New Mexico Geological Society

Downloaded from: https://nmgs.nmt.edu/publications/guidebooks/42

Third-day road log: From Inn of the Mountain Gods to Nogal, Carrizozo, White Oaks and Valley of Fires

Spencer G. Lucas, Virginia T. McLemore, Adrian P. Hunt, Michael S. Allen, Steven M. Cather, and Mark Ouimette

1991, pp. 47-70. https://doi.org/10.56577/FFC-42.47

in:

Geology of the Sierra Blanca, Sacramento, and Capitan Ranges, New Mexico, Barker, J. M.; Kues, B. S.; Austin, G. S.; Lucas, S. G.; [eds.], New Mexico Geological Society 42 nd Annual Fall Field Conference Guidebook, 361 p. https://doi.org/10.56577/FFC-42

This is one of many related papers that were included in the 1991 NMGS Fall Field Conference Guidebook.

Annual NMGS Fall Field Conference Guidebooks

Every fall since 1950, the New Mexico Geological Society (NMGS) has held an annual Fall Field Conference that explores some region of New Mexico (or surrounding states). Always well attended, these conferences provide a guidebook to participants. Besides detailed road logs, the guidebooks contain many well written, edited, and peer-reviewed geoscience papers. These books have set the national standard for geologic guidebooks and are an essential geologic reference for anyone working in or around New Mexico.

Free Downloads

NMGS has decided to make peer-reviewed papers from our Fall Field Conference guidebooks available for free download. This is in keeping with our mission of promoting interest, research, and cooperation regarding geology in New Mexico. However, guidebook sales represent a significant proportion of our operating budget. Therefore, only *research papers* are available for download. *Road logs*, *mini-papers*, and other selected content are available only in print for recent guidebooks.

Copyright Information

Publications of the New Mexico Geological Society, printed and electronic, are protected by the copyright laws of the United States. No material from the NMGS website, or printed and electronic publications, may be reprinted or redistributed without NMGS permission. Contact us for permission to reprint portions of any of our publications.

One printed copy of any materials from the NMGS website or our print and electronic publications may be made for individual use without our permission. Teachers and students may make unlimited copies for educational use. Any other use of these materials requires explicit permission.

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

THIRD-DAY ROAD LOG, FROM INN OF THE MOUNTAIN GODS TO NOGAL, CARRIZOZO, WHITE OAKS AND VALLEY OF FIRES

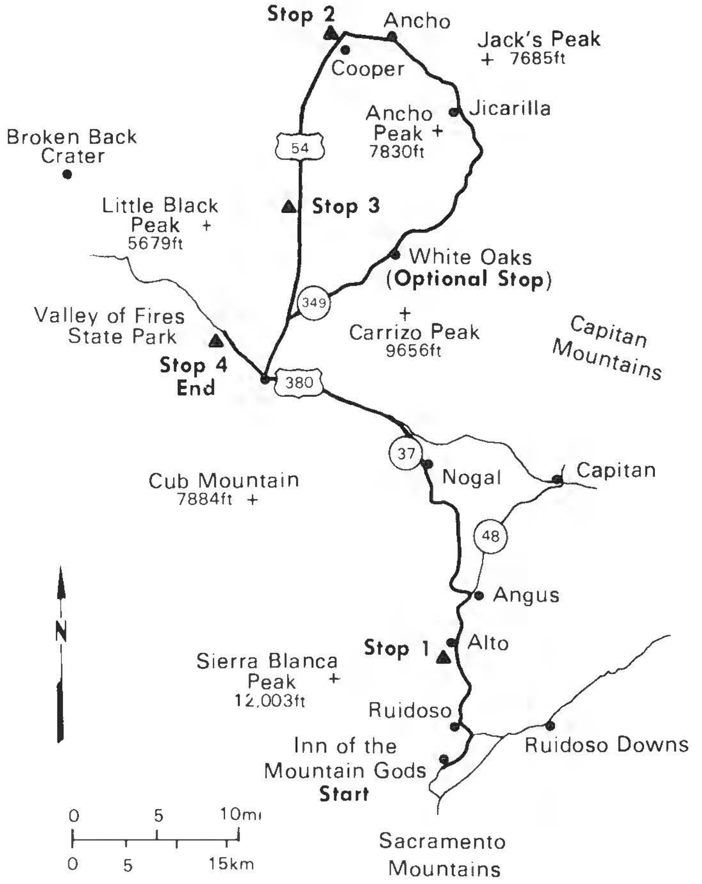
SPENCER G. LUCAS, VIRGINIA T. McLEMORE, ADRIAN P. HUNT, MICHAEL S. ALLEN,
STEVEN M. CATHER and MARK OUIMETTE

SATURDAY, OCTOBER 12, 1991

Assembly point: Inn of the Mountain Gods, near Ruidoso, New Mexico.
Departure time: 7:45 a.m.
Distance: 98.4 mi
Stops: 4

SUMMARY

Day 3 begins with a north-south traverse of the Sierra Blanca and the southern part of Lincoln County. We first examine Cretaceous (Crevasse Canyon Formation) and Eocene (Cub Mountain Formation) sedimentary rocks cut by Tertiary igneous dikes at Stop 1. We then pass through the Nogal mining district and leave the Sierra Blanca to enter the Sierra Blanca basin (Tularosa Valley) near Carrizozo. From Carrizozo the route passes north-northeast through the White Oaks and Jicarilla mining districts. The road log includes an optional stop at White Oaks. Triassic Moenkopi and Santa Rosa Formations are then examined at Stop 2 near Ancho. Just to the south, a basaltic sill intrudes the Cretaceous Greenhorn Formation at Stop 3, and the trip ends at the Quaternary olivine-basalt lava flow at the Valley of Fires Recreation Area at Stop 4. Today's route covers an area dominated by the structural Capitan lineament as shown by the numerous Tertiary igneous intrusive centers forming the Lincoln County porphyry belt (Table 3.1, Fig. 3.1). It also affords an understanding of Triassic and Cretaceous stratigraphy and sedimentation in the Sierra Blanca basin.



Mileage

0.0 Parking lot in front of the Inn of the Mountain Gods, Ruidoso. **Pass through underpass and turn right. 0.1**

0.1 **Turn right at stop sign,** toward Ruidoso onto Jicarilla Reservation Highway 4. Sierra Blanca Peak at 10:00. The Sierra Blanca complex (Oligocene-Miocene) has received much attention due to its prominence as a geographic and geologic landform and because of its associated mineral deposits. The complex consists of at least 1018 m of volcanic rocks (Thompson, 1972) with ages between 37 to 25 Ma (Table 3.1; Allen and Foord, 1991, this guidebook; Moore et al., 1991, this guidebook). Numerous plugs, dikes and breccia pipes of various compositions, ranging from syenite to andesite and alkali-feldspar granite to lamprophyre, have intruded the volcanic rocks of the Sierra Blanca (Thompson, 1972; Moore et al., 1988; Allen and Foord, 1991, this guidebook). See other papers in this guidebook for more information. **0.1**

TABLE 3.1. Summary of Tertiary intrusive centers comprising the Lincoln County porphyry belt (from various sources, including Allen and Foord, 1991, this guidebook; McLemore, 1991, this guidebook; Thompson, 1991a; Griswold, 1959). Location of intrusive centers is shown on Fig. 3.1.

Intrusive Center	Predominant Lithology	Age (Ma) (Mostly K/Ar)	Minerals Produced (minerals present)
1. Capitan pluton	granite to alkali granite	26.5	U(Th,Cu,Ag,Au,Fe)
2. Gallinas Mountains	andesite, latite, trachyte microsyenite, rhyolite	?	F,Cu,Fe,Zn,Pb,REE (U,Th)
3. Tecolote HIlls	syenite to syenogabbro	?	Fe
4. Jicarilla Mountains	syenite to syenogabbro to monzonite	37.3-38.2	Au,Ag,Fe,Cu (Pb,Zn)
5. Baxter Mountain	syenogabbro to syenite, lamprophyre dikes	35.2-29.8	Fe,Au,Ag,Cu,Pb,W (White Oaks)
6. Lone Mountain	quartz syenite to alkali granite	?	Fe(U)
7. Patos Mountain	rhyolite, syenite, monzonite	?	None known
8. Carrizo Mountain	quartz syenite to alkali granite	?	Fe(U)
9. Vera Cruz Mountain	trachyte	?	Au,Ag(Mo,Cu)
10. Black Mountain	gabbro to syenite	37.5-36.3	
11. Sierra Blanca complex	rhyolite to granite, lamprophyre dikes	37.3-25.8	Au,Ag,Cu,Pb Zn(Mo) (Nogal, Schelerville)

0.2 Poor exposures of Permian Grayburg Formation in roadcut on right and to the left are overlain by Dakota Formation at top of hill (Moore et al., 1988). Valley on left is underlain by Mancos, Dakota and Grayburg Formations. **0.3**

0.5 Dam of Mescalero Lake on left. At far end of dam outcrops are of Permian Grayburg Formation (red beds) overlain by a resistant cliff of Cretaceous Dakota Formation (Fig. 3.2). **0.8**

1.3 Large scar in hill at 10:00 is quarry in gray limestone of Permian San Andres Formation (Rio Bonito Member). **0.3**

1.6 Cattle guard. Leave Mescalero Indian Reservation. Carrizo Lodge on left; San Andres Formation outcrops ahead. Enter Carrizo, a suburb of Ruidoso. **0.3**

1.9 Grayburg Formation on right in scar of abandoned quarry. **0.2**

2.1 Outcrops of San Andres Formation on left. **0.6**

2.7 Paved road to left. Note igneous dikes cutting strata in roadcuts to left. Continue straight. **0.3**

3.0 Outcrops of San Andres Formation limestone cut by Tertiary igneous dikes on the left. **0.6**

3.6 Stop sign. **Turn left** onto Sudderth Drive, the main street of Ruidoso. **0.1**

3.7 To the right, outcrops beneath the house are Quaternary alluvial-fan gravels. **0.6**

4.3 Slope at 3:00–4:00 consists of San Andres Formation overlying Yeso Formation. **0.4**

4.7 Traffic light; continue straight. **0.7**

5.4 Road junction at traffic light. **Turn right** onto NM-48.

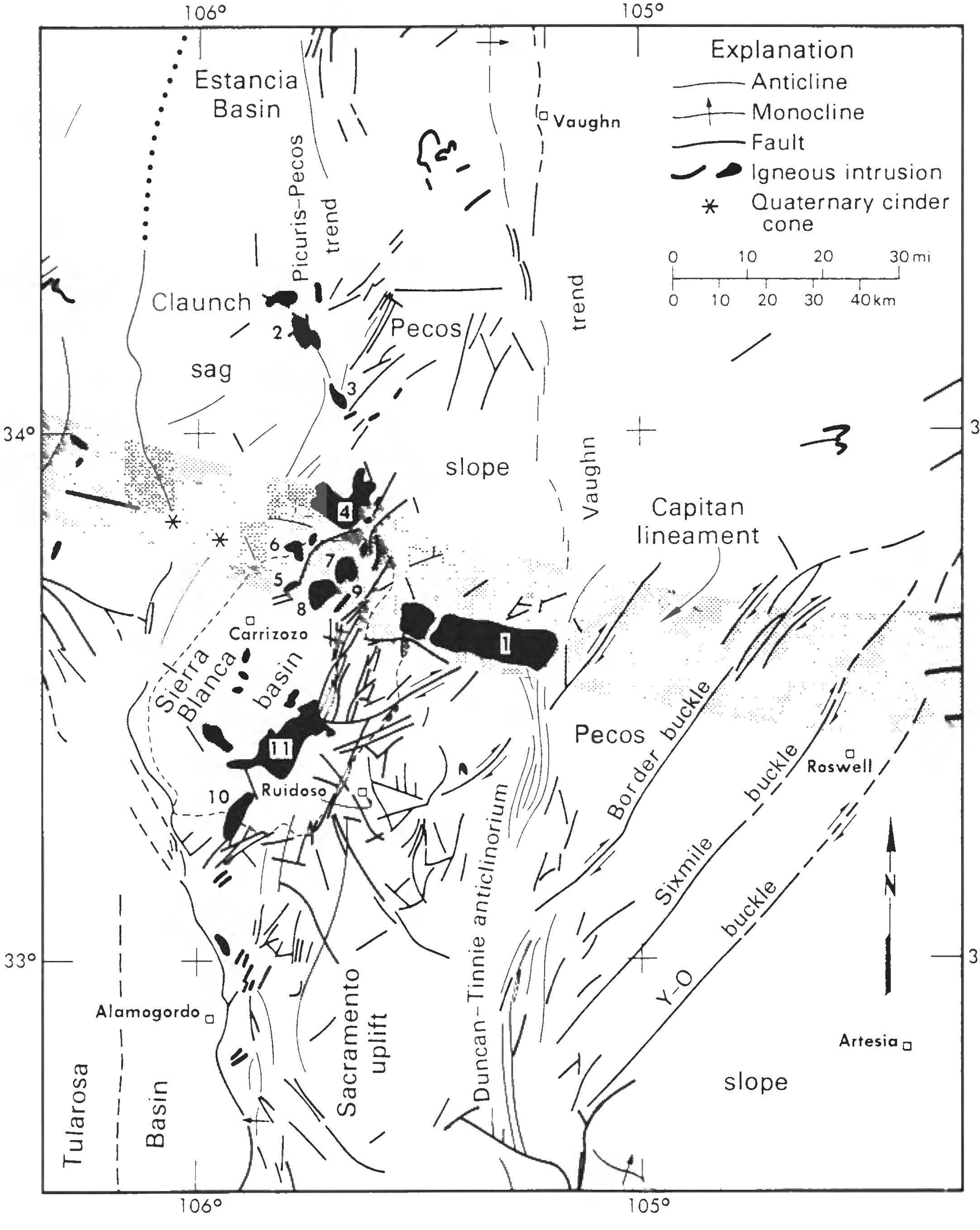


FIGURE 3.1. Map showing location of intrusive centers, the Capitan lineament and principal mineral deposits. Numbers are keyed to list of intrusive centers in Table 3.1 (from minipaper by Cather, Part Two, Second-Day Road Log, mile 19.4).

FIGURE 3.2. Outcrops of Permian Grayburg Formation overlain by Dakota Formation at Mescalero Lake Dam.

Note Sierra Blanca Peak at 12:30. **0.6**

6.0 Note red mudstones and yellow/tan fluvial sandstones of Eocene Cub Mountain Formation on left of highway. **0.1**

6.1 Milepost 4. Debris-flow deposit, part of the Sierra Blanca Volcanics, on left. **0.6**

6.7 Lincoln Forest Ranger Station on left. Road to Cedar Creek Recreation Area on left past Forest Ranger Station. Continue straight. **1.2**

7.9 Valley on right is drainage of Eagle Creek. **0.3**

8.2 Outcrops behind the businesses on left are debris-flow and fluvial sandstone and conglomerate of Sierra Blanca Volcanics, cut by numerous dikes. Pebble imbrication indicates easterly paleoflow. **0.7**

8.9 Roadcuts reveal igneous dikes cutting Sierra Blanca Volcanics. **0.9**

9.8 **STOP 1. Carefully pull off to left onto shoulder and follow directions of flaggers.** We will examine the roadcuts near the crest of the hill (Fig. 3.3) after a discussion at the wide spot on the left (west) side of the highway. Cretaceous Mesaverde Group (Crevasse Canyon Formation) and Cub Mountain Formation(?) are both cut by several igneous dikes of diverse lithologies. Calcite veins have filled fractures in the dikes and the sediments and along the intrusive contacts. The Crevasse Canyon Formation here is dominated by medium dark-gray, very fine- to fine-grained, micaceous, and feldspathic sandstone. The overlying Cub Mountain Formation consists of grayish-red mudstones and moderate yellowish-green, very fine- to medium-grained, subarkosic sandstones.

FIGURE 3.3. View of Stop 1 showing a Tertiary andesite dike (on which person is climbing), intruding Cretaceous Crevasse Canyon Formation.

The northernmost dike is a meter-wide andesite porphyry with medium-grained euhedral, unzoned plagioclase (An_{45}) in a groundmass of orthoclase, quartz and microcrystals. The dike is chemically an alkali gabbro to syenogabbro (Fig. 3.4) according to the classification of De la Roche et al. (1980). The southernmost dike is a lamprophyre with medium-grained hornblende and hedenbergite (determined by X-ray diffraction) in a groundmass of altered plagioclase and chloritized mafic minerals. Calcite occurs as a groundmass mineral phase. Vugs and veinlets are filled with calcite. Chemically, the dike (Fig. 3.3) is an olivine gabbro according to the classification of De la Roche et al. (1980). Both of these dikes are alkaline (Table 3.2, Fig. 3.5). **After the stop continue north on NM-48. 0.4**

10.2 Highway crosses Gavilan Canyon. **0.3**

10.5 Outcrops of Cub Mountain on left are cut by numerous dikes. **0.4**

10.9 Historical marker and turnoff on left to Mon Jeau Lookout (12 mi to the west). Mon Jeau Lookout is at an elevation of 10,000 ft and provides an excellent scenic view of the area. It is used by the U.S. Forest Service for firewatch, and has a deck open to visitors year-round. Also note Alto Post Office. Alto, named from the Spanish for high, was first settled in 1882 by W. W. Brazel and later named by the postmaster, W. H. Walker, in 1901 for its high elevation of 7300 ft (2225 m) (Pearce, 1965). **0.9**

11.8 In the distance, the Capitan Mountains form the skyline. See papers by McLemore and Phillips (1991), Allen and McLemore (1991), and Phillips et al. (1991), all in this guidebook. **0.2**

12.0 Milepost 10. **0.3**

12.3 Note outcrops of Mesaverde cut by igneous dikes in left roadcut. **0.3**

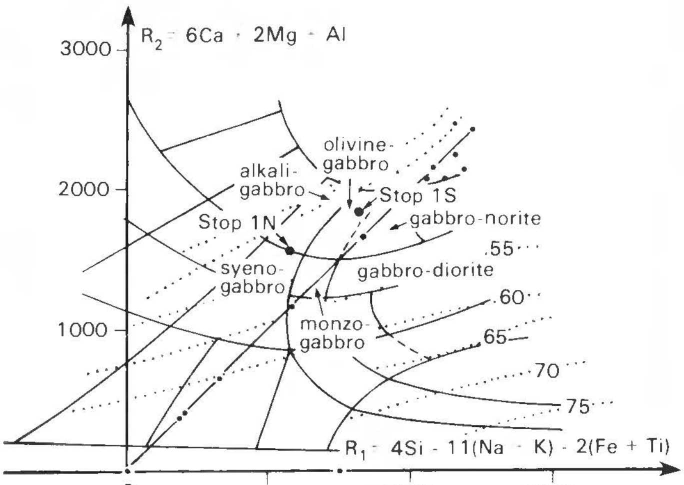


FIGURE 3.4. R_1-R_2 chemical plot of samples from Stop 1.

