Scenic Trips to the Geologic Past No. 4

Southern Zuni Mountains New Mexico

Zuni-Cibola Trail

SCENIC TRIPS TO THE GEOLOGIC PAST No.

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“Man-made highways and automobiles crisscross this world but hardly penetrate it…”

J. FRANK DOBIE
Apache Gold and Yaqui Silver

Ramah Lake

SCENIC TRIPS TO THE GEOLOGIC PAST

NO. 4

Southern Zuni Mountains

Zuni-Cibola Trail

BY

ROY W. FOSTER

PHOTOGRAPHS BY
H. L. JAMES

SKETCHES BY
PATRICIA C. GICLAS

1971

STATE BUREAU OF MINES AND MINERAL RESOURCES
NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY
CAMPUS STATION SOCORRO, NEW MEXICO 87801

NEW MEXICO STATE
BUREAU OF MINES AND MINERAL RESOURCES
DON H. BAKER, JR., *Director*

A Division of

NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

STIRLING A. COLGATE, *President*

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Preface

The "Scenic Trips to the Geologic Past" booklets are published by the New Mexico State Bureau of Mines and Mineral Resources to acquaint the visitor, as well as the New Mexico resident, with the many scenic and geological attractions of the State. Other publications in this series describe areas around Santa Fe, Taos, Roswell, Silver City, Pecos, Raton, Clayton, Albuquerque, Deming, and Lordsburg.

The first part of the book consists of a summary of the geologic, archaeologic, and recent events that have shaped the landscape and culture along the Zuni-Cibola Trail. The second part is a series of road logs that give distances between points of interest, descriptions of these points, and places to stop to examine geologic features. Because mileages taken from one odometer do not necessarily coincide with another, features such as road junctions, bridges, and cattle guards are included to aid the reader in locating himself en route.

Many names are used in the text in discussing various rock units. A brief explanation of how these units are named and used will help in the understanding of this guide. The geologist subdivides rocks into units based primarily on type, that is, limestone may constitute one unit, sandstone another, and granite another. Often a unit is distinguished by containing many rock types that may be deposited in very thin beds. This variation in rock types thus sets this unit apart from others of more uniform composition. After separating the various units, names are assigned from some local cultural or geographic feature. The rock units are called formations, and if most or all of the unit is of one rock type, it can be called, for example, the San Andres Limestone, to distinguish it from other limestones. If made up of many rock types, none of which is greatly dominant over the others, the term "formation" is attached to the name and we have something like the Yeso Formation. Most of the names used in the text originated in other areas. San Andres comes from the San Andres Mountains in south-central New Mexico, Yeso from Mesa del Yeso near Socorro, Dakota from the town of Dakota, Nebraska, and so on. Over the years correlations from one area to the next have been fairly well established. It often happens that different names are applied to the same formation in widely separated areas. In this instance, the different names may be retained with the change commonly coming at such geologically arbitrary places as state boundaries. The San Andres is called the Kaibab Limestone in Arizona. The source of this name is the Kaibab Plateau, through which the Colorado River has carved the Grand Canyon. We New Mexicans naturally claim a priori rights for the San Andres, but our Arizona colleagues have been unable to see the error of their ways. By studying the rock sequence, tracing units from one area to the next, identifying fossils, and by measuring radioactive decay of certain elements, geologists can determine how long ago, and under what conditions, the rocks were deposited. Based on these studies, the various rock units are grouped into periods of time that are agreed upon by geologists all over the world. Thus we have Permian from the province of Perm in northeastern Russia, where there is an almost complete section of rocks of this age; Triassic, because of the threefold development of these rocks where first studied in Germany; and Cretaceous from the Latin word *creta*, for chalk, a common rock type found in beds of this age in France and England. The White Cliffs of Dover are an example.

In addition to the basic scientific value of explaining the history of the Earth, this type of knowledge also enables us to predict where minerals of economic value may be found, and is the fundamental basis for all mineral exploration. From this we know that the important uranium deposits in the Grants area are found in rocks deposited during the Jurassic Period, that coal occurs in rocks of Cretaceous age in the western United States and Pennsylvanian age in the eastern United States, and that petroleum can be found in rocks deposited under certain marine conditions, and where these conditions prevailed during different periods of geologic times.

Although not stressed in this publication, it is noted from time to time that various life zones are crossed during the trip. In the late 1800's an eminent scientist named C. H. Merriam observed that the distribution of various plants and animals was controlled by certain factors. Of particular importance were temperature and moisture, but slope, soil and rock type, and exposure to sunlight played locally important roles. He also noted that in the mountainous areas of the southwestern United States this distribution varied with altitude. Thus, by ascending from the desert valley to the mountain tops, a distance of only a few miles, one can cross life zones similar to those that would be encountered in traveling from the Southwest to the Arctic Circle. Merriam named these zones, in ascending order, the Sonoran, Transition, Canadian, Hudsonian, and Alpine. Along the route of this trip we will see the Sonoran, Transition, and Canadian life zones. The Sonoran Zone is characterized by sagebrush, juniper, and piñon, the Transition Zone by Gambel's oak and ponderosa pine; and the Canadian Zone by aspen, fir, and spruce. In other parts of New Mexico it is possible to go from the Sonoran to the arctic tundralike Alpine Zone.

Introduction

The Zuni Mountains are a broad elongate dome almost completely ringed by high inward-facing cliffs. The cliffs consist of a series of sedimentary rocks that once formed a continuous blanket over the area now occupied by the mountains. During the uplift of the range, which began about 70 million years ago, the sedimentary rocks were tilted and eroded back from the core of the dome. The more resistant layers, such as sandstone, now appear as cliffs, whereas the softer beds, such as shale, now form slopes and valleys. Since the uplift of the mountains began there has been considerable volcanic activity in the area; activity that ended little more than 1,000 years ago.

Only a small portion of the rocks involved in the uplift of the Zuni Mountains can be seen from I-40 (U.S. Highway 66), but along the state, county, and forest roads that connect the ranches and farms of the southern Zuni Mountains with Gallup and Grants, almost the entire rock record is crossed.

From Grants, the highway (N. Mex. 53) heads south through the wide, lava-floored San Rafael Valley. Near the end of the valley the road turns abruptly west across the southeastern tip of the Zuni Mountains. On the west side of the range, after passing the Ice Cave and numerous extinct volcanoes, the road reaches a summit at the Continental Divide. From the divide the route descends rapidly into another lava-floored valley, which it crosses diagonally, to the sheer cliff and waterhole at El Morro. Beyond El Morro are the quiet village of Ramah and the bustling pueblo of Zuni. The mountains are now far to the east, and the scene is dominated by gently sloping ridges, flat-topped mesas, and narrow canyons. The road (N. Mex. 32) continues north from Zuni, past trading posts and abandoned coal mines, to the crowded trade center of Gallup.

During the period of Spanish exploration and colonization, this route, the Zuni-Cibola Trail, was the "Highway 66" of its day. It connected the Spanish settlements along the Rio Grande with the outlying pueblos of Acoma, Zuni, and Hopi. With the arrival of the railroad, and later the cross-country highways, this trail was bypassed in favor of the more direct route north of the Zuni Mountains.

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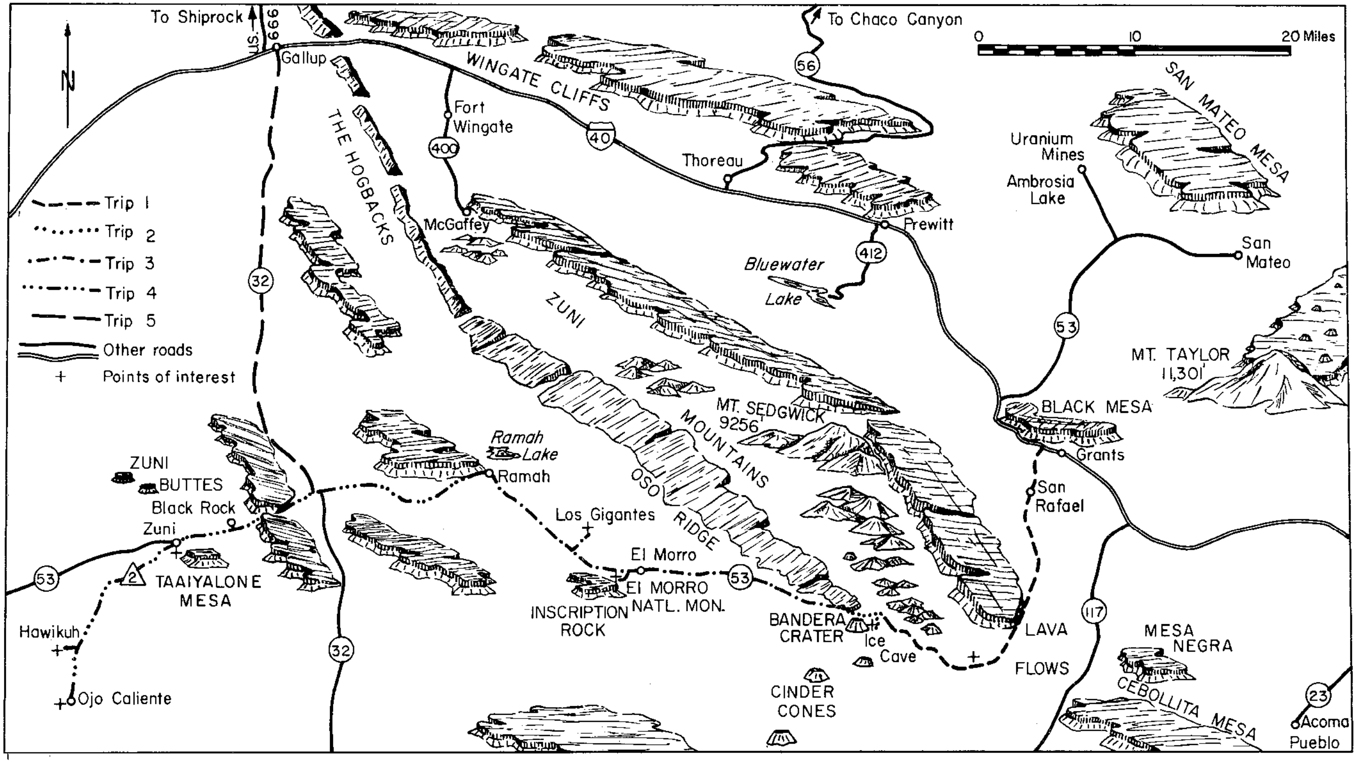


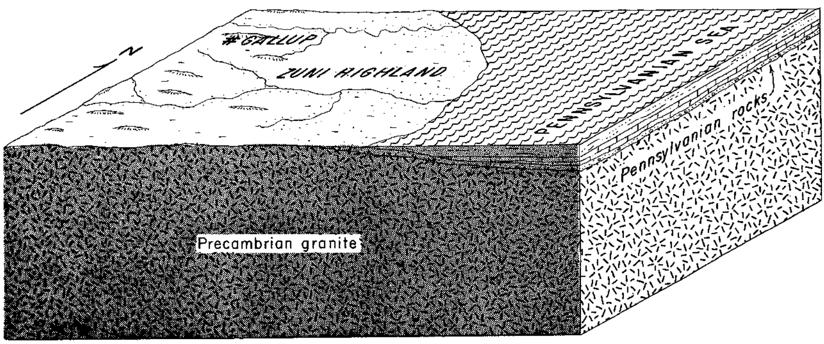
To Shiprock
US 666
Gallup
To Chaco Canyon
56
0
10
20 Miles
WINGATE CLIFFS
SAN MATEO MESA
Fort Wingate
400
40
Thoreau
Uranium Mines
Ambrosia Lake
THE HOGBACKS
McGaffey
Prewitt
412
San Mateo
Bluewater Lake
Trip 1
Trip 2
Trip 3
Trip 4
Trip 5
Other roads
Points of interest
32
ZUNI
53
MT. TAYLOR 11,301'
MT. SEDGWICK 9256'
BLACK MESA
MOUNTAINS
Grants
Ramah Lake
Ramah
ZUNI BUTTES
Black Rock
Zuni
OSO RIDGE
San Rafael
Los Gigantes
El Morro
TAAIYALONE MESA
EL MORRO NATL. MON.
INSCRIPTION ROCK
BANDERA CRATER
Ice Cave
LAVA FLOWS
117
MESA NEGRA
Hawikuh
Ojo Caliente
CINDER CONES
CEBOLLITA MESA
23
Acoma Pueblo

Geologic History

PRECAMBRIAN AND PALEOZOIC TIME

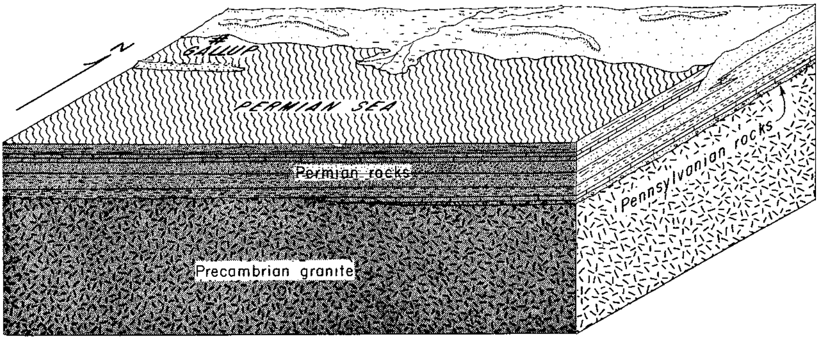
A record of the past history of the Earth is only partly preserved in this part of New Mexico. The oldest rocks, those of the Precambrian Era, are exposed in the central core of the Zuni Mountains. These rocks, granite for the most part, but including schist, rhyolite, gneiss, and quartzite, were formed over one billion years ago. The Precambrian Era ended about 600 million years ago and for the next 300 million years, until late Pennsylvanian time, there are no rocks from which to unravel the geologic events that occurred. Elsewhere in New Mexico and surrounding areas, however, this period of time is represented by thick layers of rocks, and from a study of these sediments we can infer by comparisons and projections what took place in the Zuni area.

During much of Cambrian, Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian time, the entire area was covered by a sea in which limestones, sandstones, and shales were deposited. At times parts of



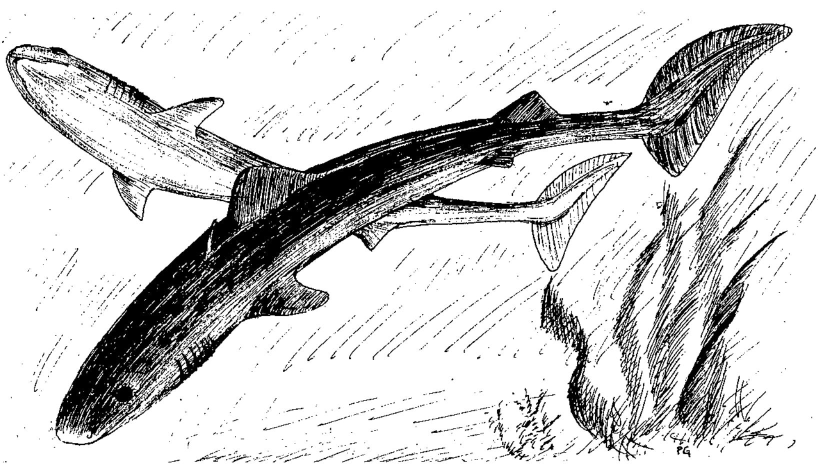
THE ZUNI HIGHLAND BEGINS TO SUBSIDE IN PENNSYLVANIAN TIME

the area were lifted above sea level and subjected to erosion. Major uplifts occurred during Ordovician, Devonian and early and late Pennsylvanian time. The site of the present Zuni Mountains was in the path of most of these uplifts, and all the rocks that had been deposited were stripped away by erosion. The first rocks to be preserved above the old Precambrian core of the mountains were thin limestones and conglomerates of late Pennsylvanian age. These beds are overlain by sediments of Permian age. During this period the sea slowly advanced from the south to form the thick lime-stone, salt, and gypsum deposits of western Texas and southern New Mexico. In early Permian time a shallow arm of the sea extended north and northwest to the vicinity of what is now El Morro. Fluctuations of the shoreline resulted in mixed rock types of marine limestone and gypsum, alternating with continental deposits of red muds and sands, to build up what we call the Abo and Yeso Formations. The final advance of the Permian sea in this area reached just north of the present Zuni Mountains. This advance is recorded by the thick limestones and sandstones of the San Andres and Glorieta Formations. Large quantities of marine fossils can be found in these beds.



ADVANCE OF THE PERMIAN SEA OVER THE ZUNI HIGHLAND

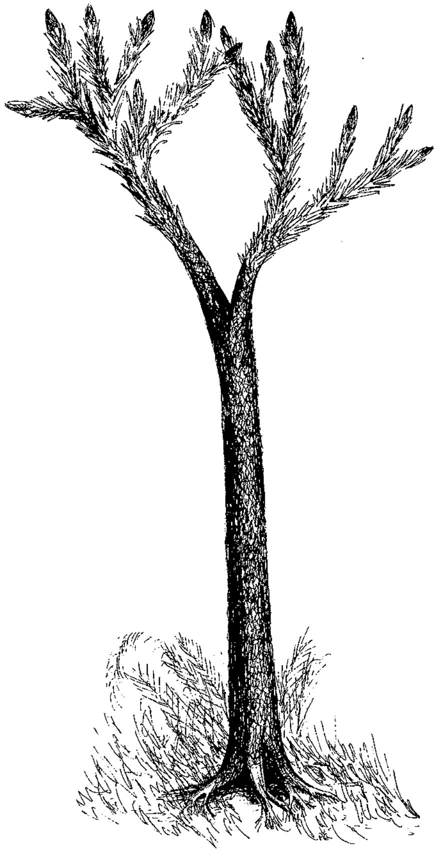
From the small number of simple life forms that existed during Precambrian time, highly developed animals and plants evolved during the Paleozoic Era. The sea bottom teemed with snails, clams, cephalopods, trilobites, brachiopods, crinoids, sponges, and coral. In the warm clear waters above, fish, including the shark, searched for food. The amphibians were the first vertebrates to walk on this planet, taking their initial steps into that strange,



DEVONIAN SHARK
Cladoselache

less-buoyant environment of air and earth some 400 million years ago. Late in the Paleozoic the most highly organized form of life yet developed arrived on the scene. This was the reptile, then small and defenseless against the dominating amphibians, but destined soon, as the awesome dinosaur, to become master of his world.

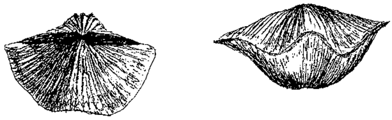
Plants, too, had their beginnings from the seaweed growing on the ocean floors to the first small land plants of the Devonian and the great forests of Pennsylvanian time. The fossil record gives no indication of birds but the



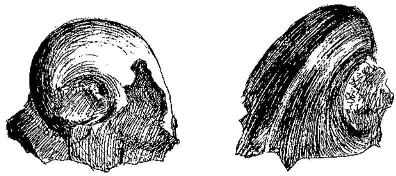
PENNSYLVANIAN FERN TREE
Lepidodendron

air was not devoid of life. Insects came into being early in the Pennsylvanian, and dragonflies with wing spans of 30 inches darted through the fern trees. On the ground, man’s old friend the cockroach, scurried about.

Thus we have seen evolved most of the major forms of life that have existed, or still exist on this earth. Yet to come were the mammals and their late-arriving offspring, man.



PENNSYLVANIAN BRACHIOPOD
Neospirifer



PERMIAN GASTROPOD
Bellerophon

ORDOVICIAN CEPHALOPOD
Orthoceras

The Paleozoic Era lasted over 300 million years. In parts of southern New Mexico sediments deposited during this time are over 20,000 feet thick. In the Zuni Mountains, only two of the Paleozoic periods are represented, the Pennsylvanian and Permian, and the total thickness of sediments is only about 1,000 feet.

Precambrian rocks can be seen in many parts of New Mexico. They form much of the west-facing scarp of the Sandia Mountains east of Albuquerque, and a considerable portion of the high Sangre de Cristo Mountains northeast of Santa Fe. Precambrian rocks are familiar to tourists in other nearby areas, such as the Black Canyon of the Gunnison in Colorado, and the inner gorge of the Colorado River in Grand Canyon National Park. Truly classic sections of early Paleozoic rocks are found in the mountain ranges of southern New Mexico, which, however, are difficult of access. An easily reached section of these rocks is along the Scenic Drive, in the Franklin Mountains at El Paso. A less-complete section can be seen at the Grand Canyon.

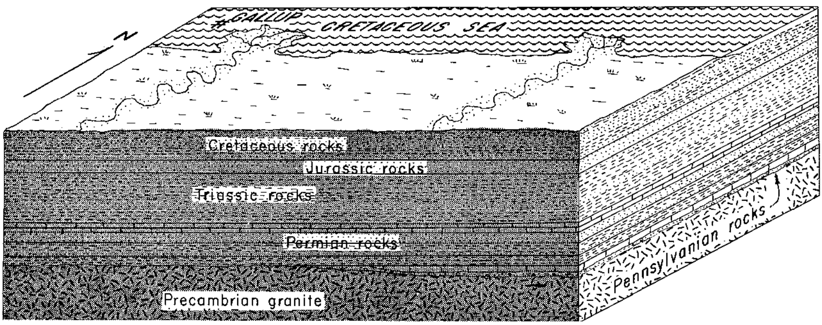
Rocks of late Paleozoic age are crossed almost continuously from Grants to west of the Ice Cave. Probably the most famous locality of Permian rocks in the United States for the nongeologist is Grand Canyon National Park, where the caprock is composed of marine limestones of this age. The vivid red sandstone cliffs at Canyon de Chelly National Monument in northern Arizona, and the thick limestones at Carlsbad Caverns are also Permian.

MESOZOIC TIME

From the beginning of Triassic time to well into the Cretaceous Period west-central New Mexico was above sea level. However, the area was a low plain and sediments derived from uplifts to the south spread out over the

PENNSYLVANIAN DRAGONFLY

partly eroded surface of Permian limestones. As climatic conditions changed, the country varied from forest to desert and back to forest. These changes are reflected in the thick red, green, and purple shales and silts left behind by rivers that meandered back and forth across the plain, and in the great sand dunes piled up by hot desert winds. At one time a shallow brackish

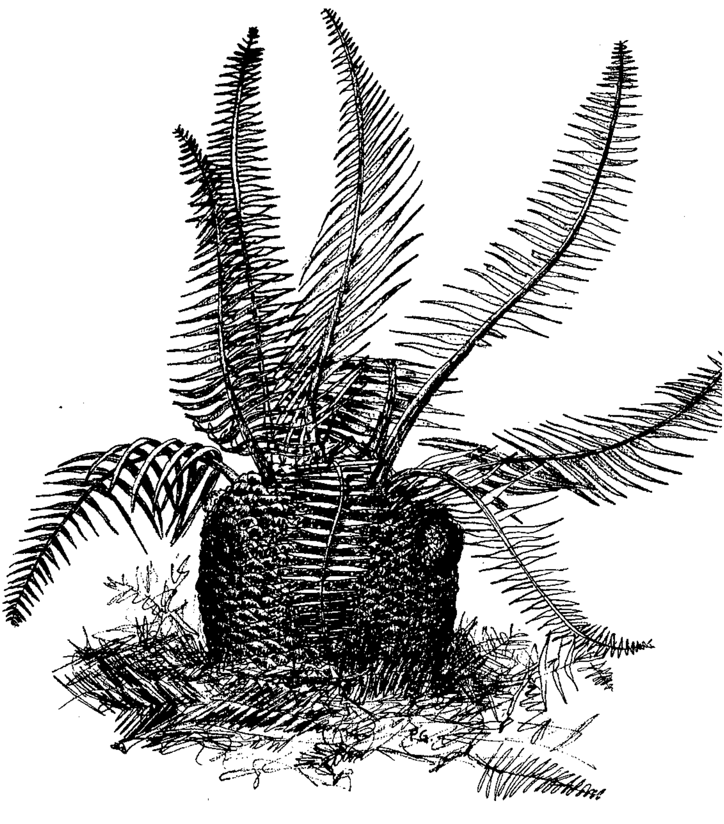


FINAL RETREAT OF THE CRETACEOUS SEA BEGINS; THE ZUNI HIGHLAND IS DEEPLY BURIED BY SEDIMENTS

sea advanced south to near the present I-40 and left evidence of its presence in thin beds of limestone and gypsum. These drab-colored sediments make a readily traceable band through the brilliant hues of the other rocks.

