SCENIC TRIPS TO THE GEOLOGIC PAST
NO. 3

Vegetation flourishes on lava flow, Valley of Fires State Park

Roswell–Ruidoso–Valley of Fires

including trips to Lincoln, Tularosa, and Bottomless Lakes State Park

Scenic Trips
to the Geologic Past Series:

NO. I-SANTA FE

NO. 2—TAOS-RED RIVER-EAGLE NEST

NO. 3—ROSWELL-RUIDOSO-VALLEY OF FIRES

No. 4—SOUTHERN ZUNI MOUNTAINS

No. 5—SILVER CITY-SANTA RITA-HURLEY

NO. 6—TRAIL GUIDE TO GEOLOGY OF THE UPPER PECOS

NO. 7—HIGH PLAINS NORTHEASTERN NEW MEXICO, RATON-CAPULIN MOUNTAIN-CLAYTON

NO. 8—MOSAIC OF NEW MEXICO'S SCENERY, ROCKS, AND HISTORY

No. 9—ALBUQUERQUE—ITS MOUNTAINS, VALLEYS, WATER, AND VOLCANOES

NO. 10-SOUTHWESTERN NEW MEXICO

NO. 11-CUMBRES AND TOLTEC SCENIC RAILROAD

NO. 12—THE STORY OF MINING IN NEW MEXICO

NO. 13—CHAmA-TAGS-EsPAIsioLA

Scenic Trips to the Geologic Past
No. 3, *third edition*

New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

Roswell-Ruidoso-Valley of Fires

including trips to Lincoln, Tularosa, and Bottomless Lakes State Park

by John Eliot Allen and Frank E. Kottlowski

SOCORRO 1981

First edition, 1958
Second edition, 1967
Third edition, 1981

Published by Authority of State of New Mexico, NMSA 1953 Sec. 63-1-4
Printed by University of New Mexico Printing Plant, September 1981

Available from New Mexico Bureau of Mines & Mineral Resources, Socorro, **NM 87801** **$5.00**

Preface

Roswell, hub of the southeast 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 and winter 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 Little Black Peak malpais at Valley of Fires. We hope that this guidebook will make visits to these areas more interesting and enjoyable.

John Allen began revision of Scenic Trip 3 in spring 1977, and Frank Kottlowski continued it in summer 1979. The first part of this third edition is designed to introduce the geology of east-central New Mexico to the informed layman. We have tried to limit our use of technical terms and to define them carefully when we do use them; we also include a glossary at the end of the book. We have added many maps and diagrams to illustrate not only geologic structures, but also the location of old mines for mineral collectors, petroglyphs for archaeology buffs, and plant and animal associations for nature lovers. A color geologic map of the entire area is in the envelope, inside the back cover.

The road log in earlier editions consisted of one loop trip, Roswell to Roswell (214 mi), and a second 35-mi trip to Bottomless Lakes State Park. The long trip has been divided into four separate and shorter trips, and four additional trips have been logged, expanding the total mileage of the nine trips to 310 mi. Use of the road logs and organization of a trip in any direction is described on p. 33.

We acknowledge the extensive use of information from articles written by over twenty authors and published in 1964 as the Guidebook to the 15th field conference, *Ruidoso Country*, by the New Mexico Geological Society.

We appreciate the photos taken by Rick Dingus and contributions by Joan Pendleton, Barbara Spence, and Robert North, who checked the road logs and made helpful suggestions for modification of the text.

John Eliot Allen
Emeritus Professor of Geology
Portland State University
Portland, Oregon

Frank E. Kottlowski
Director
New Mexico Bureau of Mines and Mineral Resources
Socorro, New Mexico

August 13, 1980

Contents

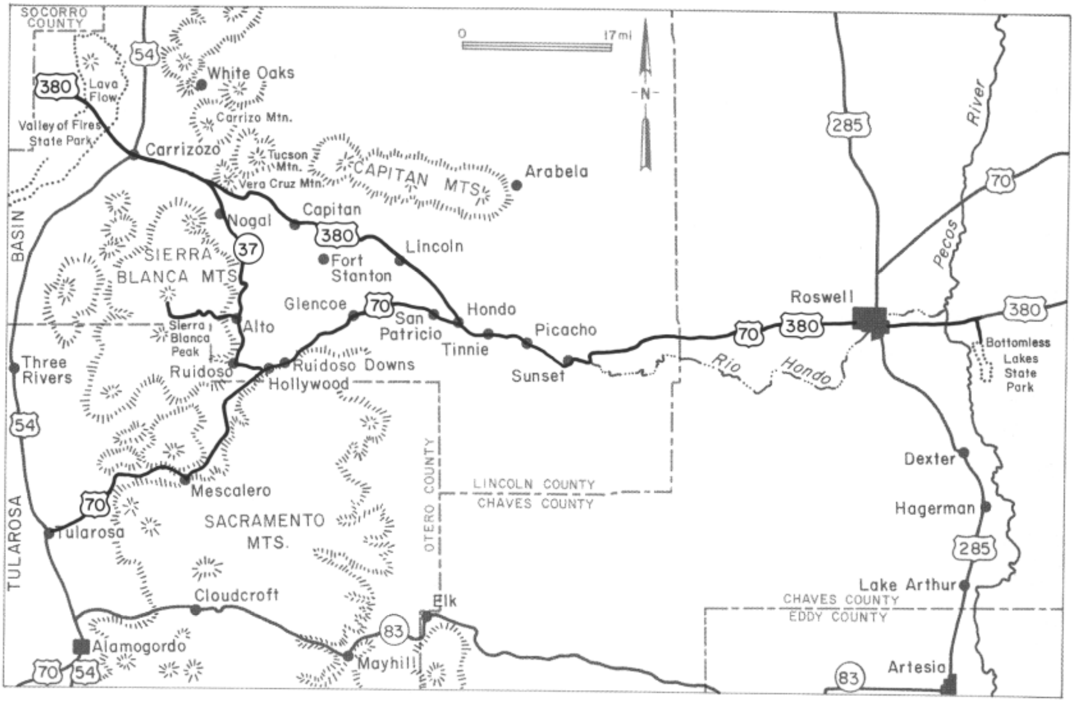
TABLES

FIGURES

PHOTOS

COLOR PHOTO GALLERY

GEOLOGIC MAP



INDEX MAP FOR SCENIC TRIP ROUTES SHOWING MAJOR TOWNS, MOUNTAIN RANGES, AND ROADS.

Introduction

Roswell is located west of the Pecos on the edge of the Llano Estacado (or staked plains, originally named for the yucca posts used as Indian trail markers). Since the days of the first white settlers, the Llano 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 ft. The mountains drop off precipitously toward the west into the great north-south elongated depression known as the Tularosa Basin.

These mountain ranges have a complicated history that extends over some 600 m.y. Their story involves advances and retreats of wide seas, long epochs of erosion by sluggish rivers (inhabited by prehistoric crocodiles and amphibians), and periods of folding and arching of the bedded rocks deposited by these seas and rivers. At times multiple injections of different kinds of molten rocks penetrated and broke the crust of the earth; these molten rocks broke out in places on the surface as volcanoes. During other periods the crust was cracked and broken. More recently, erosion has dominated. 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.

A perspective on the long period of geologic time is important, 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 can reconstruct the history of the area under study.

The geologic timetable (page 22) provides a preliminary perspective. While you observe the various rock units and structures along the highway, the chart will help you visualize some of the geologic events that took place millions of years ago.

Our trip concerns more than just the story in the rock formations; we will point out some of the common plants and animals 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. Some of these carvings in stone are surely doodles, random fancies created in leisurely moments; however, others may be religious symbols, designs from textile and pottery decorations, trail markers, records of events, and primitive expressions of art.

Physiographic and geographic setting

The area of this scenic trip lies in large part within the Sacramento Mountains of southern Lincoln County and extends east along the Rio Hondo to Roswell and Bottomless Lakes State Park in Chaves County (see index map, page viii). Cities and towns along the route with populations over 100 follow (1980 census figures): Roswell (39,676), Ruidoso (4,260), Tularosa (2,536), Carrizozo (1,222), Ruidoso Downs (949), and Capitan (762).

Alamogordo (24,024), 40 mi to the south of Tularosa; Artesia (10,385) and Carlsbad (25,496), 40 and 75 mi south of Roswell; and Socorro (7,576), 76 mi west of Carrizozo, are the only other cities of any size within 80 mi of the area.

The eastern border of the north-south-trending Sacramento Mountain complex (which includes the Sierra Blanca, Vera Cruz, and Capitan Mountains as well as the more isolated Carrizo, Patos, and Jicarilla peaks) is also the boundary between two of the largest physiographic or landform divisions of the United States: the Great Plains province, which extends eastward to the Central Lowlands of the Mississippi River region, and the Basin and Range province, which extends westward to the Sierra Nevadas in California. Southeast New Mexico is the only place where they meet; farther north they are separated by the Rocky Mountains and Colorado Plateau.

From the Pecos River, at an elevation of 3,400 ft east of Roswell, the Pecos Valley High Plains (sometimes called the Sacramento Plains) rise gently westward for 60-80 mi at a rate of about 60 ft per mi; the plains are increasingly dissected into mesa-like remnants toward the foot of the Sierra Blancas, where they reach an elevation of 7,500 ft north of Ruidoso and 7,100 ft north of Capitan.

The highest point in the area is Sierra Blanca Peak at 12,003 ft, giving a total relief for the area of over 1'h mi. The northeast side of Sierra Blanca Peak was sculptured during the ice age by a glacier approximately 1 mi long, which left moraines of three ages. This mountain may be the southernmost record of glaciation in the United States and certainly is in New Mexico.

VIEW OF RUIDOSO AREA AND SACRAMENTO MOUNTAINS while driving up to Lookout Mountain ski lift. Prominent peak is Mon Jeau (Trip 5, mile 15.8).

Most of the area east of the Sacramento divide and south of Capitan Mountains is drained by the Rio Hondo and its tributaries. The Rio Ruidoso and the Rio Bonito are the largest of these, and all three are followed by the highway and road logs for much of their length. Their valleys are seldom more than 1/2 mi in width and generally are cut less than 1,000 ft into the High Plains surface. A second surface of erosion called the Diamond A plain lies about 250 ft below the High Plains; the two appear to merge as they approach the mountain front.

West of the Sacramento divide, the Tularosa Basin is spectacularly different in aspect from the gentle slopes and narrow valleys to the east. From Sierra Blanca Peak, the elevation drops 6,000 ft in the first 5 mi to the head of one of the broad alluvial fans that slope west only 1,000 ft in the next 5 mi. These fans (sometimes underlain by bedrock covered with only a thin layer of gravels and then called pediments) extend for over 10 mi farther west out to the center of the basin, which lies at an elevation of 4,000 ft west of Tularosa but rises gently northwards to 5,000 ft west of Carrizozo. For the entire north-south length of the area, the lowest part of the basin is occupied by the malpais, a 40-mi-long flow of basaltic lava that erupted from Little Black Peak volcano only a few thousand years ago.

Mining and minerals—past and present

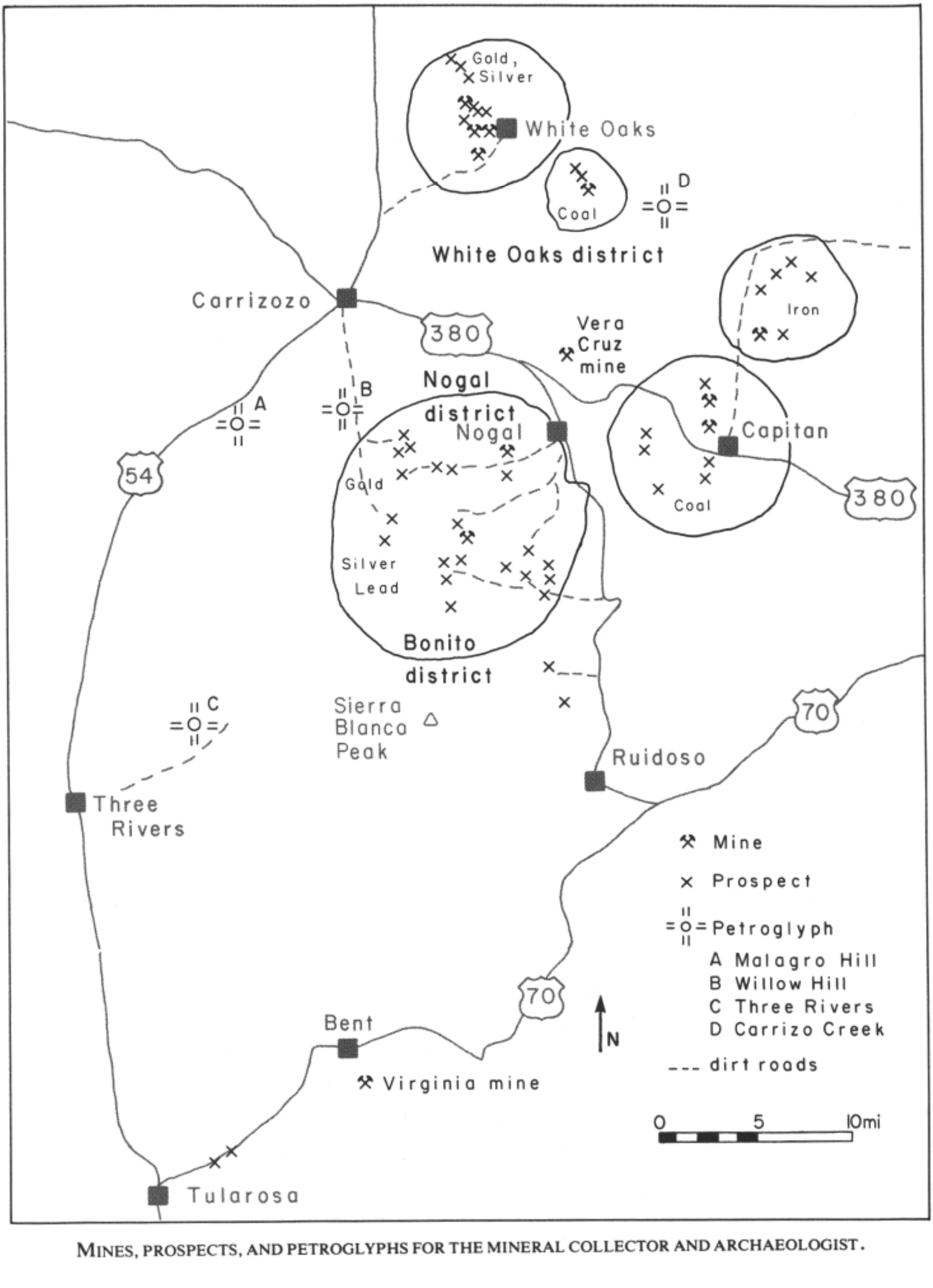
Mining was important in the area from 1880 to 1906, with a production of $4 million worth of gold, coal, iron, silver, copper, and lead. Since then, little production has been recorded, although iron ore north of Capitan, coal near Capitan and White Oaks, and molybdenum and silver occurrences in the Nogal and Bonito districts in the Sierra Blancas all have potential value.

White Oaks, 10 mi northeast of Carrizozo, is the most famous mining camp in central New Mexico, and the ghost town is worth visiting. It produced nearly $3 million in gold, mostly from three mines that were 1 mi up the canyon west of the town. Three other gold mines active 80 years ago are the Vera Cruz, 1 mi north of the trip route east of Carrizozo, the Helen Rae-American, 3 mi southwest of Nogal, and the Parsons, 3 mi west of Bonito Lake. Vein material with occasional mineral specimens may still be found in the dumps.

In addition to gold the volcanic rocks of the Nogal and Bonito Creek districts contain numerous veins of complex ore. Minerals such as galena, sphalerite, chalcopyrite, argentite, and pyrite, and some high-grade silver ores can be found. The presence of molybdenite flakes and grains in a large area of altered intrusive rock has also led to prospecting efforts by several companies.

Although 11/2 billion tons of coal might be present in the Sierra Blanca Basin, only about 600,000 tons have been produced from near Capitan and White Oaks. Further production of consequence is improbable because of the thinness of beds, depth of burial, complications of structure, and igneous intrusions.

The Capitan iron deposit, 5 mi north of that town, is the largest of some 24 known deposits of iron ore in Lincoln County and may contain as much as 2 million tons of 45-55 percent magnetite-hematite. It was being mined from a large open pit in 1977 and shipped for use as a heavy concrete aggregate.



MINES, PROSPECTS, AND PETROGLYPHS FOR THE MINERAL COLLECTOR AND ARCHAEOLOGIST.

Photo collection, Museum of New Mexico

WHITE OAKS IN THE 1890'S (TOP) AND TYPICAL VIEWS IN THE 1980'S (BOTTOM). Although a "ghost town" for many years, White Oaks is again beginning to attract settlers.

VIEWS OF PETROGLYPHS AT THREE RIVERS SITE (this page and right); these carvings include human figures, abstract designs, and animals.

Petroglyphs

We find no prehistoric cave dwellings like Mesa Verde in the field trip area, no pueblo ruins such as Abo and Quarai. One occasionally finds pottery shards at ancient camp sites, but petroglyphs are found inscribed by the tens to hundreds on the smooth faces of rocks in at least four localities.

Petroglyph means "rock carving"; the sculpturing is usually very shallow and was caused by repeated impact or hammering with a pointed (presumably rock) tool. The petroglyphs are nearly always found on surfaces of igneous rocks (dikes and sills of basalt or gabbro) that have developed a coating of desert varnish, a crust composed of black iron and manganese oxide minerals that have been leached out of the rocks and precipitated onto the surface by repeated (during hundreds or thousands of years) wetting and evaporation. The Indians pecked away at this crust, leaving the freshly exposed lighter colored gray rock to outline the figure desired.

The outstanding site in the area and perhaps in New Mexico is 5 mi northeast of Three Rivers, which is 17 mi north of Tularosa. It has been described as a mile-long array of rock faces, decorated with a fantastic number of different kinds of designs, varying from the most lifelike to the most abstract, and representing subjects as varied as the human experience of the artists.

Types of petroglyph designs:

Human: stick figures, solid figures, heads, faces, hands, footprints, masks and head-dresses

Mammals: rabbits, chipmunks, skunks, mountain lions, mountain sheep, bear tracks, wolf tracks

Birds: quail, roadrunners, turkeys, macaws?, bird tracks, bird trails

Reptiles: lizards, frogs, turtles, snakes

Insects: beetles, butterflies, centipedes, worms

Abstract patterns or symbols: circles, spirals, dots, lines of dots, triangles, rectangles, zigzags, wavy lines, looping lines, stepped terraces

Other: fish, corn plants

We will probably never know the purpose of these designs. Some undoubtedly had religious significance, perhaps as part of an initiation or annual hunting ceremonial. Many appear to be just doodles, but the symbolism of the more abstract figures also escapes us.

Geologic words

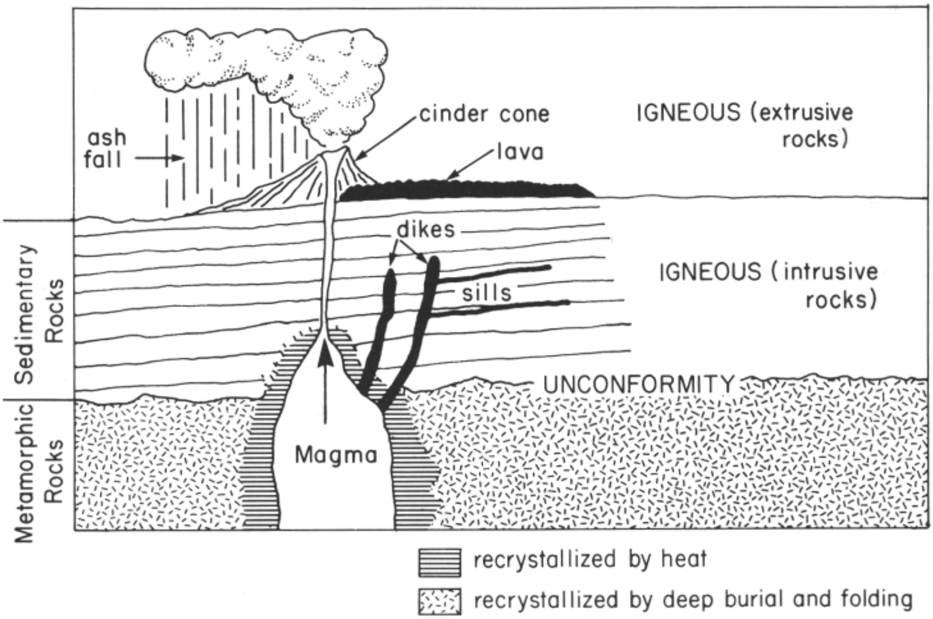
In this scenic-trip guidebook, about 100 technical terms are used (the Glossary of Geology, published by the American Geological Institute, contains over 36,000). These terms fall into five categories; geologic time, rock assemblages, rocks themselves, the architecture of the earth's crust, and fossils. Over 50 percent of these words appear on the geologic timetable (p. 22).

TERMS USED FOR GEOLOGIC TIME—These are the clock and calendar terms of geology. Instead of seconds, minutes, hours, days, years, and historical periods, we divide time into longer units, such as Era and Age (columns I and II, geologic timetable). The 22 time terms are all we need to roughly identify the relative age of any rock or fossil. No rocks older than Permian crop out in this scenic trip, and so we will need to use only 13 of the 22 terms. "Absolute" time in millions of years (obtained by analysis of radioactive rocks) is given in column II.

TERMS USED FOR ROCK ASSEMBLAGES OR FORMATIONS—A formation is a rock type or assemblage of rock types that is different enough from those near it (or above or below it) so that it can be easily recognized in the field and its areal extent shown on a map (usually with a distinct pattern or color). Column III of the geologic timetable lists 13 groups of rocks and formations in the scenic trip area; all appear on the colored geologic map. Each formation was named for a geographic feature in the locality where it is best exposed or was first observed. Sometimes a rock term is used instead of the word "formation," as in "Dakota Sandstone." This list of formations, placed in order of age from youngest (at the top) to oldest (at the bottom) is the most important part of the stratigraphic column for the area; another area would have a different list of formations.

TERMS USED FOR ROCKS—Rocks, which are made up of one or more minerals, are classified by the kinds and the size and arrangement of the minerals in them as well as by the way in which they originate. Two of the three great groups of rocks, igneous (fire-formed) and sedimentary, are found in abundance and variety in the area. Metamorphic ("changed in form") rocks need not concern us on this trip; they are mostly restricted to the Precambrian, except around the mining districts, and the Precambrian rocks do not crop out along the course of the trip.

The 12 igneous rocks found in the area are described later in the section on *igneous rocks.* The 10 sedimentary rocks naturally fall into two groups (p. 17): those that have been precipitated from a chemical solution (such as gypsum, salt, most limestone, dolomite, anhydrite) and those deposited by mechanical action



THE THREE GROUPS OF ROCKS.

of running water, currents, wind, or ice (such as conglomerate, sandstone, siltstone, shale, and some limestone). Coal and some limestones are in a third group of rocks of organic origin. The rocks of the first group are named from their chemical composition and those in the second by the size of the mineral particles, in order from small to large. The process of formation may be reversed in limestone or gypsum if underground water passes through fractures in the rocks, which may then be redissolved to form spectacular caverns such as those in Carlsbad or sinkholes such as Bottomless Lakes near Roswell.

TERMS USED FOR THE STRUCTURE OR ARCHITECTURE OF THE CRUST—Fortunately for geologists, sedimentary rocks cover much of the land surface, and changes in conditions during their deposition has resulted in an almost universal layering or stratification. Because these layers of beds were nearly all flat-lying when they were first deposited, any appreciable change from a horizontal posi-

A SIMPLIFIED CLASSIFICATION OF MOST OF THE SEDIMENTARY ROCKS FOUND IN THE AREA.

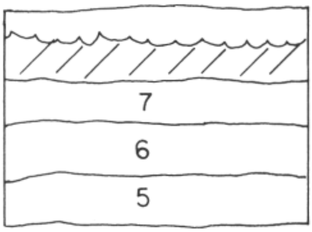
CHEMICAL AND ORGANIC		MECHANICAL	
Chemical composition	**Rock**	**Sediment**	**Rock**
$CaCO_3$ (mud)	limestone	mud	shale
$CaCO_3$ (shells)	limestone	silt	siltstone
$CaMgCO_3$	dolomite		
$CaSO_4$	anhydrite	sand	sandstone
$CaSO_4 \bullet H_2O$	gypsum		
NaCl	salt (halite)	gravel	conglomerate
Carbon (plants)	coal		

tion tells the geologist that the area has been tilted or folded; any abrupt break in the lateral continuity of the layers suggests that the rocks have been displaced by fracturing and faulting. Such breaks usually indicate times of large-scale mountain-making, whose accompanying uplift and erosion causes gaps in the succession of layers. Those surfaces where beds are missing are called unconformities.

Igneous rocks also have characteristic structures; instrusive forms include laccoliths, stocks, sills, and dikes (see glossary).

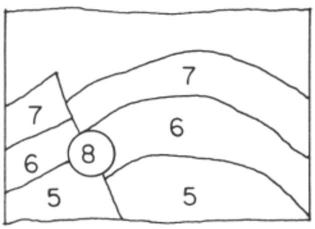
TERMS USED FOR FOSSILS—Any identifiable remnant or evidence of past life found in the rocks is termed a fossil, and each formation or series of formations

A



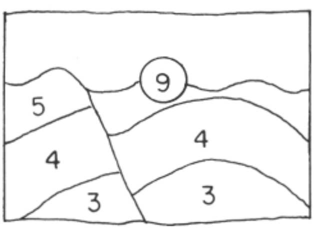
Deposition in the sea of a series of horizontal beds (1–7)

B



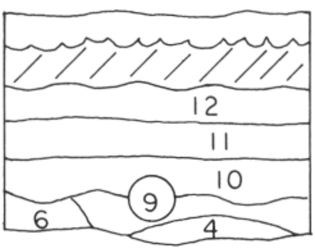
Uplift from below sea level, folding to form an anticline, and faulting (8)

C



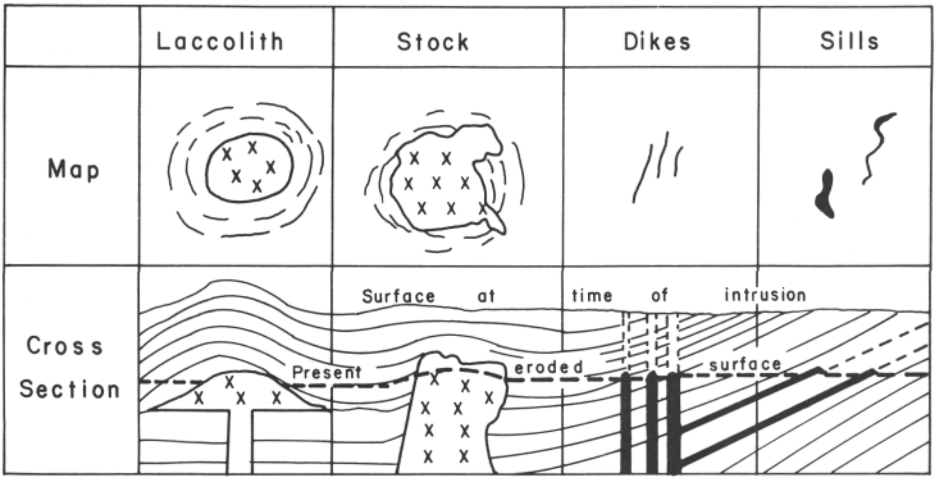
Erosion (9) of upper part of series (5–7)

D



Subsidence below sea level and deposition of new series (10–12) upon unconformity (9)

DEVELOPMENT OF STRUCTURES IN SEDIMENTARY ROCKS.