TABLE 3.2. Major element analyses of two dikes at Stop 1, the northernmost dike (1N) and the southernmost dike (1S). XRF analyses by C. McKee (New Mexico Bureau of Mines and Mineral Resources X-ray Facility). *Total iron reported as Fe_2O_3.

	Stop 1N	Stop 1S
SiO_2	43.3	43.0
TiO_2	1.38	1.27
Al_2O_3	17.5	17.0
Fe_2O_3*	10.9	10.6
MnO	0.20	0.14
MgO	5.17	7.06
CaO	9.18	11.0
Na_2O	3.16	2.10
K_2O	1.32	0.60
P_2O_5	0.71	0.49
LOI	7.31	6.56
TOTAL	100.13	99.82

12.6 Turnoff to Sierra Blanca regional airport on the right. Continue straight. **1.0**

13.6 Outcrops of dikes cutting Mesaverde Group for next 1.1 mi. Road begins descent toward Angus. **1.3**

14.9 Angus, New Mexico. Angus was first settled in 1881 by Amos Eakers. Subsequently, P. G. Peters, the first postmaster, named the town in 1898 to honor the VV Ranch, which was stocked with Pollard Angus cattle. The Southern Pacific railroad bought up the ranches in this area for their water rights and allowed the orchards and farms to fall into neglect. The post office closed in 1913 (Pearce, 1965). **0.2**

15.1 Crossing Rio Bonito. **Junction** NM-37. **Turn left** and proceed on NM-37 toward Nogal. Roadcuts ahead are Cub Mountain Formation. **0.2**

15.3 Dikes on right are cutting Cub Mountain Formation. **0.3**

15.6 Dikes on right cut Cub Mountain Formation. Thin sections from sandstone and conglomerate of the Cub Mountain Formation here show anomalously high concentrations of chert and calcareous rock fragments. Pebble imbrication shows southwest paleotransport. Taken together, these data suggest that the Cub Mountain here was largely derived from exposures of Paleozoic strata along the Mescalero arch, which bounds the eastern side of the Sierra Blanca basin. **0.2**

15.8 Tetiary intrusives in right roadcuts for next 0.5 mi. **0.6**

16.4 Mon Jeau Peak at 10:00. **0.1**

16.5 Road to left to Bonito Lake. Mon Jeau Peak at 9:00. **0.1**

16.6 Tunnel at 3:00 through trees is part of an old mine. Numerous adits, shafts and pits occur in the area as part of the Nogal mining district. The Nogal mining district contains gold placers as well as breccia-pipe and vein deposits containing gold, silver, copper, lead and zinc. The district is classified as a Great-Plains-Margin deposit (North and McLemore, 1986, 1988). Estimated production from the district amounts to about 15,000 oz of gold and 20,000 oz of silver from 1868 to 1942 (McLemore, 1991, this guidebook). In addition, some copper, lead and zinc have been produced, but production figures for them are not known.

Two of the economically important mines are the Parsons and Great Western mines. The Parsons mine is associated with the Rialto stock of calc-alkaline affinity ($Na_2O+K_2O=7.6–10.3\%$; Thompson, 1991b). The Great Western mine is associated with the Three Rivers stock of alkaline affinity ($Na_2O+K_2O=10.2–11.7\%$; Thompson, 1991b; see following minipaper by S. L. Eng). Both deposits are breccia pipes and are silicified. Reserves at the Parsons mine have been estimated by drilling as 41,000 mt and at the Great Western mine as 3,275,000 mt, with both containing <2 ppm of gold (Thompson, 1991b). High concentrations of molybdenum are associated with both deposits. **0.3**

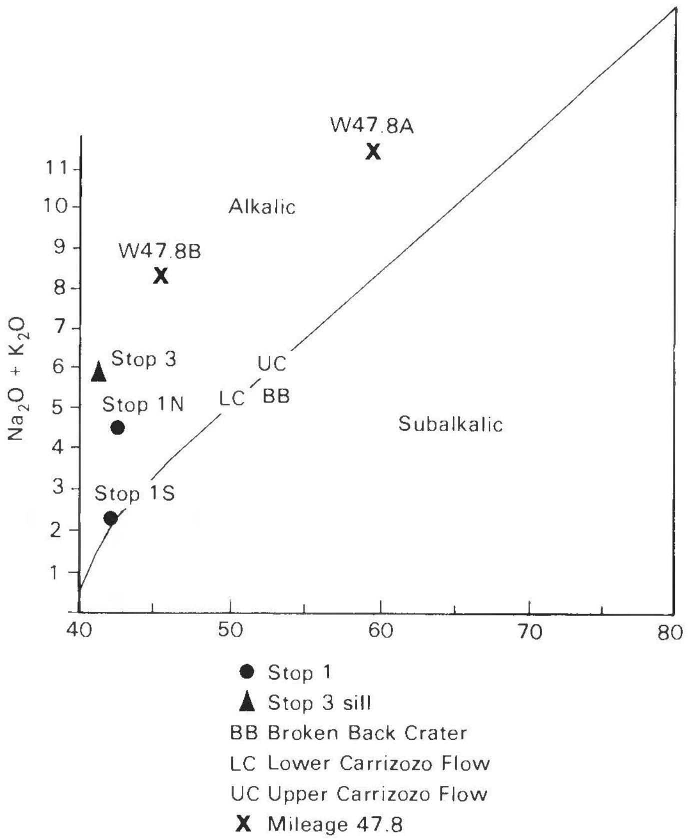


FIGURE 3.5. Plot of Na_2O+K_2O versus SiO_2 for samples from Stop 1, Stop 3, and mile 48.7. Boundary line from Irvine and Baragar (1971).

ORE MINERALOGY AND PARAGENESIS, GREAT WESTERN MINE, LINCOLN COUNTY, NEW MEXICO

Sheryl L. Eng

Geological Engineering Department, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

The Great Western mine is in the Nogal mining district, Lincoln County, New Mexico (Fig. 3.6). The earliest record of mining within

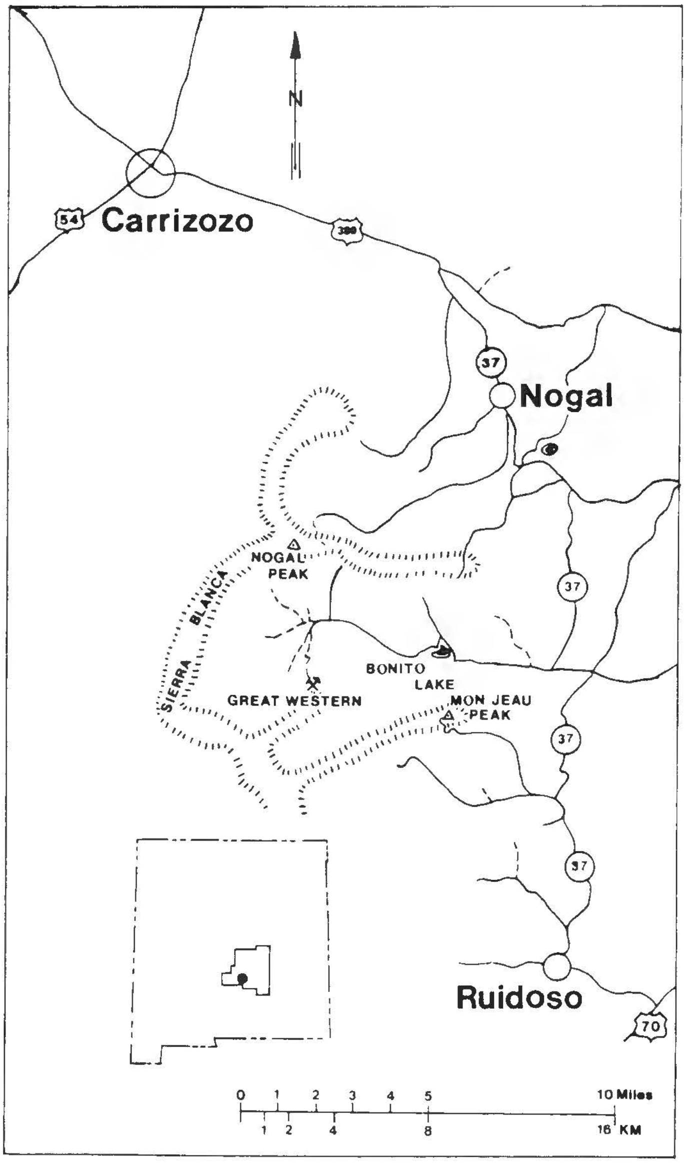


FIGURE 3.6. Location of the Great Western mine, Lincoln County, New Mexico. Modified after Griswold (1959).

the district reports that placer gold was mined along Dry Gulch in the 1860s, although prospecting and mining was presumably conducted during the period when New Mexico was ruled by the Spanish (Griswold, 1959). Other principal metals that have been mined from the district include lead, silver and copper. At the Great Western mine, disseminated gold is hosted by andesite porphyry and andesite breccia of the Walker Andesite Breccia of Tertiary age (Thompson, 1973).

The Great Western mine is owned by Pioneer Metals Corporation, Vancouver, B.C., Canada. Gold exploration was conducted during 1988 and 1989, but the property is presently inactive. The estimated gold grade is 0.04 oz/ton. The Great Western mine can be reached by traveling about 3 mi west of Bonito Lake and approximately 2 mi south on a steep road leading up Big Bear Canyon.

Drill-hole chip samples and ore cores from the main zone and the bluefront zone of the Great Western mine area were studied for ore mineralogy and mineral paragenesis. Polished sections and grain mounts were prepared, then analyzed with a petrographic microscope. Gold, silver, pyrite, chalcopyrite, sphalerite, bornite, covellite, tetrahedrite-tennantite, hematite, goethite and rutile were identified. The scanning electron microscope (SEM) was used to verify the identification of selected minerals and to determine the manner in which gold and silver occur.

SEM results show that gold occurs as gold-rich electrum in grains approximately 15 to 175 μm in diameter and as fracture-filling in chalcopyrite. Grains of electrum contain pyrite inclusions and embayments. One of the grains of electrum was depleted in silver along the rim of the grain. Grains of silver show no detectable gold and range from 35 to 90 μm in length. Silver also occurs with argentiferous tetrahedrite-tennantite, but not all tetrahedrite-tennantite analyzed contained silver.

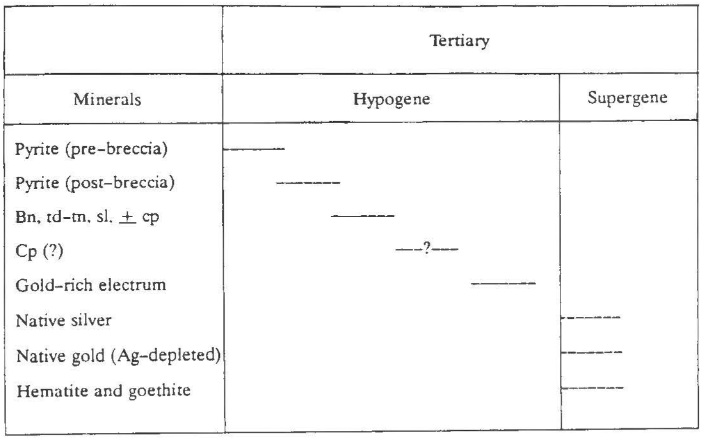
Pyrite commonly occurs associated with silica, in lithic fragments, and as veinlets surrounding lithic fragments. Inclusions of pyrite and sphalerite occur in some chalcopyrite grains. Pyrite is replaced by bornite, chalcopyrite and tetrahedrite-tennantite, and is paragenetically earlier than hematite and goethite. Hematite and goethite are supergene oxidation products of pyrite. Hematite also surrounds lithic fragments, whereas rutile and chalcopyrite are within lithic fragments.

The ore mineral occurrences suggest the following paragenetic relationships. A breccia containing pyrite in lithic fragments and as veinlets surrounding lithic fragments indicates that pyrite crystallized on at least two occasions, prior to brecciation and after brecciation (Fig. 3.7). Hematite and goethite were probably derived from the oxidation of pyrite, because such phases occur in oxidized samples in the same places where pyrite occurs in non-oxidized samples (i.e., surrounding lithic fragments). Other sulfides (bornite, chalcopyrite and the tetrahedrite-tennantite-replaced pyrite) postdate pyrite. Inclusions of pyrite and sphalerite occurring in chalcopyrite indicate that pyrite and sphalerite crystallized before chalcopyrite.

Gold-rich electrum is associated with pyrite and occurs as fracture-filling in chalcopyrite, indicating gold deposition after sulfide formation. Although the association of gold with sulfides is well established, it is not certain whether the gold is associated with the pyrite that formed before brecciation or with the pyrite formed around lithic fragments after brecciation. Most likely the gold is associated with the pyrite that developed after brecciation, because this late pyrite is much more abundant than the pyrite that occurs within the lithic fragments. Furthermore, gold is not associated with any pyrite observed in lithic fragments. Gold-rich electrum having silver-depleted rims suggests that such gold underwent supergene leaching of silver from the periphery of gold-rich electrum. Hence, the silver is thought to be supergenetically derived from the gold-rich electrum. This supposition is supported by SEM analyses showing that grains of silver contain no detectable gold.

16.9 Intrusives cutting Mesaverde Group on left of highway. **0.6**

17.5 Outcrops of Crevasse Canyon Formation cut by igneous dikes in roadcut to right. **0.5**



	Tertiary	
Minerals	Hypogene	Supergene
Pyrite (pre-breccia)	——	
Pyrite (post-breccia)	——	
Bn, td-tn, sl, ± cp	——	
Cp (?)	—?—	
Gold-rich electrum	——	
Native silver		——
Native gold (Ag-depleted)		——
Hematite and goethite		——

FIGURE 3.7. Mineral paragenesis of the Great Western mine, Lincoln County, New Mexico. Bn = bornite, td-tn = tetrahedrite-tennanite, sl = sphalerite, cp = chalcopyrite, Ag = silver.

18.0 Left roadcut reveals Crevasse Canyon cut by igneous dikes. **0.4**

18.4 Dirt road to right leads to metal gate. Capitan Mountains at 1:00–2:00, forming the skyline. Carrizo Mountain at 12:00. **0.2**

18.6 On right for next 1.2 mi note prominent igneous-intrusive rocks cutting Crevasse Canyon Formation. **1.7**

20.3 Milepost 5. **1.4**

21.7 Mesaverde cut by dikes on right. Nogal Peak at 9:30. Church Mountain at 11:30. Nogal Peak and Church Mountain consist of Sierra Blanca Volcanics and intrusives. **1.1**

22.8 Lookout Point on right. **0.5**

23.3 Milepost 8. Roadcuts in Quaternary colluvium. **0.2**

23.5 At pull-off on right of road at sharp curve note Nogal Peak at 11:00. View up Tularosa Valley on left at 10:00 shows Church Mountain at 9:30. Oscura Mountains form low ridge on western skyline. Carrizo Mountain at 11:30 (Figs. 3.8, 3.9). Vera Cruz Mountain in foreground. Roadcuts expose late Tertiary-Quaternary conglomerate. Continue descent into Nogal. **0.1**

23.6 Late Tertiary-Quaternary fluvial conglomerate caps Sierra Blanca Volcanics in roadcuts. **0.2**

23.8 Roadcuts on right and left reveal numerous igneous dikes cutting the Sierra Blanca Volcanics for next 1.4 mi. **0.5**

24.3 Nogal at 12:00 in valley below. **0.8**

25.1 Town of Nogal. About 1879, gold was discovered at what is now known as Nogal. Early prospectors initially coined the name Dry Gulch for this settlement, which soon was altered to Galena and finally to Nogal. Nogal (Spanish: walnut tree) was named for the many walnut trees that grow in the town and in the canyon along the Hondo River as well as in the Sierra Blanca. The nearby Helen Rae and American gold mines were large producers in the early 1880s. Other mines are clustered around Nogal Peak farther to the southwest. After the closing of the gold mines, the town went into decline. **0.4**

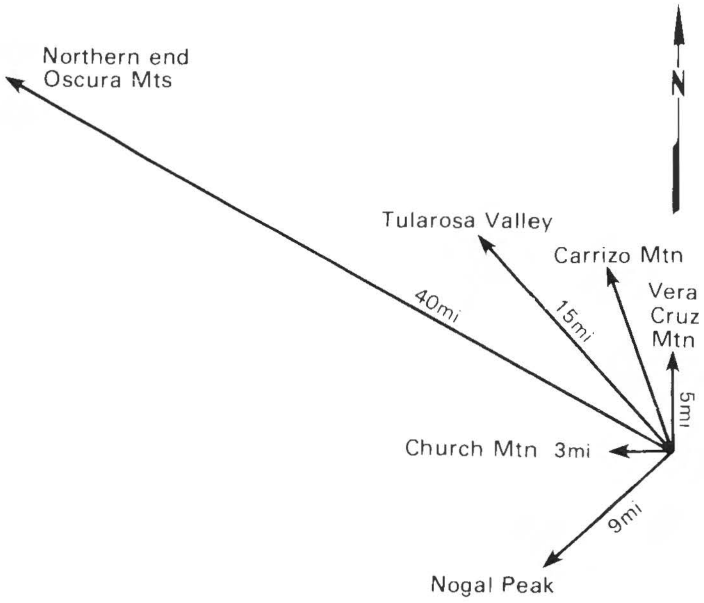


FIGURE 3.8. Panoramic index at mile 23.5.