During Late Cretaceous time the sea advanced and retreated several times across what is now the Zuni Mountains, leaving behind a mixture of marine and continental deposits. Thick gray and black shales containing abundant fossil clams, and thinner, lighter colored sandstones were left to mark the advances of the sea. During periods of emergence, sands and muds were deposited by the sluggish streams that built deltas out into the slowly receding sea. Large lagoons and swamps with lush vegetation bordered the sea as it retreated, and in these marshes the large coal deposits of the western interior of the United States were formed. Near the end of Cretaceous time, some 70 million years ago, the sea retreated for the last time from New Mexico and from most of what is now the continental United States. During the Mesozoic Era about 6,000 feet of sediments had accumulated and the area was a flat plain, ready for the next episode of earth history.

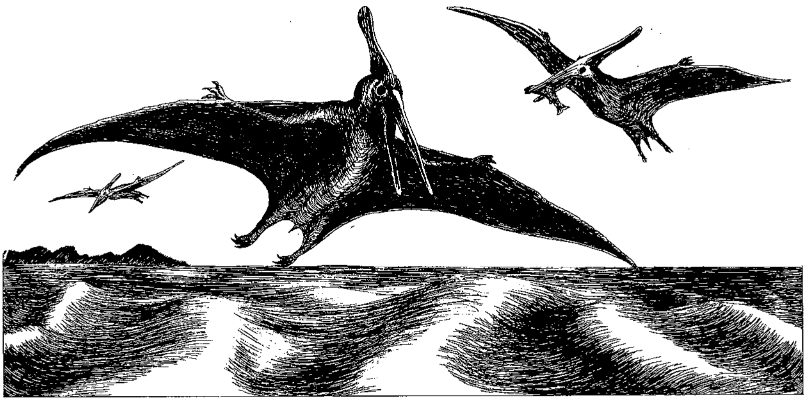
Many new species of invertebrates evolved during Mesozoic time; perhaps the most interesting was the complex shell development of the cephalopods. Most of these died out by the end of the Mesozoic. Today we are left with the pearly nautilus, squid, and octopus, as the only living relatives. Oysters and clams also increased in number during this time but the brachiopods, so numerous in the Paleozoic, were reduced to a few species. Trilobites disappeared from the scene.



CRETACEOUS TREE
Cycadeoidea

Insects continued to proliferate, including the first flies, beetles, ants, moths, butterflies, bees, and May flies.

Cycad-like plants dominated the flora but ferns continued to flourish and conifers which began in the Permian became more numerous. The huge silicified logs at Petrified Forest National Park are ancient conifers. The flowering plants, the highest type of plant life, had their beginnings in the Mesozoic. Many were similar to the modern beech, willow, maple, and birch.

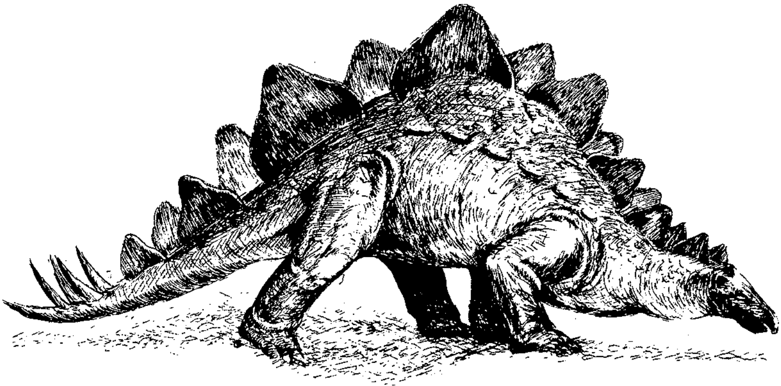


CRETACEOUS FLYING REPTILE
Pteranodon

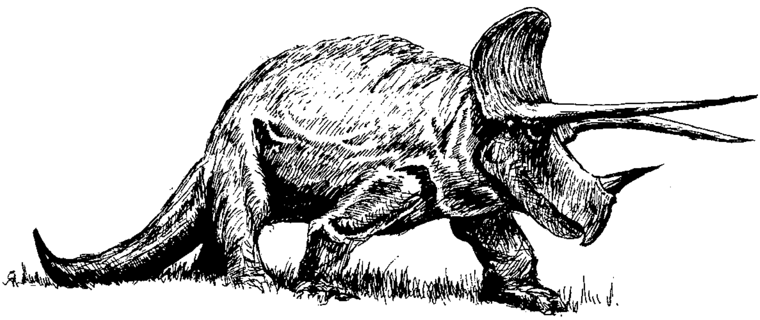
One of the most interesting life-form developments of Mesozoic time were the flying reptiles, forerunners of the true bird. How the ability to fly was developed is one of the great mysteries of life; the transition from land to air certainly is more complex than from water to land. These reptiles varied from about the size of a wren to the size of the giant Pteranodon, with a wingspread of 26 feet. Fossils of earliest birds have been found in rocks of Jurassic age. They are distinguished from reptiles, which they closely resembled, by a covering of feathers.

All of these evolutionary steps are overshadowed by that most spectacular development of all time, the dinosaurs. What child hasn't been awed at his first introduction to these fantastic animals? The great length (90 feet) of Diplodocus; the tremendous weight (40 tons) of Brachiosaurus; the enormous size (70-foot length and almost 40-ton weight) of Brontosaurus; the horns and plates of Triceratops and Stegosaurus; the fearsome teeth and the speed of Allosaurus, probably the most efficient killer of all time; and the awesome size (50 feet), brutish head (over 4 feet long) and huge teeth (up to 6 inches long) of that most terrible lizard of all, Tyrannosaurus rex.

What happened to these great animals? Only smaller descendants survived past Mesozoic time. One explanation for the disappearance of the



STEGOSAURUS
Jurassic



TRICERATOPS
Cretaceous

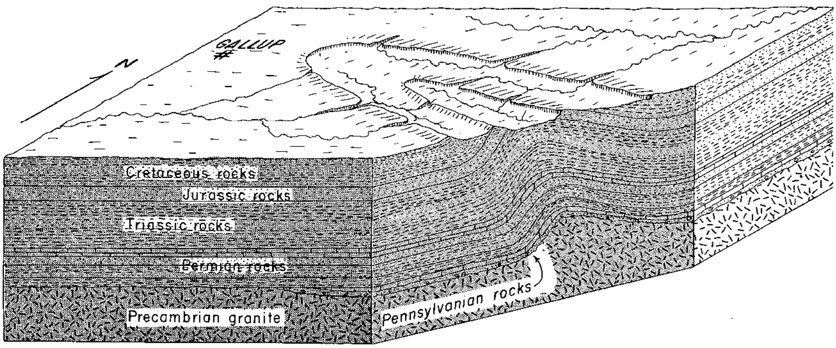
carnivores seems to have been their total dependence on their plant-eating cousins for food. Any environmental change that reduced the supply of flesh would have had serious effects on the survival probabilities of the carnivores.

Certainly it must have taken a fair amount of meat to satiate the appetite of Tyrannosaurus. We have already seen that in late Cretaceous time the land was relatively flat, and as the seas receded much of the country must have consisted of low-lying marshes. Near the close of the Mesozoic the land began to rise in one of the greatest uplifts ever recorded. In many places this mountain building has continued intermittently down to the present, and most of our spectacular mountain ranges had their beginnings at this time. As the land rose the marshes were drained and favorable areas for the herbivores were reduced and isolated. The very size of the plant eaters limited their ability to adapt to changing conditions. To support their weight they probably spent much of their time in water, browsing on

TYRANNOSAURUS REX
Cretaceous

various types of water plants. Their inability to migrate to more favorable areas, and climatic changes brought about by the processes of mountain building further endangered their chances of survival. Thus ended a cycle of evolution that man will continue to marvel at as long as he inhabits this Earth.

Rocks of Mesozoic age are the principal components of most of the spectacular scenery that attracts visitors to the Four Corners area of the southwestern United States. The vivid colors of Triassic rocks have been photographed by countless tourists and geologists at the Painted Desert, Petrified Forest, and Vermillion Cliffs. The massive sandstones of the Jurassic Period form the unforgettable cliffs at Zion and the natural arches and bridges in eastern Utah. The gray shales and yellow sandstones of the Cretaceous Period, found in northwestern New Mexico, eroded into broad, barren basins sprinkled with isolated buttes and broad tree-capped mesas,

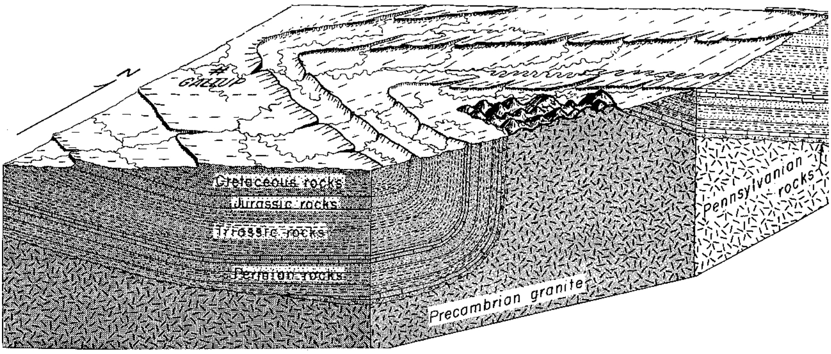


THE UPLIFT OF THE ZUNI MOUNTAINS BEGINS IN LATE CRETACEOUS OR EARLY TERTIARY TIME

have come to be a symbol of the West. In the Zuni Mountains area, limited outcrops of Triassic rocks are seen between San Rafael and El Morro. Good exposures are seen on the trip to Zuni Pueblo and north of McGaffey. Jurassic rocks form an almost complete elliptical ring of colorful cliffs surrounding the Zuni Mountains. They are best seen between El Morro and Ramah, along the trip to Zuni, and from the lookout above Fort Wingate Day School. Cretaceous rocks underlie most of the route from Ramah to Gallup.

CENOZOIC TIME

In the waning days of the Mesozoic Era, or sometime shortly after the beginning of the Cenozoic (some 70 million years ago), forces began to swell the Earth's crust along a northwest-southeast axis, bending the rocks into the broad dome of the present Zuni Mountains. On the first gentle slopes of this uplift, running water began cutting away the rocks and lowering the surface to sea level, a process still going on today. The initial streams and their tributaries first cut away the Cretaceous rocks, then the Jurassic, and

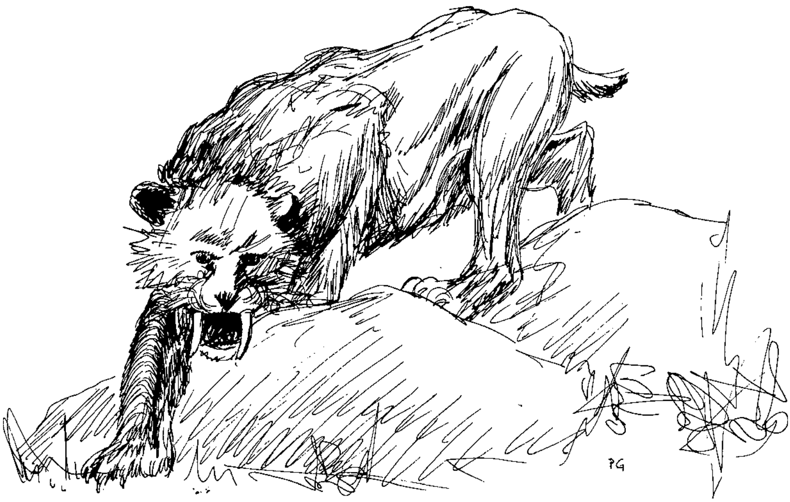


THE ZUNI MOUNTAINS TODAY

finally, most of the Triassic from the central part of the uplift. When the rivers reached the hard Permian limestone, their ability to keep pace with the uplift of the mountains was lessened. Sidecutting by major streams and their tributaries had easily stripped away the softer Mesozoic rocks, but to maintain grade the streams now began to cut deep, narrow canyons through the Permian limestone. Finally, along the axis of the uplift, the core of Precambrian granite, buried for over 200 million years, was once again exposed.

During early Tertiary time, in the areas lying south and northeast of the Zuni Mountains, the great volcanic eruptions began which geologically dominate Cenozoic time in New Mexico. By middle-Tertiary time, great lava flows and piles of ash had accumulated to thicknesses of several thou-sand feet south of the Zuni Mountains, and Mount Taylor and the Jemez Mountains were active volcanoes. By Pleistocene time, when most of the northeastern United States and Canada was covered by a sheet of ice, and the Sangre de Cristo Mountains in New Mexico were being sculptured by small mountain glaciers, volcanoes were spreading thin sheets of lava around the southern and eastern sides of the Zuni Mountains. By the close of the Ice Age the Zuni Mountain area was much as it is today.

Evolution of the mammals was exceedingly slow during Mesozoic time, but they expanded at a rapid pace in the early Tertiary. In the western United States this expansion saw the development of the horse (the first of these, Eohippus, was about one foot high), the rhinoceros, pig (some with a shoulder height of 6 feet), camel, deer (some with antlers 12 feet across), bison, elephant, saber-toothed tiger (with upper canines 8 inches long), the dog, and the giant ground sloth. It is interesting that most of these animals were extinct in the western Hemisphere long before the coming of man, but continued to evolve in many parts of Africa, Asia, and Europe. The large mammals, such as the elephant, hippopotamus, rhinoceros, and the great cats, are now rapidly approaching extinction. Whether or not this is totally the fault of man, as suggested by many, or whether they have reached the end of their evolutionary cycle, cannot be proven. Certainly



PLEISTOCENE SABER-TOOTH TIGER
Smilodon

man has accelerated the rate of extinction of these animals, and it is his responsibility to maintain their existence for as long as possible.

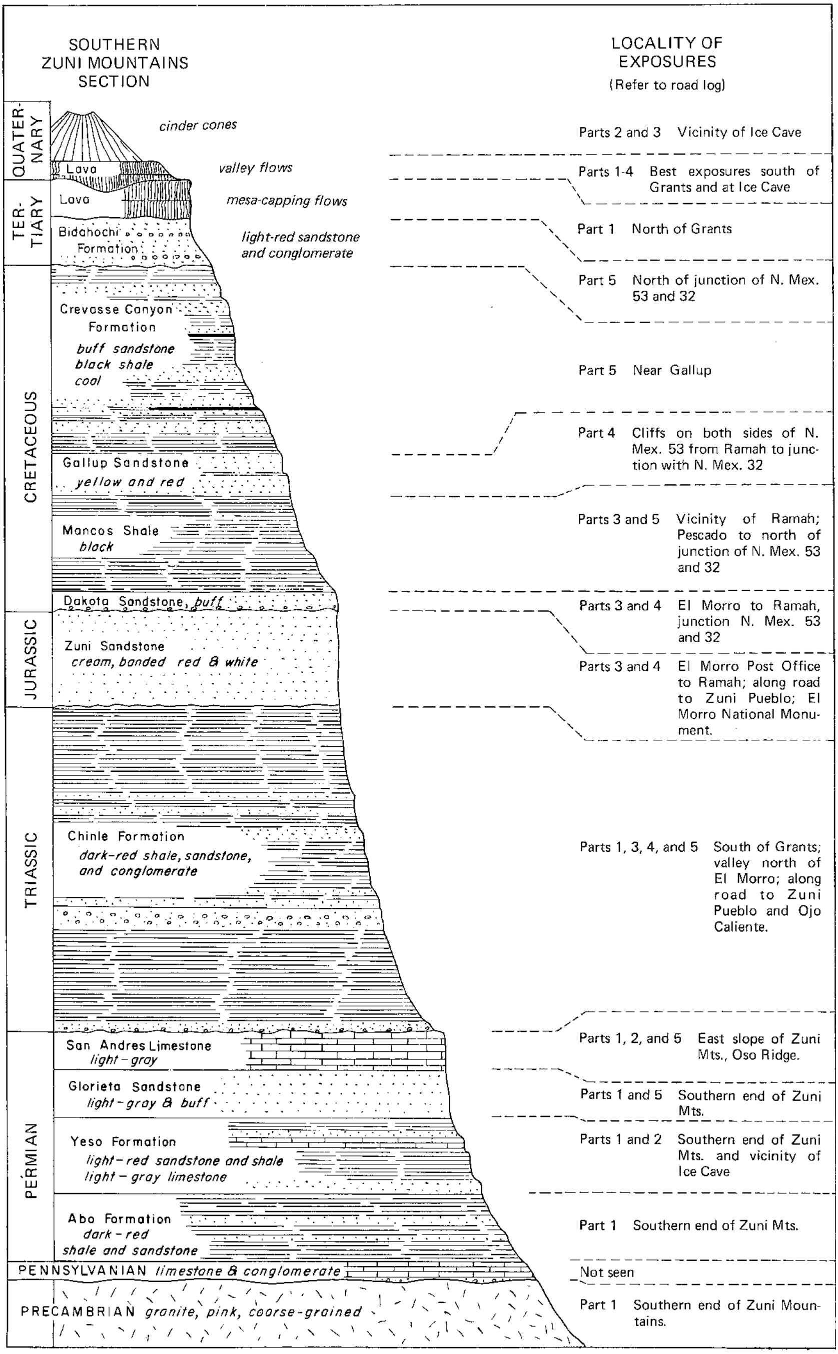
The reptiles survived into the Tertiary in forms similar to those now present, such as the lizard, turtle, alligator, and snake. Birds increased in number and species, but amphibians have remained in the limited numbers of the early Tertiary. The invertebrates were dominated, as they are today, by

COMMON TREE SHREW. A LIVING PRIMATE.

the clams, oysters, and snails. Brachiopods continued to decline and the coral to flourish. The flowering plants rapidly adapted to all types of climate and soil to spread over the earth and become far more important than the palm-like plants of the Mesozoic.

Primates are first found in beds of early Tertiary time. From these primitive beginnings the slow process of evolution to man began. Where this process will lead is speculative, but man, unlike all his forebears, has the capacity to alter the natural course of evolution and to change his environment. Whether or not man also possesses sufficient knowledge to accurately foresee the effects of these changes on future generations of man and other animals probably will not be known until they are fact and not speculation.

Rocks of Tertiary age also add to the physical beauty of the southwest. The pink-colored cliffs of Cedar Breaks and Bryce Canyon are of this age, as are the pastel greens and reds of the eastern San Juan Basin. Tertiary volcanics form the bulk of the picturesque San Juan Mountains in southern Colorado, and the vast volcanic field of the Gila Wilderness in New Mexico. In the Zuni country there are limited outcrops of Tertiary sands and gravels along the road to Gallup, and many fine examples of Quaternary cinder cones and lava flows from Grants to Zuni.



ROCK SEQUENCE IN SOUTHERN ZUNI MOUNTAINS

Eras & Life	Periods	Geologic Sequence of Events in Zuni Mountains Area	Other Areas Where Rocks of Similar Age Can Be Seen
	Quaternary 1 mill yr. — Recent, Pleistocene	Lava flows fill valleys around south and east sides of Zuni Mountains. Violent eruptions give rise to cinder cones near Ice Cave.	Carrizozo lava flow, New Mexico; Sunset Crater National Monument, Arizona
CENOZOIC 70+million years Mammals	Tertiary 70 million years — Pliocene, Miocene, Oligocene	Lava flows north of Grants and south of Zuni Mountains. Deposition of Bidahochi Formation in Pliocene time. Continued erosion of Zuni Mountains.	Cedar Breaks National Monument, Utah; Rio Grande Valley, New Mexico
	Eocene, Paleocene	Uplift and subsequent erosion of present Zuni Mountains begins. Considerable volcanic activity south of Zuni Mountains. Eruption of Mt. Taylor.	Jemez Mts. and ranges of western New Mexico; Bryce Canyon National Park, Utah; Cedar Breaks National Monument, Utah.
MESOZOIC 155 million years Reptiles	Cretaceous *65 million years*	Sea advances and retreats over Zuni Mountains area several times, leaving thick marine shales (Mancos) and sandstones (Dakota and Gallup). During periods of emergence, sandstones and coals (Crevasse Canyon Formation) are deposited by streams and in lagoonal areas.	Northwestern New Mexico; Mesa Verde National Park, Colorado
	Jurassic *45 million years*	Thick sand dunes (Zuni) further bury old Zuni upland. Shallow sea advances south to vicinity of Grants and leaves deposits of limestone and gypsum.	North of U.S. 66 from Grants to Gallup; Zion National Park, Utah
	Triassic *45 million years*	Erosion of Permian rocks followed by stream deposition of thick intervals of red shale and sandstone (Chinle Formation).	Petrified Forest National Park, Arizona; Vermillion Cliffs, Utah.
PALEOZOIC 375 million years — Trees, amphibians	Permian *45 million years*	Stream deposition of red shale and sandstone (Abo-Yeso Formations), followed by deposition of beach and bar sandstones (Glorieta) and marine limestone (San Andres). Sea retreats south in late Permian time.	Grand Canyon National Park, Arizona; Carlsbad Caverns National Park, New Mexico
	Pennsylvanian *40 million years*	Gradual submergence of Zuni Mountains area and deposition of marine limestones, followed by retreat of the sea.	Sandia and Sangre de Cristo Mountains, New Mexico; Garden of the Gods, Colorado
Crinoids	Mississippian *40 million years*	No sedimentary record. Some sediments deposited as seas advanced over area but removed during various periods of uplift.	Grand Canyon National Park, Arizona. Franklin Mountains, Texas, and numerous mountain ranges in southwestern New Mexico
Brachiopods, corals, fish	Devonian *50 million years*		
	Silurian *40 million years*		
Trilobites & cephalopods	Ordovician *60 million years*		
	Cambrian *100 million years*		Grand Canyon National Park, Arizona; Sangre de Cristo and Sandia Mountains, New Mexico; Franklin Mountains, Texas; Black Canyon of the Gunnison, Colorado
	Precambrian *4000 million years*	Numerous cycles of intrusion, volcanism, sedimentation, metamorphism, uplift, and erosion.	

