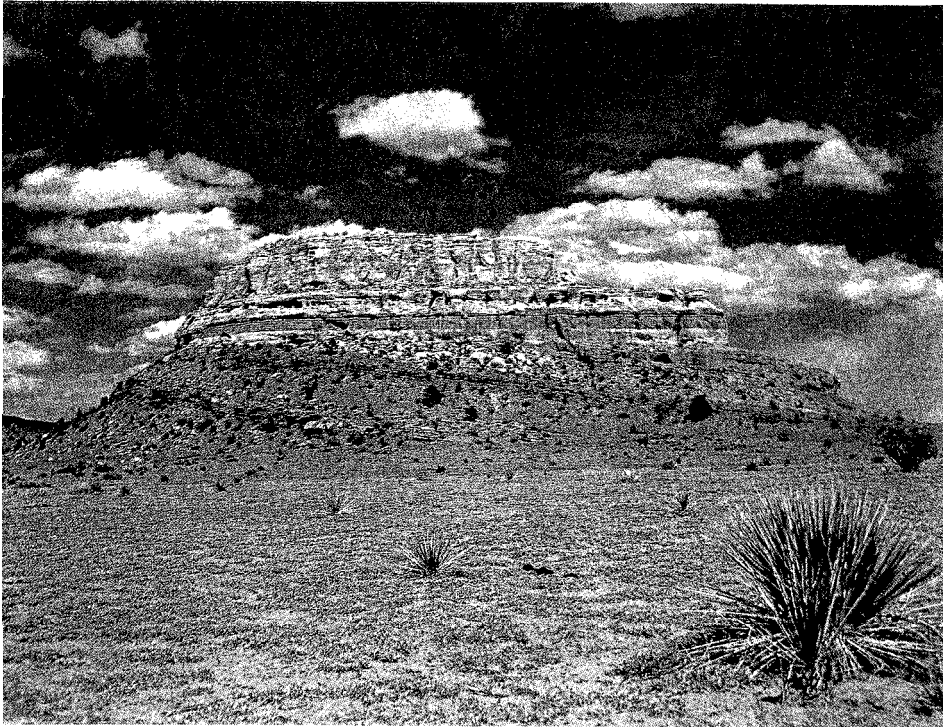


HIGH PLAINS

northeastern new mexico



scenic trips to the geologic past

capulin mountain

clayton raton

SCENIC TRIPS TO THE GEOLOGIC PAST

- No. 1 - Santa Fe, New Mexico, 1955 (25 Cents).
- No. 2 - Taos-Red River-Eagle Nest, New Mexico, Circle Drive, 1956 (25 Cents),
- No. 3 - Roswell-Capitan-Ruidoso and Bottomless Lakes Park, New Mexico, 1958 (25 cents).
- No. 4 - Southern Zuni Mountains, New Mexico, 1958 (25 cents).
- No. 5 - Silver City-Santa Rita Hurley, New Mexico, 1959 (25 cents).
- No. 6 - Trail Guide to the Upper Pecos, New Mexico, 1960 (\$1.00).
- No. 7 - High Plains - Northeastern New Mexico, Raton-Capulin Mountain-Clayton, 1961 (50 cents).

SCENIC TRIPS TO THE GEOLOGIC PAST
NO. 7

High Plains

Northeastern New Mexico
Raton Capulin Mountain -Clayton

BY
WILLIAM R. MUEHLBERGER
BREWSTER BALDWIN
AND
ROY W. FOSTER

1961
STATE BUREAU OF MINES AND MINERAL RESOURCES
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY
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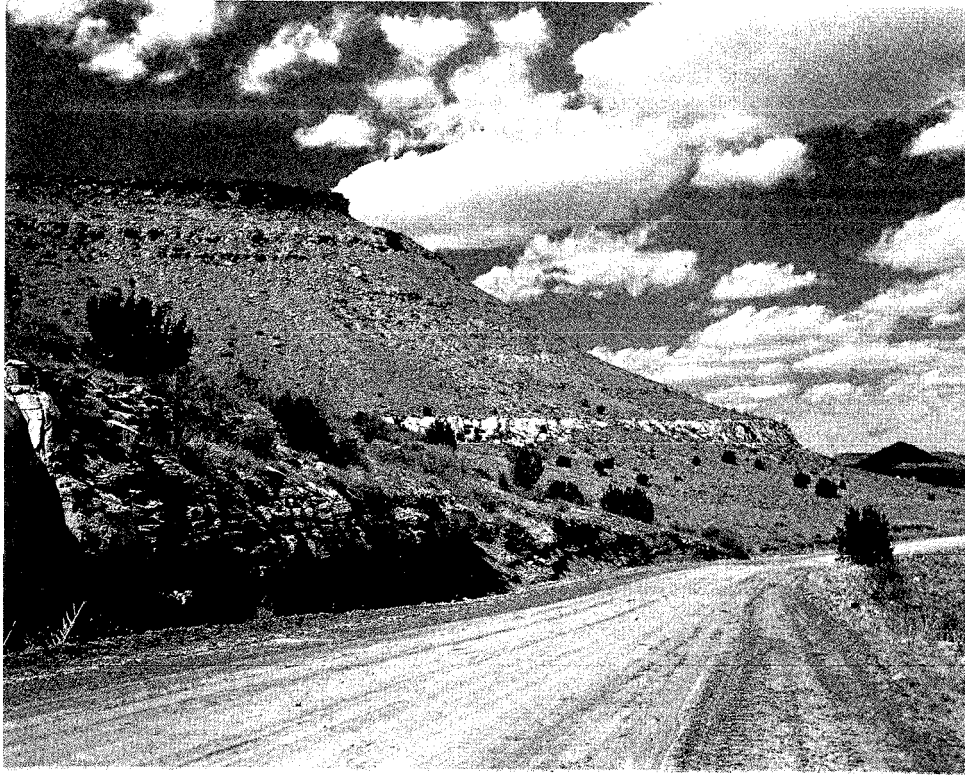
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PREFACE

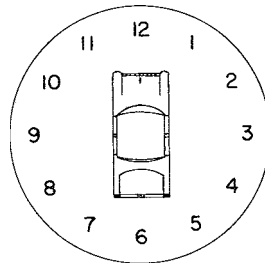
Geology, the science of the earth, embraces many specialized fields. Among these are petrology, stratigraphy, geophysics, mineralogy, paleontology, geochemistry, and volcanology. Several or all of these specialized fields may be utilized to interpret the geologic history of any particular locality. In addition to solving fundamental problems dealing with the history of the earth, the geologist, through careful geologic mapping and examination of the rocks, can indicate areas of possible economic importance. These may include the best places to drill for water or oil, the possible location and extent of metal deposits, the nearest place to find the material needed for highway construction or repair, the best location for a dam, or the location of commercial deposits of lime, clay, sand, or gypsum. Geologic projects in the area of this log were specifically designed to study the availability of ground water in Union and Colfax Counties. From these studies the farmer can determine whether there is an adequate supply of water for irrigation (and where he can find it), the rancher knows how far he has to drill to find the small quantity of water needed for his stock, and the cities and villages can tell where to locate additional good water to satisfy the demands of their expanding populations. These same studies, although designed for a specific purpose, also aid in the evaluation of the other mineral resources of the area.

The information gained from these studies is then published so that it may be available to all interested persons. Such publications are often necessarily technical, but many of the geologic features that are described are the same features that attract thousands of people every year to view the scenic wonders of the southwestern United States. In order to share in the understanding and thus further the enjoyment of these geologic features, the New Mexico Bureau of Mines and Mineral Resources publishes a series of booklets, such as this one, entitled "Scenic Trips to the Geologic Past." Other booklets in this series are listed inside the front cover.

INTRODUCTION

Much of northeastern New Mexico is covered by vast sheets of lava that poured from the more than 100 extinct volcanoes found in this region. The volcanic eruptions began possibly 10 million years ago and have continued intermittently until very recent times. Because of the great areas covered by these rocks and the excellence of the exposures, much of this guide is devoted to explaining and exploring this complex series of lava flows. In some areas, such as along the Dry Cimarron River and around Raton, there is also an opportunity to observe the much older rocks that underlie the lava cover.

Four road logs make up the principal part of this guidebook. These describe the geology of a large portion of northeastern New Mexico as seen from the major State and Federal highways. The road logs indicate the distances between points of interest and a running total of the mileage covered on each log. Suggested stops are strategically placed where the geologic features that have been seen can be reviewed. The logs can be used independently, but they interlock to make one grand tour of the whole area. In order to locate points of interest, the o'clock system is used, with the front of the car being 12 o'clock, the rear 6 o'clock, etc. The diagram below illustrates this system.



In addition to the road logs, there is a route map indicating the four planned trips and showing the distribution of volcanic rocks in northeastern New Mexico; a glossary of geologic terms that have been underlined in the text; a brief sketch of the geologic history of the area for the last billion years or so; and a more detailed discussion of the relatively recent volcanic history. Included also are brief historical sketches of the towns you will see along the way and of the famous Santa Fe Trail, the ruts of which are still visible along the route of the tour.

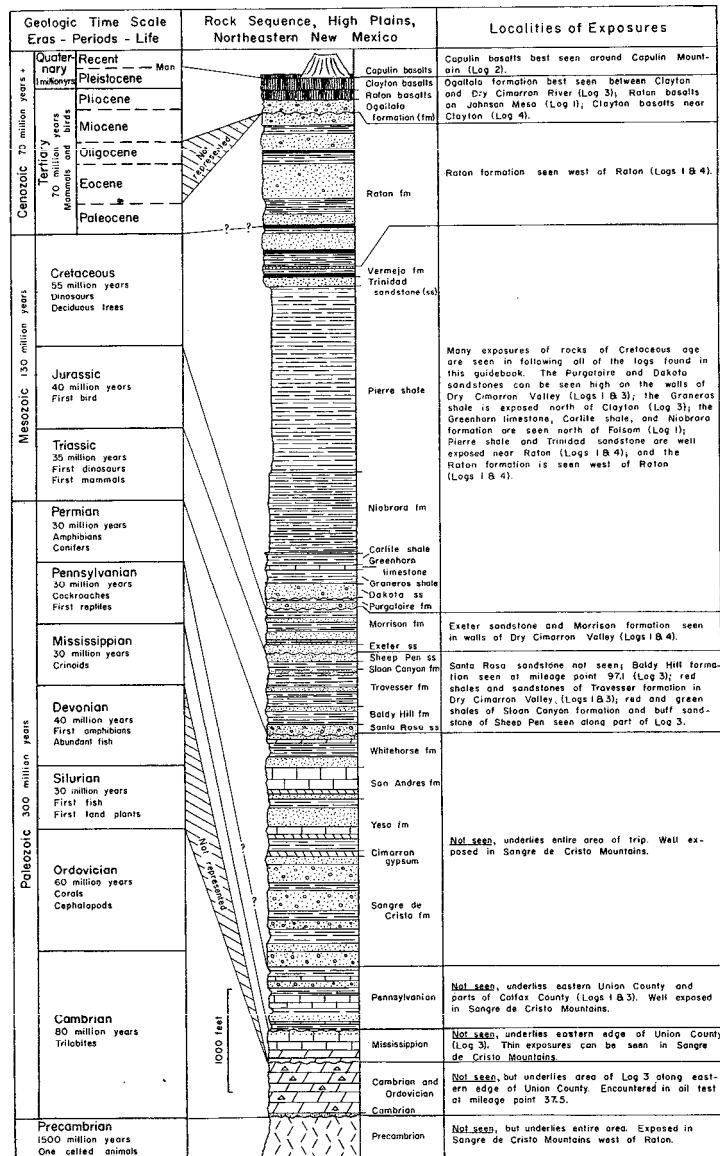
Northeastern New Mexico encompasses some of the most attractive scenery to be found in the southwestern United States, from gently rolling grass-covered ranch lands to lofty volcanic peaks, and from high mesas to deep, colorful canyons. At opposite ends of the area are the small, clean, hospitable cities of Raton and Clayton, both providing excellent overnight accommodations. The authors hope that this guidebook will add to your understanding and enjoyment of this fascinating region, whether you are a native of New Mexico or just passing through. Naturally, the major Federal highways are governed by the shortest distance between two points and the path of least resistance, a combination that usually takes us away from the more scenic areas. In particular, it is hoped that this booklet will tempt you (if time is available) to leave the more frequented paths to see parts of New Mexico only rarely visited.