FIGURE 3.9. Town of Nogal (center), Carrizo Mountain (center skyline) and Vera Cruz Mountain (right skyline) at mile 23.5.

25.5 Post office on left. **0.1**

25.6 Leaving Nogal. We are now leaving the Sierra Blanca volcanic field and entering the Tularosa Basin. The Capitan lineament passes through the area ahead. The Capitan lineament is a major west-northwest-trending zone which traverses central New Mexico (Fig. 3.1) and is roughly perpendicular to the Rio Grande rift. It is characterized by the alignment of various igneous and structural features (Kelley and Thompson, 1964; Chapin et al., 1978; Allen and McLemore, 1991, this guidebook; Allen and Foord, 1991, this guidebook), including the Matador arch of west Texas, the 27.9 ± 1.4 Ma diabase dikes near Roswell (Aldrich et al., 1986), the 26.2 ± 1.2 Ma Capitan pluton (Allen, 1988), other intrusives of the Lincoln County porphyry belt (Table 3.1), the Carrizozo basalt flows (1000–1500 yrs old; Weber, 1964), the northern truncation of the Carrizozo anticline (Kelley and Thompson, 1964), and the 27.9 ± 1.1 Ma Jones Camp dike in eastern Socorro County (Aldrich et al., 1986). Near Socorro, the Capitan lineament is juxtaposed to the Socorro accommodation zone, also known as the Socorro transverse shear zone (Chapin, 1989). The western extension of the Capitan lineament is currently under study.

The Capitan lineament is a major, tectonic, deep-seated structure that has periodically leaked magma since about 33 Ma. The Moho is relatively shallow in this area (30 km; Keller et al., 1990), and this implies a relatively thin crust, which controls the emplacement of mantle-derived magmas such as the Carrizozo lava flows. The crust gradually thickens from 30 km in the Tularosa Valley west of the Lincoln County porphyry belt to 50 km east of the Pecos River and east of the belt. The diversity of igneous rocks (Table 3.1) and the mineral deposits (McLemore, 1991, this guidebook) suggests that this is an area of complex magmatic differentiation and fractionation resulting in the Lincoln County porphyry belt and associated mineral deposits that may be related to crustal thinning to the west. This diversity may be the result of partial melting of different levels of the mantle and crust. Thus, the magmas and associated hydrothermal fluids were channeled by the Capitan lineament and the tectonic zone of crustal thickening toward the stable Great Plains province. **0.7**

26.3 Milepost 11. **0.7**

27.0 Vera Cruz Mountain (elevation 2380 m) straight ahead. The dumps of the Vera Cruz gold mine are visible halfway up the slope (Fig. 3.10). Vera Cruz Mountain consists of a quartz-monzonite stock or laccolith that has intruded shales of the Crevasse Canyon Formation (Upper Cretaceous). The Vera Cruz gold mine is considered the northern extent of the Nogal mining district. The ore deposits were discovered in the 1880s and patented in 1889. The ore occurs in breccia pipes in the quartz monzonite near the intrusive contact with the Cretaceous sedimentary rocks. Gentle doming of the Cretaceous rocks has occurred as a result of the intrusion of the quartz monzonite. Kaolinization and silicification are common (Griswold, 1959). Production is unknown, but 20,000 to 50,000 tons of ore were probably treated at the mill during the 1900s. The breccia pipes occur at the intersection of east-west-trending faults and fractures with a N20°E trend (Ryberg, 1991). The breccia pipe is 200 m long and up to 60 m wide. It is composed of various clasts of sedimentary rocks and intrusive fragments that are angular to subangular. Underground sampling showed gold values up to 5.43 oz/ton (see Ryberg, 1991, this guidebook). Recent drilling by the Vera Cruz Minerals Corporation, a Canadian firm, indicates ore is present below existing workings. Assays of drill samples from 80–90 m deep were as high as 1.44 oz/ton Au and 0.75 oz/ton Ag (Vera Cruz Minerals Corporation, news release, January 12, 1989). Pyrite, chalcopyrite, chalcocite and sphalerite occur in the breccia zones together with anomalously high values of molybdenum. **0.1**

27.1 Exposures along roadside are of Eocene Cub Mountain Formation, probably the basal part. Sandstone on north side of road contains pebbles of quartzite, chert and altered volcanics that are as much as 3 cm in diameter. A single paleocurrent measurement, based on pebble imbrication, suggests northeast transport. **0.8**

27.9 Small, dome-shaped mountain west of Vera Cruz Mountain at 2:30 consists of Cretaceous Mesaverde Group strata. Nogal Creek on right; deeply entrenched bank reveals river and fan gravels. **1.7**

29.6 **Highway junction** with US-380. **Turn left** onto US-380 and head west. Oscura Mountains form skyline at 10:00–11:30. Chupadera Mesa is at 11:30–12:30. In the middle ground at 12:00–1:30, the Tularosa Valley is filled by an olivine-basalt lava (Valley of Fires). Little Black Peak at 1:00; Lone Mountain at 2:00, to the northwest of Carrizo Mountain and, at 2:30–3:00 is Carrizo Mountain. Some quartz-syenite outcrops are visible in the cliffs near the top of the mountain. **1.5**

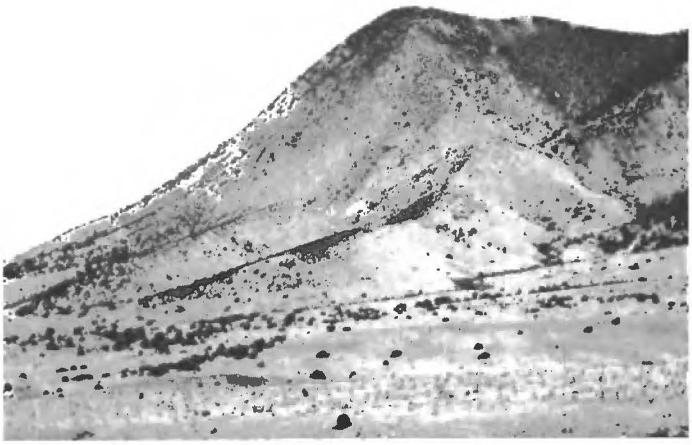


FIGURE 3.10. Vera Cruz Mountain looking to the north. Note mine dumps halfway up the mountain slope.

31.1 Dirt road to left; good view of Sierra Blanca to left with Church Mountain at 8:30 and Diamond Peak at 9:00. **0.7**

31.8 Cub Mountain at 9:30. Willow Hill at 10:00. Several abandoned coal mines developed in Cretaceous Mesaverde strata are located on the south side of Willow Hill. **0.4**

HISTORY OF COAL MINING IN THE SIERRA BLANCA COAL FIELD, LINCOLN AND OTERO COUNTIES, NEW MEXICO

Edward S. Slagle

U.S. Bureau of Land Management, Battle Mountain, Nevada 89820

The earliest known commercial extraction of coal in the Sierra Blanca coal field occurred in the year 1880, when J. W. Kelly opened a mine in the NE$^{1}/_{4}$ SE$^{1}/_{4}$ SE$^{1}/_{4}$ sec. 5, T7S, R13E, southeast of White Oaks, Lincoln County (Wharton, 1900; Wegemann, 1914). A number of other coal mines and prospects were also opened in the same section, as well as in secs. 31 and 32, T6S, R13E, from 1880 to 1900. The most long-lived of these was the Old Abe mine—not be confused with the nearby Old Abe gold mine of the same ownership (Wharton, 1900; Wegemann, 1914; Haines, 1968). After 1900, the two main producers of coal in the White Oaks area were the Old Abe and Wild Cat mines. (Fig. 3.11).

In the 1880s and 1890s attempts had been made by several companies to lay a railroad track from El Paso, Texas to the coal and gold mines at White Oaks. Initial efforts had proved unsuccessful, and it was not until Charles B. Eddy (for whom Eddy County, New Mexico was named), with backing from eastern financial interests, incorporated the El Paso and Northeastern Railroad Company on October 28, 1897, that an adequately financed and successful construction effort began. During the course of that effort, the towns of Alamogordo and Carrizozo were created. Although the primary objective of the railroad construction project had been to obtain coal, the railroad company decided around 1900 to bypass White Oaks. As a result of that decision, large-scale mining, of both gold and coal, decreased dramatically in the White Oaks area. Coal continued to be produced at a slow but fairly steady rate (primarily to supply the power plant) from the White Oaks deposits until 1938, and sporadically (mainly to fulfill school contracts) for a number of years afterward. This was the longest active span of production of any of the coal deposits in the Sierra Blanca coal field (Griswold, 1959; Keleher, 1962; State Inspector of Mines Annual Reports).

Although records of coal production at White Oaks during the first phases of mining are unavailable, well over 50,000 tons of coal are known to have been extracted from the White Oaks deposits (Wegemann, 1914; State Inspector of Mines Annual Reports). The actual production of White Oaks coal was probably about twice that amount. The report of the State Inspector of Coal Mines for the year that ended October 31, 1929, indicated that the mine in secs. 31 and 32, T6S, R13E, which furnished coal for the power plant at White Oaks, was opened by a slope 1200 ft long on a dip of 13°, and was worked by use of the room-and-pillar method. White Oaks coal was used primarily to provide power for gold milling and to fire the power plants supplying electricity to White Oaks, Carrizozo and such nearby communities as Nogal and Parsons. It was also used, in smaller amounts, for heating, cooking and blacksmithing purposes, both locally and in towns as far away as Roswell and Tularosa (Wharton, 1900; Hailey, 1913; Wegemann, 1914).

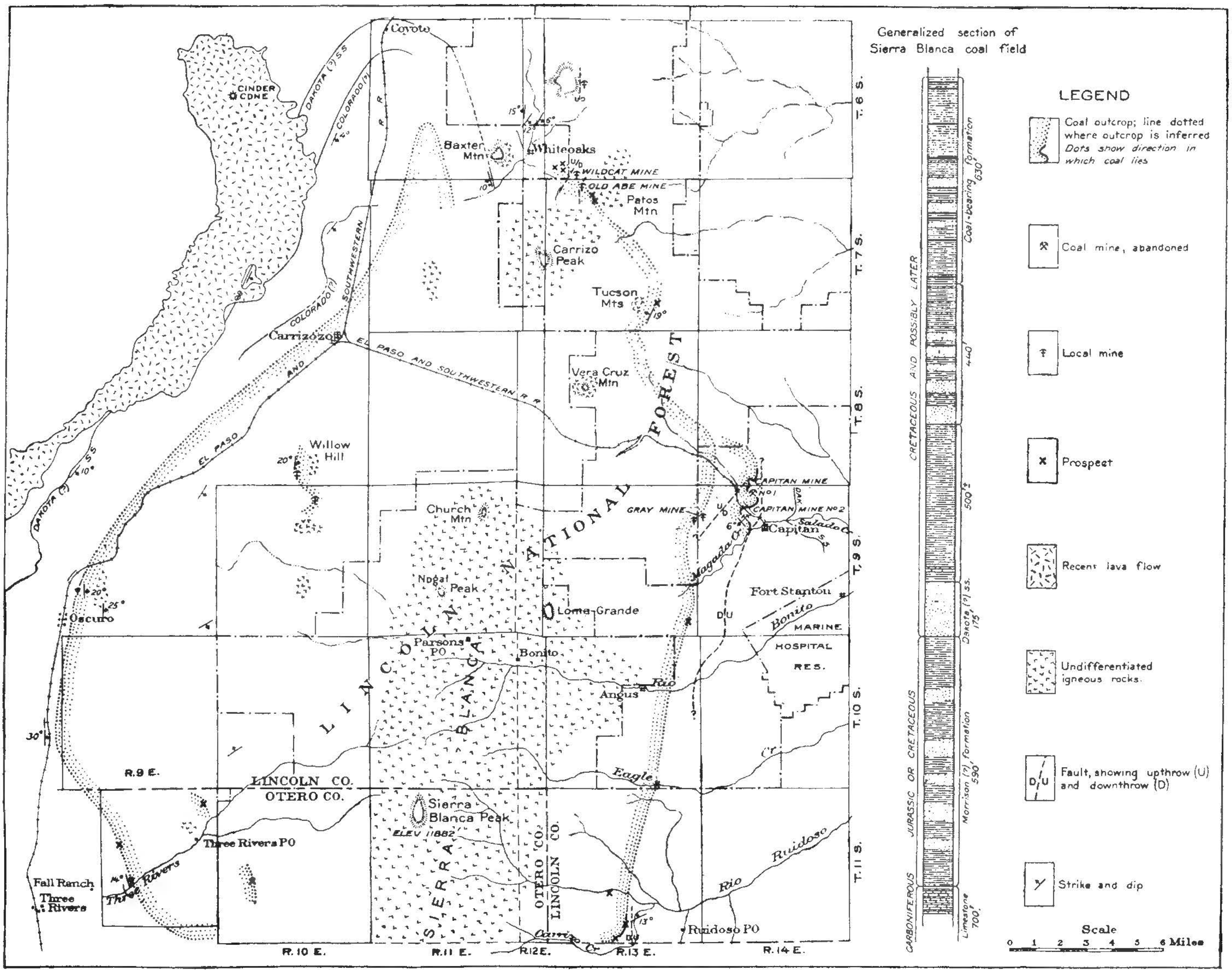


FIGURE 3.11. Map and generalized section of the Sierra Blanca coal field, Lincoln and Otero Counties, New Mexico (modified from Wegemann, 1914, plate XXVII).

In 1884, coal was discovered near the present town of Capitan. That portion of the Sierra Blanca coal field was known for a time as the Salado coal field, and later as the Capitan coal field. The earliest mining was in the vicinity of what later came to be known as the Linderman and Gray mines, located a little over 3 km west of Capitan. Development of the mines at the Salado coal field in the early years took place largely through the efforts of James A. Alcock, one of the owners of the Carrizo Cattle Ranch, among others. In 1885 Seaborn T. Gray opened up a coal mine in the SW1/4 sec. 7, T9S, R14E. At first, coal from this new discovery was used for heating and cooking purposes at the facilities at nearby Fort Stanton (Wharton, 1900; Wegemann, 1914; Bodine, 1956; Keleher, 1962; Stanley, 1964; BLM and U.S. Bureau of Mines files).

In 1899, a rail spur was laid to a new deposit at Coalora by the El Paso and Northeastern Railroad (later renamed the El Paso and Southwestern Railroad). Experienced coal miners were brought in from Pennsylvania, and Coalora, 2 km northwest of Capitan, soon attained a population of several hundred. On April 1, 1898, development of the mines at Coalora was begun by the New Mexico Fuel Company, and on September 30, 1899, the first railway car of coal was shipped from the area (Fig. 3.12). From 1900 through 1905 more than 600,000 tons of coal were extraced from the Coalora mines, most of which was shipped to El Paso (Figs. 3.13–3.16). In 1901, Lincoln County ranked third among the counties of New Mexico in production of coal. The mining camp of Coalora was soon superseded in size by the town of Capitan, which Charles Eddy and his brother John bought and platted in February 1900. Prior to that date the village located where Capitan

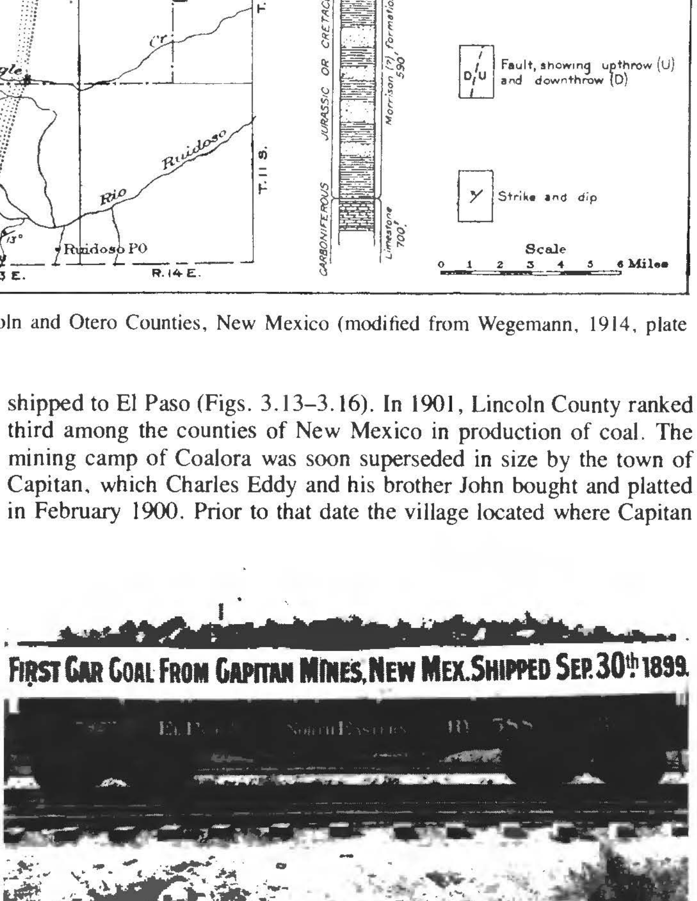


FIGURE 3.12. Initiation of rail transport of coal from Capitan, New Mexico (Photo courtesy of Cornelius W. Hauck, Cincinnati, Ohio).