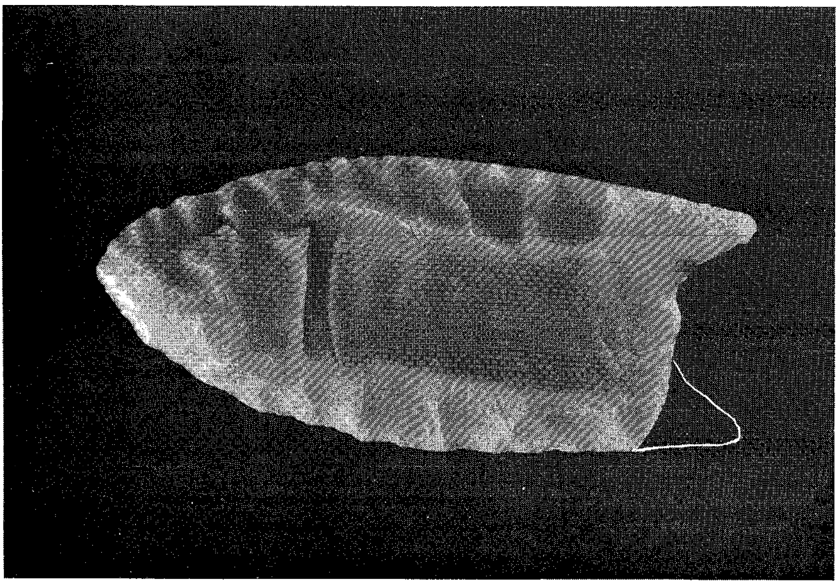
STANDARD GEOLOGIC TIME SCALE

The Imprint of Man

The southwestern part of the United States has been populated by man continuously since before the end of the Ice Age. A succession of peoples and cultures, beginning with prehistoric Sandia, Clovis, and Folsom man have made this region their home. Civilizations that followed include the Basket Makers, Pueblo and Plains Indians, Spaniards, Mexicans, and Anglo-Americans. The southwest has become one of the most important areas of study for anthropologists and archaeologists in the Western Hemisphere because of its rich variety of peoples and cultures, and its long period of habitation.

Sandia and Clovis man represent the earliest known record of human life in North America. They are known, not from skeletal remains, which as yet have not been found, but from stone points associated with now-extinct species of camels, bison, and mammoths. These points were originally discovered in the Sandia Mountains east of Albuquerque, and at Blackwater Draw near Clovis. Similar points have since been found in many parts of North America. The radioactive dating of Carbon 14 found in charcoal associated with the points, and comparisons with glacial stages, indicate that Sandia and Clovis man inhabited New Mexico about 12,000 years ago.

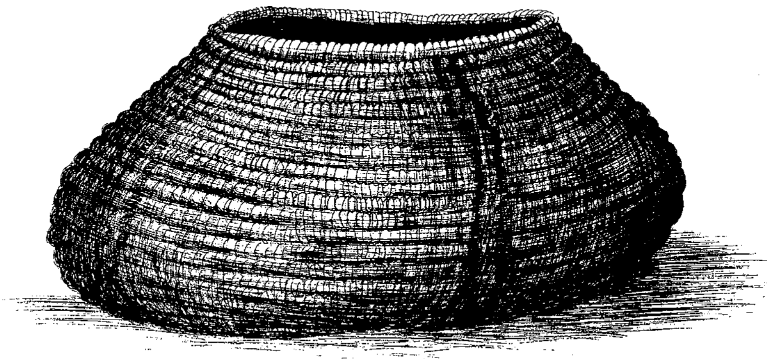
Folsom man also is known only from points associated with extinct



FOLSOM POINT; PLASTIC REPLICA WITH MISSING EAR RESTORED
Original point at Denver Museum of Natural History

animals. Similar points have been found from Texas to Canada, but the initial find was in northeastern New Mexico near the town of Folsom. He is thought to have inhabited New Mexico between 11,000 and 12,000 years ago, and is known to post-date Clovis man because his points occur in a layer of sediment above the Clovis points at Blackwater Draw. Representatives of these early cultures depended entirely on hunting and gathering for a food supply, and probably lived in natural shelters, such as caves or overhanging ledges.

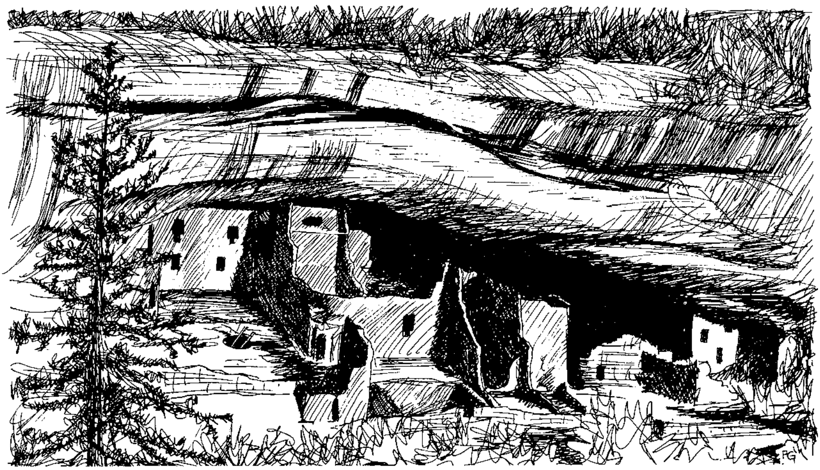
Until recently, there was a gap in the record of man's habitation of New Mexico between Folsom man and the Basket Maker culture that began about the time of Christ. The discoveries of two sites in western New Mexico have done much to fill this gap. One of these, near Grants, is thought to have been inhabited from about 6,000 years ago to 1500 B.C. The other, south of the Zuni Mountains, in the San Agustin Plains, apparently was occupied almost continuously from about 6,000 years ago to as recently as 500 A.D. A primitive variety of maize, considered to be 4,000 years old, was discovered at this site. This gives evidence that at least some of the early inhabitants of New Mexico had learned to cultivate crops and were not entirely dependent on hunting and gathering food for survival.



COILED BASKET PROBABLY USED FOR HOLDING TRINKETS
Basket Maker period

The Basket Makers were seminomadic, following game, particularly the bison and deer, but also growing some maize. They were, as their name implies, adept at weaving baskets. The change from the Basket Maker to the Pueblo cultural period represents a gradual mixture of two different peoples. The Pueblo people entered the area around the 8th century A.D. and brought with them the art of stone masonry, to replace the pit houses of the Basket Makers, and fired, rather than sun-dried, pottery. Their early houses were crude structures consisting of only one story. Generally, there was a square or circular kiva (ceremonial chamber).

The early Pueblo Indians settled in such localities as Chaco Canyon, Mesa Verde, and Canyon de Chelly, but the greatest development of these areas came in the 10th century, when the San Juan River and other tributaries to the Colorado River became the center of the Pueblo world. It was during this classic period of the Pueblo culture that the several-storied cliff dwellings and mesa-top pueblos of the Four Corners area were constructed. Both were designed primarily for protection from raids of nomadic tribes, such as the Utes and Apaches. This was the peak of the Pueblo civilization, and at this time it was more advanced than any Indian culture north of the Rio Grande. The cliff houses and pueblos of these peoples compare in size and construction with the fortress castles of 12th century Scandinavia and England. In addition, their pottery is a truly fine utilitarian art form. The classic Pueblo period coincides approximately with the highest development of Indian civilization in the western Hemisphere, that of the Aztecs and Incas of Central and South America.



CLIFF HOUSE

The Pueblo Indians developed a society based primarily on agriculture. The variety of crops was small, being limited to squash, maize, and beans. Unlike his contemporary in Europe or the Nile Valley, the Indian did not have the horse or oxen to aid in planting and cultivating his crops, the only domesticated creatures being the dog and turkey. Attempts of these people to domesticate the bison, if made, were a failure, just as were those of the Spanish under Oñate. In addition, fertile land was limited to the flood plains of intermittent or small streams and was subject to variable amounts of rainfall. A long period of drought in the late 13th century is thought to have forced these peoples to abandon the San Juan area and migrate to the Rio Grande, where most of the pueblos of New Mexico are now located. A few other pueblos such as Zuni, Gran Quivera, Puyé, and Pecos also were settled at this time. Most of these outlying pueblos were finally abandoned in the 19th century because of repeated raids by the Plains Indians.

The Spanish exploration and conquest of the New World began in the first half of the 16th century. The chief purpose of this conquest was the enrichment of Spain with gold, silver, and precious stones, an aim effectively carried out by Cortez in Mexico and Pizarro in Peru. Early explorations, therefore, were made into New Mexico to determine the value of the virtually unknown lands north of the Rio Grande. Following Fray Marcos de Niza's fabulous claims about the Seven Cities of Cibola (Zuni) in 1539, an expedition under the leadership of Francisco Vasquez de Coronado was sent to explore the northern territories.

Coronado conquered Hawikuh (one of the Zuni pueblos) in 1540 and explored as far east as Kansas, returning to Mexico in 1542 with a very unfavorable report.

A similar view of New Mexico was later given by Father Escobar, who accompanied Don Juan de Oñate on his trip to the Gulf of California in 1604. Escobar wrote;

"Three hundred and sixty leagues from the city of Mexico (Mexico City) toward the north pole, on the banks of a large river named the Rio del Norte (Rio Grande) because it flows toward the south, there are seven or eight provinces and nations of peoples, all of different languages. The Spaniards generally call these provinces New Mexico. They must contain thirty thousand souls or more. The country is very poor and cold, and has much snow, but is quite habitable for a Spanish colony of moderate size, provided the people have clothing to wear and that they will bring cattle from New Spain to provide food and to till the soil, for none of these are produced here, and although the cattle multiply readily, the land is too limited in resources to raise large numbers of them."

Laws enacted by Spain, shortly after Coronado's exploration of New Mexico, forbade the use of Indians as chattels and allowed only missionaries to visit remote Indian villages. Although the laws were not observed wholeheartedly and the harsh treatment of the Indians continued, the period of conquest gave way at least in spirit to one of colonization. The Spanish court naturally remained interested in anything of value that could be obtained from their possessions, but the emphasis had been shifted to the protection and livelihood of the Indians converted to Roman Catholicism. Even in New Mexico, where very little of value was found by the Spanish, they continued to support the area with a considerable amount of money and supplies "for as long as one Christian Indian remained."

In 1598, on Juan de Oñate crossed the Rio Grande near the present site of El Paso with a large party of soldiers, settlers, and missionaries, and a grant from Spain to colonize New Mexico. Having spent his own fortune to outfit the expedition, Oñate was intent on finding riches similar to those of the earlier Spanish conquistadores. He forced conversion on the Indians and used the number of converts and the necessity of bringing the Christian faith to other farflung tribes, as a basis for obtaining money and equipment to further his explorations. In his 11 years as the first governor of

New Mexico, he traveled from Kansas to the Gulf of California in this search, only to discover that the Indians of this area had not acquired the use of metals. Their pots were made of clay, and their jewelry of shells and turquoise; they apparently knew nothing of gold, silver, or copper. Oñate's harsh treatment of the Indians, coupled with a mutual dislike that existed between him and the viceroy of New Spain, led to his dismissal as governor and banishment from New Mexico in 1609.

The persecution of the Indians by the Spanish did not end, however, with the dismissal of Oñate. In 1680, the Pueblo Indians revolted, driving all the Spanish and most of the converted Indians from almost all of New Mexico. The Spanish returned in 1692 under Don Diego de Vargas, and, except for a minor rebellion 4 years later, the Pueblos were submissive during the remaining period of Spanish rule.

The Spanish colonization of New Mexico lasted over 200 years and left a cultural background that is still prevalent in many areas of the State today. Their colonization was, however, mostly centered around the Rio Grande valley, and little change is noted in the Zuni Mountains area. The Zuni Indians strongly resisted the conversion attempts of the Spanish missionaries, and, being rather far removed from the Spanish settlements, were infrequently subjected to the harshness of Spanish rule. The Spanish made no permanent settlements in the area, but on several occasions used the trail past El Morro, where they left a record of their discoveries and conquests.

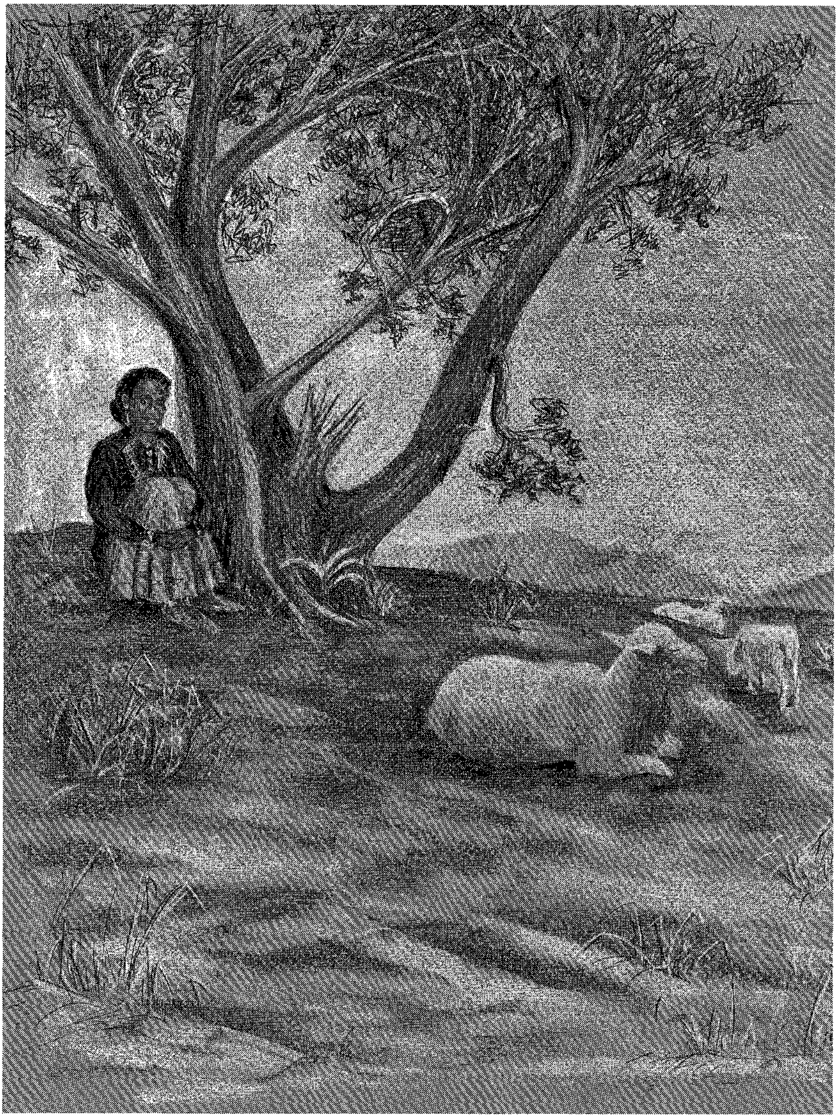
Perhaps the most significant change wrought in Indian culture was in the way of life of the nomadic tribes. The introduction of sheep and cattle made these Indians less dependent on the hunt for food and clothing. The horse added a new dimension to the terror the Apache had already instilled by raiding his Pueblo and Spanish neighbors. Not until 1886 was the Apache subdued in the United States, and in Mexico the last raiding party was caught in the 1920's.

In addition to domesticated animals, the Spanish brought a greater variety of crops, improved methods of irrigation, and a new religion. What the Spanish gave to the Indian was superimposed on his ancient beliefs and customs, and is today curiously Indian in nature. The Navajos and their sheep, the Pueblos and their adornment of the Christian religion, are synonymous with the culture of our southwestern Indians.

North of the Rio Grande, the territories owned by Spain became part of the Republic of Mexico following the Mexican revolution of 1812. In 1836, following the Texas war with Mexico, most of eastern New Mexico became a part of Texas, and in 1846, one year after Texas statehood, the Mexican War gave control of the New Mexico Territory to the United States. In 1850, an Act of Congress established the present eastern boundary of New Mexico, and in 1853, the Gadsden Purchase enlarged and fixed the southern boundary. After the Gadsden Purchase, the territory of New Mexico included the present states of Arizona and New Mexico, plus a small portion of southern Colorado. The present boundaries of the State were established in 1863 when the Territories of Arizona and Colorado were created. Statehood came to New Mexico in 1912. During these changes of government, the Pueblo lands, as set out by the Spanish grants, were ratified by Mexico and, following American occupation in 1848, by the Treaty of Guadalupe Hidalgo. Since that time, additions to the Pueblos have been made through purchase and by Federal grants.

Settlement of the Zuni Mountains area by Americans began shortly after the defeat of the Navajos by troops under the command of Kit Carson at Canyon de Chelly. The town of San Rafael, settled in 1869 by Spanish Americans, is on the site of old Fort Wingate, from which Carson conducted his campaign. During the early 1870's the Mormon settlement of the Little Colorado and San Juan drainage areas began. In 1876, Mormon missionary farmers established the town of San Lorenzo, and the following year settled at Savoia. In 1885, the Mormons built the community of Ramah, where there was a more favorable location for a dam. The Atlantic and Pacific Railroad (Santa Fe Railway) was completed to Los Alamitos, the present site of Grants, in 1882. The city of Gallup, being in 1880 a stop on the Westward Overland Stage, was also settled about this time. Soon afterward, because of the large coal deposits nearby, it became an important point on the railroad.

The settlement of this area by people other than Indians is comparatively recent, owing, in part, to the late subdual of the Navajos. Settlers were attracted by the advent of the railroad, which supplied an economic outlet for the resources of the area. For many years, coal mining, farming, and ranching were the important factors in the economy of the area. Although still very important to the basic economy, they have been overshadowed by the discovery of large deposits of uranium ore. Also of prime importance is the rapid economic recovery of the Zuni and Navajo Indians, who today, as in the past, play a significant role in the development of the Zuni country.



Road Logs

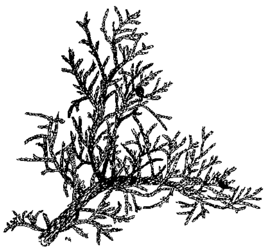
I. THE OLDEST AND YOUNGEST ROCKS

(24.4 miles)

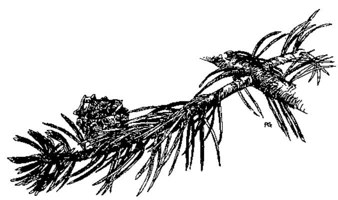
The altitude gradually increases from 6,460 feet at Grants, to almost 7,600 feet at the end of this segment of the trip.

The route heads south along the east flank of the Zuni Mountains for a distance of about 14 miles, then west across the southeastern tip of the range.

Piñon and juniper trees of the Upper Sonoran life zone dot the east slope of the mountains, giving way slowly in the higher elevations to the Transition zone trees of ponderosa pine and Gambel's oak.



JUNIPER



PINON

Rocks of Precambrian, Permian, Triassic, and Recent age will be seen along the highway. To the east, across the lava-floored San Rafael Valley, Cretaceous rocks capped by Tertiary lava flows form the bulk of Mesa Negra and Cebollita Mesa. At the base of the mesas, the massive, light-colored Jurassic Zuni Sandstone is exposed.

Excellent views of the high volcanic cone of Mount Taylor, northeast of Grants, are obtainable, weather permitting, until blocked by the Zuni Mountains.

The major economic activities of the area are ranching, lumbering, agriculture, and mining.

The discovery of uranium in 1950 at Haystack Butte just west of Grants, and the subsequent mining and processing of this ore has been responsible for the recent growth of the town from a little more than 2,000 inhabitants in 1950 to more than 11,000 today. The source for the uranium deposits is believed to have been mineralized waters associated with local volcanic activity. The uranium, in solution, was carried through permeable beds of sandstone and limestone until it reached favorable areas where chemical changes in the solutions caused precipitation of the uranium minerals. Circulating ground waters further concentrated the uranium into deposits of economic value. The major deposits of uranium in the United States are located in Wyoming, Colorado, Utah, Arizona, and New Mexico. New Mexico leads in the production and known reserves of this valuable metal.

In addition to uranium, perlite is mined northeast of Grants and processed at a mill on the east side of town. Large deposits of gypsum occur east of Grants along I-40, but have not been developed.

There are many interesting areas to visit within easy driving distance of Grants. Some of these are the uranium mines at Ambrosia Lake and Jackpile, Chaco Canyon National Monument, Bluewater Lake State Park, Mount Taylor, and the Acoma and Laguna Indian Reservations. Particulars regarding these points of interest can be obtained at the Grants Chamber of Commerce.

0.0 Junction U.S. Highway 66 and N. Mex. 53 on west side of Grants. Drive south on N. Mex. 53 toward San Rafael and El Morro. Railroad crossing. Main line of Santa Fe Railway.

0.2

0.2 Bridge over Bluewater Creek, a tributary of Rio San Jose. This is part of the Rio Grande drainage system emptying into the Gulf of Mexico.

Just ahead the road crosses the edge of a lava flow. This and similar flows floor the broad valley south of Grants. The most recent flow parallels the east edge of the valley near the base of Mesa Negra and Cebollita Mesa. Some of the vents from which the lava poured will be seen near the Ice Cave. These are the youngest rocks in the area; some probably not much over 1,000 years old. To the right the high mesa north of U.S. Highway 66 is capped by an older lava flow. Lava, being fluid, flows out into valleys that exist at the time of the eruption. When the lava capping the mesa to the north was extruded the land surface in this area was about 500 feet higher. It subsequently was eroded to its present level prior to the eruption of the flows along N. Mex. 53. The jumbled mass of black rock ahead to the left and right is part of this young flow.

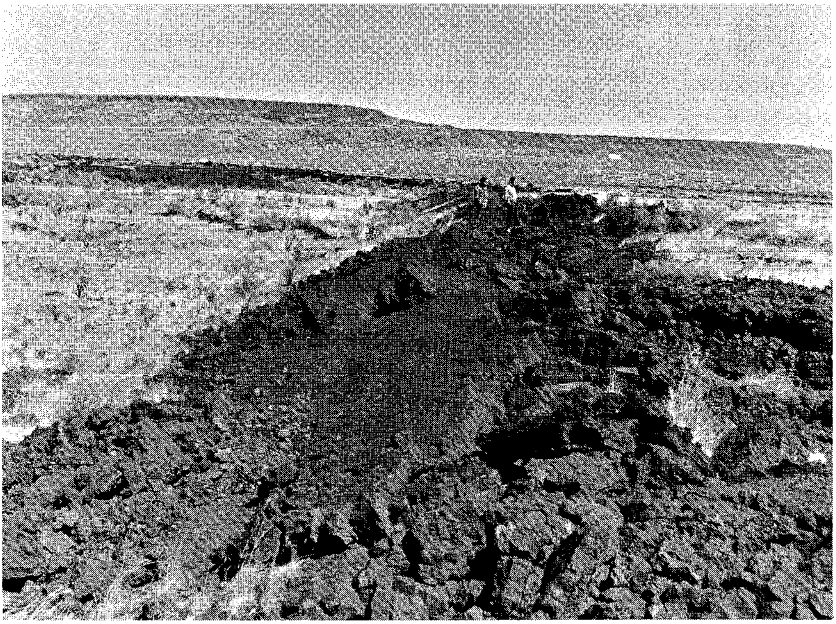
0.3

0.5 Junction with Zuni Canyon road. This road rejoins N. Mex. 53 a short distance west of the Ice Cave. A lumber company constructed a narrow gauge railroad up Zuni Canyon in 1925; the grade and some sections of track can still be seen.

The long, narrow mounds seen from the road are called pressure ridges. They are believed to have been formed by obstructions in the path of the lava flow. Features of lava flows will be discussed more fully in the Ice Caves area.

1.8

2.3 Roadcuts here and ahead are in sandstone and limestone of the San Andres Formation. These deposits were laid down in a sea that covered the Zuni Mountains area during part of Permian time. The



PRESSURE RIDGE SOUTH OF GRANTS

farthest advance of this sea in western New Mexico was just north of the present Zuni Mountains. Following the deposition of the San Andres Limestone, the sea retreated from the area south of U.S. Highway 66 until Upper Cretaceous time, a period of about 100 million years.