INTRUSIVE IGNEOUS-ROCK STRUCTURES (TKi ON GEOLOGIC MAP) SEEN IN WESTERN LINCOLN COUNTY.

in an area may contain a fossil or assemblage of different fossils representing life that only existed during the time those rocks were being deposited (see column VI, geologic timetable). Fossils, therefore, are valuable for the determination of the relative age of rocks and formations in which they are found.

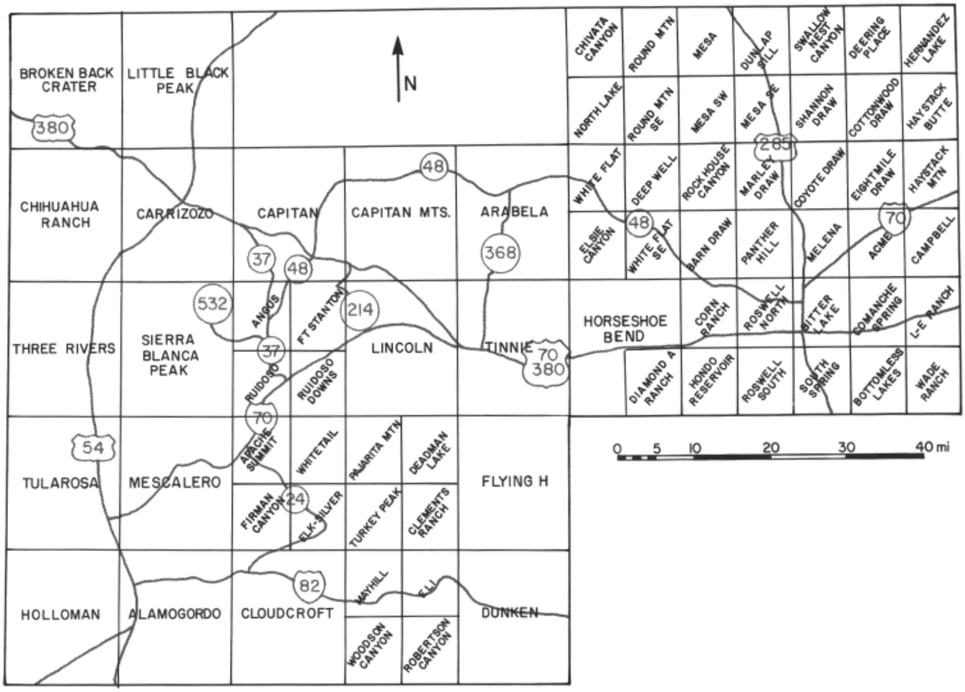
The study of fossils (paleontology) is so specialized that most geologists who are mapping an area collect fossils and send them to experts for identification and interpretation; such information enables a geologist to match up the formations in his area with those elsewhere, even though the rocks may not be similar. Furthermore, the life forms represented by the fossils can tell much about the landscape in which they lived, such as in the deep sea (fish), near the shoreline (many invertebrates), or on dry land (horses).

Fossil names and descriptive terms are latinized, so that they can be recognized worldwide; we will try to avoid using too many paleontological terms here. New Mexico has more than its share of excellent fossil localities, although they are not particularly abundant in the area of this trip. See the Suggested Reading list for books about fossils.

Geologic symbols

Geologists are great believers in the maxim "one picture [or diagram or chart or map] is worth a thousand words," and the symbols used to represent geologic words in these pictures are also comparatively few and relatively easy to understand and use.

The geologist's basic tool is the map. It may be only a road map or a forest map; but it is probably a topographic or contour map, upon which the elevations above sea level are shown by brown lines (see p. 20). The geologist places an amazing amount of information on these maps. He also uses aerial photographs, which help him locate a point by the nearest pine tree or juniper bush and also frequently show the presence of geologic features. Satellite imagery has recently become valuable in indicating features that cannot be seen from the ground or even from an airplane.



ROAD MAP AND INDEX TO U.S. GEOLOGICAL SURVEY TOPOGRAPHIC MAPS OF THE AREA. These maps are indispensable for anyone who plans to get off the main roads and highways. Order by name from New Mexico Bureau of Mines and Mineral Resources or from U.S. Geological Survey, Federal Center, Denver, Colorado 80225.

If a good topographic map is a basic tool of a geologist, the geologic map (in pocket) is most often his primary product. In order to put geologic information on the topographic map, the geologist has developed sets of abbreviated symbols to indicate rock formations, lines of contact between formations, and structures (folds, faults, and dikes for instance).

Each kind of geologic map may use a different set of symbols, usually described in a corner or along the edge of the map and called the legend or explanation. Note that a formation is identified first by pattern of color and also by the capitalized time symbol, followed by lower-case initials of the name or rock type. The symbols on this map should be compared with the symbols of other maps with different purposes.

Possibly the second most important product of the geologist is the stratigraphic column or timetable (p. 22), which places the formations in their natural order, the oldest on the bottom and the youngest on top, and summarizes their time span, composition, thickness, and fossil content.

A third geologic product is a geologic cross section (p. 41), which is a vertical slice of the sedimentary layer cake beneath a topographic profile of the surface elevations; it shows the geologist's interpretation of what goes on deep underground.

Geologic history from the layered rocks

Reconstructing the past

To many geologists, a fascinating exercise is to take all the observations of rock distribution, formations, structures, and fossils in a given area and fit them together so that they can be interpreted to tell the story of the consecutive events that occurred during the geologic past.

In this type of analysis, sedimentary rocks tell us much more about the past than do igneous or metamorphic rocks, primarily because they are bedded and contain fossils. Some of the simple rules for interpretation of sedimentary rocks are:

1) Layers that are not horizontal today have been tilted or folded since they were deposited *(Law of original horizontality).*

2) Layers lying on top of other layers are younger (were deposited later) than those beneath *(Law of superposition).*

3) Igneous rocks intruded into other rocks are younger than the rocks they intrude *(Law of crosscutting relationships).*

4) More highly evolved animals appear as fossils later in the record than do more primitive forms of life *(Theory of evolution).*

In addition, deductions can be made about environment and origin from the kind of sedimentary rock or from the fossils contained within it. For instance:

Gypsum, salt—closed basin in a hot, arid climate such as the Dead or Caspian Seas

Coal, sand, clay, shale—heavily vegetated swamp, lagoon or estuary, or river floodplain

Sandstone containing oysters—sand bar near shore

Limestone with invertebrates—shallow open sea

Red sandstone or shale—river floodplain in a hot, arid landscape

Thick crossbedded sandstones—desert sand dunes

Incompleteness of the record

The recorded geologic history of the Roswell-Ruidoso area is less complete than that in many other parts of the state. Geologic history is recorded in the rocks, mostly during periods of sediment deposition in ancient seas, lakes, or along river courses, but also during periods of igneous activity when granitoid rocks are being intruded into the crust or lava and ash is being thrown out on the surface by volcanos. Periods of activity in the crust (diastrophism) when the rocks crumple or fold, break or fault, uplift or subside may record mountain-making episodes. But, by lifting the land above the sea, sometimes to mountain heights, this activity may also cause extensive erosion, which can wear away thousands of feet of rock and destroy the record of millions of years. Inspection of the geologic timetable and a little calculation demonstrates that during the 570 m.y. (million years) since the Precambrian (when life first became abundant on

TABLE OF GEOLOGIC TIME (MILLIONS OF YEARS DURATION) AND STRATIGRAPHIC COLUMN.

I ERA	II GEOLOGIC AGE	III ROCK UNITS	IV ROCK TYPES	V Thick-ness(ft)	VI DOMINANT LIFE
CENOZOIC	PLIOCENE 5 MIOCENE	Continued faulting and extensive erosion	Little Black Peak basalt Qb Alluvium, terraces Ogalalla pediment gravel Qal	usually less than 100	Man Modern mammals
	22.5 OLIGOCENE	Dikes, Sills, and Laccoliths	Basalt and gabbro to rhyolite and microgranite TKi		Archaic mammals
		Sierra Blanca	Andesitic lavas & breccia Tvi	700-4000	
	37.5 EOCENE 53.5 PALEOCENE	Folding of Sierra Blanca Basin and erosion			
	65	Cub Mountain	Pale sandstones to purplish siltstone Tbc	500-2000	
MESOZOIC	CRETACEOUS "K"	Slight erosion			Dinosaurs and other reptiles
		Mesaverde	Sandstone, shale and coal Kmv	500-1500	
		Mancos	Shale and limestone Km	400-700	
		Dakota	Sandstone Kd	100-150	
	136 JURASSIC "JR"	Long-continued erosion Some uplift and slight tilt to the north			
	195 TRIASSIC "TR"	Chinle	Red shale TR	0-300	
		Santa Rosa	Conglomerate TR	0-300	
	225	Erosion to a great plain. Gentle arching			
PALEOZOIC	PERMIAN "P"	Artesia	Gypsum, siltstone, dolomite, limestone, anhydrite Pat	30-355	Amphibians
		San Andres	Limestone, dolomite, siltstone, gypsum, shale, incl. Glorieta Ss Psa	400-700	
		Yeso	Sandstone, siltstone, dolomite, gypsum, limestone, salt Py	0-1400	
		Abo and Bursum	Red sandstone, shale conglomerate Pa & Pb	0-1400	
	280	Record missing for 290 million years			Fish Invertebrates
PRECAMBRIAN "pЄ"			Gneiss, diabase, gabbro, granite		Primitive life

earth), we have had five depositional and igneous periods in this area; these five lasted a total of only 127 m.y., or 22 percent of the time. The history of the remaining 78 percent of the time is absent in the area and must be inferred from the rock record in other parts of the state. In this scenic trip area, the rocks of the Jurassic and most of the Paleozoic were either never deposited or were removed by uplift and subsequent long-continued erosion.

In spite of this incomplete record, a surprisingly detailed story of the consecutive events which occurred has been described by geologists familiar with the area (see Suggested Reading list.) Here we can only give a brief outline beginning with 500 m.y. ago.

Precambrian—before abundant life

We begin our survey of what happened with a study of the oldest rocks (Precambrian, more than 570 m.y. old). These rocks crop out at the surface in the Oscura and San Andres Mountains west of the Tularosa Basin, but are known in our scenic trip area only from outcrops in Pajarito Mountain, near Bent, and from rock samples taken from the bottom of a few deep exploration wells. These specimens indicate that western Lincoln County is underlain by a basement composed of altered (metamorphosed) granitoid rock and gneiss, which have been determined by radioactive methods to be perhaps as much as 1 1/2 b.y. old. Beneath eastern Lincoln and Chaves Counties the Precambrian rocks are made up of less altered sedimentary and igneous rock (diabase) somewhat younger in age.

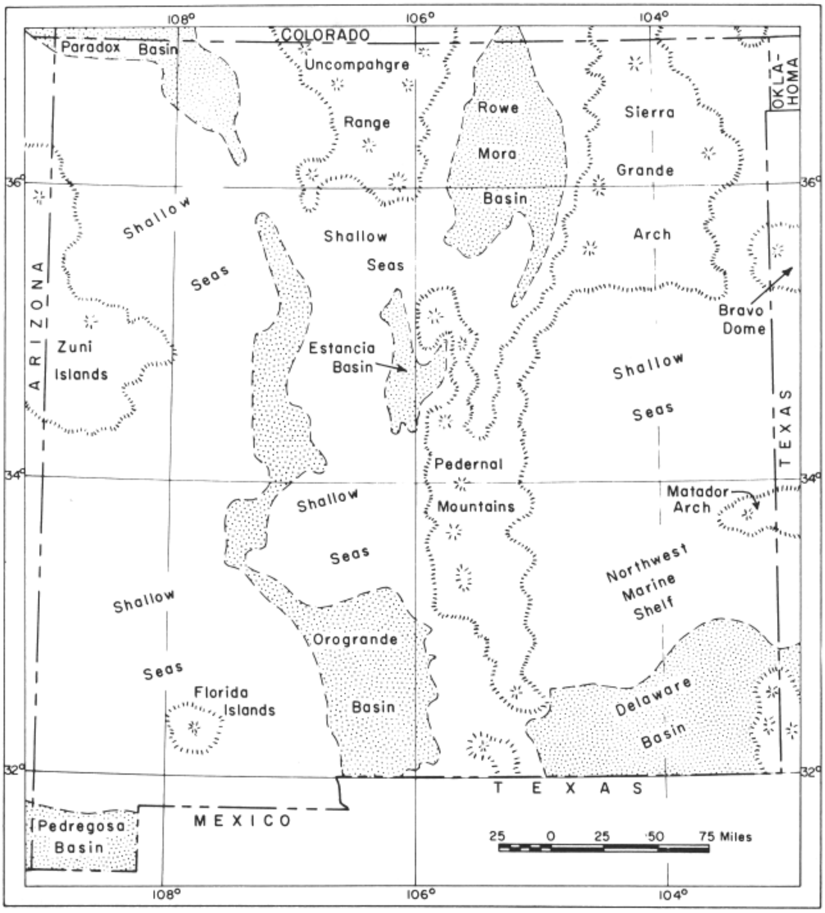
Both areas were probably originally buried more deeply than they are at present and were extensively altered. Subsequently, during 1 b.y. of Precambrian and 300 m.y. of Paleozoic time, they were above sea level in a landmass where tremendous thicknesses of rock could be removed by erosion before submergence in seas of Permian time.

Paleozoic—ancient life

The area of this scenic trip sits astride an ancient, now deeply buried landmass composed of Precambrian metamorphic rocks, known as the Pedernal uplift. Lower Paleozoic rocks are missing over the area either because the seas never covered the Pedernal land or because Paleozoic rocks eroded away after the land began to rise above the Pennsylvanian seas nearly 300 m.y. ago. The uplifted land formed a north-south-trending range of mountains that began to shed erosional debris into the basins to the east and west. If this mountain range did exist during the lower and middle Paleozoic, it must have been a grim and barren terrane for 250 m.y., occupied by only a few sparse twigs of primitive plants, a few insects, and perhaps fresh-water fish and crustaceans.

Pennsylvanian seas spread broadly over New Mexico and may have covered the area. Before the end of Pennsylvanian time, however, the Pedernal landmass was rising rapidly to form a range of mountains whose flanks soon became mantled with red conglomerate, sandstone and shale of the Bursum and Abo Formations (Permian), representing river and swamp deposits. Farther to the south and east, a remarkable downwarping of the crust began and lasted for over 50 m.y. throughout Permian time. This Permian Basin extends far into Texas and contains oil-rich marine sediment, mostly evaporite (salt and gypsum, for instance) over 2 mi thick. The scenic trip area lies on its northwest edge, where only the older parts of the sequence are pressent and are only a few thousand feet thick.

The warm, tropical shallow seas surrounding the Pedernal mountains of Yeso time gradually rose as they filled up with evaporite sediments, algal limestone,



NEW MEXICO DURING PENNSYLVANIAN TIME.

and coral reefs. During succeeding San Andres time, sediments consisting dominantly of limestone were deposited in seas that nearly covered all but the highest peaks. Interbedded layers of gypsum, dolomite, and siltstone deposited during the following Artesia time indicate continued evaporation in shallow seas while the arching Pedernal landmass was again lifted just above sea level. In Upper Permian time filling of the basin to the southeast continued, but no sediments were deposited in the Pedernal area; by Upper Triassic time most of the rest of New Mexico had emerged from the sea and had been worn down by erosion for over 50 m.y. so that broad plains with sluggish meandering streams stretched for hundreds of miles.

Mesozoic—middle life

The first deposits upon this new surface (now an unconformity) were widespread, thin sheets of coarse conglomerate and sand (Santa Rosa Formation), probably deposited by great river floods from some distant high mountain range (perhaps in the Sangre de Cristo region). The succeeding fine red muds of the Chinle Formation represent less energetic, gradual build-up of river floodplains, populated with a variety of strange-looking trees (now preserved at the Petrified Forest) and tropical swamp-dwelling great amphibians, crocodile-like reptiles known as phytosaurs, and a few tiny primitive dinosaurs *(Coelophysis).*

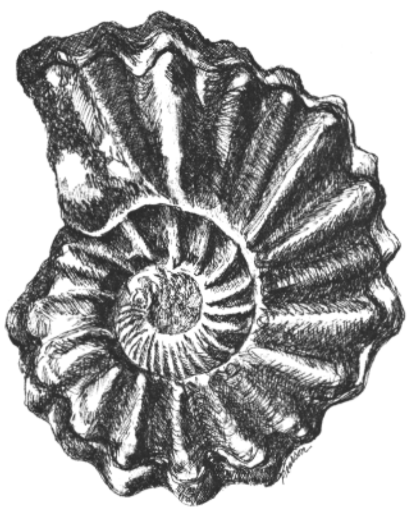
For the next 80 m.y. following this relatively short-lived Upper Triassic interval or until Upper Cretaceous time, no rocks were deposited in the scenic trip area.

During this long time span, gentle tilting to the north and subsequent extensive erosion was followed by flooding, for the first time since the Permian, by a shallow Upper Cretaceous sea that advanced from the northeast across New Mexico and deposited the widespread beach sands now known as the Dakota Sandstone. Many miles north of the trip area, the Dakota rests upon Jurassic rocks, and, coming south, it successively covers the Triassic and the Artesia and San Andres (Permian) beds south of the area. The contact is a gentle widespread unconformity.

As the land continued to subside and this last great sea (the second largest of all time in North America) deepened across New Mexico, the shoreline sand of the Dakota changed to the open-sea marine shale and limestone of the Mancos. As sediment accumulated, the sea grew shallow again until an uneasy balance was achieved, with the north-west-trending shoreline fluctuating back and forth across the area, giving an alternation of marine shale, beach sandstone, and river-floodplain shale and coal beds, representative of the Mesaverde Formation.

In the Cretaceous seas lived abundant ammonites (coiled shellfish), large clams, and both small and giant oysters. The river floodplains and lagoons behind the offshore and beach bars were the site of forest trees and swamp plants that were beginning for the first time to approach modern tropical forms. A few dinosaurs still roamed the plains—in particular the horned ceratopsians, among the last to become extinct.

During Upper Cretaceous time the first activity of the Laramide mountain-making episode that was to form the ancestral Rocky Mountains caused the sea to



COLLIGNONICERAS WOOLLGARI WOOLLGARI × .7;
Specimens of this Upper Cretaceous ammonite can be found in the Scenic Trip area.

retreat once and for all from the area. Gentle folding produced a slight basin where the nonmarine purplish siltstone and pale sandstone of the Cub Mountain Formation were deposited during latest Mesozoic and early Cenozoic times.

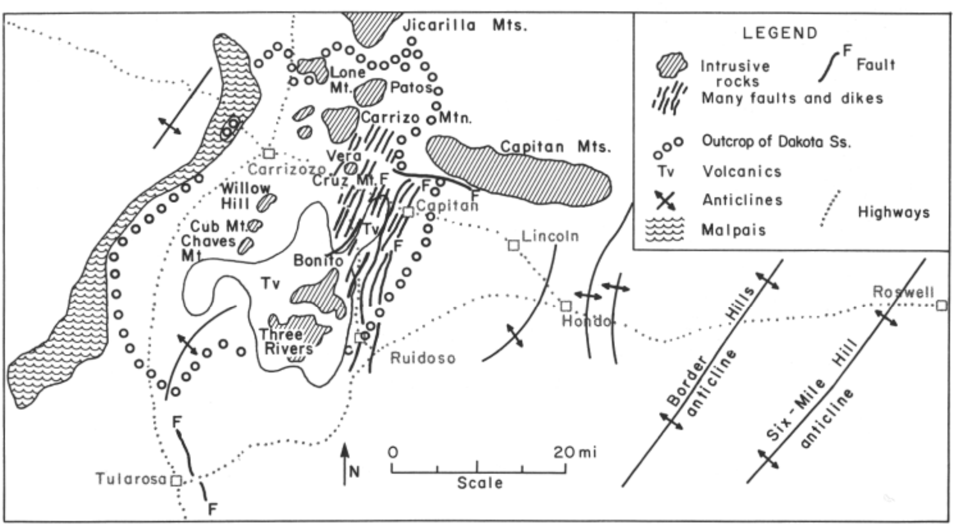
Cenozoic—recent life

Continental deposition of the Cub Mountain Formation did not continue for long, however, and terminated during the Paleocene Epoch. Laramide movements continued to lift and fold the area, and during the next 20 m.y. erosion stripped away most of the accumulated Cretaceous rocks that had covered southeastern New Mexico and left only those that had been folded down into the Sierra Blanca syncline or basin. The outcrop of the Dakota Sandstone, which now outlines the rim of the ancient Sierra Blanca basin, encompasses an area about 50 mi long and about 20 mi wide, or about 1,000 sq mi. Erosion of the rocks of this basin continued until the Oligocene, when volcanism appeared for the first time since the Precambrian.

Igneous rocks

Igneous or fire-formed rocks are those that originate in the depths of the earth as liquid magma (molten rock) and work their way up into the crust as intrusives or to the surface as lavas. They are given names on the basis of 1) the kinds and amounts of minerals they contain and 2) the size and arrangement of the mineral crystals.

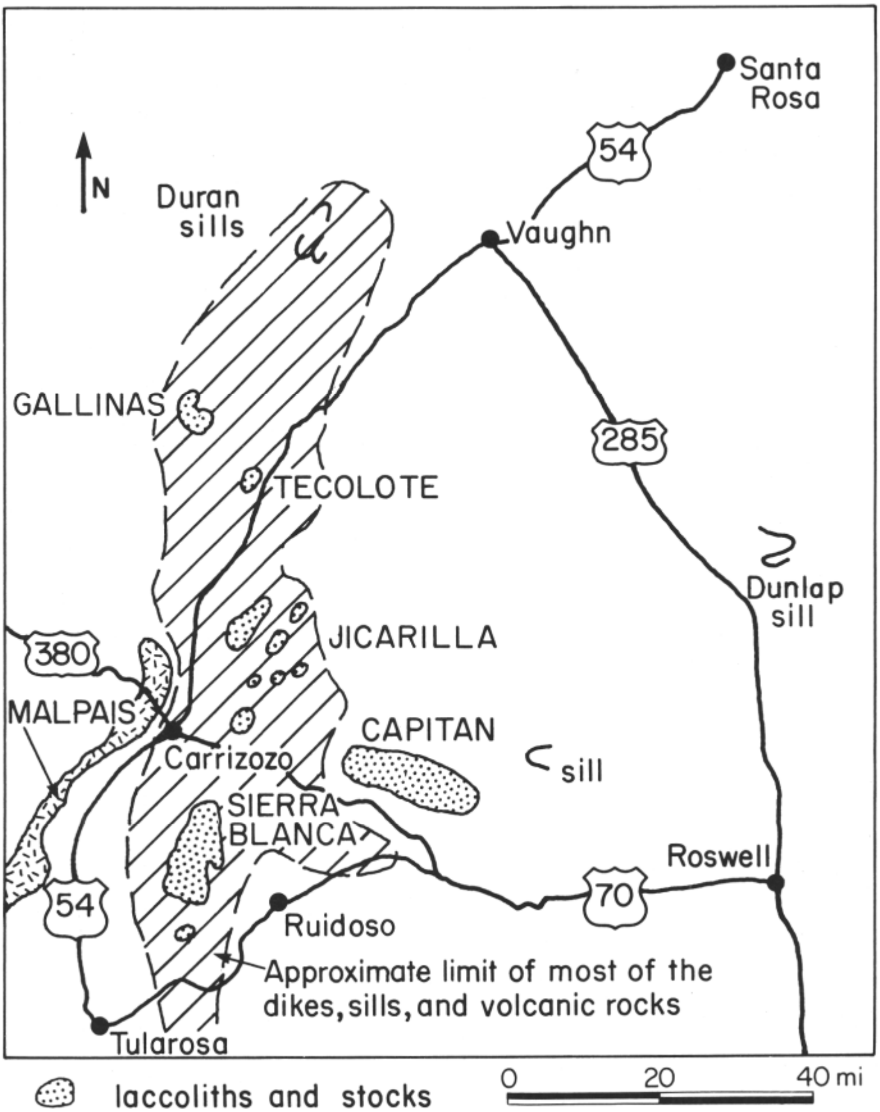
For over 60 mi, from the Corona on the north to beyond Ruidoso on the south, a series of peaks and ridges ranging in elevation from 6,500 ft to 12,003 ft at



Major structural features of Scenic Trip area. **The outcrop of Dakota Sandstone outlines the rim of the ancient Sierra Blanca Basin (modified from Campbell Craddock, 1964, *in* New Mexico Geological Society, Guidebook 15th field conference, *Ruidoso Country*).**

Sierra Blanca Peak exposes what is probably the greatest concentration of Tertiary igneous intrusive centers in New Mexico. Laccoliths, stocks, dikes, and sills in extraordinary abundance characterize the upland landscape. The scenic trip crosses much of the southern part of this remarkable area.

In the lower Oligocene nearly 40 m.y. ago, molten rock (magma) formed tens of miles below western Lincoln County and began working its way toward the surface. The more viscous magma (rhyolite, syenite, monzonite, and granite) did



IGNEOUS ROCKS IN EAST-CENTRAL NEW MEXICO.

not reach the surface but came up as stocks or squeezed between the layers of sedimentary rock to form the sills and laccoliths; the more liquid magma (andesite) erupted at the surface to form volcanos.

The few radioactive dates available indicate that igneous activity lasted throughout nearly all of the Oligocene Epoch. The intrusion of eight laccoliths began nearly 40 m.y. ago in the north, bulging up the cover of at least 2,500 ft of Permian and Mesozoic sediments. Soon thereafter, an andesitic volcano with a center northwest of Ruidoso broke through to the surface and for several million years poured out lavas and fragmental material (breccia) to build up a shield at least 3,000 ft high and 20 mi in diameter (covering more than 500 sq mi), while emitting at least 185 cu mi of magma. During and after the construction of this great volcano, the underlying rocks as well as the volcano were intruded by countless dikes and sills and finally (26 m.y. ago) by several great stocks northwest of Ruidoso. The characteristics of these igneous structures are tabulated from north to south in the table below. The dates in the right-hand column make it hard not to speculate as to an apparent southward progression of the major intrusive activity. A little calculation gives a rate of southern movement of about 2'h inches per year. More abundant radioactive dates could prove or disprove such a tentative hypothesis.

