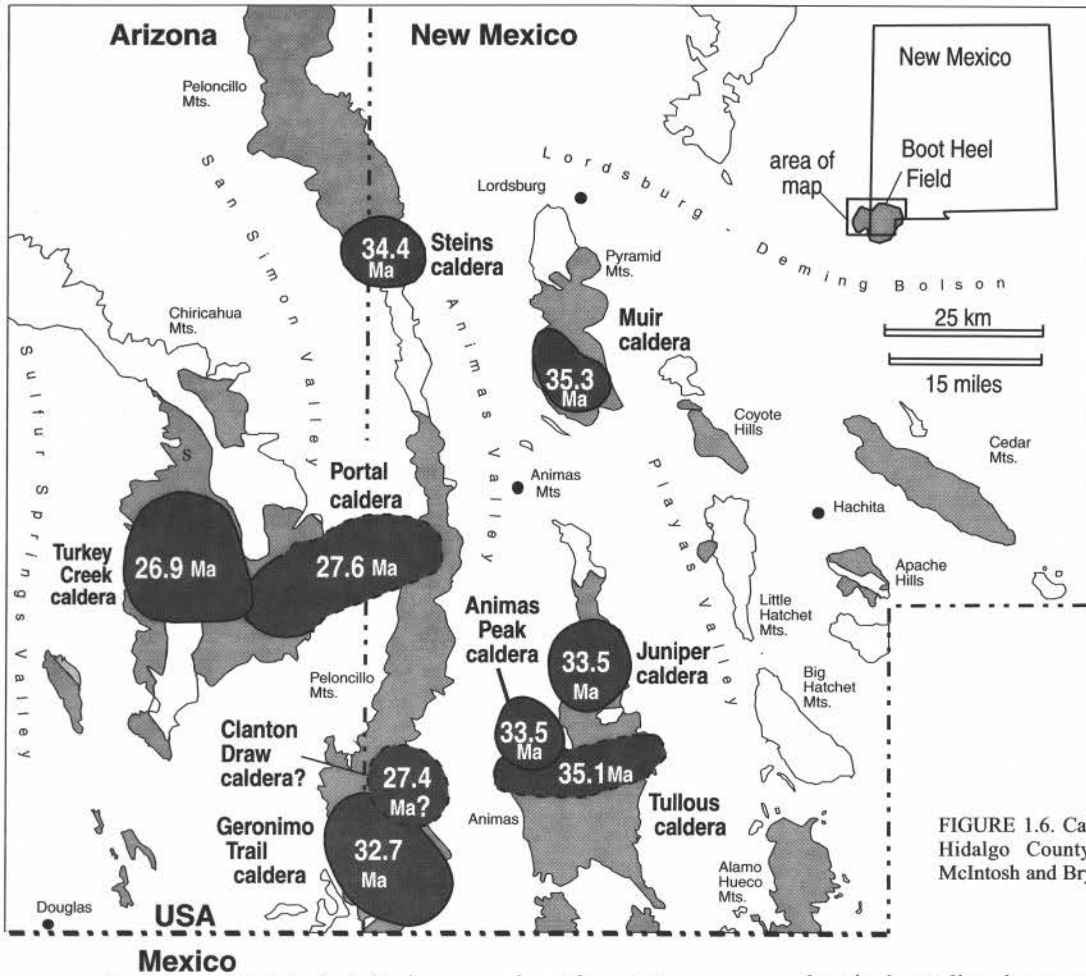


FIGURE 1.6. Calderas in the Bootheel of southern Hidalgo County, New Mexico (Bryan, 1995; McIntosh and Bryan, this volume).

moderately welded ignimbrite is exposed on the west side of Twelve Mile Hill. These outcrops were originally mapped as tuff members 4, 5, 6, and 7 of the Rimrock Mountain Group by Elston et al. (1983). Subsequent $^{40}Ar/^{39}Ar$ dating, together with paleomagnetic and geo-

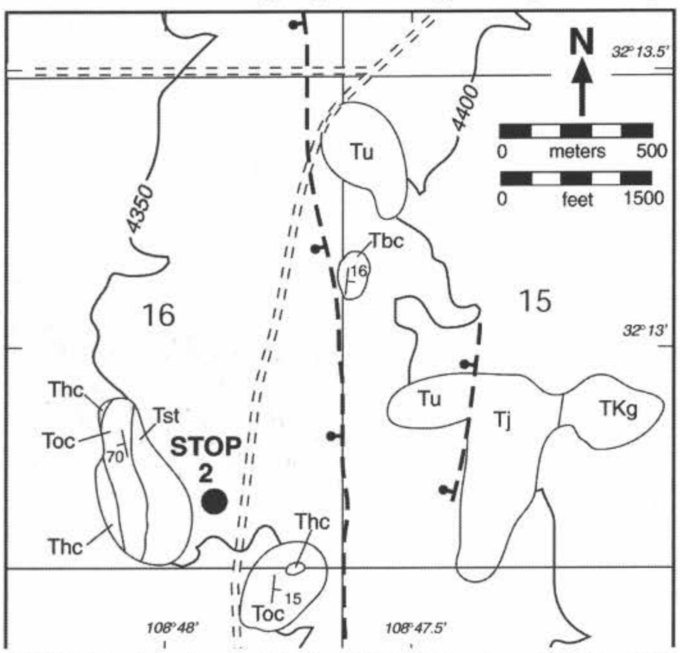


FIGURE 1.7. Geologic map of Twelve Mile Hill (Stop 2; modified from Elston et al., 1983). Units explained in Figure 1.8.

chemical studies have refined correlations of the Rimrock Mountain tuffs and other ignimbrites of the Boot Heel area, placed them in a regional stratigraphic context (Fig. 1.8), and linked many with their respective source cauldrons (Fig. 1.6, Table 1.2; McIntosh and Bryan, this volume). The lower ignimbrite sheets exposed on the east side of Twelve Mile Hill are actually multiple cooling units of the 34.4-Ma tuff of Steins, erupted from the Steins cauldron near stop 5, in the Peloncillo Mountains 15 mi northwest of Twelve Mile Hill. The overlying ignimbrite, which forms the ridge top, is the 33.5-Ma Oak Creek Tuff (Figs. 1.9, 1.10), which erupted from the Juniper cauldron, in the Animas Mountains 36 mi to the south. The youngest ignimbrite, exposed on the west side of Twelve Mile Hill, is the 27.6-Ma tuff of Horseshoe Canyon, erupted from the incompletely understood Portal cauldron in the Chiricahua and Peloncillo Mountains directly to the west.

