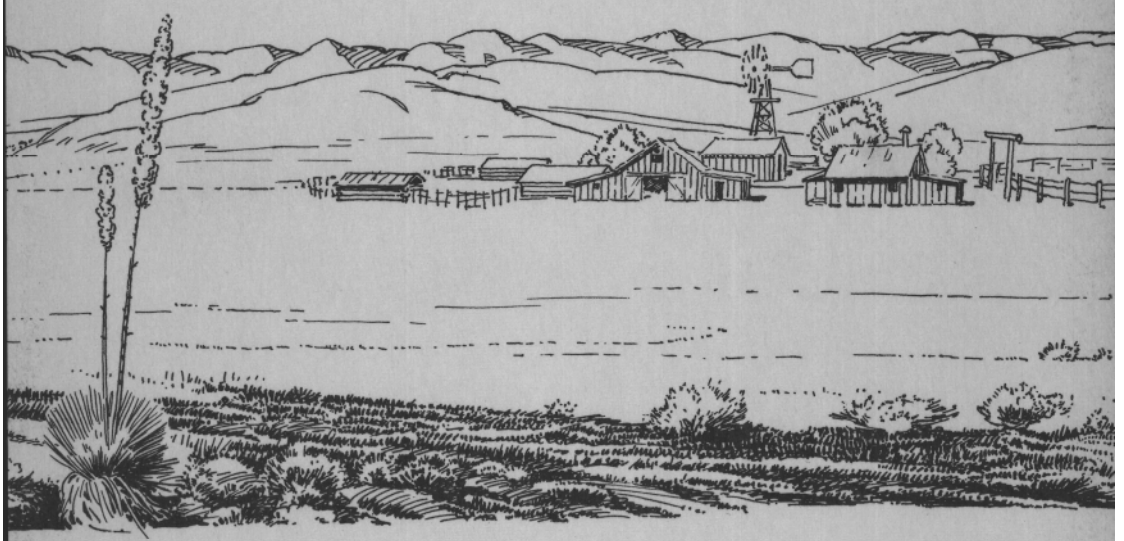
SCENIC TRIPS to the GEOLOGIC PAST

No. 3



Roswell-Capitan-Ruidoso and Bottomless Lakes State Park New Mexico

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SCENIC TRIPS TO THE GEOLOGIC PAST
NO. 3

Roswell—Capitan—Ruidoso and Bottomless Lakes State Park, New Mexico

BY
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AND
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STATE BUREAU OF MINES AND MINERAL RESOURCES
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Preface

Roswell, hub of the southeastern New Mexico petroleum industry, is also a tourist center for many of the scenic and geologic features that make New Mexico the "Land of Enchantment." To the south are the world-famous Carlsbad Caverns; to the southwest, beyond the Sacramento Mountains, the glistening dunes of White Sands and the nearby rocket installations; and to the northwest, the ancient pueblo ruins at Gran Quivira, Abo, and Quarai.

Closer to Roswell are other historic sites and scenic areas less frequently visited by tourists. Among these are the Sierra Blanca summer playground (near Ruidoso and the headwaters of the Rio Hondo), the historic sites of the Lincoln County cattle wars, and the awesome black wasteland of the Carrizozo malpais. The present guidebook is designed to add interest and enjoyment to visits to such areas.

One of the functions of the New Mexico Bureau of Mines and Mineral Resources is to describe the geologic features of the State. Most of this information is provided in technical reports adapted to the requirements of professional geologists, mining engineers, and prospectors.

The Scenic Trips to the Geologic Past series, however, is designed to serve the needs of the general public. It is hoped through these popular guidebooks to make geologic observation interesting both to local residents and to tourists passing through the areas described. It is the aim of the series to present in nontechnical language a picture of what has been going on during the millions of years of the geologic past in this land of scenic and historic enchantment.

Introduction

Roswell is located "west of the Pecos," on the edge of the Llano Estacado (Staked Plains). Since the days of the first white settlers this has been the land of the cowboy and the cattle ranch. Although the plains stretch monotonously eastward into Texas, they rise westward in gradual slopes to the Sacramento and Sierra Blanca mountains, whose highest peak exceeds 12,000 feet in altitude. These mountains drop off precipitously toward the west into the great elongate depression known as the Tularosa Basin.

These mountain ranges have a complicated history extending over some 600 million years. It involves advances and retreats of wide seas; long epochs of erosion by sluggish rivers inhabited by prehistoric crocodiles and amphibians; periods of folding and arching of the bedded rocks deposited by these seas and rivers. There were times when the crust of the earth was penetrated and broken by multiple injections of different kinds of molten rocks, which in places broke out on the surface as volcanoes. During other periods the crust was cracked and broken, and the arched rocks collapsed. More recently the story has been one of erosion. The present valleys and canyons, cut by streams much greater than those today, were scoured out, and much of the once thick pile of sedimentary and volcanic rocks was worn away.

The detailed study of such geologic events is often of great practical value. It can aid the prospector in determining the extent and value of ore deposits in once molten rocks. It assists in the discovery of petroleum in the sedimentary rocks. It may reveal the best places to drill for water, to build a dam, to lay a pipeline, or to build a road.

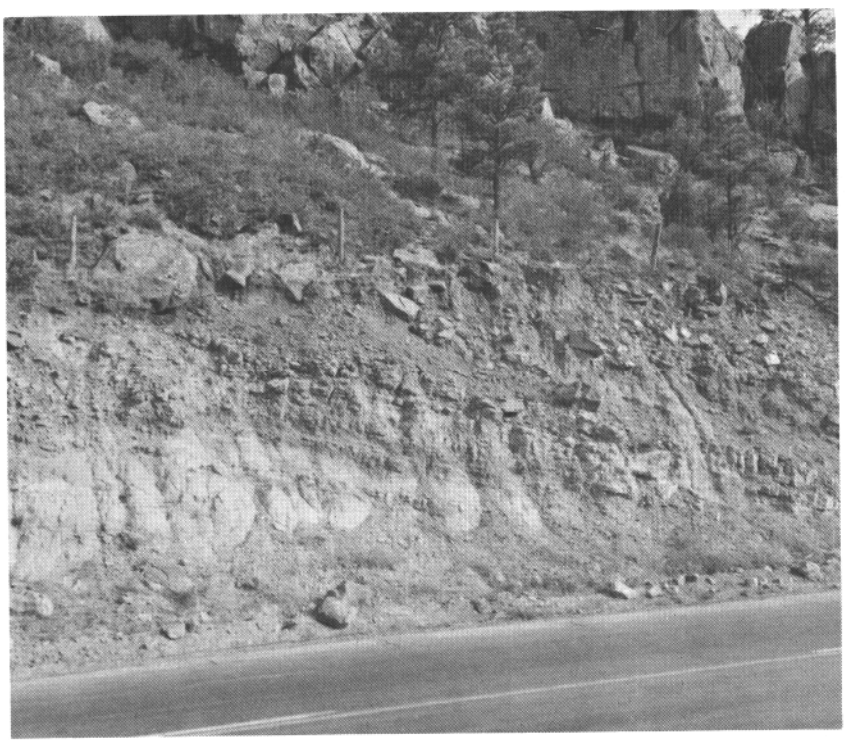
It is important, therefore, to obtain a perspective of the long period of geologic time. And so the geologist examines the rock exposures and makes deductions from what he sees. By applying the scientific method in the field and along the highway, he is enabled, in part at least, to reconstruct the history of the area under study.

The geologic timetable (page 4) gives you a preliminary perspective. As you observe the various rock units along the highway, you can, with the help of this chart, visualize some of the events that took place in nature millions of years ago.

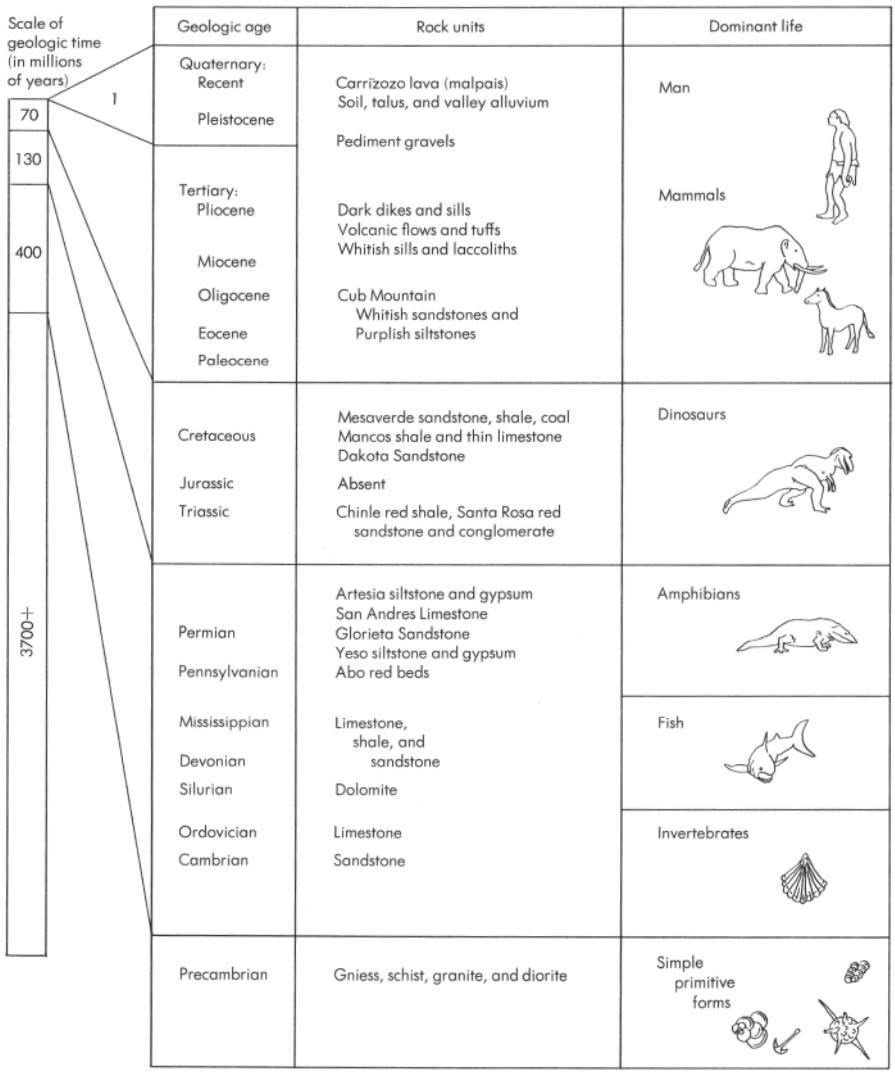
It will not be an entirely rocky road, however; some of the common plants will be pointed out, as well as historic locales. And near the route are many of the rock drawings that occur throughout the well-watered east slopes of the Sierra Blanca and Sacramento mountains—the petroglyphs pecked in solid rock by prehistoric native Americans. These carvings in stone are in part "doodles," random fancies created in leisurely moments, but some are religious symbols, designs from textile and pottery decorations, trail markers, records of events, and primitive expressions of art.

Petroglyph or pictograph? Carved figures in rock are petroglyphs; literally, rock glyphs or rock grooves. Pictographs are primitive types of writing in which events are presented pictorially on any kind of material. Painted figures on rocks also have been called pictographs. You are welcome to disagree with our interpretation of the meaning of individual petroglyphs; only the original carver can referee, and he is long departed!

The theme of the trip is rock structure. We shall note how the bedded rocks, originally horizontal, are now bent, twisted, broken, or tilted. The shapes and relationships of massive, once molten, rocks are shown. And where are the younger rocks exposed? On the tops of mountains? In some instances, yes; however, we shall see a great downwarp of the earth's crust in which a thick blanket of younger rocks has been preserved from recent erosion. And west of our route, the oldest of rocks cap high peaks.



TILTED TRIASSIC ROCKS AT MILEAGE 69.5



GEOLOGIC TIMETABLE

Use of the Road Log

Mileage is given at the various points of interest and also at "check points," such as bridges and road junctions, so that the common variations among speedometers can be corrected as the trip progresses.

The driver should have the road log read to him by a passenger who can watch the mileage on the speedometer. The reader should try to keep about one station ahead of the car.