Dike swarms

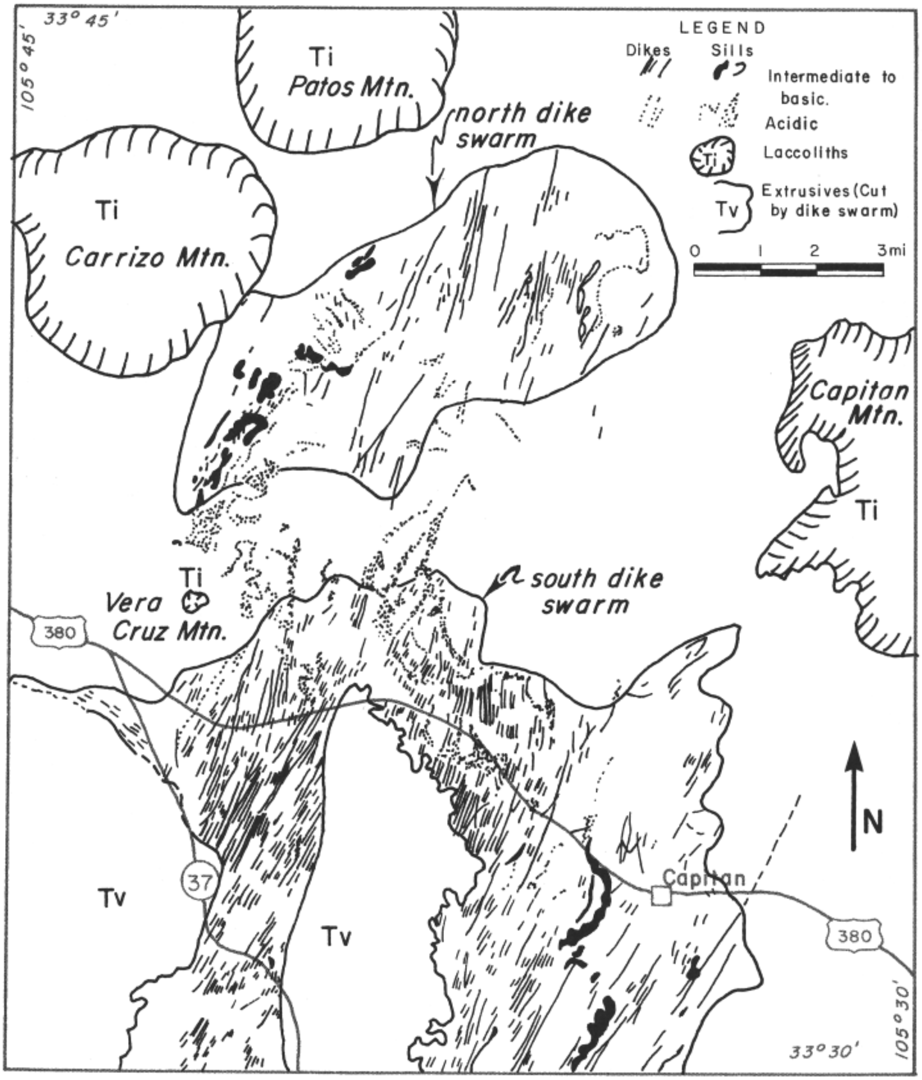
One of the most remarkable and spectacular swarms of dikes in America lies west of Capitan and is well exposed in roadcuts along our trip route for 10 mi.

CHARACTERISTICS OF INTRUSIVE IGNEOUS STRUCTURES IN WESTERN LINCOLN COUNTY (modified from V. C. Kelley and T. B. Thompson, 1964, *in* New Mexico Geological Society, Guidebook 15th field conference, *Ruidoso Country,* and V. C. Kelley, 1971, New Mexico Bureau of Mines and Mineral Resources, Mem. 24).

Name	Maximum elevation (in ft)	Rock composition	Area (sq. mi)	Igneous structure	Age in m.y. when known
Gallinas	8,615	trachyte	16	laccoliths	
Tecolote	7,290	trachyte-rhyolite	5	laccoliths	
Jicarilla	7,895	monzonite, diorite	25	laccolith and stocks	37.7
Lone-Baxter	8,100	syenite, monzonite	6	stock and laccolith	30–37
Patos	8,508	rhyolite	7	laccolith	
Carrizo	9,650	syenite	11	laccolith	
Vera Cruz	7,800	monzonite	1	stock	
Capitan	10,230	quartz syenite or microgranite	110	laccolith and stock	
Willow Hill	6,792	syenite porphyry	2.5	sill and dike	34.4
Church Mountain	8,805	latite porphyry	—	upper flow	31.8
Cub Mountain	6,850	syenite	1.5	sill and dike	
Chaves	6,992	syenite	1	sill or stock	
Hollow Hill	7,000 ±	rhyolite	0.25	laccolith	
Godfrey Hills	7,138	trachyte	?	sill	26.6
Bonito Lake	9,625	syenite	12	stocks	26.6
Three Rivers	12,003	syenite	24	stocks	25.8

The map of igneous rocks of the Capitan quadrangle shows areas where there are outcrops of approximately 1,000 single, multiple, and compound dikes and sills.

The dikes and sills intrude both Cub Mountain sediments and older Mesozoic rocks but are just as abundant in the Sierra Blanca Volcanics, where they could not be mapped. They range from less than 1 ft to 60 or 70 ft in width and in length to at least 5 mi. All but a few trend from due north to N. 30° E. Their composition is dominantly diabasic (four varieties), but rhyolite, latite, trachyte and phonolite dikes also occur. Although in the Capitan area the seven varieties of dikes cut across and intrude one another so that an age sequence could be established, this sequence does not appear to hold elsewhere in the Sierra Blanca Basin.



IGNEOUS ROCKS OF THE CAPITAN QUADRANGLE. **Ti**-igneous dikes, sills, laccoliths, and stocks. Many of the dikes shown as single lines are multiple and compound.

In a distance of less than 10 mi nearly 200 parallel dikes occur along one series of traverses across the swarm. In a few places the density is near 30 dikes per mile. Intrusion of this total thickness of rock (averaging 15 ft per dike) in the swarm must have dilated the area by more than 1/2 mi. This dilation might have been part of the cause of the multiple folding to the east near Lincoln.

Whereas 60-70 percent of the dikes are dark colored, sills tend to be dominantly rhyolitic or latitic. These light-colored sills are especially abundant west of the axis of the Capitan laccolith, where few dikes occur. They might be related in origin to the nearby laccolithic intrusions.

Water, ice, and fire

For the last 20-25 m.y. (since the end of the Oligocene) the dominant geologic processes have been uplift and erosion rather than deposition. As the great Sacramento and Oscura Mountain fault blocks rose for over 1 mi and tilted gently eastward during the latter part of this period of time, at least 1/2 mi of rock was eroded off and carried away by streams, particularly the ancestral Pecos River (which was then many miles west of its present course), and by some ancient Rio Grande tributary that flowed south down the Tularosa Valley.

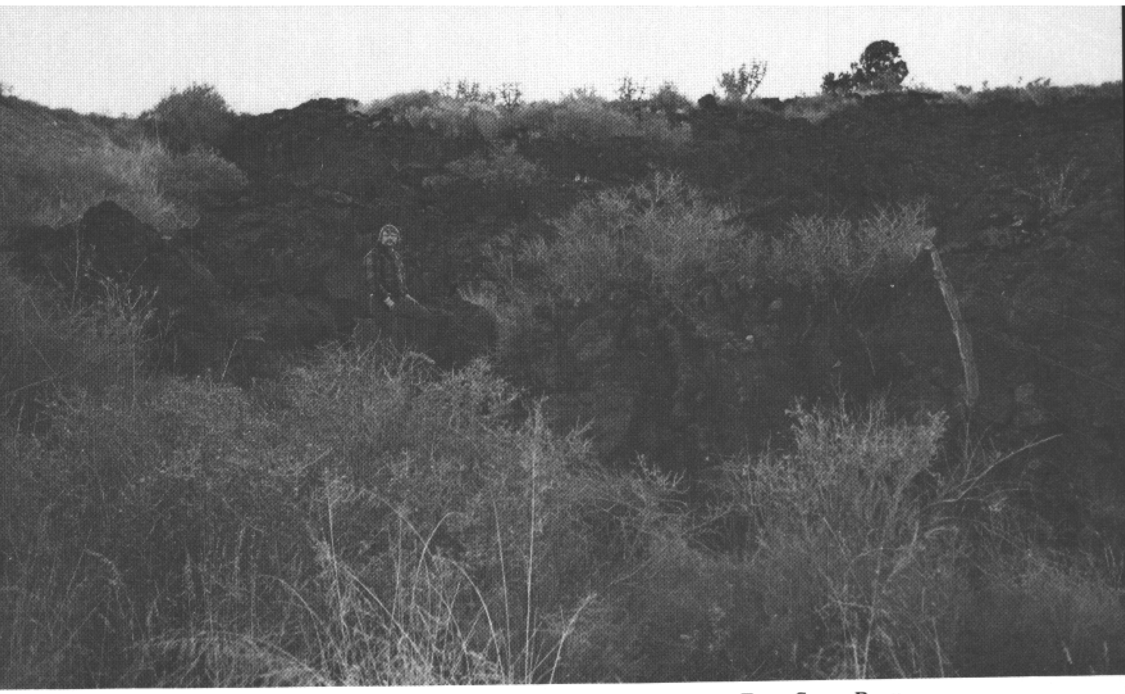
By Pliocene time, the area had been reduced by erosion to broad gravel-coated plains or pediments, which sloped away very gently to the east and west from a north-south ridge of relatively low hills—the remains of the volcanoes, stocks, and laccoliths of Oligocene time, still a few thousand feet high because of their more resistant composition.

Subsequent continued uplift during the last 10 m.y. and renewed erosion have again carved out these mountains to their present prominence, and only portions of the uplifted High Plains surface remain today. East of Sierra Blanca, however, the ridge tops correspond closely in elevation from ridge to ridge, as you can see from any of the higher viewpoints; only a few prominences of more resistant rock, such as the Capitan Mountains and the Pajarito Peak dome, stand out above this ghost of the ancient High Plains surface.

East of the Pecos River in Curry, Roosevelt, and Lea Counties, the High Plains are underlain by a gravel cap known as the Ogallala Formation, which may possibly correspond to the higher gravel-capped ridge tops found between 6,800 and 7,400 ft north of Capitan, near Fort Stanton, and between Capitan and Ruidoso.

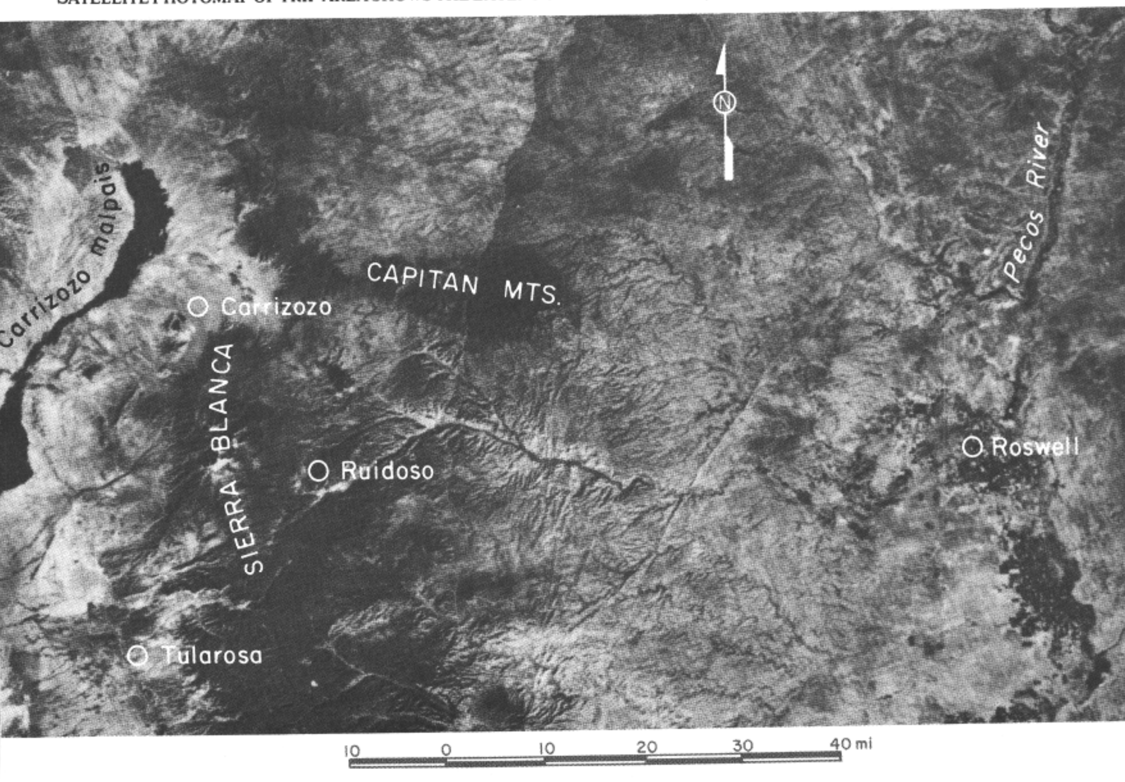
Most of the last 2 million years is the Pleistocene or the ice age. In the latitude of central New Mexico it was merely a period of much greater rainfall and hence more rapid erosion by slope wash and by streams. Ice did form, however, on the highest elevation in the area and carved a glacial cirque on the northeast side of Sierra Blanca Peak. The glacier was only a mile in length. During the ice age the valleys were deepened, and at least one period of broadening formed terraces at elevations below the High Plains surface. Many geologists believe that the present climate is merely an interglacial period between advances of the ice and that the ice age is not yet over.

The final episode of our geologic story was the outburst only a thousand years ago of a new volcano, Little Black Peak, in the northern end of the Tularosa Valley. This explosion was the first resurgence of volcanic activity here in over 20



Exploring the edge of the lava flow at Valley of Fires State Park.

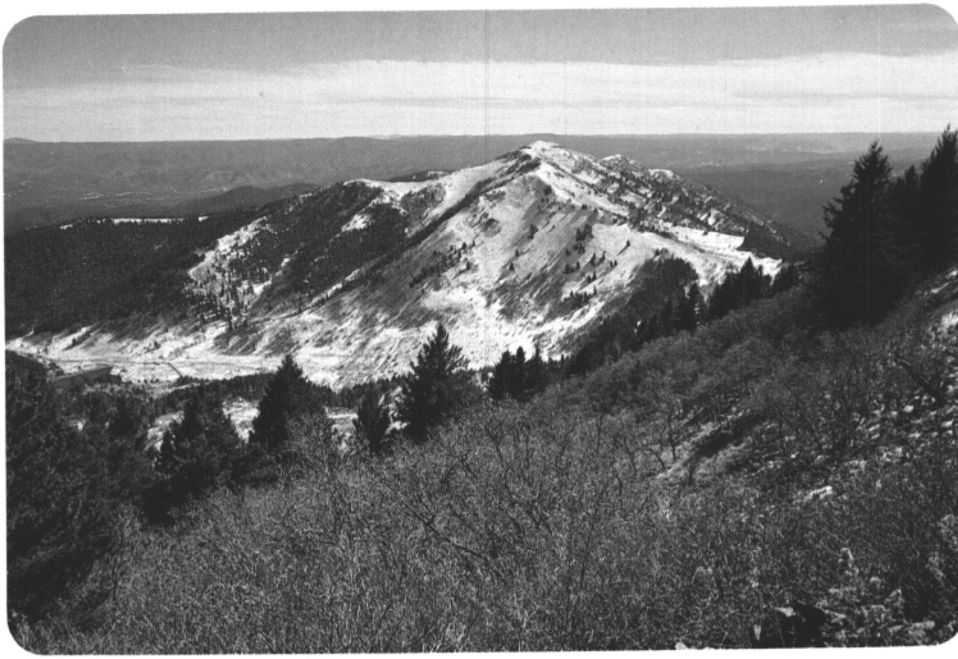
Satellite photomap of trip area shows the extent of the lava flow; it continues far beyond the edge of the photo.



m.y. Starting as a cinder cone, like Paricutin in Mexico in 1942, it soon built up to a height where the internal liquid basalt could no longer be contained in the conduit and broke through the sides of the cone to pour out and down the valley towards the south, eventually for 40 mi. The malpais that resulted is now called Valley of Fires.

Color photo gallery

(next four unnumbered pages)



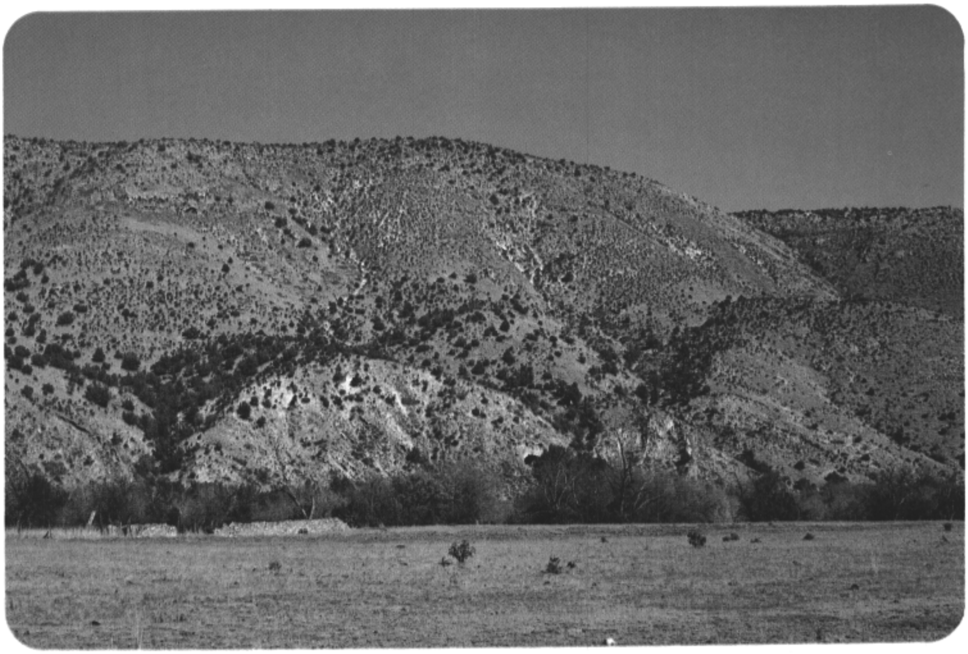
VIEWS FROM LOOKOUT MOUNTAIN, TRIP 5.

LAVA FLOW AND VEGETATION AT VALLEY OF FIRES STATE PARK.

RED AND PURPLE PORPHYRY ALONG ROUTE OF TRIP 5.

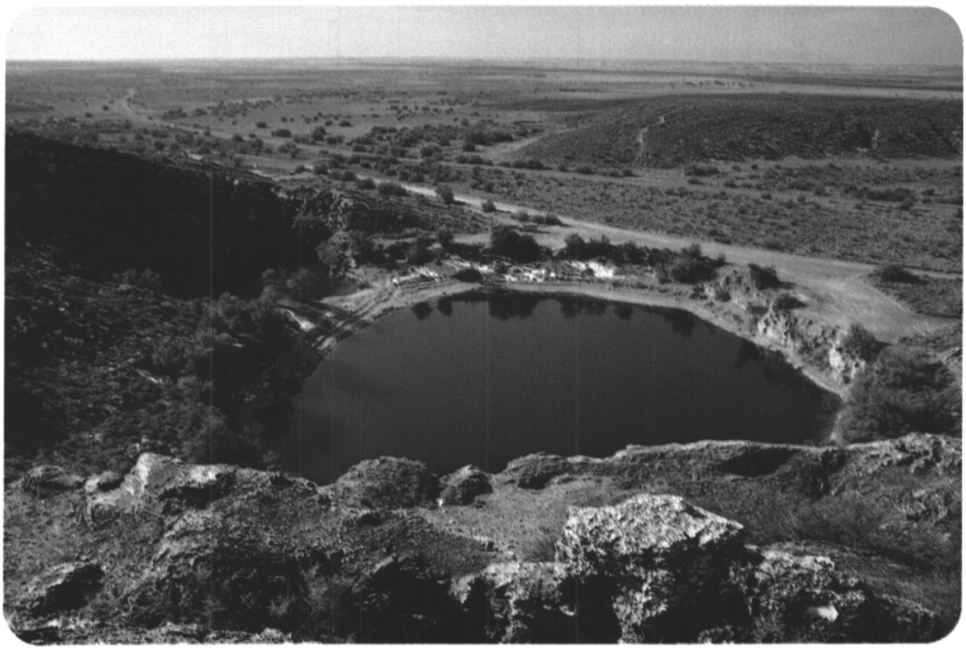
DESERT VARNISH ON DAKOTA SANDSTONE.

LINCOLN FOLDS.



Vera Cruz Mountain.

Mirror Lake, Trip 7



Road logs

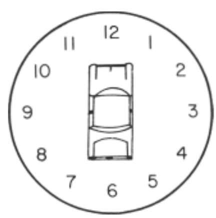
Use of the road logs

Don't try to read the road log yourself! Please have a passenger who can watch the odometer and read the log to you, keeping far enough ahead of the car so that the description can be completed before you reach the next point of interest. The distance to each succeeding point of interest is given in boldface type at the end of each discussion so that you can tell how soon to begin looking for the next point.

We hope we don't have to remind a driver not to stop suddenly without checking for a following car, not to park on the roadway, and most of all, not to look too long at the geologic attractions while the car is in motion.

Check-point mileages such as bridges and road intersections are logged so that the common variations among odometers can be corrected as the trip progresses.

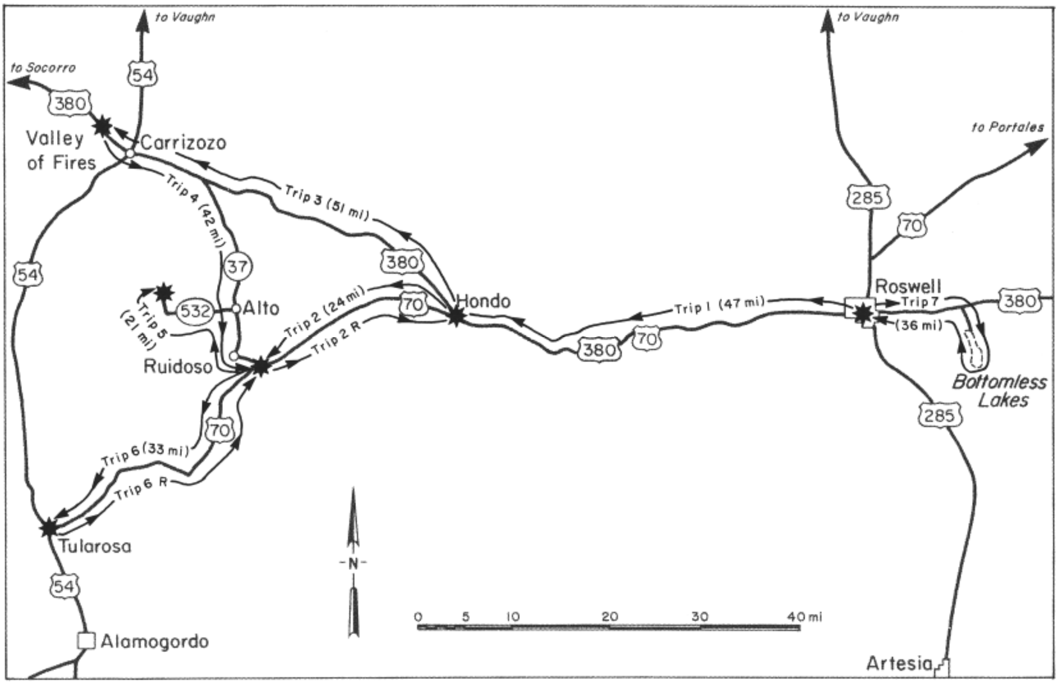
"Where to look" is usually given in the clock-face terminology used by air pilots: 12:00 is straight ahead; 9:00 is due left; 3:00 is due right. Such directions as 6:00 (behind the car) have been avoided.



STOP is indicated at points of special interest (and *stop* is used at highway stop signs); one can adjust the number of stops made to the time available or even stop at additional points as well.

The English meanings of Spanish words are given in parentheses after the word is used.

Shortest route from Roswell to Ruidoso, 75 mi.
Longer route from Roswell to Ruidoso, 140 mi.
Loop route from Ruidoso and return, 118 mi.
Side trip to ski lift from Ruidoso and return, 35 mi.
Side trip to Tularosa from Ruidoso and return, 65 mi.
Return route from Ruidoso to Roswell, 75 mi.
Side trip to Bottomless Lakes from Roswell and return, 36 mi.



KEY TO TRIP PLANNING.

Begins on page no.	Trip no.	Course of trip	Trip mileage
35	1	Roswell to Hondo Junction	47
44	2	Hondo Junction to Ruidoso Junction	24
48	2R	Ruidoso Junction to Hondo Junction	24
52	3	Hondo Junction to Valley of Fires State Park	51
66	4	Valley of Fires State Park to Ruidoso Junction	42
75	5	Ruidoso Junction to Lookout Mountain ski lift (one way)	21
79	6	Ruidoso Junction to Tularosa Junction	33
82	6R	Tularosa Junction to Ruidoso Junction	33
86	7	Roswell to Bottomless Lakes State Park and return	36

(47 miles) **Trip 1**

Roswell to Hondo Junction

(US-70-US-380)

Preview

Roswell (altitude 3,570 ft; population 39,676 in 1980), the third largest city in the state, is the Chaves County seat. Its many industries include cotton gins, creameries, oil refineries, and meat-packing plants. The New Mexico Military Institute is located here.

In 1869 Van C. Smith built an adobe general store, post office, and inn; he 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 effort 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 Railroad 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 has an average annual rainfall of only 13 inches, which falls mostly between May and December. The Roswell Artesian Basin underlies the topsoil and valley fill of the area. It supplies the hundreds of artesian wells with water from the upper part of the San Andres Limestone and is regarded as one of the best examples in the world of a rechargeable artesian aquifer. The honeycomb channels form when broken limestone and occasional gypsum layers are dissolved and act as conduits that catch water from heavy rains falling on the foothills west of Roswell. The porous San Andres Limestone extends underground beneath the Roswell area, serving as a natural sheetlike channel to convey the water downward under the Pecos Valley. It takes 4-5 years for water falling on the foothills to reach the center of the Roswell Basin, a distance of 6-20 mi, moving at a rate of up to 70 ft per day.

The Pecos Valley is underlain by the Permian System of rocks. 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 floodplains. 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 first 30 mi of Trip 1, the bedrock is 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 or beds of finer and coarser materials of different kinds. Although most of these rocks are limestones, thin layers of shale (consolidated mud) and gypsum ($CaSO_4 \cdot H_20$) separate the limestone layers. If the consolidated muds were composed of larger particles, they might be called siltstone (silt-sized), sandstone (sand-sized), or conglomerate (pebble-sized particles).

The San Andres Limestone is a geologic formation 600-1,400 ft thick, a group of beds that have more or less similar recognizable characteristics. It can be separated, therefore, from adjacent formations in mapping, and a line or contact can be drawn between the formations on the map.

In the areas where mountains have been formed (by deep-seated forces whose origin is still not certain), 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.

Mile

0.0 Main and Second Streets, Roswell. *Go west* on Second (US-380). **1.5**

1.5 The radio-tv building on the right has walls faced with tan Austin Limestone imported from Texas. This limestone is very fossiliferous and is sprinkled with shells of ancient snails and clams. **2.1**

3.6 Roswell city limits. Capitan Mountains on skyline at 1:00. We will be ascending from the valley fill onto the high plains that form the east slope of the Sacramento Mountains. **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 been carved to the surface, forming roughly circular depressions that dot the plains in this area. These collapse structures are called sinkholes and are usually filled by a jumble of broken limestone blocks such as those that occur in the roadcuts here. This 12-mile-wide region of sinkholes that lies immediately west of the alluviated Pecos Valley (miles 5 to 17) is the principal "intake" area for the underground water in the

SUMMIT OF SIX-MILE HILL ANTICLINE, Trip 1, mile 5.9. This is San Andres Limestone.