Numerous ignimbrite textural features are readily observable in outcrops at Twelve Mile Hill. Flattened pumice (fiamme) and gas cavities (lithophysae) demonstrate the variable degree of welding in the ignimbrites. Lithic fragments in the tuffs were either ripped from the vent walls during eruption or entrained in the ignimbrite during flow. Differences in the mineralogy of the 34.4- and 33.5-Ma ignimbrites (quartz, sanidine, plagioclase, biotite, and hornblende) compared with that of the 27.6-Ma ignimbrite (quartz and sanidine) demonstrate the

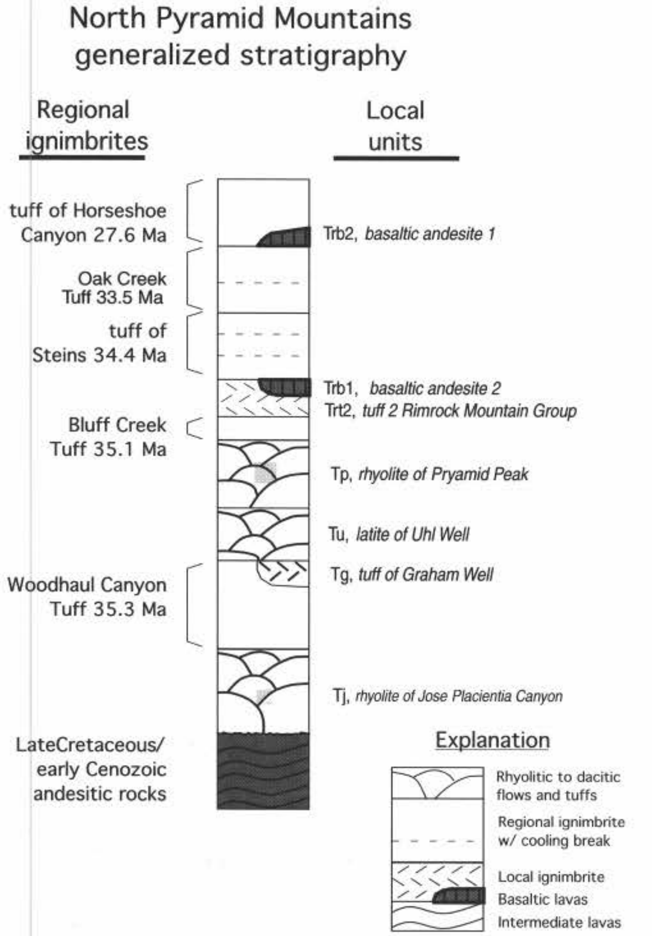


FIGURE 1.8. Stratigraphy of northern Pyramid Mountains (Elston et al., 1983; Bryan, 1995).

general increase in silica and decrease in volatile content during geochemical evolution of the Boot Heel volcanic field (Elston, 1984; Bryan, 1995; McIntosh and Bryan, this volume).

The ridge top of Twelve Mile Hill affords an excellent overview of the topography and distribution of Oligocene cauldrons in the Boot Heel volcanic field (Fig. 1.11). Twelve Mile Hill is located on the western margin of the Animas Valley. The Peloncillo Mountains form the western margin of the Animas valley, with the Chiricahua Mountains visible on the skyline behind them. The Pyramid Mountains form the eastern margin of the Animas Valley, and the Animas Mountains extend southward from the southern end of the Pyramids. The Animas, Pyramid, Peloncillo, and Chiricahua Mountains contain all nine of the calderas currently recognized in the Boot Heel volcanic field (Fig 1.7; Table 1.2; McIntosh and Bryan, this volume). During evolution of the field, caldera volcanism shifted from east to west, similar to the trend seen in the Mogollon-Datil volcanic field to the north (McIntosh et al., 1992). The numerous elongate ranges that currently expose the Eocene–Oligocene volcanic rocks of the Boot Heel volcanic field are a consequence of Basin-and-Range extension. A higher degree of extension distinguishes the Boot Heel volcanic field from the less extended Mogollon-Datil volcanic field to the north; the

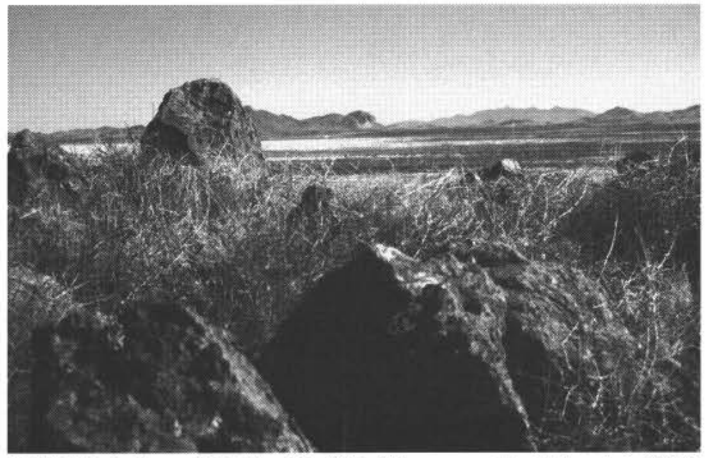


FIGURE 1.9. View of Oak Creek Tuff (Tuff 6 as mapped by Elston et al., 1983) on top of Twelve Mile Hill, stop 2, day 1. Steins Pass and the Peloncillo Mountains form the skyline. I-10 crosses the Animas basin and passes through Steins Pass.

two volcanic fields were probably contiguous prior to extension.

Twelve Mile Hill and other nearby hills are small fault blocks along the frontal fault between the Pyramid Mountains and the Animas Basin. Structural attitudes vary widely among the various blocks. Most dip gently to the east, but the ignimbrites at Twelve Mile Hill dip as steeply as 70° to the west, probably due to drag along the frontal fault.