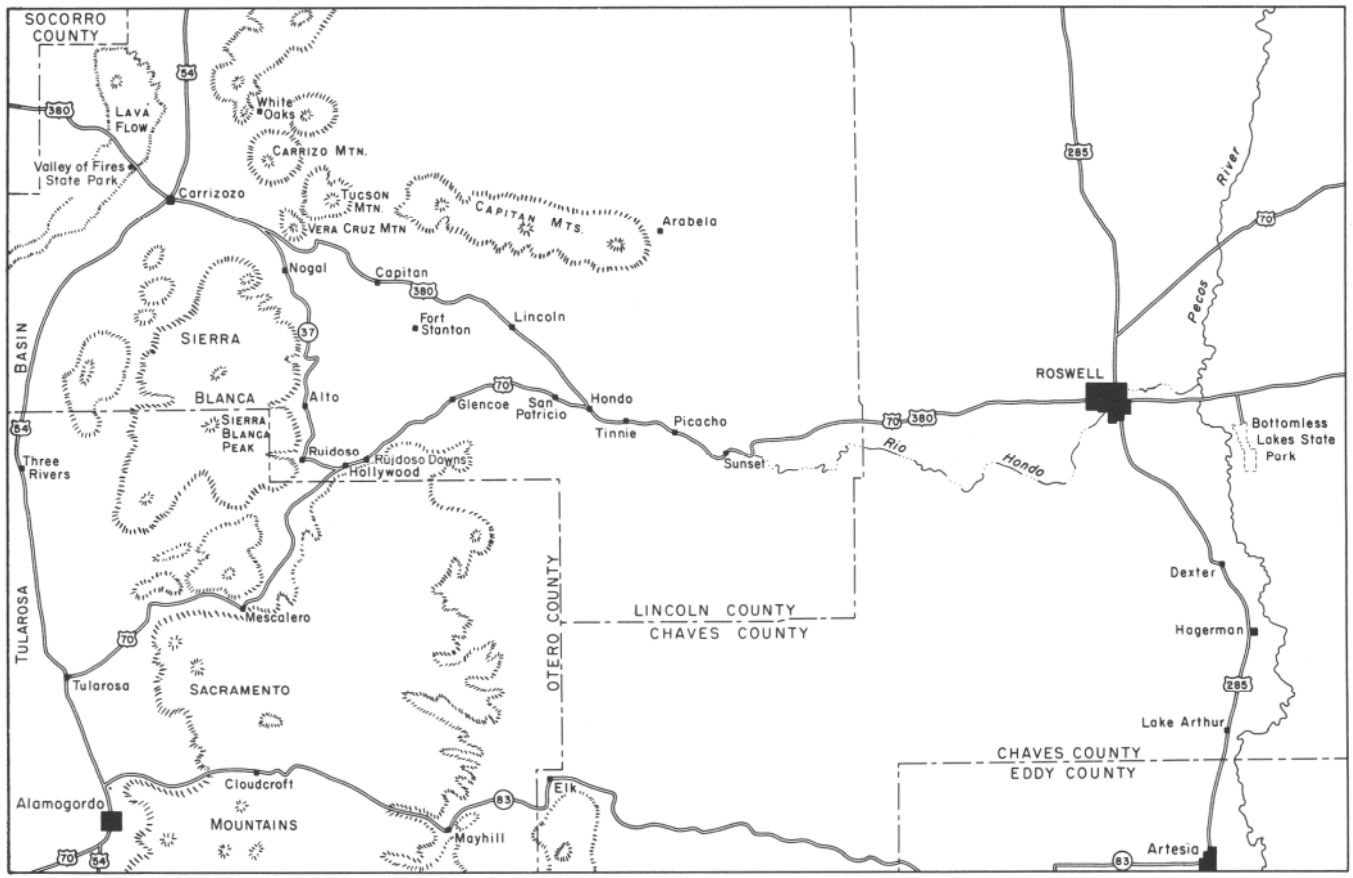
The convenient system of directions used by airplane pilots has been adopted. Twelve o'clock is straight ahead, 9 o'clock is due left, and 3 o'clock due right. Such directions as 6 o'clock (behind the car), though occasionally necessary, have been avoided.

Distances between points of interest are also given, so that one can tell how soon to begin looking for the next point. Stops at particular points are indicated, but of course one can make others as well.

Meanings of Spanish words are given in parentheses.

The principal trip described in this guidebook is 214 miles long and requires about 5 hours of driving time. It can be shortened by leaving out the 30-mile round trip to the lava beds west of Carrizozo. Most of the route leads through high plateau and mountain country (altitudes from 6000 to 7500 feet), so that it will be many degrees cooler than in Roswell. With the exception of 10 miles, the trip is all on good paved road.

A shorter excursion (35 miles round trip) to Bottomless Lakes State Park, east of Roswell, is also presented.



INDEX MAP—SCENIC TRIP—ROSWELL, CAPITAN, RUIDOSO, BOTTOMLESS LAKES

Roswell—Capitan—Ruidoso

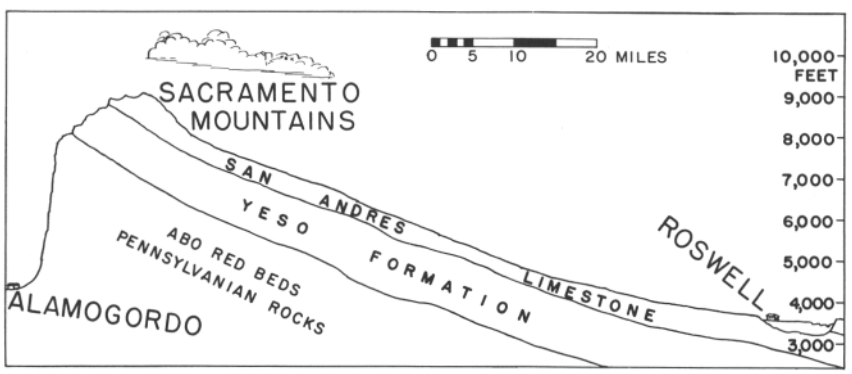
214 miles

Roswell (alt. 3570 ft; pop. 39,500), the second largest city in the State, is the county seat of Chaves County. Its many industries include cotton gins, creameries, oil refineries, and meat-packing plants. The New Mexico Military Institute is located here.

Roswell began in 1869 when Van C. Smith built an adobe general store, post office, and inn. Smith was appointed postmaster in 1874 and named the place *Roswell* after his father. Captain Joseph C. Lea bought Smith out in 1877. The influence of the Lea family in maintaining peace during the Lincoln County War (1877-1879) and the efforts of its members to provide education and an orderly and improved community established Roswell as an important trading center. The accidental discovery of artesian water near Roswell in 1891 led to the present extensive irrigation system, which each year provides millions of dollars from cotton, alfalfa, apples, corn, and other crops. The arrival of the Southern Pacific in 1894 and the discovery of oil in adjacent areas were significant events leading to the growth of the city.

The climate of the Pecos Valley near the city is semiarid, Roswell having an average annual rainfall of only 13 inches. The Roswell Artesian Basin underlies the top soil and "valley fill" of the area. It supplies the hundreds of artesian wells with water from its San Andres Limestone beds. The honeycomb channels of this porous limestone catch water from heavy rains and melting snows in the mountains to the west. The limestone crops out on the east flank of the Sacramento Mountains and extends underground to the Roswell area, serving as a natural sheetlike
channel to convey the water downward into the Pecos Valley.

0.0 Main and Second streets, Roswell. Go west on Second



GEOLOGIC PROFILE OF SAN ANDRES WATER-BEARING BEDS

1.2

1.2 Texaco Station on northeast corner of Second and Louisiana streets (1400 block west) contains the excellent private museum of Fred A. Miles (remarkable Indian mummies, artifacts, and minerals). A little farther on, notice the radio-TV building on right. Walls faced with tan Austin Limestone imported from Texas. This limestone is very fossiliferous and is sprinkled with shells of ancient snails and clams.

2.4

3.6 Roswell city limits. Capitan Mountain on skyline at 1 o'clock. Ascending from the valley fill onto the high plains that form the east slope of the Sacramento Mountains.

The Pecos Valley is underlain by the Permian System of rocks *(see* geologic timetable, p. 4). These are *sedimentary* rocks—rocks that have been deposited as *sediments* (composed of particles of minerals and rock fragments) in layers or *beds* in the ocean, in inland seas, in lakes, or on river flood plains. After the sediments are laid down in flat layers, they are compacted and consolidated into rock by the weight of overlying material and by the action of underground water that dissolves and precipitates minerals in the spaces between the individual grains.

For the next 30 miles, the bedrock will be the San Andres Limestone, composed of calcium carbonate deposited in an ancient inland sea. *Bedding* in these limestones shows that there were variations in the kind and size of materials as they were laid down, so that the rocks are composed of alternating layers of finer and coarser materials of different kinds. Although most of these rocks are limestones, thin layers of *shale* (consolidated mud) separate the limestone layers.

If the consolidated muds were of larger particles, they might be called *siltstones* (silt size), *sandstone* (sand size), or *conglomerate* (pebble-sized particles).

The San Andres Limestone is a geologic *formation,* 400 to 700 feet thick, a group of beds that have more or less similar recognizable characteristics. They can be separated, therefore, from adjacent formations in mapping, and a line or *contact* can be drawn between them on the map.

In the areas where mountains have been formed (by deep-seated forces whose origin is still not certainly known), the originally flat-lying beds may be tilted up gently, as they are here (dipping at low angles toward the Pecos Valley), or they may be more tightly folded, crumpled, and even broken. The upward arched folds are known as *anticlines* and the downwarps are called *synclines.* A large downwarp consisting of several smaller folds is a *synclinorium.* When the rocks are broken and the sides of the fracture have moved relative to each other, the break is called a *fault.*

1.6

5.2 Starting up the first rise. This is Six-Mile Hill, an anticline (upwarp) faulted (broken) at the top.

0.7

5.9 Summit of Six-Mile Hill structure. The San Andres Limestone, easily dissolved by underground water, contains more than eight caverns on the east side of the hill, within a few miles of the highway. Some of these caverns have caved to the surface, forming roughly circular depressions that dot the plains in this area. These collapse structures are called *sinkholes* and commonly are filled by a jumble of broken limestone blocks such as occur in the road cuts here.

ANTICLINE AT SIX-MILE HILL

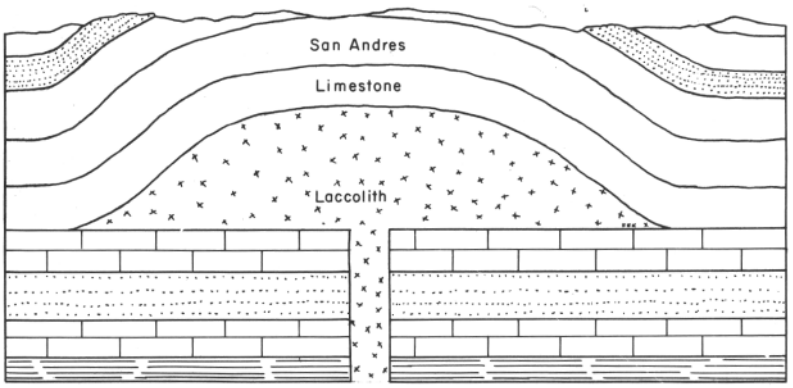
Note Capitan Mountain at 1 o'clock and Sierra Blanca at 12 o'clock. We shall have much to say about these huge rock masses later.

1.1

7.0 End of four-lane divided highway. Sorry!

0.4

7.4 Bridge. Capitan Mountain, which you saw a moment ago at 1 o'clock, is made up of *igneous* rock. This means that it originated deep beneath the crust of the earth as a molten mass, heated to fusion by such processes as pressure or accumulated radioactive heat. This plastic mass (called a *magma)* was then forced upward along a great east-west fracture close to the surface, where it spread out along the bedding planes of the rocks beneath the San Andres Limestone. It lifted and arched the limestone, then cooled and solidified, so that a cross section looks like this:



This kind of igneous structure is called a *laccolith.* If the magma merely follows along the bedding of sedimentary rocks as a sheet of liquid material, it is called a *sill* when it cools. If the magma cuts across the bedding, it is called a *dike.* You will see hundreds of dikes and many sills, as well as several additional laccoliths, later in the trip.

4.4

11.8 Hill top. Capitan Mountain at 1:30 o'clock. Road cuts ahead are in San Andres Limestone.

1.2

13.0 Side road to left (south) to Two Rivers Reservoir project.

0.2

13.2 Rest area on right (north). Chisum Trail marker: "John Chisum, owner of the famous South Spring River Ranch, trailed several herds of cattle from the Pecos Valley to the San Carlos Indian Reservation in Arizona, under government contract, in the early 1870's. The trail left the Pecos at Seven Rivers and swung westward to follow roughly the present route of U.S. 70 into Arizona."

2.9

16.1 Summit. Highest point of Sierra Blanca on skyline at 12:30 o'clock; Capitan Mountain at 1:30 o'clock. Gravels cap hills for next few miles. Rounded pebbles and cobbles in gravels are like those capping Llano Estacado east of Pecos Valley, as are interbedded lenses of reddish sand and silt. Notice the thin white caliche at the top of the gravels; it is a thin type of "caprock."

1.8

17.9 Rest area on left (south).

0.2

18.1 Summit. Top of Sierra Blanca at 12:00 o'clock and another view of Capitan Mountain off to the right. Most laccoliths are circular in outline, but Capitan is elongated and extends for 20 miles in an east-west direction. There are a number of patches of San Andres Limestone left on the top, although most of the rock that once arched up over the laccolith

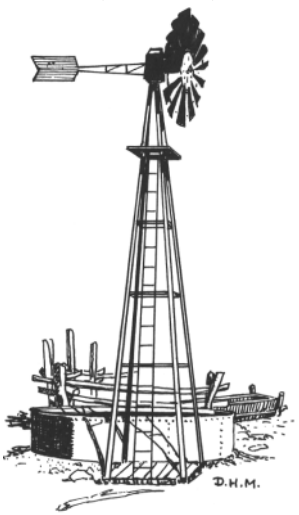
has eroded away. The juices and vapors given off by the cooling magma altered and replaced the limestone here and there with iron ore. Commercial deposits are found on the flanks; one such deposit lies near the western summit. Deposits of thorium-bearing minerals (allanite) also occur in veins on the sides of the laccolith.

3.1

21.2 Enter Lincoln County; leave Chaves County.

2.1

23.3 Hill top. Ridge ahead is the surface expression of the Border Hills faulted anticline. This fold, like the Six-Mile structure, extends northeast-southwest for more than 30 miles.



1.4

24.7 STOP A. Quarry on left; turn off on right and walk back to quarry. Fossil collectors will want to stop, climb up to the quarry, and dig ancient (240 million-year-old mollusks from the east-dipping (35°) beds of limestone. These beds are best exposed on the east side of the quarry.

0.3

25.0 Summit of Border Hills faulted anticline. Just before the summit, notice almost vertical beds along the fault; then breccia zone of the axis of the faulted anticline; and, to the west, west-dipping beds. For the next 5 miles you will drive over an undulating surface on the San Andres Limestone (such as you saw in the quarry). The beds dip very gently to the east. In the distance ahead, you can catch occasional glimpses of the great volcanic pile of the Sierra Blanca (White Mountains) Range, about 55 miles away. When molten igneous rock, such as formed the Capitan laccolith, reaches the surface, it may either flow out as liquid lava flows (such as that east of Carrizozo) or build up into sizable volcanoes. When the magma contains considerable gaseous matter (mostly water vapor), it blows out explosively. Thus are formed beds of volcanic *ash, cinders,* or *lapilli* (of fine, medium, and coarse size). Sierra Blanca, although it contains some *intrusive bodies* (those that didn't reach the surface), is largely made up of *extrusive* flows, ash, and bouldery volcanic material. This huge volcano was built up perhaps as long as 35 million years ago, so that much of the original pile has eroded away by the constant washing action of rain and streams. The highest peak is now 12,003 feet above sea level, the highest southernmost mountain in the United States. At one time it must have been much higher.