Roswell basin. Note Capitan Mountains at 1:00 and Sierra Blanca at 12:00. We shall have much to say about these huge rock masses later. 1.1

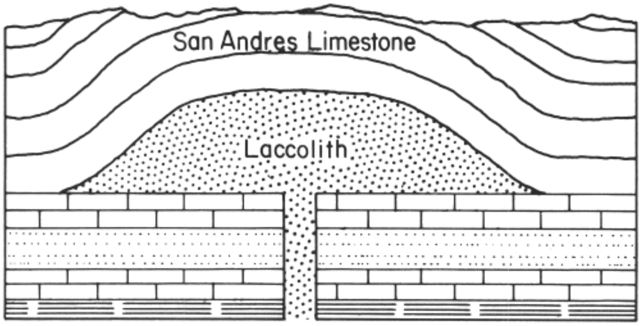
7.0 End of four-lane divided highway. **0.3**

7.3 Bridge. Capitan Mountains, which you saw a moment ago at 1:00, are made up of igneous rock. The rock originated deep beneath the crust of the earth as a molten mass, heated to melting 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 to near 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. A cross section would look like that on p. 38. 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 until it cools, it is called a sill. 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**

11.7 Hilltop. Capitan Mountains at 1:30. Roadcuts ahead are in San Andres Limestone. **1.2**

12.9 Side road left (south) to Two Rivers Reservoir. **0.2**

13.1 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**



LACCOLITH.

16.0 Summit. Highest point of Sierra Blanca (12,003 ft) on skyline at 12:30; Capitan Peak (10,083 ft) at 1:30. Gravels cap hills for the next few miles. Rounded pebbles and cobbles in gravels are like those capping Llano Estacado east of the 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 caprock composed of lime precipitated near the surface by evaporation. **1.8**

17.8 Rest area on left (south). **0.2**

18.0 Summit. Top of Sierra Blanca at 12:00 and another view of Capitan Mountains off to the right. All other laccoliths in the area are circular in outline, but Capitan is elongated and extends for 20 mi in an east-west direction. Most of the rock that once arched up over the laccolith has eroded away, but there are several small patches of San Andres Limestone left on the top. The liquids and vapors given off by the cooling magma altered and replaced the limestone with iron ore in some places. Commercial iron deposits are found on the flanks of the Capitan Mountains; one such deposit being mined in 1977 lies near the western end. Deposits of thorium-bearing minerals (allanite) also occur in veins on the side of the laccolith. **3.0**

21.0 Enter Lincoln County; leave Chaves County. **2.1**

23.1 Hilltop. 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 mi. **1.4**

24.5 STOP. 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-m.y.-old) mollusks from the east-dipping (35°) beds of limestone. These beds are best exposed on the east side of the quarry. **0.3**

24.8 Top of Border Hills faulted anticline. Just before the summit, notice almost-vertical beds along the fault, then breccia zone on the axis of the faulted anticline, and west-dipping beds to the west:. For the next 5 mi 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, 50 mi away. When molten igneous

EXPLORING THE OLD QUARRY ALONG TRIP 1, mile 24.5.

TOP OF BORDER HILLS FAULTED ANTICLINE, showing near-vertical beds, Trip 1, mile 24.8.

rock reaches the surface, it may either flow out as liquid lava (as it did west of Carrizozo) or build up into sizable volcanoes. When the magma contains considerable gaseous matter (mostly water vapor), it blows out explosively. The explosion forms 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 angular blocks of volcanic material known as breccia. This huge volcano was built up 35 m.y. ago; by now much of the original pile has been eroded away by the constant washing action of rain and streams. The highest peak is 12,003 ft above sea level and is the highest mountain in the United States south of the latitude of Mt. Whitney. **0.3**

25.1 Rest area on right. **1.5**

26.6 Hilltop. The ridge from 9:00 to 10:30 is the Border Hills anticline. **1.6**

28.2 Hilltop. Top of Sierra Blanca on skyline at 12:15; ridge at 9:00 is Border Hills anticline; Capitan Mountains at 1:30. **1.2**

29.4 Roadside park on left has one of many tables erected by the New Mexico Highway Department for your convenience. You will find many such sites available for your picnic lunch later! **0.4**

29.8 This summit is at about 5,100 ft elevation. You now leave the High Plains surface 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 mi. Instead of being on top of the 600-ft-thick San Andres Limestone, you go beneath it, into the next older geologic formation, the Yeso (gypsum) Formation (geologic timetable. Prickly pear cactus and ocotillo cap the hill; in the spring, the 10-ft-long ocotillo branches are speckled with scarlet blossoms. **0.7**

30.5 San Andres Limestone beds in roadcuts. **0.3**

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

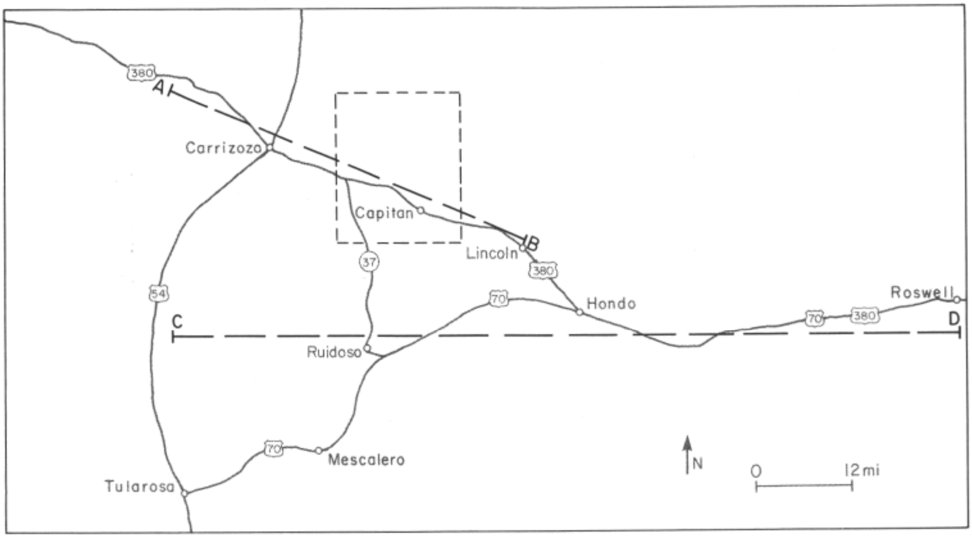
The *Yeso Formation* contains 1,400 to 1,500 ft of orange and pinkish sandstone and siltstone, as well as beds of gypsum (pure massive gypsum is known as alabaster) and limestone. The gypsum was deposited in an inland sea by evaporation of waters rich in concentrated calcium sulfate. Gypsum is a soft, weak rock (number 2 on the 10-unit scale of hardness) and is 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 occurs at and defines the contact between the Yeso and San Andres Formations. **0.7**

31.5 Bottom of Picacho Hill. Enter Rio Hondo Valley; *cross bridge.* **0.7**

32.2 Riverside. The contact of the Yeso and San Andres Formations occurs at outcrops of Glorieta Sandstone close to the road level. **1.2**

33.4 Entering Sunset. Yeso beds in roadcuts on right. Pink, red, and yellow silty



INDEX TO MAP AND CROSS SECTIONS. **Dashed outline represents area covered by figure on p. 29; A–B represents line of section on p. 52; C–D represents line of section below.**

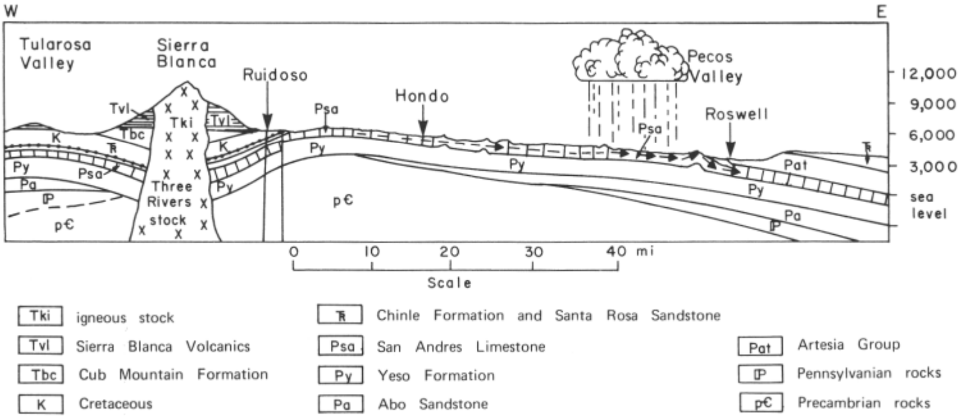
sandstone, with minor limestone and gypsum. Notice irrigated fields on the valley bottom on left. **1.0**

34.4 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**

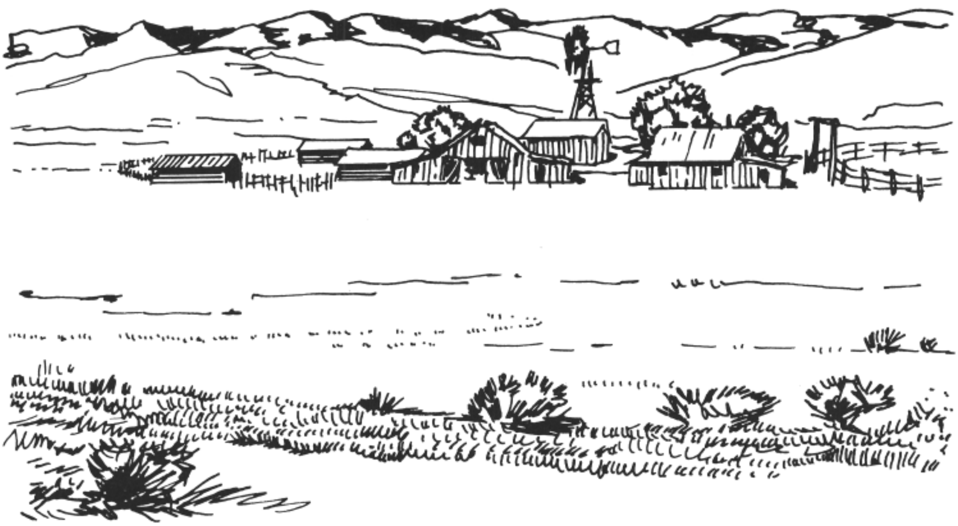
34.9 Outcrops of Yeso; some San Andres Limestone brought down to road level by landsliding. **0.8**

35.7 Conical butte at 10:00, capped by San Andres Limestone. **1.3**

37.0 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 an elongated dome. Two wildcat test wells



GEOLOGIC CROSS SECTION ALONG ROUTE OF TRIPS 1 AND 2 showing course of underground recharge of ground water in the Roswell Basin (arrows) and structure across the Sierra Blanca Basin (modified from V. C. Kelley and T. B. Thompson, 1964, *in* New Mexico Geological Society, Guidebook 15th field conference, *Ruidoso Country*). This section is represented by line C–D on map above.



A TYPICAL DESERT FARMHOUSE IN THE SCENIC TRIP AREA.

have been drilled on this structure, but no oil was found. The tests went into Precambrian rocks beneath the Abo red beds. **1.5**

38.5 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 Grande 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**

39.5 West-dipping beds in the roadcut on right are on the west flank of the anticline. **0.3**

39.8 On left is a steel bridge across the Rio Hondo. The dirt road to the south winds through the eastern foothills of the Sacramento Mountains for nearly 50 mi and joins NM-83 near Elk. **1.2**

41.0 Hilltop, curve to left. The road is on alluvial fans washed into the main valley by streams from side canyons; notice gravel in roadcuts. **1.0**

42.0 "The Adobe Hacienda," home of Louise Massey, who wrote the song of that name, on left. **1.5**

43.5 Entering Tinnie. Apple orchards in the valley. On left is Penny Mercantile Company, Silver Dollar Saloon, Steak House, and Museum. **0.5**

44.0 Road to right, NM-368, leads around the east end of Capitan Mountain to the little hamlet of Arabela, a distance of 17 mi. About 8 mi on gravel road beyond Arabela, NM-368 joins paved NM-48, which loops west around the north side of the Capitan Mountains to the town of Capitan, 26 mi west of here. **0.4**

44.4 Steeply dipping beds of the Tinnie folds can be seen in the canyons to the right of the highway. Roadcut on right exposes sills of gray igneous rock intruded into Yeso beds. **0.6**

45.0 Steel bridge to left across Rio Hondo follows NM-395 leading southeast to Alamo Canyon. **0.2**

45.2 Roadside table on left; lower slopes of canyon wall across valley on left are outcrop of Yeso; upper ledges are San Andres. **2.1**

47.3 Junction of US-70 *(turn left* to continue with Trip 2 to Ruidoso) and NM-380 *(turn right* to continue with Trip 3 to Carrizozo).

END OF TRIP 1.

Trip 2 (24 miles)

Hondo Junction (US-70-US-380) to Ruidoso Junction (US-70-NM-37)

Preview

During this trip to Ruidoso, the upper slopes of the increasingly high valley walls are composed of San Andres Limestone, while the rocks exposed in road-cuts are, except for one short stretch, dominantly Yeso Formation. This section of orange and pinkish-colored sandstone and siltstone (over 1,000 ft thick) also contains smaller amounts of gray limestone or dolomite and pure white gypsum. Because of the solubility and the relative weakness of the gypsum, the normal flat-lying beds of the Yeso are frequently distorted by folds and fractures; the distortion is probably caused by local landsliding into the valley of the overlying 600-ft-thick San Andres Limestone.

During the erosion of the Rio Ruidoso valley, there was at least one period of slow-down in erosion, when the river cut sideways instead of downwards to widen the valley rather than to deepen it. Later it again cut downwards to the present level, leaving terraces covered with a thick mantle of river sand and gravel along the sides of the valley. Tributary streams have deposited small fans of sand and gravel upon these terraces and in the valley where they enter the Rio Ruidoso. The terraces may be related to glacial events in the mountains.

Mile

0.0 Coming from Roswell on US-380, *turn left* on US-70, which goes up Rio Ruidoso (Noisy River) to the town of Ruidoso. **0.1**

0.1 Bridge across Rio Bonito (Pretty River). **1.1**

1.2 Uppermost Yeso in roadcuts, overlain by San Andres Limestone above. **0.8**

2.0 The landslide block of San Andres Limestone on right has slid down at least 300 ft. **0.8**

2.8 Distorted Yeso in roadcuts on right. **0.5**

3.3 Junction on left to hamlet of San Patricio, home of Peter Hurd, the famous artist. **0.4**

3.7 Note interesting whitewashed church with bells on left. **0.5**

4.2 San Patricio Trading Company on right. **0.5**

4.7 Vertical Yeso gypsum beds in roadcuts on right. These exposures of Yeso are similar to but not as spectacularly distorted as those on NM-380 near Lincoln to the north (Trip 3). **0.3**

5.0 Interbedded gypsum and limestone. **0.7**

5.7 Note terraces at 9:00 across Rio Ruidoso. **0.7**

6.4 Entering apple and cherry orchard area. **1.3**

7.7 Note terraces at 12:00-2:00, 30 ft above highway level. **1.1**

8.8 Bridge across arroyo, followed by several roadcuts in terrace gravels. **0.6**

9.4 Highway climbs up onto terrace. **0.5**

9.9 Highway drops down off terrace. These terraces represent a former stage

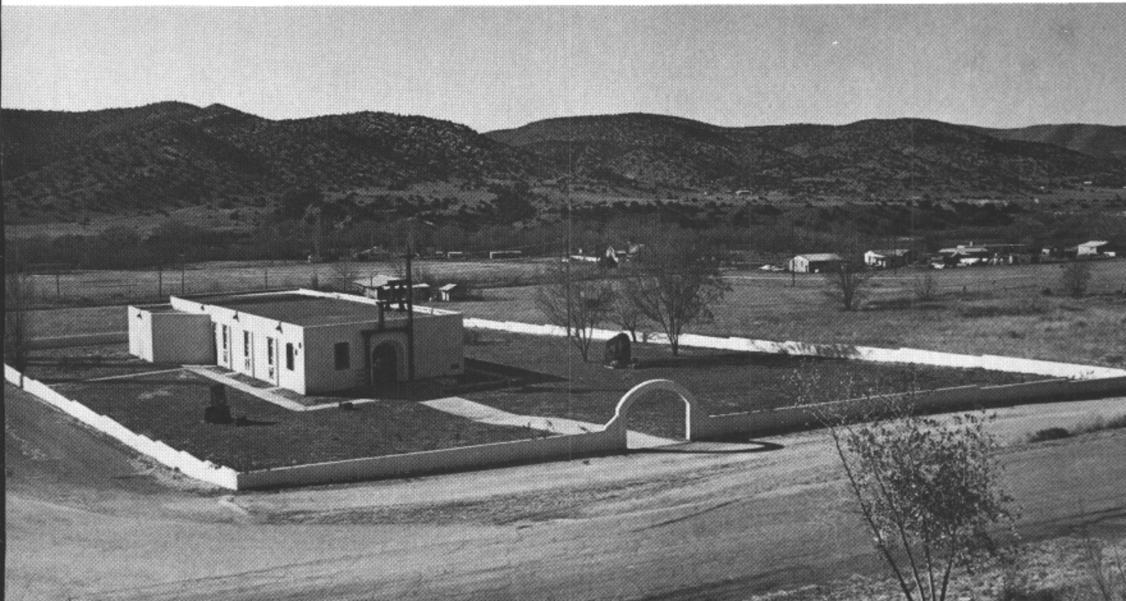
LANDSLIDE BLOCKS OF SAN ANDRES LIMESTONE, Trip 2, mile 2.0.

of erosion when the Rio Ruidoso did not cut downward and for a while widened its valley at an elevation now above the present one. When the obstruction was eroded away, a new cycle of erosion cut down to present level. **0.3**

10.2 Bridge across the arroyo; at right is intersection of NM-214, leading to Fort Stanton (9 mi). **0.3**

10.5 Glencoe junction on left. **0.7**

WHITEWASHED CHURCH NEAR SAN PATRICIO, Trip 2, mile 3.7.



11.2 Note Yeso in roadcut on right, with large pop-out or slump. For approximately the next mile, roadcuts are mostly in terrace gravel. **1.6**

12.8 Deep roadcut in San Andres Limestone, with an igneous intrusion (sill) forming lower part of exposure. The igneous rock is greenish gray and shows rounded (spheroidal) weathering, in contrast to the pitted cavernous weathering of the San Andres Limestone. The upper part of the cliff is limestone, and the contact with the sill is along bedding planes; the limestone is silicified and partly engulfed by the sill. **0.7**

13.5 Limestone quarry above on hill at right. **1.1**

14.6 Igneous dike cuts across bedding in San Andres Limestone at west end of roadcut on right. **0.8**

15.4 Greenish-gray igneous sill in roadcut on right. Notice old channel cut in limestone and filled with terrace gravels. **0.2**

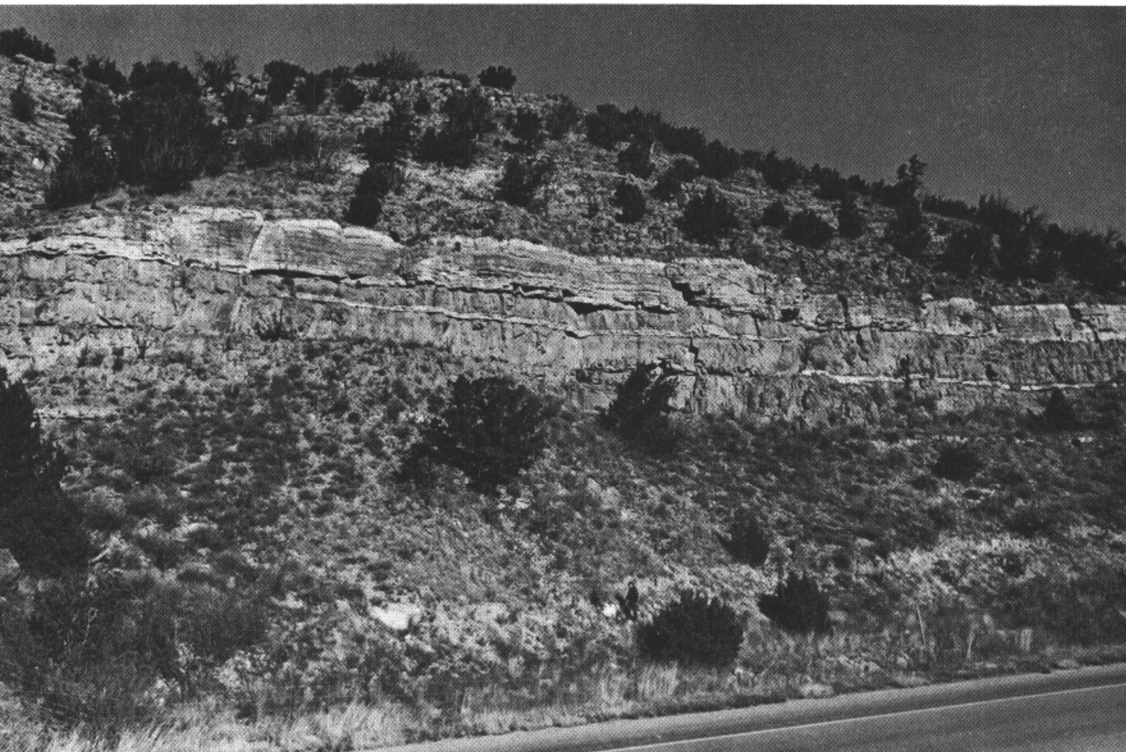
15.6 Fox Cave turnoff on right (a walled-up overhang in San Andres Limestone). Sill is exposed on left in far river bank below highway level. **1.2** 16.8 Distorted Yeso outcrops for next 1/2 mi. **1.2**

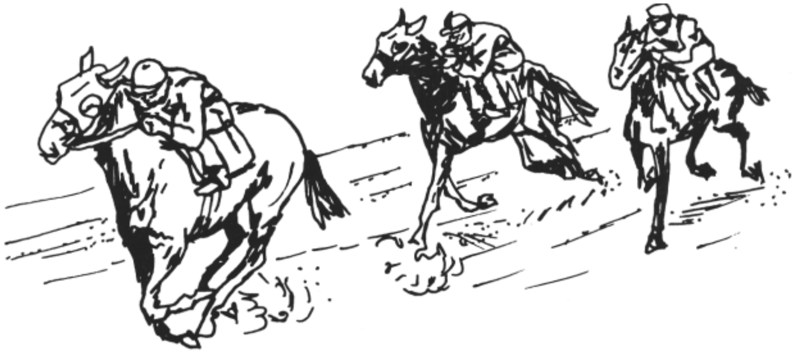
18.0 Bridge over Rio Ruidoso. For the next few miles, the highway crosses broad alluvial fans on the south side of the valley. **2.2**

20.2 STOP. Turn out on right to examine distorted Yeso beds in roadcut on left. Note small anticline at west end of cut; channel cut by tributary stream and filled with coarse alluvial gravels. Good view from 12:00 to 2:00 of Ruidoso Downs housing developments. **0.3**

20.5 Begin divided highway. **1.5**

ROADCUT IN SAN ANDRES LIMESTONE INTRUDED BY SILL OF IGNEOUS ROCK, Trip 2, mile 12.8.





A RACE AT RUIDOSO DOWNS.

22.0 Ruidoso Downs Racetrack on right—famous especially for quarter-horse events with large prizes. **1.5**

23.5 Junction of US-70 and NM-37. Go *straight ahead* to Ruidoso on NM-37 for Trip 5 to Lookout Peak; or *turn left* for Tularosa and Alamogordo on US-70 for Trip 6. Entering town of Ruidoso.

END OF TRIP 2

Trip 2-Reverse (24 miles)

Ruidoso Junction (US-70-NM-37) to Hondo Junction (US-70-US-380)

Preview

Only two sedimentary formations, both Permian, the Yeso (variegated red to yellow sandstones, siltstones, and white gypsm) and the San Andres (mostly gray limestone) will be seen on this trip, but as elsewhere in the area, igneous intrusions also appear. Between miles 5 and 10, sills and a few dikes of greenish-gray-weathering igneous rock intruded into the San Andres limestone appear in at least six roadcuts, mostly on the left. The most prominent sill forms the lower 10 ft of the large roadcut just beyond Fox Cave.

During the trip, the Yeso-San Andres contact is folded down below road level in a syncline approximately between miles 7 and 10; it rises to its highest point (the axis of an anticline) near mile 20.

Mile

0.0 Intersection of US-70 and NM-37. To the west on US-70, Tularosa is 32 mi; and Alamogordo 44 mi. *Proceed east* toward Roswell (75 mi). **1.2**

1.2 Enter Ruidoso Downs. **0.2**

1.4 Entrance to Ruidoso Downs racetrack on left. **0.4**

1.8 Entrance to Ruidoso Downs Heights on right. **1.5**

3.3 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), 'A mi south of the highway, once fed an Indian acequia (ah-SAY-kee-ah, irrigation ditch), possibly 900 years old, that skirts the foothills from 2:00 to 3:00 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**

3.6 Folded beds of the Yeso in right roadcut are overlain by U-shaped channel fill of boulder gravel deposited by an ancient higher level of Rio Ruidoso and its side streams. **0.2**

3.8 High roadcut on right of interbedded gravel and reddish silt deposited as old alluvial fans derived from streams entering Rio Ruidoso valley from the south. Notice abrupt transition from silt to coarse gravel. **1.2**

5.0 Side road to right to Half Lake. Roadcuts ahead on right are alluvial gravel and silt. Dislocated landslide blocks of Yeso and San Andres limestones are strewn on the other side of Rio Ruidoso valley. **0.6**

5.6 Bridge over Rio Ruidoso. **0.3**

5.9 Begin roadcuts on left in Yeso gray gypsum and limestone, red shale, and yellow sandstone. 1.3

7.2 On broad S-curve to right, then to left, San Andres Limestone dips eastward down to road level. Entering the west flank of a syncline and the east side of an anticline. **0.7**

HIGH ROADCUT IN ALLUVIAL-FAN GRAVELS, Trip 2R, mile 3.3.

7.9 Fox Cave turnoff on left. Walled-up overhang of San Andres Limestone. **0.2**

8.1 Roadcut on left; greenish-gray igneous sill where liquid lava squeezed between beds of the San Andres Limestone and solidified. Cut by channel fill of alluvial gravels with vertical contact of bedrock and gravels along sides of ancient stream channel. **1.2**

9.3 Deep roadcut in San Andres Limestone with igneous dike at west end. **1.2**

10.5 Leaving Lincoln National Forest. Roadcuts on left; alluvial gravel and silt

FOX CAVE, showing overhang of San Andres Limestone, Trip 2R, mile 7.9.