The name Peloncillo may be derived from the Spanish *peloncillo* meaning "little baldy" or from the Spanish *piloncillo* meaning "sugar lump" or conical pieces of unrefined sugar (Julyan, 1996); either term is certainly appropriate for this mountain range, which closely follows the southern New Mexico/Arizona border. In addition to the late Eocene/Oligocene volcanic and intrusive rocks that make up most of the Peloncillo Mountains, Cretaceous and Proterozoic granite and Paleozoic, Mesozoic, and Paleocene sedimentary rocks are exposed in northwest-trending fault blocks (Armstrong et al., 1978; Erb, 1979; Drewes and Thorman, 1980; McIntyre, 1988; Richter et al., 1990; Bayona and Lawton, this volume). A mid-Tertiary granite at Granite Gap in the central Peloncillo Mountains has been dated by $^{40}Ar/^{39}Ar$ as 33.2 ± 0.20 Ma (biotite; McLemore et

FIGURE 1.10. Close-up view of Oak Creek Tuff (Tuff 6).

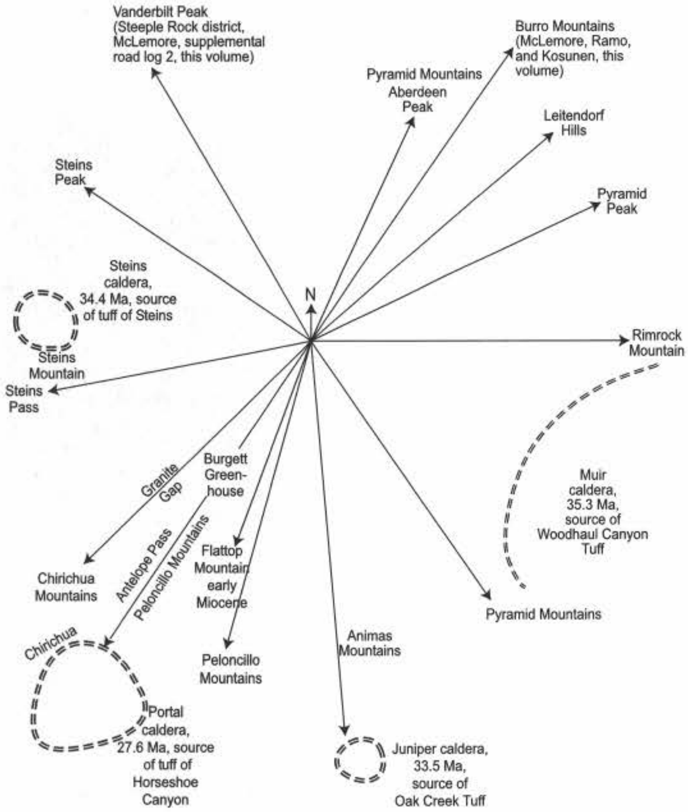


FIGURE 1.11. Geographic features seen from top of Twelve Mile Hill.

al., 1996a). There are three passes in the central Peloncillo Mountains. The southern pass is Granite Gap (Fig. 1.11). Steins is at the central pass, forming the skyline at 11:00 (I-10 is located in this pass). Doubtful Canyon is the northern pass. In the late 1800s, travelers would wait for reports of which route was free of Apache Indians before proceeding west.

The north-trending Animas Valley system is an interconnected group of three structural and geohydrologic basins (Cloverdale or San Luis, Upper Animas, and Lower Animas) that extends northward from the International Boundary to the Lordsburg Mesa-Summit Hills area, which overlooks the deeply entrenched Duncan-Virden segment of the Gila River valley (see McLemore, Supplemental Road Log 2, this volume). The hydrogeologic framework and geomorphic features of the area have been described by Schwennesen (1918), Reeder (1957), O'Brien and Stone (1983), Vincent and Krider (1998), Hawley et al. (2000) and Hibbs et al. (this volume). Late Quaternary pluvial lakes in the topographically closed Cloverdale and Lower Animas subbasins and aquifers of the perennial–intermittent upper Animas Creek fluvial system were originally described by Schwennesen (1918) and detailed studies of pluvial Lake Animas and Lake Cloverdale have been completed by Fleischhauer and Stone (1982) and Krider (1998), respectively.

As originally recognized by Schwennesen (1918), a large permanent lake (Lake Animas) flooded much of the valley floor north and west of this stop in latest Pleistocene time. Detailed mapping and soil-geomorphic studies by Fleischhauer (1978) and Fleischhauer and Stone (1982) document a late Wisconsin Lake Animas high-stand at 4193–4196 ft and two slightly lower stands at ~4186 and 4177–4180 ft, that are characterized by prominent beach ridges. These relict shoreline features flank much of the interior alluvial-flat and ephemeral-lake plain area. Two large vadose playas (South and North Alkali Flats) occupy much of the northern basin floor (Hibbs et al., this volume). An extensive fluvial-deltaic complex extending north from the mouth of Animas Creek (near the village of Animas) forms the southern part of the former lake plain west of this stop. Eolian deposits with dune fields cover lake beds and alluvium northwest of the Alkali Flats near the lower end of Lordsburg basin (Drewes et al., 1985).

Fleischhauer and Stone (1982) show that all Animas beach-ridge soils are weakly developed in comparison to much stronger soils on fan-piedmont surfaces predating the 4196-ft lake stage. Fan-piedmont soils commonly have well-developed calcic horizons and occur in both relict-surface and buried landscape positions. On the basis of correlation with late Quaternary soils of the Desert Project (Gile et al., 1966, 1981) and the regional paleoenvironmental record, Fleischhauer and Stone (1982) suggest that (1) the high-shore ridge is of late Wisconsin age, with a "minimum probable date" of about 11,000 yrs, and (2) the two lower beach ridges formed during a mid–late-Holocene interval as late as 6000–3000 yrs. It is also possible that all three shore ridges could have been deposited during the 20,000–8000-yr interval, because active fluvial- and pluvial-lake systems are known to have existed in nearby areas of Sulphur Springs Valley, Arizona, at about this time (Schreiber, 1978; Waters, 1985, 1989). Krider's (1998) work on pluvial Lake Cloverdale at the south end of the Animas basin system supports the possibility of at least two middle–late Holocene episodes of lake expansion, as well as major late Wisconsin high stands as early as 18,000–20,000 C^{14} years B.P. (Krider, 1998). Remains of *Mammuthus columbi* recovered from Lake Animas deposits in Lordsburg Draw also establish a late Pleistocene age for deep-lake sediments (Fleischhauer and Stone, 1982; Hallman and Hallman, 1997).