FIGURE 3.13. The coal mining camp at Coalora, New Mexico, around the year 1900 (Photo courtesy of Mr. J. N. McDaniel, Carrizozo, New Mexico).

FIGURE 3.14. Loading coal at Coalora, Lincoln County, New Mexico, around the year 1900 (Photo courtesy of Mr. J. N. McDaniel, Carrizozo, New Mexico).

FIGURE 3.15. El Paso and Northeastern Railroad tipple, Capitan No. 1 Coal mine, near Capitan, New Mexico, around the year 1902 (Photo by Royal A. Prentice, courtesy of The Museum of New Mexico, Negative No. 101787).

FIGURE 3.16. Entrance to coal mine near Capitan, New Mexico, around 1902 (Photo by Royal A. Prentice, courtesy of The Museum of New Mexico, Negative No. 101783).

now stands had been called Gray (Wharton, 1900; Sheridan, 1905; Haley, 1913; Wegemann, 1914; Bodine, 1956; Keleher, 1962).

In 1905, the railroad company, which had purchased the mines at Coalora, began to obtain its coal from the Dawson mines in Colfax County. Most of the homes at Coalora were dismantled and moved to Dawson. The last shipment of coal by rail from Capitan occurred on June 3, 1905 (Sheridan, 1905). From that time onward, shipments of coal from the Coalora area were made by wagon, and production of coal from those mines dwindled to relative insignificance, although extraction continued to supply local demand on a small scale until the 1930s.

Significant amounts of coal from the Sierra Blanca coal field were also produced southwest of Carrizozo from mines at Willow Hill, Cub Mountain, north of Three Rivers, and near the once-thriving town of Oscuro (formerly known as Milagro Hill) (Arkell, 1983; State Inspector of Mines Annual Reports). Although the New Mexico Fuel Company prospected for coal about 5 km south of Milagro Hill as early as 1899, the earliest known production of coal from the beds south of Carrizozo occurred in late 1906, when the Willow Springs Coal Company opened a mine about 5.5 km southeast of the El Paso and Southwestern railway stop of Polly Station. Although production records for this area are sketchy, the bulk of the production from the coal mines south of Carrizozo appears to have occurred around World War I. In addition to supplying the local market, operators in this portion of the Sierra Blanca coal field shipped coal by rail to El Paso. Most of the coal mined south of Carrizozo is believed to have come from the Cub Mountain deposits, although mining also took place as far south as in secs. 11 and 12, T10S, R8E. The last known production of coal south of Carrizozo was 100 tons, reported by the State Inspector of Mines for the year ending October 31, 1939. Available records suggest that no more than a few thousand tons of coal were produced from all of the coal deposits south of Carrizozo (Hailey, 1913; Read et al., 1950; U.S. Mine Inspector for Territory of New Mexico Annual Reports; State Inspector of Mines Annual Reports; BLM records).

Coal production in the White Oaks area was dealt a death blow largely because the railroad company could not gain financial control of the deposits there, and thus decided not to build a line to the coal mines in that area. Coal production in the vicinity of Capitan ceased largely because of the thinness and variability of the coal units, the many faults and dikes offsetting the coal horizons, and eventually the low quantity of the economically minable coal. In that portion of the Sierra Blanca coal field south of Carrizozo, coal production was never large because of generally inferior quality (Wegemann, 1914; Griswold, 1959; Keleher, 1962). Although exploration occurred in a number of other areas in the Sierra Blanca coal field, no other coal deposits were found in sufficient quantity, and of sufficient quality, to be successfully mined (Fisher, 1904; Campbell, 1907; Wegemann, 1914; Read et al., 1950). All actual production in the Sierra Blanca coal field took place using underground mining methods.

Judging by the age and types of strata and the fossil flora and fauna found in or near the coal deposits, by the generally circular configuration of the deposits, and by the apparent inlet and outlet sites (Fig. 3.11), the coal horizons in the Sierra Blanca field appear to have been deposited around the shoreline of an estuarine or lacustrine body of water during Late Cretaceous time. The coal beds in the Mesaverde Group crop out along the flanks of, and dip into, a structural basin. Tertiary sedimentary and igneous rocks make up the synclinal core. Subsequent igneous activity during Tertiary time intruded and tilted the coal strata in many places, particularly in the vicinity of Capitan. Coal in the Sierra Blanca coal field, particularly in the vicinity of White Oaks and Capitan, can be generally characterized as being a low-sulfur, high-ash, high-volatile C bituminous coal (Wegemann, 1914; Ellis, 1936; Bodine, 1956; Haines, 1968; Arkell, 1983). Measured reserves for the Sierra Blanca coal field are 3.3 million short tons, indicated reserves are 8 million short tons, and inferred reserves are 1.633 billion short tons (Read et al., 1950). At the present time, the Phelps Dodge Corporation retains a large portion of the mineral holdings in the coal deposits around Capitan and Three Rivers.

The author is indebted to the following people for the information they supplied during the course of this investigation: Alice Blakestead, Terry Day, Jerry Dutchover, Bob Eveleth, Christine Harkey, Jack Harkey, Cornelius W. Hauck, Nora Henn, Gretchen Hoffman, Rich Kness, Stanley Korzeb, Robert Leslie, J. N. McDaniel, Howard B. Nickelson, Fred Pfingsten, John Simitz, Johnson Stearns, Herbert Lee Traylor and Larue Wetzel. Organizations that provided help during this project include the New Mexico Bureau of Mines and Mineral Resources, New Mexico Abandoned Mine Land Bureau, Lincoln County Historical Society, White Oaks Historical Society, Museum of New Mexico Photo Archives, New Mexico State Records Center and Archives, Colorado Railroad Historical Foundation, BLM Library in Lakewood, Colorado, and the New Mexico State University Library. Much additional information was gleaned from the annual reports of the State Inspector of Coal Mines (who after 1932 was called the State Inspector of Mines) for New Mexico, and the annual reports of the United States Mine Inspector for the Territory of New Mexico. The in-house files of the U.S. Bureau of Land Management and the U.S. Bureau of Mines also were extremely helpful.

32.2 West-tilted San Andres Mountains on skyline at 10:30. Mockingbird Gap is visible at 10:30. The Oscura Mountains, at 11:00–11:30 to north, are east-tilted. Note black lava field ahead at 12:00. **2.7**

34.9 At 9:00, the ridge east of Cub Mountain contains the best-exposed section of the lower Cub Mountain Formation. The upper part of the Cub Mountain is not exposed at Little Cub Mountain. Cub Mountain strata at this section (Fig. 3.17) produced fossil mammals and turtles indicative of an Eocene, probably late Wasatchian–early Bridgerian (50 ± 2 Ma) age (Lucas et al., 1989). This is the only direct evidence of the age of the Cub Mountain Formation, and suggests it is approximately correlative with the Baca Formation of west-central New Mexico and the Galisteo Formation of north-central New Mexico. Prior to discovery of these fossils, some authors (e.g., Kelley and Thompson, 1964; Thompson, 1966) equated the Cub Mountain Formation with the Upper Cretaceous McRae Formation of Sierra County to the west. However, as Chapin and Cather (1981) argued, the Cub Mountain Formation was deposited in an Eocene Laramide basin, their Sierra Blanca basin, by rivers flowing mostly to the northeast. Whether the source of

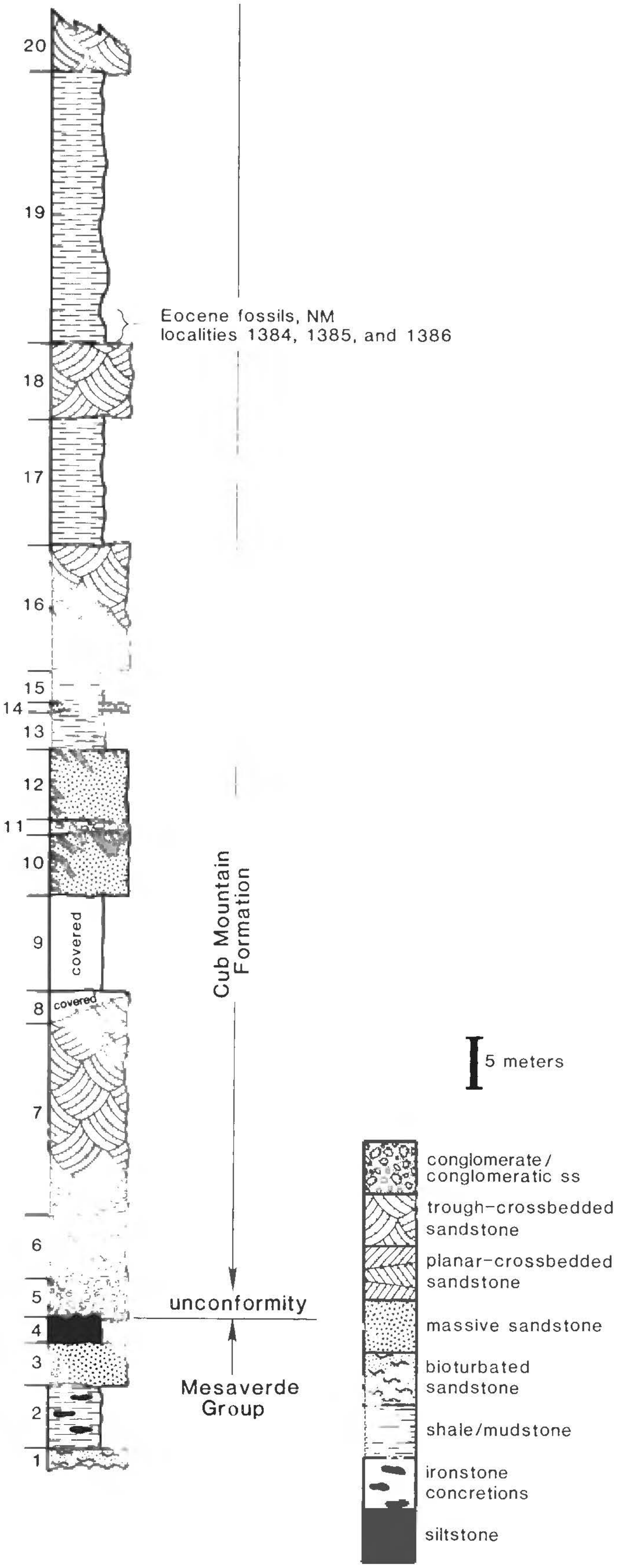


FIGURE 3.17. Measured stratigraphic section of the lower Cub Mountain Formation on the northern slope of Little Cub Mountain showing the location of localities that yielded Eocene fossil vertebrates (from Lucas et al., 1989).

Cub Mountain sediments was the Rio Grande uplift of Seager and Mack (1986), a northwest-trending, late Laramide uplift in south-central New Mexico, or the Tularosa uplift (Chapin and Cather, 1981), a poorly documented uplift that may have collapsed to form the present Tularosa Basin, is unclear (Fig. 3.18). **0.7**

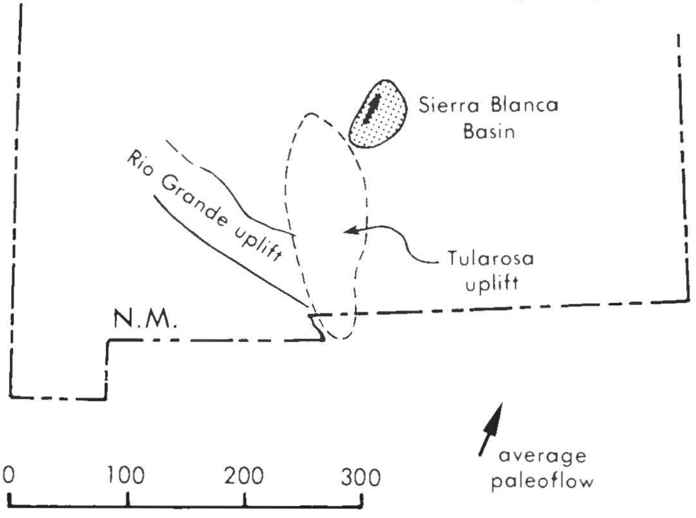


FIGURE 3.18. Laramide paleogeographic map showing Sierra Blanca basin, average paleoflow in the Cub Mountain Formation at Little Cub Mountain and the postulated source areas for this unit (from Lucas et al., 1989).

VEGETATION AND PLANT COMMUNITIES OF LINCOLN COUNTY, NEW MEXICO

Paul J. Knight

Marron, Taschek and Knight, 4686 Corrales Road, Corrales, New Mexico 87048

The vegetation of the Lincoln County area exhibits influences of the Chihuahuan Desert, Mexican Highlands, Great Plains and Rocky Mountain floras. For the most part, the representatives of these floristic influences are arranged on altitudinal gradients. This progressive change in vegetation with elevation is most pronounced on the west side of the Sacramento Mountains. The Sacramento Mountains are one of the few areas in North America where one can travel from Chihuahuan Desert to subalpine boreal forest within an hour's time.

The Chihuahuan Desert flora dominates the lowlands of this area. Typically it occurs between 4500 and 5500 ft in elevation. At slightly higher elevations, grassland species with affinities to the Great Plains flora begin to intermingle with Chihuahuan Desert flora. These grasses form the transition between the arid desert flora and the lower threshold of piñon-juniper woodland. Between 6000 and 7500 ft in elevation a complex mixture of Rocky Mountain, Mexican Highland and grassland species occurs. Piñon-juniper woodland is the most common plant association encountered within this altitudinal band. In many areas, piñon-juniper woodland is codominant with dense grasslands resulting in the plant community taking on a savanna-like appearance. Above 7500 ft in elevation, elements of mixed-conifer woodland begin to appear. Typically this includes Rocky Mountain juniper and ponderosa pine. As elevation increases, Douglas fir and occasionally white fir appear. Above 8500 ft, Douglar fir often becomes the dominant tree, but with increased elevation white fir and spruce begin to replace it. Typically, the cool, wet tips of the higher mountains (such as Sierra Blanca) are dominated by spruce-fir woodland. These communities are dense boreal forests populated with white fir, cork-bark fir, blue spruce and Engelmann spruce. It should be noted that these altitudinal gradients are not absolute delimiters on vegetation. Aspect plays a major modifying role in the composition of plant communities. For example, many of the warmer and drier habitats, such as southern slopes, between 6500 and 8500 ft in elevation are devoid of piñon, juniper or ponderosa pine, and are dominated by dense thickets of Gambel oak.

CAPTIVE MOUNTAIN WATERS

(from the paper, "Water Supplies near Carrizozo, New Mexico," by J. B. Cooper, NMGS Guidebook 15, 1964)

Condensed by Russell W. Jentgen

Bureau of Land Management, P.O. Box 1449, Santa Fe, New Mexico 87504

In early 1908, the Bonito pipeline system was constructed and began delivering water to the Tularosa Basin. The system was built by the El Paso and Northeastern Railroad to supply boiler water for steam locomotives. Wells in the Carrizozo vicinity produced water so hard that it caused poor locomotive performance and high maintenance. The pipeline served the railroad and some of the settlements all the way from Carrizozo past Vaughn to Pastura.

The source of this water was the South Fork of the Rio Bonito, about 15 mi southeast of Carrizozo, on the eastern slope of Sierra Blanca. Originally, the stream was diverted by a small concrete dam into a 16-in. wood-stave pipe, which carried the water to Nogal Lake about 2 mi southeast of the village of Nogal. Nogal Lake initially had a storage capacity of 422 million gallons. From the lake, the pipeline dropped 15 mi north into the basin to the station of Coyote. From there the lines extended north and south along the railroad, using four storage reservoirs and two pumping stations. The pipeline totaled 116 mi in length, only 19 mi of which were iron. All the rest was wood-stave pipe.

By the early 1930s, Nogal Lake had developed excessive leakage at high-water stages. The Southern Pacific Co., which now controlled the railroad lines, reduced the capacity of Nogal Lake to 163 million gallons. In addition, it constructed a new dam across the Rio Bonito below the confluence of Bonito Creek and the South Fork of Rio Bonito. With an initial capacity of 400 million gallons, Bonito Lake became the primary storage reservoir for the pipeline. The dam was constructed of rock with a concrete apron on the upstream face. Originally, the dam was 480 ft long at the crest, and had a maximum height of 111 ft.

The conversion of the railroad to diesel locomotives in the early 1950s made the water system unnecessary for the railroad's use. In 1955, the water rights were sold in various amounts to Holloman Development Center, the city of Alamogordo, the town of Carrizozo, and the Nogal Water Users Association. The railroad retained a portion to meet commitments to water users associations and towns along the line. In 1957, the Air Force replaced the wooden pipeline with an iron pipeline from Bonito Lake to Carrizozo and then south along US-54 to Alamogordo.