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 Limestone. Upper cliffs are limestone; contact with sill is along bedding planes; limestone is being silicified and partly engulfed in the sill. **1.2**

11.7 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**

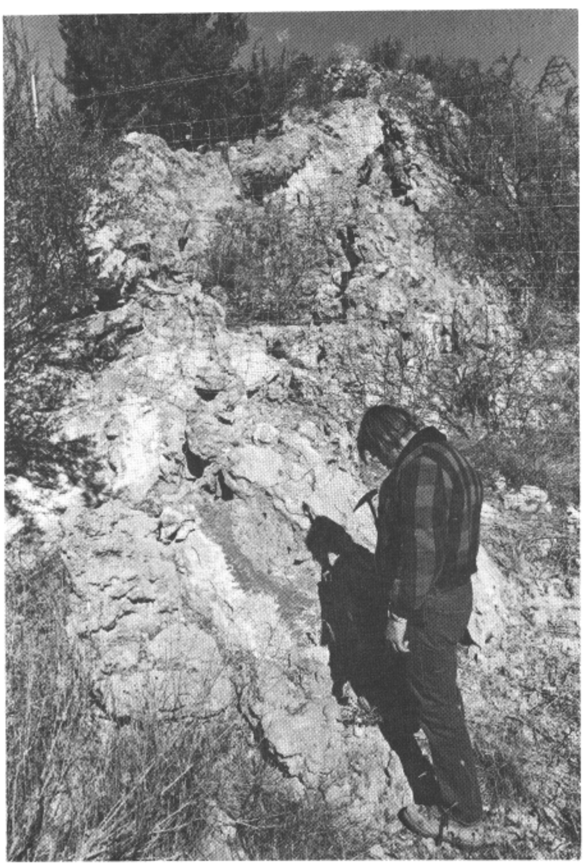
12.1 Roadcuts in alluvial gravels. **0.5**

12.6 Glencoe Post Office on right. Many apple and cherry orchards. **0.7**

13.3 Road junction and bridge; continue straight ahead. NM-214 leads to Fort Stanton (9 mi). Gravel terrace above road ahead was the site of a prehistoric Indian village excavated in 1956 by archaeologists from Texas Technological College. Note Yeso outcrops in roadcuts and small anticline west of bridge. **0.3**

13.6 Dumps from excavations on bridge at 10:00. Notice lenses of stream gravel in terrace deposits in the roadcut. **1.2**

14.8 Bridge. Many roadcuts in alluvial terrace gravels. **1.6**



CONTORTED BEDS OF YESO FORMATION (gypsum), Trip 2R, mile 19.

16.4 Bridge. San Andres Limestone caps canyon walls; Yeso Formation on lower slopes. **1.2**

17.6 White gypsum of Yeso Formation in roadcut on left. Notice terraces along sides of valley. **0.4**

18.0 Yeso beds tilted in all directions (from a landslide?). **1.0**

19.0 Contorted beds of Yeso Formation. Lincoln-type folds. **0.7**

19.7 Passing San Patricio. Home of Peter Hurd, famous artist and an ardent palomino polo player, lies across the Rio Ruidoso. Old San Patricio Church on right. **1.8**

21.5 Landslide block of San Andres Limestone in roadcut (has slid down at least 300 ft). **1.6**

23.1 Entering Hondo (Deep). **0.6**

23.7 Junction with US-380. *Turn left* for Trip 3. For the rest of the trip to Roswell (48 mi), *turn right*, and read Trip 1 (page 35) of the road log in reverse (miles 47.3 to 0).

END OF TRIP 2 REVERSE

Trip 3 (51 miles)

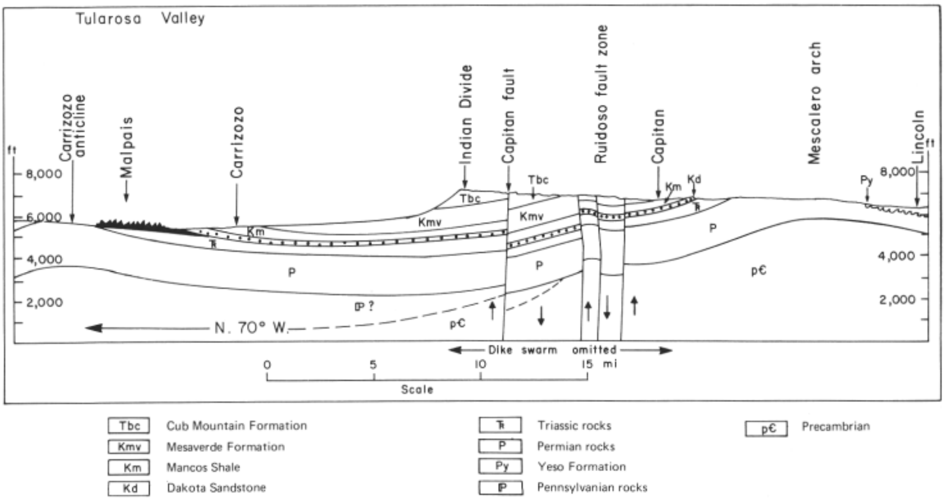
Hondo Junction (US-70-US-380) to Valley of Fires State Park

Preview

Trip 3 is our favorite, because it poses more spectacular questions than it answers. What caused the remarkable "Lincoln folds"? Why are Capitan Mountains elongated for over 22 mi east and west when the other laccoliths are nearly circular in shape? Why do we find thousands of igneous dikes and sills, most of them trending a little east of north and most of them within the 25 by 40-mi Sierra Blanca Basin, as outlined by the outcrops of Dakota Sandstone? Why have geologists found that all the igneous rocks dated so far (by radioactive methods) are of Oligocene age, 22-37 m.y. old? These include dikes, sills, laccoliths, stocks, lavas, and breccias. Why did volcanism reappear only a thousand years ago northwest of Carrizozo? Perhaps the sights to be seen in the next 50 mi will give some clues to possible answers.

Trip 3 passes through the folded Yeso Formation and the overlying nearly flat-lying San Andres Limestone for 17 mi and then enters the Sierra Blanca Basin. Within only 8 mi, the west-dipping beds successively consist of the Artesia, Santa Rosa, Chinle, Dakota, Mancos and Mesaverde stratigraphic units.

From Capitan westward, the trip passes for 10 mi through Mesaverde and Cub Mountain sedimentary rocks, which are intruded by a swarm of hundreds of north-trending igneous dikes, many of them compound—that is, dike intruded into dike. To complicate the picture further, several faults run parallel to the dikes; these faults have uplifted or downdropped long blocks from 1/2- to 2-mi wide so that the Mesaverde and Cub Mountain rocks are repeated along the course of the trip.



GEOLOGIC CROSS SECTION ALONG ROUTE OF TRIP 3, miles 10 to 50, across Sierra Blanca structural basin. Dikes and many faults are omitted. This section is represented by line A–B on map, p. 41.

From Indian Divide (elevation 7,000 ft), the trip descends rapidly into the broad Tularosa Valley and ends at the 40-mi-long lava flow (malpais or "bad land"), that occupies the bottom of the valley at 5,200 ft elevation.

Mile

0.0 Junction of US-70 and US-380. Roadside tables on the north side of the highway; historical marker describes the picturesque village of Lincoln, 10 mi to the west. This junction is also at the point where the Rio Ruidoso (Noisy River) and the Rio Bonito (Pretty River) join to form the Rio Hondo (Deep River). *Proceed west* on US-380 up the Rio Bonito valley. **1.1**

1.1 Notice folded beds to the left across the valley at the base of the valley wall. **1.0**

2.1 Flash floods from the canyon to the right have built up a high alluvial fan of unsorted and jumbled rock debris cut by the highway. A cloudburst up this canyon could stop traffic (and has!) for many hours. **0.6**

2.7 Highly contorted Yeso rocks in roadcuts for the next few miles. Notice landslide blocks of San Andres Limestone near the highway level. They originated much higher on the hillside. **1.8**

4.5 Roadcuts in alluvial fans and talus cones; note angularity of pebbles and boulders and poor sorting. **0.9**

5.4 Bridge across the Rio Bonito. A good outcrop showing Yeso, thin Glorieta Sandstone, and San Andres formations, all in roadcut on left. **1.1**

6.5 Notice disturbed beds of San Andres Limestone across valley at 3:00. **1.0**

7.5 Glimpse of Capitan Mountains through saddle at 1:00. **0.3**

7.8 Here begin the highly controversial (among geologists) Lincoln folds, which 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 phenomenon caused by solution and landsliding, by intrusion of the sharp edge of the Capitan Mountains laccolith into the weaker beds, or by gravity sliding of the upper beds over the underlying weak ones? Geologists are still divided. **0.4**

8.2 The huge boulders of limestone on the right rolled down from the high cliffs on the left. Approaching the historic town of Lincoln, center of the Lincoln County cattle war and base of operations of Billy the Kid (William Bonney) and Sheriff Pat Garrett. Historical marker reads: "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 the 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 the opposing faction." **1.1**

9.3 Cemetery on right; graves of the famous and infamous. Folded Yeso beds across the valley on right. Notice anticline across river at 3:00 and other folds. **0.4**

9.7 Entering Lincoln. Those interested in history or in Billy the Kid should walk through town to read the 11 historical markers set up on both sides of the highway by the Lincoln County Memorial Association. **0.2**

9.9 STOP. 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. **0.3**

10.2 Old Lincoln County Courthouse (on left) contains one of the finest local historical museums in the Southwest. So that you can obtain a complete story of the Lincoln County War, as well as see relics of the early Indian occupation, we recommend a visit. A pageant re-enacting the escape of Billy the Kid from jail is part of the Billy the Kid festival held every August. **0.1**

10.3 Leaving Lincoln. Capitan Mountains at 2:00. Lincoln folds still continuing across the valley. **1.2**

11.5 Distorted Yeso beds in roadcuts. **3.1**

14.6 Entrance (right) to picnic grounds under the cottonwood trees and double crossing of the Rio Bonito. Capitan Mountains at 3:00. This point is almost the western limit of the area in which contorted Yeso beds appear at the surface. The valley joining the Rio Bonito here from the north is that of the Rio Salado (Salt River). The highway will cross over into the Rio Salado valley in about 5 mi. **0.6**

15.2 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**

15.8 Small faults offsetting the massive limestone at 3:00 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 Basin. **0.4**

16.2 Small turnout (right) on curve to right; last outcrop of Yeso occupies the lower 6 ft 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**

16.6 Government Spring, along the river bank on the right, through the double fence post; well house just beyond the spring. This spring was one of the few early sources of permanent fresh water from the permeable Glorieta Sandstone. It might be fed from underground streams connected with the Fort Stanton caverns a mile to the south. **0.3**

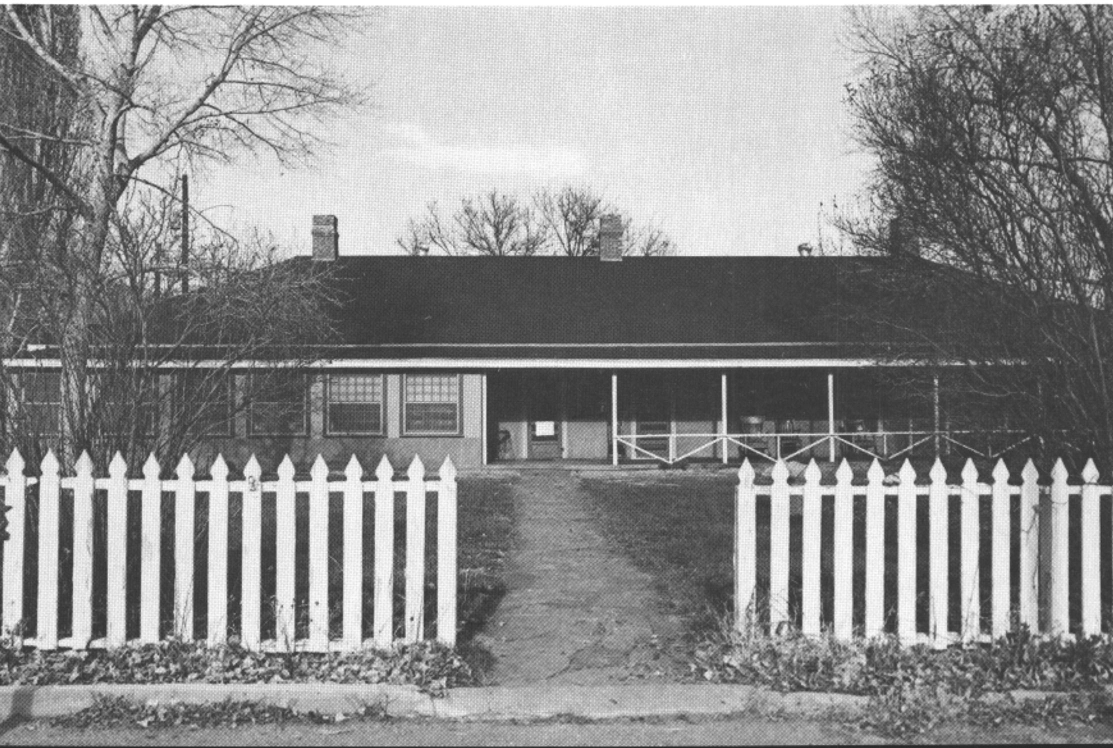
16.9 The site of a prehistoric Indian village on the slopes 200 ft to the left of the road. Smetnick Cave, just above the top of the low cliffs directly across the valley to the north, has yielded many artifacts. At 12:00, the flat surface on the skyline is a remnant of a widespread ancient surface of Pliocene erosion and deposition, now mostly cut down and worn away by the modern stream system. **0.4**

17.3 Culvert. Fort Stanton is visible up the valley in the distance, at 10:00. About 1/2 mi upstream on the left is the entrance to Fort Stanton Cave, said to be more than 4 mi long. Sierra Blanca in the distance, up the valley. **0.4**

17.7 Bridge over the Rio Bonito. Fort Stanton lies about 2 mi upstream to the south. Fort Stanton was established in May 1855 in an atttempt to control the Mescalero and White Mountain Apaches and was named after Captain

THE OLD DOLAN HOME IN LINCOLN; J. J. Dolan participated in the Lincoln County War; the house later served as an inn.

THE WORTLEY HOTEL IN LINCOLN.



igneous rocks). They are so well rounded and polished that they probably traveled hundreds of miles in the Triassic streams. **0.5**

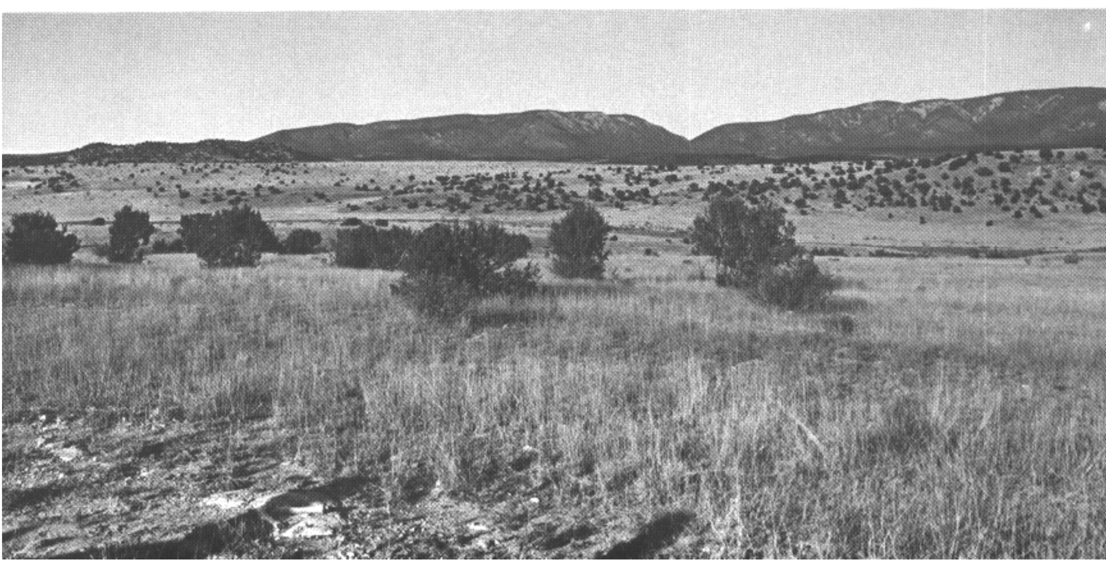
19.5 Capitan Mountains, from 2:00 to 4:00, can now be seen in their entirety; they are a long igneous mass, shaped like an inverted canoe—a laccolith. The rock resists erosion so much more than the surrounding sediments that it dominates the horizon (elevation 10,083 ft at the east end). **0.1**

19.6 On right is Smokey Bear Vista and marker. The gap in Capitan Mountain to the north was the birthplace of Smokey Bear. Historic marker: "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."

The highway now traverses the south edge of plains eroded by the Rio Salado. The Santa Rosa Sandstone and conglomerate form the low dark cliff at 3:00. Farther west, the red Chinle shales, 180 ft thick, can be seen. Both are formations of the Dockum Group of Triassic rocks. The cliffs ahead are of Dakota Sandstone (134 ft thick), 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—all of Jurassic and Lower Cretaceous time, when 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, 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 (at least 50 percent) of the North American continent; New Mexico was probably completely submerged. The rocks deposited in those seas, however, have largely eroded away in the 70 m.y. since the Cretaceous Period. Except in the San Juan Basin in the northwestern part of the state,

VIEW OF CAPITAN MOUNTAINS. Capitan Gap was the birthplace of Smokey the Bear.



they remain only in small patches, such as in the Sierra Blanca Basin, which we are about to cross. **1.0**

20.6 The even crests of the cliffs ahead and of the hills to the south (left) are caused by the long period of Pliocene erosion mentioned at mile 16.9. 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 Sierra Blanca, Capitan, Tucson Mountain (the high peak at 1:00), and the igneous hills west of here stood above the plain. Subsequent erosion by the present streams has left only remnants of the gravels capping the ridges. **0.4**

21.0 Rodeo Bar. Notice erosion channels in red Chinle shale (Triassic) at 2:00. 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 causes the hummocky topography on both sides of the Rio Salado at this point. To the north (right), notice the low terraces along the river. **0.4**

21.4 Junction with Capitan Gap road leading to birthplace of Smokey Bear. This road cuts through the Capitan Mountains in the low pass at 4:00. **0.4**

21.8 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. **0.4**

22.2 STOP. Road cuts through Chinle rocks. 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 between the Chinle and the overlying Dakota lies above these limestone beds and represents a time interval of nearly 100 m.y.

The black coating on the blocks of Dakota Sandstone near 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 of the rock to be reprecipitated during drying.

If you walk west up the highway 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 ft thick. As the advancing sea became deeper, the Dakota Sandstone beds got thinner, and the shale beds became gradually thicker until the rock was almost entirely shale. The contact between formations is drawn at the point where the shale becomes more than 50 percent of the beds. Also at the crest of the hill are dikes of igneous rock cutting through the sandstones and shales. These are the first of hundreds of such dikes in the Cretaceous and later rocks and will be seen in most of the roadcuts for the next 10 mi. **0.2**

22.4 Top of hill. Roadcut in Dakota Sandstone; like most of the dikes in this area, the dikes in this sandstone trend from north to 20 degrees east of north. You are now looking across the Capitan Valley, underlain by the less resistant Mancos Shale. Cliffs of the Mesaverde Formation, which is at least 600 ft thick, overlie the Mancos west of the town of Capitan. Thin beds of limestone in the lower part of the marine shale (note low knoll at

11:00) sometimes contain small clams and, rarely, ammonites—those strange coiled shellfish (sometimes reaching diameters of up to 10 ft) which are related to our modern chambered nautilus and octopus. The Mancos Shale generally underlies valleys because shale is less resistant to erosion than the sandstone beds above (to the west) and below (to the east). **0.3**

22.7 Culverts over deep arroyos. This gully cutting is said to have been initiated in the late 1860's (by overgrazing?). 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. Farther along the route you will notice the extensive efforts to curb erosion by tearing down the juniper trees and throwing them into the gullies. This experimental project of the U.S. Soil Conservation and Forest Services is designed to increase the amount of grass by making available the water and space that the junipers would use. **0.2**

22.9 *Cross bridge* over Magado Creek; enter Capitan, 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. **0.7**

23.6 Junction of US-380 and NM-48. Highway to left is paved 20 mi to Ruidoso; to right it goes around the north side of Capitan Mountains, 33 mi to Pine Lodge, and eventually to Roswell. The largest of the Capitan iron deposits lies only 6 mi to the north. Ore was being mined for use as a heavy concrete aggregate during 1977. **0.1**

23.7 STOP. Smokey Bear Museum on right features exhibits of the natural resources of Lincoln County. **0.5**

24.2 Leaving Capitan; entering the Capitan coal field. Notice the old mine dumps at 2:00. Reserves for the Sierra Blanca Basin have been estimated at more than a billion tons of bituminous coal, with more than 2 million tons in the Capitan area. Most of this enormous tonnage cannot be mined economically because of depth, intrusion by dikes, and, most of all, faulting of the beds. These mines were operated in the late 1890's and early 1900's by the New Mexico Fuel Company and other operators and produced an aggregate of more than 600,000 tons of coal. The coal was shipped 30 mi to the west to Carrizozo, where a spur line joined the present main line of the Southern Pacific Railway.

The low, dark ridge ahead from 1:00 to 2:00 is not Mesaverde sandstone; it is a sill, a layer of igneous rock intruded as molten lava between the sandstone beds 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, at least 600 ft thick. **0.7**

24.9 Top of hill. Outcrops of sill (dark andesite porphyry) on right. **0.5**

25.4 STOP. Beyond bridge over Oso (Bear) Creek. West-dipping ledges of Mesaverde sandstone contain abundant fossils for the collector. One layer in the stream bed, 250 ft upstream from the bridge, is made up almost entirely of small oyster shells *(Crassostrea soleniscus* and *Ostrea anomioides).* Giant *(Inoceramus deformis)* clam casts (more than 8 inches across) occur in the white sandstone just west of the bridge. **0.3**

25.7 Roadcut, with large dike cutting across the west-dipping Mesaverde sandstones. Almost every roadcut for the next 9 mi shows similar dike intrusions. The hills on the skyline from 10:00 to 11:00 are Tertiary volcanic rocks that overlie the sediments in the center of the Sierra Blanca Basin. The highway skirts the northern edge of this old volcano. **0.8**

26.5 Roadcut in purple siltstone is the lower Cub Mountain Formation (Tertiary), named for Cub Mountain south of Carrizozo, where good outcrops show that its thickness there may be as much as 2,200 ft. 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, lakes, and river floodplains in very earliest Cenozoic time, perhaps even during latest Cretaceous time. **0.3**

26.8 Roadcuts in the Cub Mountain Formation, cut by dikes. **0.3**

27.1 Top of hill. **0.5**

27.6 Culvert across the Rio Salado, here called Salado Creek. Nine miles due north of here, abundant petroglyphs have been found on smooth surfaces of a dike. **0.2**

27.8 Roadcut exposing a west-dipping sill of pale-yellow rhyolite (a siliceous igneous rock) similar in composition to the larger intrusions, such as Carrizozo laccolith. **0.3**

28.1 Two cuts expose multiple dikes, with only small patches of Cub Mountain white sandstone and purple shale. **0.6**

28.7 Cub Mountain purplish siltstone in roadcut. Along the highway 10 mi west of Capitan, nearly 200 dikes, averaging 15 ft in thickness, can be seen. The crust of the earth must have been pulled apart over half a mile within this 10-mi stretch to have permitted these dikes to shove their way into their present positions. **0.6**

29.3 South-dipping gray Cub Mountain siltstone in cut on right. **0.5**

29.8 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. Crossing Sierra Blanca Volcanics for next 1/2 mi. **0.5**

30.3 Indian Divide (elevation 6,996 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. The slippage here has brought Mesaverde rocks up to the surface west of the fault with a displacement of more than 500 ft. Notice the old railroad grade on the left and the sharp point of Nogal Peak on the skyline to the south. **0.4**

30.7 Mesaverde shales intruded by small dikes. Railroad grade to left makes a sharp switchback up the canyon to the south. **0.3**

31.0 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**

31.5 Contact between Mesaverde yellowish sandstone and overlying Cub Mountain purple siltstone and white sandstone in the long roadcut just before the sharp bend. **0.2**

31.7 STOP. Pull off to right just before reaching roadcut on old road to right. Five dikes are exposed in this single roadcut in the Cub Mountain sandstone! The contrast between the white sandstone and the black igneous rock makes this a good exposure to photograph. **0.5**

32.2 Boundary marker of Lincoln National Forest. Nogal Peak, the sharp high peak, at 9:00. **0.6**

32.8 Road cuts a large rhyolite dike, which extends to the north, forming the high ridge for nearly 2 mi. You are now in the Tularosa (red reed) Valley, 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. **1.2**

34.0 Gate on right. This road leads 1.3 mi to the old mine workings on the south slope of Vera Cruz Mountain, the rounded peak at 3:00. Vera Cruz Mountain is a small stock that tilted the bedded rocks away from it in all directions when it was forcibly intruded. The intrusion brought in gold-bearing fluids that deposited the gold mined here in the early part of the century.

At 2:00 is the high mass of Carrizo Mountain (9,656 ft); after Capitan, the largest laccolith in the area. One interpretation of its structure is that the surrounding rocks dip inward beneath it; originally, they also arched up over it.

Church Mountain, at 9:00, is not a laccolith; it is composed of Sierra Blanca Volcanics, a pile of nearly horizontal lava and breccia flows. **1.2**

VIEW OF DIKES IN ROADCUT OF CUB MOUNTAIN SANDSTONE at mile 31.7, Trip 3.

VERA CRUZ MOUNTAIN.

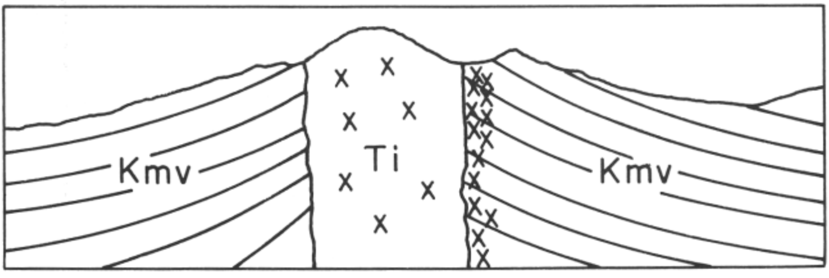
35.2 Bridge of Nogal (Walnut) Creek. **0.4**

35.6 Nogal Junction. *Keep straight ahead.* Coming back, we will turn off toward Ruidoso after a visit to the Little Black Peak 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-mi round trip should turn left here and pick up the continuation of the road log at mile 14.8 of Trip 4.

The source of this large, recent lava flow is the small (from this distance) black knob at 1:00. This is Little Black Peak, a volcanic cinder cone; from its base most of the lava flowed. The low light-colored ridges at 2:00 are rhyolite sills, possibly derived from the Carrizo Mountain intrusive. **2.4**

38.0 Siphon on left for water pipeline. Notice the lower smooth slopes on the west side of Carrizo Mountain at 3:00. 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 few years in July and August to form alluvial fans. The lower parts of the alluvial fans grade in turn into pediments, which have only a thin skim of gravel on bedrock. This profile is typical of arid areas.

The ghost 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.*



CROSS SECTION OF VERA CRUZ MOUNTAIN.

Famous names like Billy the Kid, Pat Garrett, and Lew Wallace are closely associated with the area."