The highest Lake Animas shoreline (4196 ft) and the lowest drainage divide on the northern Animas valley perimeter (4239 ft at Summit) precluded any surface discharge across Lordsburg Mesa into the Gila River basin during middle–late Pleistocene time. However, ground-water discharge into the adjacent Duncan-Virden valley probably has occurred since initial river valley entrenchment in early Pleistocene time (Schwennesen, 1918; Reeder, 1957). Axtell (1978) proposed that a single, "Early Pleistocene Lake Morrison" (named in honor of pluvial-lake specialist R. B. Morrison) inundated the floors of the Lower Animas and Gila River basins; he suggested that Morrison's (1965) "lake gravel 5" of the Lordsburg Mesa area was deposited at that time. However, neither Morrison (1965) nor Fleischhauer and Stone (1982) have found any evidence that a deep lake in the Gila River basin (Duncan section) coalesced with any early Pleistocene lakes in the Lower Animas valley area (Fleischhauer and Stone, 1982, p. 9). In any case, thick, fine-grained basin-floor facies of the Pliocene "upper" Gila Group do underlie early–middle Pleistocene deposits in the Lordsburg Mesa area (Drewes et al., 1985; Hawley et al., 2000). It is possible that shallow lakes or interconnected systems of ponds and marshes (cienegas) associated with an ancestral Gila fluvial-fan complex extended across present basin boundaries prior to Gila Valley incision in the early Pleistocene (Hawley, 1975, fig 2).

Clearly visible in the valley bottom south of Twelve Mile Hill are several large white buildings occupied by Burgett Floral Greenhouses and the AmeriCulture Tropical Fish Hatchery, which we will visit at Stop 4. The town of Cotton City is southeast of the greenhouses.

Turn around and retrace route to Animas Road. **1.2**

12.5 Animas Road. **Keep right**. Retrace route to Robert E. Lee mine. **0.5**

13.0 Road junction. **Keep left**. **0.5**

13.5 Road junction. Keep straight through cattle guard. **1.1**

14.6 Top of hill. Robert E. Lee mine is at 1:00. **Be prepared to turn right ahead**. **0.3**

14.9 Road junction. **Turn right** and go through locked gate. **Sign reads NO TRESPASSING. Visitors must have permission to pass through the gate.** **0.3**

15.2 Road junction. **Keep left**. **0.1**

15.3 Road junction. **Keep straight (middle)**. **0.2**

15.5 Road junction. **Keep left**. Headframe of the Venus (Viola, Leitendorf) mine at 11:00 (Fig. 1.2). The Venus mine is one of the oldest mines in the South Pyramid subdistrict; about 1880, the mine was first operated and consisted of a pan-amalgamation mill, houses, and a stage station. The mill operated from 1883 to 1893 (Jones, 1907). Seven foundations are found at the mine today. Total production is unknown, but it is reported that from 1880 to 1904, the mine produced $150,000–200,000, mostly consisting of silver (Lindgren et al., 1910). The mine consists of several shafts; the deepest is 400 ft deep with 2020 ft of drifts, cross cuts, and stopes. The main vein of the Venus mine strikes N25–40°E. Smelter returns of 411 ppm Ag, 1 ppm Au, 0.75% Cu, 2.0% Pb are reported (Lasky, 1938). West of the main vein, a N50–60°E vein probably connects with the northern Last Chance vein. The Last Chance mine developed a quartz-barite-ankerite-argentite vein that strikes N75°E and assayed 20 oz/st Ag. On the 275-ft level, the grade was 15.5 oz/st Ag, 0.005 oz/st Au, 0.25% Cu, and 61% silica. A 50-stpd mill operated at the Last Chance mine from 1922 to 1923. The Susie mine (Fig. 1.2) was worked in 1958–1962. **0.3**

15.8 Road junction with road to Venus mine. **Keep right**. **0.3**

16.1 Road junction. **Turn right** and pass windmill. Road ahead passes through valley between Pyramid Peak to the east (left) and Leitendorf Hills to the west (right). Rimrock Mountain at 1:00 (Fig. 1.12). The northwest-trending Leitendorf fault forms part of the valley (Elston et al., 1983). The northern ring-fracture zone of the Muir cauldron may also form part of this valley. Pyramid Peak and the upper parts of Leitendorf Hills consists of rhyolite domes, which are interpreted as the outer bands of the ring-fracture domes of the Muir caldera (Elston et al., 1983), and are approximately the same age as the tuff of Woodhaul Canyon, 35.3 Ma (McIntosh and Bryan, this volume). The rhyolite of Pyramid Peak contains <5% small phenocrysts of sanidine, quartz, and biotite.

Approximately 5000 st of perlite was mined from three quarries in the Leitendorf Hills in the 1940s and 1952–1953. Perlite was initially shipped to St. Louis until a plant was built at Lordsburg. The perlite occurs in glassy zones of the rhyolite of Pyramid Peak (Elston et al., 1983); however, the presence of worthless stony rhyolite (devitrified) within the perlite deposits made production uneconomic. Flege (1959) conservatively estimated perlite resources as 30 million yds^3. **1.5**

17.6 Go through gate and pass Pyramid well, which is operated by solar power. The Leitendorf fault is just south of the windmill. Follow road around bend to the right. **1.2**