35.6 At 2:30, note Gallinas Mountains in distance; Lone Mountain in foreground at 3:00. **1.8**

37.4 Carrizozo town limit (Fig. 3.19); historical marker on

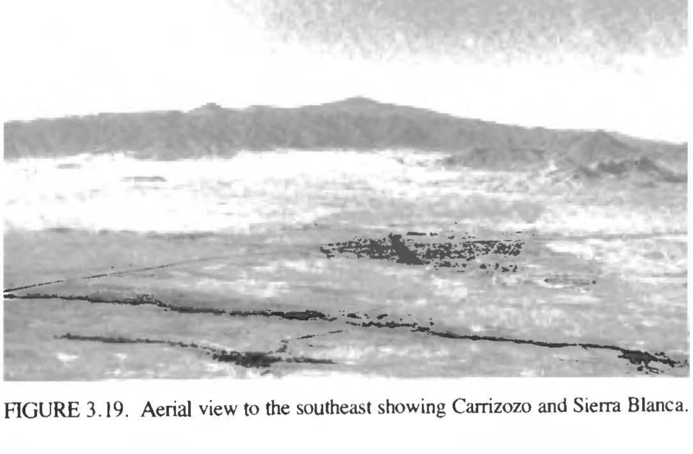


FIGURE 3.19. Aerial view to the southeast showing Carrizozo and Sierra Blanca.

right. Carrizozo is named for the carrizo, or reed grass, that grew at Carrizo Springs. James Allcook, the foreman of a local cattle ranch, added "zo" to Carrizo, to indicate the abundance of the reed grass. Carrizozo was founded because the El Paso and Northeastern Railroad bypassed White Oaks and created a junction here. With the building of a roundhouse and repair shops, the town grew and became the supply center and shipping point for much of Lincoln County. The population peaked at over two thousand from 1910–1920. First, a railroad strike in 1923, and then the advent of diesel locomotives, led to declining employment related to the railroad. Now Carrizozo is smaller, with a population of about 1000, but it is still the seat of Lincoln County (Pearce, 1965; Chilton et al., 1984). **0.3**

37.7 Cross bridge over railroad. **0.1**

37.8 **Junction** with US-54 at flashing yellow light. **Turn right** onto US-54 and proceed north. **0.5**

38.3 Baxter Mountain at 12:00; Lone Mountain at 11:30. Baxter Mountain consists of a large assortment of alkali igneous rocks including both intrusive and volcanic components. The intrusives were emplaced as dikes and breccia pipes along north-northeast-trending faults about 29.6 to 35.2 Ma in age (Thompson, 1991a). They range in composition from syenogabbro to syenite to lamprophyre (Griswold, 1959; Haines, 1968; Grainger, 1974; Allen and Foord, 1991, this guidebook).

Lone Mountain is a circular-shaped, compositionally and texturally zoned pluton. Compositions range from a core of quartz syenite to a peripheral, alkali-feldspar granite (Allen and Foord, 1991, this guidebook). Earlier workers identified the composition of the pluton as kali-alaskite (Butler, 1964) and granodiorite to quartz monzonite (Schacke, 1977). According to the chemical classification of igneous rocks of De la Roche et al. (1980), the pluton is quartz syenite; it is termed an alkali-feldspar granite by Allen and Foord (1991, this guidebook). **0.6**

38.9 Railroad tracks parallel highway on right. **2.3**

41.2 **Turn right** to White Oaks on NM-349. Patos Mountain at 11:00, Carrizo Mountain at 12:00, Baxter Mountain at 10:30, Lone Mountain at 9:30, Vera Cruz Mountain at 1:00, Nogal Peak at 2:30, and Cub Mountain at 3:30. Plain in foreground is Yucca Flats.

Patos Mountain consists of a Tertiary laccolith. The laccolith is compositionally and texturally zoned, with a more mafic and porphyritic core and more siliceous margins (Haines, 1968). The composition has been reported as syenite (Patton, 1951), monzonite (Kelley and Thompson, 1964) and rhyolite (Haines, 1968). Additional petrographic study is in progress.

Carrizo Mountain is a compositionally and texturally zoned stock that varies from a core of quartz syenite to a margin of alkali-feldspar granite (Allen and Foord, 1991, this guidebook). Several iron-skarn deposits occur in limestone roof pendants and along contact zones between limestone of the San Andres Formation and the pluton (Sheridan, 1947; Kelley, 1949; Griswold, 1959; Harrer and Kelly, 1963). Calc-silicate mineral assemblages are developed along the margins of some of the iron-skarn deposits. A few iron deposits contain anomalously high concentrations of uranium (McLemore, 1983). Cross Southern Pacific Railroad tracks. **0.6**

41.8 Bald Hills at 1:00–2:30 in front of Carrizo Mountain; Lone Mountain at 10:00–11:00. **1.3**

43.1 Milepost 2. **1.8**

44.9 Flat Mesa in distance at 9:00 is defended by Dakota Group above Triassic strata. **1.7**

46.6 Cattle guard. Upper Cretaceous Gallup Sandstone caps ridge to left. **0.2**

46.8 Terra-cotta upper Cenozoic sediments on right. **0.1**

46.9 To left, note slope of olive-gray, very fine-grained, micaceous sandstones and mudstones of the Mancos Shale in arroyo cut. **0.1**

47.0 Quaternary bouldery alluvium in roadcuts. **0.2**

47.2 Bridge over arroyo. South face of Baxter Mountain on left consists of Mancos Shale. **0.5**

47.7 Abandoned buildings on right. **0.1**

47.8 Cattle guard. Outcrop in arroyo on left is Niobrara Formation cut by steeply dipping Tertiary dikes. The shoulders of the mountain slope are also formed by dikes, and the drainages are in the shale (Fig. 3.20). The major dike shown in Fig. 3.20, exposed in the arroyo, consists of a 3.3-m-wide andesite porphyry and a 1.3-m-wide syenogabbro. The andesite porphyry consists of medium-grained plagioclase laths (An$_{34}$) and is altered mostly to sericite and chlorite. The syenogabbro consists of medium-grained laths of sericitized plagioclase (An$_{41}$) with hematite and chlorite replacement of mafic minerals. Both dikes are alkaline (Table 3.3). The adjacent shale is silicified. **0.2**

48.0 Outcrops on slopes to left are Niobrara Formation. Osburn and Arkell (1986) illustrated these exposures and interpreted them to represent the top of the Dakota through the Tres Hermanos Formations. We, however, believe that a portion of the sequence which Osburn and Arkell (1986, fig. 5) referred to the Mancos Shale is more properly referred to the Niobrara Formation because of the presence of a thick sequence of gray limestones and calcareous shale containing the characteristic Niobrara fossil clam *Inoceramus* aff. *I. labiatoidiformis*. If this correlation is correct, it is the first identification of the Niobrara Formation in Lincoln County. Furthermore, these strata lithologically and paleontologically appear to belong to the lower, Fort Hays Limestone Member of the Niobrara Formation of late Turonian age (Scott

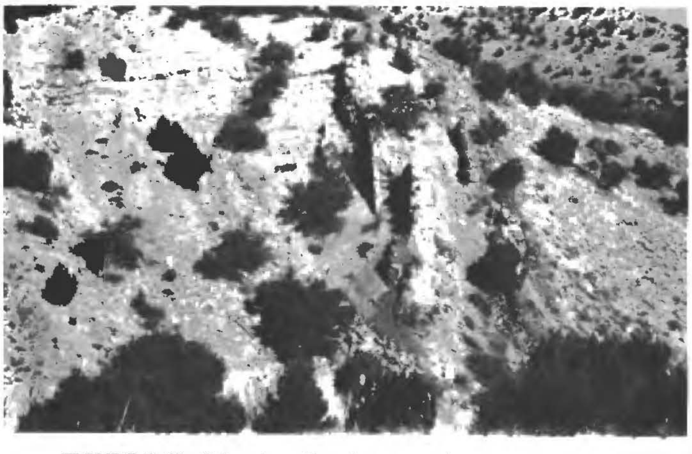


FIGURE 3.20. Dikes intruding Cretaceous Niobrara Formation.

TABLE 3.3. Major element analyses of two dikes exposed in the arroyo at mile 47.8 near White Oaks. XRF analyses by C. McKee (New Mexico Bureau of Mines and Mineral Resources X-ray Facility). *Total iron reported as Fe_2O_3.

	W47.8A	W47.8B
SiO_2	58.8	45.7
TiO_2	0.76	1.50
Al_2O_3	19.3	16.8
Fe_2O_3*	3.64	9.58
MnO	0.10	0.21
MgO	0.66	3.35
CaO	2.20	6.45
Na_2O	5.52	4.03
K_2O	5.89	4.32
P_2O_5	0.12	0.93
LOI	2.89	6.03
TOTAL	99.88	98.90

et al., 1986; Laferriere, 1987). Deposition of the Fort Hays took place during the transgressive phase of the Niobrara cyclothem, and its rhythmically bedded limestones and shales are thought to reflect orbitally forced climatic variations (Laferriere, 1987). **0.4**

48.4 White Oaks ahead. **0.3**

48.7 **OPTIONAL STOP. Slow and carefully pull onto the right shoulder;** the shoulder is narrow but traffic is infrequent. White Oaks cemetery (Cedarvale Cemetery) on right. Some of the headstones date back to the 1880s. The metallic and coal resources of the White Oaks and surrounding areas are subjects of several speakers; also see both the following road log and minipapers.

After the discussion, return to your vehicles for the rest of the trip to Stop 2. **0.4**

49.1 Cattle guard. Entering greater White Oaks (Fig. 3.21). White Oaks was founded in 1879 because of gold discoveries near the springs between the Patos (Spanish: ducks) and Carrizo Mountains. The town was named for the many white oaks surrounding the two large springs near the town. Within 25 years, about $3,000,000 of gold and silver were taken from the mines. About 163,500 oz of gold and 1000 oz of silver were produced from the district during 1880–1942. In addition, about 450 lb of copper and 12,200 lb of lead have been produced from this area (McLemore, 1991, this guidebook). Tungsten was also produced from these deposits.

The population of White Oaks rapidly grew to over 2500 people. Coal was also found nearby, and so the El Paso and Northeastern Railroad planned to continue the main line from Carrizozo to White Oaks. However, the exorbitant price of land around White Oaks caused the railroad to go via a more mountainous route near Corona. The post office, which was opened in 1880, finally closed in 1954, after all local mining had ceased. Emerson Hough, a reporter for a Lincoln paper, set his 1905 novel, *Heart's Desire,* in White Oaks during its heyday (Pearce, 1965; Chilton et al., 1984).

Mine and mill site on left. **0.3**

FIGURE 3.21. Greater White Oaks in 1991.

WHITE OAKS: GOLD, COAL AND SCANDAL, BUT NO RAILROAD

Spencer Wilson

Humanities Department, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

White Oaks, located in Lincoln County, was the site of, among other things, the Lincoln County War, the Billy the Kid legend, and, at one time, large deposits of gold and coal. The exploration for these minerals attracted miners and camp followers, but never a railroad, to White Oaks. The mining potential of the White Oaks area was developed in the late 1870s. The first strike was made at the Homestake mine and the rush to White Oaks began. By the early 1880s, the town of White Oaks was abuilding. The booming gold strike brought more people and the usual assortment of saloons to cater to the miners.

White Oaks was named for the trees around a spring. The rich gold deposits initially brought the people, but it was coal that prompted the first efforts to build a railroad. White Oaks is perhaps unique among mining camps because it never had a railroad built directly into the town. In mining camps elsewhere the lack of a railroad usually spelled disaster.

Railroad fever was endemic in the West. The long distances, and the need for supplies, food, water and a way to ship the ores out made a rail connection a great necessity. During the 1880s and 1890s, a number of rail projects were proposed, but it was a long time before the rails came close to White Oaks—and never into the town and camp.

El Paso was the center of various projected railroads. The terrain from El Paso toward the northeast and White Oaks was well suited for a railroad. Relatively flat territory through the Tularosa Basin meant that a rail line would not have to build with steep grades. This was important in that the steeper the grade, the more motive power was needed, causing a reduction in the amount of freight and ores hauled for a given locomotive size. The flatness of the valley was deceiving, however, because most mineral deposits were located high in the mountains, although this was not entirely true of White Oaks.

Railroads were projected mostly from El Paso, but even Socorro joined the rail mania. Socorro was also the center of a great deal of mining activity—especially to the west in the Magdalena Mountains. Socorro's developers were also looking toward White Oaks. By 1881, the Atchison, Topeka and Santa Fe Railroad (AT&SF) had arrived in Socorro and was pushing south and west for a connection to California. By the mid-1880s the AT&SF had also built a branch to tap the mines of the Magdalenas and had built another branch to Carthage and Tokay to serve the coal mines there via San Antonio.

The San Antonio branch appears to be the logical place for an extension to White Oaks. In the 1880s there was already a stage line operating between the two towns. That was not good enough, however, for the Socorro boosters. They wanted a railroad, for they wanted Socorro to become a railroad center. The Socorro *Bullion* from 1883 to 1886 constantly assured readers that a railroad from "Carthage to White Oaks will be built. . . ." There might well have been some cause for the editor to be so insistent. On November 14, 1885 the papers reported that "eight ox trains from White Oaks came in yesterday." On November 12, the paper headlined: "Hurry Up on Our New Railroad!" The editor went on to express the fear that El Paso would get there first. Indeed, El Paso interests were determined to do just that, but it did not happen right away.

There were at least five railroad companies that tried to get to White Oaks, but it was 15 years before anyone came near. One company named the El Paso, St. Louis and Chicago Railway and Telegraph Company did start to build in 1885. The only lasting evidence of this effort was 5 mi of graded roadbed. Another effort in 1888 was an ambitious scheme named the Kansas City, El Paso and Mexico Railroad (KCEP&M). The KCEP&M Railroad actually laid about 10 mi of rail and operated a couple of excursions, just to convince the public and backers that construction had begun. From then on things went downhill. Drought and the depression of 1893 stopped projects, including the mining activities and rail projects, around Socorro and El Paso.

In 1897, a New Mexico promoter finally started a railroad from El Paso to White Oaks, with branches into the Sacramento Mountains and to Capitan and the Salado coal fields. Charles Baker Eddy was already a successful promoter and builder in the Pecos Valley in eastern New Mexico. There, Eddy built the Pecos Valley Railroad, an irrigation company, and dreamed of heading northeast to link up with the Rock Island line. Eddy successfully got his financial house in order and had incorporated the El Paso and Northeastern Railroad Company (EP&NE) in both New Mexico and Texas. The entire project was also aided by the improvement of the national economy.

The new railroad, soon called a railway, was built through flat and dry country. Water resources were located by drilling wells and construction proceeded swiftly. At the site of the present town of Alamogordo, Eddy stopped and built another railroad into the Sacramento Mountains to tap the lumber and eventually to build a grand tourist hotel.

Construction continued toward White Oaks and arrived in the railroad town of Carrizozo, 12 mi southwest of White Oaks. There the EP&NE built east to Capitan by 1901, but this was still short of White Oaks! The following year the EP&NE joined with the westering Rock Island at Santa Rosa, New Mexico, and El Paso had a direct line to Chicago.

But White Oaks did not have a railroad to anywhere. Eddy meant to build directly through White Oaks Canyon, passing through the town, and heading on north and east to meet with the Rock Island. When the construction crews started out of Carrizozo toward White Oaks, they ran into problems caused by the lack of right-of-way in White Oaks Canyon. Landowners were not offered enough for the land for the railroad so Eddy went west of White Oaks about 12 mi to Ancho Canyon and bypassed the mining camp.

The lack of a rail connection was not the only reason for the decline of White Oaks in the early part of this century. Mine production fell off during the same period. These two blows doomed both the town and the mines. Like so many New Mexican mining areas, the boom lasted a couple of decades or so and then the mines closed.

The White Oaks district and town had its boom period in the 1880s and 1890s. In 1901 White Oaks had a population of 500, four churches (two with proper church buildings), two general stores, a dry goods store, a bank, one saloon and a public school with three teachers. In the early 1880s the tent city of early exploration was already being replaced with brick and frame buildings. The Homestake mine was joined by other gold mines called the Old Abe, Lady Godiva, Boston Boy, Compromise and the Rita. The Old Abe was a coal mine that was still in operation in 1901.

One of the perennial problems for western camps was the lack of water. Even in 1901 that disadvantage was addressed with projects to bring water from springs some miles away in the Carrizozo Mountains. Another supply of water was pumped about a mile through a 3-in. pipe.

The Old Abe supplied coal at the mine for $1.75 per ton, and delivered at White Oaks at $3.75 per ton. The Old Abe reportedly produced about $650,000. Even at that price, the coal was of poor quality. The gold mines were equally prosperous and reportedly produced ores worth millions of dollars.

White Oaks was also typical of mining camps by having scandals, including one scheme that robbed the owners of one of the mines. The scandal involved the owners of the Compromise mine, who were pitted against the villains of the piece—a local U.S. marshal turned judge and his girlfriend. She owned the local title and abstract company and the combination was deadly for White Oaks.