GEOLOGIC HISTORY OF NORTHEASTERN NEW MEXICO

The oldest rocks known in northeastern New Mexico are the Precambrian granites, gneisses, and schists exposed in the Sangre de Cristo Mountains, west of Raton. These rocks are buried east of the Sangre de Cristo Mountains and have been warped down into a deep trough under Raton called the Raton basin. The eastern limb of this basin is the Sierra Grande arch, a structurally high element where the Precambrian basement granites are brought to about 4,000 feet above sea level along a line that trends nearly parallel to the Colfax—Union County line. East of this, near the Texas-Oklahoma line, the basement surface slopes downward to below sea level,

The Sierra Grande arch apparently has been uplifted several times since the Precambrian because we find evidences of materials being derived from it and deposited in nearby areas. This is particularly well demonstrated in Union County where several wells have penetrated all the sedimentary rocks to the Precambrian and have enabled us to outline the geologic history of these early times.

Early Paleozoic rocks are neither well represented nor well known in this area. Cambrian and Ordovician marine limestone and sandstone are found only in the eastern part of Union County. Mississippian marine limestone extends across the older limestones into central Union County. The late Pennsylvanian uplift of the Sierra Grande arch, as well as part of the area now occupied by the Sangre de Cristo Mountains (the ancestral Rocky Mountains), furnished a tremendous amount of clastic rocks -- arkoses, mudstones, conglomerates, and sandstones that were spread in broad flood plains across northeastern New Mexico. The Sierra Grande arch supplied some of the earlier materials to the region of Union County and probably supplied the eastern part of Colfax County as well before it was buried by the tremendous mass of alluvial detritus from the ancestral Rocky Mountains to the west. Much of this is known as the Sangre de Cristo formation, which underlies all of Colfax and Union Counties and is exposed along the east front of the Sangre de Cristo Mountains. This formation is overlain by thin layers that were deposited near shore in a shallow arm of the deep Permian sea that occupied southeastern New Mexico and west Texas. Evaporites, such as gypsum, and sandstones and mudstones of the near-shore and continental facies of the Permian sea make up what is now called the Yeso formation. These rocks are overlain by a marine sequence of limestone,



Rock sequence northeastern New Mexico and standard geologic time scale

gypsum, and sandstone which constitutes the San Andres formation. These rocks were slightly folded, warped and eroded prior to the deposition of rocks of Triassic age. These are generally sandstones and mudstones of flood-plain origin, again material being derived from the ancestral Rockies and spreading out in broad, long river flats.

The Triassic units contain dinosaur bones in eastern New Mexico, and the tracks of some of these dinosaurs have been found in the northeast corner of Union County. At the close of Triassic time, the sediments were slightly warped and eroded before they were covered by sediments of Jurassic age. The Jurassic rocks begin with the Exeter sandstone, a sand dune deposit, probably near a shallow sea or lake. Brown silts of the overlying lower Morrison formation represent lake bottom deposits. Most of the remainder of the Morrison formation consists of the typical flood-plain silts and muds of slow, sluggish streams. During Cretaceous time the sea once again gradually encroached upon this area. The Purgatoire formation at the base of the Cretaceous interval consists of a lower sandstone interval (probably nearshore marine deposits) overlain by a black clay or black mud layer (offshore marine deposits). This is overlain, with a slight unconformity, by the Dakota formation which consists of a lower portion of sandy flood-plain stream deposits derived from the Rocky Mountain region, a middle portion that contains some coals, and an upper portion of marine sandstone. The upper sandstone was deposited in a sea that covered most of west-central North America during the final invasion of marine waters into the interior of the continent. The thick black shales (Niobrara and Pierre) and thin dark limestones (Greenhorn and Fort Hays) seen in the Raton area, were also deposited in this sea.

There are no rocks of early and middle Cenozoic age in this area, but events of that part of geologic time can be inferred from studies of areas to the west in and near the Sangre de Cristo Mountains. The late Cretaceous sea, in which were deposited the Benton group, the Niobrara formation, and the Pierre shale, began to drain off near the end of the Cretaceous period. Uplift in or west of the Sangre de Cristo Mountains evidently began late in the Cretaceous period and continued to the end of the Eocene Epoch. The non-marine sediments of latest Cretaceous and early Tertiary age, now exposed in the big cliffs near Raton, were derived from rocks in the uplifted area and were spread as littoral and continental deposits eastward toward and perhaps into Union County. Although the uplifting may have originally consisted largely of

upwarping, it later involved intense folding and thrusting, which is dated as late Eocene. By the end of the Eocene Epoch the gross features of the eastern part of the Sangre de Cristo Mountains were formed. Piedmont deposition east of the mountains continued until about the end of the Eocene Epoch after which the region was eroded by streams. Mild deformation and the formation of the Sierra Grande arch as it is today occurred at the time of the folding and thrusting in the mountains to the west. In the Chico Hills area of southeastern Colfax County thick sills of igneous rocks were intruded at this time.

East of the Sangre de Cristo Mountains, erosion during the Oligocene and Miocene Epochs produced a rolling plain, sloping eastward and possibly southeastward from the Raton region. In the vicinity of Clayton local relief on this plain is as much as 200 feet. Except in local areas where limestone beds served as protective caps to preserve soft shale hills, streams east of Raton removed most of the soft Cretaceous marine shales and limestones down to the resistant sandstones of the Dakota formation. In parts of the south panhandle of Union County, and in monoclinal warps, erosion exposed beds as old as the Jurassic Morrison formation and the Triassic Dockum group. From late Miocene into the Pliocene Epoch, and indeed almost to the present, there was continued uplift of mountain blocks, forming the present day mountains of north central New Mexico. As a result of this mountain building, the Rio Grande structural trough formed and was filled with (Santa Fe group) sediments eroded from the rising mountains. The streams draining the eastern flank deposited an extensive blanket of upland deposits clay, silt, sand, and gravel -- east of the mountains. This material, mostly the Ogallala formation, was deposited at first in valleys and, as the valleys filled, moved across the hills of the mid-Cenozoic piedmont plain. As a result, the late Cenozoic sediments rest on different Mesozoic formations in different places. Volcanic activity probably began late in the Pliocene Epoch and has continued almost to the present day. Downcutting and the formation of local alluvial deposits have accompanied the volcanic activity.

The present erosion cycle began with the warping of the piedmont in the Late Pliocene and the uplifting of the mountains to the west.

VOLCANIC SEQUENCE (LATE CENOZOIC ERA) IN NORTHEASTERN NEW MEXICO

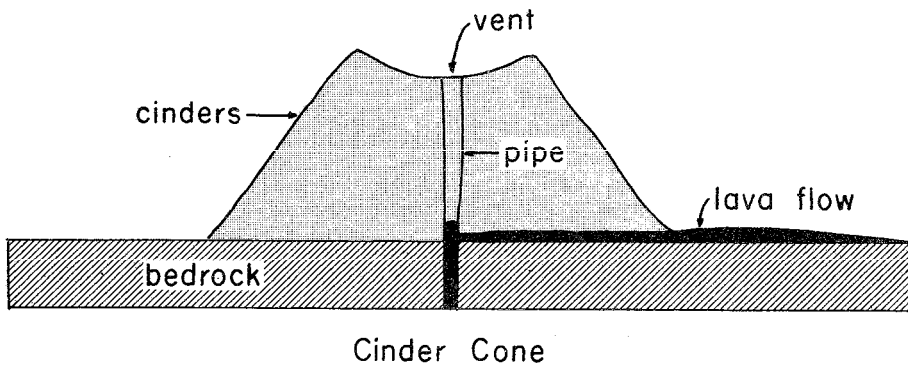
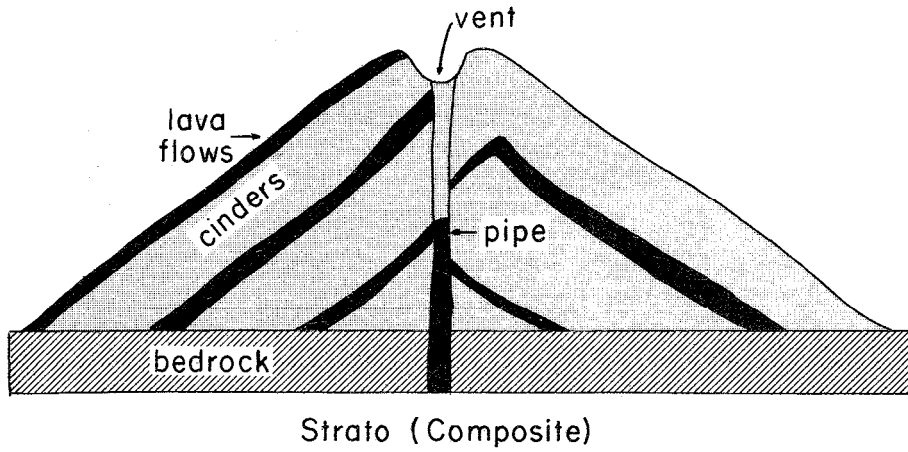
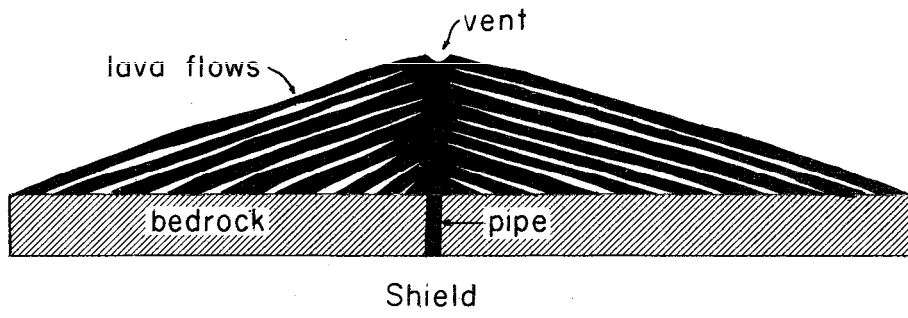
Volcanic rocks cover about one-fourth of the area of this guidebook. The rocks are mostly basaltic and consist of lava flows -- commonly called "malpais" -- and piles of cinders and volcanic centers. Northeastern New Mexico is part of a larger volcanic province which extends northward into the southeastern portion of Colorado. More than a hundred volcanoes have been recognized in this region. All of them were active intermittently from Pliocene to Recent time (for the past 5 or 10 million years), and there is no reason to believe that activity has ceased completely

Classification of Volcanoes

Geologists classify volcanoes according to their shapes into cinder cones, shield volcanoes, and stratovolcanoes. These shapes tell us whether the eruptions were relatively quiet or very explosive. We also can tell how liquid the lava was -- as thick as molasses in January or as thin as molasses on a hot day in July.

Shield volcanoes: A very fluid lava that allows its contained gases to escape easily will flow away rapidly from its point of exit. Successive layers will tend to be thin and widespread. The slope of the layers will be low. As this type of lava freezes, it builds a broad, gently sloping cone that is called a shield volcano. The best known examples of this type are Mauna Loa and Kilauea on the Island of Hawaii. An example in Union County, New Mexico, is Cieneguilla del Burro Mountain, near Mt. Dora. Sierra Grande, the largest volcano in northeastern New Mexico, is probably of this type. Although the steepness of slope of Sierra Grande suggests that it may be intermediate into the stratovolcano group, that steepness is probably the result of the composition of the lava.

Lava flows from these broad, low shield volcanoes cover large areas. Because the lava was so fluid, it often failed to form a mound over the vent and in some areas the vent itself cannot be found. When hardened, the lava is more resistant to erosion than are the underlying sands and shales. The cap of lava thus protects the soft rock under it from wind and rain so that the stream valleys into which the lava once flowed now stand as the high mesas above the modern stream valleys. Johnson Mesa, Oak Canyon



Types of volcanoes.

Mesa, Larga Mesa, Clayton Mesa, and others show this inversion of relief (the old stream valleys are now high areas) in northeastern New Mexico.

Stratovolcanoes: Material blown out of a volcano freezes in the air and lands as solid material. The largest pieces are still soft and bend when they hit. Some of the pieces are shaped like bullets and bombs, although most are irregular. This type of material, ranging in size from dust to fragments 5 or more feet long, is collectively called pyroclastic rock to distinguish it from flow rock.

Pyroclastics can build steep-walled cones because of the shapes and sizes of material involved (like a giant sand and gravel heap).