18.8 **STOP 3. Lunch at Rock House Canyon** (Fig. 1.13). Park in open area around water tank. An early masonry dam was built across the creek near the mouth of the canyon, probably in early 20th century, and has subsequently filled with sediment. A rock house is approximately 330 ft up the canyon (Fig. 1.14). Hike up canyon to see outcrops of densely welded ignimbrites displaying large flattened pumice clasts (Fig. 1.15). Outcrops on the east flank of the canyon, immediately east of the parking area, expose a poorly welded interval between two densely welded ignimbrite cooling units. The ignimbrite sequence in the Rock House Seep is similar to that seen at Twelve Mile Hill (Stop 2). Multiple cooling units of the 34.4-Ma tuff of Steins are exposed near the parking area and at the entrance to the canyon (mapped as Rimrock Mountain tuff members 3 and 4 by Elston et al., 1983). This unit is overlain by two cooling units of the 33.5-Ma Oak Creek Tuff (mapped as Rimrock Mountain tuff members 4 and 5 by Elston et al., 1983). These two lithologically similar ignimbrites can be readily distinguished by their paleomagnetic polarity, normal for the tuff of Steins and reversed for the Oak Creek Tuff (McIntosh and Bryan, this volume). You may notice paleomagnetic sample drill holes in this

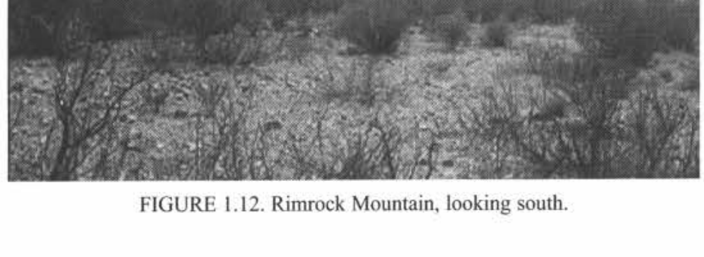


FIGURE 1.12. Rimrock Mountain, looking south.

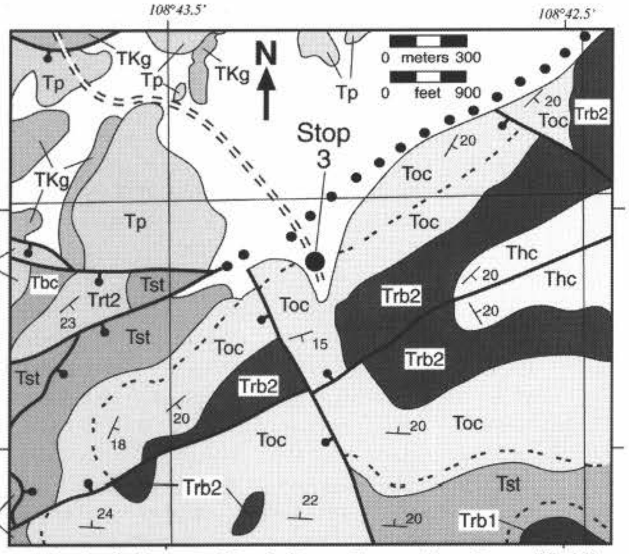


FIGURE 1.13. Geologic map of Rock House Canyon (Stop 3; modified from Elston et al., 1983). Units explained in Figure 1.8.

area. Other regional outflow facies ignimbrites exposed near Rock House Seep include tuff of Bluff Creek (35.1 Ma), tuff of Horseshoe Canyon (27.6 Ma), and Park Tuff (27.4 Ma) (Table 1.2). The sequence of regional ignimbrites rests on rhyolite lava domes and lithic-rich tuffs mapped as the rhyolite of Pyramid Peak by Elston et al. (1983). The rhyolite of Pyramid Peak was erupted near the northern margin of the Muir cauldron (Fig. 1.6), and may represent either precursor lavas or post-cauldron ring-fracture eruptions. Beginning about 4 mi south of Rock House Seep are extensive, thick deposits of the tuff of Woodhaul Canyon, interpreted as the intracaldera-facies ignimbrite filling the Muir Caldera (Elston et al., 1983).

Turn around and retrace route to Animas Road. **1.1**

19.9 Pass well and go through gate. **1.4**

21.3 Pass windmill and **be prepared to turn left ahead**. **0.1**

21.4 **Turn left.** **0.2**

21.6 Road junction. **Keep left**. Road to right goes to Venus headframe. **0.1**

21.7 Road junction. **Keep right**. **0.5**

22.2 Road junction. **Keep right**. **0.4**

22.6 Go through gate. **Turn right** onto Animas Road and continue southwest past Stop 2. **1.9**

24.5 Road junction. Keep straight. **0.5**

25.0 Junction with road to Stop 2 (Old Animas Road). Continue around the bend to the right (west) into Lower Animas Valley. Four Mile Hill at 12:30. **1.0**

26.0 Four Mile Hill at 3:00. **0.9**

26.9 Crossing low scarp of Animas Valley fault, which displaces upper Quaternary (<15,000 yrs) piedmont-slope deposits (Machette et al., 1998, fault #2093). **0.9**

27.8 Crossing beach ridges of pluvial Lake Animas for the next 0.3 mi (Fleischhauer and Stone, 1982). Elevation of the most prominent late Quaternary shoreline features is between 4196 and 4177 ft. Holocene alluvial-fan deposits locally obscure beach ridge and swale landforms. **0.5**

28.3 Road junction. **Keep left** past ranch house and continue west across relict Animas Lake plain surface with thin upper Holocene alluvial and eolian cover. **2.0**

FIGURE 1.14. Rock house in Rock House Canyon.

30.3 Road junction. **Turn left** onto paved NM-338. **1.1**

31.4 MP-4. Approaching toe of fan-delta of ancestral Animas Creek, which forms much of the Animas Valley floor from here to approximately 6 mi south of Animas (Hawley et al., 2000, plate 1). **3.0**

34.4 MP-7. Approximately 3 mi to the east, the 7405 ft Cockrell No. 1 Federal Pyramid exploration well was completed in Precambrian rock on 9/20/69. Basin-fill deposits (mostly Gila Group) are approximately 1880 ft thick and overlie mid-Tertiary volcanics (Thompson et al., 1977). **2.0**

36.4 MP-9 north of Cotton City. Cotton City is a small community centered around a cotton gin. **0.1**

36.5 **Turn left** (east) onto paved road to Burgett Floral Greenhouses and AmeriCulture Tropical Fish Hatchery. Pyramid Mountains form the skyline. The Muir district is located in the southern Pyramid Mountains ahead (McLemore and Elston, this volume). Mineral occurrences in the district are mostly fluorite and volcanic-epithermal veins. Fire clay occurrences also are in the area. Past production and known resources in the Muir district are generally small, but the district has not been extensively explored. Approximately 100 oz of Ag have been produced from the Silver Tree mine, and \$40,000–60,000 worth of fluorite has been produced from the Doubtful mine, including 9175 st of fluorspar ore containing 60% CaF_2 between 1942 and 1953. **2.5**

FIGURE 15. Close-up of Oak Creek Tuff in Rock House Canyon.