It seems that the owners of the Compromise wanted to sell but could not because of "litigation." The "litigation" prevented the sale and, according to the tale, did White Oaks "serious injury." The marshal-turned-judge and his girlfriend lusted after the Compromise and proceeded to conspire to gain control of the property through a series of legal actions, which had the effect of tying up the property and preventing its sale. This action also prevented anyone from working the mine. Using the combination of his position and her company, the Judge eventually gained control of all the producing mines at White Oaks. Then, for reasons known only to himself, he stopped production! He is supposed to have spent the rest of his life bragging about his gold mines but never put any of them back into production. A nephew worked the Smuggler for a while and began to steal the best gold ore. The other workers found him out, and then joined with him. The Judge banished the whole lot, providing only a dollar for the nephew in his will. Production at the mine ceased and White Oaks died. Passions can still run high when this story is mentioned in polite society (C. Dotson, personal comm., 1991).

White Oaks today is called a ghost town. There are substantial structures—the school house, a couple of homes, brick stores (minus their fronts)—and a few folks still living there. There is some mining activity, but nothing on the scale of the boom years of the last century. And the railroad never got there.

49.4 White Oaks historical marker; enter town. **0.2**

49.6 Museum/casino/saloon on left. **0.2**

49.8 Cattle guard. Leave White Oaks. End of paved road. **0.1**

49.9 **Road forks. Bear left.** Note borrow pit straight ahead in hillside. **0.2**

50.1 Sandstone of Crevasse Canyon Formation caps ridge on left. The term Mesaverde Group (Formation) is applied to sedimentary rocks in the Sierra Blanca basin and vicinity that consist mostly of the coal-bearing Crevasse Canyon Formation of Coniacian-Santonian age. The Crevasse Canyon Formation is the source of all coal that was mined in Lincoln County. It is as much as 180–240 m of sandstone, siltstone, claystone and coal that overlies and intertongues with the Turonian-Coniacian Gallup Sandstone and is overlain by the Ash Canyon Member of the Mesaverde Formation. Crevasse Canyon deposition took place in coastal plain and deltaic environments during and after the R-2 regression of the Late Cretaceous (Molenaar, 1983). **0.2**

50.3 Crevasse Canyon outcrops on right of road are carbonaceous mudstones and crossbedded/bioturbated sandstones. **0.1**

50.4 Crossing Oaks Draw. **0.4**

50.8 At 1:00, Mesaverde sandstone caps escarpment. **0.7**

51.5 **Road forks. Keep left.** Patos Mountains at 2:00. Bluff at base is capped by Crevasse Canyon sandstone. Road crosses Niobrara Formation outcrops of dark greenish-gray, micritic limestone. Road ahead and valley to right in Mancos Shale. **0.8**

52.3 Cattle guard. **0.3**

52.6 Niobrara Formation crops out to left of road. **1.0**

53.6 Crest of hill. At 9:30–10:30, Jicarilla Mountains, which consist of intrusive igneous rocks of diverse composition. **0.4**

54.0 Road **junction** with Forest Road 139. **Continue left** over cattle guard. **0.8**

54.8 Cattle guard. Outcrops of Niobrara Formation limestone. Colluvial rubble of Crevasse Canyon Formation is medium-gray, micaceous sandstone in abandoned quarry to left. **0.5**

55.3 Cattle guard. Road **junction** with Forest Road 483; **keep right. 2.0**

57.3 Entering Jicarilla Mountains. Road on weathered monzonite-diorite (Ryberg, 1968; McLemore et al., 1991, this guidebook). Most of the arroyos in these mountains have been worked for gold placers. The various dumps seen along this road are the remains of these operations. **0.6**

57.9 Cattle guard. **0.2**

58.1 West front of Capitan Mountains across plains at 3:00. **0.1**

58.2 Cattle guard. **1.4**

59.6 Gold placer mine sites on left along Warner Gulch (Fig. 3.22). **0.5**

60.1 Outcrops of weathered monzonite(?) on left. **0.8**

60.9 Road **junction** with Forest Road 72A. **Continue left** on Forest Road 72. **0.6**

61.5 Jicarilla town site. Jicarilla was a mining and stock-raising community with a post office from 1892–1942. Jicarilla means "little basket cup" in New Mexico Spanish, and the Apaches in this area were called "Basket Maker Apaches" and hence became known as the Jicarilla Apaches (Pearce, 1965). **0.3**

61.8 Cross bridge. **0.2**

62.0 Cattle guard. Gallinas Mountains at 12:00. **0.9**

GALLINAS MOUNTAINS MINING DISTRICT, NEW MEXICO

Virginia T. McLemore

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

The Gallinas Mountains mining district (Red Cloud mining district) is about 6 km west of Corona, New Mexico, and is the northernmost mining district in Lincoln County (Fig. 3.23). Two types of deposits occur in the Gallinas Mountains—copper-fluorite-bastnaesite deposits and iron-skarn deposits. The first mining claims in this district were filed in the 1880s and some ore was produced, but the amount of this early production is unknown. From 1909 to 1955, approximately $170,000 of copper, silver, lead, zinc and minor gold was produced from the copper-fluorite-bastnaesite deposits (Table 3.4). Bastnaesite (a rare-earth-element carbonate) was discovered in the district in 1943 (Glass and Smalley, 1945; Soulé, 1946) and in the early 1950s approximately 146,000 lbs of bastnaesite concentrate were produced (Table 3.5; Griswold, 1959). In addition, some fluorite has been produced. Iron-skarn deposits have produced about 14,000 tons of iron ore averaging 40–56% iron (Table 3.5; Kelley, 1949; Griswold, 1959). Specific ore deposits are described by Griswold (1959), McAnulty (1978), Perhac (1970), Kelley (1949) and Rothrock et al. (1946).

FIGURE 3.22. Placer mine along Warner Gulch.

A series of Tertiary igneous intrusives has intruded Permian sedimentary rocks of the Abo and Yeso Formations and the Glorieta Sandstone (Perhac, 1964, 1970). The intrusives are diverse and include porphyritic latite, trachyte, microsyenite, andesite and rhyolite. Intrusive breccias are common (Perhac, 1970). The age relationships are obscure because of poor outcrop and absence of contact relationships. If the differentiation trend toward more siliceous lithologies present elsewhere in the Lincoln County porphyry belt holds here (Allen and Foord, 1991; Allen and McLemore, 1991), then the more mafic lithologies, such as andesite, are older than the more siliceous rocks, such as rhyolite. Detailed petrographic, geochemical and isotopic studies are required to understand the petrogenesis of igneous intrusives in the Gallinas Mountains.

North and McLemore (1986, 1988) classified the copper-fluorite-bastnaesite deposits as Great Plains margin deposits (GPM) on the basis of similarity to GPM deposits in New Mexico. GPM deposits in New Mexico lie along, or near, the border of the Great Plains with the Southern Rocky Mountains or Basin and Range provinces (McLemore, 1991, this volume) and include gold-bearing breccia pipes and quartz veins, copper and/or lead/zinc skarns and iron skarns. They are typically associated with alkalic rocks and with deposits of iron, molybdenum, rare-earth elements, fluorite, tungsten and niobium. The copper-fluorite-bastnaesite deposits in the Gallinas Mountains occur in breccia deposits or along fractures, breccias and shear zones of sandstone and shale of the Yeso Formation in the vicinity of Tertiary intrusives. The fractures, breccias and shear zones within the Permian sediments probably formed by doming of the sediments as a result of intrusion of the Tertiary igneous rocks (Perhac, 1970). Many breccia deposits are circular to oval in plan view and may be due to intrusion, gaseous explosion or collapse (Griswold, 1959). The mineralogy is diverse and consists of essential fluorite, quartz, barite, pyrite, iron oxides and accessory bastnaesite, calcite, chalcedony, galena, bornite, chalcocite, pyromorphite, anglesite, chrysocolla, malachite and azurite (Perhac, 1964, 1970; McAnulty, 1978). In addition, DeMark (1980) reported the local presence of secondary agardite (an yttrium-arsenic oxide), mimetite, wulfenite, vanadinite, mottramite and cerrussite. The copper-fluorite-bastnaesite deposits filled open spaces and therefore are probably epithermal. Geothermometric fluid-inclusion studies indicate a temperature of formation of 175–185°C (Perhac and Heinrich, 1964). Additional selected chemical analyses are in Table 3.6.

Several iron-skarn deposits occur throughout the Gallinas Mountains and are spatially associated with the Tertiary intrusives. These deposits typically consist of iron-replacement bodies in limestone of the Permian Yeso or San Andres Formations. Ore minerals consist of magnetite, hematite and martite in a gangue of calcite, quartz, fluorite and phlogopite. The grade of iron ore is typically low, less than 50%, although the grade could be increased by hand sorting (Table 3.5).

The mineral-resource potential of the Gallinas Mountains is moderate. Selected samples containing bastnaesite assay as much as 10,550

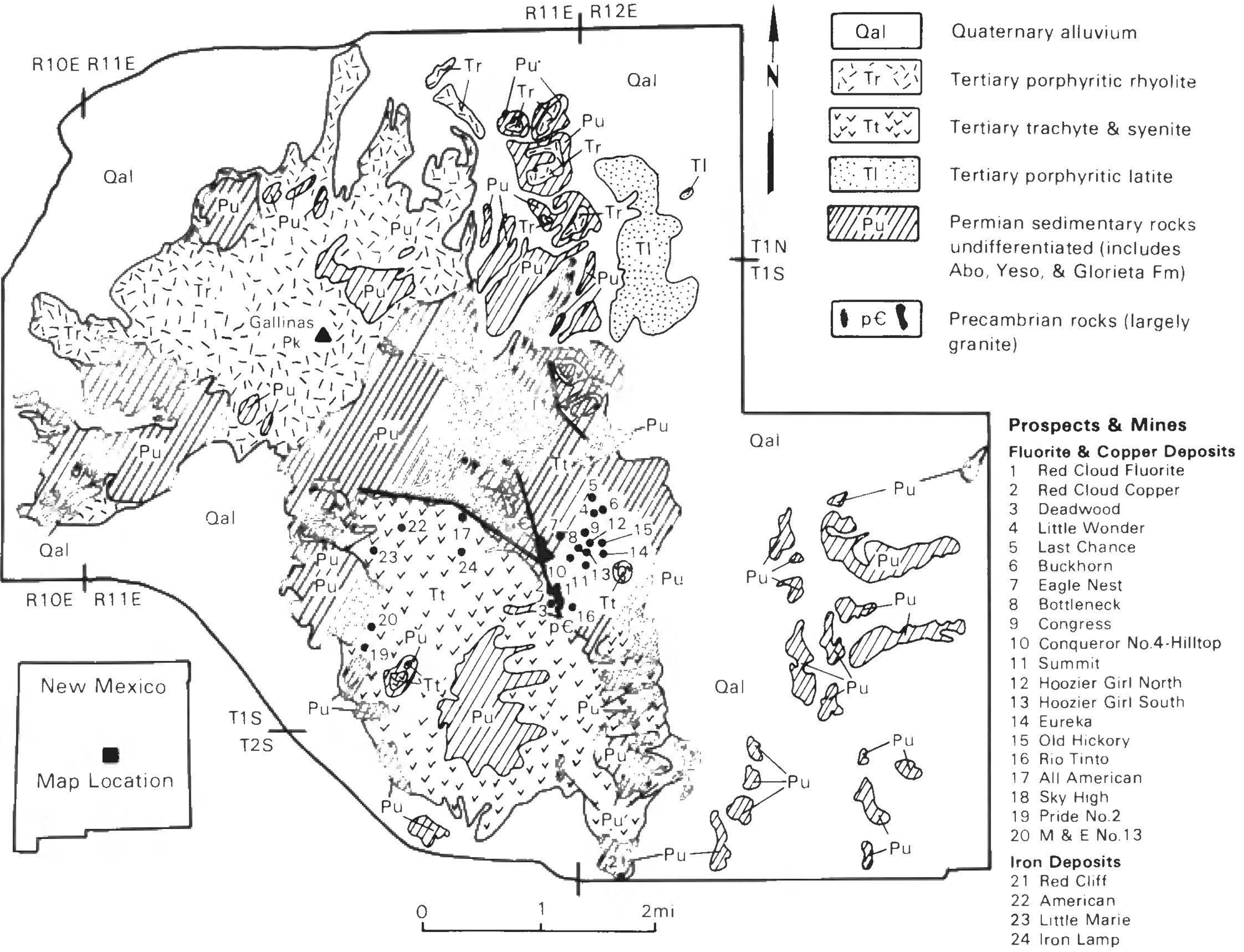


FIGURE 3.23. Geology and mineral deposits in the Gallinas Mountains (simplified from Perhac, 1970).

ppm La and 14,060 ppm Ce (Table 3.6). The potential for rare-earth element resources is good. Molycorp, Inc. drilled a few areas of the district and encountered several mineralized zones, but were unable to prove any reserves. The Gallinas Mountains have moderate potential for GPM gold deposits, specifically gold-bearing breccia deposits. Although gold resources have not been reported in the intrusive-breccia deposits of the Gallinas Mountains, they are similar in appearance to gold-bearing breccia deposits at Ortiz, Santa Fe County (Schutz and Nelsen, 1990). Gallinas Mountains breccia deposits require surface sampling and subsurface drilling and sampling to test the gold-resource potential. The resource potential from iron and fluorite is low because of low grade, impurities and small tonnage.

The mineral deposits in the Gallinas Mountains, like those elsewhere in Lincoln County (Allen and Foord, 1991; McLemore, 1991, both this volume) are related to the Tertiary intrusives. The Tertiary intrusives are probably a result of complex differentiation and fractionation of an upper mantle or lower crustal source as shown by enriched light rare-earth elements and alkalic lithologies.

Many thanks to Russell Schreiner and James Barker for their reviews of an earlier version of this manuscript. Darren Dresser is acknowledged for assistance on sample preparation and compiling Fig. 3.23.

62.9 Jacks Peak at 2:30. Iron mines on slope. **0.7**

63.6 Roadcuts in San Andres Formation are medium-gray, micritic limestone. **0.3**

63.9 Road **junction. Continue to left.** Road to right goes to mines. **0.4**

64.3 Crossing Rico Gulch. **0.3**

64.6 Monzonite in contact with Yeso Formation. **0.3**

64.9 Note outcrops of Triassic strata. Strata of San Pedro Arroyo Formation (formerly Chinle or Santa Rosa Formations or Dockum Group: see Lucas, 1991, this guidebook) to right across valley are grayish-red and purplish-gray bentonitic mudstones and channel sandstones. **0.2**

65.1 **Junction** with Forest Road 72B. **Continue straight. 0.3**

65.4 Cattle guard. Leave National Forest and enter Wilson ranch. **0.1**

65.5 Permian Glorieta Sandstone in left roadcut and on ridge to right, with Triassic red beds (San Pedro Arroyo Formation) beyond, is characteristic yellowish-gray, very fine- to fine-grained quartzarenite. **0.2**

65.7 **Road forks. Go right. 0.1**

65.8 Cattle guard. **0.9**

TABLE 3.4. Base and precious metals production from the Gallinas Mountains mining district, New Mexico (from NMBM&MR files and U.S. Bureau of Mines mineral yearbooks). Production prior to 1902 is unknown and not included.

Year	Ore (short tons)	Copper (lbs)	Gold (oz)	Silver (oz)	Lead (lbs)	Zinc (lbs)	Total value ($)
1902-1908	No production reported						
1909	14	361	---	42	7,907	---	409
1910	No production						
1911	8	555	---	70	6,620	---	404
1912	131	8,337	---	879	103,911	---	6,593
1913	157	7,068	0.18	895	94,010	---	5,777
1914	82	15,068	3.44	649	10,641	---	2,849
1915	46	5,091	0.11	243	13,277	---	1,640
1916-1919	No production						
1920	363	11,386	---	1,345	171,925	---	17,315
1921	378	49,240	---	2,552	155,222	---	15,889
1922	1,893	213,072	---	11,015	700,072	---	78,284
1923	578	38,966	---	3,065	232,657	---	24,527
1924	121	8,596	---	409	26,912	---	3,553
1925-1926	No production						
1927	60	3,382	---	381	21,683	---	2,025
1928	18	667	---	77	7,000	---	547
1929	No production						
1930	23	700	0.19	151	12,000	---	753
1931	No production						
1932	24	1,000	0.58	103	11,500	---	449
1933	42	1,000	0.39	123	14,000	---	18,317
1934	30	4,400	0.29	221	13,850	---	1,017
1935	61	2,000	0.40	185	17,300	---	1,005
1936-1942	No production						
1948	1,015	10,000	---	854	74,000	16,000	633
1949	Production not reported						
1950	No production						
1951	11	---	---	31	4,000	---	720
1952	No production						
1953	39	4,529	---	183	14,351	1,344	3,466
1954	23	---	---	45	6,000	---	863
1955	250	---	1	205	7,900	---	1,398
	-----	-------	----	------	---------	------	-------
TOTAL	5,367	385,418	6.58	23,723	1,726,738	17,344	170,749

TABLE 3.5. Other mineral production from the Gallinas Mountains mining district, New Mexico.

Mineral Produced	Mine Name	Years of Production	Amount Tons	Grade (%)	References
Iron Ore	American	1942-1943	3944	55.7	Kelley (1949)
	Gallinas	1942	6410	48.7	Kelley (1949)
	other mines	--	3326	----	Kelley (1949)
Fluorite	All American	--	129	----	McAnulty (1978)
	Conqueror (Rio Tinto)	--	300	----	McAnulty (1978)
	Red Cloud	--	1000	----	McAnulty (1978)
Bastnaesite	Conqueror No. 9	1954-1955	60	----	Griswold (1959)
	Conqueror No. 10	1956	11	----	Griswold (1959)

TABLE 3.6. Chemical analyses on selected samples from mines in Gallinas Mountains, New Mexico. Cu and Pb are by atomic absorption spectroscopy and reported in percent (%) and Y, La, Ce, Nd and Yb are by induced-coupled plasma spectroscopy and reported in parts per million (ppm) (Lynn Brandvold, analyst, NMBM&MR Chemical Laboratory).