Beyond Carrizo Mountain and White Oaks Canyon is the town of Baxter and Lone Mountain, a laccolith and stock of syenite that produced the minerals in the gold mines. The White Oaks mines were discovered in 1865, and production from this and nearby mining districts totaled over $5 million, mostly before 1906. The largest production (nearly one-half million dollars) came during 1888 and 1901. Although gold was the chief metal produced at White Oaks, coal was also mined from the Mesaverde Formation nearby. **5.3**

43.3 Historical marker. East edge of Carrizozo (from Carrizo, Spanish for "reed grass"; in 1907, James Allcook added a "zo" to indicate abundance). San Andres Mountains on skyline from 10:00 to 11:00, Oscura Mountains from 11:00 to 12:00, and Chupadera Mesa from 12:00 to 2:00 **0.3**

43.6 Southern Pacific Railway overpass. **0.2**

43.8 Junction with US-54. Keep straight ahead. Carrizozo business district and Alamogordo (57 mi) to left; Vaughn (81 mi) and Santa Fe (168 mi) to right. Also to right, Gran Quivira (56 mi), Quarai (90 mi), and Abo (90 mi). **1.0**

44.8 Leaving Carrizozo; Little Black Peak at 1:30. The Little Black Peak lava flow or malpais is one of the youngest in the United States, comparing in the 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 field (California), and the Capulin Mountain flow (northeastern New Mexico). In all probablility, the Little Black Peak lava flowed out within the last 1,000 years. It did not come out all at once, however; it is made up of many flow units, each representing an individual river of lava. The combined flow is 44 mi long. To the northwest it spreads out to a width of 3-4 mi, but 10 mi to the south is a narrows about 10 mi long where the flow is only a little more than a mile in width. The average slope of the flow is 30 ft to the mile, its average width is 3 mi, and its average thickness is 42 ft, although in the center of the valley it exceeds 150 ft thick. The flow covers 127 sq mi, and its volume is very close to 1 cu mi.

The surface features you will observe are those exhibited by fresh lava flows of basaltic 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 whose roof later caved in), and kipukas (a term used by Hawaiians for islands of older rock surrounded by a sea of lava). Notice the kipuka of Dakota Sandstone at 11:30, where the Dakota dips eastward; you are now on the western edge of the Sierra Blanca Basin. **1.5**

46.3 On left, abandoned mill of the New Mexico Copper Corporation. **0.8**

47.1 Bridge. **0.2**

47.3 Sill of rhyolite intruding Mancos Shale, in low roadcut on left. **0.1**

47.4 Edge of lava flow, here about 20 ft thick. **0.4**

47.8 Entering kipuka of Dakota Sandstone forming hill at 9:00. 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 other small turnouts along the highway. **0.2**

48.0 Entrance to Valley of Fires State Park is on the left (better to visit on our return trip). 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 desert 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 to soil. **1.6**

49.6 STOP. 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. **1.3**

50.9 West edge of the basalt lava flow. **0.2**

51.1 *Turn around* on wide turnout on left side of the highway, near windmill. The bedrock is the San Andres Limestone, dipping to the east. The entire Dockum Group (Triassic) of rocks is hidden beneath the lava flow.

END OF TRIP 3

VIEW AT EDGE OF LAVA FLOW, Trip 3, mile 47.7. In background is Carrizo Mountain.

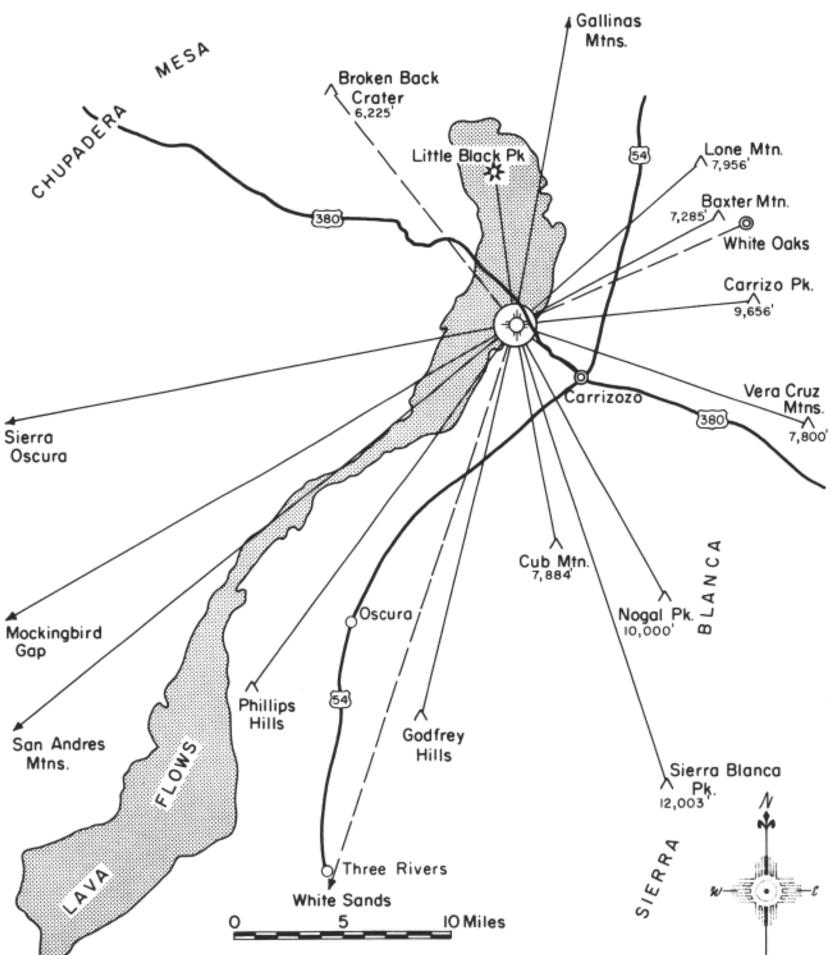
Trip 4 (42 miles)

Valley of Fires State Park to Ruidoso

Preview

The panorama of the Sierra Blanca and Sacramento Mountains from the malpais is an exceptional one because most of the larger igneous structures discussed in the introduction can be seen from this point.

The kipuka upon which the state park picnic grounds are located is composed of gently east dipping beds of Dakota Sandstone, which we last saw outside Capitan, 25 mi to the east. The rim of the Sierra Blanca structural basin may be traced by discontinuous outcrops of Dakota Sandstone completely around both sides of the basin from southwest of Ruidoso to north of White Oaks, a north-south distance of over 40 mi.



Panoramic index at Valley of Fires State Park.

As we enter the basin during Trip 4, we will first cross Triassic rocks beneath the malpais, then buried Mancos Shale, Mesaverde and Cub Mountain Formations, and finally Sierra Blanca Volcanics. We will also cross several faults that alternately bring several of these units to the surface to be observed in roadcuts. At Alto (mile 33.1), 5 mi north of Ruidoso, one may pick up and take Trip 5 (at mile 8.9) and climb 2,400 ft in 12 mi up a series of switchbacks to the Sierra Blanca ski resort. There, if it is in operation, the tramway will take you up another 1,700 ft to the top of Lookout Mountain at an elevation of 11,400 ft.

The last mile or so of Trip 4 from Alto to Ruidoso is designed to bypass much of downtown Ruidoso so that you may see some interesting geology.

Mile

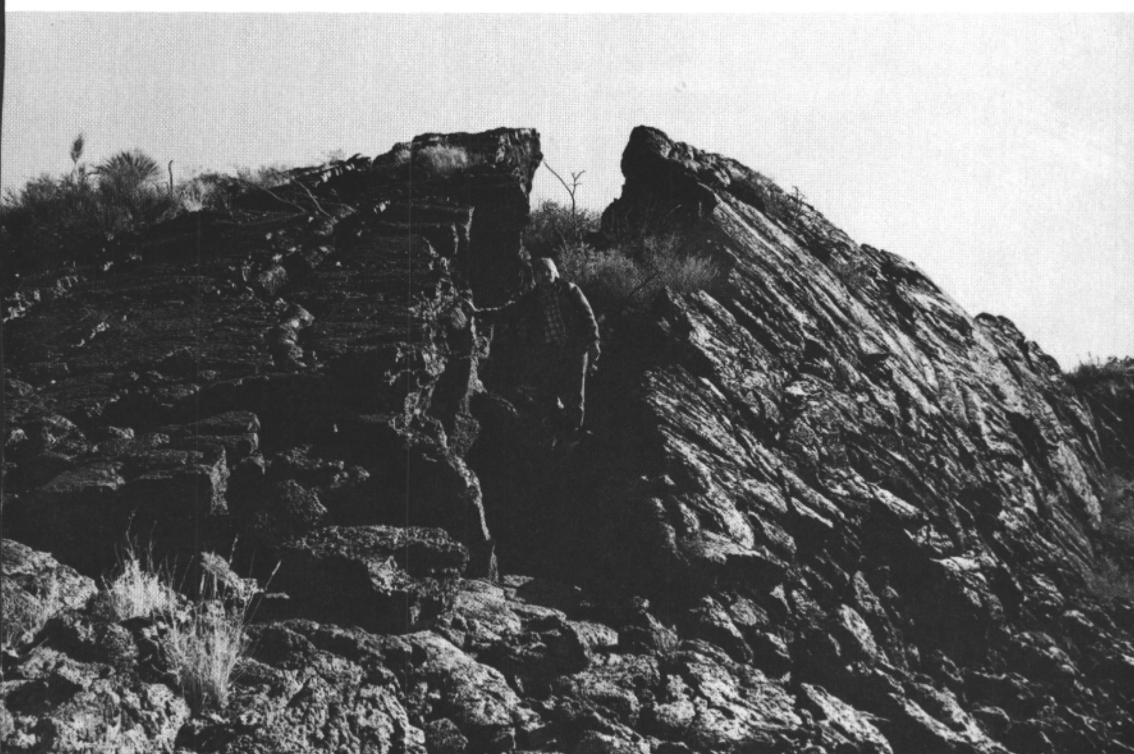
0.0 *Turn around* beyond west edge of malpais, near windmill. The bedrock is San Andres Limestone, dipping to the east. The Santa Rosa Sandstone and the Chinle Formation (both Triassic) are buried beneath the lava flow. **0.5**

0.5 Turnout on left. **0.4**

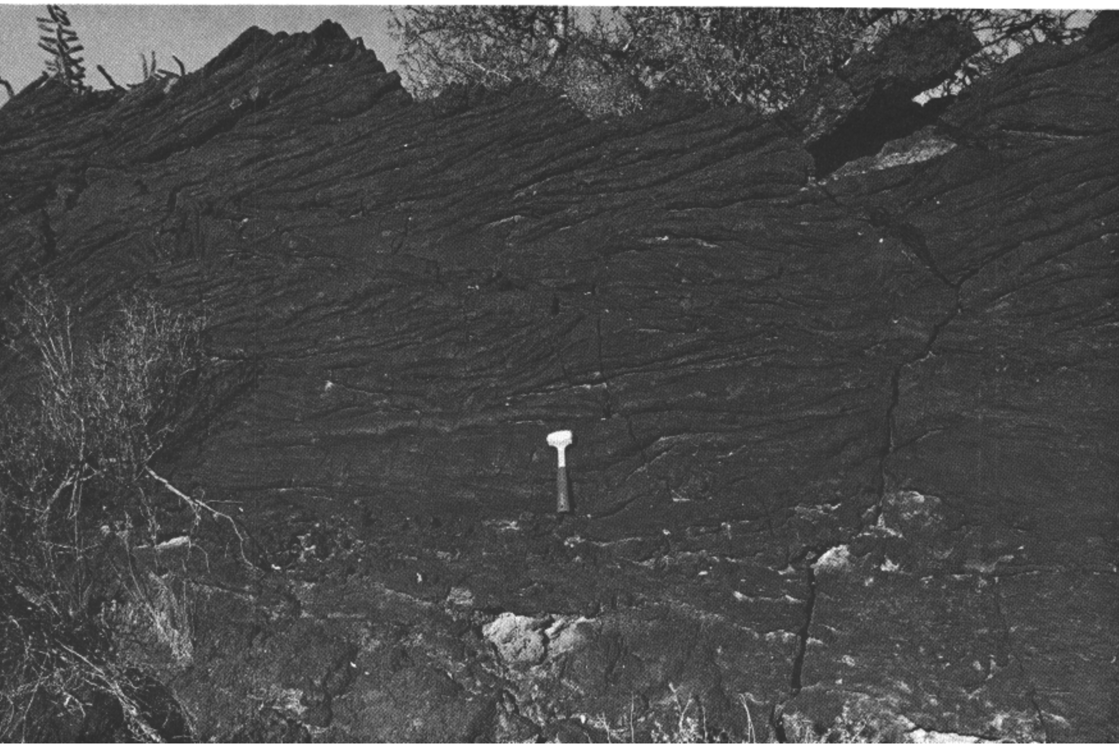
0.9 Turnout on right. The small animals that live on the lava flow are world famous. Most of the common types are darker than the same species in surrounding areas; inasmuch as the lava beds are relatively recent, this shows an extremely rapid adjustment to environment. The dark mice, lizards, snakes, woodrats, rock squirrels, and kangaroo rats are in sharp contrast to the pale or white species common in White Sands only 70 mi to the south. **0.5**

1.4 Historical marker. Turnout and picnic table on left. **0.4**

A CRACK IN LAVA FLOW.



Views of pahoehoe at Valley of Fires.



1.8 Top of rise; highway crosses pressure ridge. White Oaks Canyon at 9:50, Carrizo Mountain at 10:00, Vera Cruz Mountain at 11:00, Church Mountain at 12:00, Nogal Peak at 1:00, Sierra Blanca at 2:00, and Cub Mountain at 2:15. **0.6**

2.4 Turnout opposite pressure ridge. **0.1**

2.5 STOP. Side road at right to Valley of Fires State Park (picnic tables and rest rooms). If you do drive into the park for the view, lunch, or a rest stop, be sure to reset your odometer upon return. **0.5**

3.0 East edge of basalt flows. **0.2**

3.2 *Cross bridge.* **0.6**

3.8 Approaching Carrizozo. The name is derived from the Spanish word "carrizo," the common reed grass that grows in the surrounding valley. The second "zo" syllable was added later, presumably to indicate the local abundance of the grass. The town was established by the El Paso and Northeastern Railroad in 1899; a roundhouse was erected, and the town became a supply center and shipping point.

You are now exactly 33 mi due east of Trinity, 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 the Jornada del Muerto (Journey of Death)—an intermontane valley just west of the Oscura Mountains, about 36 mi southeast of Socorro. **2.0**

5.8 Entering Carrizozo. **0.7**

6.5 Junction of US-380 with US-54. Keep straight ahead across the overpass. Alamogordo is 58 mi south (right), and Santa Rosa is 118 mi northeast (left). We are now starting a gentle climb of 75 ft per mi for 8 mi up towards Nogal Creek and Church Mountain. Similar gentle slopes from Carrizo Mountain and Vera Cruz Mountain come together or coalesce to form what is called a pediment (at the foot) of bedrock, thinly covered by alluvial gravels and debris that thicken as the slope steepens towards the mountain canyons and gullies from which they are derived. This is the characteristic profile formed by erosion in a desert basin or bolson. The skim of gravels covering the Mesaverde Formation near Carrizozo is so thin that on air photos the underlying bedding can be seen in many places, although it cannot be detected on the ground. Nearer the mountains the alluvial fans from each canyon and gully and the talus from the cliffs become thicker and coarser, and their contact with the steeper bedrock exposures is obvious and sharp. On the south side of Carrizo Mountain it comes at 7,000-ft elevation, on Vera Cruz about 400 ft lower. **8.3**

14.8 STOP. Nogal Junction of US-380 with NM-37 to Ruidoso (25 mi). Turnout with Forest Service direction sign on right. Paved road except for 5 mi of graded gravel; after severe summer rainstorms, you might prefer to keep straight ahead to Capitan and take NM-48 to Ruidoso instead; it is all paved and only 7 mi longer. *Turn right* towards Nogal (Walnut) and Alto (High). **1.5**

16.3 Low hills from 1:00 to 3:00 are igneous sills in the Cub Mountain Formation. The steeper slopes above on Church Mountain are composed of Sierra Blanca Volcanics. Notice Ranchers camp-meeting grounds on skyline at 11:00 and Vera Cruz stock at 9:00, surrounded by Mesaverde sediments dipping away from it. Vera Cruz mine is low on the southwest ridge; it was a gold producer early in the century. **0.9**

17.2 At 3:00 a prospect shaft in the Cub Mountain Formation. **0.6**

17.8 Bridge. Low hills on either side of the road are expressions of igneous sills intruded between beds of the Cub Mountain Formation. **0.9**

18.7 Entering Nogal, almost a ghost town, relic of the mining days of the 1880's and 1890's. There are 24 mines and prospects in the Nogal and Bonito mining districts to the south. Most of them once produced lead, zinc, and silver ores, although the Helen Rae-American mine, 3 mi southwest of Nogal, was a substantial producer of lode gold from a north-south striking fissure vein and also of placer gold from Dry Gulch below the vein outcrop. **0.4**

19.1 Bridge across Dry Gulch. Mines are 21/2 mi up this canyon. Church Mountain at 3:00. **0.3**

19.4 Bridge across Nogal Creek. We have crossed the contact between the Cub Mountain Formation and the overlying Sierra Blanca Volcanics; the outcrops between here and the top of the hill are composed of purple to green andesitic volcanic lava flows, breccia, and interbedded ash beds that make up all of Church Mountain and a large part of Sierra Blanca to the south. **0.2**

19.6 Junction with road on right, which goes up Nogal Creek. Begin ascent of long steep hill, rising 600 ft in 2 mi. **0.2**

19.8 Sign at boundary of Lincoln National Forest. Pition and juniper forest interspersed with grassy meadows. **1.4**

21.2 Road curves to the left and crosses a major fault, along which the Sierra Blanca volcanic rocks on the west are dropped down and the Mesaverde Formation on the east is raised up at least 500 and perhaps as much as 1,000 ft. Behind us, andesite lava crops out in low roadcuts; ahead on the left, tan Mesaverde sandstone appears. Coal beds are sometimes visible 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 4:00. **0.1**

21.3 Nearing top of grade. Turnout with picnic tables coming up on the left. **0.3**

21.6 Nogal Lake Junction. Picnic and camp grounds 1/2 mi to the left. Nogal Lake was originally a reservoir for the pipeline from Bonita Dam, 8 mi to the south. The dam was built by the Southern Pacific Railroad 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 mi. A new pipeline was completed in 1956 to Alamogordo, 58 mi south of Carrizozo, and the lake is now used for fishing and camping. **1.0**

22.6 Junction. Keep straight ahead towards Ruidoso. Road on the left goes to Capitan (6 mi). **0.6**

23.2 Outcrops across the valley amid trees at 2:00 are Mesaverde sandstone beds, dipping east. Roadcuts for the next 2 mi are all in Mesaverde sandstone and shale. **0.9**

24.1 STOP. Excellent viewpoint at top of hill. The main mass of the Sierra Blanca, composed of volcanics with a central core of intrusive granitic rocks, occupies the skyline from 12:00 to 3:00. The entire length of the Capitan laccolith can be seen from 7:00 to 8:00. The concordant ridge crests on the skyline from 8:00 to 10:00 cut across all sediments in the area and slope gently to the east, with skim of ancient (ice age or perhaps even Pliocene?) pediment gravels. The hill at 9:30 is a resistant mass of volcanic rock, as are the hills from 6:00 to 7:00. Mesaverde sandstone crops out along the road. 0.3

24.4 Bridge at bottom of hill; white buildings at left. Pipeline follows the road for several miles. **0.2**

24.6 Bridge, pipeline on right. The chief forest trees in this area are ponderosa pine and pition; we are about 7,000 ft in elevation, on the boundary between the Pition-Juniper and the Transition Zones. Mesaverde sandstone beds cross the road near here and veer off to the east. **0.3**

24.9 Ranch road on right. **0.6**

25.5 Bridge. We are now in Sierra Blanca Volcanics, having crossed one of the numerous north-south trending faults in the area. **0.9**

26.4 Ranch road to right and bridge. Notice huge ponderosa pine on left. **0.5**

26.9 Cattleguard, among pine forest. **0.4**

27.3 Roadcuts in Mesaverde sandstone for a short distance. **0.5**

27.8 STOP. Road junction in the Rio Bonito (Pretty River) valley. *Turn left.* The Bonito Dam is 4 mi to the west (right). Picnic and recreation grounds at the lake were opened in 1957. **0.3**

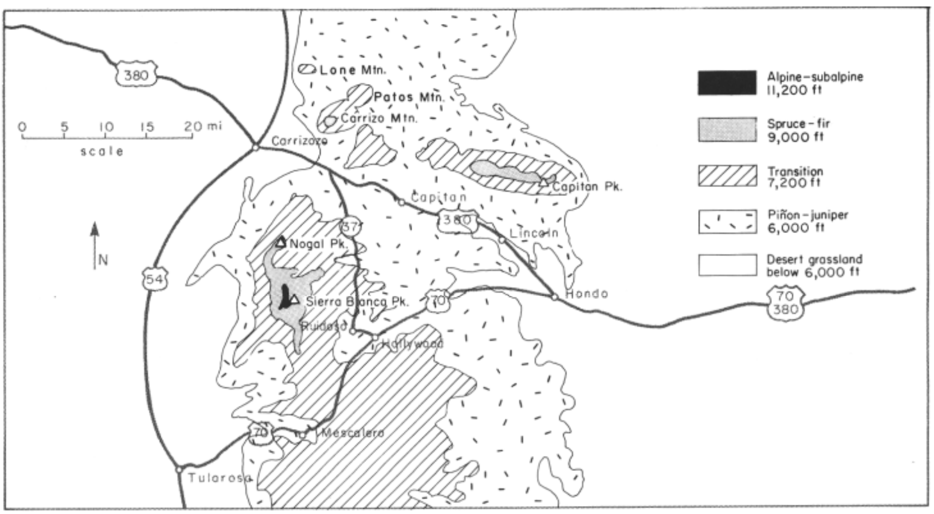
28.1 Were the sediments worked for placer gold here? **0.6**

28.7 Gas station; approaching village of Angus. **0.4**

29.1 *Stop.* Road junction of NM-37 and NM-48. End of unpaved road. Highway leaves Sierra Blanca Volcanics and reenters Cub Mountain Formation, whose purple siltstones are excellently displayed in the large roadcut up the hill to the left. NM-48 to the left goes to Capitan (9 mi). *Turn right.* **0.1**

29.2 Bridge across the Rio Bonito. **0.2**

29.4 Road junction to town of Angus and Church of Nazarene summer camp. **0.2**



GENERALIZED DISTRIBUTION OF LIFE ASSOCIATIONS OF THE AREA (modified from W. C. Martin, 1964, *in* New Mexico Geological Society, Guidebook 15th field conference, *Ruidoso Country*).

29.6 South-dipping Mesaverde shale between igneous dikes in roadcut. **0.2**

29.8 Thin coal beds in Mesaverde shale and sandstone between here and top of hill are cut by numerous dikes and sills. Most of the dark rocks are sedimentary; the light rocks are igneous. **1.1**

30.9 Top of hill. From 2:00 to 3:00 in the distance, the intrusive granitoid rocks that make up the higher elevations of the Sierra Blanca can be seen. **0.5**

31.4 Roadcut in the poorly exposed transition beds between the Mesaverde Formation and the overlying Cub Mountain Formation, which crops out along much of the route between here and Ruidoso. **0.7**

32.1 Cub Mountain Formation in roadcuts from here to top of hill. **0.5**

32.6 Top of hill. Extensive housing developments on right. **0.5**

33.1 Alto Post Office, on Eagle Creek, and junction with NM-37 and NM-532. If you wish to take the side trip to the ski lift at Lookout Mountain, turn right and climb 2,400 ft in 12 mi (begin Trip 5 at mile 8.9). The views along this paved road are highly rewarding and so is eating lunch on the skyline ridges. If the lift is in operation, it will take you another 1,700 ft up to the 11,400-ft elevation on Lookout Mountain. Continuing straight ahead on NM-37 towards Ruidoso, we see the light-colored Cub Mountain sandstones from here to the top of the hill. **1.1**

34.2 On left, the Cub Mountain white sandstone and multicolored siltstone here and in roadcuts since Alto have been cut by numerous igneous dikes. Slow down for steep downgrade for next mile. Forest largely of ponderosa pine. **1.0**

35.2 Side road on right to Alpine Village development. **1.2**

36.4 Ruidoso Airport in distance on left, is underlain by Mancos Shale. The roadcuts since the top of the hill have been in Cub Mountain Formation and in Sierra Blanca Volcanics. Because these formations are not normally adjacent to Mancos Shale, there must be a large fault to bring them into contact. The downthrown side is on the west, and the Mancos Shale has been brought up on the east. The hills on the far side of the valley to the east are of west-dipping Dakota Sandstone, which normally underlies the Mancos. Another fault (which we will see later) cuts it off farther east and brings up San Andres Limestone, which makes up the skyline. **0.9**

37.3 *Slow.* Smokey Bear Ranger Station on right. Ruidoso city limits. *Prepare for difficult left turn against oncoming traffic.* **0.1**

37.4 *Turn left* 45 degrees and *take right-hand fork* of road. Left fork parallels south side of Innsbruck Estates. **0.3**

37.7 Entering golf-course estates. *Keep left.* Right fork goes to Peterbilt Estates. This side trip avoids much of downtown Ruidoso (Noisy) and allows viewing of some interesting geological features. **0.6**

38.3 Cree Meadows Club House on right. Golf course is in west-dipping Mancos shale; high roadcut in ridge at 10:00 is Dakota Sandstone. *Keep on paved road.* **0.2**

38.5 *Turn sharp left* up the hill towards Ruidoso Lookout Tower. **0.1**

38.6 Junction; road to right. *Take left fork.* **0.2**

38.8 Entrance to Lookout Estates development on right. *Go straight ahead* on dirt road. **0.1**

38.9 STOP. Parking area. Trail to tower, 300 ft. (Do not drive beyond parking

LOOKOUT TOWER, Trip 4, mile 38.9.

VIEW FROM LOOKOUT TOWER.

area.) A panorama of Ruidoso and the peaks that cap the Sierra Blanca range is visible from the tower. Sierra Blanca Peak itself (elevation 12,003 ft) lies just north of due west; Mon Jeau Peak lies northwest. The tower is set on Dakota Sandstone; a north-south fault lies in the saddle just east of the parking area. **0.3**

39.2 *Drive back* to Lookout Tower junction; keep straight ahead onto pavement and down steep hill, with sharp curves. Right fork goes back to golf course. **0.1**

39.3 Junction; *take left fork.* **0.2**

39.5 STOP. Park on either side of bridge over the Rio Ruidoso. The cliff downstream at 9:00 is Dakota Sandstone for about 300 ft from the road; then one branch of Ruidoso fault cuts it off abruptly, and the rocks beyond are composed of San Andres Limestone. Movement along this fault must have been at least 700 ft down to the west. The entire section of Triassic rocks is cut out. If you walk down the river bank past the cave, you can put your hand on the fault surface. **0.1**

39.6 *Stop.* Junction with NM-37. Downtown Ruidoso on the right. *Turn left.* **0.1**

39.7 Cliff of San Andres Limestone beneath Lookout Tower at 9:00. **1.4**

41.1 Entrance to the city picnic grounds on right. **0.2**

41.3 Junction (on right) with shortcut to Tularosa and Alamogordo. Keep straight ahead for Roswell. Along the valley the upper part of the wall is San Andres Limestone, the lower part is now in the Yeso Formation. **0.9**

42.2 *Stop.* Main junction with US-70. *Bear left* to Roswell for Trip 2R; bear right to Tularosa for Trip 6.