39.0 Road junction at stop sign. **Turn right**. **0.2**

39.2 Park in parking lot for **STOP 4, Burgett Floral Greenhouses**. AmeriCulture Tropical Fish Hatchery is to the left.

Geothermal waters were first discovered in the Animas Valley in 1948 when steam (240°F) was encountered in a water well (Kintzinger, 1956; Elston et al., 1983). The area was declared the Lightning Dock Known Geothermal Resource Area (KGRA) by the state in 1974. Federal and state leases for the geothermal water were issued. The geothermal waters in the Animas Valley are used to heat houses and greenhouses and may be used to generate small amounts of electricity in the future.

The geothermal waters have a complex origin (Elston et al., 1983). The hot water appears to be localized along a deep fault zone and is channeled to the surface at the Animas Valley fault, which may be coincident with the ring-fracture zone of the Muir caldera (Elston et al., 1983). The water flow is to the north. The water may be heated by a deep basaltic magma (Elston et al., 1983) or by deep basin conventional heating along faults (Wichter, 1988). Late Pleistocene–early Holocene piedmont deposits have been offset by the Animas fault, indicating the latest movement along the fault (Elston et al., 1983; Machette et al., 1998, fault #2093).

In 1977, Dale Burgett moved his greenhouse business from Cloudcroft to Cotton City, New Mexico, and began growing roses using geothermal waters as a heat source. The greenhouses and geothermal well fields occupy 32 acres. The water is approximately 244ºF with a flow rate of 2000 gpm. Heat capacity is 32.8 MWt and the annual energy output is 61.2 Gwh. Some roses are grown hydroponically in buckets and others are grown conventionally in soils. Burgett grows 31 varieties of roses and ships as many as 25,000 roses a day as far as 480 mi.

In 1995, AmeriCulture began producing genetically-improved, male *Tilapia nilotica* fingerlings in greenhouses north of the Burgett Geothermal greenhouses. *Tilapia nilotica* or Nile Tilapia, a breed of tropical, fresh-water fish native to Africa and the Middle East. The fish are bluish-gray, with light vertical stripes and can grow to more than 7 lbs. Geothermal waters heat the greenhouses; the fingerlings are grown in cooler well water. The tropical fingerlings are produced in enclosed facilities in order to protect the fish from diseases and changes in weather conditions. AmeriCulture is the largest domestic Nile Tilapia producer and produces approximately 7 million fingerlings a year. The fingerlings are placed in plastic bags with water and oxygen, boxed, and shipped by UPS throughout the country.

After tour of greenhouses, return to NM-338. Peloncillo Mountains at 12:00, Granite Gap at 11:00 and Chiricahua Mountains forming the skyline at 11:00. **0.2**

39.4 Return to paved road. **Turn left**. **2.5**

41.9 **Turn right** (north) onto NM-338. **6.0**

47.9 Animas Road to Lordsburg and stops 1–3 on right (past MP-3). Continue straight on NM-338. Grassy flat is relict floor of Lake Animas. **2.7**

50.6 Cross over I-10 overpass. Continue to I-10W. **0.2**

50.8 **Turn left** onto I-10W. I-10 and the railroad skirt the south edge of South Alkali Flat, the largest ephemeral lake plain (vadose playa) in the Animas-Lordsburg basin system (Fig. 1.16). This playa and the North Alkali Flat complex to the north are the sumps for surface flow in the Lower Animas and Lordsburg basins (Hibbs et al., this volume). The zone of saturation has historically ranged from 46 to 125 ft below the playa surfaces and the potentiometric surface slopes toward the Duncan-Virden segment of the Gila River valley approximately 18 mi to the north (Reeder, 1957). O'Brien and Stone (1983) estimated that approximately 12,700 acre-ft of predevelopment (pre-1900) annual outflow discharged as underflow to the Gila River basin aquifer system. Flow is probably primarily through "upper" Gila Group basin fill beneath the Lordsburg Mesa area flanking the Summit Hills. However, upper Oligocene–lower Miocene basaltic andesites that form the bulk of the Summit Hills uplift may also serve as conduits for interbasin ground-water flow. W. B. Lang (1943) was the first to describe the giant dissectation cracks that are a distinguishing feature of South Alkali Flats (see Fleischhauer and Stone, 1982, frontispiece). **4.9**

55.7 Road Forks exit 5. Continue on I-10. Exit 5 is also NM-80, which passes through Granite Gap in the Peloncillo Mountains. Road Forks is at the junction of NM-80 and I-10 and was settled about 1925. A U.S. Post Office was established 1925–1955 (Julyan, 1996). Today it is a truck stop servicing I-10. Beach ridges of Lake Animas are well preserved east of the truck stop. **2.9**

58.6 Road cuts in Tertiary andesite. The andesite is green–gray, fine grained, and consists of feldspar and groundmass. A sample of the andesite was dated as 33.75 ± 0.22 Ma (whole rock, $^{40}Ar/^{39}Ar$; Fig. 1.17), which is discordant with the 34.4 Ma sanidine age of the overlying tuff of Steins. Steins quarry at 12:00. **0.7**

59.3 Exit I-10 at Steins exit 3. **Turn right** at stop sign. **0.2**

59.5 Park in parking lot for **STOP 5** and barbecue dinner. In 1888, the Southern Pacific Railroad built a station along Steins Creek and called it Steins Pass. Buildings were

FIGURE 1.16. Looking northwest across South Alkali Flat, a playa lake in Animas Valley, towards northern Peloncillo Mountains. The highest point is Steins Peak. Photo taken from I-10 at Animas exit (exit 11).