0.7

3.0 San Rafael (altitude 6,462 feet; population about 2,000). San Rafael occupies the site of Old Fort Wingate, which was abandoned in 1869 and moved to Gallup. The town was settled by Spanish-Americans invited here by the commanding officer of the fort. Old Fort Wingate was the headquarters of Kit Carson during his campaign against the Navajos at Canyon de Chelly.

After leaving San Rafael, the even scarp ahead on the right represents a fault or break in the Earth's surface. The rocks on the right (San Andres Limestone) have been pushed up several hundred feet along this break, in relation to the Triassic rocks that underlie the valley.

The cultivated area (La Vega, the meadow) skirted by the road south of San Rafael has an interesting and recent geologic history. Before the lava filled the broad valley to the east, a tributary of the Rio San Jose occupied the valley. Streams flowing off the east slope of the Zuni Mountains emptied into this tributary and built up a broad fan along the base of the mountains. The highway is built on this fan. Lava coming from vents to the south filled most of the valley, blocking the streams from the mountains. With no outlet for drainage, an intermittent lake was formed between the eastward-sloping fan and the lava. Filling in of the lake bed by fine sediments finally caused the lake to overflow at a low spot in the lava east of San Rafael. This outlet joins the Rio San Jose about 2 miles east of Grants.

1.6

4.6 Cattle guard.

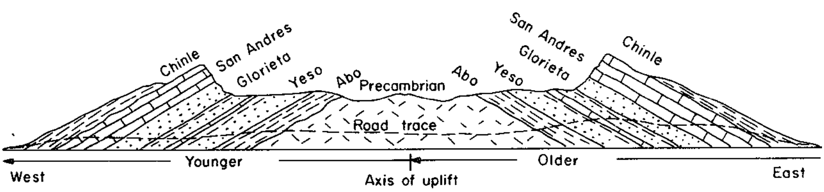
3.8

8.4 Cattle guard. In the hills ahead to the right, with sparse cover of juniper trees, the lower gray slopes are part of the San Andres Lime-stone. Above this at the break in slope are red-colored beds of the Triassic Chinle Formation. This unit consists of shales, conglomerates, and sandstones colored red by small amounts of iron oxide. The gravels and sands were deposited by meandering streams that flowed north and west from highlands to the south. Mountains also were present in southern Colorado during Triassic time, but most of northern New Mexico and Arizona was a broad, almost flat plain. During the earlier parts of Triassic time there were dense stands of conifers in the southwestern United States. As you continue you will see more exposures of red Triassic rocks, particularly in the hills to the left of the road. Notice the red color of the soils. These soils owe their color to alluvium derived from the Triassic rocks.

Good view of Mount Taylor to the north.

6.4

14.8 Curve to right at crest of hill. Yeso limestones and sandstones in ridge on right and in valley ahead. The dip of the rocks here is to the east, so in a geologic sense we descend through older and older rocks as we drive from east to west. Farther ahead, after we cross the axis of the Zuni uplift, the rocks dip in a westerly direction and we will go back through the same section over younger and younger rocks. The following sketch illustrates this point.



0.9

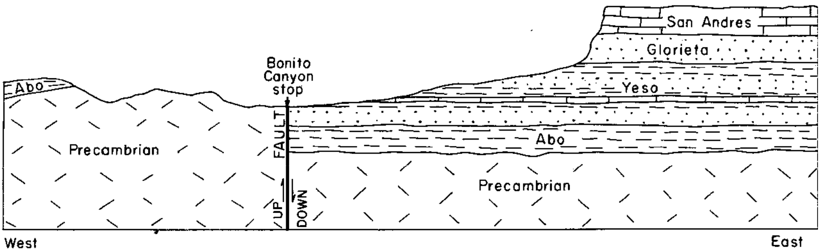
15.7 Cattle guard. Outcrops of basaltic lava on right. In part, the lava has been covered in this area by material washed down from the mountains.

0.4

16.1 Outcrops of Yeso limestone in gully on right. The limestone is made up of marine fossils, particularly small well-preserved snail shells that weather out on the surface of the bedding planes.

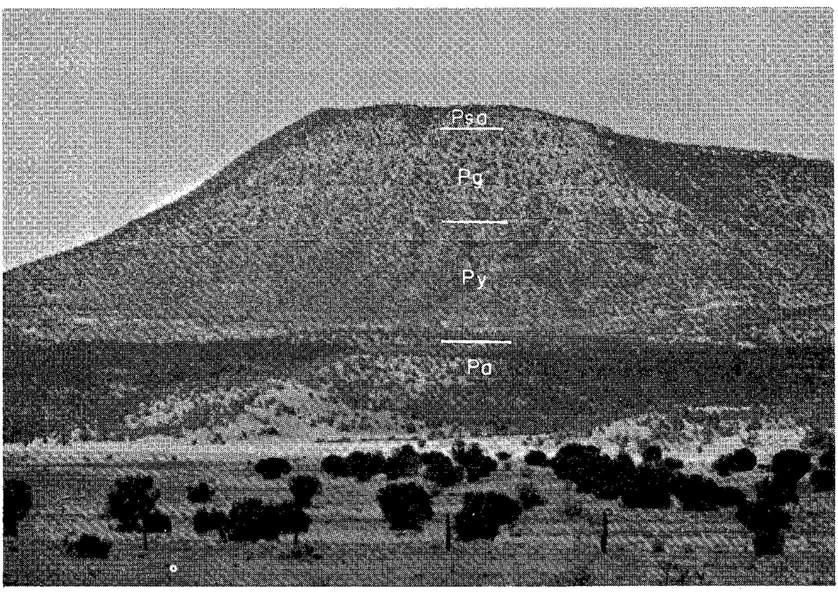
0.7

16.8 Junction with Bonita Canyon road on right. STOP for view of Permian rocks. At this point we are nearly on a fault that brings the ancient Precambrian granites to the west (hills ahead) up against the Yeso Formation on the east (hills on right). Because of the variation



in the amount of the vertical displacement along this fault the oldest Permian rocks, the Abo Formation, are not exposed at the surface near this stop as they are to the north. The sketch above shows why this happens.

The sequence of Permian rocks present in the Zuni Mountains is exposed in the bare slope of the highest hill, Gallo (rooster) Peak, to



GALLO PEAK

the north. The history of this area during Permian time can be interpreted from the rocks exposed in this hill. Early deposits represented by sandstones and shales of the Abo Formation (Pa) and the lower part of the Yeso Formation (Py) were laid down by streams on a relatively flat flood plain. Upper Yeso beds were deposited under both marine and continental conditions with the shoreline fluctuating back and forth across the area. Along with sandstone, beds of gypsum and limestone are present in this interval. The final advance of the Permian sea was preceded by beach and bar deposits, and, farther inland, by dune sands, all of the Glorieta Sandstone (Pg). As the land continued to subside and the sea advanced, limestone was deposited over the beach sands to form the San Andres Limestone (Psa). Deposition of the limestone ceased as the sea retreated from the area in middle Permian time. By looking at other outcrops of these rocks in widely scattered areas, it can be seen that the sea advanced from the south and that the sands and muds were derived from uplifted areas to the north. It also can be determined that the Permian sea continued to cover southeastern New Mexico for a considerable length of time, about 20 million years, following the deposition of the San Andres Limestone in Northern New Mexico.

2.3

19.1 Cattle guard. Cibola National Forest. Hills to right are Precambrian granites; to left, Permian Abo, Yeso, and Glorieta Formations. The hills of Permian rocks are completely surrounded by lava, a feature called steptoes by geologists. The local geographic name applied to these hills is Little Hole-In-The-Wall.

0.3

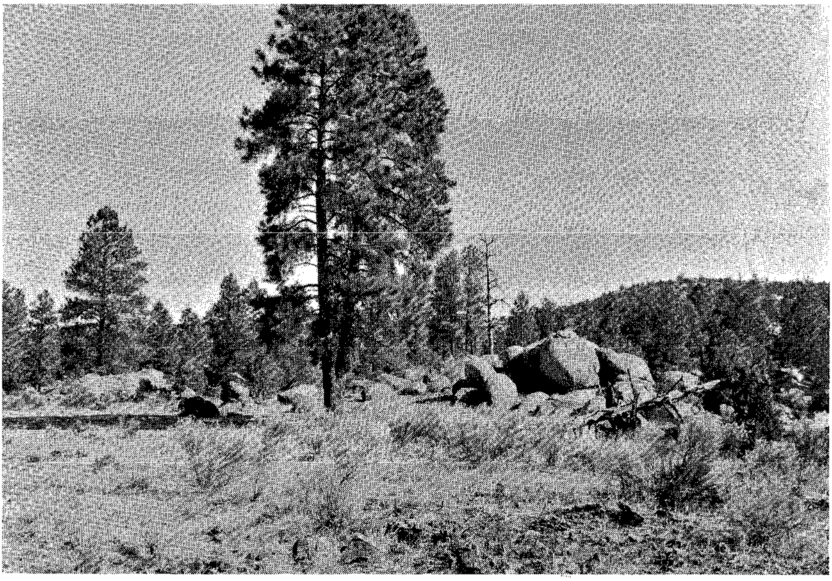
19.4 Curve to right. Outcrops of Precambrian rocks on both sides of road. The axis of the Zuni Mountains uplift is to the northwest from this vicinity. Along this axis, which represents the greatest amount of uplift in the range, the old Precambrian rocks have been exposed by erosion as far northwest as McGaffey, a distance of some 30 miles. Sedimentary rocks of Paleozoic and Mesozoic age were originally deposited over the present area of the mountains in beds that were almost horizontal in their attitude. They now slope away from this axis of uplift in both directions, and have been removed by erosion from the axis.

0.6

20.0 Road on right leads to several fluorspar mines. The fluorspar occurs in veins in broken zones in Precambrian granite. Considerable tonnage was mined during World War II and the Korean War, but little has been shipped since. Most of the ore was milled in Grants and Los Lunas. The processed fluorspar was used in aviation gasoline and in the manufacture of abrasive soap.

2.0

22.0 The granite exposed on the right weathers in place into boulder-like



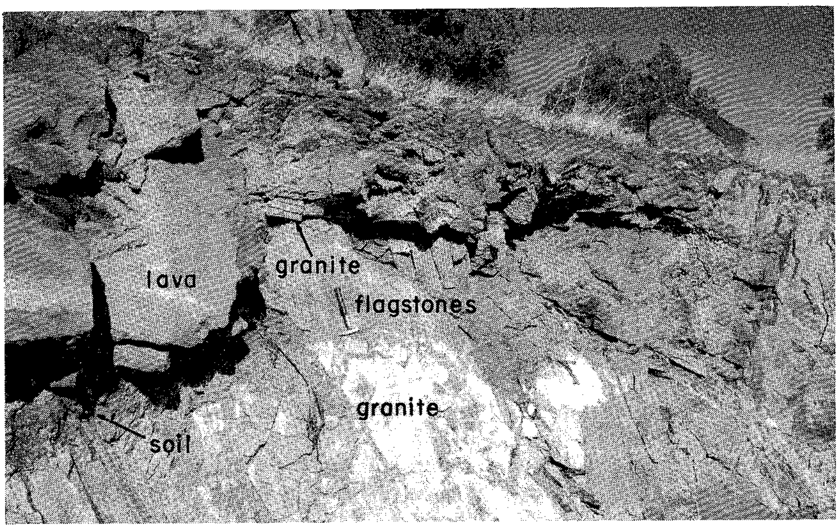
BOULDERS OF DECOMPOSITION IN GRANITE

forms. This type of erosion is common in hard, massive rocks of uniform composition. It is caused by spalling off of the surface of the rock primarily by chemical decomposition aided by freezing and thawing. The size of the "boulders" is determined by the spacing of fractures in the rock.

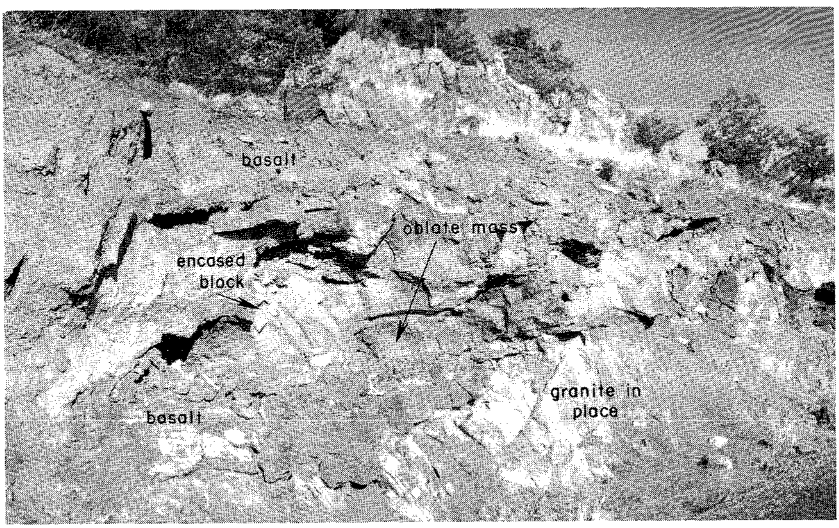
1.3

23.3 STOP at east end of roadcut, pulling off the highway as far as possible. Although not very impressive from an engineering standpoint the geologic features exposed in this roadcut are quite interesting. The parts of the cut to be examined are on the north side of the road and can be found by referring to the photographs that follow. At the east end there are exposures of black, vesicular basaltic lava. The direction that the lava flowed was from west to east. If you watch the bottom of the cut as you walk along you will see a red- to pink-colored rock. This rock is similar to the granites just seen along the road except that it is distinctly banded. The banding or foliation of the rock is caused by concentrations of various mineral grains, and shows up primarily because of the colors of the different minerals. The contact between the black basalt and the red granite represents over 1 billion years of Earth history for which there is no record at this spot. Some of this record, as we have seen, is preserved in other parts of the Zuni Mountains. Elsewhere in New Mexico we have an almost complete rock record of this billion years of geologic time.

In the first photograph (both photographs were taken looking east) there is a ridge of granite over which the basalt flowed. To the left, and preserved beneath the basalt, is a red rocky soil developed on the granite. Note that the banding in the granite is almost perpendicular. At the top of the granite directly overlain by the basalt there are a few small flagstone-like pieces of_ granite. In these the banding or foliation is about parallel to the road. These were loose pieces of granite lying on top of the ridge when the flow came along. The fact that they were not pushed off by the flow tells us something of the way lava flows move at a point some distance from the vent.



FLAGSTONE



ENCASED GRANITE

Forward movement is at a very slow rate; the surface and base of the lava "freezes" as soon as it comes in contact with the cooler air and underlying soil and rock. The still semiviscous center pushes with a slight pressure causing the front to break away. An eyewitness to the eruption of Paricutin volcano reported that the sound of the lava as it broke away from the front of the flow was like that of thousands of glass wind chimes. After the front breaks off, the lava moves ahead an inch or so before again "freezing." In a sense it spreads out over the land like "Brand A" peanut butter, leaving the underlying rocks and soil undisturbed. The upper surface may split and be carried along a short distance, but normally the movement is restricted to the interior and front of the flow. It seems incredible, but it is actually possible to step up and walk on the surface of an active flow. The temperature is not overly uncomfortable even though the lava is still red hot just a few inches below.

Above this ridge and the next, you will notice that the surface of the flow buckled upward slightly in passing over the ridge. Pressure ridges probably form in this manner.

About 60 feet farther west (second photograph) there is a large block of granite that appears to be encased in basalt. An alternative explanation is that the basalt is welded to the granite on the side facing the road and does not underlie this isolated block. The second explanation seems to be the best because the banding in the granite above the basalt has the same attitude as the obviously in-place granite beneath the basalt. This suggests that the two apparently separate pieces of granite are continuous behind the basalt. This is a minor geologic problem that could be solved in about 5 minutes with a double jack but it seems best to leave it as it is, to point out the variables that must be considered when attempting to explain geologic phenomena.

On the right side of the ridge at the base of the flow there is an oblate-shaped mass of lava. These are formed on the downstream side of obstructions. Usually only a few inches at the base of the flow "freezes." Here the viscous lava dropped over the obstruction, filling part of the downstream side with a thicker mass of stationary flow material. The interior of this mass cooled much more slowly, allowing large gas bubbles to form before the rock became completely solid. Holes at the edges of these masses are much smaller.

1.1

24.4 Cattle guard. The lava on the left looks as fresh as it did when it first cascaded down a canyon cut in the ridge ahead and spread out on the valley floor. The ridge is held up by westerly dipping beds of Permian age covered for the most part by loose cinders blown out of the numerous vents in the immediate vicinity.

END OF TRIP 1

2. FIRE AND ICE
(5.1 miles)

The altitude at the beginning of this section is just below 7,600 feet. The highest point reached is 7,882 feet, at the Continental Divide. The direction is to the west over the southeastern tip of the Zuni Mountains.

This part of the trip continues in the Transition life zone. Ponderosa pine and Gambel's oak are the most common trees. Ponderosa pine, also known as western yellow pine, is the most valuable timber-producing tree in the southwestern United States. It is second to the Douglas fir in total stand among all the different tree species of the United States. The mature tree develops large, flat, red plates.

PONDEROSA PINE AND GAMBEL'S OAK

Recent lava flows and cinder cones dominate the scene, although there are some exposures of sandstones and limestones of Permian age. Here, some thousand years ago, there were violent eruptions of cinders that rapidly built the steep-sided cones, while from the flank and base of these cones lava flowed down the slopes. The volcanic activity has long since subsided, and incongruously, in a lava cave there is perpetual ice!

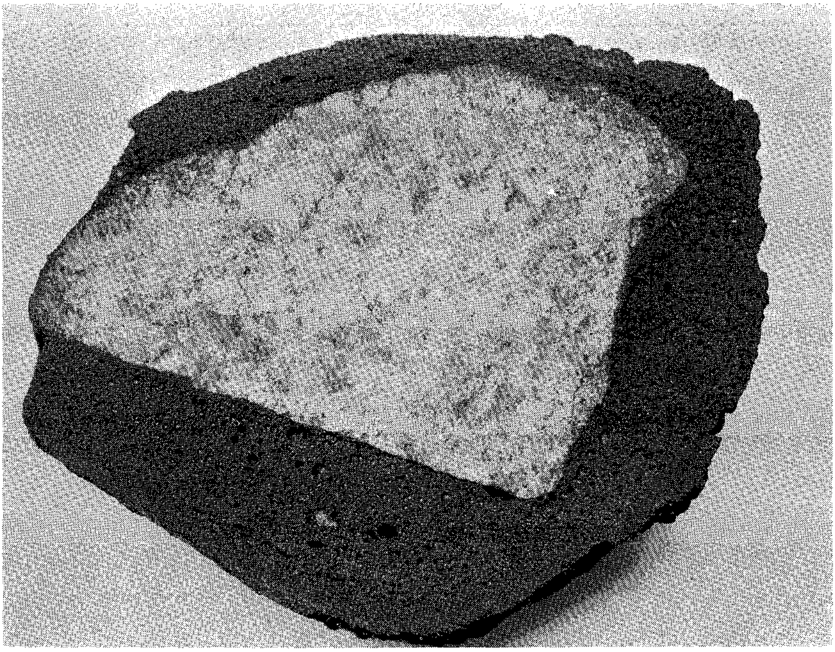
0.0 Cattle guard.

0.7

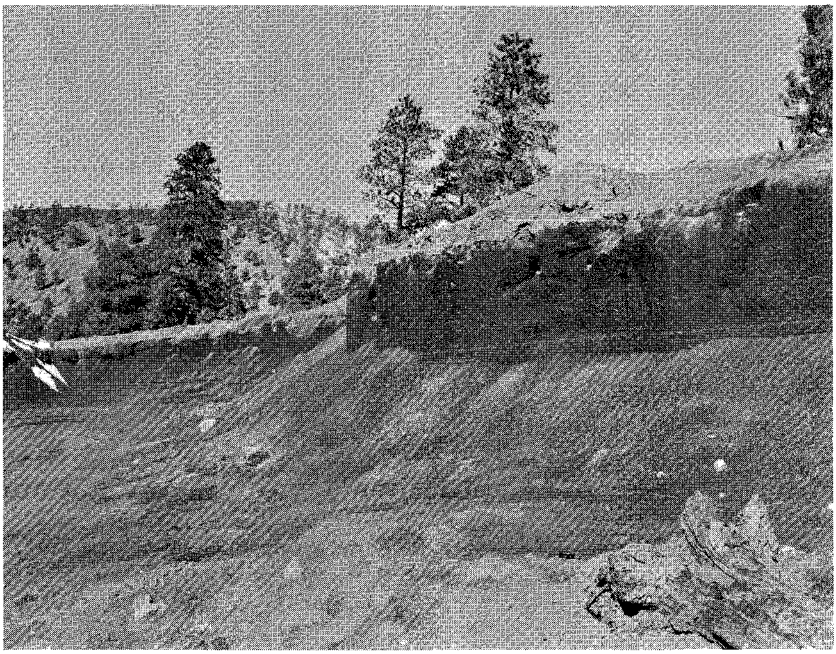
0.7 Road on right to Paxton Springs. Begin ascent of ridge that forms the southwest flank of the Zuni Mountains. After the first big curve, if you look back to the left, there is an excellent view of the fresh lava flow just passed. In road cuts near the top of the hill red sandstones of the Permian Yeso Formation are exposed beneath the black volcanic cinders.

0.9

1.6 Pit on right is used for road material. This is a good place to stop and examine volcanic cinders. These cinders are of basaltic composition, that is, compared with other volcanic rocks they are low in silica and



BOMB WITH CORE OF OLIVINE GABBRO



SOIL ZONE ON BASALTIC CINDERS

high in such elements as iron and magnesium. This is the reason for the black or dark-red color of this type of rock. The source for the cinders is Bandera (flag) Crater to the west on the other side of the road. The cinders are mostly small, but in some cases fragments of considerable size (called bombs and blocks) were blown out of the vent. Naturally, most of these larger fragments fell back on the cone. Some of the fragments contain pieces of other rock types that were torn from the throat of the volcano and encased in lava as it was blown into the air.

Volcanic cones composed of loose cinders, like the cones in this area, are easily eroded, supplying evidence as to the recency of the eruptions. A striking yellow soil zone is developed on the cinders and is very well exposed in the pit.

0.1

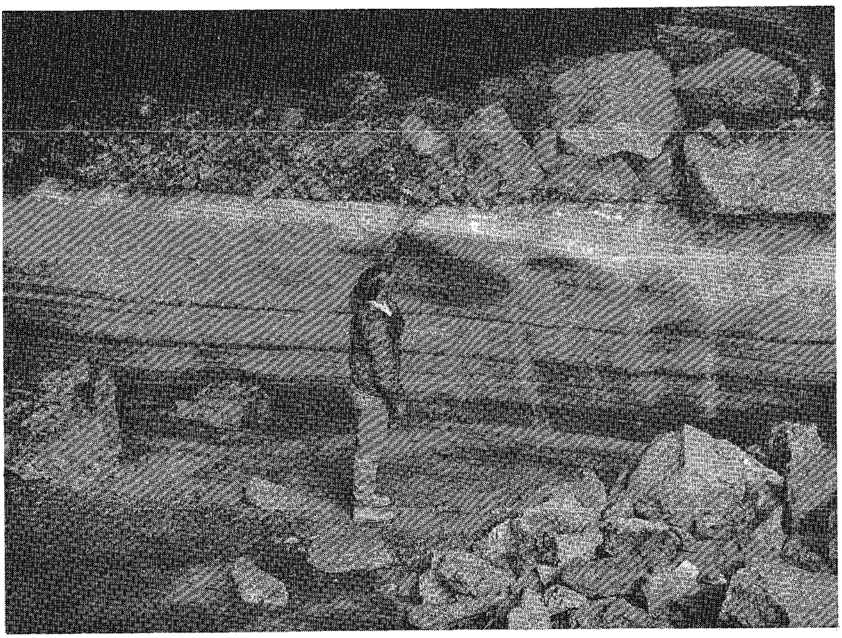
1.7 Junction with Ice Cave road; turn left.