Stratovolcanoes have steeper slopes than shield volcanoes because the eruptions were violent enough that considerable amounts of pyroclastics, as well as lava, were erupted. A cross-section through a stratovolcano shows alternate layers of flow rock and pyroclastic rock. Thus the outer slope gets steeper as you go up the cone. Stratovolcanoes vary in shape and size, depending on the relative proportions of pyroclastic to flow rock and on how much volcanic material was erupted. Many of the famous volcanoes of the world are stratovolcanoes: Mt. Fujiyama, Japan; Vesuvius, Italy; Mt. Etna, Sicily; Mts. Lassen and Shasta, California; Mt. Rainier, Washington; and many others. Many of the prominent peaks of the Raton-Clayton region belong in this group. Erosion of the cones since their eruptions has destroyed the typical shape, but the remnants show that they are composed of both pyroclastic and flow rocks. Robinson Mountain, Sierra Clayton, Rabbit Ears Mountain, and Laughlin Peak are examples of small stratovolcanoes although they all tend to be closer to the next variety

Cinder cones: The best preserved volcanoes in northeastern New Mexico, and also the most recent, are those composed only of pyroclastic material, the cinder cones. The fact that these are called cones and not volcanoes indicates that they are generally small. Capulin Mountain is a truly outstanding example of this type. The road spiraling up its side is notched into the cone, and the layering of the cinders is visible in the cuts. Twin Mountain, Baby Capulin, and Horseshoe Mountain (all visible from Capulin Mountain) are also excellent examples of cinder cones. Capulin Mountain is at least 4,500 years old and is less than

10,000 years old. Both Baby Capulin and Twin Mountain are younger than Capulin, although how much younger is not known. The relative age of Horseshoe Mountain (5 miles south of Capulin Mountain) is not known, although it is believed to be of the same general age as the other cinder cones in the vicinity.

Associated with the cinder cones are lava flows which poured out of cracks in the base of the cones rather than spilling over the top as in shield volcanoes and stratovolcanoes. Because cinder cones are too weak to hold together under the pressure of lava filling it to the rim, they break, and lava pours out the base.

Any of the above volcano types could erupt from a long crack in the ground rather than a round hole. The volcano would then be elongated along the direction of the crack. An excellent example of this is Twin Mountain, a typical fissure vent with associated cinder cones, which are known as the Purvine Hills. Strings of volcanoes along lines are indications of the planes of weakness up which the lava rose to the surface. Many alignments can be demonstrated in northeastern Union County. The outstanding example is the Don Carlos Hills in southwestern Union County. Here 16 extinct volcanoes lie along a line only 14 miles long, a perfect example of a fissure eruption. Other good examples of alignments are Baby Capulin, Twin Mountain, and the Purvine Hills, the vents between Cieneguilla del Burro Mountain (Mt. Dora) and Rabbit Ears Mountain, and the string of volcanoes extending WNW-ESE through Sierra Clayton. The alignments are all from west to west-northwest in this region.

Volcanic Sequence .Northeastern New Mexico

The various flows and pyroclastic deposits found in north-eastern New Mexico have been grouped into three major periods of eruptions (see map of area covered by this guide). The earliest of these is the Raton sequence of flows that now caps the high mesas (Johnson, Oak Canyon, Black) east of Raton, New Mexico. Following erosion of the Raton-age basalts, the slightly younger Clayton-age sequence of flows poured forth. These are represented by extensive areas of basaltic rocks between Clayton and Sierra Grande. The more silicic rocks of Sierra Grande, Laughlin Peak, and Red Mountain probably also represent Clayton-age eruptions. The most recent phase of volcanic activity is represented by the Capulin-age flows and cinder cones such as Capulin, Baby Capulin, and Mud Hill.

Present Features of Volcanic Rocks

The older flows, such as the Raton basalts, now have smooth, grassed-over upper surfaces with only scattered outcrops of basalt. The basalt cliff that rims the high, basalt-capped mesas represents only the lower part of the flow; for the ground rises beyond the cliff. Evidently the more porous and broken basalt in the upper part of the flow has been weathered back from the margin, pressure ridges have been weathered down, and low places have been largely filled. Ditches for sewer lines in the town of Clayton have shown that the surface of the malpais is uneven, although the present land surface is smooth. Probably all of the flows originally had a rough surface the true malpais, characterized by pressure ridges and natural levees such as can be seen in the more recent flows like those from Capulin Mountain. The Capulin-age flows that cover the broad flats and valleys of the present land surface have scarcely been modified by geologic processes in the few thousand years since they were formed.

The older volcanic centers have also been considerably modified by erosion. Rabbit Ear Mountain is a good example; the face that slopes southwest on the southwest flank is all that remains of the outer surface of the original volcano. Sierra Clayton is better preserved, although the crater has been breached by streams. Robinson Mountain and José Butte are similar in preservation to Sierra Clayton. Older volcanoes have been almost completely destroyed by erosion. These have been recognized as volcanic centers only because they stand somewhat above the surrounding land and because loose cinders are found in the vicinity. On the other hand, the most recent volcanoes are scarcely modified by erosion. Capulin Mountain has been set aside as a national monument because it is such a perfect example of a cinder cone.

An interesting feature of many of the volcanoes is that the craters open to the southwest or west. This breaching of the craters suggests that when the volcanoes were active, the prevailing winds were from the southwest or west and that the cinders tended to accumulate on the opposite flank.

GLOSSARY
(Words underlined in road logs)

- AGATE - A transparent or translucent variety of quartz which has a waxy luster and in which the different colors are in bands, clouds, or distinct groups.
- ALLUVIUM - A general term for all detrital material deposited by modern rivers, thus including the sediments laid down in river beds, floodplains, lakes, or fans.
- ANDESITE - A volcanic rock composed principally of plagioclase feldspar.
- ANGULAR UNCONFORMITY - The older strata dip at an angle different from the younger strata, the two angles of dip meeting at a surface of erosion cut on the older strata.
- ANTICLINE - A fold in which the rocks dip away from a common axis.
- ARTESIAN WATER - Groundwater that is under sufficient pressure to rise above the level at which it is encountered in a well. The water may or may not rise above the surface of the ground.
- ASH - Fragments blown from a volcano about the size of small peas or shot.
- AUGITE - A mineral belonging to the pyroxene group consisting of a silicate of calcium, magnesium and iron.
- BASALT - A dark-colored, dense to fine-grained igneous rock consisting of the minerals feldspar (generally the plagioclase feldspars bytownite or labradorite which are silicates of calcium, sodium, and aluminum), olivine, and pyroxene (silicates containing iron and magnesium).
- BASIN - A large depressed area with strata dipping inward toward a common axis.
- BOMBS - Fragments from the size of an apple upward blown from a volcano.
- BUTTE - An isolated hill or mountain separated from a mesa by erosion, thus a small mesa.
- CALCITE - See calcium carbonate.
- CALCIUM CARBONATE - (CaCO_3) A solid, occurring in nature as the mineral calcite.
- CALICHE - Gravel, sand, silt, etc., cemented by calcium carbonate. Also may consist of almost pure calcium carbonate. Occurs at the surface or near the base of the upper soil layers.
- CARBON DIOXIDE - (CO_2) A heavy, colorless gas, when solid is known as dry ice.

CEPHALOPOD - A marine invertebrate that in most fossil forms consists of a calcareous shell divided into numerous chambers. Living forms are the pearly nautilus, squid, and octopus

CHALCEDONY - A transparent to translucent variety of quartz having a waxy luster. May be white, blue, brown, gray, or black.

CINDERS - Nut-sized fragments blown from a volcano during eruption.

CLASTIC PLUG - A sandstone mass that cuts across the bedding of a sedimentary formation or formations having been intruded as mobile sand either from above or below.

CLAY - A material with plastic properties made up of grains less than 1/256 mm.

COAL - A black-colored, compact and earthy organic rock formed by the accumulation and partial decomposition of plant material.

CRATER - A steep walled depression on top of a volcanic cone above the pipe or vent that feeds the volcano.

CROSSBEDDING - Internal lamination of strata inclined to the bedding planes of sedimentary rocks.

DACITE - A volcanic rock consisting of the minerals feldspar (both plagioclase and orthoclase feldspars, which are silicates of sodium, calcium and aluminum), quartz, and dark minerals such as pyroxene.

DIKE - A tabular body of rock that cuts across another rock or rocks.

DIP - The angle between a horizontal line and the inclination of any planar feature, such as bedding in sedimentary rocks.

EROSION - Lowering of ground surface through removal of material by streams or wind.

FAULT - A fracture in rocks along which one side has moved relative to the other side.

FISSURE VENT - An elongate crack in the earth's surface from which is erupted lava or pyroclastic material.

FOLD - A bend in any planar structure,

FORMATION - A rock unit, established for convenience of mapping or description, consisting of one or more types of rocks deposited essentially without interruption and usually distinctive from rock units above and below.

GRAVEL - Unconsolidated, water-transported rock or mineral fragments ranging in size from 2 mm. up.

GROUP - A rock unit combining two or more formations.

GYPSUM - A colorless, or white, gray, brown, red, black, or yellow mineral made up of calcium, sulfur, oxygen, and

water. Varieties are selenite, alabaster, satin spar and others. Used to make plaster of paris and gypsum board insulation. Soft enough to scratch with a finger nail.

HAÜTYNITE – A mineral of the sodalite group consisting of a silicate of sodium, calcium and aluminum.

HEMATITE - Oxide of iron (Fe_2O_3). May be of red earthy color or metallic appearing. Principal ore of iron.

LANDSLIDE - Mass of earth, rock, or mixture of the two, which becomes loosened and slides or falls down a slope.

LAVA - Fluid rock that issues from volcano or fissure in earth's surface; also applied to same material after it solidifies.

LIMESTONE – A bedded sedimentary deposit consisting chiefly of calcite.

MALPAIS - Spanish for bad lands - usually applied to the rough-surfaced areas covered by basalt.

MESA - A flat-topped surface bounded on one or more sides by a steep cliff.

MONOCLINE - A fold in which the amount of dip of the beds changes from gentle to steep and back to gentle, usually with the beds inclined in a single direction.

MUDSTONE – An indurated sedimentary deposit made up of particles of clay, silt, and sand size.

PLUNGE POOL – A pit in the stream bottom occurring at the foot of a waterfall.

PRESSURE RIDGE - An elongate wrinkling of the crust of a lava flow, apparently caused by the viscous drag of lava moving beneath a solidified crust.

SAND - Unconsolidated grains ranging in size from 1/16 to 2 mm.

SANDSTONE - An indurated sedimentary deposit consisting of grains of minerals or rocks of sand size (1/16-2mm). Most sandstones consist largely of quartz (SiO_2).

SHALE - A finely laminated, indurated sediment composed of particles mostly of clay size (<1/256 mm).

SILT - Unconsolidated grains ranging in size from 1/256 to 1/16 mm.

SILTSTONE - An indurated sedimentary deposit consisting of grains of silt size.

SLUSH PIT - A hole dug in the ground to store the water or mud used in drilling a well with a rotary drilling rig.

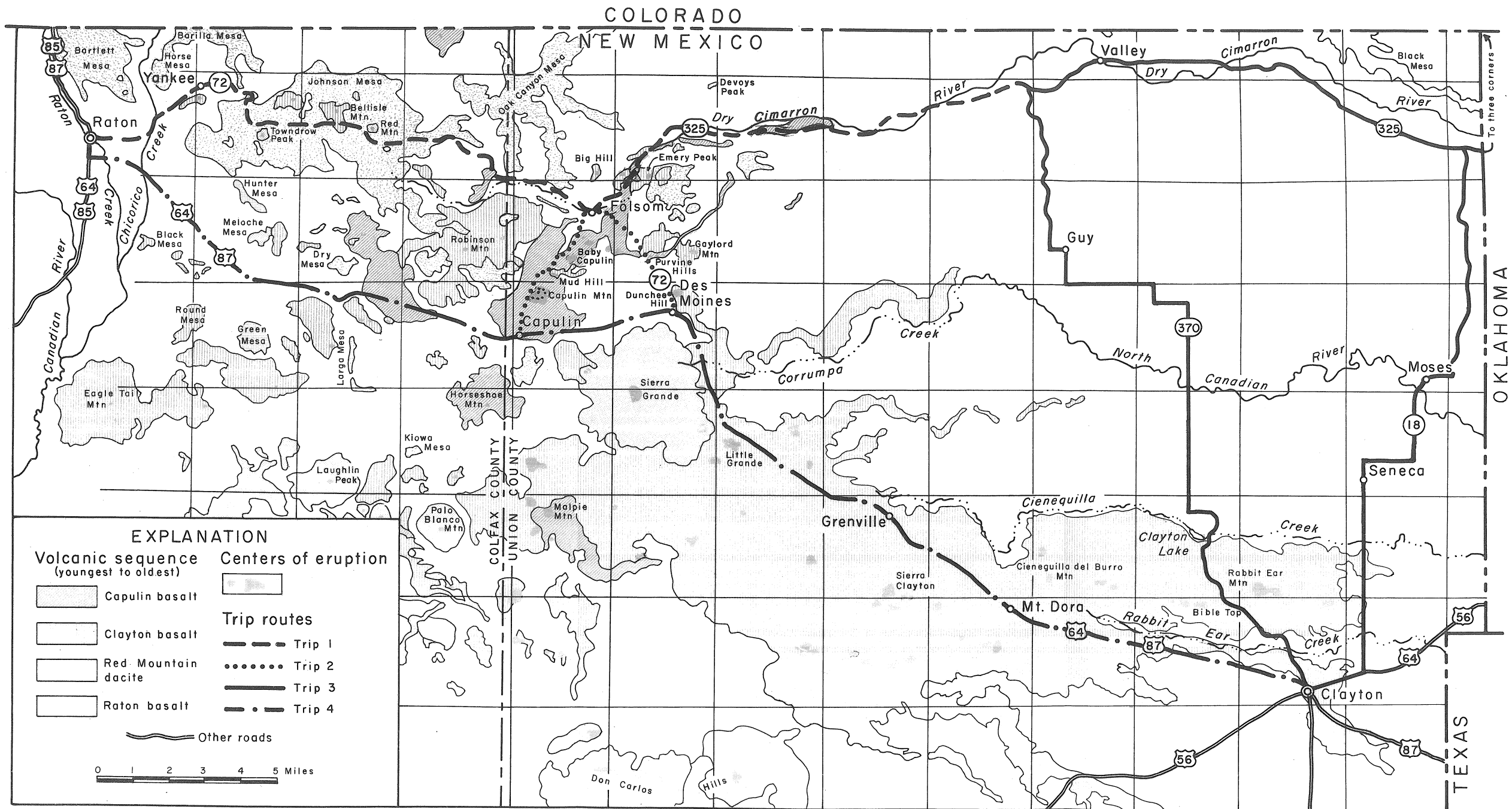
TALUS - Rock fragments piled up at the bottom of a steep slope or cliff.