END OF TRIP 4

CAVE AND FAULT AT STOP NEAR MILE 39.5, TRIP 4.

(21 miles) Trip 5

Ruidoso Junction (US-70 and NM-37) to Lookout Mountain ski lift

Preview

One objective of this trip is the spectacular view from the top of the tramway at 11,400 ft; be sure to check whether it is in operation and what the schedule is.

Sierra Blanca is the dominating mountain mass in the area; and, at 12,003 ft it culminates in the highest peak south of Santa Fe in New Mexico. It is also the easternmost range in the Basin and Range province (which extends west to the Sierra Nevada in California) and may be the southernmost peak in the United States to have a glacial cirque and moraines on its northern flank. It is composed of two large intrusions (stocks) of granitoid rocks that cut through a thick (over 3,000-ft) series of volcanic flows and fragmental breccias. It lies within and upon an ancient downfold or basin which has preserved from erosion a series of rocks ranging from nearly 300 to only 20 m.y. in age, including the Permian, Triassic, Cretaceous and Oligocene.

Although the 22 mi to the ski lift is on paved road, it is narrow, with numerous switchbacks and turns, and it climbs over 3,000 ft. *Traffic is frequently heavy; be careful.*

Mile

0.0 Beginning at junction of US-70 and NM-37 at east end of town of Ruidoso. *Proceed west* on NM-37. **0.5**

0.5 *Slow;* intersection with warning light. Sierra Blanca Peak visible at 1:00. **1.1**

1.6 STOP. Chamber of Commerce on right. *Check ski lift schedule here.* **0.3**

1.9 Side road on left to Carrizo Canyon and Mescalero Apache resort area. *Continue ahead* on NM-37. **0.4**

2.3 Yeso exposed in hill on left. **0.8**

3.1 Quarry in Yeso on left. **0.2**

3.3 Stop light. Road junction in downtown Ruidoso. *Turn right* on NM-37. **0.3**

3.6 Road bed is located approximately on north-trending fault, with Mesaverde buff-colored sandstone and nonmarine shale downthrown on the west against Yeso and San Andres Formation on east. Displacement on the fault lessens to the north, with successively younger beds appearing on the eastern upthrown side, until the Mesaverde Formation appears on both sides at a point about 12 mi to the north. **0.3**

3.9 Mesaverde exposed in roadcut on left. **0.7**

4.6 Smokey Bear Ranger Station on left. Airport and golf course at 2:00 and 3:00 are overlain by Mancos Shale; roadcuts on left in Mesaverde. **0.4**

5.0 Sierra Blanca Volcanics (andesite) on left. **1.8**

6.8 Side road on left to Alpine Village development. Roadcuts in Mesaverde Formation and Sierra Blanca Volcanics contain numerous dark-colored Tertiary dikes during the next few miles. **0.3**

7.1 Volcanic breccia (angular fragments) intruded by dikes in roadcut on right. **0.6**

7.7 Roadcut exhibits uppermost transition zones from Mesaverde type sandstone to Cub Mountain purple shale. Intruded by igneous dikes. **0.1**

7.8 Mesaverde sandstone in fault contact with Sierra Blanca Volcanics, both intruded by several dark-colored igneous dikes. **0.2**

8.0 Sierra Blanca Volcanics (breccia cut by dikes) on left. **0.4**

8.4 Mesaverde sandstone cut by dikes. **0.3**

8.7 Bridge crossing Eagle Creek. Entering Alto. **0.1**

8.8 Historical marker: "Mon Jeau Lookout, 12 miles. Elevation 10,000 ft. Offers an excellent scenic view. Used by forest rangers during fire season. Observation deck open to visitors at all times. Parking space at bottom of lookout tower. Junction to Mon Jeau in 1 mile." **0.1**

8.9 Slow! Turn left at junction of NM-37 onto NM-532; 13 mi to the Lookout Mountain ski lift. **0.5**

9.4 Roadcut in Cub Mountain Formation, containing dikes. **0.4**

9.8 Side road on right goes to Villa Madonna and Mon Jeau Lookout. Continue ahead on NM-532. Sierra Blanca Peak at 12:00. It is part of the Three Rivers stock, which ranges in composition from monzonite to syenite to granite-depending upon the chemical composition of the feldspars and the presence or absence of quartz. **0.6**

10.4 First of a series of roadcuts in Sierra Blanca andesitic lava and breccia. **1.1**

11.5 Side road on right to Eagle Creek. Continue on pavement. **0.6**

12.1 STOP. Side road on left to Mescalero recreation area. You may park here if you wish to collect specimens from the next roadcut. **0.1**

12.2 Roadcut on hill with spectacular red and purple coarse-grained porphyry containing giant white plagioclase crystals (phenocrysts). **0.3**

12.5 Volcanic breccia on left. For the next mile, you can see excellent exposures

VOLCANIC BRECCIA, Trip 5, mile 12.5.

of breccia, with the angular fragments of andesite varying widely in size. Watch for intrusions of dikes or sills into the breccia, but *drive carefully* on the curves. **1.5**

14.0 Oak Grove picnic grounds on right. **0.2**

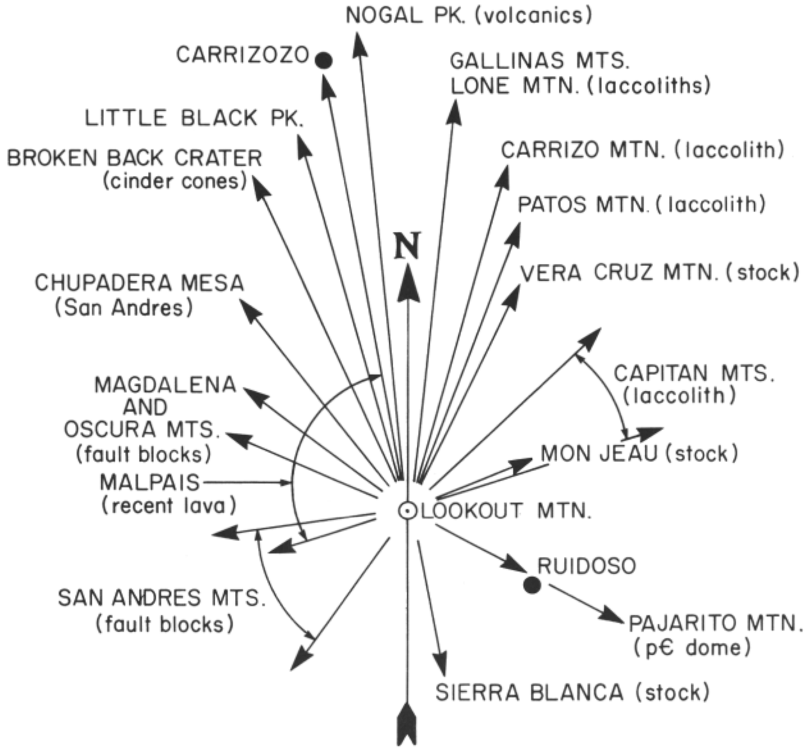
14.2 Breccia and ash units of the Sierra Blanca Volcanics here show the effect of the nearby Three Rivers stock, which apparently shoved its way forcefully into the volcanics. **0.9**

15.1 Contact of the Three Rivers stock with the volcanic breccia. The remainder of the trip to the ski lift (6 1/2 mi) will be in the intrusive rock of the stock. **0.2**

15.3 Mon Jeau Peak and lookout at 3:00. **0.5**

15.8 STOP. Viewpoint on the end of the switchback. Mon Jeau Peak at 2:30 across Eagle Creek Canyon is formed from the Bonito Lake stock. These intrusive bodies of granitoid rocks are more resistant to erosion than are the surrounding lava, breccia, or sediment. **0.5**

16.3 Pajarito Peak on skyline at 9:30. This isolated peak is a remnant mountain of Precambrian igneous rocks, which formed an island in seas of Permian age and is part of the ancient Pedernal mountain range. Permian rocks were



PANORAMIC INDEX FROM LOOKOUT MOUNTAIN.

deposited on the edges of the mountains; only the upper part of the San Andres Limestone was deposited over the remnant peaks. **1.1**

17.4 STOP. End of switchback and pulloff for picture taking. Note especially the glacial cirque on the northeast side of Sierra Blanca Peak, probably the southernmost glaciated peak in the United States. Ixtacihuatl Peak (elevation 17,343 ft) near Mexico City shows glaciation. Moraines deposited by at least five advances of the glacier during Wisconsin (late ice age) time are found along the north side of the north fork of the Rio Ruidoso down to an elevation of 9,850 ft, about 1 mi from the cirque headwall. **0.7**

18.1 STOP. End of switchback and viewpoint. Capitan and Carrizo laccoliths are visible on the skyline to the north. **0.4**

18.5 STOP. Observation and picture-taking point and good parking area at the south end of the switchback. Another fine view of Sierra Blanca Peak, with its glacial cirque and the north fork of the Rio Ruidoso below. **0.3**

18.8 Passing through dense aspen groves, spectacular with color in the fall season. **1.4**

20.2 Observation peak (gondola lift) at 9:00. **0.9**

21.1 STOP. Sierra Blanca ski resort headquarters (elevation 9,700 ft) is owned and operated by the Mescalero Apache tribe. Take tramway 1,700 ft up to the top and use guide to observation.

END OF TRIP 5

This road log was adapted from the New Mexico Geological Society's Guidebook, 15th field conference (Ruidoso Country). See Suggested Reading list.

(33 miles) Trip 6

Ruidoso (Junction NM-37) to Tularosa (Junction US-54) on US-70

Preview

The rocks to be seen on this trip are all, excepting a few intrusives, of Permian age. The Yeso Formation, composed of reddish shale, yellowish sandstone, gray limestone, and occasional gypsum is the dominant rock type. The drab gray San Andres Limestone comes down to highway level for a few miles before we reach Indian Divide (the crest of the Sacramento Mountains) and caps the ridges above the Yeso outcrops for much of the trip. West of Mescalero, the low foothills and roadcuts are in the deep red Abo sandstone and siltstone, and just before reaching Tularosa the underlying gray shale and sandstone of the basal Bursum Formation (Permian) appear. Near Bent, the Abo red beds unconformably overlie Pennsylvanian sandstones.

Mile

0.0 Junction of US-70 and NM-37. *Proceed west* on US-70. **0.1**

0.1 Cliffs on the left are Yeso overlain by alluvial silt. **0.4**

0.5 At 3:00 castellated entrance to theatre and housing development called Camelot. **0.6**

1.1 Quarry on right in Yeso Formation. **0.7**

1.8 Entering Mescalero Apache Reservation. Historical marker on right: "The Mescalero Apaches, last tribe in the United States to lay down arms, are now a friendly people, living much as they did centuries ago. Their reservation covers 472,320 acres." (That is only 738 sq mi or a block 27 mi on a side.) **0.3**

2.1 Roadcut on right displays small fold in bed of Yeso. This is almost the last outcrop of Yeso to be seen between here and Apache Summit, nearly 7 mi away. The overlying San Andres Limestone is folded and faulted down so that it appears in most of the roadcuts. **1.5**

3.6 Thick-bedded San Andres Limestone on right. **0.8**

4.4 Fence Canyon and Cow Camp junction on left. A fault, with the west side up, has been mapped near here and some Yeso does appear. **0.7**

5.1 Roadcut in San Andres Limestone. **0.4**

5.5 Road on right to Carrizo Canyon and *The Inn of the Mountain Gods,* a resort hotel owned by the Mescalero tribe. It can also be reached by the Carrizo Canyon road from Ruidoso. **1.3**

6.8 Large outcrop of thin-bedded San Andres Limestone. **0.7**

7.5 Sierra Blanca (White Mountain, elevation 12,003 ft). Historical marker on left: "This great peak, easternmost of the Basin and Range structures, is the southernmost in the United States, towering into the Arctic-Alpine life zone. In summer it is covered with flowers which attract hummingbirds by the thousands." Elevation at this point is 7,400 ft. **1.4**

8.9 Apache Summit (elevation 7,700 ft). The highway now begins a descent into Tularosa Canyon. **0.4**

Trip 6—Reverse (33 miles)

Tularosa (Junction US-54) to Ruidoso (Junction NM-37) on US-70

Preview

Before leaving Tularosa be sure to see St. Francis Church, 0.3 mi south of the junction of US-54 and US-70. In the climb up into and through the southern part of the Sierra Blancas, we will be in Permian rocks for most of the 33 mi—starting across the pediment and foothills in the Bursum (Lower Permian) beds, then rising into the deep red Abo Formation, and finally continuing in the variegated and colorful Yeso Formation. At the highway level the Yeso appears in most of the roadcuts except for one stretch east of Apache Summit where the drab, gray San Andres Limestone comes down to road level. Along the rest of the route, the San Andres forms the upper stretches of the canyon walls and the ridge crests. Abo red beds and Pennsylvanian sandstones occur near Bent.

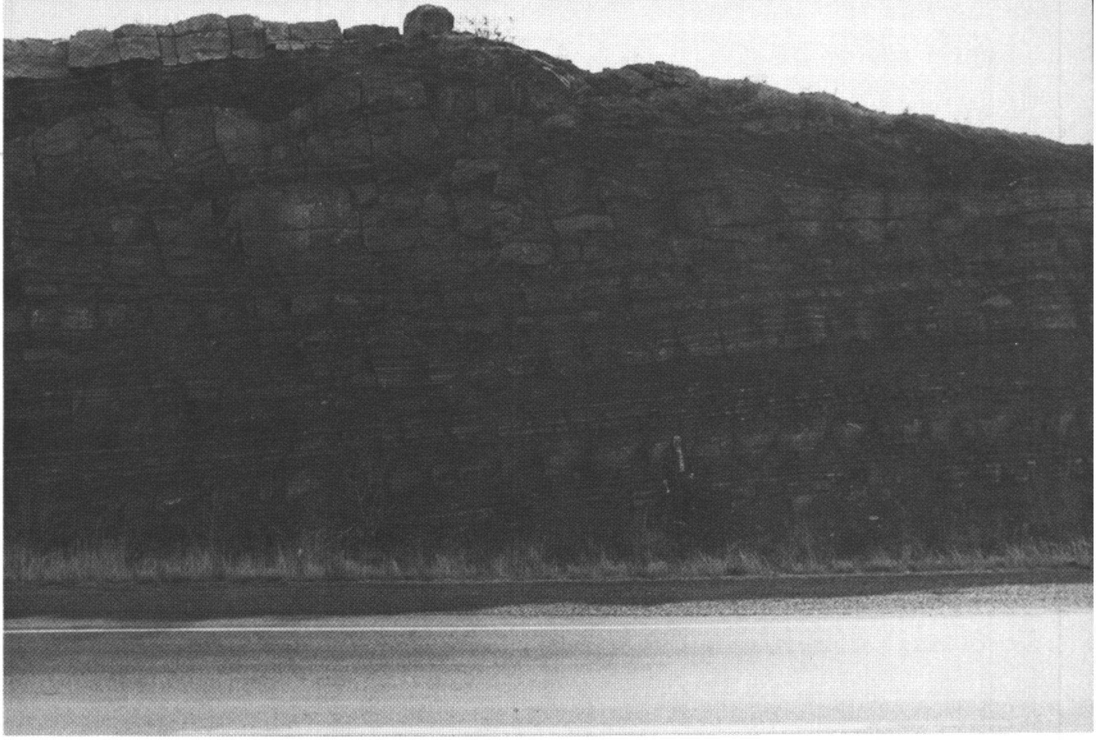
Mile

0.0 Junction of US-70 and US-54. *Turn east* on US-70. **1.1**

1.1 View of bluff several miles to left (north) shows cliffs capped by limestone mounds that are ancient Permian reefs. **0.7**

1.8 STOP. Excellent outcrop on right of the Bursum (or Laborcita) Formation, gray to brown to reddish interbedded sandstones and siltstone, dipping gently to the east beneath the Abo Formation, which we will see

ST. FRANCIS CHURCH IN TULAROSA.



VIEWS OF OUTCROP OF BURSUM FORMATION, mile 1.8, Trip 6R.

farther on. This is the only outcrop of the Bursum Formation along our tril routes. **0.1**

1.9 Historical marker. The Mescalero Apaches operate several industries, in cluding a recreation area southwest of Ruidoso. **1.1**

3.0 Approximate contact of the Abo overlying the Bursum. The low hills or either side of the road for the next several miles are composed of the gent13 east dipping Abo red beds. **2.7**

5.7 Gray-colored igneous intrusion into the Abo in roadcut on right. As yot leave the roadcut, heading east, the ridge on skyline at 11:00 is capped 1)3 San Andres Limestone with light-colored Yeso beds below. Sierra Blanca ai 10:30. **3.8**

9.5 Small peak capped with Yeso dolomite is surmounted with a cross at 3:00 This is Round Mountain, site of a battle between the U.S. Army and In. dians in 1868 as explained on the historical marker in 0.2 mi. **0.5**

10.0 Approximate Abo-Yeso contact at road level, followed by outcrops of Yeso. **0.5**

10.5 Road on right to Bent Post Office. **1.2**

11.7 Church on right; outcrops of Yeso on left at top of hill. Ridge along skyline at 8:00 to 11:00 is capped by San Andres Limestone. **0.4**

12.1 Side road to right to Nogal Canyon; dump of copper mine on south wall of valley at 2:00. This is on west edge of Bent dome. **0.2**

12.3 Crossing north edge of Bent dome. Abo red beds in left roadcut are unconformable on light-gray to brown Pennsylvanian sandstones. Contact is

ROUND MOUNTAIN, Trip 6R, mile 9.5.

very irregular, as the basal Abo red beds fill channels cut into the underlying Pennsylvanian sandstones. **0.5**

12.8 Narrow crossroad at east end of roadcut; cut is in high-level gravels and Yeso beds. **0.6**

13.4 End of divided highway. **1.0**

14.4 Entering Mescalero Village. **0.3**

14.7 Crossroads. Yeso outcrops across valley at 9:00. **1.1**

15.8 STOP. Historical marker on right for Blazer's Mill: "One of the first fights of the Lincoln County war occurred here on April 5, 1878, when several men of the McSween faction, headed by Dick Brewer and Billy the Kid, attempted to arrest Buckshot Roberts. In the battle that followed, Roberts and Brewer were killed, George Coe and John Middleton were wounded." **0.3**

16.1 Mescalero Community Center. **0.2**

16.3 Road to village on right. **1.0**

17.3 Historical marker and road to the Mission of St. Joseph on left: "The church was begun by Father Albert Braun and his Indian helpers as a memorial to Americans killed in World War I, and was constructed of local stone. After 20 years of labor, it was dedicated in 1940." **0.5**

17.8 Limestone quarry at 12:00 in a landslide block of San Andres Limestone that has come down from far above. **0.8**

18.6 Outcrop of Yeso on left. **0.7**

19.3 Massive outcrops of limestone on left. **1.3**

20.6 The straight valley for the next few miles is strongly suggestive of a fault and is parallel to several faults that have been mapped farther north. 0.6

21.2 NM-24 to the right is the ridge route to Cloudcroft, a distance of 30 mi. **1.1**

22.3 Broad upland valley was widened during an earlier cycle of erosion before the Sacramento Mountains had been uplifted to their present height. **1.3**

23.6 Yeso Formation in roadcut on left. **0.4**

24.0 Apache Summit (elevation 7,700 ft). **0.9**

24.9 Thin-bedded San Andres Limestone on both sides of the road. **0.4**

25.3 Historical marker on right: "Sierra Blanca Peak (12,003 ft) is the easternmost of the Basin and Range structures, and the southernmost U.S. peak extending into the Arctic-Alpine life zone. Its flower-covered summit attracts hummingbirds by the thousands in the summer." **0.4**

25.7 Steeply dipping San Andres Limestone at 3:00. **1.6**

27.3 Road on left to Carrizo Canyon and the Mescalero Apache recreational center, the Inn of the Mountain Gods. **0.4**

27.7 San Andres Limestone on right. **0.7**

28.4 Fence Canyon and Cow Camp road junction on right. **0.4**

28.8 Yeso in roadcuts for the next several miles. **2.3**

31.1 Lincoln County line. **1.1**

32.2 Castellated gateway to Camelot theatre and real estate development on left, followed by junction with shortcut road to NM-37, on left. **0.2**

32.4 Turn left for shortcut to Ruidoso, straight ahead to Roswell. **0.3**

32.7 Main junction of US-70 and NM-37.

END OF TRIP 6-REVERSE

Trip 7 (36 miles)

Roswell to Bottomless Lakes State Park and return

Preview

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 swimming beach with lifeguard.

The Pecos Valley is cut in sedimentary rocks laid down in an ancient arm of the Permian sea about 225 m.y. ago. Long-continued evaporation of its salty waters, similar to the present Dead or Caspian Sea, resulted in deposition of its contained salts while beds of gypsum and other salines were 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 relatively soft Permian sediments. Originally, the Pecos River probably flowed several miles west of Roswell, but the tilt of the beds caused it to slide ever eastward on the more resistant San Andres Limestone, until the river attained its present course.

Mile

0.0 Intersection of Main and Second Streets (US-380) in the heart of Roswell. *Drive east* on US-380. For the first 5 mi you will be on the wide, high Pleistocene (ice age) floodplain (now a terrace above river level) of the Pecos River. **2.5**

2.5 Roswell city limits. **0.6**

3.1 Side road to left (north) to Bitter Lake National Wildlife Refuge. **0.4**

3.5 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 the Pecos River valley alluvium and from the San Andres Limestone at depths of 100 to 700 ft; it originates from rainfall west of the valley penetrating solution cavities in the San Andres Limestone. 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 over the years, and many wells have had to be deepened. **1.1**

4.6 The road now drops down from the upper valley terrace (Orchard Park terrace, 20-55 ft above the present floodplain), onto the lower valley terrace (Lakewood terrace, 10-30 ft above the floodplain). The lower terrace was cut during a rainy period of the later part of the Pleistocene ice age. **0.5**

5.1 On left is salt-water conversion plant. Stop for a tour if you are interested. **0.2**

5.3 The road here drops down from the Lakewood terrace onto the present floodplain of the Pecos River. On the skyline ahead are outcrops of Artesia reddish siltstone and gypsum beds. Look back to right (5:00) to see edge of Lakewood terrace. **0.8**

6.1 The tamarisk, or salt cedar, growing on the floodplain was brought into this country many years ago from Spain. It is now generally regarded as a pest because it uses up much of the underground water and grows so rapidly. **1.0**

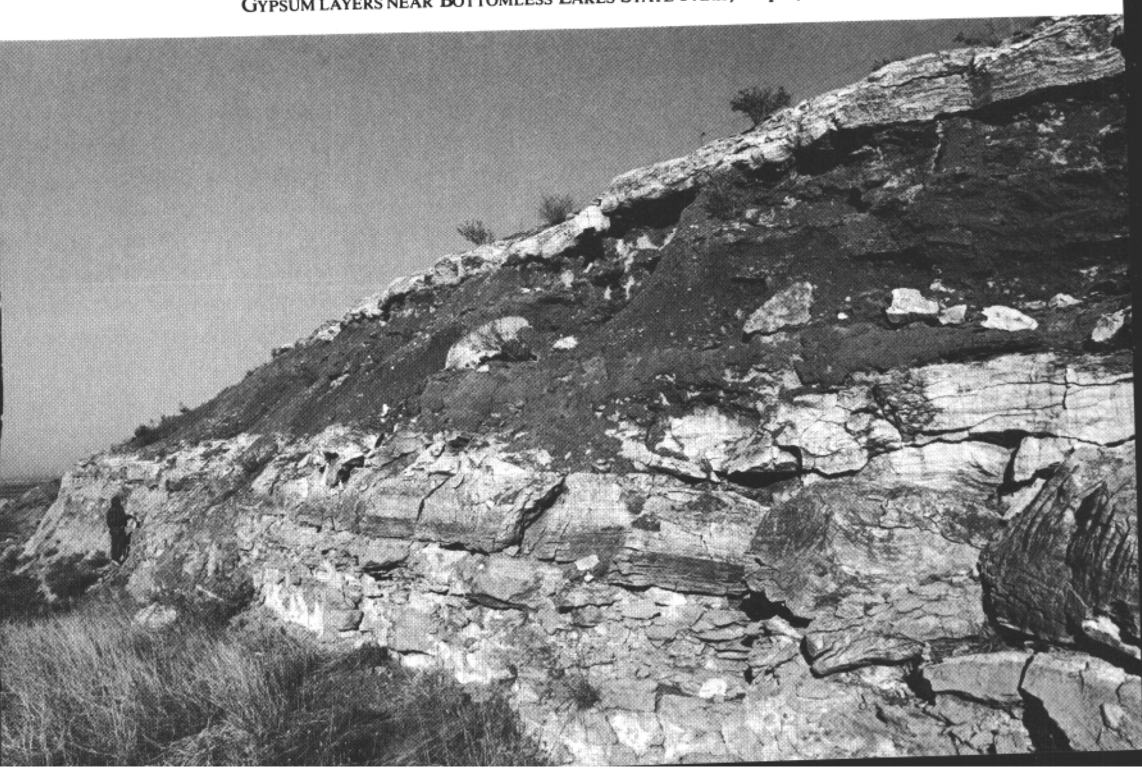
7.1 Bridge across the Pecos River. Headwaters are northeast of Santa Fe in the Sangre de Cristo Mountains. **0.5**

7.6 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 mi 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 crystals on a sunny day; they may be quartz, but gypsum crystals also reflect sunlight. Good quartz crystals are not easy to find, for many of them are imperfect; they are prominent, however, in the collections of many mineralogists. **1.3**

8.9 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**

10.1 Junction with NM-409, *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." Established in 1936, this was the first New Mexico State park. Encompassing 581 acres, the park lies near the old

GYPSUM LAYERS NEAR BOTTOMLESS LAKES STATE PARK, Trip 7, mile 7.6.



Goodnight-Loving trail, a historic cattle-drive route up the Pecos Valley between Texas and eastern New Mexico dating from the 1860's and 1870's. Lea Lake, the largest, was named for Captain Joseph C. Lea, an early-day rancher and founder of Roswell. Lea had ridden with William Clark Quantrill (the Confederate guerrilla commander) during the Civil War, as well as with Frank and Jesse James. Prior to the Lincoln County War, he was a friend of Billy the Kid.