Mine	Cu	Pb	Y	La	Ce	Nd	Yb
Red Cloud #1	0.006	0.028	186	7290	9040	1380	6.1
Red Cloud #2	0.013	0.035	286	10,550	14,060	1980	10
Red Cloud #3	0.004	0.004	310	7610	9320	1550	11
Goodman	0.0102	0.043	752	3300	7570	2010	13
All American	0.007	0.011	181	1680	1790	264	6.0
Sky High	0.858	2.22	189	3440	3690	563	5.2

66.7 Cattle guard. **0.4**

67.1 Gallinas Mountains at 12:30. Ridge at 2:00 is capped by Dakota Sandstone. Gray, refractory shale from the middle member of the Dakota was mined for the production of refractory brick. At the top of the ridge is an open pit, and underground workings are scattered on the slopes. The dip is about 45° into the ridge; the hill is a structural syncline. A wooden loading facility can be seen about midway up the slope. From there shale was transported westward to the brickyard located in Ancho.

Blue mudstones low at 3:30 are of San Pedro Arroyo Formation. **1.4**

68.5 Outcrops of Yeso gypsum on slope to right. **0.3**

68.8 Cattle guard. San Andres Formation on left forms cliff and slopes. **0.2**

69.0 Ancho on left. **0.1**

69.1 Ancho railroad crossing. **Bear left onto unpaved road** and enter Ancho. Ancho (Spanish: wide) was named for its location on the side of a wide valley. The Southern Pacific Railroad created the town in 1899, although considerable mining had been going on for a while in the nearby Jicarilla Mountains. A huge brick factory, which produced cream-colored refractory brick as well as red brick and drain tile, was on the left, southeast of the railroad tracks. The factory, established in 1902, was purchased by the Phelps Dodge Corporation in 1917, which operated it until the plant closed in 1922. Yellow Ancho No. 1 brick, used as a building brick as well as to line furnaces, is quite common in central New Mexico. Shale for the red brick and tile comes from pits in the Permian Artesia Group adjacent to the plant.

After the San Francisco earthquake in 1906, trainloads of Ancho bricks were shipped the 1460 mi to reconstruct the city. Ancho was also a busy shipping and supply point for ranchers, but in 1955 US-54 was paved and rerouted, leaving Ancho 2 mi off the main highway.

"My House of Old Things" is a private museum in Ancho located in the old railroad station and contains many historical artifacts (Pearce, 1965; Chilton et al., 1984). The local school house just to the west is constructed of Ancho No. 1 brick. **0.2**

69.3 **Turn right at road junction** onto NM-462 (paved). **0.1**

69.4 Cattle guard. **0.9**

70.3 Oscura Mountains in distance at 9:30–10:30. **1.1**

71.4 Gypsum of Permian Artesia Group forms low, gray hills to right. **0.4**

71.8 Stop sign at **junction** with US-54. **Turn left** onto US-54 and proceed south. **0.4**

72.2 **STOP 2. Carefully pull off on right side of highway** to examine Triassic Moenkopi Formation (Fig. 3.24). The Moenkopi Formation, of Early-Middle Triassic age, is mostly nonmarine red beds deposited in fluvial, lacustrine and paralic environments and principally exposed across northern Arizona and southern Utah (Stewart et al., 1972). Prior to 1985, the Moenkopi was only tentatively identified in west-central New Mexico as far east as the Sevilleta Wildlife Refuge (Stewart et al., 1972). However, work since 1985 indicates the Moenkopi Formation is present across much of northern New Mexico, and crops out as far to the southeast as Bull Gap near Oscura south of Carrizozo (Lucas, 1991, this guidebook).

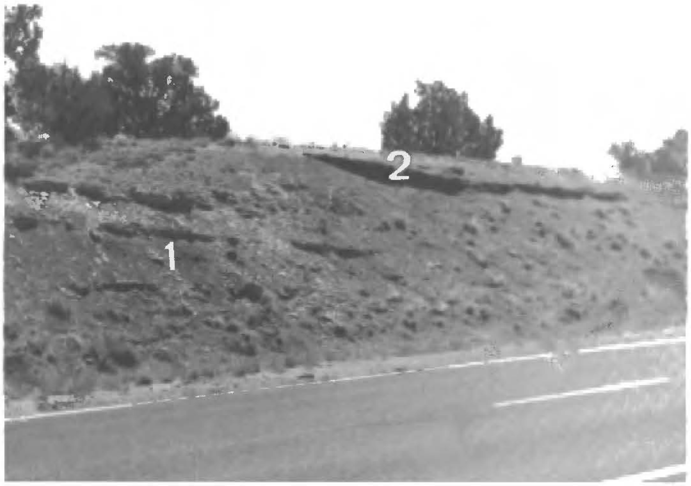


FIGURE 3.24. Santa Rosa Formation (2) overlying Moenkopi Formation (1) at Stop 2.

Identification of the Moenkopi Formation in New Mexico is based on three lines of evidence:

1. Stratigraphic position—Moenkopi strata in New Mexico overlie strata of Permian age (mostly Guadalupian rocks of the San Andres and Glorieta Formations or the Artesia Group) and, with one exception, underlie Upper Triassic strata (Shinarump, Agua Zarca and Santa Rosa Formations). The one exception is at Bull Gap, Lincoln County, where the Cretaceous Dakota Group (Mesa Rica Sandstone) rests directly on the Moenkopi Formation (Lucas, 1991, this guidebook). Thus, Moenkopi strata in New Mexico occupy the same stratigraphic position as the Moenkopi Formation in Arizona-Utah, a position consistent with, but not demonstrative of, Early or Middle Triassic age.

2. Lithology—Moenkopi strata display typical fluvial sedimentary structures, mostly trough crossbeds, are mostly grayish red and are dominated by immature sandstones (lithic graywackes and litharenites) with lesser amounts of siltstone and intraformational, siltstone- and nodular limestone-pebble conglomerate. Underlying Permian red beds, in contrast, are typically laminar, bioturbated, or massive, are reddish brown and reddish orange and are dominated by mature sandstones and siltstones that are often gypsiferous and essentially lack conglomerates.

3. Paleontology—fossils from the Moenkopi Formation in New Mexico indicate it is of Middle Triassic age. These fossils include a skull and many other bones of the capitosauroid amphibian *Eocyclotosaurus*, a Middle Triassic (Anisian) index fossil (Lucas and Morales, 1985; Ochev and Shishkin, 1989). Other fossils include ostracodes, charophytes, archosaurian reptile bones, and footprints of large *Cheirotherium* reptiles (Kietzke, 1989; Lucas and Hayden, 1989; Lucas and Hunt, 1991). These fossils are not as precise age indicators as *Eocyclotosaurus*, and only indicate an Early or Middle Triassic age.

The stratigraphic section exposed here (see Lucas, 1991, this guidebook) begins with reddish-brown, calcareous siltstone and light-gray, coarsely recrystallized limestone of the Permian Artesia Formation. (We follow Lucas and Hayden [1989] in replacing the term Bernal Formation, earlier used to refer to these Permian strata, with Artesia Formation). The overlying 23.4 m of Moenkopi Formation (Anton Chico Member of Lucas and Hunt, 1987) are dominated by sandstone (69% of the measured section) with subordinate siltstone and mudstone (30%), and trace intraformational conglomerate (1%). The sandstones are grayish-red, micaceous litharenites that are trough crossbedded or laminar/ripple laminar. The mudstones and siltstones also are grayish red and are not bentonitic. The base of the Santa Rosa Formation (Tecolotito Member of Lucas and Hunt, 1987) is marked by a prominent extrabasinal conglomerate mostly consisting of black, gray, white and yellowish-orange quartzite and chert pebbles, some of which are as much as 8 cm in diameter. The Moenkopi–Santa Rosa contact is an unconformity (Tr-3 unconformity of Pipiringos and O'Sullivan, 1978) between Middle Triassic (lower Anisian) and Upper Triassic (upper Carnian) strata. The Moenkopi outcrop at Ancho, and those to the south of Carrizozo near Oscura (about 30 mi south-southeast of this stop) are the southeasternmost outcrops of the Moenkopi Formation in the Western Interior. Moenkopi paleocurrents here and across New Mexico indicate paleoflow to the north-northwest. Moenkopi outcrops in Lincoln County are not appreciably different in thickness or lithology from those to north and northwest. Indeed, the thickest section of Moenkopi rocks thus far measured is about 102 m at Bull Gap near Oscura (see Lucas, 1991, this guidebook). We conclude that the southern edge of the Moenkopi depositional basin is not approximated by its southeasternmost outcrops.

After the stop, continue south on NM-462. 0.5

72.7 Roadcuts of Moenkopi Formation. **0.9**

73.6 Roadcuts of Artesia Group (Grayburg/Queen Formations). **0.2**

73.8 **Junction** with NM-55 to Salinas National Monument, Gran Quivira unit; **continue straight. 1.5**

75.3 Milepost 142. **0.5**

75.8 Crest of hill. Ridge on left across valley along railroad is capped by Mesa Rica Sandstone over San Pedro Arroyo Formation. Green sandstone and shale in roadcut to left is Artesia Group. **0.5**

76.3 Hill at 3:00 south of house is capped by Mesa Rica Sandstone. **0.9**

77.2 San Andres–Artesia Group contact in roadcuts to left; note gray limestones of San Andres overlain by orange siltstones and sandstones of Artesia Group. **1.8**

79.0 Outcrops of San Pedro Arroyo Formation on right are red and gray-green, bentonitic mudstones and fluvial sandstones. **0.7**

79.7 Hills to right are capped by Cretaceous Mesa Rica Sandstone over Triassic San Pedro Arroyo Formation. **0.6**

80.3 Bridge over arroyo. **0.3**

80.6 Turnoff to Lazy Z ranch on left; continue straight on US-54. Note red beds of Triassic on bluff in distance at 9:30 above white Glorieta/San Andres Formations. **0.5**

81.1 Mesa Rica capping hill at 3:00, with San Pedro Arroyo Formation at the base. **0.3**

81.4 Roadcut of Dakota above Triassic on left near crest of hill. **0.9**

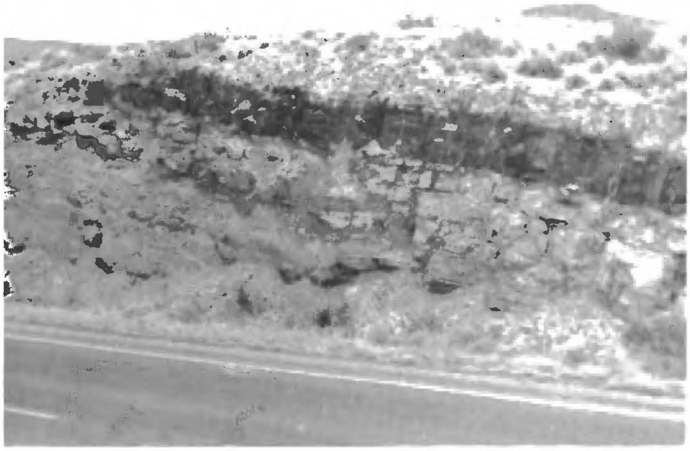


FIGURE 3.25. Basaltic sill intruding Bridge Creek Member of the Greenhorn Formation at Stop 3.

82.3 **STOP 3. Park on right shoulder of road. Beware of traffic.** Basaltic sills intrude Bridge Creek Member of the Greenhorn Formation (Fig. 3.25). *Mytiloides mytiloides,* a characteristic pelecypod of the Bridge Creek (Fig. 3.26), is present on the east side of highway at top of outcrop and on the outcrop's northeast slope as well.

Within the Late Cretaceous Western Interior sea, during the Late Cenomanian–Middle Turonian, a major accumulation of pelagic carbonate produced the Greenhorn Formation/Limestone (Fig. 3.27). The upper part of the Greenhorn Formation, the Bridge Creek Member, is characterized by rhythmic alternations of limestone and marly shale. G. K. Gilbert in 1895 was the first to suggest that the rhythmically bedded Greenhorn reflected global climate cycles. Now, Greenhorn rhythmites are thought to have been caused by orbital forcing of climatic episodes that resulted in arid and humid climatic cycles best recorded in pelagic/hemipelagic sediments in deep sedimentary basins (e.g., Hattin, 1987).

In thin section, the basaltic sill contains medium-

FIGURE 3.26. *Mytiloides mytiloides,* a characteristic pelecypod of the Bridge Creek Member of the Greenhorn Formation, collected at Stop 3. Specimen is NMMNH (New Mexico Museum of Natural History) P-19110. Scale is in millimeters.

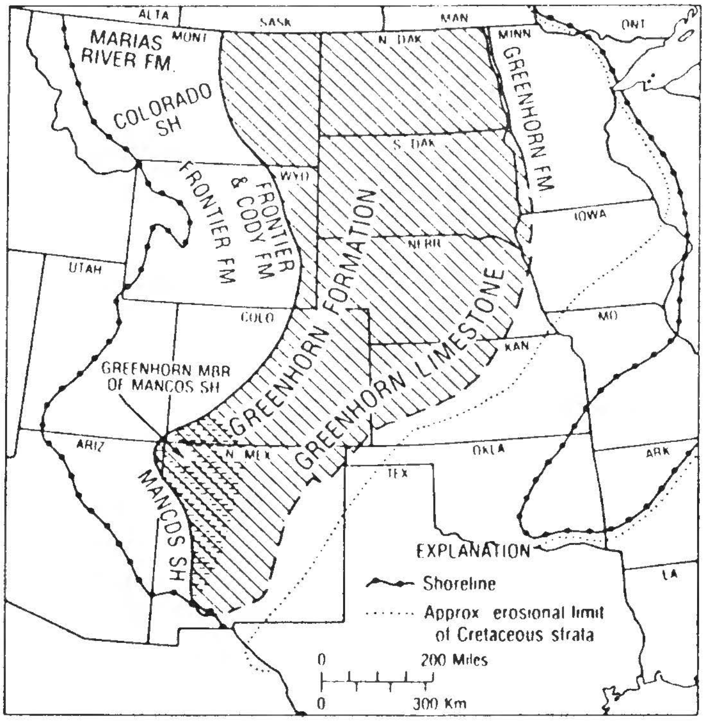


FIGURE 3.27. Map showing distribution of Greenhorn Limestone/Greenhorn Formation, and units into which the formation passes laterally. Eastern shoreline is conjectural (from Hattin, 1987).

grained euhedral augite with normal oscillatory zoning and biotite in a fine-grained groundmass of plagioclase laths (An$_{38}$). Major element analysis is in Table 3.7. The basaltic sill is lower in SiO_2 and Al_2O_3, and higher in TiO_2, Fe_2O_3, MgO, CaO, Na_2O and K_2O than the basaltic flows of the Carrizozo field (Table 3.7). Some of these differences, especially increased CaO, may result from contamination from the Greenhorn Formation. However, limited geochemical data suggest that the basaltic sill may be a differentiate of the Carrizozo lava flows (Fig. 3.28), although trace-element analysis and isotopic data are needed to verify this hypothesis. **0.3**

82.6 Roadcuts in alluvial deposits. **0.5**

83.1 Crest of hill. Sierra Blanca at 11:30 and Cub Mountain at 12:30. **7.8**

90.9 Turnoff to White Oaks (NM-349) on left. Continue straight. **3.1**

TABLE 3.7. Major element analyses of Quaternary basalts at Stop 3 and the Carrizozo flows. XRF analyses by C. McKee (New Mexico Bureau of Mines and Mineral Resources X-ray Facility). *Total iron reported as FeO. ND, not determined.

	STOP 3 Basaltic sill	Broken Back Crater	Lower Carrizozo Flow	Upper Carrizozo Flow
SiO_2	40.6	51.67	49.85	51.60
TiO_2	2.86	1.76	1.75	1.71
Al_2O_3	12.0	17.78	16.84	17.21
FeO*	10.5	9.06	9.71	9.66
MnO	0.19	0.15	0.16	0.15
MgO	8.12	6.66	6.53	6.30
CaO	13.3	8.12	8.77	8.26
Na_2O	3.84	3.40	3.51	3.71
K_2O	2.18	1.54	1.38	1.28
P_2O_5	1.39	ND	ND	ND
LOI	4.35	ND	ND	ND
TOTAL	99.33	100.14	98.5	99.88

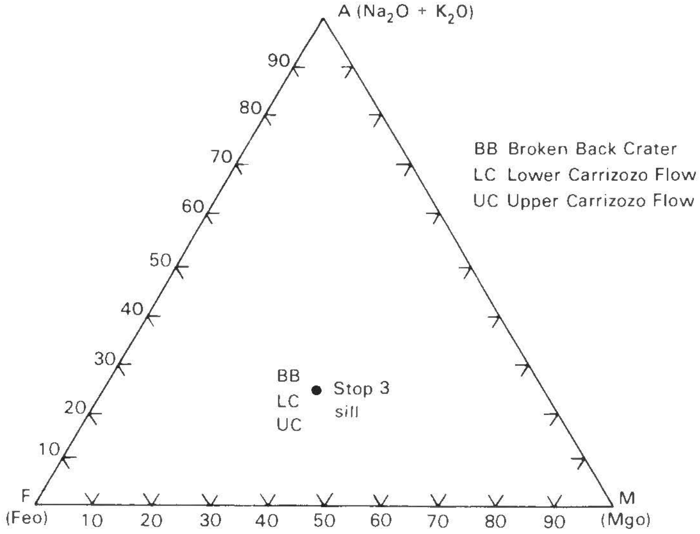


FIGURE 3.28. AFM diagram of Carrizozo lava flows and basaltic sill at Stop 3.