TERRACE - Relatively flat benches on a hillside. Generally remnants of former stream valleys.

TYPE LOCALITY - The specific location where a formation is typically displayed and from which it is named. The name

coming from a local physiographic or cultural feature such as a town or rail siding, or a hill or creek.

VOLCANO - A vent in the earth's crust from which molten lava, pyroclastic material, volcanic gases, etc. issue.



Route map and distribution of volcanic rocks, northeastern New Mexico

LOG 1: RATON-JOHNSON MESA-FOLSOM-DRY CIMARRON RIVER

(69.0 miles)

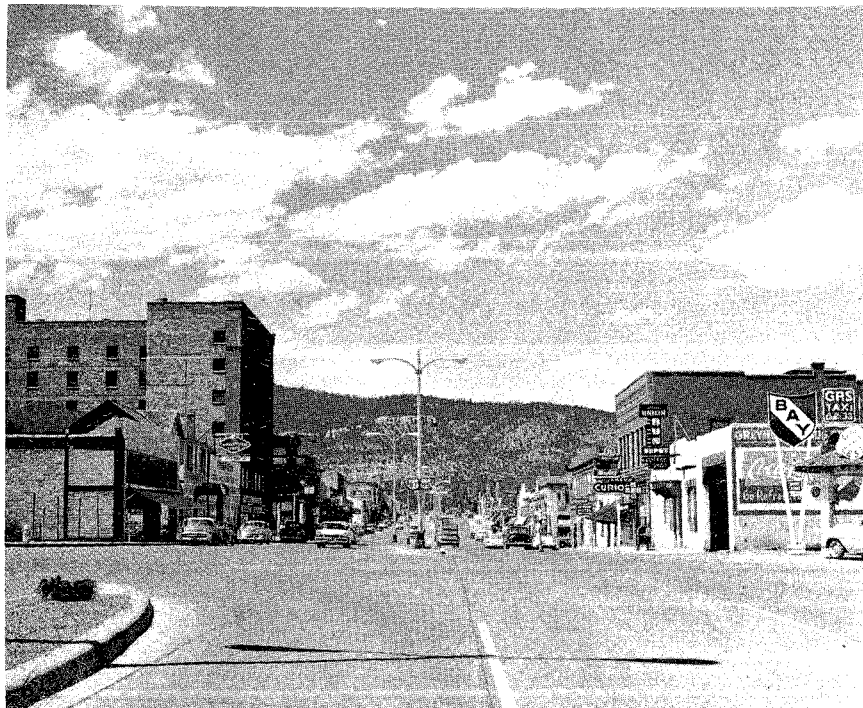
A short distance east of Raton the road (N. Mex. 72) abruptly ascends past numerous abandoned coal mines to the top of Johnson Mesa, a broad, treeless, lake-dotted, gently rolling, grassy plain. At the eastern end of this mesa, near the site of the original Folsom Man discovery, the road winds down into the headwaters and upper valley of the Dry Cimarron River. From Raton, at an altitude of 6,600 feet, the road reaches an altitude of over 8,000 feet on Johnson Mesa, then drops to about 5,500 feet at the end of the log. Both scenically and geologically, this is one of the most spectacular drives in New Mexico. Although all but a few miles of the road is unpaved, it is well maintained, and except for short periods during the winter months and following heavy summer thunderstorms, it is readily passable in a passenger car. Elsewhere in this guidebook are logs leading to Clayton, Capulin Mountain National Monument, and back to Raton via paved U. S. 64-87.

In the first 10 miles of this log the route crosses outcrops of the Cretaceous Pierre shale and Trinidad sandstone until it reaches Johnson Mesa. This high mesa is capped by part of a sequence of Tertiary flows called the Raton basalts. These rocks are traversed for about 15 miles to the east end of Johnson Mesa. As the route descends from the mesa top into the headwaters of the Dry Cimarron River, there are limited exposures of the sands and gravels of the Tertiary Ogallala formation and of the Cretaceous Niobrara shale, Fort Hays limestone, Carlile shale, and Greenhorn limestone. Also seen along this segment of the log are extensive exposures of a sequence of basalt flows, younger than the Raton basalts but also of Tertiary age, that have been grouped together as the Clayton basalts. In the valley below Johnson Mesa is a third large group of eruptive rocks that are called the Capulin basalts. This last group represents the youngest series of eruptions in northeastern New Mexico. A discussion of the complex sequence of flows in this area is included at mileage point 38.7 in this log.

Continuing down the valley of the Dry Cimarron River for another 30 miles, the oldest Cretaceous rocks present in the area, consisting of the Dakota and Purgatoire formations, cap the mesas

on both sides of the valley. Beneath these resistant sandstone cliffs the soft, colorful shales and sands of the Jurassic Morrison formation form a steep slope ending at the white sandstone cliff of the Exeter sandstone also of Jurassic age. Low on the canyon walls and flooring the valley of the river are the vivid red shales of the Triassic Travesser formation. At the end of the log the oldest rocks exposed in northeastern New Mexico, consisting of the Triassic Baldy Hill formation, are seen.

Raton (altitude 6,660 feet; population about 9,700) was settled in 1879 with the arrival of the Atlantic and Pacific Railroad (Santa Fe Railway). The extensive coal deposits in the mesas surrounding Raton contributed greatly to the growth of the town during the age of the steam locomotive. Today Raton is the central marketing area for a large part of north-central New Mexico, serving numerous widely scattered ranches and small farms. Industries, in addition to coal mining, include lumbering, manufacturing, and the very important tourist trade.



Raton, New Mexico.

- 0.0 Log starts at junction of U. S. 85 and N. Mex. 72 on north side of Raton. Go east through underpass below Atchison, Topeka & Santa Fe Railway tracks.
- 0.1 Veer right following N. Mex. 72 signs
- 0.5 Road curves left.
- 0.7 From 9 to 10 o'clock on skyline is Raton-basalt-capped Bartlett Mesa. At 8 o'clock is southern tip of Bartlett Mesa. Forming bold cliffs about half-way down are nearly horizontal layers of the light-colored Trinidad sandstone. There are other sandy formations above the Trinidad sandstone in this region, but they do not form such bold and continuous cliffs.
- 0.8 Road turns right. As you drive past the park on your right (west), you get a good view of the cliffs west of Raton, with their light-colored bands of Trinidad sandstone. Coal has been extensively mined in this region from this sequence of beds.
- 1.0 Road makes left turn.
- 1.1 Cross Interstate Highway 25.
- 1.2 Bridge over branch of Raton Creek.
- 1.3 Large gravel pit at 10 o'clock. The gravels were stream deposited in an ancient valley that is now preserved as a high ridge extending northward toward the foot of the mountains

A younger but also abandoned valley (now a terrace) can be seen extending south from the highway and rimming the lake at 3 o'clock.

Johnson Mesa, on skyline, straight ahead. Hunter Mesa, at 12:30 o'clock, Meloche Mesa (with north tilt) at 10 o'clock. Whole southern skyline is rimmed with extinct volcanoes.

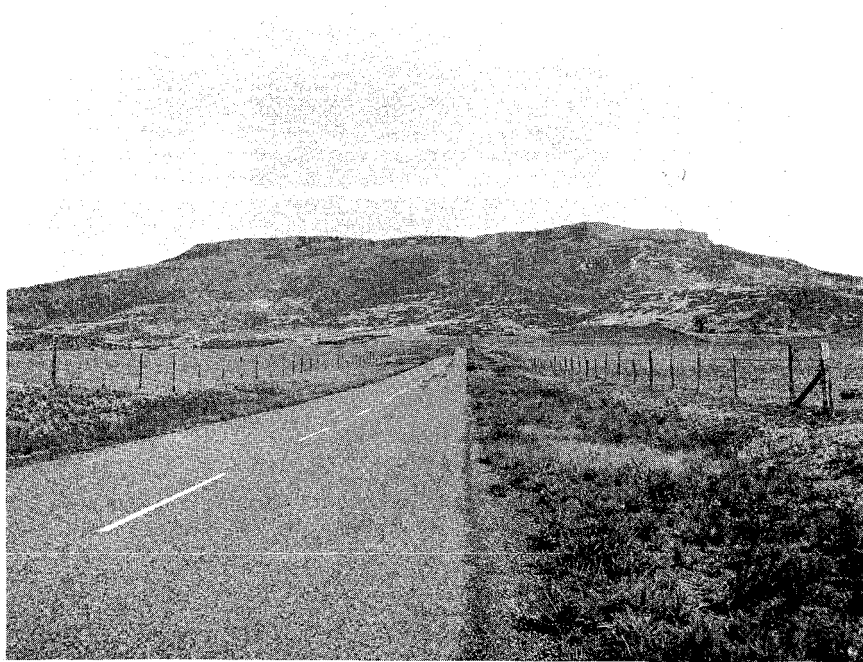
- 1.9 Crest of hill. Ranch road enters from right. Roadcut on left shows upper Cretaceous marine black shale (Pierre shale) capped by stream gravel. Ahead across the narrow valley, the road climbs onto another terrace, a gravel-capped stream valley remnant.

To the north at 10 o'clock are light-colored cliffs of Trinidad sandstone rising eastward away from the center of the Raton basin.

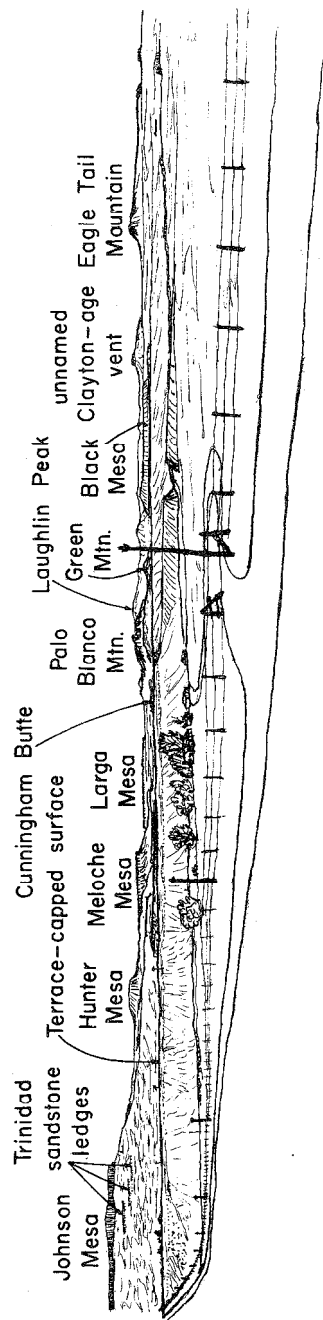
At 11 o'clock on the distant skyline is Barilla Mesa, capped by the older Raton basalt sequence.

- 2.1 Bridge.

- 2.2 Roadcuts show Pierre shale with capping of stream gravel.



Johnson Mesa: Terrace remnant just above fence on right.