0.7

2.4 Parking area. The Ice Cave and the surrounding area is privately owned. The trail to the cave begins just south of the store and a branch trail leads to the breach on the southwest side of B:andera Crater. At a slow pace it takes less than two hours to walk both trails. Grades are gentle and special shoes are not needed.

Several factors account for the preservation of the ice during the summer months. Normally in large caverns, such as Carlsbad, where there is a slow circulation of air, the temperature of the cave varies only slightly throughout the year and assumes the average yearly temperature of the outside area. The Ice Cave, which is quite small, maintains its low temperature because of the low average yearly temperature at this altitude and latitude, the character and direction of the opening, the shape of the floor of the cave at the opening, and the direction of the prevailing winds. These factors help to prevent the circulation of air, and cold air (heavier than warm air) remains in the cave. Thus, during the winter months, water freezes in the cave, and the ice formed maintains the below-freezing temperature during the summer months. Although the cave opening is to the south, the size, angle, and direction of the opening are such that sunlight reaches the base of the ice wall for only a few minutes a day from about the 16th through the 26th of December. The maximum distance sunlight reaches in the cave limits the growth of the ice wall toward the opening of the cave. Sunlight also is responsible for the recession at the base of the wall. Surface heat above the cave generated during the summer does not affect the temperature of the interior of the cave because of the excellent insulating properties of the lava.

The blue-green color of the ice is caused by algae and the laminations probably represent seasonal periods of freezing and thawing, similar in many respects to tree rings. Inspection of the ice face shows that pieces of basalt are imbedded in the ice at several places. These either fell onto the surface of the ice and were later covered by new ice or they have melted down through the ice from above. If the laminations above these fragments are examined closely it can be seen that they have not been disturbed as they would have been if the basalt fragments had sunk through the ice. The ice is quite transparent and the laminations can be followed several inches back from the face. It must be assumed, therefore, that the pieces fell from the ceiling at a time when the upper surface of the ice was at a lower level. At the top there is a thick layer of fallen basalt fragments. The contact between this layer and the ice is very sharp, indicating the material fell from the roof in a short period of time, perhaps as one rock fall. These basalt fragments are cemented by ice showing that upward growth is continuing. Eventually this layer will be incorporated as a band within the ice, provided that conditions favorable for growth are maintained. The age of the oldest ice in the cave is not known. It certainly postdates the basalt and could have begun to form sometime shortly after eruptions ceased, from 1,000 to more than 5,000 years ago. The cave is a lava tube or tunnel. As noted previously, lava crusts rapidly on the surface while below the crust molten lava continues to flow. Often the lava beneath the crust will completely drain out leaving a tunnel behind. The roof of the tunnel generally lacks sufficient support and eventually collapses in several places, forming openings for the cave below. Tunnels of this type are

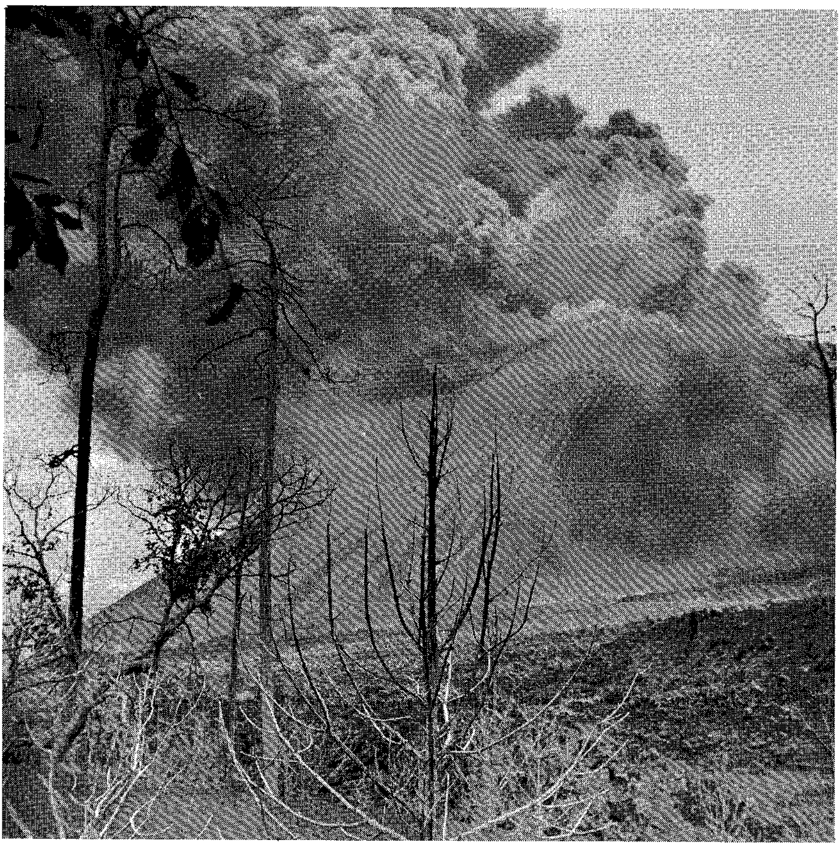


ROCK FALL CONTACT IN ICE CAVE

common in this area and many others also have the necessary conditions for preserving ice.

After visiting the cave, walk back along the trail about 100 yards to the junction on the left with the trail to Bandera Crater. With the exception of Hawaii, where volcanic activity is in progress, the volcanic features seen along this trail cannot be surpassed anywhere in the United States. In particular, the view into the crater at the end of the trail should not be missed. The total distance to the crater and return to the parking lot is less than 1.5 miles. Features of interest along the trail are not marked. Some of these are shown in the following photographs, and the reader should have little trouble orienting himself in relation to the photographs.

Paricutin volcano about 200 miles west of Mexico City is a recent example of the type of volcanic eruption that formed Bandera Crater. Geologists observed the eruptions at Paricutin from a station less than a mile from the crater. These observations covered the entire



PARICUTIN VOLCANO IN MEXICO DURING ERUPTION IN 1952
courtesy of Max E. Willard

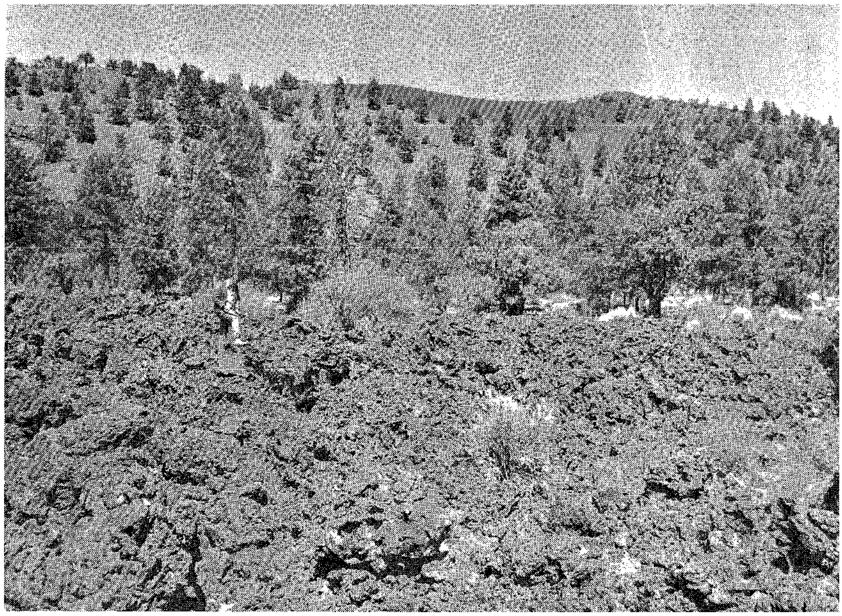
active cycle of the volcano from its birth on February 20, 1943 to the cessation of eruptions in 1952. The hole in the ground from which the volcanic eruption took place reportedly had been known for some 50 years prior to the beginning of the eruption. One local resident stated that as a child she played near the hole and heard noises like falling rock, and that the air in the hole was warm. For about two weeks before the eruption there was a series of earthquakes in the area culminating with over 300 shocks felt on February 19. At 4:00 p.m. on the twentieth the farmer who owned the small cornfield where the hole was located heard a noise like thunder. A crack opened on both sides of the hole and the ground swelled several feet. Immediately ash, smoke, and sulfurous fumes issued from the hole, accompanied by a loud hissing noise. By midnight molten rock was being thrown into the air and flashes of lightning were observed in the column of smoke and ash. The rate of growth was truly remarkable. By 8:00 a.m. the second day, the cone was 30 feet high; by mid-day it was more than 150 feet; and by the end of the week the top of the cone was 450 feet above the former land surface. Cone building was the dominant process for the first year, reaching 1,000 feet during this period. When eruptions ceased in 1952, the height was 1,350 feet.

The first lava flow occurred on the second day and flows became the primary eruptive feature after the first year. The rate of flow of the lava diminishes rapidly away from the crater. Measurements made at Paricutin were 50 feet per minute where it issued from cracks on the flanks of the crater to 20 feet per hour at the village of Paricutin, about 1.5 miles away. The longest flow traveled a distance of six miles.

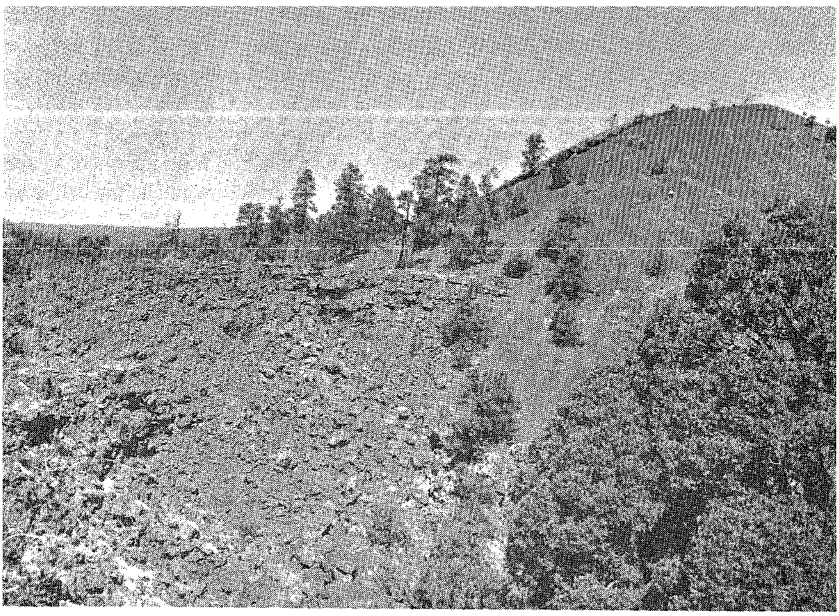
Bandera rises about 450 feet above the surrounding flows; Paricutin reached 540 feet above its flows. Based on the final height of Paricutin above the original land surface (1,350 feet) and the erosion of Bandera Crater that must amount to several tens of feet, it seems probable that Bandera rises at least 1,000 feet above the former land surface. North of the crater Permian rocks are exposed in road cuts along N. Mex. 53 and other exposures are present to the south. Be-cause of this, it appears that Bandera is only on the order of 400 feet above the former land surface, but the eruption took place in a valley that existed between these ridges of Permian rocks.

Bandera is only one of dozens of volcanoes in the immediate area. The tree-covered mountain about 1 mile to the southwest is another. The forest and degree of dissection of the cone testifies to the fact that it is older than Bandera. Other volcanoes in the area are younger.

The first thing that strikes a person walking along the trail is the jumbled character of the flows. As noted previously, the surface of a lava flow crusts over rapidly. This crust may then be broken up by drag from the underlying, still molten lava. Also, parts of the crater may collapse, adding material to the top of the flow. Great blocks of



AA LAVA BEHIND STORE AT ICE CAVES

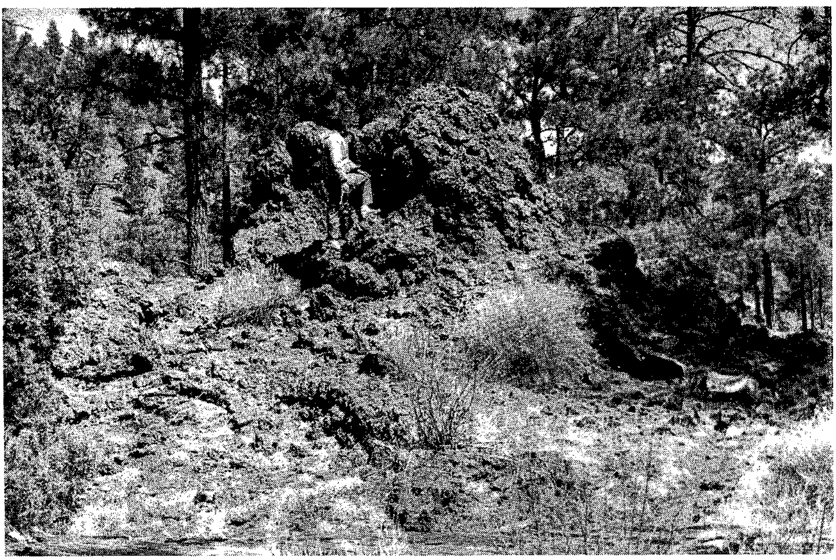


LOOKING NORTH ACROSS AA CHANNEL NEAR BREACH IN CRATER. NOTE CONTACT BETWEEN LAVA AND FINER MATERIAL OF THE CINDER CONE "frozen" lava are rafted along on top of the fluid lava piling up against obstructions like the debris in a river at flood stage. This type of flow is called "aa" (pronounced ahah) from similar flows in Hawaii.

Most of the lava flows issue from cracks that develop near the base or on the side of the cone. The point where the lava breaks out is called the boca (mouth). This point moves from place to place around the cone during the eruptive cycle of the volcano. Because the cone is composed of loose cinders and is structurally weak, it is rare for the lava to flow over the rim of the crater. The molten basalt does, however, rise up in the crater at times and a remnant of lava can be seen within Bandera Crater high on the northwest side.

Smaller eruptions of lava also may take place some distance from the main vent. These may build subsidiary cinder cones or they may take the form of a lava fountain, leaving behind a spatter cone. An excellent example of a spatter cone will be seen along the trail back to the store. Many of the volcanoes in this area have subsidiary cinder cones.

Near the cone the trail follows along the south side of a narrow, deep canyon. This canyon heads at the breach in the cone. These features are known as "aa" channels. They actually are depressions ending downstream at an abrupt wall of lava. The channel was formerly a lava river that issued from a boca located at the breach in the cone. When this particular eruption ceased the lava drained away through tunnels leaving behind the open channel. At the head of the channel, on both sides of the breach, there is a sharp contact between the flow material and the cinders that make up the cone.



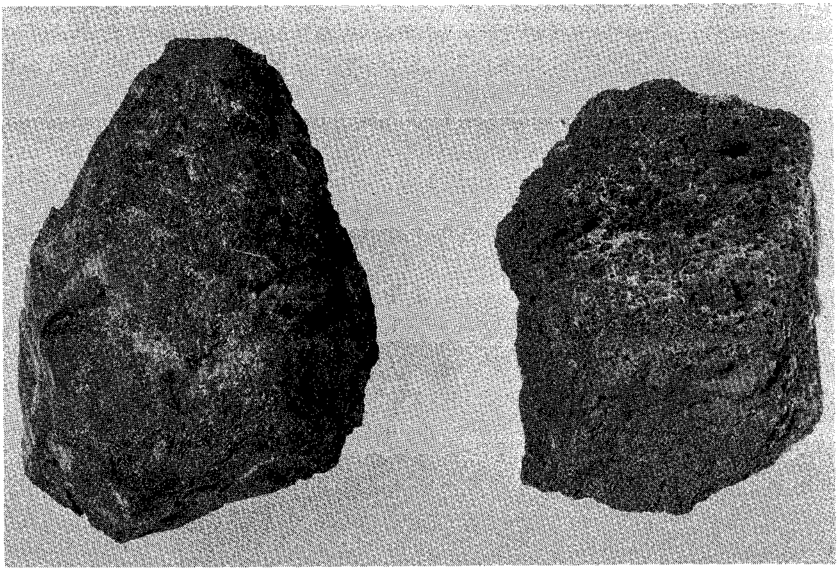
SPATTER CONE

At the end of the trail the visitor can look down into the crater. Naturally a great deal of material has fallen in from the sides, partially filling in the bottom. This has happened at Paricutin since activity ceased. Below the debris there is a core of solid lava that welled up in the throat of the volcano. Erosion eventually will remove all except this core of hard resistant lava. It will be left behind to stand up above the surrounding surface like a giant spine. Cabezon Peak and Shiprock in New Mexico are famous examples of this type of feature called volcanic necks by geologists.

The lookout is almost exactly at the halfway point of the crater. It is 320 feet to the highest point on the rim and about the same to the bottom, making the present maximum depth of the crater 640 feet. Taking into account the erosion of the crater rim and filling in of the crater floor, we can again indirectly arrive at a possible height of 1,000 feet for the crater above the original land surface.

BANDERA CRATER

Note the size and shape of some of the fragments that make up the cone. Large solid angular pieces called blocks may be blown thousands of feet into the air, breaking up when they land. When semi-molten material is blown out the fragments become spindle shaped while traveling through the air. When landing, and if still somewhat plastic, these pieces may be bent into various shapes. Rounded pieces such as these are called bombs. The finer ash from eruptions may be carried by the wind for great distances. Mexico City, almost 200 miles away, experienced several days of ash fall from Paricutin, and more violent eruptions may spread ash over thousands of square miles. The volcano Krakatoa, located on a small island between Java and Sumatra, erupted in 1833. Ash from this eruption, one of the greatest of all time, was carried several times around the world. The amount of sunlight reaching the surface of the earth in the year following the eruption was only 87 percent of normal. Spectacular sunrises and sunsets caused by the reflection of the sun's rays off dust particles were common in many parts of the world. Ocean waves created by the first violent explosion reached the English Channel some 30 hours after the eruption.



VOLCANIC BOMB ON LEFT; BLOCK ON RIGHT

Paricutin, like Bandera, was not a large volcano, yet the average amount of solid material erupted from Paricutin over its nine-year history amounted to more than 1,000,000 tons per day. The total weight of gas given off probably exceeded that of the solids.

After completing the tour return to the N. Mex. 53 junction.

0.7

3.1 Junction N. Mex. 53. Turn left.

0.6

3.7 Continental Divide (altitude 7,882 feet). The road now descends from the ridge that forms the southwest side of the Zuni Mountains to a valley carved in the soft sandstones and shales of the Triassic Chinle Formation. The floor of this valley is partially covered by lava flows. The exposures in the roadcut are part of the Permian Yeso Formation. The limestone has many solution channels filled in with sand deposited after the limestone.

Drainage west of the divide is into the Rio Pescado, part of the Colorado River system emptying into the Gulf of California.

The next roadcut ahead just before the cattle guard also is of Yeso limestone. Fossil brachiopods, snails, and clams can be collected from this limestone.

1.4

5.1 Junction on right with road to Oso (Bear) Ridge Lookout (3 miles) and McGaffey (53 miles).

END OF TRIP 2

3. EL MORRO AND THE ZUNI SANDSTONE

(31.9 miles)

The route continues west cutting diagonally across a broad valley carved in the soft Triassic rocks and subsequently partially filled in by lava flows. To the north the southward-sloping flank of the Zuni Mountains is sup-ported by the resistant Permian San Andres Limestone. On the south, from El Morro to El Morro National Monument, the road parallels the base of the massive, colorful Jurassic Zuni Sandstone. Near the end of this part of the trip Cretaceous rocks are exposed along the highway.

The road gradually descends from 7,831 feet at the Oso Ridge road junction to an altitude of 6,900 feet at Ramah, and traverses the Upper Sonoran life zone near the boundary with the higher Transition zone.

0.0

0.0 Junction with Oso Ridge road. The roadcut just ahead is in lime-stones of the Yeso Formation.

3.1

3.1 Cattle guard.

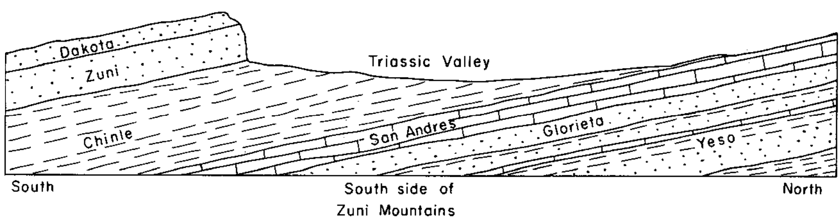
0.6

3.7 Rest area on left. The tree-covered hill in back of the rest area is another cinder cone. It has a shallow crater about 25 feet deep.

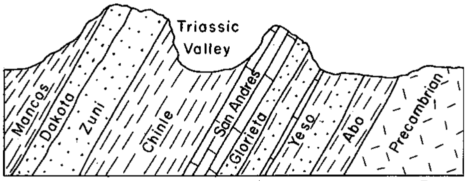
7.1

10.8 Road to Tinaja and Water Canyon on right. Tinaja was settled in 1876, by Mormons. It was then called San Lorenzo. The village is abandoned.

As noted, the valley is carved in red shales and sandstones of the Triassic Chinle Formation. The width of the valley is determined by the dip of the rock layers, and by the resistant San Andres Limestone to the north and Dakota Sandstone to the south. On the west



side of the Zuni Mountains the rocks dip very steeply away from the uplift, and in some cases are vertical to overturned. There the valley is much narrower, owing to the squeezing of the soft beds and their angle to the surface of the Earth. Along this stretch of road the dip is slight and the valley is several miles wide. The following sketches illustrate this. (Thicknesses of the formations are the same in both sketches.)



1-40 (U.S. 66) to the north and N. Mex. 53 are located on the south and east sides of the Zuni Mountains because of the valley carved in these soft Triassic rocks. Wherever one lives or travels it is interesting to try to determine why a city or highway is located in a particular place. In many cases it will be discovered that geologic conditions are the controlling factors. One also might discover reasons why some cities and highways should not have been located where they are.

0.2

11.0 Road junction on left. Just beyond the junction the road curves to-ward the mesa. From the crest of the road there is a striking view of El Morro (the headland) 2 miles ahead.

2.2

13.2 El Morro.

1.0

14.2 Entrance to El Morro National Monument. TURN LEFT. Inscription Rock is a sheer cliff, 200 feet high, of massive sandstone.