94.0 Carrizozo city limits. **0.2**

94.2 **Intersection** with US-380. **Turn right at flashing red light** and proceed west on US-380. **0.7**

94.9 Leave Carrizozo. **2.7**

97.6 Roadcut on right is gray limestone of Niobrara Formation. **0.1**

97.7 Bridge crossing. Enter lava field (Fig. 3.29). **0.5**

98.2 **Entrance to Valley of Fires Recreation Area. Turn left. 0.2**

98.4 **STOP 4.** Group shelter parking lot.

GEOLOGY OF THE VALLEY OF FIRES RECREATION AREA

Virginia T. McLemore

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

Valley of Fires Recreation Area, located about 2.4 km northwest of Carrizozo, was first established as a state park in 1966. In the late 1980s much of the Carrizozo lava field, locally known as the Malpais, was designated a wilderness area and the entire area was transferred to the administration of the U.S. Bureau of Land Management (BLM). In 1990, the state park became the Valley of Fires Recreation Area and is administered by the BLM. Camping (with electrical hookups) and

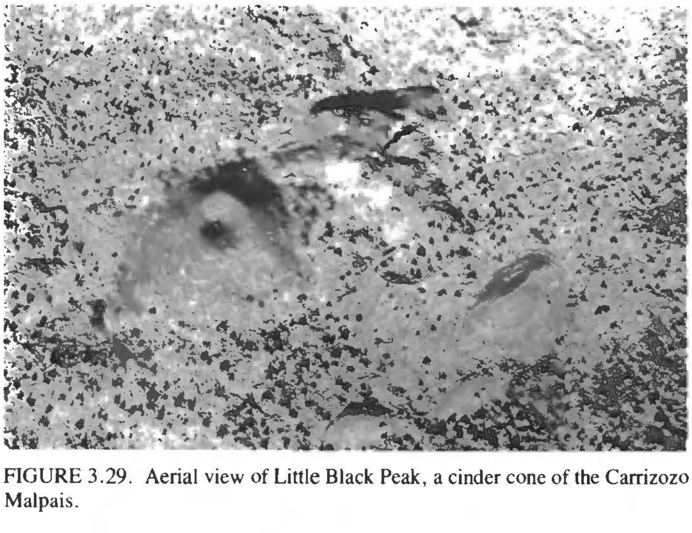


FIGURE 3.29. Aerial view of Little Black Peak, a cinder cone of the Carrizozo Malpais.

picnicking sites, drinking water, restrooms and an RV dump station are available at the site. A 2-km Malpais Nature Trail (Fig. 3.30). provides an easy hike through part of the lava field where one can examine the lava flow and observe the abundant flora.

Prehistoric Indians, probably of the Mogollon culture, inhabited the area until around 1400 A.D., as shown by pottery shards and other artifacts (Young, 1984). Soon thereafter, the Mescalero Apache Indians moved into the area. Once the Mescaleros were placed on reservations in the mid-1800s, homesteaders and ranchers moved in. The El Paso and Northeastern Railroad built a railroad along the eastern Tularosa Valley in 1899 and small towns such as Carrizozo, Oscura and Ancho grew along the newly established route.

"Malpais" is Spanish for bad country and was the name given to this lava field by the early Spanish explorers. The rough terrain of the flows obstructed travel and today even four-wheel-drive vehicles are unable to cross the flows except along US-380 and at two crossings on the White Sands Military Reservation.

The Carrizozo lava flows dominate the northern part of the Tularosa Valley. It is one of the youngest and best preserved lava flows in the United States (Weber, 1964, 1979). The field consists of three subalkaline olivine basalt flows of similar chemical composition, upper and lower Little Black Peak flows (Carrizozo flows of Renault, 1970) and Broken Back Crater flow (Fig. 3.31; Faris, 1980; Renault, 1970; Weber, 1979). They erupted from Broken Back Crater and Little Black Peak, which lie along the Capitan lineament, a major west-northwest-trending zone that transverses central New Mexico and has periodically leaked magma since about 33 Ma. The age of the flows is uncertain but Weber (1979) estimated the Little Black Peak (Carrizozo) flows to be about 1500 to 2000 years old. Morphological differences occur between the two Little Black Peak flows in air photos, but the two flows are generally indistinguishable in the field (Faris, 1980), suggesting a similar age. The Broken Back Crater flows are probably significantly older, as indicated by the more developed erosion, soil cover and vegetation cover (Weber, 1964). The molten lavas flowed southwestward from the vents and ultimately covered an area of about 204 km^2. The area covered by the flows is about 71 km long, varies in width to over 8 km and ranges up to 50 m thick (Weber, 1979).

The flows were erupted as pahoehoe lava (possibly at fissures) and as minor phreatic eruptions of small cinder cones. Structures common in Hawaiian-type pahoehoe lavas are observed along the nature trail, including ropy textures (Fig. 3.32), flow banding, lava tubes with fissure and collapse openings (including lava tunnels and sinkholes), pressure ridges, pressure domes and kipukas (islands of older rock surrounded by a sea of lava). The campground occurs on a kipuka of Dakota Sandstone. Varying degrees of vesicularity exist in the flows (as much as 20%; Faris, 1980), but the younger flows tend to be more vesicular. Vesicles range in size from 0.25 mm to several centimeters and occur in subparallel orientation (Faris, 1980). The basalt is porphyritic and consists of as much as 15% olivine phenocrysts up to a few millimeters long and a matrix of plagioclase, augite, magnetite, ilmenite, zeolites

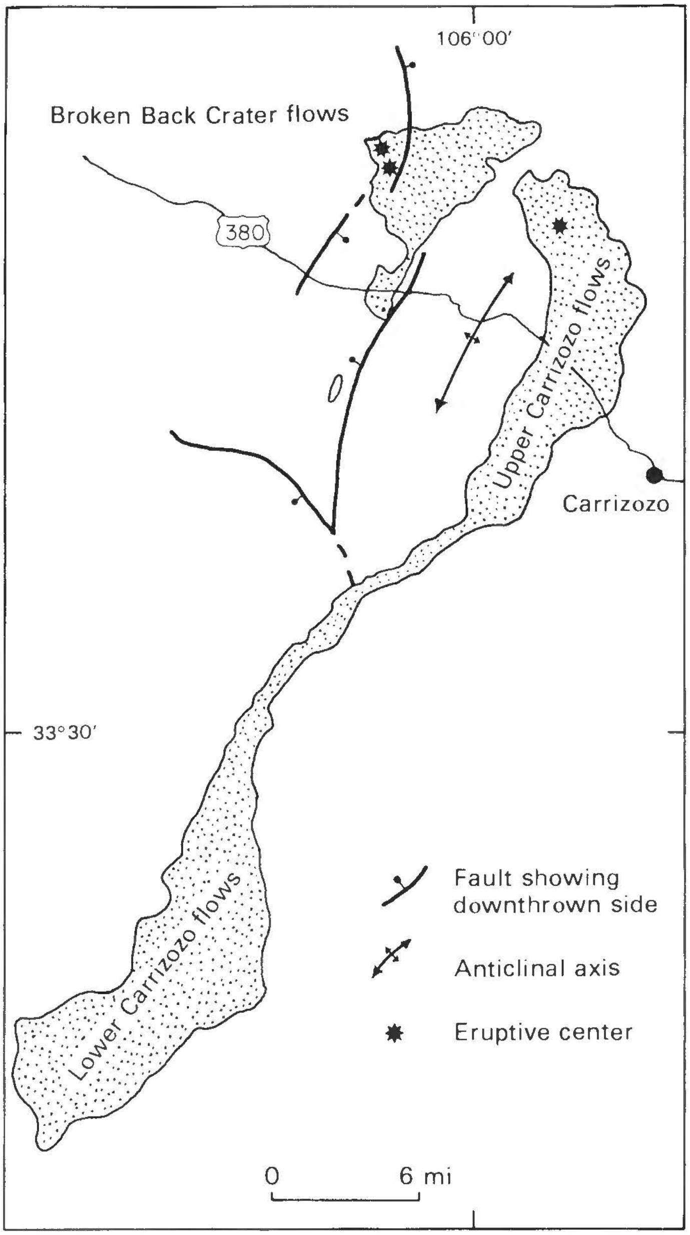


FIGURE 3.31. Map of the Carrizozo volcanic field (from Renault, 1970).

FIGURE 3.30. View of Valley of Fires Nature Trail, looking west.

FIGURE 3.32. Ropy texture in lava, along Valley of Fires Nature Trail.

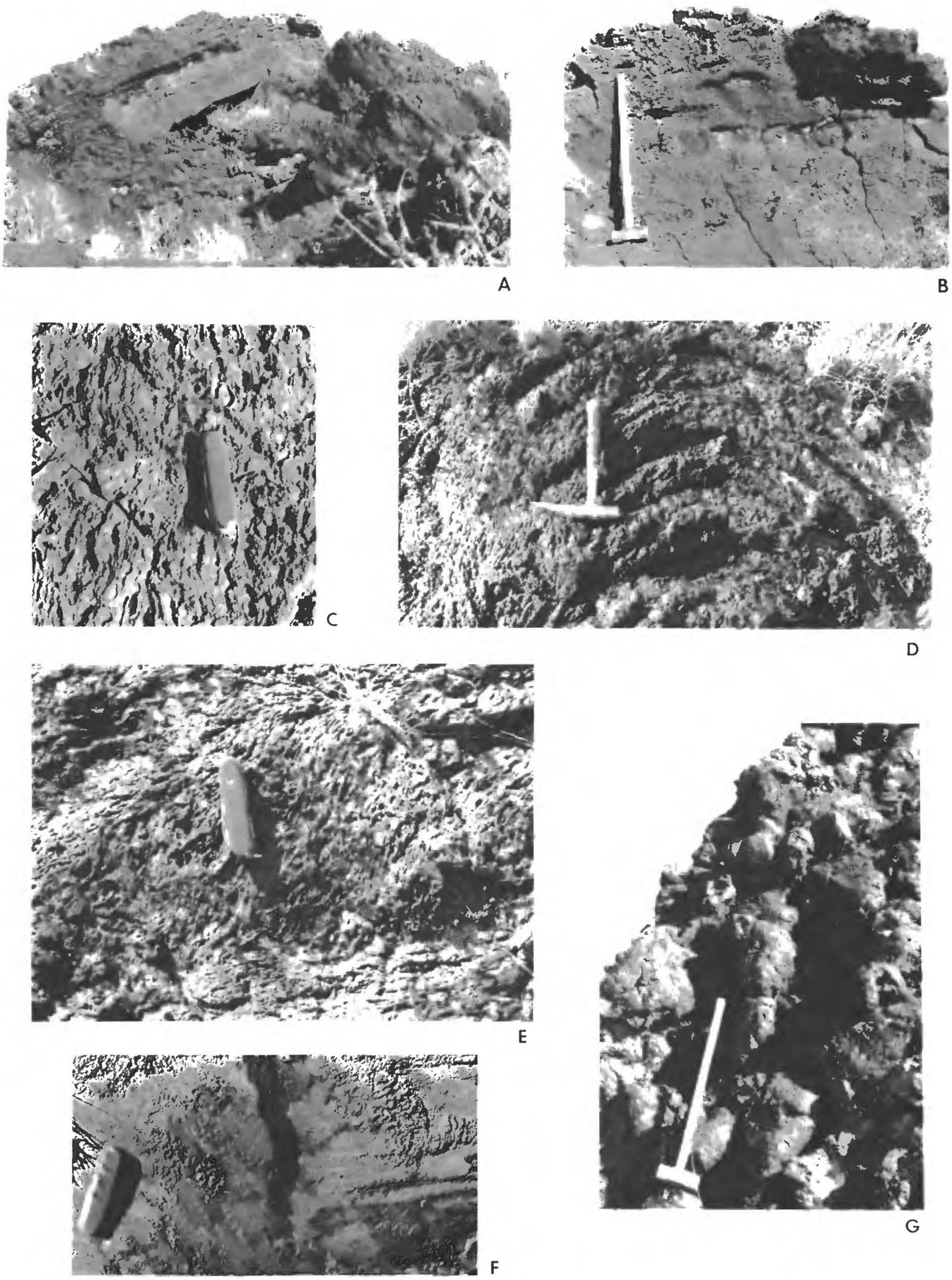


FIGURE 3.33. Primary features of the Carrizozo pahoehoe basalt flow. A, View into the end of a longitudinal pressure ridge. B, Vertical section through the top of the flow, exposed in the medial crack of a pressure ridge, showing vesicle zones. Hammer is 90 cm long. C, Elongated vesicles on the top of the flow. The blunt ends at the heads of tadpole-shaped vesicles tend to point downstream. Flow direction is from top to bottom of the photograph. Knife is 9 cm long. D, Vesicles (left), elongated while the flow was mobile, are distorted by pahoehoe ropes that formed as the crust of the flow congealed. Flow direction was toward the top of the photograph. E, Disruption of vesicle alignment by a squeezeup. Flow direction, from left to right, is indicated by elongated vesicles at the top and bottom of the photograph. In the center, a small squeezeup has disrupted the crust of the flow and vesicle alignments are discordant relative to flow. F, Striations transverse to flow direction exposed on lava at the bottom of the medial crack of a longitudinal pressure ridge. G, Bulbous squeezeups on the flank of a pressure ridge.

and olivine. Plagioclase phenocrysts (0.3%) up to 2 mm long are present in some hand specimens. Chemically, the Carrizozo basalts are high-silica, hypersthene-normative subalkaline basalts and are enriched in light rare-earth elements (Faris, 1980; Allen and Foord, 1991). They are chemically similar to basalts of the Jornada del Muerto (Socorro County) and Animas (southern New Mexico) flows in the Rio Grande rift. Other recent basaltic flows in the Rio Grande rift and adjacent areas, specifically the Geronimo (southeastern Arizona), Elephant Butte (Sierra County), Potrillo (Doña Ana County) and Palomas flows, are lower in silica and are nepheline-normative olivine basalts (Hoffer et al., 1991). ^{87}Sr/^{86}Sr isotope data of 0.70477 to 0.70482 (M. S. Allen, written comm., March 1991) suggest an upper mantle source.

The brief duration of the volcanic activity and the relatively small volume of lava suggest that the magma chamber was small and the magma was transported quickly to the surface without any major crustal contamination (Renault, 1978). The three flows were probably derived from a common magma source because they are closely related spatially and are similar in composition (Faris, 1980). Chemical data suggest the magma chamber may have been compositionally zoned (Faris, 1980). Successively deeper levels of the magma chamber were partially melted to produce the three flows. Geochemical modeling supported by geophysical data suggest these basalts were derived by 4–6% melting of a spinel peridotite parent (Faris, 1980).

Many thanks and appreciation to Robert Weber, Jacques Renault and John Hawley for their critical reviews of an earlier version of the manuscript. Thanks are due to Theresa Lopez for typing the manuscript.

SOME PRIMARY DIRECTIONAL FEATURES OF THE HOLOCENE CARRIZOZO, (VALLEY OF FIRES) PAHOEHOE BASALT FLOW, LINCOLN COUNTY, NEW MEXICO

Wolfgang E. Elston

Department of Geology, University of New Mexico,
Albuquerque, New Mexico 87131-1116

This minipaper describes some primary features of the Carrizozo basalt flow that can be seen on the north side of US-380, just east of the entrance to the Valley of Fires Recreation Area. Emphasis is on criteria that indicate flow direction and could be applied to ancient flows from unknown sources. The Carrizozo flow erupted at the north end of the Tularosa Valley and flowed south for about 65 km. It shares many characteristics with the better-known McCartys flow, crossed by I-40 about 15 km east of Grants, New Mexico, and made famous by the classic descriptions of Nichols (1946).

Nichols (1946) noted at the McCartys flow that pressure ridges could be either longitudinal or transverse. Near the eastern margin of the Carrizozo flow, they are longitudinal (Fig. 3.33A). Evidently, stress here was lateral. The medial cracks of ridges expose vertical sections of the flow, with all the vesicle zones described by Aubele et al. (1988) from west-central New Mexico (Fig. 3.33B). When seen from the top, in places where the flow is level, the vesicles are elongated. If they assume tadpole shape, the blunt heads tend to point downstream (Fig. 3.33C). Pahoehoe ropes distort vesicles (Fig. 3.33D). The ropes formed when the upper zone of the lava flow had congealed to the point where bubbles could no longer rise to form vesicles but was still sufficiently soft to be thrown into wrinkles. The convex side of the ropes points downstream. Bulbous squeezeups also distort vesicles and therefore formed at a late stage, after the flow had congealed but was still plastic (Fig. 3.33E).

Complications seen on pressure ridges formed at a late stage, after a crust had congealed, but they remained plastic, while the interior remained more mobile. As the flanks of the ridge rose and pulled apart to form the medial crack, the more mobile interior came under tension and transverse striations formed on its surface (Fig. 3.33F). Because the ridges are longitudinal, these striations are elongated at right angles to flow direction. On the steep flanks of the ridges, pahoehoe ropes formed on the plastic crust. Their convex sides point down the flank of the ridge, normal to overall direction of flow. In places, liquid lava from the interior of a ridge penetrated cracks in the crust, to form numerous bulbous squeezeups (Fig. 3.33G). At the foot of ridges, fingers of lava oozed laterally out of cracks in the crust; their pahoehoe ropes and vesicles indicate movement normal to the overall direction of the flow.

End of Third-Day Road Log.