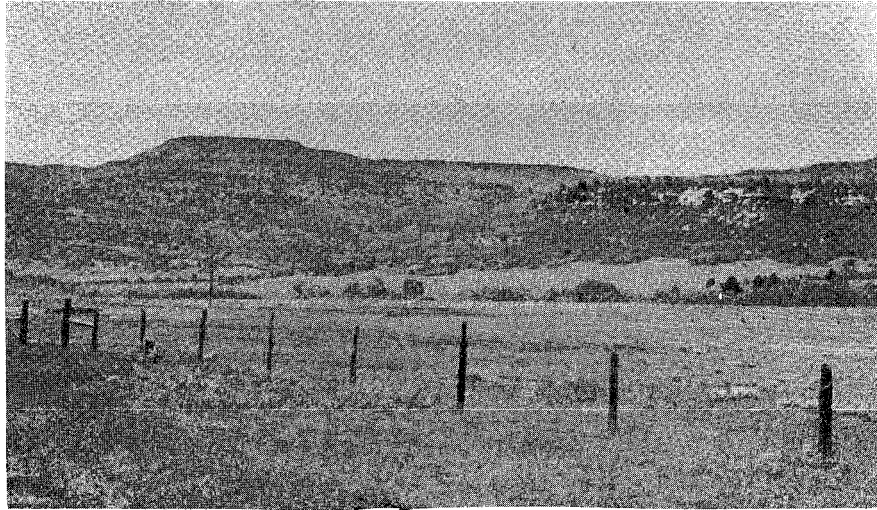


Panorama from mileage point 1.9.

- 2.9 Narrow culvert. Ahead just beyond where road turns left and extending to right are more remnants of the gravel-capped valley we were last on.
- 3.2 Road turns sharply left. Ranch road enters from right.
- 3.4 Straight ahead are cliffs of Trinidad sandstone.
- 3.5 On left are embankments of the abandoned Santa Fe railroad bed to Yankee, a ghost coal-mining community.
- Roadcuts ahead show marine Pierre shale with stream gravel caps.
- 4.0 At 12:30 o'clock in middle ground is mesa capped with basalt from Yankee volcano of Clayton age. Road now follows Chicorico Creek.
- 4.4 At 9 o'clock at left end of Trinidad sandstone cliffs is the black dump from a small coal mine.
- 4.7 Ahead is Horse Mesa, capped by the younger sequence of Raton basalt. Trinidad sandstone forms a prominent belt of cliffs on the middle of the hillside.
- 4.9 Road turns right to cross Chicorico Creek and continues up the East Fork. Lake Maloya (fishing) straight ahead.
- 5.1 Large gravel pit at 11 o'clock in gravel terrace cap of older stream valley. At 9 o'clock up main Chicorico Creek can be seen large mine dumps (both sides of valley) near the old coal mining town of Sugarite.
- 5.6 Bridge over east Fork of Chicorico Creek. Pierre shale in stream bank on right.
- 5.8 Ranch road enters from left.
- 6.2 On near skyline at 12:30 o'clock is basalt from a Clayton-age Yankee volcano.
- At 9 o'clock on left is a switchback road up to a coal mine.

- 6.7 Bridge.
- 7.1 At 1 o'clock is Yankee volcano. When it erupted, this valley floor was level with the base of the lava flow extending to 3 o'clock from the cone. Erosion since the time of its eruption has lowered the valley floor to its present position.
- At 9 o'clock, halfway up the hillside, you can see several coal mine dumps and head frames. Younger sequence of Raton basalt caps Horse Mesa above the mines.
- 7.6 Road enters from left. More coal mine dumps at 9 o'clock on left. White band of lowest bed in Trinidad sandstone forms prominent cliff from 1012 o'clock. Barilla Mesa on skyline ahead.
- 8.2 Entrance to Turner Hereford Ranch on left. o
- 8.6 Ranch road to right. The town of Yankee existed in this area for a short time. The venture was started by eastern investors who promoted the railroad line into Yankee. The venture failed, and the town was abandoned. You can see many of the coal mines, some still operated by individuals, on the slopes behind us on the flanks of Horse Mesa.
- The region is now devoted to ranching. The few pine trees are all that remain after the early logging operations.
- From this point, the gradual eastward climb of the Trinidad sandstone out of the center of the Raton basin can be seen by tracing the massive cliffs from 9 o'clock on to 12 o'clock and then onto Johnson Mesa at 1 o'clock.
- 9.6 End of pavement. Road ahead poor when rains have drenched the region. Scrub Oak, Ponderosa pine, and cottonwood trees flank Johnson Mesa in this area.

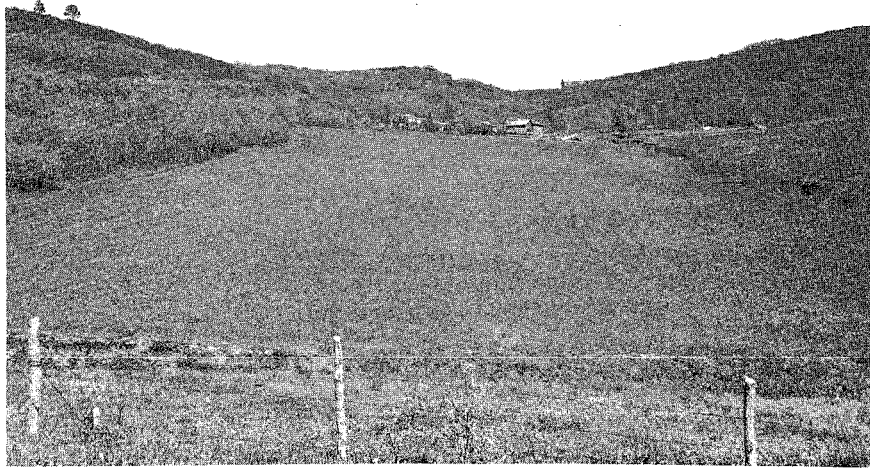
Road now begins to climb Manco Burro Pass and ultimately tops out on Johnson Mesa.



Trinidad sandstone near Yankee.

10.6 Culvert. Outcrop of Trinidad sandstone at 9 o'clock.

11 .0 Coal mine dumps on hill at 9 o'clock



Head of Chicorico Creek; Johnson Mesa on skyline.

- 11.4 Road forks. Keep right. Road ahead is over Manco Burro Pass, and we want to keep climbing onto Johnson Mesa at right.
- 11.6 Road forks. Keep left.
- 11.7 Trinidad sandstone in roadcuts.
- 11.8 Raton basalt of earlier sequence in road cuts. This outcrop shows the porous nature of many lava flows caused by gases within the molten rock escaping as bubbles.

The rounded shape of the boulders is caused by rain and ice, which decomposes the rock along the fracture surfaces, working inward by sheets, like an onion skin.



Spheroidal weathering of basalt.

11.9 We can now see westward (1:30-2:30 o'clock) to the distant peaks of the Sangre de Cristo Mountains. We can also see the grassy top of Horse Mesa, capped with younger Raton basalt. To the right is Barilla Mesa, which extends to where we are and is capped with older Raton basalt. Johnson Mesa, onto which we are now climbing, is also capped by part of the older Raton basalt sequence.

Clearly seen from here is the rise toward us of the cliffs of Trinidad sandstone, which mark the base of the coal-bearing sequence in this area.

12.2 Sharp right turn. To rear (northeast) are the plains of southern Colorado, with Raton basalt-capped Mesa de Maya on the distant skyline. Mesa de Maya continues southeastward, crosses the corner of New Mexico, and enters the Oklahoma Panhandle, where it is called Black Mesa.

13.7 Road forks, keep to left. Road straight ahead climbs what appear to be volcano remnants associated with the eruptions of the Raton basalt cap on which we are riding.

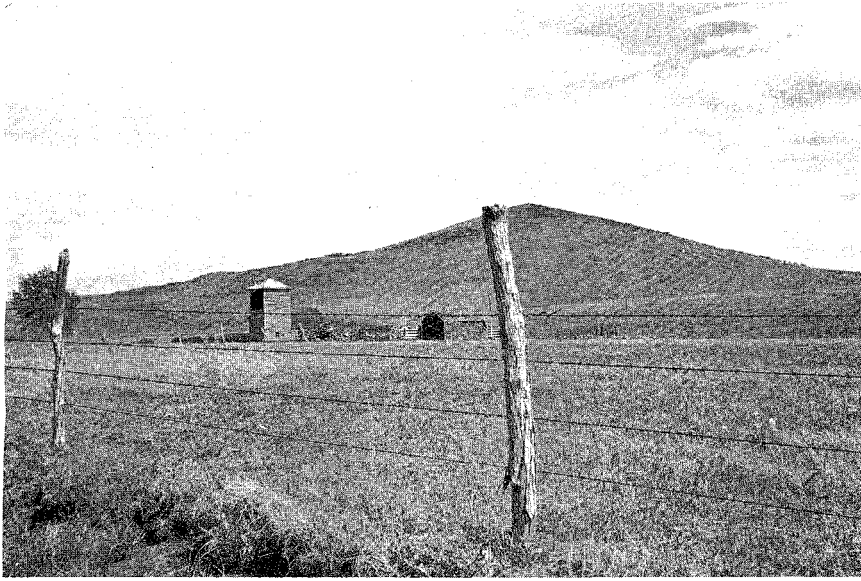
13.9 Cone-shaped Towndrow Mountain (8,609 ft.) at 1 o'clock, and Red Mountain at 11:30 o'clock, are both volcanoes punched through the Raton basalt cap and both part of the group named Red Mountain dacite. At 10 and 11 o'clock are broad hills of Clayton basalt, which also erupted through the Raton basalt cap. Lava from Bellisle Mountain (8,520 ft.) at 11 o'clock moved south across Johnson Mesa, then eastward to near Emery Peak, east of Folsom.

14.5 Ranch on right.

14.7 Towndrow Mountain at 3 o'clock.

14.9 During the summer wild iris (blue flag) covers the valley on the left.

17.1 Culvert over headwaters of Una del Gato Creek, which drains southward over edge of Johnson Mesa into Canadian River.



Towndrow Mountain

- 17.9 Church on right. Road enters from left next to cemetery. Johnson Mesa, named for the owner of a large ranch on its southern slopes, was settled in 1887 by Marion Bell. Stone construction was common for protection against winter cold, as 30° to 40° below zero are not uncommon. The soil on the mesa is remarkably rich and regular; rains and flow from springs keep it well watered.
- 18.6 Stock tank on right. Road now climbs onto basalt from Bellisle Mountain, at 9 o'clock. Cinder pit for road gravel near east end of mountain.
- 19.1 Stop at abandoned school. From here a spectacular panorama of volcanoes can be seen between 12 and 3 o'clock. Starting from Red Mountain, in foreground at 12:30 o'clock, is Sierra Clayton, over 40 miles away on distant skyline above right base of Red Mountain; Jose Butte at 1 o'clock; Capulin Mountain (8,215 ft.), just to right and behind it; Sierra Grande, (8,720

ft.), the huge mountain on skyline; Robinson Mountain, in front of right flank of Sierra Grande. At 2 o'clock on skyline are Malpais Mountain (left) and Horseshoe Mountain (right); at 2:30 o'clock, triple-peaked Palo Blanco Mountain; then Timber Buttes and at 3 o'clock Laughlin Peak (8,820 ft.).



From left: Red. Mountain, Jose Butte, Capulin Mountain, Sierra Grande, and Robinson Mountain.

- 19.6 Mesa de Maya at 10:30 o'clock on distant skyline.
- 19.9 Ranch road enters from right. Main road curves gently to right to skirt the base of Red Mountain. On skyline at 12:30 o'clock behind north base of Red Mountain is Every Peak (7,350 ft.).
- 24.1 View at 10 o'clock over north edge of Johnson Mesa into Colorado. Columnar jointing of the basalt; can be seen along the cliffs.

Numerous lakes and meadows, like one at right, are low areas on the tops of the lava flows, broadened and deepened through disintegration and de-composition of the basalt by rain, snow, and vegetation.

- 25.3 View at 9 o'clock to the plains of Colorado. Cliffs of Johnson Mesa show the successive lava flows that built up the older sequence Raton basalt cap of the mesa.
- 25.9 Road starts down off Johnson Mesa, an island in the sky. Roadcuts show the Raton basalt cap. Platy layering was formed when the lava was still moving yet getting nearly stiff enough to tear. **Many curves ahead.**
- 26.5 Borrow pit on left in orange-colored sands and gravels of Ogallala formation which underlies the Raton basalt cap of Johnson Mesa. The Ogallala sands and gravels were deposited by rivers in a broad blanket stretching east from the early Rocky Mountains. This broad plain of sediments also caps the High Plains from the Texas Panhandle to Nebraska.