0.4

25.4 Rest area on right.

1.4

26.8 Hill top. The ridge from 9 to 10:30 o'clock is the Border Hills anticline.

AXIS OF BORDER HILLS ANTICLINE

1.6

28.4 Hill top. Top of Sierra Blanca on skyline at 12:15 o'clock; ridge at 9 o'clock is Border Hills anticline; Capitan Mountain at 1:30 o'clock.

1.1

29.5 Roadside park on left. These are some of many roadside tables erected by the New Mexico Highway Department for your convenience. You will find many such sites for your picnic lunch later!

0.6

30.1 This is the summit. You now leave the High Plains cut on the San Andres Limestone and descend Picacho (Summit) Hill into the valley of the Rio Hondo (Deep River), which the road follows for the next 16 miles. Instead of being on top of the 400-foot-thick San Andres Limestone, you go beneath it, in the next older geologic formation *(see* geologic timetable p. 4), the Yeso (gypsum) Formation. Prickly pear cactus and ocotillo cap the hill; in the spring, the 10-foot-long ocotillo branches are speckled with scarlet blossoms.

0.8

30.9 San Andres Limestone beds in roadcuts.

0.3

31.2 Notice old road at right, built on a bedding plane of the San Andres Limestone. The walls of the quarry ahead and the roadcuts for the next 35 miles are in the San Andres, but the roadbed lies mostly on the Yeso Formation. Although the rock layers in most places dip very gently to the east, they are warped into northeast-trending folds in several others.

The Yeso Formation contains 1500 to 2000 feet of orange and pinkish sandstone and siltstones, as well as beds of *gypsum* (pure massive gypsum is known as alabaster) and limestone. The gypsum was deposited in an inland sea by evaporation of waters rich in concentrated calcium sulfate. Gypsum is a soft, weak rock (number 2 on the 10-unit scale of hardness) soluble in water; the weight of overlying rocks is commonly sufficient to fold and crumple it. Numerous blocks of the overlying limestone have slid downhill over the gypsum.

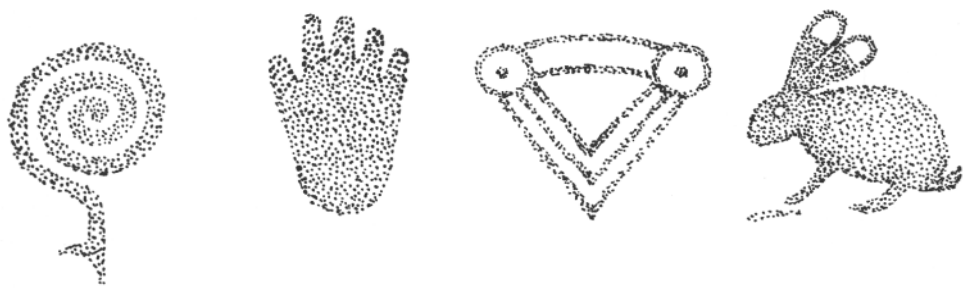
Separating the San Andres from the Yeso is a relatively thin bed of pure white (yellow-weathering) quartz sandstone, known as the Glorieta Sandstone. This sandstone is used for mapping the contact between the Yeso and San Andres formations.

0.7

31.9 Bottom of Picacho Hill. Enter Rio Hondo Valley; cross bridge.

32.6 0.7

Riverside. Contacts of Yeso and San Andres formations at outcrops of Glorieta (yellowish-weathering) Sandstone occur close to the road level.



PETROGLYPHS

1.2

33.8 Entering Sunset. Yeso beds in roadcuts on right. Pink, red, and yellow silty sandstones, with minor limestone and gypsum. Notice irrigated fields in the valley bottom on left.

1.0

34.8 Good outcrops of red and yellow Yeso Formation. Notice the line of cottonwoods, suggesting the age of the irrigation ditch along which they were planted.

0.5

35.3 Outcrops of Yeso; some San Andres Limestone brought brought down to road level by landsliding.

0.8

36.1 Conical butte at 10 o'clock, capped by San Andres Limestone.

1.3

37.4 Notice that beds of San Andres across the valley are tilted (dipping) toward the east; you are entering the east flank of the Picacho anticline. It is a short elliptical fold, sometimes called a *dome.* Two wildcat test wells have been drilled on this structure. but no oil was found.

1.5

38.9 Entering Picacho. You are close to the axis (line where the dips change from east to west) of the anticline. Picacho, named for the conical peak that dominates the little village, is the center for fruit orchards, truck farms, and nearby sheep, cattle, and goat ranches. The first settlers came from the Rio Grand Valley about 1865, just after the Civil War. Sheep ranchers and cattlemen arrived about a decade later, after most of the Apaches had been settled on reservations.

1.0

39.9 West-dipping beds in the roadcut on right are on the west flank of the anticline.

0.2

40.1 On left is a steel bridge across the Rio Hondo. The dirt road to the south crosses the eastern foothills of the Sacramento Mountains and joins State Highway 83 near Elk *(see* index map p. 6).

1.2

41.3 Hilltop on curve to left. The road is on alluvial fans washed into the main valley by streams from side canyons; notice gravel in roadcuts.

1.1

42.4 "The Adobe Hacienda," home of Louise Massey, writer of the song of that name, on left.

1.5

43.9 Entering Tinnie. Apple orchards in the valley. On left is Penny Mercantile Company Silver Dollar Saloon, Steak House, and Museum.

0.5

44.4 Road to right, State Highway 368, leads around the east end of Capitan Mountain to the little hamlet of Arabela.

0.4

44.8 Steeply dipping beds of the "Tinnie folds" can be seen in the canyons tc the right of the highway. Roadcut on right exposes igneous sills of gray rock intruded into Yeso beds.

0.6

45.4 Steel bridge to left across Rio Hondo follows State Highway 395 leading southeast to Alamo Canyon.

CONTOUR FARMING IN HONDO VALLEY

0.2

45.6 Roadside table on left. Lower slopes of canyon wall across the valley on left are outcrops of the Yeso Formation; upper ledges are San Andres Limestone.

2.1

47.7 Roadside tables at right; entering Hondo. Keep right. Junction with U.S. Highways 70 (left) and 380 (right). Historical marker describes the town of Lincoln, about 10 miles to the west. The merging of the Rio Ruidoso (Noisy River) on the left and the Rio Bonito (Pretty River) on the right forms the Rio Hondo (Deep River) below this point. For the next 20 miles, the beds of the Yeso Formation are in most places much crumpled and contorted. Above, the San Andres rocks are essentially fiat-lying (or gently east-dipping). This folding of the Yeso beds may be due to solution of the gypsum by underground water and consequent collapse or in part to landsliding. Some geologists believe that the entire upper layer of resistant San Andres Limestone has slipped eastward down the slope toward the Pecos Valley. This could cause the distortion of the weaker Yeso beds and produce the faults and folds you have seen since leaving Roswell.

1.1

48.8 Notice folded beds to left, across the valley at the base of the valley wall.

0.6

49.4 Picnic tables on right, in the shade, at Fritz's Spring, one of the best sources of good water in the entire area. The spring normally flows about

400 gallons a minute. The water comes out of the quartz-rich Glorieta Sandstone. Most other water from this area contains dissolved gypsum from Yeso beds and is quite unpalatable.

0.4

49.8 Flash floods from the canyon to the right have built up a high alluvial fan of unsorted and jumbled rock debris, which is cut by the highway. A cloudburst up this canyon could stop traffic (and has!) for many hours.

0.6

50.4 Highly contorted Yeso rocks in roadcuts for the next few miles. Notice landslide blocks of San Andres Limestone near the highway level. They "belong" much higher on the hillside.

1.8

52.2 Roadcuts in alluvial fans and talus cones; note angularity of pebbles and boulders and poor sorting.

0.9

53.1 Bridge across the Rio Bonito. Yeso, Glorieta, and San Andres formations in roadcut.

1.1

54.2 Notice disturbed beds of San Andres Limestone across valley at 3 o'clock.

1.0

55.2 Glimpse of Capitan Mountains through saddle at 1 o'clock.

0.3

55.5 Here begin the highly controversial (among geologists) "Lincoln folds" that are exposed in the low bluffs for several miles on the north side of the valley. The Yeso beds are crumpled into a series of tight folds (anticlines and synclines), but the San Andres beds above are almost flat-lying! Is this caused by solution and landsliding, by intrusion of the sharp edge of the Capitan Mountain laccolith into the weaker beds, or by sliding of the upper beds over the underlying weak ones? Geologists are still uncertain.

0.5

56.0 The huge boulders of limestone on the right rolled down from the high cliffs on the left. Glad you weren't here then?

1.1

57.1 Cemetery on right; graves of the famous and infamous. Folded Yeso beds across the valley on right. Approaching the historic town of Lincoln, center of the Lincoln County Cattle War of 1877-1879 and base of operations of Billy the Kid (William Bonney) and Sheriff Pat Garrett. Slow down to read the Historical Marker (read both sides): "Lincoln Town: Turbulent center of the Lincoln County War 1875-1881 [?!]; historic points include the graves of J. H. Tunstall, whose murder set off hostilities, and Alexander McSween, leader of one of the warring factions; Penfields' store, formerly owned by McSween; site of the McSween house, where final battle of the War was fought; the adobe walls from whose shelter Billy the Kid shot and killed sheriff Brady; the

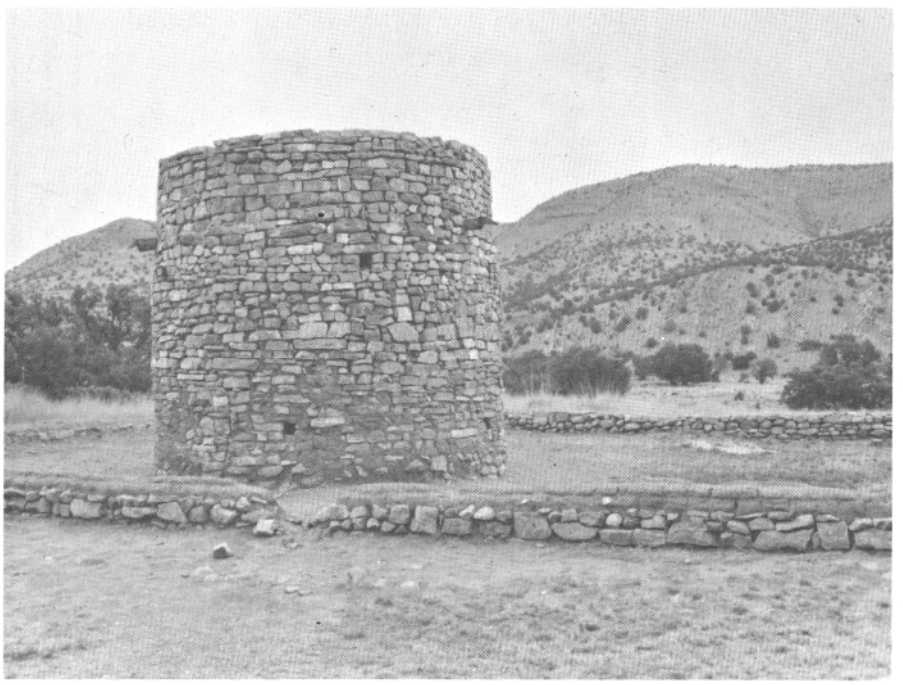
Ellis House, where Governor Lew Wallace, author of *Ben* Hur, conferred with Billy the Kid in a vain effort to persuade him to accept a pardon and lay down his arms; and the old courthouse, originally the store of Fritz and Murphy, rivals of Tunstall and McSween, and leaders of the opposing faction."
Notice anticline across river at 3 o'clock and other folds.

0.4

57.5 Entering Lincoln. Those interested in history, or Billy the Kid, should read the 11 historical markers set up on both sides of the highway by the Lincoln County Memorial Association.

0.2

57.7 Replica of original fort tower on right, built in 1850 to help ward off marauding Mescalero Apaches. Notice syncline in brightly colored Yeso beds across the valley.



TOWER FORT

0.3

58.0 STOP B. Old Lincoln County Court House (on left). This is one of the finest local historical museums in the southwest (admission, 25 cents). To obtain a complete story of the Lincoln County War, as well as to see relics of the early Indian occupation, a visit is recommended. A pageant re-enacting the escape of Billy the Kid from jail is staged annually in August by local residents.

0.1

58.1 Leaving Lincoln. Capitan Mountain at 2 o'clock. "Lincoln folds" still continuing across the valley.

1.2

59.3 Distorted Yeso beds in roadcuts.

2.5

61.8 Entrance (right) to picnic grounds under the cottonwood trees and "double crossing" of the Rio Bonito, Capitan Mountain at 3 o'clock. This is almost the western limit of the area in which contorted Yeso beds appear at the surface. The valley joining the Rio Bonito (Pretty River) here from the north is the Rio Salado (Salt River), which we shall enter in about 5 miles.

0.6

62.4 Notice large landslide blocks of San Andres Limestone on left. Across the valley the San Andres is now at stream level; you will soon leave the Yeso Formation.

0.6

63.0 Small faults offsetting the massive limestone at 3 o'clock lie at base of San Andres, above the yellowish-weathering Glorieta Sandstone. The beds are beginning to dip toward the west into the Sierra Blanca synclinorium.

0.4

63.4 Small turnout (right) on curve to right; last outcrop of Yeso occupies the lower 6 feet of the cliff to the left. Ledges of the tan Glorieta Sandstone are at the west end of the roadcut. The massive beds extending high above are San Andres Limestone, with fossils in the lowermost limestone bed.

0.4

63.8 Government Spring, along the river bank on the right, through the double fence posts; one of the few early sources of permanent fresh water from the permeable Glorieta Sandstone. It is believed to be fed from underground streams connected with the Fort Stanton caverns a mile to the south. Modern well house just beyond the spring.

0.1

64.1 The site of a prehistoric Indian village on the slopes 200 feet to the left of the road. Smetnick Cave, just above the top of the low cliffs directly across the valley to the north, has yielded many artifacts. At 12 o'clock, the flat surface on the skyline is a remnant of a widespread ancient surface of Pleistocene erosion and deposition, now mostly cut down and worn away by the modern stream system.