This treasure of great natural beauty is a surprise in an area so dominated by aridity. There are six small lakes in the park; Lea Lake has 15 acres of surface area. The water of the lakes is crystal clear and varies in depth from 45 ft in the shallow lakes to about 100 ft in the deeper ones. They were created as sinkholes when water dissolved large areas of underground gypsum, resulting in cave-ins. The lakes now offer extensive recreational facilities for the people of New Mexico and for tourists passing through or visiting the area. **3.2**

13.3 Entrance to Bottomless Lakes State Park. *Caution:* curves down into Comanche Draw. **0.3**

13.6 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**

14.0 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**

14.9 Television relay tower on left. **0.4**

15.3 STOP. *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**

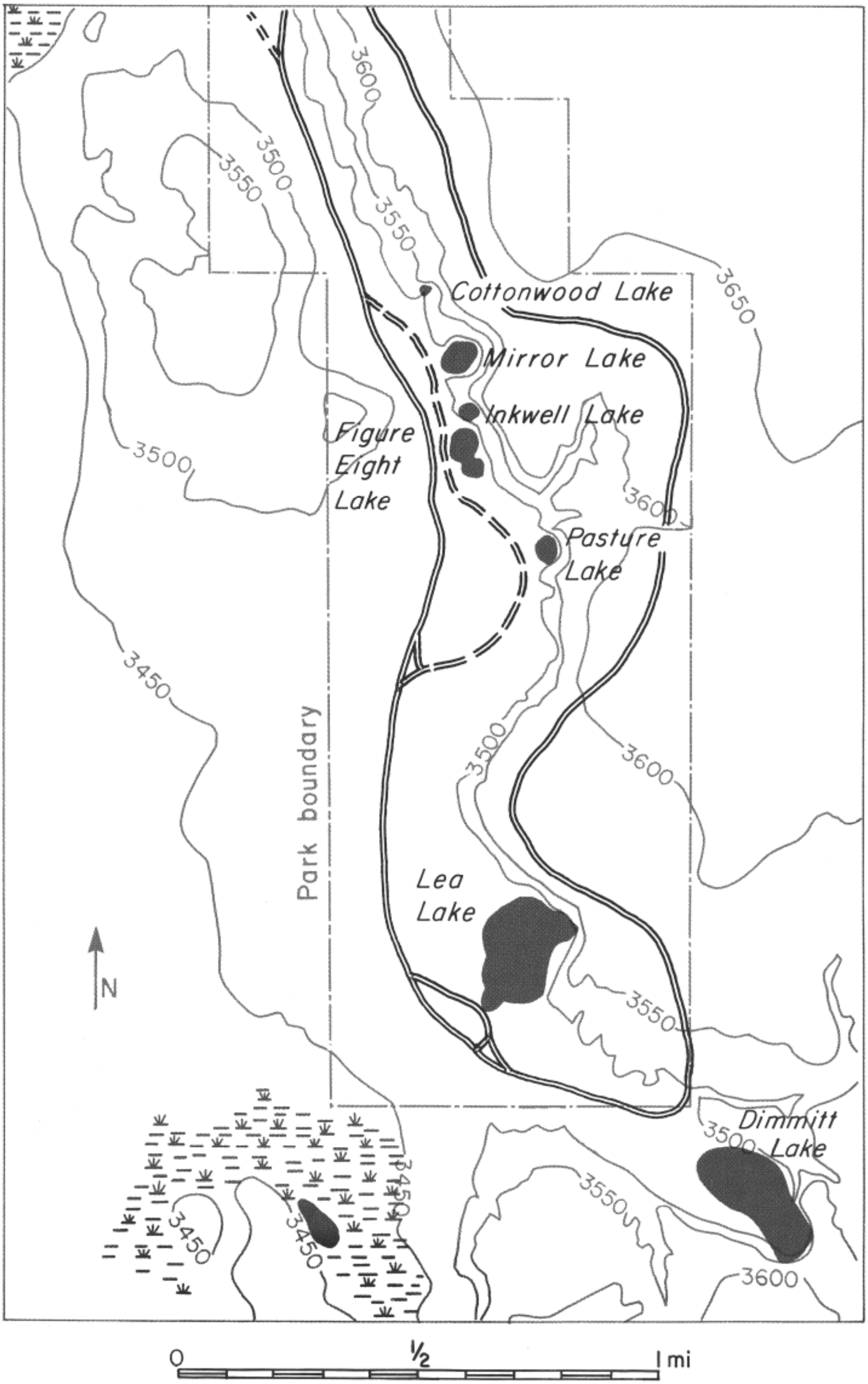
16.9 Lea Lake on right. This largest lake has an area of 15 acres and depths of 50 to 80 ft. Park Headquarters and recreational facilities are along the southwest shore. **0.1**

17.0 STOP. Turnout and viewpoint on right, above Lea Lake. A sharp flexure (monocline), occurs 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**

17.3 *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 good hunting areas for the Pecos diamonds, the perfect quartz crystals for which the Artesia Formation is famous. **0.6**

17.9 Junction; road to left to Dexter. **0.2**

18.1 Road junction; *keep right* to park headquarters. **0.2**



MAP OF BOTTOMLESS LAKES STATE PARK.

LEA LAKE.

18.3 STOP. Park Headquarters: swimming pool, canteen, horseback riding, picnicking, peacocks, camping area, playgrounds, boating, and sunbathing. **0.3**

18.6 North edge of park; *cross runway.* **0.7**

19.3 *Turn right* onto Lake Loop graded gravel road. **0.4**

19.7 Pasture Lake. **0.3**

20.0 Figure Eight Lake—caused by the near coalescence of two sinks. **0.1**

20.1 Devil's Inkwell—a small circular sink with steep walls and clear water (except after rains). Mirror Lake—a larger depression, made up of two adjacent sinks. **0.2**

20.3 STOP. Cottonwood Lake. This lake is almost 100 ft deep but is only about 150 ft 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**

20.4 Junction. To return to Roswell, *keep to the right.* Those wishing to go back to Park Headquarters should turn left. **0.1**

20.5 Notice deep gashes cut by solution channels in hillside on right. **0.1**

20.6 Picnic spot and fireplace on right, in cove. **0.1**

20.7 Notice circular sink on hillside. **0.3**

21.0 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 mi. It marks a former channel of the Pecos River, which has since shifted to the west. Favorite haunt of the road runner *(Geococcyx),* the state bird of New Mexico. **0.5**

21.5 Landslide blocks of gypsum above road. **0.2**

21.7 Begin ascent to 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**

22.6 Junction. *Turn left* to Roswell. **0.7**

23.3 Park entrance. **2.5**

25.8 Junction with US-380. *Turn left;* Roswell, 7.7 mi. **1.9**

27.7 Crest of Comanche Hill. Begin descent into Pecos River valley. View of Capitan Mountains to west at 1:00; Sierra Blanca at 11:45. **1.1**

28.8 Center of bridge across Pecos River. **7.2**

36.0 Center of Roswell; intersection of Main and Second Streets.

END OF TRIP 7

Suggested Reading

Fossils

Clark, D. L., 1968, Fossils, paleontology, and evolution: Dubuque, Wm. C. Brown, 130 p.

Cowen, R., 1976, History of life: New York, McGraw-Hill, 145 p.

Fenton, C. L., and Fenton, M. A., 1958, The fossil book: New York, Doubleday, 482 p.

Northrop, S. A., 1962, New Mexico's fossil record: New Mexico Quarterly, v. 32, nos. 1 and 2, 75 p.

Ratkevich, R., and LaFon, N., 1978, Field guide to New Mexico fossils: Alamogordo, New Mexico, Dinograph Southwest, 84 p.

Geology

Allen, J. E., and Jones, S. M., 1951, Capitan-Carrizozo Chupadera Mesa region, Lincoln and Socorro Counties, New Mexico: Roswell Geological Society, Guidebook 5th field conference, 12 p.

Ash, S. R., and Davis, L. V., editors, 1964, Guidebook of the Ruidoso Country: New Mexico Geological Society, Guidebook 15th field conference, 95 p., 11 tables, 63 figs., 2 pls.

Bodine, M. W., Jr., 1956, Geology of Capitan coal field, Lincoln County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circ. 35, 27 p.

Chapin, C. E., Siemers, W. T., and Osburn, G. R., 1975, Summary of radiometric ages of New Mexico rocks: New Mexico Bureau of Mines and Mineral Resources, Open-file Rept. 60, compilation kept up to date

Craddock, Campbell, 1964, The Lincoln fold system: New Mexico Geological Society, Guidebook 15th field conference, p. 122-123

Dane, C. H., and Bachman, G. 0., 1965, Geologic map of New Mexico: U.S. Geological Survey, 2 sheets, scale 1:500,000

Elston, W. E., and Snider, H. I. 1964, Differentiation and alkali metasomatism in dike swarm complex and related igneous rocks near Capitan, Lincoln County, New Mexico: New Mexico Geological Society, Guidebook 15th field conference, p. 140-147

Griswold, G. B., 1959, Mineral deposits of Lincoln County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bull. 67, 117 p.

____, 1964, Mineral resources of Lincoln County: New Mexico Geological Society, Guidebook 15th field conference, p. 148-151

Hallinger, D. E., 1964, Caves of the Fort Stanton area, New Mexico: New Mexico Geological Society, Guidebook 15th field conference, p. 181-184

Havenor, K. C., 1968, Structure, stratigraphy, and hydrogeology of the northern Roswell artesian basin, Chaves County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circ. 93, 30 p.

Kelley, V. C., 1949, Geology and economics of New Mexico iron-ore deposits: University of New Mexico, Publications in Geology No. 2, 246 p.

_____, 1952, Origin and pyrometasomatic zoning of the Capitan iron deposit, Lincoln County, New Mexico: Economic Geology, v. 47, p. 64-83

_____, 1968, Geology of the alkaline Precambrian rocks at Pajarito Mountain, Otero County, New Mexico: Geological Society of America, Bull., v. 79, p. 1565-1572

____, 1971, Geology of the Pecos country, southeastern New Mexico: New Mexico Bureau of Mines and Mineral Resources, Mem. 24, 75 p.

_____ 1972, Geology of the Fort Sumner sheet, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bull. 98, 55 p.

Kelley, V. C., and Thompson, T. B., Tectonics and general geology of the Ruidoso-Carrizozo region, central New Mexico: New Mexico Geological Society, Guidebook 15th field conference, p. 110-121

Kottlowski, F. E., 1963, Paleozoic and Mesozoic strata of southwestern and south-central New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bull. 79, 100 p.

Leonard, A. B., and Frye, J. C., 1975, Pliocene and Pleistocene deposits and molluscan faunas, east-central New Mexico: New Mexico Bureau of Mines and Mineral Resources, Mem. 30, 44 p.

Martin, W. C., 1964, Some aspects of the natural history of the Capitan and Jicarilla Mountains and the Sierra Blanca region of New Mexico: New Mexico Geological Society, Guidebook 15th field conference, p. 171-176

Muehlberger, W. R., and Denison, R. E., 1964, Precambrian geology of south-central New Mexico: New Mexico Geological Society, Guidebook 15th field conference, p. 62-69

Perhac, R. M., 1970, Geology and mineral deposits of the Gallinas Mountains, Lincoln and Torrance Counties, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bull. 95, 51 p.

Rabinowitz, D. D., 1972, Environmental tritium as a hydrometeorological tool in the Roswell Basin, New Mexico: Ph.D. thesis, New Mexico Institute of Mining and Technology, 268 p.

Richmond, G. M., 1961, Glacial deposits on Sierra Blanca Peak, New Mexico: New Mexico Geological Society, Guidebook 15th field conference, p. 79-81

Smith, C. T., and Budding, A. J., 1959, Little Black Peak quadrangle, east half, Lincoln and Socorro Counties, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Geol. Map 11, scale 1:62,500

Summers, W. K., 1972, Geology and hydrology of the Pecos River basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Rept. 37, 208 p.

Thompson, T. B., 1964, A stratigraphic section of the Sierra Blanca Volcanics in the Nogal Peak area, Lincoln County, New Mexico: New Mexico Geological Society, Guidebook 15th field conference, p. 76-78

______ 1972, Sierra Blanca igneous complex, New Mexico: Geological Society of America, Bull., v. 83, p. 2341-2356, 7 figs.

Ungnade, H. E., 1972, Guide to the New Mexico Mountains: Albuquerque University of New Mexico Press, 235 p.

History

Burns, W. N., 1926, The saga of Billy the Kid: Penguin Publishing, 256 p.

Ellis, R. N., 1971, New Mexico past and present: Albuquerque, University of New Mexico Press, 250 p.

Fergusson, Erna, 1948, Murder and mystery in New Mexico: Armitage, 193 p.

Hammond, G. P., and Donnelly, T. C., 1936, The story of New Mexico: Albuquerque, University of New Mexico Press, 333 p.

Jones, F. A., 1968, Old mines and ghost camps of New Mexico (reprinted from New Mexico mines and minerals, 1905): Fort Davis, Texas, Frontier Book Company, 214 p.

Nolan, F. W., 1965, Life and death of John Henry Tunstall: Albuquerque, University of New Mexico Press, 480 p.

Pearce, T. M., 1965, New Mexico place names: Albuquerque, University of New Mexico Press, 187 p.

Rickards, C., 1970, How Pat Garrett died: Santa Fe, Palomino Press, 117 p.

Scanland, J. M., 1971, The life of Pat Garrett: El Paso, Filter Press, 42 p.

Sonnichsen, C. L., and Morrison, W. V., 1955, Alias Billy the Kid: Albuquerque, University of New Mexico Press, 136 p.

WPA authors, 1940, New Mexico, guide to the colorful state: Albuquerque, University of New Mexico Press, 458 p.

Minerals and rocks

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

Dana, E. S., and Hurlbut, C. S., 1953, Minerals and how to study them: New York, John Wiley, 323 p.

Hurlbut, C. S., 1970, Minerals and man: New York, Random House, 304 p.

Northrop, S. A., 1959, Minerals of New Mexico: Albuquerque, University of New Mexico Press, 665 p.

Pough, F. H., 1960, A field guide to rocks and minerals, Peterson guide: Boston, Houghton Mifflin, 340 p.

Tarr, W. A., 1929, Doubly terminated quartz crystals occurring in gypsum: American Mineralogist, v. 14, p. 19-25

Thompson, T. B., 1973, Mineral deposits of Nogal and Bonito mining districts, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circ. 123, 30 p.

U.S. Geological Survey, 1965, Mineral and water resources of New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bull. 87, 437 p.

Glossary

acequia —I ndian or Spanish irrigation ditch

alluvial fan—a cone-shaped deposit formed where streams undergo a reduction in slope from mountains to lowlands, such as at the mouths of canyons

alluvium—unconsolidated mud, sand, and gravel deposited by rivers or sheetwash

ammonite—an extinct marine invertebrate related to the present-day chambered nautilus

andesite—a volcanic rock intermediate in composition between rhyolite and basalt

anticline—an archlike fold in which strata dip in opposite directions from a common ridge or axis

artesian well—a deep well in which water is forced up to the surface by internal hydrostatic pressure

ash—volcanic sediment formed when escaping gases force out a fine spray of magma

basalt—a fine-grained, dark-colored volcanic rock composed chiefly of calcium-rich plagioclase, pyroxene, and olivine

basement—the oldest rocks recognized in a given area; a complex of igneous and metamorphic rocks underlying all the sedimentary formations

bed—a layer of rock

bolson—alluvium-floored desert valley with no drainage outlet

breccia—a rock composed of very angular fragments

caliche—a desert soil formed by the near-surface crystallization of soluble minerals by upward-moving solutions

cinder—volcanic sediment larger than ash, smaller than lapilli

cirque—steep-walled semicircular depression at the head of a high mountain valley, caused by quarrying and scraping out of solid rock by movement of glacial ice

conglomerate—sedimentary rock composed of rounded gravel cemented together by another mineral material

contact—the place or surface where two different kinds of rocks meet

desert varnish—a lustrous surface stain or crust of manganese or iron oxide, brown or black in color, which characterizes many exposed rock surfaces in the desert

diastrophism—activity by which the crust of the earth is deformed

dike—narrow vein or layerlike body of intrusive igneous rock that (while in the form of molten magma) has penetrated older rock deep in the crust

dome—a round or elliptical upwarp of strata

extrusive rock—volcanic rock poured out onto the surface of the earth

fault—fracture in rocks along which the two sides have moved relative to each other

flow unit—an individual river of lava

fold—archlike or troughlike undulations of rocks best seen in layered rocks; usually caused by corn-pressional forces in the earth's crust

formation—a rock type or assemblage of rock types that are or once were horizontally continuous, that share distinctive features, and that are extensive enough to be mapped

fossil—identifiable remains or traces of an ancient animal or plant preserved in rock

gabbro—dark-colored, medium- to coarse-grained igneous rock consisting mainly of pyroxene and calcium plagioclase

granite—a light-colored, medium- to coarse-grained intrusive igneous rock consisting chiefly of orthoclase, sodium-plagioclase, and quartz, with minor biotite

gypsum—a common mineral of evaporites used in making plaster of paris; $CaSO_{.},2H_{2}0$

igneous rock—rock formed by solidifying and crystallizing from magma deep in the earth's crust (plutonic) or from lava on the earth's surface (volcanic)

intrusive rock—body of igneous rock that penetrated (when molten) older rock and cooled at depth

kipuka—a term used by Hawaiians for an island of older rock surrounded by a sea of lava

laccolith—body of igneous (plutonic) rock intruded between older rock layers, doming the layer above

lapilli—fragments of sand-sized to cobble-sized volcanic rock formed when magma is ejected into the air

Laramide—the period of time when the eastern Rocky Mountains underwent deformation, about 65 m.y. ago

latite—extrusive volcanic rock composed of potash, feldspar, and plagioclase

lava—magma or molten rock that has reached the surface

lava tube—a hollow tunnel formed when the outside of a lava flow cools and solidifies and the liquid lava passing through it is drained away

limestone—sedimentary rock composed of calcium carbonate; the consolidated equivalent of calcite mud, calcareous sand, or shell fragments

magma—the molten rock material that forms igneous rocks when it cools

malpais—Spanish word for badlands; refers to area of lava flows at Valley of Fires

metamorphic rock—a rock that has been altered chemically and structurally by extreme heat and pressure, causing new structures and minerals to form

monzonite—grayish, medium- to coarse-grained igneous rock consisting of approximately equal amounts of orthoclase and plagioclase with minor biotite and hornblende

moraine—an accumulation of rock fragments deposited by melting glacial ice

pahoehoe—basaltic lava flow with glassy, smooth, ropy surface

paleontology—the study of fossils, their environment, and the record of their evolutionary development

Pecos diamonds—small, perfect, doubly terminated quartz crystals found along the east side of the Pecos Valley

Pedernal uplift—in this scenic trip area, an ancient landmass of Precambrian metamorphic rocks, formed in late Paleozoic time

pediment—broad, flat or gently sloping erosion surface typically developed in arid or semiarid regions at the base of a mountain range

Permian Basin—an area of New Mexico and Texas, downwarped during Permian times, containing oil-rich marine sediments

petroglyphs—drawings hammered into solid rock by prehistoric Indians

phenocryst—conspicuous, relatively large crystal, inset in igneous rock

pluton—a large igneous intrusion formed at depth in the crust

porphyry—rock containing two distinctly different size mineral crystals

pressure ridge—an uplift of the hardening crust of a lava flow, probably due to the pressure of the still-flowing lava underneath

rhyolite—light-colored, very fine grained volcanic rock; extrusive equivalent of granite

sandstone—sedimentary rock consisting of cemented sand, predominantly quartz

sedimentary rock—rock formed by the accumulation of sediments after having been transported by water, wind, or ice, or composed of organic material mixed with sediments

semiarid—the type of climate in this scenic trip area; characterized by 10-20 inches of rain per year and by sparse grasses as major vegetation

shale—sedimentary rock composed of indurated mud that tends to split apart easily

sill—intrusive tabular body of igneous rock emplaced parallel to the bedding of the intruded rock

siltstone—a very fine grained consolidated clastic rock composed predominantly of particles between and Y256 mm in diameter

sinkhole—small, steep-walled depression caused by dissolution of rock and the subsequent collapse of subterranean caverns

squeezeup—area in a lava flow where once-liquid lava came up through cracks in the hardened crust

stock—large, irregular igneous intrusive that cuts through the older rocks

stratification—in sedimentary formations, recognizable parallel beds of considerable lateral extent

stratigraphic column—list of formations, by age, which compose the geologic history of an area

syenite—rock similar to granite but without much quartz

syncline—trough-like fold in layered rocks

synclinorium—a broad, regional syncline

talus—a sloping heap of coarse rock fragments at the foot of a cliff or steep slope

terrace—one of a series of level surfaces in a stream valley, elongated more or less parallel to the stream channel, representing the dissected remnant of an abandoned floodplain or valley floor produced during a former state of erosion or deposition

unconformity—surface of erosion or nondeposition representing an undocumented period of geologic time in the area of the unconformity

vesicles—frozen gas bubbles in hardened lava

volcano—an opening through the earth's crust that has allowed magma to reach the surface

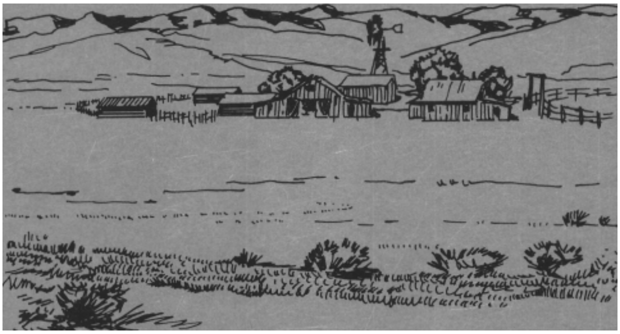
Geologic map of Carrizozo-Ruidoso-Roswell area

(in pocket)

Type faces:	Text in 10-pt. English Times, leaded two points
	References and Index in 8-pt. English Times, leaded one point
	Display heads in 18-pt. English Times
Presswork:	Miehle Single Color Offset
	Harris Single Color Offset
Binding:	Smyth sewn with softbound cover
Paper:	Cover on 10-pt. silver Currency
	Text on 70-1b. white Matte
	Color photo gallery on 80-lb white enamel
	Pocket map on 50-lb white Mead opaque
Quantity:	3000

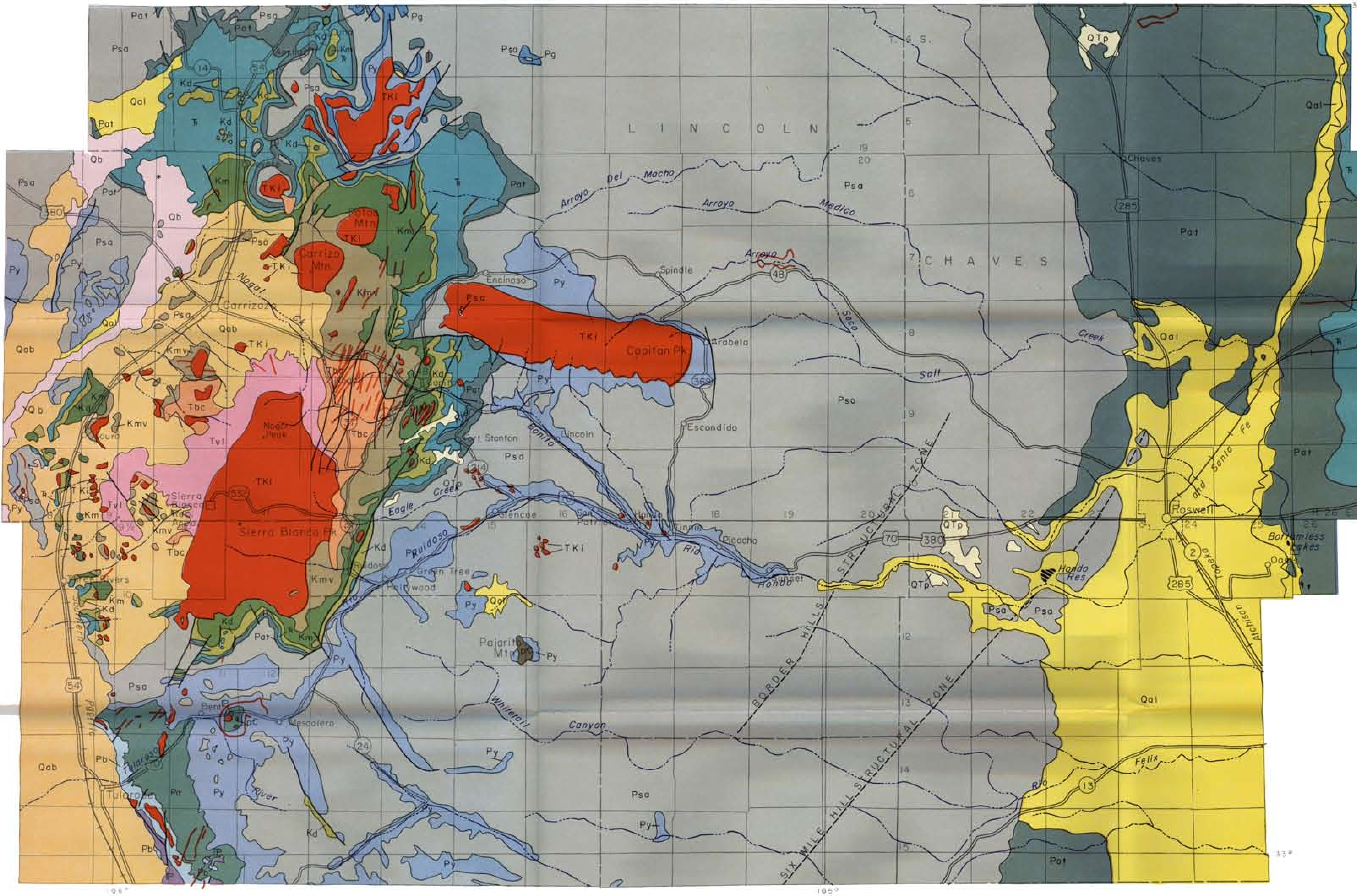
$5.00

Our scenic trip to the geologic past takes us on a visit to a land of many contrasts—from lava flows to snow-covered mountains with traces of glaciation, from dry arroyo beds to mountain streams, from cactus-covered plains to pine-covered mountains. Take a day or two to explore this area and learn about the dynamic processes that shaped the face of the earth. Seven detailed trip logs include information about more recent events as well—including the Lincoln County Wars. Authors are *John Eliot Allen,* Professor Emeritus of Geology, Portland State University, and *Frank E. Kottlowski,* Director, New Mexico Bureau of Mines and Mineral Resources.



New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY



Qb Little Black Peak Basalt; Qab alluvial fan and pediment gravels; Qal valley alluvium on floodplains — Quaternary

QTp terrace and pediment gravels; caliche

Tvl Sierra Blanca Volcanics

Tbc Cub Mountain Formation — Tertiary

TKi igneous dikes, sills, laccoliths, stocks

Kmv Mesaverde Formation

Km Mancos Shale

Kd Dakota Sandstone — Cretaceous

Ꞃ Chinle Formation and Santa Rosa Sandstone — Triassic

Pat Artesia Group

Psa San Andres Limestone

Pg Glorieta Sandstone

Py Yeso Formation

Pa Abo Sandstone

Pb Bursum Formation — Permian

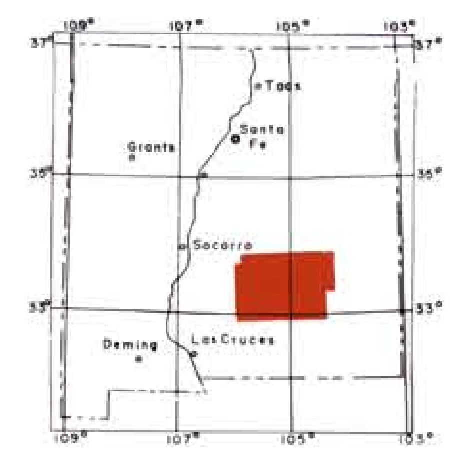
IP Pennsylvanian rocks, undivided — Pennsylvanian

p€ Precambrian rocks, undivided — Precambrian

structural zone

fault

* volcanic vent



Index map

Geology from Dane and Bachman, 1965, USGS

Cartography by S. Landregan, 1979

Geology of Carrizozo-Ruidoso-Roswell area

0 10 20 mi

1 inch equals approximately 7 mi

1981