0.4

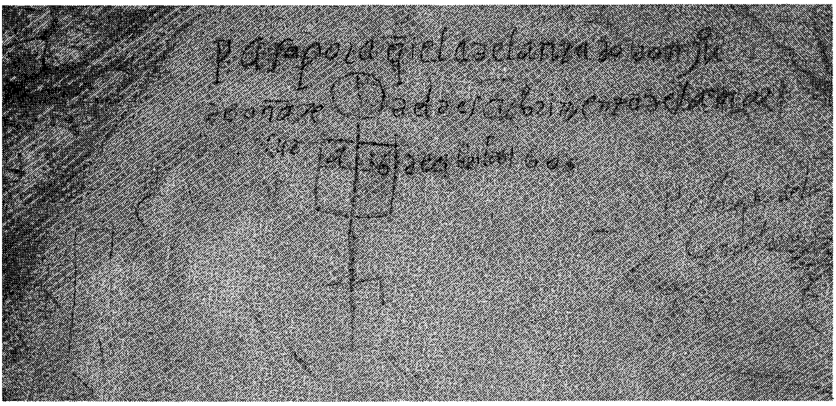
14.6 Road to picnic area on left.

0.6

15.2 Visitors' Center. El Morro National Monument was established in 1906 to preserve the inscriptions carved on the rock by early settlers and explorers of the southwestern United States. The earliest inscription known is that of Don Juan de Oñate, the first governor of New Mexico under Spain. Oñate carved his inscription in April of 1605 on his return from the "discovery" of the sea of the south (Gulf of California). Actually Cortez had attempted to start a settlement on the gulf side of Lower California, near the present site of La Paz, as early as 1535. Another Spaniard, Francisco de Ulloa, explored the entire coastline of the gulf in 1539 and 1540, and Hernando d'Alarcon discovered the mouth of the Colorado River in 1540.

Other Spanish inscriptions include that of Don Diego de Vargas, who reconquered New Mexico for Spain in 1692, following the Pueblo revolt of 1680.

Famous early American explorers who carved their names here while camping near the waterhole include Lt. J. H. Simpson, Lt. E. F. Beale, and the artist R. H. Kern. Lt. Beale is famous for hav-



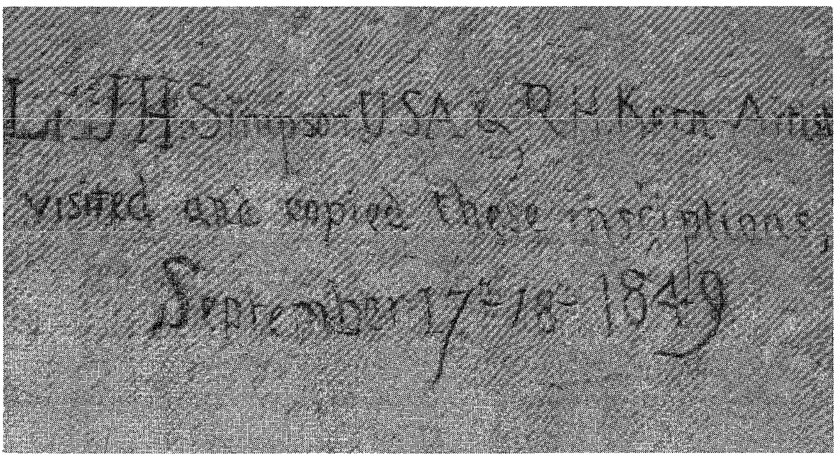
ONATE'S INSCRIPTION

Translation:

I passed by here governor general Don Juan de Oñate from the discovery of the south sea April 1605

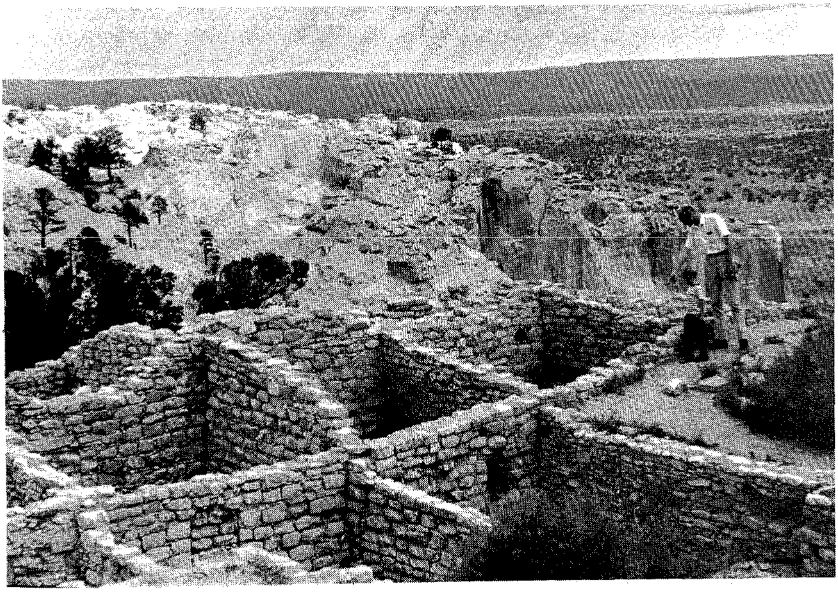
ing been in charge of a caravan of camels imported to the Southwest as an experiment.

The Monument also includes partly excavated early Indian ruins on top of the mesa. This mesa-top pueblo, known as Atsinna, was occupied during the 13th and 14th centuries before the arrival of the



INSCRIPTION OF LT. J. H. SIMPSON AND R. H. KERN

Spanish explorers in the area. The water supply and the natural protection of the cliffs made this an excellent site for a pueblo at that time. These early people also made carvings on the cliff walls, and perhaps their carvings prompted others to leave their names and messages.



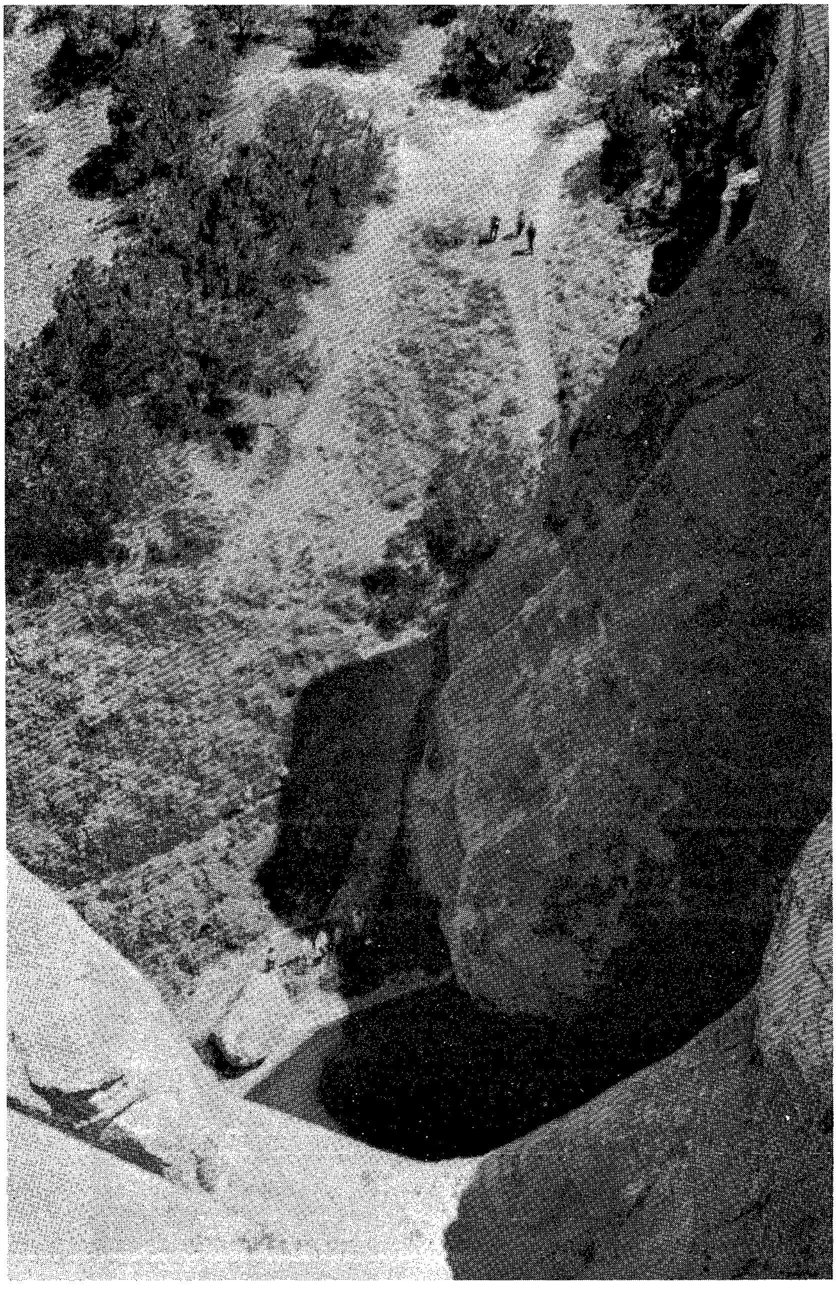
ATSINNA

A self-guided tour follows the base of the cliff past the inscriptions and the waterhole. The trail continues to the top of the mesa and re-turns to the Visitors’ Center down the east side. A leisurely walk over the mesa takes about an hour and is well worth the time, not only to see the ruins, but for the views of the surrounding country. It also affords an opportunity to inspect more closely the Zuni and Dakota Sandstones which were deposited under different conditions. The Zuni Sandstone consists largely of semi-consolidated sand dunes that spread over vast areas of the southwestern United States about 150 million years ago during the Jurassic Period. The dark-brown Dakota Sandstone that caps the mesa was deposited along a Late Cretaceous shoreline some 100 million years ago, and is a mixture of stream, lagoon, and ocean deposits.

The geology and vegetation along the trail are described in a pamphlet available at the Visitors' Center. The following notes pro-vide some additional information and interpretation of how some of the geologic features were formed.

High above the pool, notice a very smooth surface on the sandstone. The unweathered and relatively unstained appearance of this surface indicates that it has been recently exposed. It probably was the source for the rock fall of 1942 that partly filled in the pool.

From stakes 1 and 2 along the trail to the top you will notice two types of recesses in the cliff face. One consists of shallow, cave-like depressions roughly circular, and varying in size. The other consists of either vertical or horizontal notches. The Zuni Sandstone is por-

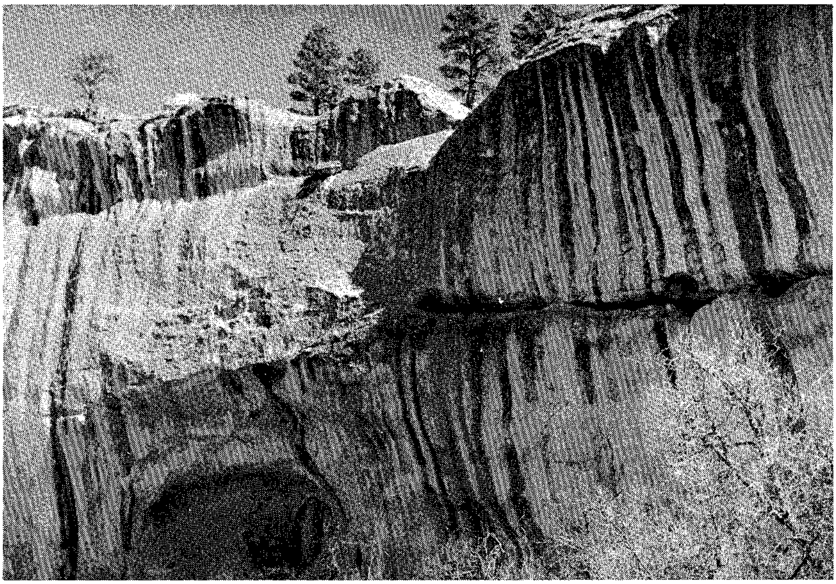


POOL AT EL MORRO

El Morro

Los Gigantes

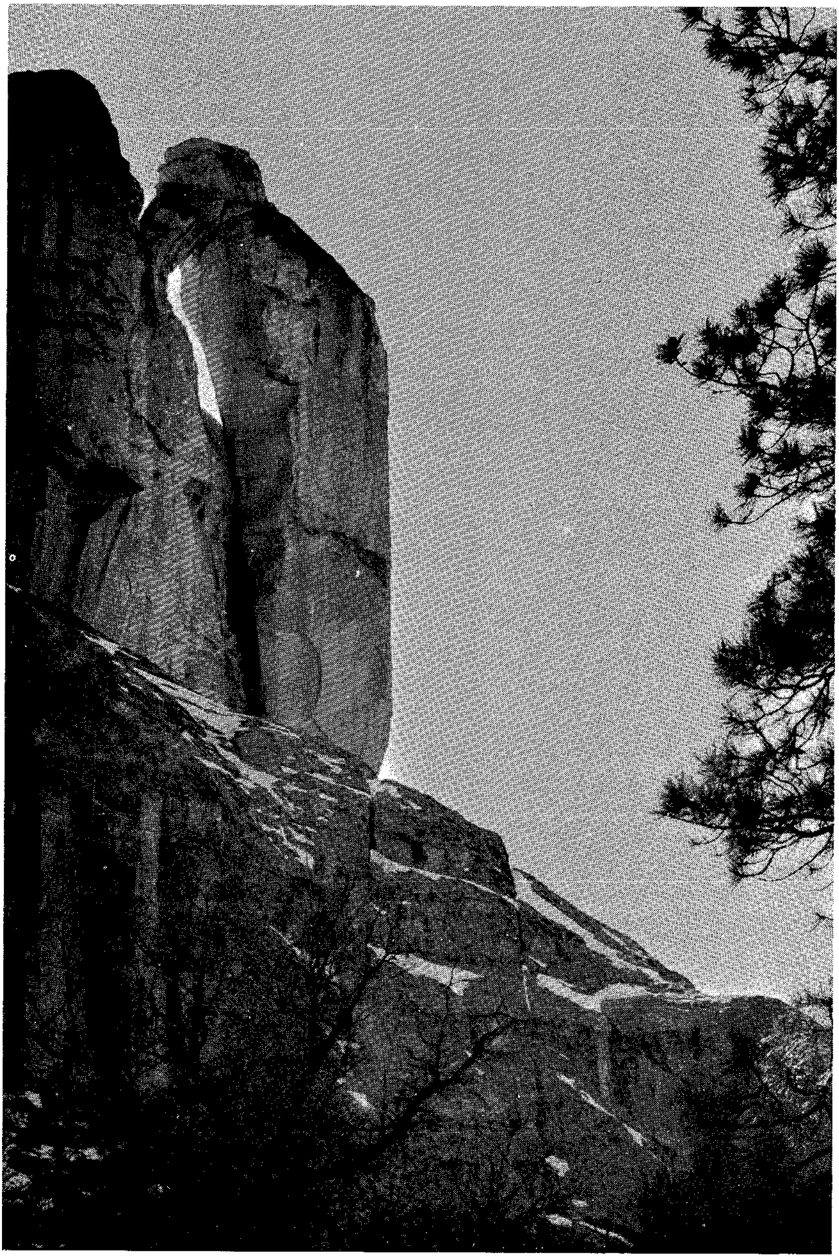
ous; water from rain or snow rapidly sinks into the sand where it is exposed. Some of this water seeps out on the face of the cliff and additional water runs down the face from above. The sand grains are loosely compacted and can easily be broken away. The carvings on the rock testify to the softness of this sandstone. Water seeping from the cliff face dislodges grains and forms small holes. These are then en-larged as sand grains are removed by seeping water from the top, sides, and bottom of the hole. The larger the hole becomes the more surface area is involved and the amount of sand removed becomes greater. Water running down the cliff face, particularly in the early stages of formation of the recesses, runs back into the hole, and be-cause of the force of the water, rapidly removes large amounts of the sand. As the hole deepens inward it becomes more protected from this surface runoff. Under dry conditions wind aids in the removal of the sand grains loosened but left behind by the water. As the hole is enlarged, the upper part has a tendency to spall off in curved



NOTCH AND CAVE IN ZUNI SANDSTONE PROM STAKE 2

pieces that break up as they fall. Daily to weekly cycles of freezing and thawing of the water aid in this spalling process but, like the wind, are of much less importance in the erosion of the cliff than that of running water.

The vertical notches called joints are common, particularly in mas-sive rocks like the Zuni Sandstone. These features are caused by stresses in the rock that occurred during various periods of uplift of the area followed by subsidence and burial during Cretaceous time.

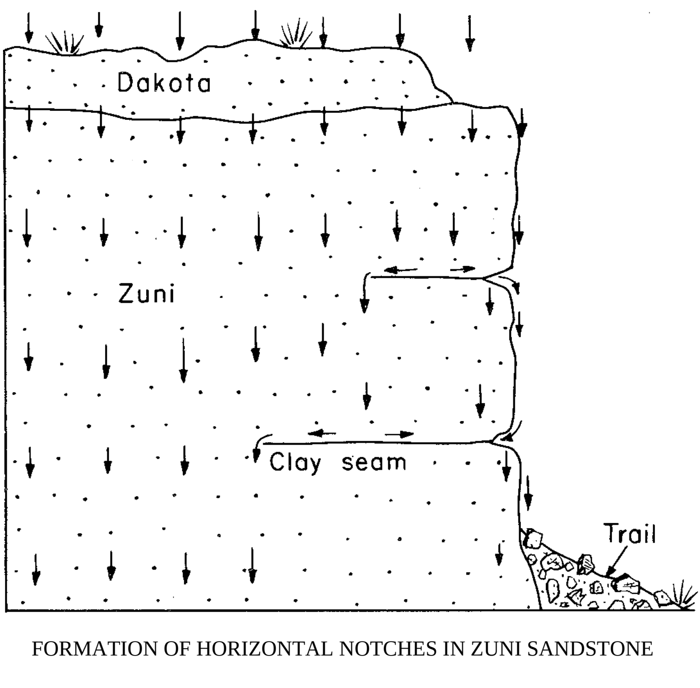


WOODPECKER ROCK. JOINT BLOCK ALMOST COMPLETELY SEPARATED FROM CLIFF FACE

Fractures of this type may develop in one direction such as east-west, or there may be more than one set of joints such as an east-west and a north-south set intersecting at 90°. Usually one set is more prominent than the other. At El Morro there are two sets of joints, the prominent one striking N. 65°E. and the other N. 10°W. These fractures form open passageways for water. Removal of sand grains is fairly rapid and the joints are easily widened. Eventually the outside block is completely free from the main rock mass and falls away. This helps to maintain the steepness of the cliff face. The better-cemented caprock of the Dakota Sandstone slows this process. If it were not present this mesa would long ago have been reduced to the level of the surrounding plain.

The horizontal notches are formed in a different way. At these notches there are thin layers of green-colored clay probably deposited in small intermittent ponds that existed amid the dunes. The clay layers readily break down into fine particles in water. This process is faster than removal of the sand grains, although the notches are widened by the removal of sand. The following simplified sketch, a cross-section through the rock, shows how this is accomplished.

At stake 5 you can see the difference between the Zuni and Dakota Sandstones. The color difference, nearly white for the Zuni Sandstone and brown for the Dakota Sandstone, is one way the two can be separated. However, this is not the most important criterion and could lead to mistakes as will be seen at stake 7. The most im-

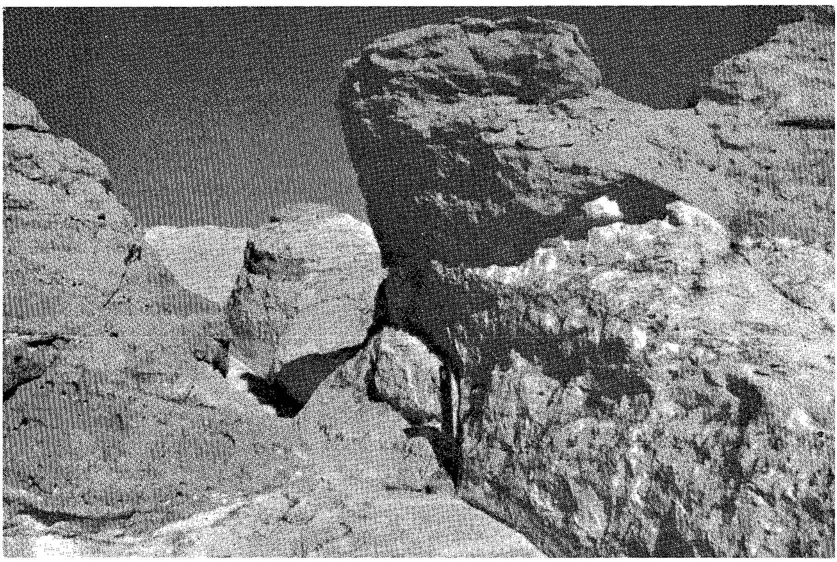


FORMATION OF HORIZONTAL NOTCHES IN ZUNI SANDSTONE portant factors for recognition of the contact between the two are the uneven surface at the base of the Dakota and the change in size and degree of rounding of the sand grains. Some 50 million years elapsed following deposition of the Zuni Sandstone and invasion of the Cretaceous sea. During this time erosion cut away at the younger Jurassic rocks deposited over the Zuni and eventually carved the upper part of the Zuni Sandstone into numerous channels. As the Dakota sea advanced over the area there was additional erosion of this surface. This uneven contact between the Dakota and various Jurassic rocks can be traced over a large part of the southwestern United States. This type of contact is known as an unconformity.

A magnifying lens is needed to see the difference in the smaller grains of the two units. The quartz sand grains in the Zuni have a higher degree of rounding and are more uniform in size than the grains in the Dakota. Readily visible are small rounded pebbles in the Dakota Sandstone; similar pebbles are not present in the Zuni.

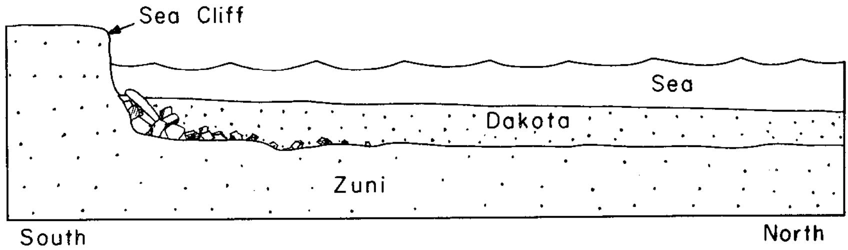
At stake 7 the uppermost exposures are brown Dakota Sandstone. Below this is a white sandstone that resembles the Zuni but also is part of the Dakota. If you examine this white sandstone along the trail from here to stake 8 you will find that it contains pebbles. Be-low this sandstone there is another brown sandstone that is the basal unit of the Dakota. The remaining massive white-to-yellow sandstone below this is the Zuni.

Large-to-small fragments of Zuni Sandstone are enclosed in an interlacing network of Dakota sand at stake 8. This debris was prob-



ACTUAL CONTACT BETWEEN- DAKOTA AND ZUNI SANDSTONE AT BASE OF STAKE 8 ably broken away from a sea cliff by wave action during deposition of the Dakota. The sketch shows how this type of deposit may have been formed.

Continue along the trail to the Visitors' Center and return to N. Mex. 53.



INTERPRETATION OF HOW FEATURES AT STAKE 8 WERE FORMED 1.0

16.2 Junction Monument road and N. Mex. 53. TURN LEFT.

0.5

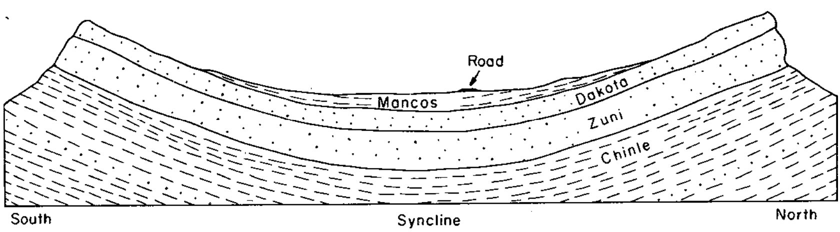
16.7 Cattle guard. Inscription Rock on left.