0.4

64.5 Culvert. Fort Stanton is visible up the valley in the distance, at 10 o'clock. About half a mile upstream on the left is the entrance to Fort Stanton Cave, said to be more than 4 miles long. Sierra Blanca in the distance, up the valley.

0.4

64.9 Bridge over the Rio Bonito. Fort Stanton lies about 2 miles to the south. It was established in 1855 as a headquarters for the campaigns against the Mescalero and Gila [HEE-la] Apaches. The post was abandoned during the Civil War and partly burned by Union forces; later it was briefly occupied by the Confederates. From 1899 to 1953, it was used by the U. S. Public Health Service as a tuberculosis sanatorium for merchant seamen. In 1953, it was taken over by the New Mexico Department of Public Welfare, later by the State Tuberculosis Hospitals Board.

Between the Rio Bonito bridge and Fort Stanton Junction, you cross beds of the Artesia Formation, 350 feet thick (best seen east of Roswell on the Bottomless Lakes trip). The formation consists of reddish siltstone, thin limestone, and thick gypsum beds, so easily eroded that they do not crop out well. They lie upon the San Andres Limestone and comprise the uppermost beds of the Permian System of rocks in this area.

Approaching the junction, you leave the Permian rocks, which dip down to the west beneath the younger rocks occupying the center of the Sierra Blanca synclinorium, and cross rocks of Triassic age, known as the Santa Rosa Sandstone (300 feet thick). Primitive reptiles abounded on the river flood plains that crossed the wide, flat, semiarid terrane of Triassic time, about 160 million years ago.

1.3

66.2 STOP C. Fort Stanton Junction; historical marker. The knolls on either side of the highway are capped by a bed of pebble conglomerate (cemented gravel), which is in about the middle of the Santa Rosa Sandstone. This pebble bed provides one of the geological problems of the Southwest. It is generally thin (here not more than 6 feet thick), but it,

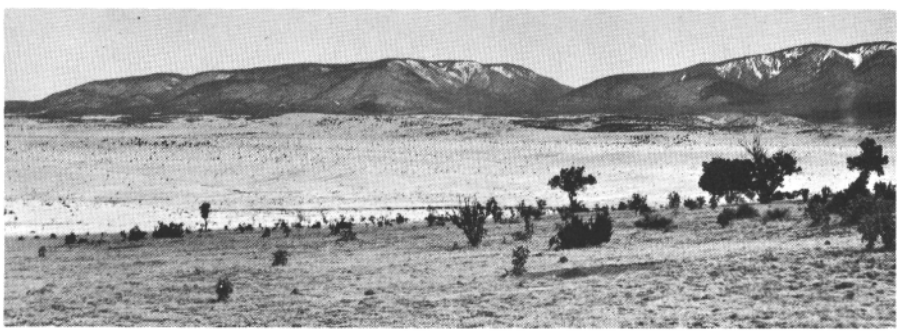
or a similar bed, appears in New Mexico, Utah, Arizona, and Colorado, covering hundreds of thousands of square miles. In parts of Arizona and Utah, a similar bed is known as the Shinarump Conglomerate, or Moss-back Conglomerate, and contains valuable uranium deposits (none found here as yet!) How a thin sheet, made up of pebbles derived from some long-vanished mountain range in southwestern Arizona, could be so widespread and so thin has not been satisfactorily explained. You can pick up pebbles in the roadcut west of the junction or climb either of the hills to see the rock in place. Notice how the pebbles vary in kind (chert, quartzite, igneous rocks). They are so well rounded and polished that they probably traveled hundreds of miles in the Triassic streams.

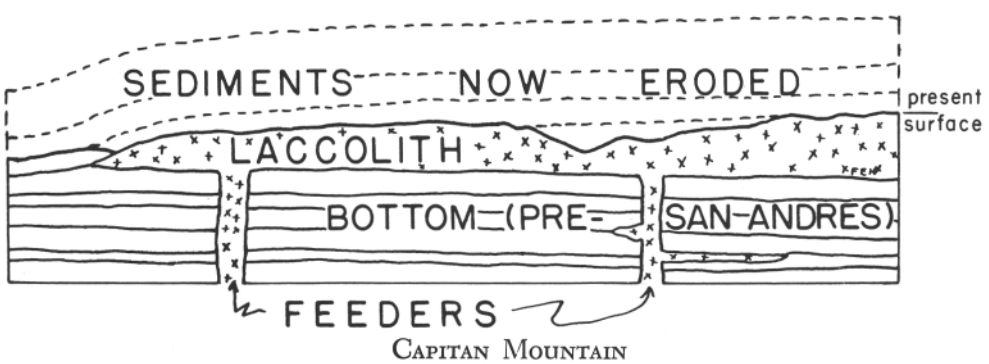
0.5

66.7 Capitan Mountain, from 2 to 4 o'clock, can now be seen in its entirety; a long igneous mass, shaped like an inverted canoe—a laccolith. The rock resists erosion so much more than the surrounding sediments that it dominates the horizon in this area (alt. 10,023 ft at the east end).

0.1

66.8 On right is Smokey Bear vista. Lincoln National Forest was the birthplace of Smokey Bear. The highway now traverses the south edge of plains eroded by the Rio Salado. The Santa Rosa Sandstone and conglomerate form the low black cliff at 3 o'clock. Farther west, the red Chinle shales, 180 feet thick, can be seen. Both are formations of the Dockum Group of Triassic rocks. The cliffs ahead are of Dakota Sandstone (134 feet thick),





CAPITAN MOUNTAIN

the lowest formation of the Cretaceous System of rocks. The sandstones lie upon the Chinle shales but are separated from them by a time gap of many millions of years during which no rocks were deposited and erosion dominated. This kind of contact between formations is known as an *unconformity*. The Dakota is Late Cretaceous in age, the Chinle is Late Triassic. The entire Jurassic System of rocks, which is several thousand feet thick in northwestern New Mexico, and the Lower Cretaceous rocks, many thousands of feet thick in southwestern New Mexico, are entirely missing here!

The Late Cretaceous seas were the last extensive marine bodies to cover much (about 50 per cent) of the North American continent; New Mexico was completely submerged. The rocks deposited in those seas, however, have largely eroded away in the 70 million years since the Cretaceous Period. Except in the San Juan Basin in the northwestern part of the State, they remain only in small patches, such as in the Sierra Blanca synclinorium.

1.0

67.8 The even crests of the cliffs ahead and of the hills to the south (left) are due to the long period of Pleistocene erosion mentioned at mile 64.1. This erosion beveled the sedimentary rocks of the region after they had been folded. The upland surface was covered at one time with a thin layer of gravel and formed a plain sloping gently eastward. Only such peaks as Capitan, Tucson Mountain (the high peak at 1 o'clock), and the volcanic hills west of here stood above the plain. Subsequent erosion by the present streams has left only remnants of the gravels capping the ridges.

0.5

68.3 Rodeo Bar. Notice erosion channels in red Chinle shale at 2 o'clock. Landslides of Dakota Sandstone from the cliffs above are almost always present and cover most of the outcrops of the soft and weak red Chinle shale. Landsliding caused the hummocky topography on both sides of the Rio Salado at this point. To the north (right), notice the low terraces along the river.

0.3

68.6 Junction with Capitan Gap road. This road cuts through the Capitan Mountains in the low pass at 4 o'clock.

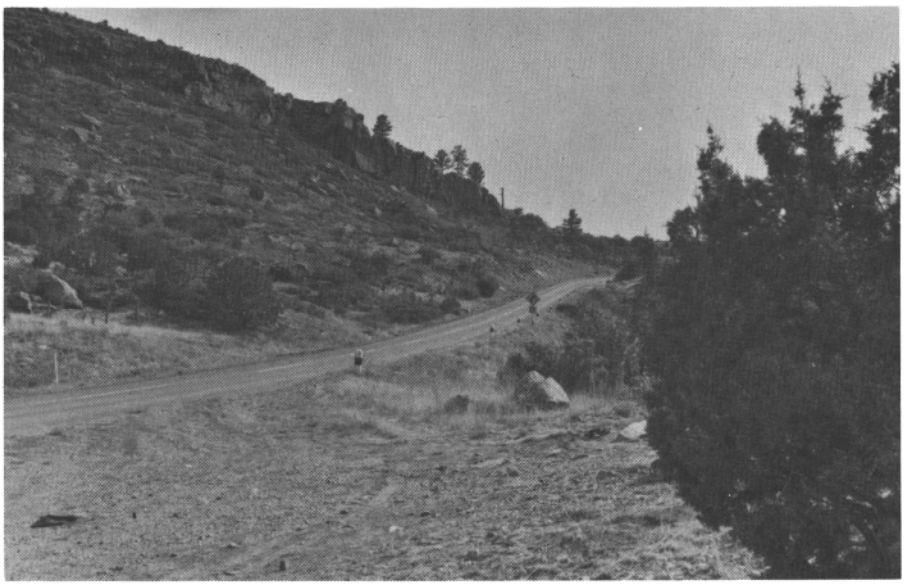
0.4

69.0 Roadcuts in red Chinle shale. You are approaching the contact between the Chinle and the overlying Dakota Sandstone. Prepare to stop at turnout (right) near large landslide boulders of Dakota Sandstone.

0.5

69.5 STOP D. The road cuts mostly through rocks called *Chinle.* The several feet of thin limestone are probably of fresh-water origin; the limestone contains chert nodules and is irregularly bedded, with silty layers between

the beds. The unconformity (mile 66.8) lies above these limestone beds. The black coating on the Dakota blocks next to your car is "desert varnish," a surface film caused by the slow withdrawal of minerals from the sandstone because of alternate wetting and evaporation. Minerals (mostly iron and manganese oxides) are dissolved during the wetting and then brought to the surface to be reprecipitated during drying.



DAKOTA CLIFFS ON SKYLINE

If you walk up the road to the crest of the hill, you will see the gradation from the Dakota into the next higher formation, the Mancos Shale, which is nearly 400 feet thick. The sandstone beds get thinner and the shale beds become gradually thicker, until the rock is almost entirely shale. The contact is drawn at the point where shale becomes more than 50 per cent of the beds. Also at the crest of the hill are dikes of igneous rocks cutting through the sandstone. These are the first of hundreds of such dikes in the Cretaceous and later rocks exposed in the next 10 miles.

0.2

69.7 Top of hill. Roadcut in Dakota Sandstone; in the sandstone are dikes which, like most of the dikes in this area, trend about 20 degrees east of north. You are now looking across the Capitan Valley, cut in Mancos Shale. Cliffs of the Mesaverde Formation, nearly 600 feet thick, which overlies the Mancos, are visible west of the town of Capitan. The Mancos Shale includes thin beds of limestone in its lower part (note low knoll at 11 o'clock), which contain clams and, rarely, ammonites—those strange coiled shellfish related to our modern chambered nautilus and octopus. The Mancos Shale generally underlies a valley, because shale is less

resistant to erosion than the sandstone beds above (west) and below (east).

0.3

70.0 Culverts over deep arroyos. This gully cutting is said to have been initiated in the late 1880's. It has lowered the water table in the valleys over much of New Mexico and Arizona so that the rich meadow grasses reported by early travelers are no longer abundant. You will notice farther along the route the extensive efforts to curb erosion by tearing down the juniper trees and throwing them into the gullies. This is an experimental project of the U.S. Soil Conservation and Forest services. It is also hoped this will increase the amount of grass by making available the water and space that the junipers would use.

0.2

70.2 Cross bridge; enter Capitan. This is the home of "Smokey Bear." As the sign states, "A little bear cub, his feet badly burned, was rescued from a forest fire near here (in Capitan Gap) in 1950. The cub was nursed back to health and flown to Washington, D.C., to become the living symbol of Smokey the Bear in the U.S. Forest Service's fire prevention program."

Capitan was named for the Capitan Mountains. In 1897, the former El Paso and Northeastern Railway built a line to nearby coal deposits. At that time, the village was called Gray, after a local homesteader and rancher. The town is now a center for stockraising, farming, some mining, and hunting in the nearby mountains.

0.5

70.7 Smokey Bear Museum on right features exhibits of the natural resources of Lincoln County.

0.5

71.2 Leaving Capitan; entering the Capitan coal field. Notice the old mine dumps at 2 o'clock. Reserves for the region are estimated at more than a billion tons of bituminous coal, with more than 2 million tons in the Capitan area. These mines were operated in the late 1890's and early 1900's by the New Mexico Fuel Co. and other operators. The coal was shipped over a spur line to Carrizozo, 30 miles to the west, where it joined the present main line of the Southern Pacific Railway. The mines in this area produced an aggregate of more than 600,000 tons of coal.

The low, dark ridge ahead from 10 to 2 o'clock is not Mesaverde sandstone; it is a sill, a layer of igneous rock formed between the sandstone beds as molten lava, where it cooled. You are now leaving the Mancos Shale and going up into the Mesaverde Formation, which consists of sandstones, shales, and coal beds, nearly 600 feet thick.

0.6

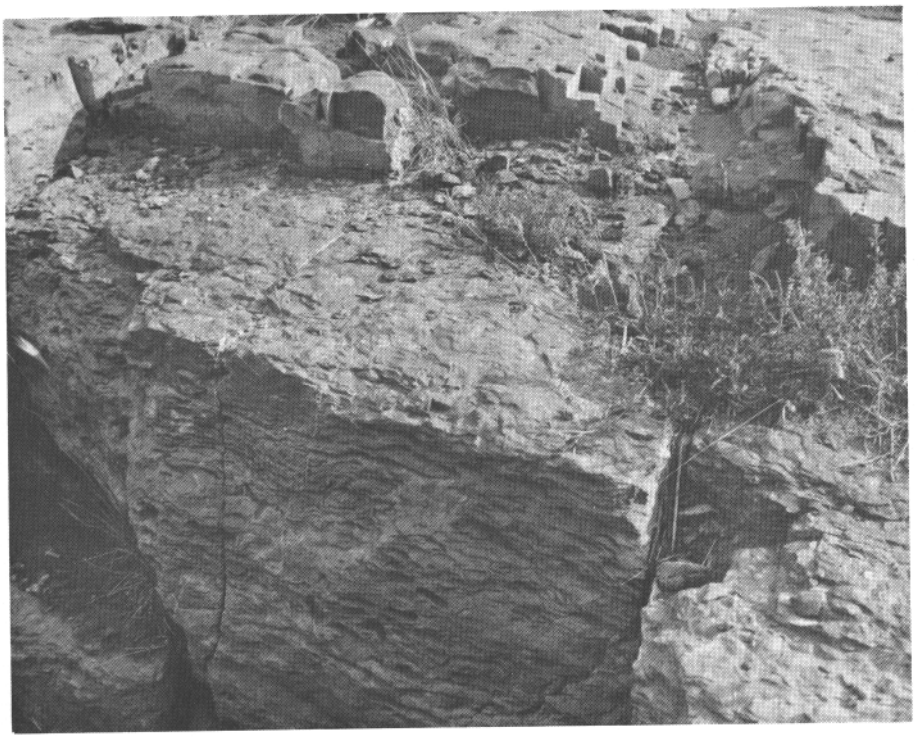
71.8 Outcrops of sill (dark andesite porphyry) on right.