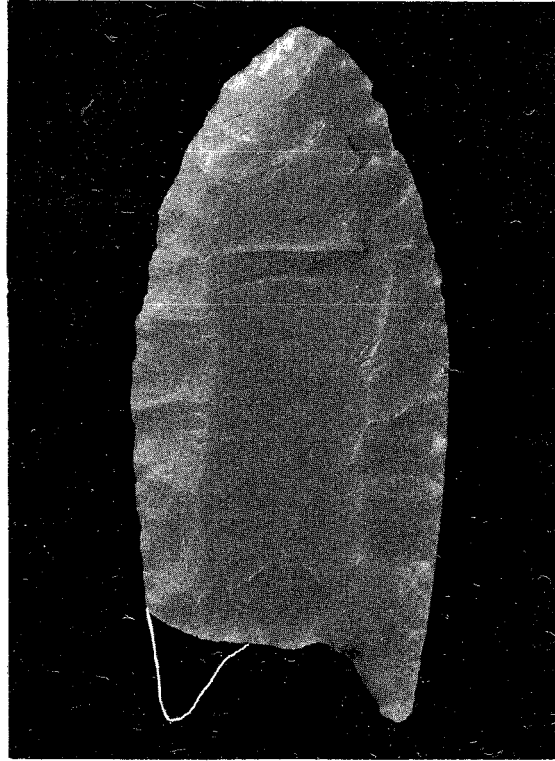
Ahead is Sierra Grande, largest volcano of this region; to right and nearer is Capulin Mountain, with a road spiraling to the top.

Jose Butte, just to right and in front of Capulin, was the last Clayton-age volcano to erupt in this vicinity. Immediately preceding it was Robinson Mountain, at 1 o'clock. Preceding these was Bellisle Mountain. Basalt from Bellisle Mountain underlies the grassy bench below the skyline that extends from 3 o'clock around to 12 o'clock. The higher bench on the skyline at 2 o'clock is capped by Raton basalt.

- 27.6 STOP – Historic Marker – "Folsom State Monument," 1-1/2 miles. Site of original discovery of the famed "Folsom Point" imbedded in skeleton of an extinct species of buffalo. This find established the existence of prehistoric man in America around 10,000 years ago - a forerunner of the American Indian in the southwest. Folsom Man lived in this area prior to the eruption of Capulin Mountain.

On left is rim of Johnson Mesa. Ahead on sky-line is Oak Canyon Mesa. The Raton basalt cap on this mesa was formerly continuous with the Johnson Mesa basalt.

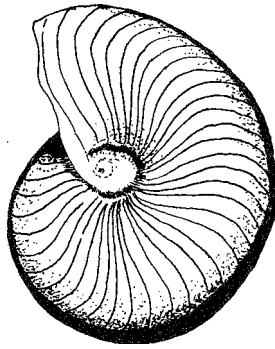
Low cone-shaped hills in valley below are not extinct volcanoes but are capped with remnants from Bellisle Mountain basalt (on right) or Raton basalt (tree-covered hills beyond ranch buildings on left). The valley known as Hereford Park, is the headwaters of the Dry Cimarron River.



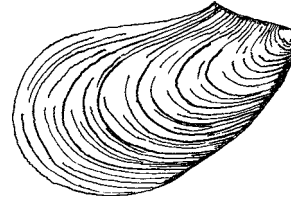
Folsom point; photograph of plastic replica with missing ear restored. (Original point at Denver Museum of Natural History)

- 28.6 Curve right – hill: Caution.
- 29.2 Junction. Road turns right down terrace a gravel-capped remnant of the early valley, to the Clayton-age basalt sheets which form the grassy mesas on the other side of the valley.
- Road entering from left over Trinchera Pass—do not use in wet weather.
- 29.6 Gravel pit at right. Other remnants of this old valley, now preserved as sloping terraces, can be seen at 3 o'clock.
- 30.1 Gravel pit at left.
- 30.4 Low mounds at right of highway are small cinder cones which erupted before the arrival of Folsom Man. Lava from these vents filled the valley beyond. In roadcut ahead are cinders from flank of cone.
- 30.5 Another small vent on left.
- 30.7 On left, easternmost of the 4 alined vents known as the Folsom vents. Basalt from these volcanoes can be seen in the valley at 2 o'clock. The road ahead for next 0.2 miles is on basalt from this earliest of Capulin basalt eruptions.
- 31.2 Narrow bridge. White layers in creek banks are limestone beds in the Fort Hays limestone member of the, Niobrara formation, mostly black shales like the over-lying Pierre shale.
- 31.3 Enter Union County; leave Colfax County.
- 31.5 White limestone beds in roadcut on left are part of the Fort Hays limestone .
- Valley rim on right is columnar-jointed Clayton-age basalt from Bellisle Mountain.
- 32.1 Roadcuts in blocks of Fort Hays limestone in a large landslide mass. Numerous fragments and whole casts of oysters, clams, and a few cephalopods found in this

limestone demonstrate that these rocks were deposited in the ocean.



Cephalopod.



Pelecypod (clam)

- 32.7 Hill on left about 50 feet above road is capped by the Fort Hays limestone
- 33.1 Broad valley opening to left is called Fisher Park. Fort Hays limestone caps hill behind windmill. Oak Canyon Mesa, with its older Raton basalt cap, rims Fisher Park.
- 33.2 Ranch road enters from right. Capulin Mountain looms on skyline behind ranch buildings which nestle under the Bellisle Mountain basalt rim.
- 33.5 Road turns sharp right onto terrace cap.
- 33.8 Road turns; sharp left off terrace cap. Ahead at end of terrace is high knob of gravel graded to the top of the Bellisle Mountain basalt that forms rim on far side of valley.
- 33.9 Narrow bridge.

- 34.1 To the right down small canyon can be seen cliffs of Bellisle basalt which now rim valley on both sides of Dry Cimarron River.
- 34.4 Roadcuts in thin-bedded Greenhorn limestone.



Greenhorn limestone.

- 34.5 Straight ahead, the barren volcano in front of Sierra Grande, is Baby Capulin Mountain. The forested area in front of it is on basalt from Capulin Mountain (at 1 o'clock). The lower cone to the left of Capulin is Mud Hill (at 12:30 o'clock).
- 34.7 Ahead on the skyline is Twin Mountain. The dark red scars on it are from cinder pits from which the Colorado and Southern Railway get road ballast. To the left of Twin Mountain on the skyline are small fissure vents called the Purvine Hills.

On left at 9 o'clock is a small outcrop of the orange-colored Ogallala formation just under the Raton basalt cap of Oak Canyon Mesa.

- 36.2 Thin-bedded brown Dakota sandstone forms rim of valley on left. Ridge on right is held up by Bellisle Mountain basalt with a thin cap of gravel.
- 36.3 Dakota sandstone in cut on right.
- 36.7 Tongue of basalt from Capulin Mountain covers valley on far side of the Dry Cimarron River valley (at 3 o'clock).
- 36.8 Road crosses horseshoe bend of Colorado and Southern Railway. For tour of Folsom area and Capulin Mountain National Monument, turn right over bridge to road junction in town to join Log 2, at mileage point 7.5. Turn left to continue this tour down the Dry Cimarron River toward Oklahoma. In the 1890's Folsom had the largest stockyards north of Fort Worth.
- 37.2 Roadcut in sands and silts of uppermost Morrison formation.
- 37.4 Junction with N. Mex. 325.
- 37.6 Turn right.
- 37.7 Turn left.
- 37.9 Road turns sharp right up hill, then makes a left zig and a right zag.
- 38.1 Cemetery on right.
- 38.7 STOP. This is a good place to review some of the geologic features visible from here. Volcanic centers and flows that can be seen are Emery Peak at 11 o'clock; Raton basalt cap with columnar jointing below Emery Peak; Emery Peak basalt in cliffs below skyline at 10 o'clock; Big Hill in middle distance on skyline at 9 o'clock; East Big Hill halfway between Big Hill and Emery Peak; East Emery Peak in ridge on skyline beyond Emery Peak; low mounds from Augite vents at 3 o'clock; Purvine Mesa basalt on skyline ridge between 1 and 2 o'clock; Mud Hill, the tree-covered hill in front of Capulin Mountain; José Butte at 5:30 o'clock; Capulin Mountain at 4 o'clock; Twin Mountain with

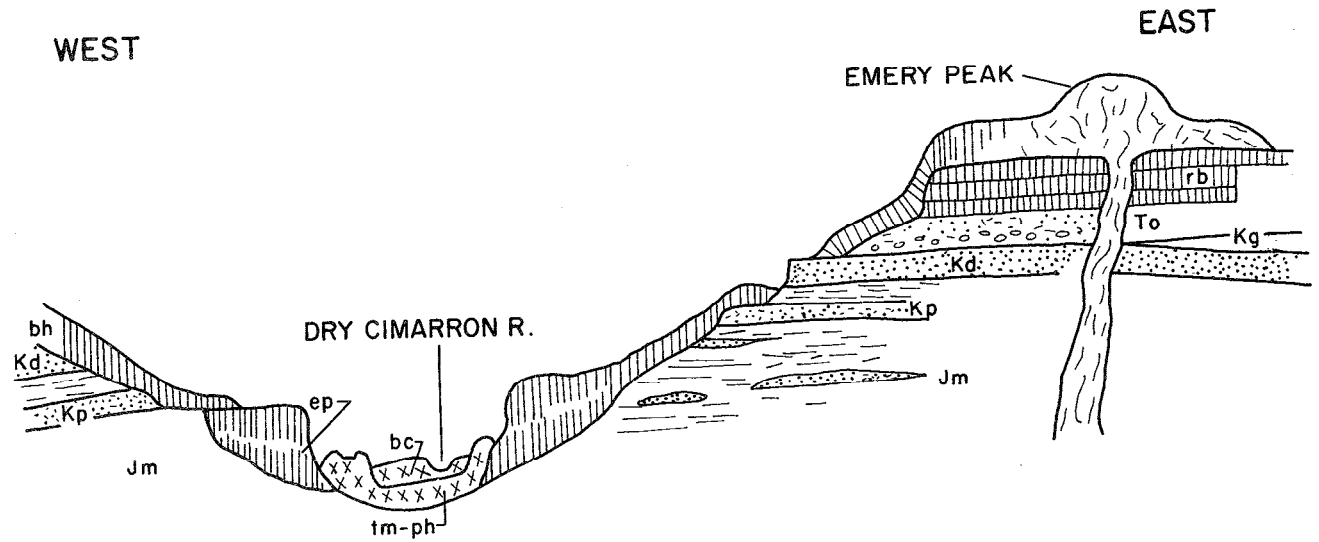
cinder-pit at 3 o'clock; Purvine Hills, low ridges on skyline at 2:30 o'clock; Baby Capulin, nearest volcano this side of Capulin Mountain; Sierra Grande on sky-line at 3 o'clock; and Oak Canyon Mesa capped by Raton basalts to the left (north)

The Folsom sequence of Clayton-age basalt eruptions began with Emery Peak erupting through the Raton basalt cap and pouring lava into Dry Cimarron River. At about the same time Big Hill, East Big Hill, and East Emery Peak also erupted. This dammed the river, and into the lake thus formed poured lava from the following volcanoes, in the order named: Augite vents, Purvine Mesa basalt, Mud Hill, Bellisle Mountain (not visible from here, on Johnson Mesa, 20 miles to west), Robinson Mountain (not visible, behind José Butte), and lastly José Butte. A long period of erosion ensued which was interrupted by the Capulin-age sequence of basalt eruptions. These started with Folsom vents (not visible), Capulin Mountain, then Twin Mountain, Purvine Hills, and finally Baby Capulin. This ended the sequence of eruptions in this area.

Earlier than any of those already described is Sierra Grande, and the oldest of all are the Raton basalts capping Oak Canyon Mesa.

Straight ahead, behind the red and white ranch-house are two level bands of light-colored sandstone; the lower, which is nearly white, is the Purgatoire formation; the upper, which is reddish brown and caps the mesa, is the Dakota formation. The scarp is about on the crest of the Sierra Grande arch. Beyond it these rocks slope gently eastward, with only minor wrinkles, all the way to Texas. Coming this way (westward), the rocks slope gently westward into the Raton basin west of Raton.

39.0 Ruts at left, going into erosion control tank, are result of military wagon trains carrying supplies to Ft. Union from Ft. Dodge in the 1870's. This road goes down the valley ahead and turns north up Toll Gate Canyon past Branson, Colorado. To the south the trail skirts the east side of Capulin Mountain, goes through Capulin, and continues southwest to Ft. Union (now a National Monument).



Section across Dry Cimarron River 3 miles below Folsom, at gorge dammed by Emery Peak basalt. Symbols from oldest to youngest: Jm, Morrison formation; Kp, Purgatoire formation; Kd, Dakota formation; Kg, Graneros shale; To, Ogallala formation; rb, Raton basalt; ep, Emery Peak basalt; bh, Big Hill basalt; tm-ph, Twin Mountain-Purvine Hills basalt; bc, Baby Capulin basalt.