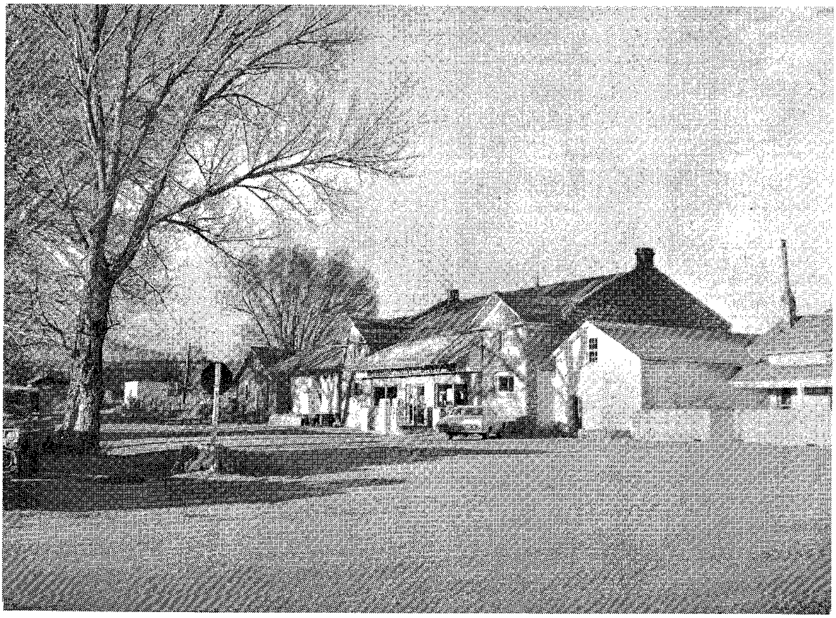
3.0

19.7 Road junction on left. From here to Ramah the road follows the axis of a small syncline (see sketch). The rocks dip inward toward the road from both the north and south. The Dakota Sandstone seen on the top of Inscription Rock is exposed along the road at this point and caps the slopes to the right and left. The soft Mancos Shale that overlies the Dakota Sandstone is preserved in this syncline, and outcrops will be seen near Ramah. The Mancos Shale consists of fine particles of quartz and clay deposited in the deeper parts of the Cretaceous sea that covered this area. As this marine basin continued to subside, the shoreline moved farther and farther south and these offshore deposits were laid down over the areas that at one time had been part of the coast.

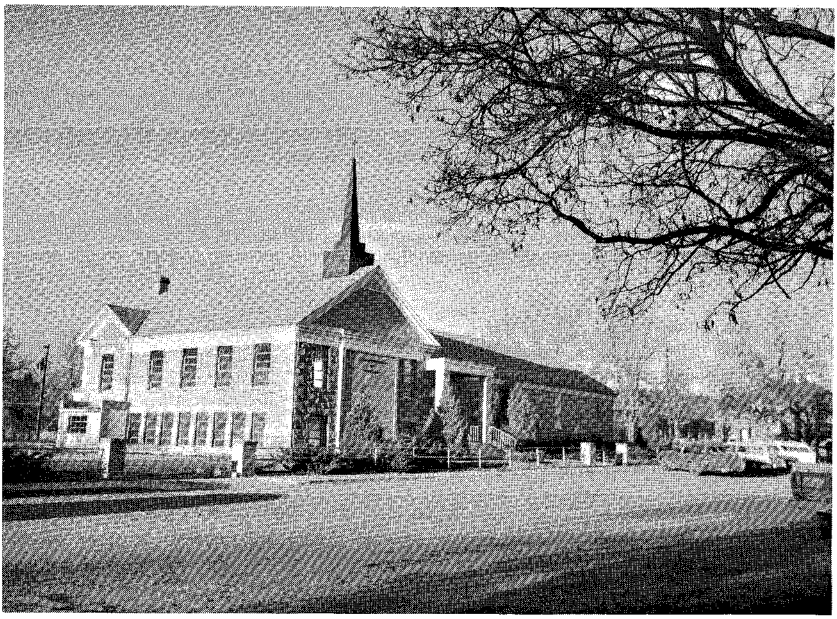
From the crest of the hill ahead, the opposing inward dips of the syncline can readily be seen.

1.2





TRADING POST



CHURCH OF JESUS CHRIST OF LATTER DAY SAINTS

20.9 Road junction. TURN RIGHT on dirt road to Los Gigantes (the giants). The erosional remnants of the Zuni Sandstone that form the statue-like features are called pedestals or pinnacles. From here to the recommended turn-around point there are many places to take pictures of these features. You also may wish to climb the slope to get some idea of the size of these figures.

Here the Zuni Sandstone is banded red and white; at El Morro it was yellow. The banding is characteristic of this sandstone and will be seen again near Zuni Pueblo. The difference in colors from red to white to yellow is caused by variations in the amount of iron-bearing minerals, the permeability of the sand, exposure, groundwater and climatic conditions now and in the past. All of these things contribute to the present degree of oxidation of the iron and the resulting color of the sandstone.

2.1

23.0 Road forks. RETURN TO N. MEX. 53.

2.1

25.1 N. Mex. 53. TURN RIGHT.

4.6

29.7 Leave Valencia County; enter McKinley County.

1.1

30.8 Stock pens against bluff of Dakota Sandstone. Road on right leads to the ruins of a small cliff dwelling (0.7 miles). Poorly exposed Mancos Shale in the roadcuts ahead.

0.9

31.7 Entering Ramah.

0.2

31.9 Crossroads. Trading Post on right.

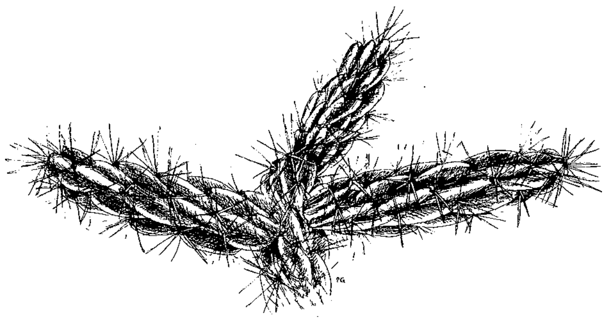
Ramah was settled in 1882 by Mormon missionary-farmers sent to this area from the Little Colorado River country in Arizona. The first Mormon settlers came in 1876, stopping first at San Lorenzo (Tinaja) and later founding a settlement at Savoia a short distance to the west. Dry farming proved unsuccessful, and the necessity for a dam and reservoir was apparent. The most favorable site in the vicinity was just north of Ramah, where a narrow canyon cuts through the Zuni Sandstone.

As in most Mormon communities, the roads are laid out according to the cardinal points of the compass. The road through town is due east-west.

END OF TRIP 3

4. INDIAN COUNTRY
(66.0 miles)

As the route follows down the drainage of the Zuni River, the altitude decreases from 6,900 feet at Ramah to 6,200 feet at Zuni Pueblo. This part of the trip is entirely in the Upper Sonoran life zone characterized by piñon, juniper, sagebrush, cactus, mesquite, and creosote.



CHOLLA CACTUS

Soon after leaving Ramah, you enter the Zuni Indian Reservation. The reservation extends to the Arizona border and comprises over 500 square miles. About 5,000 Zunis live on the reservation. The area south and southeast of Ramah and around El Morro is inhabited by Navajos living on scattered sections of Indian land.

Cretaceous rocks are seen from Ramah to the junction with N. Mex. 32. Immediately west of the junction, the route follows the Zuni River through a short, narrow canyon or water gap bordered by sheer walls of bright-colored Zuni Sandstone, and into a broad valley carved in Triassic rocks. The trip continues to Zuni Pueblo where you can visit the restored Catholic Mission and the Arts and Crafts center. Beyond the Pueblo is the almost abandoned village of Ojo Caliente (hot springs). The partially excavated ruins of Hawikuh, the first of the Zuni Pueblos seen by Coronado in 1540, are located a short distance west of the road to Ojo Caliente.

0.0 Center of Ramah. Valley from here to cliffs ahead is cut in the Mancos Shale.

1.4

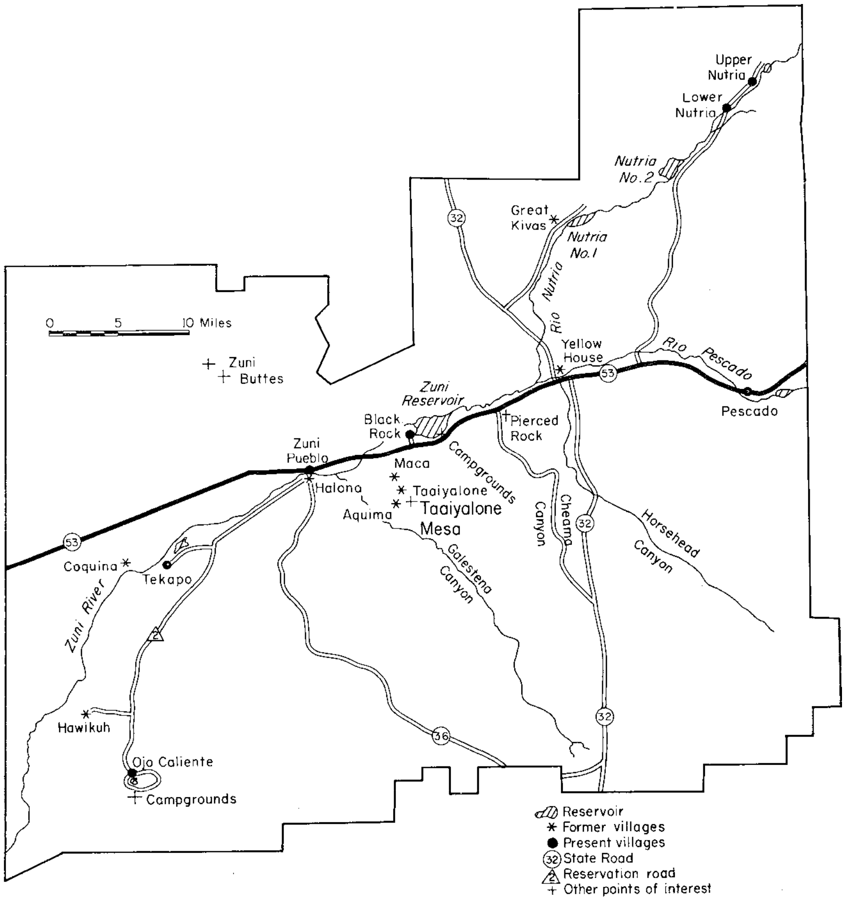
1.4 Highway Department compound on right. Behind are outcrops of Gallup Sandstone. In part, the Gallup represents the sand left behind during a retreat of the Cretaceous sea. This widespread northern retreat of the sea followed the deposition of the Mancos Shale.

Note that the rocks are dipping to the west. This is the east limb of Allison syncline, a long feature that borders the Zuni Mountains on the west side. The rocks dip west for a short distance to the axis of the syncline, where they flatten out and are almost horizontal. Farther west, the rocks can be seen dipping back toward the east on the west limb of the syncline.

1.5

2.9 Cattle guard. Entering Zuni Reservation. You are now crossing the approximate axis of the syncline. Looking ahead the rocks dip back to the east at a low angle.

The following map of the reservation shows passable roads, present villages, ruins, and recreation areas. The Zunis have plans to develop many of these areas, excavating the ruins, providing overnight camping and other facilities, and a Visitor's Center near Yellow House where there will be programs depicting the history of the Zuni Indians, traditional Zuni dances, and guided tours of historical sites on the reservation.



ZUNI INDIAN RESERVATION

Whether there were six or seven occupied villages at the time of Coronado in 1540 is not known. According to accounts of an expedition in 1581 there were six. These are shown on the map.

2.6

5.5 Pescado (fish).

0.5

6.0 Bridge over Rio Pescado

3.7

9.7 Road junction on right. Nutria-Lake, 11 miles; Nutria campground, 12 miles; Nutria village, 14 miles. The cliffs straight ahead on the skyline are Zuni Sandstone capped by Dakota Sandstone. The valley is cut in the Mancos Shale, and the mesas on both sides of the road are capped by Gallup Sandstone.

2.3

12.0 Road junction on left with N. Mex. 32 to Fence Lake, Quemado, and U.S. 60. Notice the long, even, eastward-dipping slope to the north. This was caused by the stripping back by erosion of the weak Mancos Shale above the resistant Dakota Sandstone on the west limb of the Allison syncline.

0.5

12.5 Bridge over Horsehead Creek and junction with N. Mex. 32 to Gallup. Trip 5 begins at this point. Continue ahead to Zuni and Ojo Caliente on N. Mex. 53.

1.2

13.7 Passing through water gap in massive red and white banded Zuni Sandstone, the same unit seen at El Morro and Los Gigantes. The valley here is cut in the Triassic Chinle Formation and is partially filled in by lava that flowed down the valley from the east.

0.6

14.3 Pierced Rock on left. The window was formed by the same process as the recesses in the cliff at El Morro. The recesses worked inward from both sides of the promontory, eventually cutting out an opening.

0.8

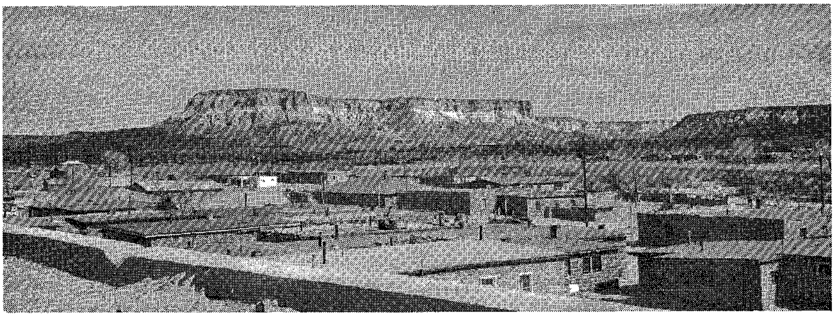
15.1 Bridge over Cheama Arroyo. Outcrops in roadcuts and near road consist of red sands and shales of the Chinle Formation overlain by recent lava flows.

3.2

18.3 Junction with road to Black Rock on right. Taaiyalone (corn) Mesa on left is a sacred mountain to the Zunis. It was on this mesa that they sought refuge from the Spanish.

1.9

20.2 Bridge over Zuni River.



TAAIYALONE MESA

0.8

21.0 Entering Zuni Pueblo. Zuni School on left. Tribal Headquarters and Zuni Craftsmen Cooperative Association are located in the large building ahead on the right.

The Zuni Pueblo of today consists mostly of one-story dwellings, replacing the many-storied structures of ancient times. As in the past, the Zuni Indians are primarily farmers. In addition to corn and beans, they now raise wheat and livestock, particularly sheep. The Zunis are world famous for their jewelry of silver and turquoise. They began to work with silver in the 1870's and by 1890 had started to use turquoise. Inlays of jet, shell, coral, and turquoise were developed in the 1930's. Original silverwork, pottery, bead work, carvings, and paintings by Zuni Indians may be purchased at the shop at the west end of the Tribal Headquarters building or at various Trading Posts within the Pueblo and in the surrounding area.

0.9

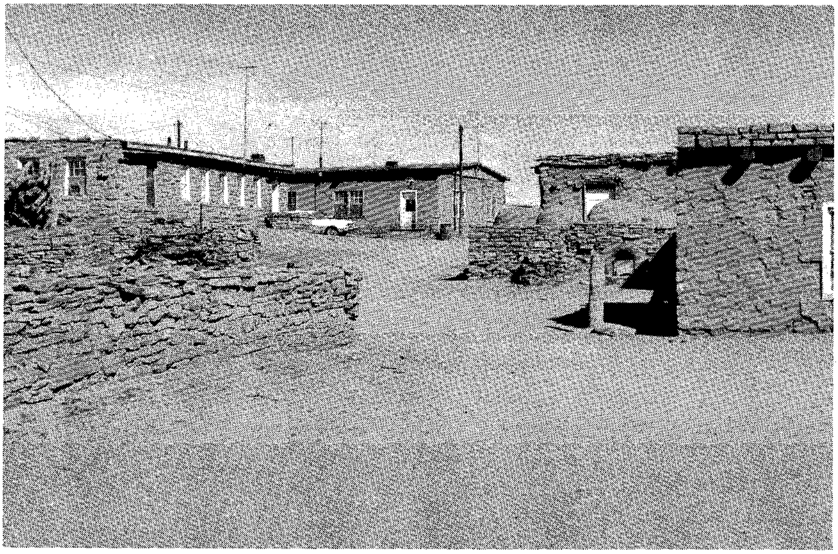
21.9 Crossroads. The recently restored Catholic Mission, Nuestra Senora de Guadalupe de Halona, is to the left behind the first row of buildings.

0.2

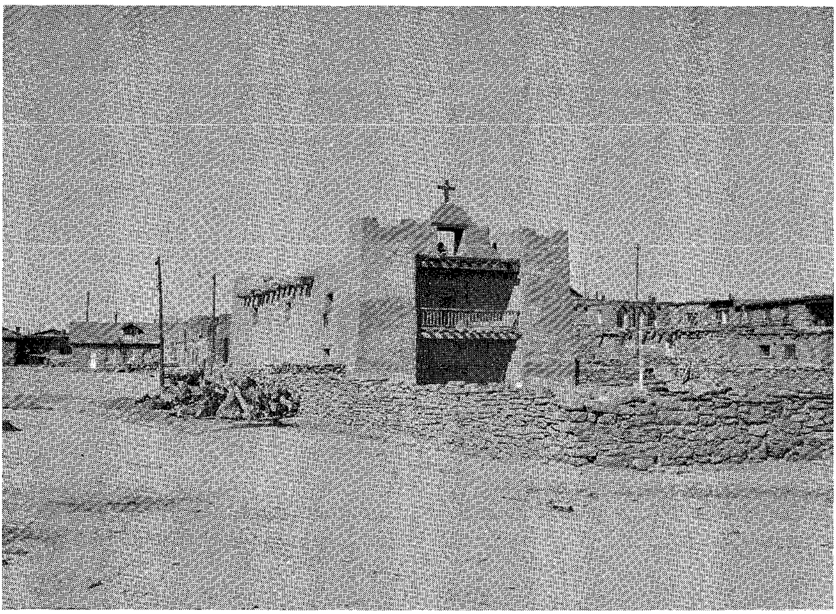
22.1 Junction N. Mex. 53 and Reservation 2. TURN LEFT. Tekapo, 6 miles; Hawikuh, 14 miles; Ojo Caliente, 15 miles. Overnight camping facilities are available on the south side of the reservoir at Ojo Caliente. Fishing permits can be obtained at Tribal Headquarters. The old Zuni-Cibola Trail continued west from here to the Hopi villages in northeastern Arizona.

0.1

22.2 Bridge over Zuni River. Road curves to right. Christian Reformed Church, Zuni Mission on left. The road follows the east side of the broad Zuni River valley from here to Ojo Caliente. The valley is carved in Triassic rocks capped by terrace deposits left behind by the Zuni River when the valley was at a much higher level.



STREET SCENE, ZUNI PUEBLO. BEEHIVE-SHAPED STRUCTURES ARE HORNOS *(ovens)*



NUESTRA SENORA DE GUADALUPE DE HALONA

3.4

25.6 Road on left to gravel pit in high-level terrace deposits of the Zuni River.

1.1

26.7 Bridge. Road on right to Tekapo.

2.7

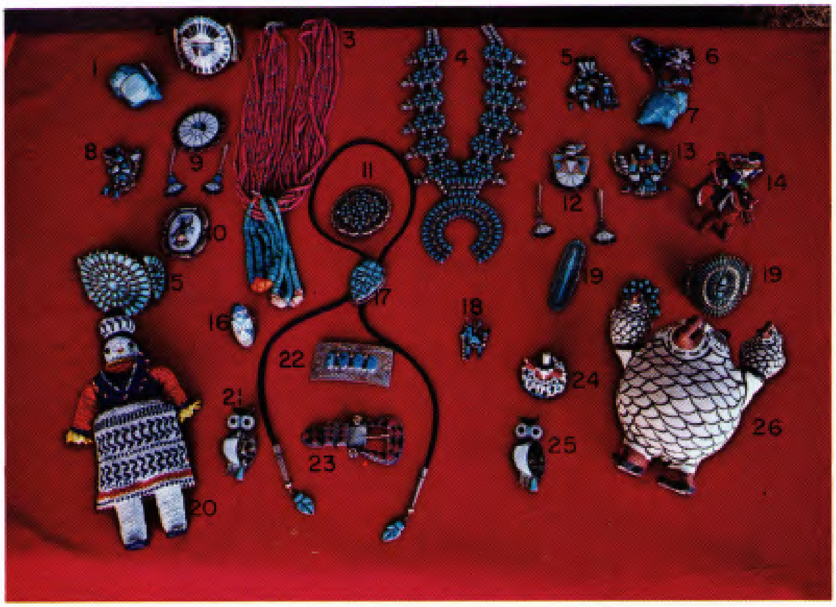
29.4 Bridge.

1.4

30.8 Bridge.

2.1

32.9 Outcrops of Triassic sands and shales.

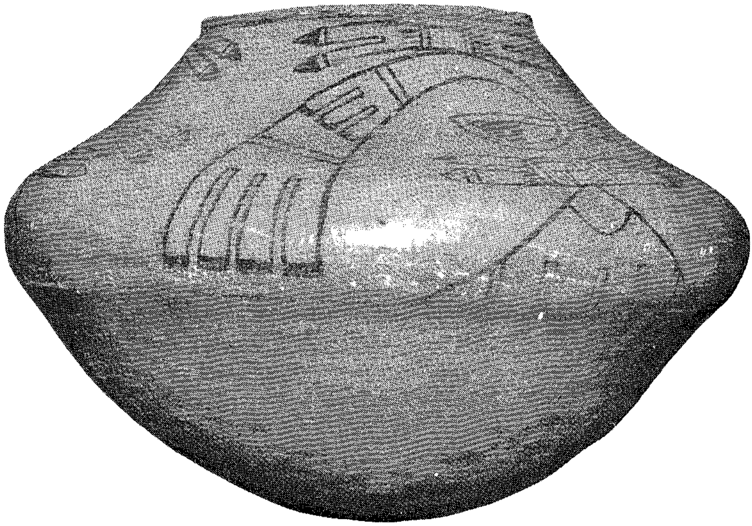


courtesy of Vanderwagon's Trading Post, Zuni, New Mexico

ZUNI CRAFTS

1. Fetish
2. Multicolor headdress bracelet
3. Coral neckless with turquoise jaclos
4. Squash blossom cluster neckless
5. Multicolor bolo (mother-of-pearl, turquoise, jet)
6. Horse bolo
7. Fetish
8. Multicolor brooch
9. Sunburst bolo and tips
10. Apache devil dancer (set in mother-of-pearl)
11. Cluster pin with silver border
12. Thunderbird bolo with tips
13. Knife wing multicolor bolo
14. Seed-bead horse and rider
15. Cluster-type bracelet
16. Turquoise channel ring
17. Turquoise nugget bolo tie
18. Multicolor deer (pin)
19. Thunderbird bolo with tips
20. Seed-bead doll with olla in native costume
21. Owl (bolo)
22. Turquoise overlay (buckle)
23. Coral-jet (buckle)
24. Seed-bead doll
25. Channel inlay owl (pin)
26. Clay owl

Multicolor or rainbow pieces are made with combinations of shell, coral, jet, and turquoise



HAWIKUH GLAZE-ON-RED OLLA. GREEN GLAZE ON A RED GROUND *Found in small cavity in lava flow*

Collections in the Museum of New Mexico

ASHIWI POLYCHROME OLLA. BLACK AND RED MATTE PAINTS ON A WHITE GROUND

One of few examples found at Zuni

Collections in the Museum of New Mexico

0.8

33.7 Junction with road to Hawikuh ruins. TURN RIGHT.

1.4

35.1 Road forks; KEEP LEFT.

0.2

35.3 Hawikuh. The ruins were partially excavated a number of years ago and then back-filled to preserve the walls and floors. The rock used for construction is almost exclusively sandstone from local outcrops of the Chinle Formation. The Spanish mission church at the base of the slope to the south is made of adobe.