0.7

72.5 Cross bridge over Oso (Bear) Creek. STOP E, beyond bridge. West-


SMOKEY
SMOKEY

dipping ridges of Mesaverde sandstone contain abundant fossils for the collector. One layer in the stream bed, 150 feet upstream from the bridge, is made up almost entirely of small oyster shells. Giant clams (more than 8 inches across!) occur in the white sandstone just west of the bridge.



FOSSILS IN SANDSTONE

0.3

72.8 Roadcut, with large dike cutting across the west-dipping sandstones. Almost every roadcut for the next 9 miles shows similar dike intrusions. The hills on the skyline from 10 to 11 o'clock are of Tertiary volcanic rocks that overlie the sediments in the center of the Sierra Blanca synclinorium. The highway skirts the northern edge of this area of old volcanoes.

0.8

73.6 Roadcut in purple siltstone. This is the lower Tertiary Cub Mountain Formation, named for Cub Mountain south of Carrizozo, where good outcrops show that its maximum thickness is at least 2200 feet! It overlies Cretaceous rocks and underlies the andesite volcanic rocks of the Sierra Blanca area. It consists of white, sugary sandstones and thin beds of conglomerates, in addition to the purple and maroon siltstones. These sediments were laid down in landlocked basins and lakes.

0.3

73.9 Roadcuts in the Cub Mountain Formation, cut by dikes.

0.8

74.7 Culvert across the Rio Salado, here called Salado Creek.

0.2

74.9 Roadcut exposing a west-dipping sill of pale-yellow rhyolite (a siliceous igneous rock). This is probably a tongue from a large siliceous laccolith similar to the Capitan laccolith.

0.9

75.8 Cub Mountain purplish siltstone in roadcut. Along the highway within 10 miles west of Capitan, there are nearly 300 dikes, averaging 15 feet in thickness. The crust of the earth must have been pulled apart almost a mile within this 10-mile stretch to have permitted these dikes to shove their way into their present positions.

0.9

76.7 Nogal Lake Junction. Three miles south on this road is the famous Nogal Mesa Ranchman's Camp Meeting grounds. An annual 5-day nondenominational religious meeting is held in July for ranchers from all parts of southeastern New Mexico.

0.5

77.2 Indian Divide (alt. 6996 ft). CAUTION: Sharp curves on downgrade. The road crosses a large fault, a break in the crust of the earth, along which movement has taken place. Here the slippage has brought Mesaverde rocks up to the surface again west of the fault with a displacement (movement) of at least 200 feet. Several such faults have been crossed in the last 6 miles, one having a displacement of more than 500 feet. Notice the old railroad grade on the left, and the sharp point of Nogal Peak on the skyline.

O.4

77.6 Mesaverde shales intruded by small dikes. Railroad grade to left makes a sharp switchback up the canyon to the south.

0.3

77.9 Coal-bearing Mesaverde shales, cut by numerous dikes. Here the shales dip south beneath the Cub Mountain Formation, which makes up the south wall of the canyon.

0.5

78.4 Contact between Mesaverde yellowish sandstone and overlying Cub Mountain purple siltstone and white sandstone in the long roadcut just before the sharp bend.

0.4

78.8 STOP F. Pull off to right just before reaching roadcut. Five dikes along old road are exposed in this single roadcut in the Cub Mountain sand-

DIKES CUTTING CUB MOUNTAIN SANDSTONES

stone! This is a good rock exposure to photograph because of the contrast between the white sandstone and the black igneous rock.

0.5

79.3 Boundary marker of Lincoln National Forest. Nogal Peak, the sharp high peak, at 9 o'clock.

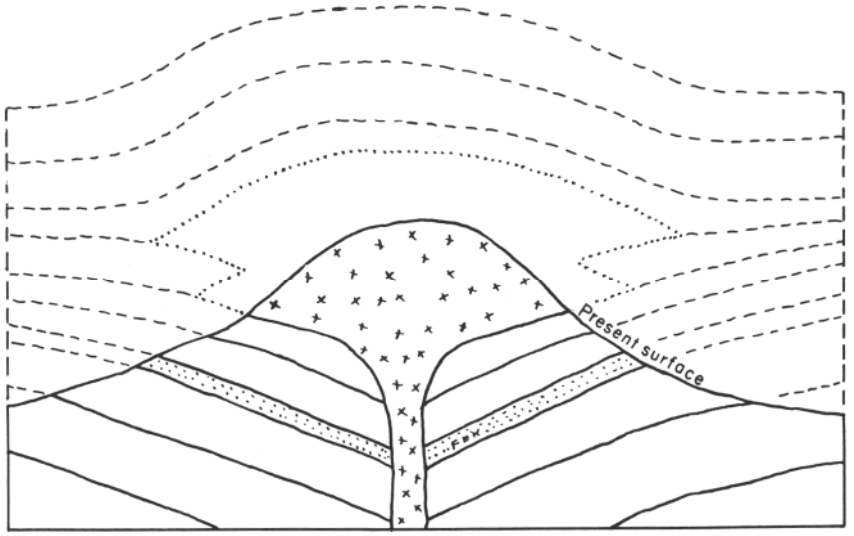
0.6

79.9 Road cuts a large rhyolite dike, which extends to the north, forming the high ridge for nearly 2 miles. You are now crossing the divide toward the Tularosa (Reed Rose) Basin, a long wide depression that extends south beyond Alamogordo and White Sands. It is bounded on the east by the Sierra Blanca and Sacramento mountains, and on the west by the San Andres and Oscura mountains. Most of the basin lies within the White Sands Missile Range and is "off limits" for civilians.

81.2 1.3

Gate on right. This road leads to the old mine workings on Vera Cruz Mountain, the rounded peak at 3 o'clock. Vera Cruz Mountain is a small laccolith that arched the bedded rocks above into a dome. The intrusion brought in gold-bearing juices that deposited the gold mined here in the early part of the century.

At 2 o'clock is the high mass of Carrizo Mountain (9656 feet), a much larger laccolith. The surrounding rocks dip inward beneath it; originally, they also arched up over it, as shown below.



CARRIZO MOUNTAIN LACCOLITH

Church Mountain, at 9 o'clock, probably had a similar origin.

1.2

82.4 Bridge of Nogal (Walnut) Creek.

0.4

82.8 Nogal Junction. KEEP STRAIGHT AHEAD. Coming back, we'll turn off toward Ruidoso from a visit to the Carrizozo malpais (badlands), or lava flow, now visible as a dark streak along the valley bottom far ahead. Those who cannot take time for this 30-mile round trip should turn left here and pick up the continuation of the road log at mileage 113.6.

The source of this large, recent Carrizozo lava flow is the small (from this distance) black knob at 1 o'clock. This is Little Black Peak, a volcanic cinder cone, from the base of which flowed most of the lava. The low light-colored ridges at 2 o'clock are rhyolite sills, probably derived from the Carrizo Mountain intrusive.

2.4

85.2 Siphon on left for water pipeline. Notice long, gentle slopes on west side of Carrizo Mountain at 3 o'clock. These are talus deposits (talus cones) composed of debris weathered from the steeper cliffs above. Their lower parts are reworked by the flash floods that wash down the mountain every summer in July and August to form alluvial fans. The profile is typical in semiarid areas. The ghost mining town of White Oaks lies in

a canyon just beyond Carrizo Mountain. On the historical marker ahead: "The crossroads of history-northeast is the ghost town of White Oaks, a once booming mining camp, where Emerson Hough lived and laid the scene of his book *Heart's Desire.* Famous names like Billy the Kid, Pat Garrett, and Lew Wallace are closely associated with the area."

5.0

90.2 Water tank for Carrizozo, on right.

0.3

90.5 Historical marker. Notice descent into the north end of Tularosa Basin. San Andres Mountains on skyline from 10 to 11 o'clock, Oscura Mountains from 11 to 12 o'clock, and Chupadera Mesa from 12 to 2 o'clock. East edge of Carrizozo (Carrizo, Spanish for "reed grass"; in 1907, James Allcook, a ranch foreman, added a "zo" to indicate abundance).

0.4

90.9 Southern Pacific Railway overpass.

0.2

91.1 Junction with U.S. Highway 54. KEEP STRAIGHT AHEAD. Town business district and Alamogordo (57 miles) to left; Santa Fe (168 miles) to right. Also to right, Gran Quivira (56 miles), Quarai (90 miles), and Abe (90 miles).

1.0

92.1 Leaving Carrizozo. Little Black Peak at 1:30 o'clock. The Carizozo lava flow, or malpais, is one of the youngest in the United States, comparing in recency of its outpouring with such flows as Craters of the Moon (Idaho), McKenzie Pass and Bend (Oregon), McCarty's flow (near Grants, New Mexico), Jornada flows (southwest of San Marcial, New Mexico), the Modoc lava fields (California), and the Capulin Mountain flow (northeastern New Mexico). In all probability, the Carrizozo lava flowed out within the last 1000 years. It did not come out all at once, however; it is made up of many "flow units," each representing individual rivers of lava. The flow is 44 miles long. To the northwest, it spreads out to a width of 3 to 4 miles, but 10 miles to the south is a narrows, about 10 miles long, where the flow is only a little more than a mile in width. Below the narrows, it spreads out again to a width of 10 miles. The average slope of the flow is 30 feet to the mile, its average width is 3 miles, and its average thickness is 42 feet, although in the center of the valley it exceeds 150 feet thick. The flow covers 127 square miles, and its volume is almost exactly 1 cubic mile.

The surface features you observe are those exhibited by fresh lava flows of basalt rock all over the world: Pressure ridges (where the hardened crust was arched up and broken), collapsed lava tubes (where the outer part of the flow froze and the molten liquid ran out, leaving an open tube or cave), and kipukas (a term used by Hawaiians for islands of older rock surrounded by a sea of lava; also called *steptoes).* Notice the

kipuka of Dakota Sandstone at 11:30 o'clock, where the Dakota dips eastward; you are now on the western edge of the Sierra Blanca synclinorium.

1.5

93.6 On left, abandoned mill of the New Mexico Copper Corp.

0.8

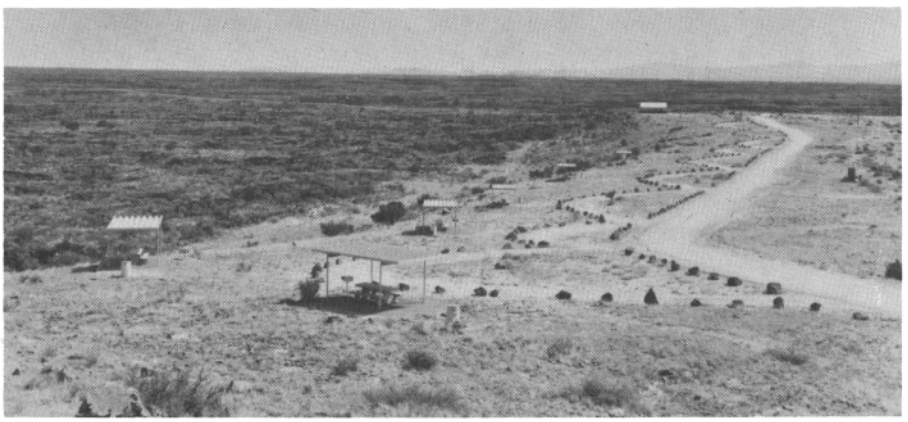
94.4 Bridge.

0.2

94.6 Sill of rhyolite intruding Mancos Shale, in low roadcut on left.

0.1

94.7 Edge of lava flow, here about 20 feet thick.



KIPUKA IN VALLEY OF FIRES

0.4

95.1 Entering kipuka of Dakota Sandstone forming hill at 9 o'clock. It is an island of Dakota Sandstone surrounded by the "sea" of the malpais basalt. You can look closely at the lava here, or there are many small turnouts along the highway. In a quarter mile, entrance to Valley of Fires State Park is on the left. It has rest rooms, playgrounds, many shaded picnic tables, and water. CAUTION: Do not park on the highway; always use the turnouts on the right, both going and coming. Notice that the vegetation on the basalt differs from that which you have been seeing. It is a typical Upper Sonoran assemblage: cholla and prickly pear cactus, yucca, greasewood, mesquite, and rabbit brush. The soil in which these plants grow was blown in by windstorms; the basalt rock is too young to have weathered at all.

1.7

96.8 STOP G. Historical marker; wide turnout and picnic table on right. Climb around on the lava and notice the ropy nature of the surface (pahoehoe of the Hawaiians), the numerous frozen gas bubbles in the rocks (vesicles), and the squeezeups where once-liquid lava came up through cracks in the hardened crust.

PAHOEHOE LAVA

1.2

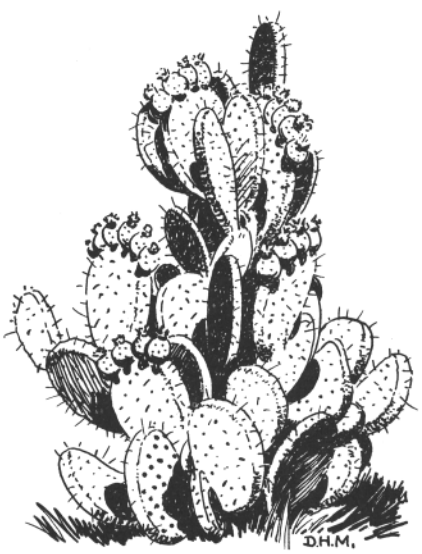
98.0 West edge of the basalt lava How.