- 39.2 Road turns sharp left. Road straight ahead to ranch 6 house.
- 39.9 Gravel pit at right in topmost fill of lake that was dammed by the Emery Peak basalt.
Ruts on left were formed by military wagon trains of Santa Fe Trail days and by the Goodnight Cattle Trail herds which later moved north along this route
- 40.0 In gully bottom is Purvine Mesa or Augite Vent basalt (the two are identical and cannot be distinguished—they probably erupted simultaneously).
- 40.3 In roadcuts can be seen bedded ash and cinders (that were deposited in the Clayton-age lake) from Mud Hill.
- 40.4 Road turns left through gap cut in Emery Peak basalt. This flow formed the dam for the Folsom sequence of Clayton basalt.
Note bent ash layers in cuts on right. Probably deformed by overlying load of lava and sediments.
- 40.5 Narrow bridge
- 40.6 Platy columns of Emery Peak basalt form walls of valley (both sides); basalt from Twin Mountains, Purvine Hills, and Baby Capulin in valley floor; tall columns of Raton basalt high on hillside under Emery Peak; and brown, blocky, and massive-appearing Dakota sandstone all visible from here.
- 40.8 Beyond step stile is waterfall over Baby Capulin basalt with a plunge pool below cut into Twin Mountain or Purvine Hills basalt (they are identical and were nearly simultaneous in their eruptions). Excellent swimming hole, but has a few submerged rocks.
Cliffs on left (north) are massive basalt, probably from Big Hill, although basalt from it is identical with the 3 others in line East Big Hill, Emery Peak, and East Emery Peak.

- 41.5 Basalt to right of road is Twin Mountain-Purvine Hills type.
- 41.8 On left East Big Hill basalt forms rim. Ahead brown Dakota sandstone forms rim with white Purgatoire sandstone ledge below it.
- 42.5 Emery Peak basalt flowed down from skyline at 3 o'clock and filled the Dry Cimarron River valley whose floor was then above us at the level of the base of the flows forming the mesa ahead of us and the valley rim to our right.
- Basalt outcrops in stream at right are Twin Mountain-Purvine Hills type.
- 42.6 Narrow Bridge.
- 43.0 Ridge on right along road marks end of Twin Mountain-Purvine Hills basalt. Beyond this point lava from only Baby Capulin flowed down the Dry Cimarron River.
- Ahead at 12:30 o'clock the white band of the Purgatoire sandstone can be recognized. Capping it is the brown Dakota sandstone.
- 43.2 On distant skyline at 12:30 o'clock is Devoy's Peak (6,740 ft.), easternmost remnant of the earlier Raton basalt sequence that extends from Raton.
- Baby Capulin basalt in stream walls on right.
- 43.7 Narrow bridge.
- 44.0 Emery Peak basalt holding up spur at right. This is good place to visualize how it flowed down the side of the valley. The shape of the cliffed valley can be seen under the flow and the smooth upper surface of the lava flow gives a rounded appearance to the new valley.
- On left at 10:30 o'clock is white Purgatoire sandstone overlain by brown Dakota sandstone
- 44.4 Ranch road enters on right. At 3:30 o'clock, about 100 yards from road, is a stone-walled dugout built by

original settlers in 1870's. Broad mesa at 1:30 o'clock is capped by basalt from East Emery Peak. In valley bottom can be seen the ridge of Baby Capulin basalt.

- 45.2 Junction with road to Branson, Colorado (to left), up Toll Gate Canyon. This is the only low pass into Colorado between here and Raton. A toll road through here was built and operated by Bill Metcalf in the 1870's. The military wagon trains and the Goodnight Cattle Trail went this way. We turn right.

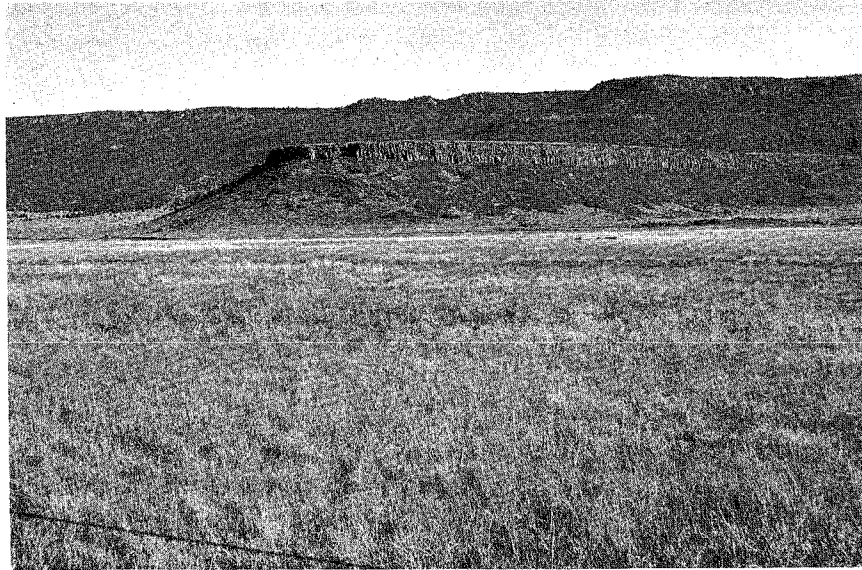
The Dry Cimarron River Canyon is rimmed throughout its length in New Mexico by the Dakota sandstone (brown) which is underlain by the Purgatoire sandstone (white cliffs). The slopes below these sand formations are generally mantled by landslide debris but at places the greenish, reddish, or purplish silts and muds of the Morrison formation can be seen. We will also be able to see along the foot of the slope the white Exeter sandstone under the Morrison as well as the older redbeds (Dockum group) farther down valley.

- 45.5 Bridge.

- 47.1 At 3 o'clock, on left end of East Emery Peak basalt mesa, is the Triassic Dockum (redbeds at base) , Exeter sandstone (2 white cliffs), and capping these is the Morrison formation (greenish and reddish siltstones).

- 48.2 In roadcut can be found small pieces (like bubbles) of red chalcedony known as the "agate bed." This layer, in some places thicker, can be found in the lower part of the Morrison formation throughout northeastern New Mexico, Colorado, east of Rocky Mountains, western Kansas, and southern Nebraska. Its origin is not certain, although recent studies suggest that it is glass (dust) from a stupendous volcanic eruption that was later altered to its present form. If true, this marks the surface of the earth at that instant of geologic time in the states where it is preserved.

- 48.7 Baby Capulin basalt next to road on right. On left the typical double cliff of Dakota sandstone (brown) over Purgatoire sandstone (white) is well developed.



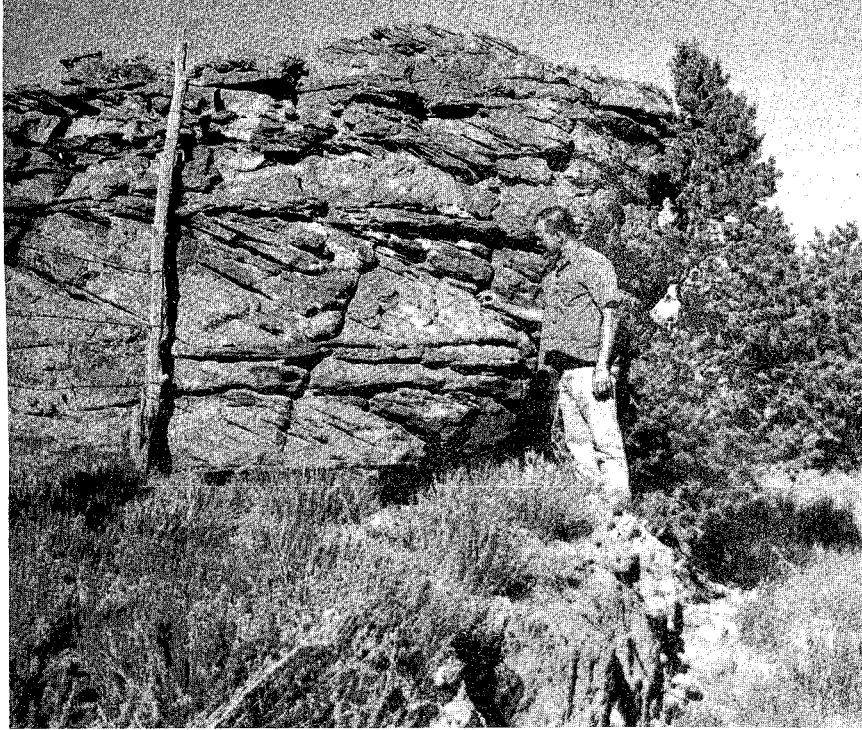
Raton basalt caps mesa on skyline; Dakota sandstone forms cliff in slope below Raton basalt; Emery Peak basalt caps low mesa in middle; Triassic rocks to left and beyond Emery Peak basalt.

- 49.1 On left are large landslide-blocks of Dakota sandstone. These have been etched by rain and wind, the better cemented layers standing out as ridges.

Mesa across valley at 1 o'clock is capped by the easternmost earlier Raton basalt (south of Devoy's Peak). Under it are very thick cliffs of Dakota and Purgatoire sandstones.

- 50.0 Briggs Canyon entering from right. Basalt from Purvine Hills flowed down at least as far as the narrow mouth of the canyon. Whether it is under this broad alluvial valley is unknown. However, only Baby Capulin basalt crops out downstream from this point. Low hill in the center of the valley is part of the lower Morrison formation.

- 50.3 Large block of cross-bedded Dakota sandstone in fence line. These crossbeds are of the type known as torrential and are deposited by rapidly moving currents, usually a river. If the block-is right-side up, then the current moved toward the road.

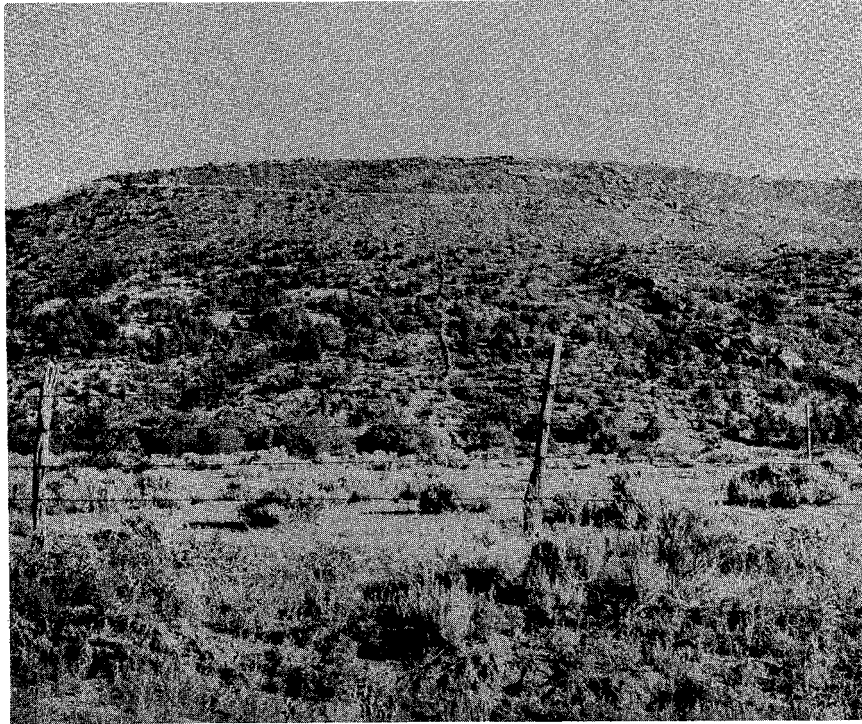


Cross-bedded Dakota sandstone.

- 50.7 Low red hill at 11 o'clock beside road is composed of Triassic Dockum shales. On left skyline is spectacular rim of brown Dakota over white Purgatoire sand-stones.
- 50.9 Ranch road enters from left. On skyline at head of canyon behind ranch house is Devoy's Peak.
- 51 .3 Bridge over irrigation ditch. Stone fence at 9 o'clock on hill

- 51.5 Baby Capulin basalt along road at left.
- 51.6 Ranch road entering on left. Old stone ranch house of Madison Devoy, first settler in this region (about 1870), is still in use on Brown Ranch behind hill. Beyond the house are thin beds of sandstone in the Dockum red beds.
- 51.8 Narrow bridge over Dry Cimarron River.
- 51.9 At edge of valley at 1 o'clock are red cliffs composed of the Dockum formation.
- 52.7 Baby Capulin basalt dots whole valley floor. Note how thin the Exeter sandstone (yellow-white sand cliffs low on valley wall) is in this region. This area was a broad low hill when the sand dunes that now compose the Exeter sandstone blanketed this area.
- 53.3 Long ridge of Baby Capulin basalt extending from road to right is terminal pressure ridge of one flow.
- 53.9 At 9 o'clock Triassic Dockum red beds are visible along the base of the slope. Dakota sandstones (brown, underlain by white Purgatoire sandstones) still hold up the mesa rims.
- 54.1 Gully exposing Baby Capulin basalt.
- 55.1 Lenticular sands of Dockum at 3 o'clock. The Dockum formation was deposited on a broad floodplain dotted with lakes.
- 55.9 On left is the end of another of the long lava flows from Baby Capulin Mountain.
- Note Dockum "island" surrounded by basalt in the middle of the valley.
- The zig-zag roads up the valley walls take ranch owners to the mesa tops. South from the Dry Cimarron Valley, are continuous plains for many tens of miles—nearly to Tucumcari.
- 56.6 Bridge.