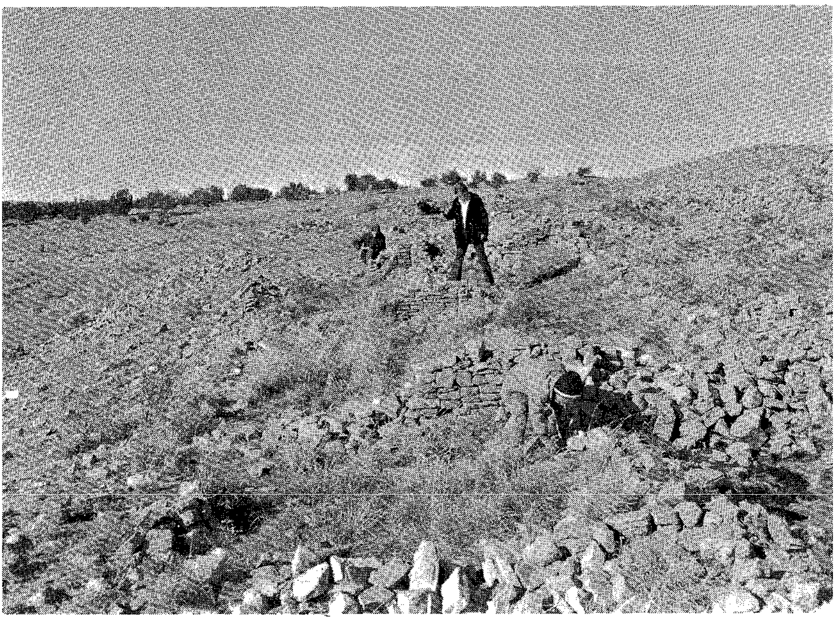
This spot, well removed from the usual tourist haunts, is an excellent place to relax and to reflect on the historic events that took place here more than 400 years ago.

In 1536 Alvar Nuñez Cabeza de Vaca and three companions, Andres Dorantes de Carranza, Alonso del Castillo Maldonado, and Dorantes' slave, a Barbary Negro named Estevan, found their way to the Spanish settlement of Culiacan, Mexico. These men were survivors of the ill-fated Narvaez expedition to Florida in 1527. They had wandered aimlessly for nine years, from the Gulf of Mexico across Texas to civilization in New Spain. In their reports to Don Antonio de Mendoza, First Viceroy of New Spain, they included stories they had heard of large cities to the north. These cities were supposed to contain buildings of four and five stories.

In September 1538, Mendoza commissioned Fray Marcos de Niza to explore the country to the north and to discover the cities reported by de Vaca. With Estevan as guide, and with a large group of Indians, Fray Marcos set out on his exploration of New Mexico. Estevan, traveling in advance of the main party, was captured by the Zunis, apparently at Aquima, a village at the southwest base of Taaiyalone Mesa. In attempting to escape Estevan was killed, but several Indians who had accompanied him managed to return and report to Fray Marcos of the discovery of the cities and the death of Estevan. The priest advanced to within sight of Hawikuh, took possession in the name of the Spanish Crown and began his return journey without having actually entered any of the Zuni villages. He reached Mexico City in August 1539.

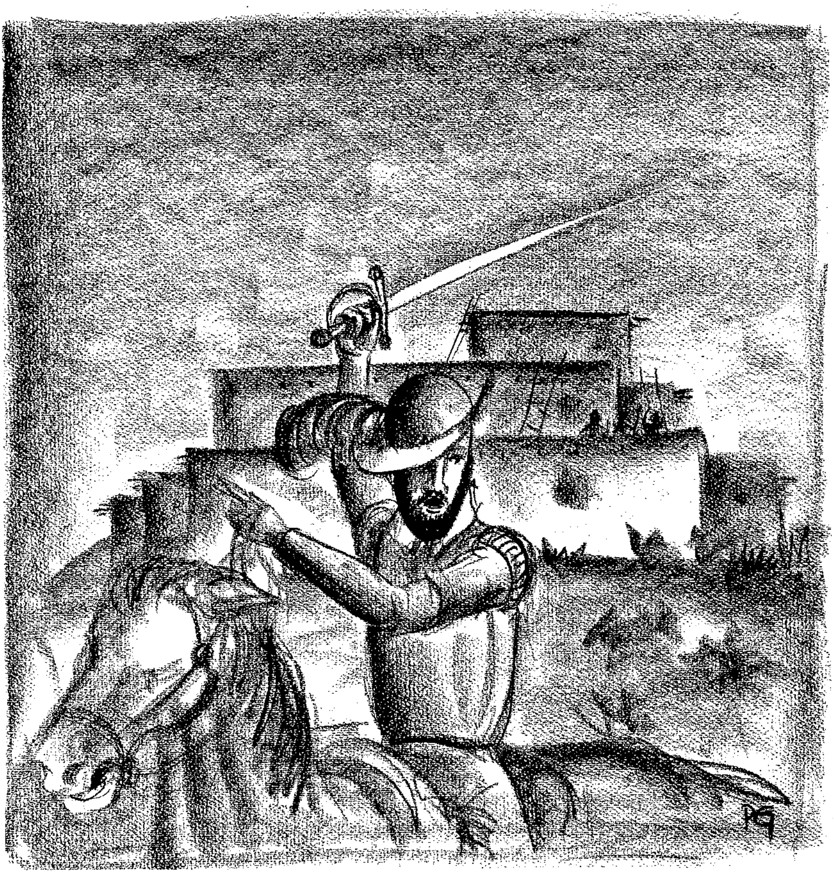
The somewhat exaggerated reports of Fray Marcos on the "Seven Cities of Cibola," as they came to be known, were expanded by others into tales of streets paved with gold. This naturally sparked the imaginations of the Spanish leaders with dreams of riches similar to those of the Aztecs and Incas. Among others, Cortez made a bid to lead an expedition to New Mexico. Leadership was finally bestowed on Francisco Vasquez de Coronado. The total expedition consisted of 200 horsemen, an equal number of infantrymen, 300 Indians, 1,000 horses, and a large number of oxen, cows, and sheep for a fresh meat supply. The soldiers wore armor and carried swords, lances, crossbows, harquebuses, and shields. They also took with them two small cannons.

The expedition set out in 1540, eighty years before the Pilgrims landed on the east coast of what is now the United States. After reaching Culiacan, Coronado, with Fray Marcos, his guide, and 100 soldiers went in advance of the main army. By the time they reached Hawikuh the party was dangerously weakened by the forced march and a severe shortage of food. From the ridge to the south Coronado gazed upon the pueblo of Hawikuh and made his plans. With Fray Marcos and one soldier he rode down to the plain to accept the peaceful submission of the Indians. The last thing he wanted at this time was to be engaged in a battle. The Zunis however, knew of his coming, of the Spanish enslavement of Indians and their forced conversions to Catholicism. They were prepared for the defense of their city with methods probably very effective against other Indians, but a bit outdated against Europeans. Only warriors remained at the village, and a large number of these immediately attacked Coronado, killing one of the horses and hitting Fray Marcos' robe with an arrow. Reacting swiftly, Coronado rode back to his men on the ridge and ordered a charge. Against the horse, sword, and lance the Indians rapidly dispersed, some making it back to the temporary safety of the walled village, others fleeing east to the hills. Wasting no time, Coronado stationed soldiers at all sides of the Pueblo to prevent escape, dismounted and led an assault up the slope to the walls of



HAWIKUH RUINS

the village. The assault was repulsed by a hail of rocks and arrows from the roof tops. Coronado, in his ornate armor, was a prime target and twice was felled by rocks and had his foot pierced by an arrow at the entrance to the village. He probably would have been killed except for the action of two of his officers who, at the risk of their own lives, dragged him back from the wall. Changing strategy, the



CORONADO AT HAWIKUH

Spanish stood out of range of rocks and arrows, and using cannons, harquebuses, and crossbows, quickly forced the defenders to surrender. After brief talks, the Indians were allowed to leave Hawikuh in order to pass the word to the other villages of the invincibility of Spanish arms. This also gave Coronado an opportunity to inspect the village and help himself to the food supplies. As so often happens to treasure hunters there was no gold to be found. It can be imagined that Coronado had a few choice words for Fray Marcos before shipping him back to Sonora. After exploring as far east as Kansas, Coronado returned to Mexico in 1542, his expedition a failure.

During the Spanish colonization of New Mexico, beginning in 1598, there was little conflict between the Zuni Indians and their Spanish conquerors. Spanish settlements were located along the Rio Grande, and because of its remoteness, garrisons were maintained at Zuni only for short periods of time. Contacts thus were limited to visits by the Spanish governors and investigations into the deaths of several Franciscan missionaries. The Zunis played an active role in the Pueblo Revolt of 1680, helping to drive the Spanish from New Mexico.

After visiting the ruins return to Reservation 2.

1.6

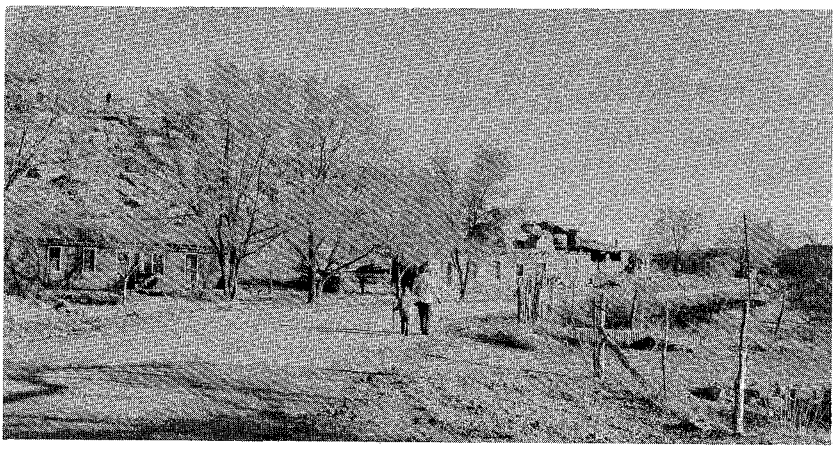
36.9 Junction with Reservation 2. TURN RIGHT.

0.7

37.6 Bridge.

1.2

38.8 Entering Ojo Caliente.



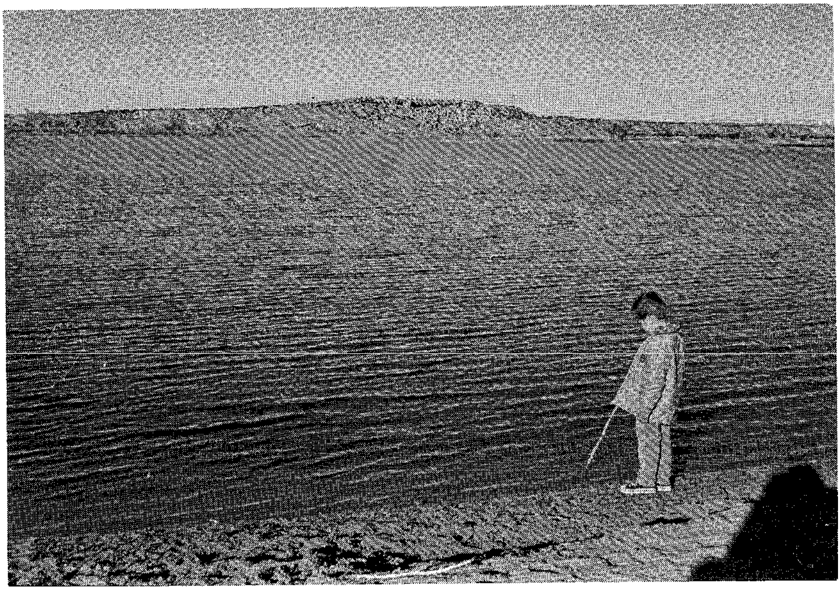
OJO CALIENTE

0.3

39.1 Bridge. Turn right and follow upper road along edge of reservoir.

1.6

40.7 The light gray, angular boulders along the road are fragments of old spring deposits that cap the low mesas on the south side of the valley. Deposits of this type are called calcareous tufa. They are common in areas where there are warm or hot springs in which the waters contain large amounts of calcium carbonate.

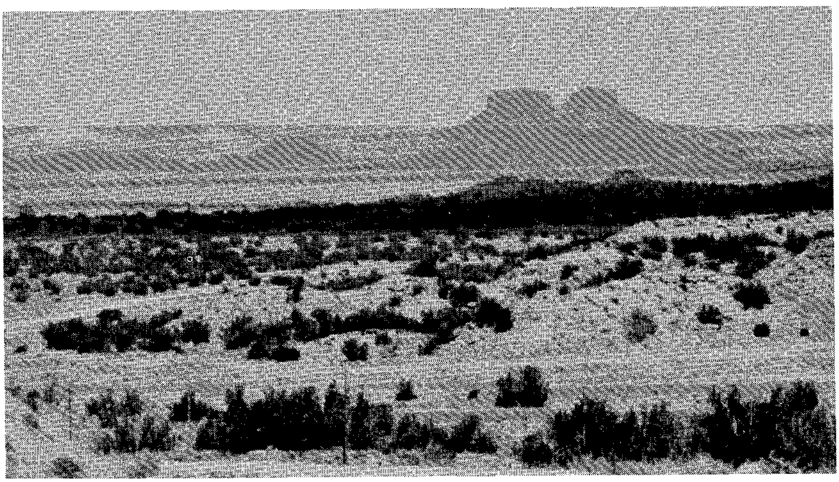


RESERVOIR AT OJO CALIENTE

0.4

41.1 The round stone tank on the left is one of the major warm springs in the area. The water can be seen welling up in the bottom of the tank with a flow of about 450 gallons per minute. The temperature is about 70° F.

0.1



ZUNI BUTTES

41.2 Turn left just beyond spring.
1.2
42.4 Complete loop at bridge. Retrace route to Zuni Pueblo and the junction of N. Mex. 53 and 32.
3.3
45.7 From the crest of this rise there is an excellent view of the Zuni Buttes twelve miles to the north.
10.7
56.4 Junction N. Mex. 53. TURN RIGHT.
1.1
57.5 Leaving Zuni Pueblo. Taaiyalone Mesa ahead to the right.
2.7
60.2 Junction on left with road to Black Rock.
3.3
63.5 Junction on right with Cheama Canyon road. Better view of Pierced Rock.
2.5
66.0 Junction with N. Mex. 32. TURN LEFT.

END OF TRIP 4

5. COAL AND THE CRETACEOUS PERIOD

(29.5 miles)

Altitude along the route is from 7,200 feet at the high point north of the junction of N. Mex. 32 and 53 to 6,500 feet at Gallup. Vegetation is representative of the Transition life zone with mixed stands of ponderosa pine, pinon, and juniper. Open flats are covered with sagebrush.

This part of the trip is over rocks of either Cretaceous or Tertiary age. Near Gallup thin seams of coal will be seen.

Mineral resources of economic importance are located in the vicinity of Gallup. Of major importance are deposits of uranium and coal. The origin of uranium has been discussed previously so we will concern our-selves here with a discussion of coal. It has been well established that coal is formed from plants. The environment must be one in which there is a dense growth of trees and other vegetable matter. The dead plants must be protected from the chemical decomposition that occurs with oxidation, and in order to have high purity deposits there has to be a limited influx of other materials such as sand and clay. Conditions must remain comparatively stable for an adequate length of time to build up coal beds thick enough to be of economic value. Fresh-to-brackish-water swamps best meet these conditions, because an adequate plant growth can be sustained, and as the plants die they are protected from oxidation by a covering of water. Swamps are stagnant, or nearly so, limiting the influx of other material.

Through various stages of decomposition certain parts of the plant are destroyed. Preservation of the remainder is the result of the toxic and reducing environment of the swamp. The material preserved forms peat, a low grade fuel still being formed in many parts of the world. Man has used this fuel for thousands of years. The transition from peat to coal is brought about by burial beneath other sediments causing an increase in pressure and temperature with the subsequent loss of oxygen and water. The increased loss of oxygen, along with an increase in the amount of carbon, gives rise to higher and higher ranks of coal. Thus, in general, the peat changes to lignite, then to subbituminous, bituminous and finally to anthracite coal. Anthracite, containing over 86% carbon, is found only where the rocks have been intensely folded or where coal is adjacent to igneous intrusions. It has been estimated that it takes 150 years to accumulate enough plant material to form one foot of bituminous coal.

Coals found in the eastern United States and Europe are primarily of late Paleozoic age, that is Mississippian, Pennsylvanian, or Permian. Extensive coal deposits border the Rocky Mountains from Canada to New Mexico in the western United States. These deposits are of Cretaceous age.

Prior to the complete changeover to diesel-electric locomotives, large quantities of coal were mined from several areas in New Mexico. Annual production to 1949 amounted to over one million tons. By 1958 coal production was down to 85,000 tons, and coal mining areas such as Madrid had become ghost towns. Then came the need for coking coals for the steel mills of the west coast and electricity for the rapidly expanding populations and industries of Phoenix and Los Angeles. The coal mining industry of New Mexico now is of even greater importance than it was prior to 1950. In 1967 production amounted to more than 3 million tons and future plans are for even greater annual production, particularly for use in power plants.

One of the major coal mines in the state is located a few miles northwest of Gallup.

0.0

0.0 Junction N. Mex. 53 and 32; turn north on N. Mex. 32.

0.1

0.1 Bridge over Rio Pescado. Yellow House ruins next to road on right. The road follows a valley carved by tributaries of the Zuni River. The even slope to the west is the dip slope on the Dakota Sandstone; cliffs capping the mesas to the right are Gallup Sandstone; the valley has been cut in the intervening Mancos Shale.

1.5

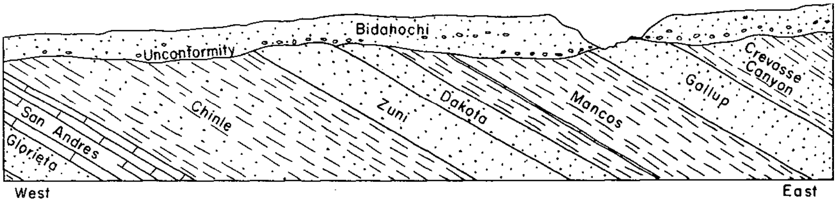
1.6 Bridge over Rio Nutria.

1.8

3.4 Road junction. Road leading past windmill on right passes exposures of Mancos Shale containing numerous fragments of fossils. The distance to the nearest outcrops is 0.6 mile. The great kivas, shown on the map of the Zuni Reservation, are reached via this road.

4.4

7.8 The red and white flat-lying beds to the left are the Tertiary Bidahochi Formation. This unit helps the geologist to date the uplift of the Zuni Mountains. Fossil beavers indicate that the Bidahochi Formation is Pliocene, late Tertiary, in age. The underlying Cretaceous rocks were deposited in an almost horizontal position but, sometime prior to the deposition of the Bidahochi beds, were tilted to their pre-sent position during the same uplift that formed the Zuni Mountains. The Bidahochi beds now cut across the tilted Cretaceous beds as shown in the following figure. Thus it can be seen that the uplift of the range occurred between late Cretaceous and Pliocene time, some-where between 70 and 10 million years ago. Evidence from other areas indicates that this event took place closer to 70 million years ago.



The Bidahochi Formation once covered most of this area, but a period of erosion, probably initiated in Pleistocene time, has left only isolated remnants on the divides between streams.

0.9

8.7 Roadcut just before cattle guard in Bidahochi Formation. The rocks consist of soft clayey sandstones and conglomerates containing volcanic pebbles. Continue through roadcuts in this unit for next 3.7 miles.

3.5

12.2 Descending into narrow canyon with bluffs of Gallup Sandstone. This is the same sandstone that caps the mesa along Pescado and Nutria Creeks, west of Ramah. The road has crossed this sandstone where it was concealed by the Bidahochi Formation, and is now near the top of the Gallup. In this area stands of ponderosa pine are closely controlled by rock type. Very few of these trees grow on the clayey beds of the Bidahochi or the shales in the Cretaceous. Slope and altitude are of much less importance here than the favorable, well-drained soils developed on the sandstones.

0.4

12.6 Whitewater Trading Post. Road is now above the Gallup Sandstone and continues in the Crevasse Canyon Formation of sandstone, shale, and coal. Exposures of the uppermost unit of the Gallup Sandstone are visible in the slope to the west. The road continues through outcrops of the Crevasse Canyon Formation for the next 2.3 miles.

The sands and shales of the Crevasse Canyon were deposited by streams on the broad flats left behind after a northward retreat of the sea. The sea advanced over this area again, but the deposits left behind after this retreat have been removed by erosion.

2.3

14.9 Bidahochi Formation in roadcuts. The Zuni Mountains are on the distant skyline to the right. Numerous hogans can be seen between here and Gallup. Although some hogans are permanent homes for the Navajos in this area, most are only used while tending flocks of sheep or goats. One Navajo family may have several hogans, moving from one to the next with their flocks.

3.0

17.9 Junction on right with road to Pinehaven, McGaffey, Fort Wingate, and 1-40.

3.0

20.9 Begin roadcuts in sandstone, coal and shales of the Crevasse Canyon Formation. Thin seams of coal are common between here and Gallup. They can. be seen most often just below ledges of sandstone.

3.6

24.5 Bridge.

3.0

27.5 Cattle guard. Gallup ahead.

0.9

28.4 Cattle guard.

1.1

29.5 Gallup city limits (altitude 6,515 feet). Junction N. Mex. 564. Indian Hospital to the right.

In 1880, Gallup was a stop on the westward Overland Stage, and consisted of a saloon (the Blue Goose) and a general store. In 1882 the Atlantic and Pacific Railroad (Santa Fe Railway) was completed to Gallup. The town rapidly became an important station, owing to the large supply of nearby coal. Today the city is a trade center for an area of about 15,000 square miles of New Mexico and Arizona. More than half of the 85,000 people of this area belong to the Navajo, Zuni, and Hopi Indian tribes. The city of Gallup has a population of about 18,000.

From Gallup there are many interesting and scenic side trips. The larger pueblo ruins of Chaco Canyon National Monument are located 94 miles to the northeast. U.S. 666 north from Gallup crosses the Navajo Indian Reservation to the Colorado state line passing one of the west's most famous landmarks, the sheer volcanic plug known as Shiprock. Other roads cross this sprawling reservation to the Navajo Headquarters at window Rock, Arizona, and on to Canyon de Chelly National Monument, Monument Valley, the Four Corners, Petrified Forest, and the Painted Desert. Gallup itself has many points of interest and a trip to the Chamber of Commerce is recommended for additional information on the city and surrounding area.