0.2

98.2

TURN AROUND on wide turnout on left side of highway, near windmill. The bedrock is the San Andres Limestone, dipping to the east. The entire Dockum Group of rocks is hidden beneath the lava flow.

YUCCA (STATE FLOWER)



PRICKLY PEAR CACTUS

0.5

98.7 Turnout on left.

0.4

99.1 Turnout on right. The small animals that live on the lava flow are world famous. Most of the common types are darker than the same species in surrounding areas; inasmuch as the lava beds are relatively recent, this shows a rapid adjustment to environment. The dark mice, lizards, snakes, woodrats, rock squirrels, and kangaroo rats are in sharp contrast to the white species common in nearby White Sands.

0.5

99.6 Historical marker; turnout and picnic table on left.

0.4

100.0 Top of hill; highway crosses pressure ridge. White Oaks Canyon at 9:50 o'clock, Carrizo Mountain at 10, Vera Cruz Mountain at 11; Church Mountain at 12, Nogal Peak at 1, Sierra Blanca at 2, and Cub Mountain at 2:15.

0.6

100.6 Turnout opposite pressure ridge.

0.7

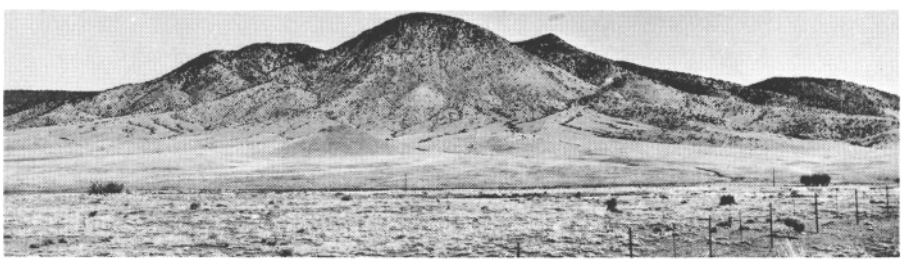
101.3 Side road to right to Valley of Fires State Park picnic area.

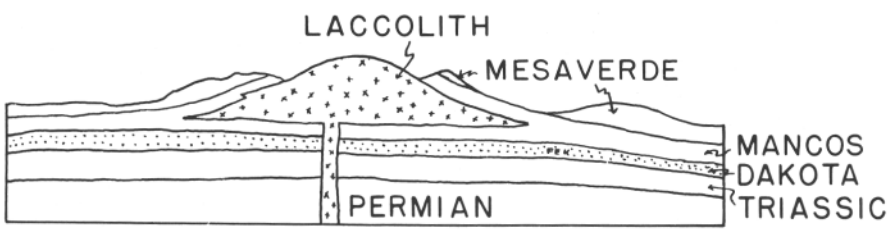
0.5

101.8 East edge of basalt flow.

0.2

102.0 Bridge.





VERA CRUZ MOUNTAIN

0.6

102.6 Carrizozo ahead. Village of White Oaks at 9 o'clock, Carrizo Mountain at 10, Vera Cruz Mountain at 2:15. Carrizozo is derived from the Spanish word "carrizo," the common reed grass that grows abundantly in the surrounding valley. The second "zo" syllable was added later. The town was set up by the El Paso and Northeastern Railroad in 1899; a round-house was erected, and the town became a supply center and shipping point.

2.0

104.6 Entering Carrizozo.

0.7

105.3 Junction with U.S. Highway 54; KEEP STRAIGHT AHEAD.

8.3

113.6 Nogal Junction. Turn right off U.S. Highway 380 onto State Highway 37 to Ruidoso (25 miles). Paved road except for 10 miles of graded gravel and dirt road between Nogal (Walnut) and Alto (High). CAUTION: Do not attempt this stretch after severe summer rainstorms; it can be exceedingly slippery.

1.5

115.1 Low hills from 1 to 3 o'clock are held up by south-dipping igneous rock sills in the Cub Mountain Formation and in volcanic rocks. Notice Ranchers Camp Meeting on skyline at 11 o'clock and Vera Cruz Mountain at 9 o'clock, underlain by east-dipping Mesaverde rocks (arched up by the Vera Cruz laccolith).

0.9

116.0 Prospect shaft in the Cub Mountain Formation, just below sill, at 3 o'clock. No ore visible!

0.6

116.6 Bridge. Low hills on either side of road are expressions of igneous rock sills intruded between beds of the Cub Mountain Formation.

0.8

117.4 Entering Nogal, a ghost town, relic of the mining days of the 1880's and 1890's; the mines are up the canyons to the southwest (2 o'clock).

0.4

117.8 "Ford" Dry Gulch (mines are $2^1/2$ miles up this canyon). Church Mountain at 3 o'clock.

0.3

118.1 "Ford" Nogal Creek. We are above the Cub Mountain Formation which dips south beneath the Tertiary lavas; the outcrops between here and the top of the hill are the andesitic (purple to green rock) volcanic flows, breccias, and agglomerates that make up the main mass of the Sierra Blanca to the south.

0.1

118.2 Junction with road up Nogal Creek. Keep left; steep crooked grade, rising 600 feet in 2 miles. This is the only really bumpy part of the road on the entire loop route.

0.3

118.5 Cattle guard; boundary of Lincoln National Forest. Notice juniper and pinon forest interspersed with grassy meadows.

JUNIPER

1.6

120.1 Top of grade. We are about to cross a major fault along which the volcanic rocks on the west were dropped down against the Mesaverde Formation on the east. Here the displacement is probably more than 500 feet and may be as much as 1000 feet.

0.2

120.3 Road curves to right. Cross fault. Behind, andesite crops out in low roadcuts; ahead, on left, Mesaverde tan sandstone crops out. If you collect specimens of each, notice that the sandstone is granular and shows thin bedding, whereas the andesite has scattered lathlike crystals of feldspar and small, dark needles and plates (weathered greenish) of hornblende and biotite, all in an earthy matrix. Coal beds crop out in the creek bed below the road, on the right. A large spring on the fault zone feeds the grassy patch in the canyon at 4 o'clock.

0.2

120.5 Curve to left; ranch road joins highway from right.

0.1

120.6 Nogal Lake junction. Picnic and camp grounds half a mile to left. Nogal Lake was formerly a reservoir for the pipeline from Bonita Dam, 8 miles to the south. The dam was built by the Southern Pacific Railway to supply water to the division yards at Carrizozo and to the town. One branch of the pipeline originally went as far north as Vaughn, a distance of 95 miles! A new pipeline was completed in 1956 to Alamogordo, 57 miles south of Carrizozo, and the lake is no longer used as a reservoir. Water is one of the chief problems of the Southwest!

0.6

121.2 Bridge. Notice the numerous low ridges held up by dikes in the Mesaverde Formation. Deep gully to right.

0.7

121.9 Junction. Turn right across bridge; follow sign to Ruidoso (Noisy). Road straight ahead goes back to Capitan (6 miles).

0.6

122.5 Bridge. Outcrops across valley amid trees at 2 o'clock are Mesaverde sandstone beds, dipping east.

PIÑON NEEDLES

0.5

123.0 Culvert. Rocks at 3 o'clock are Mesaverde sandstone and crop out sparsely west of the road for the next mile.

0.4

123.4 STOP H. Viewpoint at top of hill. The main mass of Sierra Blanca occupies the skyline from 12 to 3 o'clock. The entire length of the Capitan Mountain laccolith can be seen from 7 to 8 o'clock, and the pediment gravel surface, cutting across all the other sediments in the area, shows clearly on the skyline from 8 to 10 o'clock. The hill at 9:30 o'clock is a resistant volcanic mass, as are the hills from 6 to 7 o'clock. Mesaverde sandstones crop out along the road.

0.4

123.8 Bridge at bottom of hill; white buildings to left. Pipeline follows the road for several miles.

0.2

124.0 Bridge; pipeline and ponderosa pine on right. Mesaverde sandstone beds cross the road near here and veer off to the east.

0.3

124.3 Road right to ranch.

0.6

124.9 Bridge. Road leaves outcrops of sedimentary rocks and enters a volcanic terrain again. Probably a fault causes the abrupt change, but this area has not been mapped in detail as yet.

1.2

126.1 Ranch road to right. Cross bridge. Huge ponderosa pine on left. Notice contour-terraced field on right.

0.5

126.6 Small bridge amid pine forest.

PONDEROSA PINE

0.4

127.0 Roadcuts in sandstone for a short distance.

0.4

127.4 Road junction, along Rio Bonito (Pretty River) valley. Turn left. The Bonito dam is 4 miles to the west and can be reached by forest road. Picnic and recreation grounds at the lake were opened in 1957.

You are almost directly east (54 miles) of the site of the first atomic-bomb test. The explosion occurred at 5:29 a.m. on July 15, 1945, in the northern part of an intermontane valley aptly called Jornada del Muerto (Journey of Death), about 36 miles southeast of Socorro.

1.4

128.8 Road junction; turn right. End of unpaved road. Road leaves volcanic rocks and enters outcrops of the Cub Mountain Formation, whose purple siltstones can be seen in the large roadcut to the left. State Highway 48 to left goes back to Capitan (13 miles).

0.1

128.9 Bridge across the Rio Bonito.

0.2

129.1 Road junction to town of Angus and Church of Nazarene summer camp.

0.2

129.3 Mesaverde shales between dikes in road cuts.

0.2

129.5 Thin coal beds in Mesaverde shale and sandstone between here and the top of the hill; cut by numerous dikes and sills. Most of the dark rocks are sedimentary; the light rocks are igneous.

1.0

130.5 Top of hill. Intrusive granitoid rocks of Sierra Blanca can be seen on the skyline from 2 to 3 o'clock.

0.5

131.0 Roadcut in the poorly exposed transition beds from the Mesaverde Formation into the Cub Mountain Formation, which crop out over much of the route between here and Ruidoso.

0.7

131.7 Roadside picnic table on left. Cub Mountain transition beds in roadcuts from here to top of hill.

0.7

132.4 Top of hill; sawmill on right, below summit.

0.5

132.9 Alto (High) Post Office, on Eagle Creek. State Highway 532 to right leads to Mon Jeau Lookout (8 miles; alt. 10,000 ft) and Sierra Blanca ski and recreation area (12 miles) on the crest of Sierra Blanca. The views along the steep forest road are highly rewarding, as is eating lunch on the skyline ridges.

White sandstones of the upper Mesaverde and lower Cub Mountain formations crop out from here to top of hill.

1.1

134.0 On left, white sandstone and multicolored siltstone here and in roadcuts since Alto have been cut by dikes. Steep downgrade for 1 mile; drive slowly. Beautiful forest, chiefly of tall ponderosa pines.

2.1

136.1 Ruidoso airport junction. The airfield is in the Mancos Shale. The roadcuts since the top of the hill have been of the Cub Mountain Formation and volcanic rocks. As these are not normally adjacent, we must have crossed a large fault which brought them into contact. The downdropped side is on the west, and the Mancos Shale has been brought up on the east. The hills on the other side of the valley are of west-dipping Dakota Sandstone, which normally underlies the Mancos, but it too is abruptly faulted off farther east, so that the skyline is composed of San Andres Limestone. This fault will be seen farther along the route.

1.0

137.1 Ruidoso Ranger Station on right. Ruidoso city limits.

0.5

137.6 Ruidoso golf course junction. Turn sharp left for 2 miles of good road which avoids the downtown traffic in Ruidoso (Noisy) and allows viewing some interesting geologic features.

0.2

137.8 Turn left at T-Junction.

0.5

138.3 Paradise Canyon road. Keep straight ahead past golf course.

0.2

138.5 Golf course clubhouse. Course is in west-dipping Mancos Shale.

0.2

138.7 Turn sharp left uphill to Ruidoso Lookout Tower.

0.4

139.1 STOP I. Parking area. Trail to tower, 300 feet. (Do not drive beyond parking area!) A panorama of the peaks that cap the Sierra Blanca range is visible from the tower. Sierra Blanca Peak (alt. 12,003 feet) lies just

north of due west; Mon Jeau lies northwest. The tower is set on San Andres Limestone. The fault lies in the saddle just west of the parking area; the west end of this hill is composed of Dakota Sandstone.

0.3

139.4 Lookout Tower junction. Turn left; down steep hill, several sharp curves.

0.3

139.7 STOP J. Park on either side of bridge over the Rio Ruidoso. The cliff at 9 o'clock is Dakota Sandstone for about 300 feet from the road; then the Ruidoso fault cuts it off abruptly, and the rocks beyond, as well as the upper cliffs, belong to the San Andres Limestone. The movement along this fault must have been at least 700 feet. The entire section of Triassic rocks is cut out. If you walk down past the cave, you can put your hand on the fault surface.

0.1

139.8 STOP. Junction with State Highway 37. Downtown Ruidoso to the right. Turn left.

0.1

139.9 Cliff of San Andres Limestone beneath Lookout Tower at 9 o'clock.

1.4

141.3 Entrance to city picnic grounds on right.

0.2

141.5 Junction. Keep straight ahead. Road to right is a shortcut to Tularosa and Alamogordo. Along the valley, the upper part of the hills is San Andres Limestone, whereas the lower slopes are the Yeso Formation.

0.9

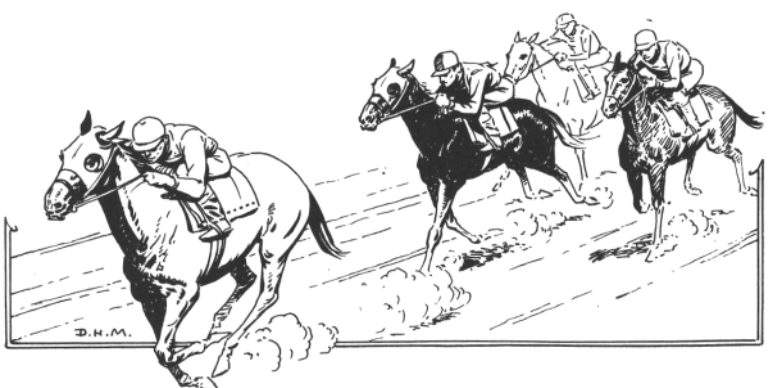
142.4 STOP. Main junction with U. S. Highway 70. Bear left to Roswell. Road to right leads to Tularosa (32 miles) and Alamogordo (44 miles).