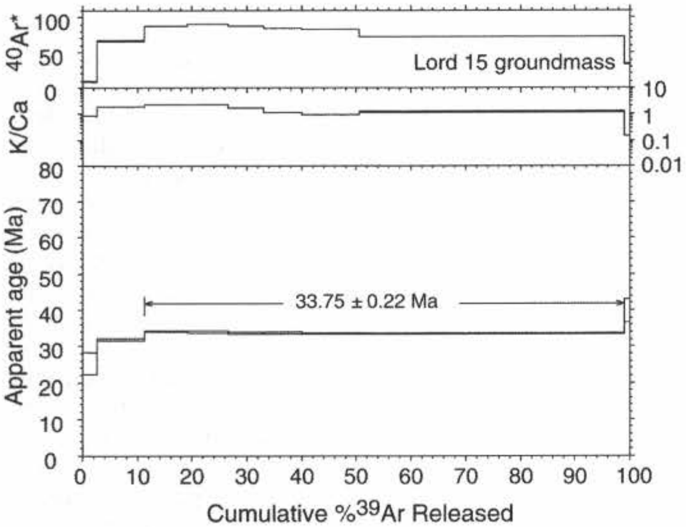


FIGURE 1.17. Apparent $^{40}Ar/^{39}Ar$ age spectra of andesite sample from road cut on I-10.

constructed of lumber, adobe, and railroad ties. Water was hauled from Doubtful Canyon approximately 7 mi to the north. The town had numerous businesses, including saloons, a boarding house, and a general store. A rock crushing plant was established in 1880–1920 to provide material for the Southern and Pacific Railroad (Figs. 1.18–1.20). A U.S. Post Office operated from 1888 to 1905 as Steins Pass and from 1905 to 1944 as Steins. After World War II, the railroad changed from steam to diesel and the Steins station was closed.

Steins is not to be confused with the pass approximately 7 mi to the north, which was named Doubtful Canyon by travelers heading towards California, because the chances of avoiding ambushes by Apache Indians were doubtful (Julyan, 1996). Major Enoch Steen with the U.S. Army camped near the pass in 1856 while exploring the Gadsden Purchase and several geographic features with his misspelled name appeared, including Steins Peak, Steins, and Steins Creek. A topographer misspelled Steen as Steins on early maps of the area and the misspelling has persisted. The Butterfield Overland Stage route went through the northern pass in 1858 and the company built a station called Steins Peak Station. A garrison of soldiers was established at the station to accompany west-bound travelers through the canyon. Although numerous accounts have confused Steins Creek and Doubtful Canyon as Steins Pass, modern maps recognize the northern Doubtful Canyon and southern Steins Creek, but not Steins Pass.

FIGURE 1.18. Crusher at Steins quarrry (courtesy of the Arizona Historical Society #29690).

Warren Garrison purchased Steins in 1977 when only one building remained standing, and he began restoring the abandoned town (Fig. 1.21). Garrison rebuilt the homes of the Reyes, Ortega, and Jimenez families. Antiques were donated and purchased to make the town look authentic for the late 1890s. In 1988, Larry and Linda Link bought the town and continued restoration and started giving tours. Today, Steins is a true ghost town with ten buildings housing beds, furniture, clothing, and tools, all providing a glimpse of the past.

The town of Steins is near the southeastern margin of the Steins cauldron, the source of the 34.4 Ma tuff of Steins, the regional outflow facies ignimbrite exposed at Stops 2 and 3 in the Pyramid Mountains. This cauldron has been mapped in detail by Drewes and Thorman (1980) and Richter et al. (1990) who identified thick intracaldera-facies ignimbrites containing abundant megabreccias and used numerous rhyolitic and dacitic lavas domes and intrusions to delineate the structural margins of the Steins cauldron. The steep,

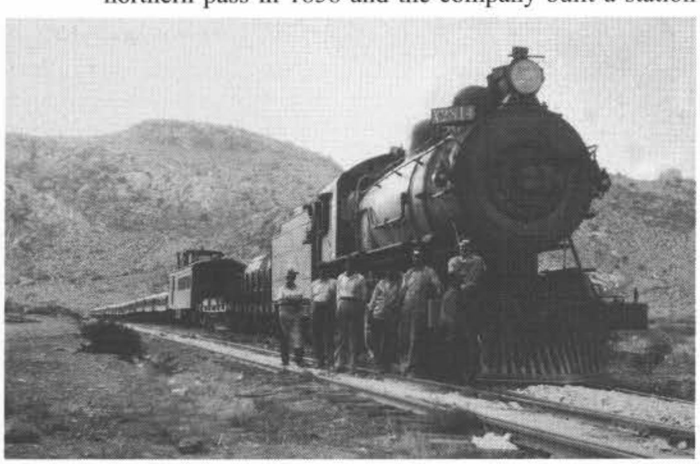


FIGURE 1.19. Crew and ballast train at Steins Siding (courtesy of the Arizona Historical Society #29681).

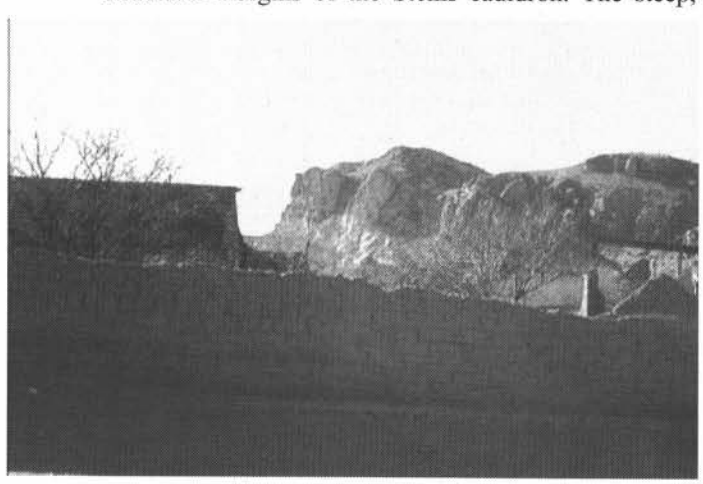


FIGURE 1.20. View of Steins quarry from ghost town of Steins.