0.2

142.6 Enter Ruidoso Downs.

1.0

143.6 Entrance to Ruidoso Downs racetrack on left.



0.4

144.0 Entrance to Ruidoso Downs Heights (!) on

1.5

145.5 Divided highway ends; red and yellow beds of Yeso Formation in right roadcut. Highway is up on terrace and alluvial fan gravels that border the south side of Rio Ruidoso Valley. The Hale Spring (230 gallons a minute), one-quarter mile south of the highway, once fed an Indian acequia (ah-SAY-kee-ah, irrigation ditch), possibly as much as 900 years old, that skirts the foothills from 2 to 3 o'clock on the Agua Fria (Cold Water) Estates. Segments of the caliche deposits formed from lime precipitated in these irrigation ditches are visible just inside the entrance to the Estates.

0.3

145.8 Folded beds of the Yeso in right roadcut overlain by U-shaped channel-fill of boulder gravel deposited by an ancient higher level of Rio Ruidoso and its side streams.

0.3

146.1 High roadcut on right of interbedded gravel and reddish silt deposited as old alluvial fans derived from streams entering Ruidoso Valley from the south. Notice abrupt transition from silt to coarse gravel.

1.2

147.3 Side road to right to Half Lake. Roadcuts ahead on right are alluvial gravel and silt. Dislocated blocks of Yeso and San Andres limestones are strewn on the other side of Ruidoso Valley as landslide blocks.

0.6

147.9 Bridge over Rio Ruidoso.

0.3

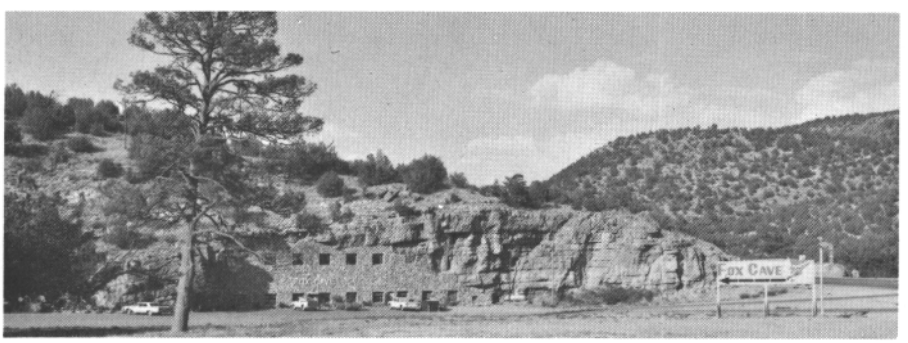
148.2 Begin roadcuts on left in Yeso gray gypsum and limestone, red shale, and yellow sandstone.

1.3

149.5 On broad S-curve to right, then to left, San Andres Limestone dips westward down to road level. Entering the west flank of a syncline and the east side of an anticline.

0.7

150.2 Fox Cave turnoff on left. Walled-up overhang of San Andres Limestone.



Fox Cave

0.2

150.4 Roadcut on left; greenish-gray igneous sill where liquid lava squeezed between beds of the San Andres limestones and solidified. Cut by channel-fill of alluvial gravels with vertical contact of bedrock and gravels along sides of ancient stream channel.

1.2

151.6 Deep roadcut in San Andres Limestone with igneous dike at west end.

1.2

152.8 Leaving Lincoln National Forest. Roadcuts on left, alluvial gravel and silt plastered on bedrock. Lower rocks are greenish-gray igneous sill that show rounded bouldery (spheroidal) weathering in contrast to pitted cavernous weathering of San Andres limestones. Upper cliffs are of limestone; contact with sill is along bedding planes, limestone being silicified and partly engulfed in the sill.

1.2

154.0 Outcrops of Yeso Formation in left roadcuts. The San Andres Limestone, rising on the east limb of the syncline, is now above the highway level. Apple orchards in valley on right.

0.4

154.4 Roadcuts in alluvial gravels.

0.5

154.9 Glencoe Post Office on right. Many apple and cherry orchards.

0.7

155.6 Road junction. Continue straight ahead. Road on left leads to Fort Stanton (9 miles). Gravel terrace above road ahead was the site of a prehistoric Indian village excavated in 1956 by archaeologists from Texas Technological College. Yeso outcrops in roadcuts.

0.3

155.9 Dumps from excavations at 10 o'clock. Notice lenses of stream gravel in terrace deposits in the roadcut.

1.2

157.1 Bridge. Many roadcuts in alluvial gravels.

1.7

158.8 Bridge. San Andres Limestone caps canyon walls; Yeso Formation on lower slopes.

1.2

160.0 White gypsum of Yeso Formation in roadcut on left. Notice terraces along sides of valley.

0.4

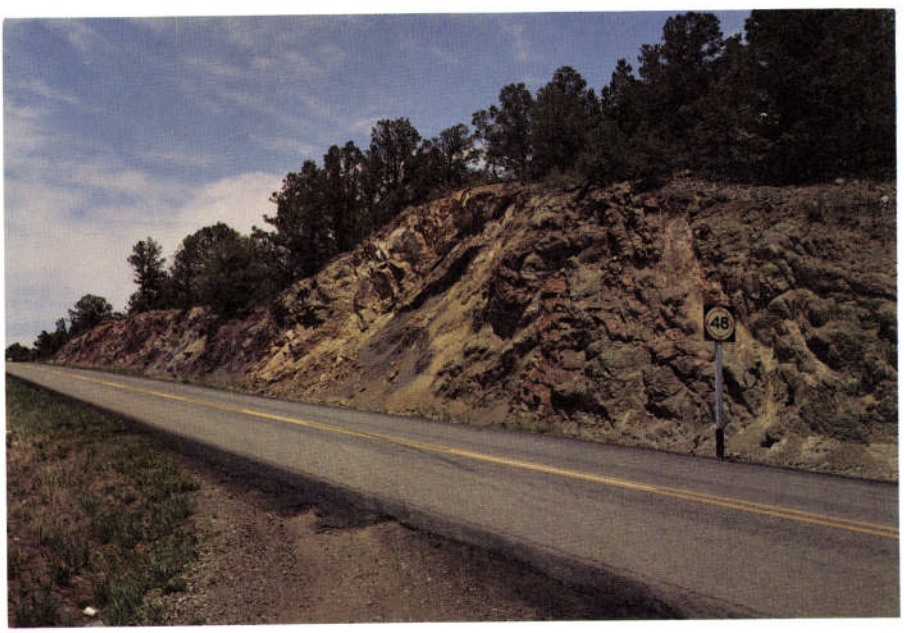
160.4 Yeso beds tilted in all directions (landslide?).

1.0

161.4 Contorted beds of Yeso Formation. Lincoln-type folds.

0.7

162.1 Entering San Patricio. Home of Peter Hurd, famous Southwest artist and an ardent palomino polo player, lies across the Rio Ruidoso.



Cub Mountain Formation at Mileage 128.8

Ruidoso Downs Action

1.8

163.9 Landslide block of San Andres Limestone in roadcut (has slid down at least 300 feet).

1.6

165.5 Entering Hondo (Deep).

0.6

166.1 Junction with U. S. Highway 380. Keep right. For the rest of the trip to Roswell (48 miles), read the first part of the road log in reverse (mileages 48 to 0).

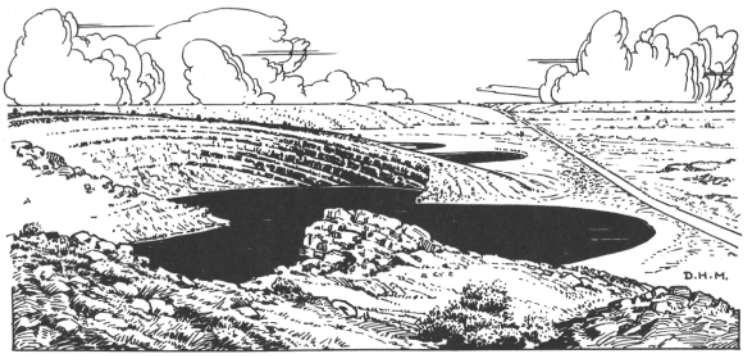
48.0

214.1 Center of Roswell. Main and Second streets.

Bottomless Lakes Side Trip

35 miles

The side trip to Bottomless Lakes leads to an area of considerable geologic interest. Additional attractions are the numerous camping and picnic sites among the seven beautiful lakes and swimming, boating, and horseback riding centered at the largest, Lea Lake, where there is a well-developed recreation area and a large pool with lifeguard.



0.0 Intersection of Main and Second streets in the heart of Roswell. Drive east on U.S. Highway 380. For the next 5 miles you will be on the wide, high Pleistocene (Ice Age) flood plain (now a terrace above river level) of the Pecos River. The Pecos Valley is cut in sedimentary rocks laid down in an ancient arm of the Permian sea about 225 million years ago. This arm of the sea, similar to the present Baltic Sea, was at times cut off from the open ocean and dried up, depositing its contained salts as beds of gypsum and other salines interspersed with reddish silts of the Artesia Formation. The whole area was later tilted very gently to the east (only 2 or 3 degrees), and the Pecos Valley was cut in these Permian sediments. Originally, the Pecos River probably flowed several miles west of Roswell, but the tilt of the beds caused it to move ever eastward as its cutting action continued, until the river attained its present course.

2.5 2.5
Roswell city limits.

3.1 0.6
Side road to left (north) to Bitter Lake National Wildlife Refuge.

3.6 0.5
Junction. Keep straight ahead. Road to south to East Grand Plains. Notice irrigated cotton and alfalfa fields. The water used for irrigation is obtained from Pecos River Valley alluvium and from the San Andres Limestone at depths of 100 to 700 feet; it originates high on the east slopes of the Sierra Blanca and Sacramento mountains many miles to the

Artesia Formation on Comanche Hill (Mileage BL 7.7)

Figure Eight Lake (Mileage BL 14.7)

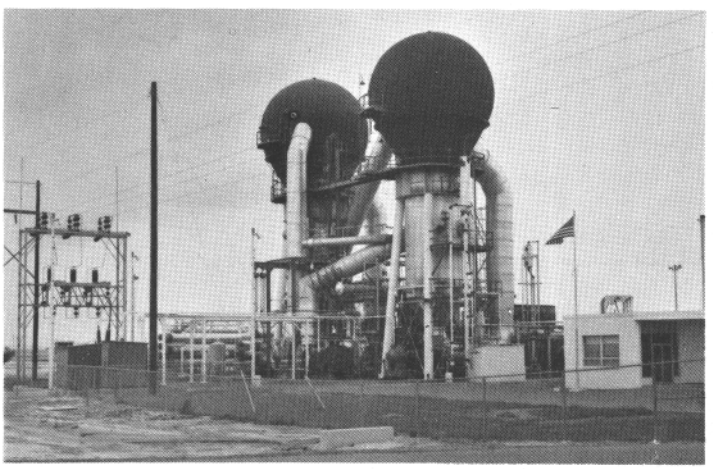
west. As more and more water is used, the underground water is actually "mined" and must be sought at increasing depths. This depth to underground water has increased by more than 50 feet in the last few years, and many wells have had to be deepened.

1.0

4.6 The road now drops down from the upper valley terrace (Orchard Park terrace, 20 to 55 feet above the present flood plain) onto the lower terrace of the valley (Lakewood terrace, 10 to 30 feet above the flood plain). The lower terrace possibly was cut during a rainy period of the later part of the Pleistocene Ice Age.

0.4

5.0 On left is salt water conversion plant, saline water purification. This is one of the four saline water demonstration plants built in the nation in the early 1960's to investigate methods of making pure water from salt water. This plant produces one million gallons a day. Information is available at the plant's visitors' center.



SALT-WATER CONVERSION PLANT

0.2

5.2 The road here drops down onto the present flood plain of the Pecos River. On the skyline ahead are outcrops of reddish siltstone and gypsum beds. Look back to right to see edge of Lakewood terrace.

0.8

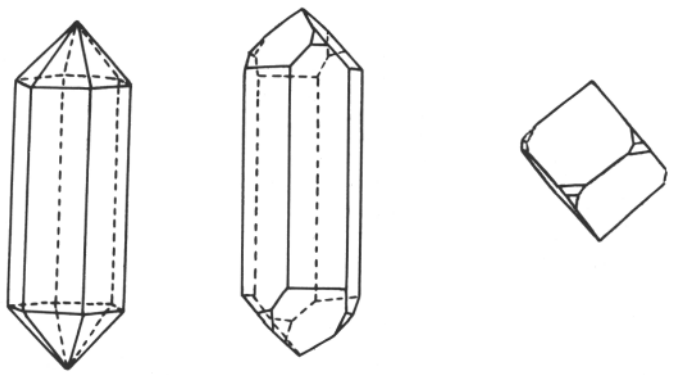
6.0 The tamarisk, or salt cedar, growing on the flood plain was brought into this country many years ago from Spain. In many places it is now regarded as a pest because it uses up much of the underground water and grows so rapidly.

1.1

7.1 Bridge across the Pecos River. Headwaters are northeast of Santa Fe in the Sangre de Cristo Mountains.

0.6

7.7 Ascending Comanche Hill on the east wall of the Pecos Valley. Roadcuts are in pink, green, and red siltstone beds and grayish gypsum layers of the Artesia Formation. This formation is noted for the small, perfect, doubly-terminated quartz crystals ("Pecos diamonds") found for nearly 100 miles along the east side of the Pecos Valley, from Dunlap in De Baca County to the north across Chaves County to just south of Artesia in Eddy County. In areas where the gypsum beds come to the surface, one can see the sparkle of quartz crystals on a sunny day; gypsum crystals also reflect sunlight. Good quartz crystals are not easy to find, as many of them are imperfect; they are prominent, however, in the collections of many mineralogists. Quartz crystals are described by Albright and Bauer in the July-August (1955) issue of the *Rocks and Minerals Magazine,* and a technical description has been given by Tarr in the *American Mineralogist,* vol. 14 (1929).