FIGURE 1.21. Steins Mercantile Store in January 2000.

quarried cliffs visible from Stop 5 (Fig. 1.20) expose a sequence of hydrothermally altered breccias and lithic tuffs formed during eruption of a rhyolite lava dome that predated caldera formation (Drewes and Thorman, 1980). The correlation between the intracaldera facies and outflow facies tuff of Steins is based in large part on similarity of $^{40}Ar/^{39}Ar$ ages and paleomagnetic remanence directions (McIntosh and Bryan, this volume). The stratigraphy of the Steins area is shown in Figure 1.22. The Steins mining district is described by McLemore and Elston (this volume).

After dinner, go under I-10 overpass. **0.1**

59.6 **Turn left** onto I-10E for return to Lordsburg. Pass cemetery. **2.1**

61.7 Road Forks exit 5. Continue east on I-10. Crossing shoreline belt. **0.5**

62.2 Crossing lower end of Lake Animas floor (fluvial-deltaic plain); South Alkali Flat to the north. **5.0**

67.2 Exit 11, NM-338 to Cotton City. Continue east on I-10 across South Alkali Flat. Pyramid Peak at 2:00. **3.0**

70.2 Crossing high shorelines of Lake Animas. **0.6**

70.8 MP-14. Gravel pits in Cretaceous-Eocene granodiorite at 11:00 (Fig. 1.23). **1.5**

72.3 Gary exit 15, continue east on I-10. Gary was a small railroad community. Road cuts ahead are in altered andesite and rhyolite. Hills north of I-10 are capped by two outflow-facies ignimbrites mapped by Thorman and Drewes (1978a) as Tr overlain by Trw. $^{40}Ar/^{39}Ar$ dating (McIntosh and Bryan, this volume) indicates that the upper tuff is the tuff of Steins (34.4 Ma), which was erupted from the Steins caldera 12 mi to the west. The lower tuff is 35.4 Ma. Although the source of this unit is not established, it may represent outflow-facies ignimbrite erupted from the Muir cauldron in the central Pyramid Mountains, 18 mi to the south. Alteration and mineralization in this area may be related to intrusive breccia pipes (such as Fraggle Rock) and the granodiorite stock. **1.0**

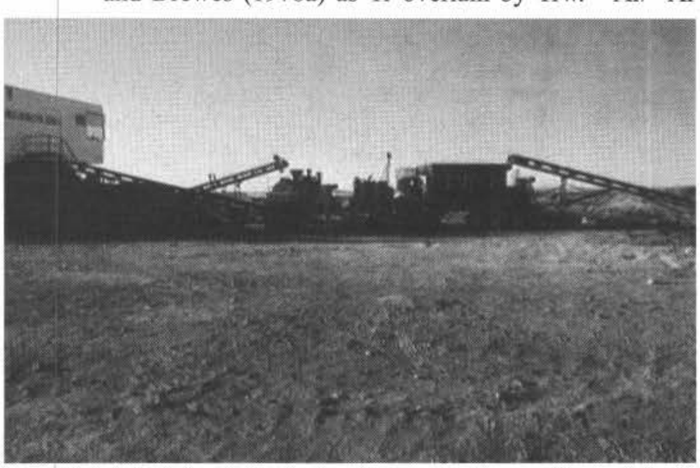


FIGURE 1.23. Crusher at gravel pit near MP-14 north of I-10.

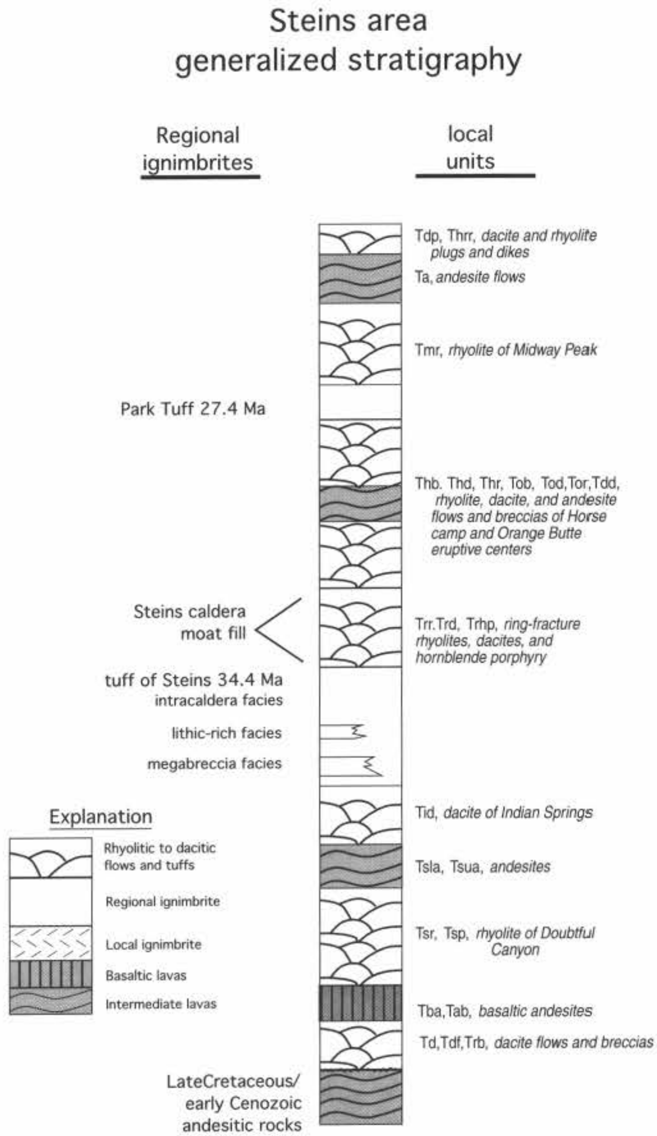


FIGURE 1.22. Stratigraphy of Steins area (Richter et al., 1990; Bryan, 1995).

73.3 MP-16. Continue east into Lordsburg on north piedmont slope of the Pyramid Mountains. Lordsburg Draw to the left. **1.0**

74.3 MP-17. Mid-Tertiary tuffs exposed. **2.2**

76.5 Exit 20A, Lordsburg city limits, Motel Drive exit. Continue east on I-10. **1.9**

78.4 **Take Main Street** (NM-494) exit 22 and **turn right** toward Holiday Inn Express. **0.2**

78.6 Holiday Inn Express.

End of Day 1 road log.