PECOS DIAMONDS (QUARTZ CRYSTALS)

1.3

9.0 The gentle eastward dip of the Artesia beds can be seen here. However, in places solution of the white gypsum by ground water causes anomalous dips and small folds in directions that do not fit into the regional structure.

1.2

10.2 Junction. Turn right. The sign states: "Bottomless Lakes State Park. A series of crystal-clear lakes of great depth located in interesting geological formations. Picnic facilities are provided—swimming, boating, and fishing are favorite sports." Actually, none of the lakes is more than 100 feet deep. "Bottomless" usually means that the lake is deeper than the longest line you happen to have for sounding. As one wag remarked, "If the lake had no bottom, wouldn't the water run out?" As you will see, it doesn't!

2.5

12.7 Entrance to Bottomless Lakes State Park. CAUTION: Curves down into Comanche Draw.

0.3

13.0 The gray and white rock in the roadcuts is gypsum. In pure, fine, granular form, it is known as alabaster and was used by the ancients to carve into amphora (wine jugs) or smaller bottles (Egyptian tear bottles). Gypsum is so soft that it can be scratched by one's fingernail.

0.4

13.4 Junction; Lake Drive. Keep straight ahead. On the return loop, we shall return to the paved road at this point. A lake (after rain) under bluff on right, at edge of Pecos River Valley.

0.9

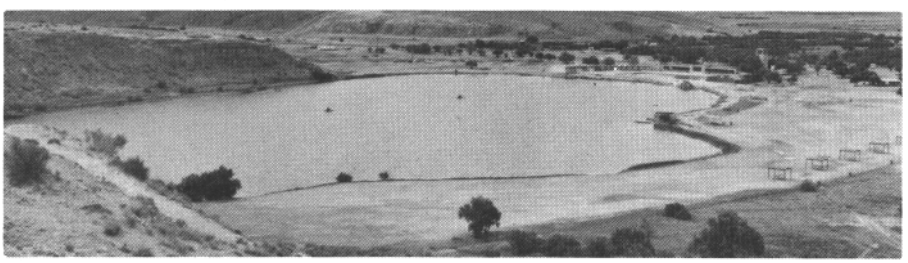
14.3 TV relay tower on left.

0.4

14.7 Park on right and walk west to cliff edge for scenic view of several of the Bottomless Lakes: (from left to right, or southeast to north): Dimmitt, Lea (Park Headquarters), Pasture, Figure Eight, Devil's Inkwell, Mirror, and Cottonwood.

1.6

16.3 Lea Lake on right. This is the largest of the lakes, with an area of 15 acres and depths of 50 to 80 feet. The Park Headquarters and recreational facilities are along the southwest shore *(see* map p. 48).



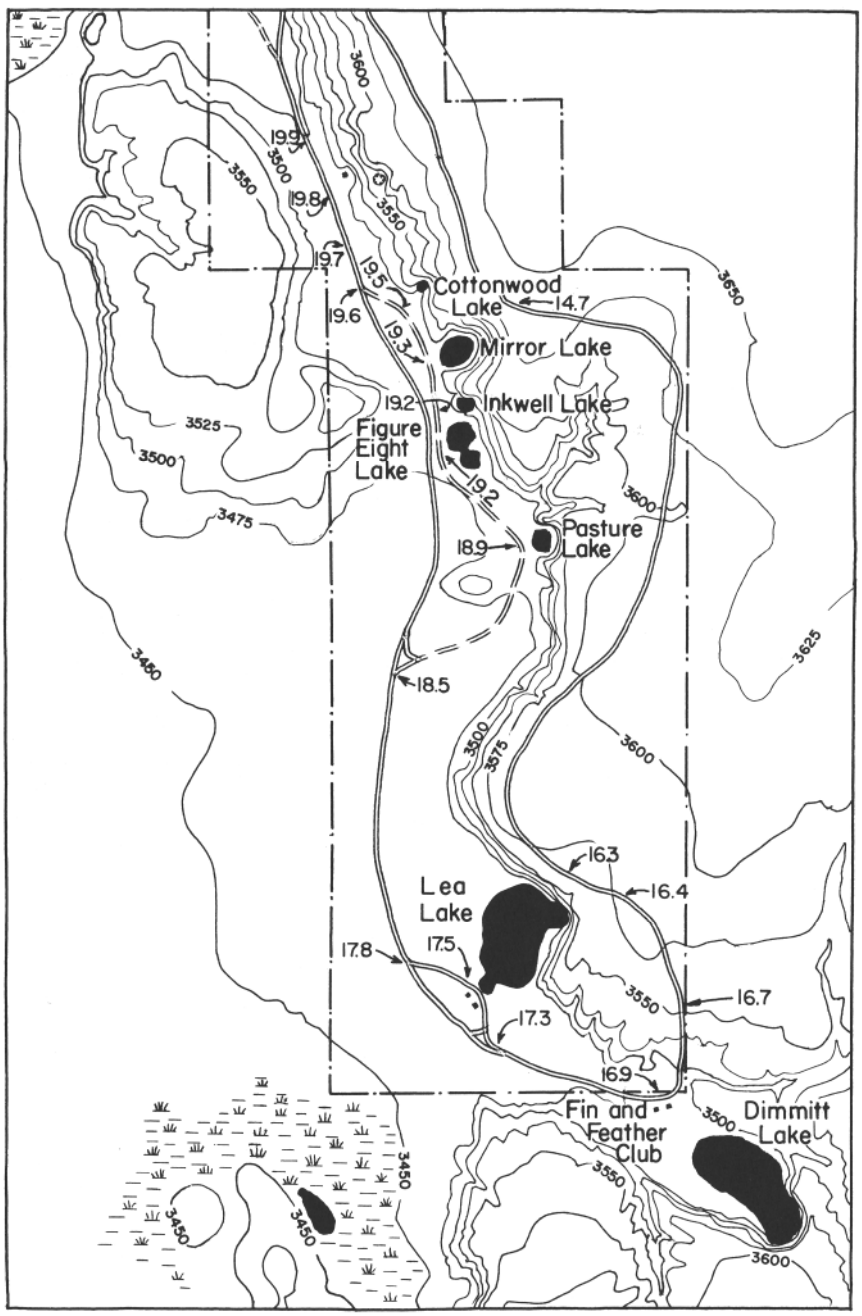
Lea Lake

0.1

16.4 Turnout and viewpoint on right, above Lea Lake. There is a sharp flexure (monocline) here in the Artesia beds. The gently east-dipping beds are folded so that they dip rather steeply to the south and west along this escarpment or bluff. This steep dip may be caused by the solution of gypsum in the Artesia Formation or by solution in the underlying San Andres Limestone. Ground water formed underground channels and caverns in these soluble rocks, and the caverns have caved in to the surface, resulting in the deep steep-walled depressions occupied by the lakes. Such collapse structures formed by solution of rocks are called *sinks.*

0.3

16.7 Descend hill. Dimmitt Lake lies under the red cliffs ahead. This lake is the property of the "Fin and Feather Club." North and west of the club grounds are said to be good hunting areas for the "Pecos diamonds," the perfect quartz crystals for which the Artesia Formation is famous.



Bottomless Lakes State Park

0.2

16.9 Entrance to Fin and Feather Club.

0.2

17.1 Junction; road to left to Dexter.

0.2

17.3 Road junction; keep right to Park Headquarters.

0.2

17.5 Park Headquarters; swimming pool, canteen, horseback riding, picnicking, peacocks, camping area, playgrounds, boating, and sun bathing.

0.3

17.8 North edge of park; cross runway.

0.7

18.5 Turn right onto Lake Loop graded gravel road.

0.4

18.9 Pasture Lake.

0.3

19.2 Figure Eight Lake. Caused by the near coalescence of two sinks.

0.1

19.3 Devil's Inkwell. A small circular sink with steep walls and clear water (except after rains).

0.05

19.35 Mirror Lake. A larger depression, made up of two adjacent sinks.

0.15

19.5 Cottonwood Lake. This lake is almost 100 feet deep but is only about 150 feet in diameter. The water is usually very clear and transparent; the rock walls, which seem to be almost perpendicular, can be seen for considerable distances below the water's surface. Dense growths of dark-green moss coat the bottoms of these lakes, giving the impression of great depth.

0.1

19.6 Junction. To return to Roswell, keep to the right. Those wishing tc go back to Park Headauarters should turn left.

0.1

19.7 Notice deep gashes cut by solution channels in hillside on right

0.1

19.8 Picnic spot and fireplace on right, in cove.

0.1

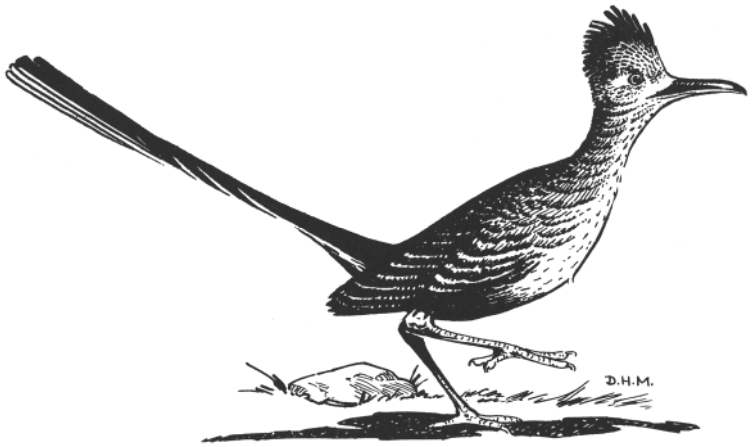
19.9 Notice circular sink on hillside.

0.3

20.2 Intermittent lake, Lazy Lagoon, on left. After heavy rains, this lake extends as a long, narrow body of water along the east edge of the Pecos River Valley for nearly 4 miles. It marks a former channel of the Pecos River, which has since shifted to the west. Favorite haunt of the road runner, the State bird of New Mexico.

0.5

20.7 Landslide blocks of gypsum above road.



ROAD RUNNER

0.2

20.9 Begin ascent of bluff. Roadcut in gypsum and siltstone of Artesia Formation. View of Pecos Valley and Roswell, to west, from top of bluff. Notice wavy bedding, crinkly beds, and thin laminations in gypsum beds; some are blood red.

0.9

21.8 Junction. Turn left to Roswell.

0.7

22.5 Park entrance.

2.5

25.0 Junction with U.S. Highway 380. Turn left; Roswell, 7.7 miles.

1.9

26.9 Crest of Comanche Hill. Begin descent into Pecos River Valley. View of Capitan Mountains to west at 1 o'clock; Sierra Blanca at 11:45.

1.1

28.0 Center of bridge across Pecos River.

7.2

35.2 Center of Roswell; intersection of Main and Second streets.

Hasta la vista!

Some Additional Reading

If you'd like to learn more about geology, the following books will help:

*Geology—Merit badge Series: Boy Scouts of America, 1953. (An excellent introductory booklet on geology.)

Down to Earth: C. G. Croneis and W. C. Krumbein, University of Chicago Press, 1936. (Readable college text; well illustrated.)

The Rock Book: C. L. and M. A. Fenton, Doubleday, Doran & Co., Inc., 1940. (About minerals and rocks.)

Rocks and Minerals: H. S. Zim, P. R. Schaffer, and R. Perlman, Simon & Schuster, 1957. (Golden Nature Guide, $1.00 paperback edition; beautiful colored illustrations.)

The Rocky Mountains: Wallace W. Atwood, Vanguard Press, 1945. (Geology, scenery, folk lore, and landforms of the Rockies.)

If you'd like to read more about the geology of this area:

Doubly Terminated Quartz Crystals Occurring in Gypsum: W. A. Tarr, American Mineralogist, v. 14, p. 19-25, January 1929. (Technical description of "Pecos diamonds.")

*Geology of Capitan Coal Field, Lincoln County, New Mexico: Marc W. Bodine, Jr., Circular 35, N. Mex. Bureau of Mines and Mineral Resources, 1956. (Technical report on coal beds near Capitan.)

*Geology and Economics of New Mexico Iron-Ore Deposits: V. C. Kelley, N. Mex. Univ. Pub., geology series, no. 2, 1949. (Technical report on iron-ore deposits in the State, including those near Capitan.)

Guidebook of the Capitan—Carrizozo—Chupadera Mesa Region, Lincoln and Socorro Counties, New Mexico: Roswell Geological Society, Fifth Field Conference, 1951. (Technical guidebook with geological road log from Roswell to Oscura Mountains, and geologic notes on mining districts, the Carrizozo malpais, and regional structure.)

Pecos Valley "diamonds" (quartz crystals): J. L. Albright and R. M. Bauer, Jr., Rocks and Minerals, v. 30, p. 346-350, 1955. (Popularized description of quartz crystals.)

*Guidebook of the Ruidoso Country: New Mexico Geological Society, Fifteenth Field Conference, 1964. (Technical guidebook with road logs, descriptions of the rocks, and notes on the mining districts.)

If you'd like topograhic maps of parts of the area:

*Topographic maps (U.S. Geological Survey) are available for most of the area. Obtain a free topographic map index from New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico, or U.S. Geological Survey, Denver, Colorado. (These maps show cultural and drainage features, such as streams, arroyos, towns, roads, and houses and depict the topography by contours of equal altitudes.)

If you'd like to learn more about New Mexico:

*Mosaic of New Mexico's Scenery, Rocks, and History: New Mexico Bureau of Mines and Mineral Resources, Scenic Trips No. 8, 1967 (2nd ed.). (Describes rocks, history, flora, fauna, geology, landscapes, and parks.)

New Mexico—A Guide to the Colorful State: Hastings House, 1953. (Describes, in nontechnical manner, history, plants and animals, geology, industry, and geography, and includes excellent logs for most of the main roads.)

New Mexico, Land of Enchantment: E. B. Mann and F. E. Harvey, Michigan State University Press, 1955. (Describes government, culture, history, and geography.)

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* For sale by the New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico 87801.