- 56.7 Thin-bedded fine sandstones of Dockum red beds in roadcuts on right.
- 57.6 On left, the line of big trees marks the absolute end of the lava flows. This point is about 22 miles from Baby Capulin volcano, where they started. This long distance implies that they must have been very fluid. Otherwise the lava would have frozen before it reached this far.
- 57.8 Ranch road enters on left. (Cross L Ranch house, At one time this ranch covered most of northeastern New Mexico.) At 3 o'clock, below red beds, is old stone wall.
- 58.3 Spur on mesa at right (3 o'clock) has prominent ledge of white Purgatoire sandstone under dark Dakota sand-stone cap. (Exeter sandstone is not visible on top of Dockum red beds at base of slope.) Morrison formation, in between, covered with landslide as usual
- 59.1 Narrow bridge over Dry Cimarron River. At 10 o'clock on middle of hillside is greenish-gray outcrop of Morrison shale.
- The top of the Dockum red beds are now lower down the canyon walls than they were a few miles back.
- 59.4 Sharp turn to left. On south canyon slope (at 3 o'clock before making turn) are the remains of an old stone wall. We know these walls were built prior to 1870 because they were marked on the original U. S. Government Land Office surveys made in the early 1870's. Ahead on far mesa edge is exceptionally thick Dakota sandstone rim.
- 59.5 Dakota rim ahead at 1 o'clock has a thin-bedded upper sandstone overlying the main cliff-forming sandstone.
- 59.9 Road turns right beyond ranch house on left.
- 61.1 Gravel pit from slightly older stream valley fill on right of road.



Old stone fence.

Gleason Canyon at 3 o'clock.

- 61.7 A thick sequence of Dockum red beds is exposed on the left. The Exeter sandstone is missing here, and the Dockum is overlain by a thin Morrison formation, a small white cliff of Purgatoire sandstone, capped by 3 cliff-forming beds of brown Dakota sandstone.
- 62.2 Ranch road from left up Long's Canyon.
At 11:30 o'clock is prominent white Purgatoire sandstone under double Dakota sandstone cap.
- 63.2 Narrow bridge over Dry Cimarron River.

- 63.3 Above red beds at 9 o'clock is a thin white band of Exeter sandstone. From here east, notice the progressive thickening of the Exeter sandstone.
- 63.7 Crossing of Colorado Interstate Gas Company pipeline to Pueblo, Colorado.
- 65.1 To left rear is small waterfall in gully bottom over resistant sandstone in lower Dockum red beds.
- 65.6 The boulder of Dakota sandstone on knoll at 1 o'clock is locally known as Lizard Rock.
- 67.8 Cross cattle guard and STOP. Baldy Hill ahead at 11:30 o'clock is capped by the Morrison formation, underlain by Exeter sandstone (white band), and Dockum red beds. On left in valley are low benches held up by bluish sands of the principal subdivision of the Dockum, the Travesser formation. Below it are the oldest exposed rocks in northeastern New Mexico, consisting of the Triassic Baldy Hill formation. North skyline is in Colorado. Seven L Buttes, a continuation of Mesa de Maya (Raton basalt cap) is on the skyline at 9 o'clock. Ahead and to the right is another Dakota-capped mesa.
- 67.9 Ranch road enters from left.
- 69.0 Junction with N. Mex. 370. Turn right up Travesser (Spanish short cut) Canyon on Log 3, mile 98.4, or down Dry Cimarron River reversing Log 3.

LOG 2: DES MOINES-FOLSOM-CAPULIN MOUNTAIN
NATIONAL MONUMENT-CAPULIN

(22.6 miles)

The route skirts the well preserved cinder cones of Twin Mountain, Baby Capulin, and Capulin Mountain, as well as many older volcanoes from Des Moines to Folsom and on to the entrance to Capulin Mountain National Monument on the west side of the peak. The log follows up the spiral road to the summit of Capulin Mountain and a view that encompasses all of northeastern New Mexico as well as parts of Texas, Oklahoma, and Colorado. The deep crater of Capulin volcano can also be seen from the summit. Returning from the crest to the junction of the Monument road and N. Mex. 325 the log continues into the village of Capulin where it rejoins U. S. 64-87. Altitudes along the route vary from a low of about 6,600 feet at Des Moines and Capulin to 8,215 feet on the rim trail on Capulin Mountain.

Only limited exposures of older rocks are seen along the route of this log. These include the Cretaceous Dakota sandstone and Purgatoire formation, and the Jurassic Morrison formation. Most of the trip is on various basaltic flows of the quite recent sequence of flows known as the Capulin-age basalts. Many features of lava flows and volcanoes can be seen on this route. Also seen are some of the Clayton-age volcanoes and Raton-age flows, the latter being the older.

- 0.0 Log starts at junction of N. Mex. 72 and U. S. 64-87 on west side of Des Moines. Travel north road is paved to Folsom.
- 0.3 Cross Colorado and Southern Railway.
- 0.4 Contour ridges in valley on right are to prevent soil erosion by runoff from torrential summer rains.

Beyond at 3 o'clock is Dunchee Hill, the eroded remnant of a Clayton-age volcano.

- 0.9 At 10 o'clock, Capulin Mountain looms over horizon; scar on side is road to crater rim. Other peaks visible beyond and to the right (north) of Capulin Mountain are Robinson Mountain and José Butte (farthest to right).
- 1.7 Road to left to carbon dioxide compressor plant. We are now over a carbon dioxide gas field. Well casings can be seen in the small corrugated steel houses near the railroad at 11 o'clock, on skyline at 3 o'clock, and one uncovered casing in the field at 1:30 o'clock. The plant is presently not active. The following discussion, taken from New Mexico Bureau of Mines and Mineral Resources Circular 43 by E. C. Anderson, points out some of the processes involved in producing carbon dioxide and some of its uses.

All CO₂ produced in New Mexico is recovered by means of natural pressure. The gas is delivered from the wells directly to the processing plants through pipe lines whose length ranges from a few hundred feet to as much as 18 miles. The rate of delivery is controlled by valves at the well head.

When pressure of the gas is below the "critical" level for liquefying, compressors are used to boost it to the required point.

The compressed gas is chilled to the liquid state in refrigerating coils. Although ammonia usually is used as the refrigerant, CO₂ gas itself may be used. Liquefaction takes place at -15° to -18° C.

From a well-insulated, high-pressure storage tank, the carbon dioxide is either fed into bottles or tanks for delivery to those who use the gas in liquid form, or blown into the ice or snow chamber. This is a receptacle 20 inches square and 30 inches high. Here the liquid CO₂ precipitates as snow, filling the chamber loosely. The top of the chamber is the plunger of a hydraulic press, which is forced down under approximately 200 tons pressure and compresses the carbon dioxide snow to a dense, solid block of dry ice about 10 inches thick. Any portion of the carbon dioxide that has not become snow is bled back into the

liquid circuit. The liquid weighs about 93-1/2 pounds per cubic foot, and the ice weighs 96 pounds per cubic foot. It requires 10 cubic feet of gas at about 350 pounds well-head pressure to make 1 pound of ice. The temperature of the ice is -109° to -115°F.

The blocks of ice from the press are sawed twice across; the sawed blocks, 10-inch cubes weighing nearly 60 pounds, are packaged in specially designed sacks of heavy paper. The wrapped blocks are placed in well-insulated storage bins or loaded directly for shipment.

From the plants located on the railroad, dry ice is shipped in standard refrigerator cars specially insulated on all sides and on the floor. Liquid carbon dioxide is shipped by rail in specially insulated, high-pressure tank cars or in high-pressure steel bottles. Use of extra insulation in regular refrigerator cars has reduced the loss in transit to less than 1 percent per day of travel.

A large part of the ice and liquid gas produced is shipped by trucks having specially designed and insulated bodies. Using a layer of loose dry-ice particles between the kapok insulating mattresses and the packaged ice has reduced the loss in transit to less than 1 percent per day of travel. A truck payload ranges from 10 to 20 tons. When liquid gas is shipped by tank truck, specially designed tanks are necessary. They must withstand pressures exceeding 3,000 pounds per square inch and be very heavily insulated. Bottled gas is handled by truck in much the same manner as is oxygen, hydrogen, or helium. The payload of the tank truck is usually 5 to 10 tons.

Dry ice is used principally as a refrigerant. It is especially useful in the long-distance shipment of fruits, vegetables, flowers, chemicals, and medicines. Pound for pound, it is from 10 to 15 times as effective as water ice for these purposes, and it is much less bulky. It is also used in the quick freezing of fresh fruits, vegetables, and meats, a process which requires temperatures far below "water ice-cold." In

heavy industry, dry ice shrinks metals and other materials, helps control temperature for storage, and is basic in air conditioning.

Liquid carbon dioxide has long been used in fire extinguishers, where it serves the double purpose of smothering the flame and lowering temperatures, in the manufacture of carbonated water and beverages, as a preservative for foods, and for a variety of other purposes.

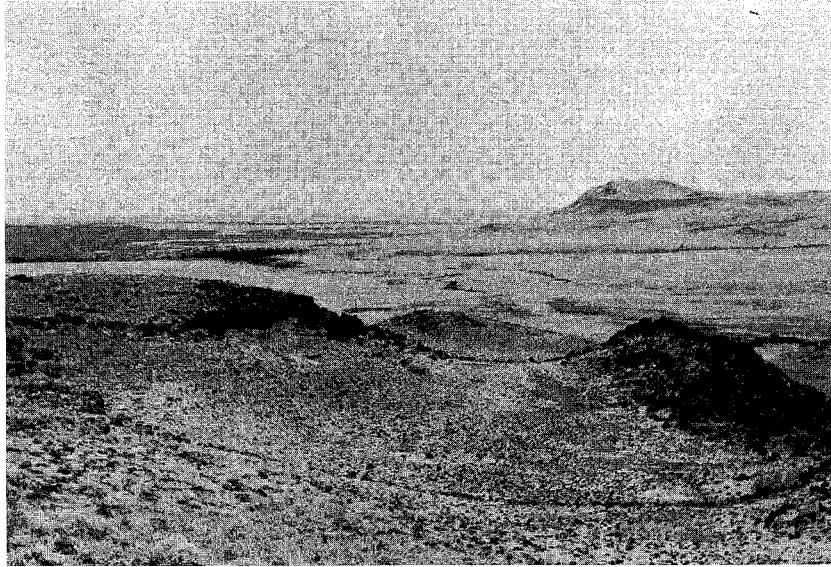
In recent years, large quantities of dry ice have been used by research laboratories where precise temperature control is necessary. The biggest market for ice produced in New Mexico, reportedly, is with the White Sands Missile Range, Holloman Air Force Base, Sandia Base, and Los Alamos Laboratory. Other markets are with packing houses, food-processing plants, ice cream and carbonated beverages manufacturers and dispensers, florists, and shippers of perishable commodities.

Liquid carbon dioxide has replaced explosives for some purposes, as in coal mining. Expanding more slowly than dynamite, the liquid carbon dioxide breaks the coal more cleanly and with fewer fines. It has also been used experimentally as a noiseless propellant of bullets and projectiles, and is finding uses in many phases of industry where inert gases are required.

It is estimated that about 22,000 tons of carbon dioxide solids (dry ice and liquid gas) were produced in New Mexico in 1958. About 410,000 million cubic feet of gas were delivered from the wells to the processing plants.

- 1.8 Gaylord Mountain at 2:30 o'clock on skyline is another Clayton-age volcano.
- 2.0 Road curves left. About 2 miles ahead on skyline are three elongate ridges (at 12 o'clock, 12:30 o'clock, and 1 o'clock - - this last one not quite on skyline) that are the fissure vents of the Purvine Hills. These fissures and Twin Mountain, to left of highway at 11 o'clock,

are on line, have identical compositions and probably erupted simultaneously.

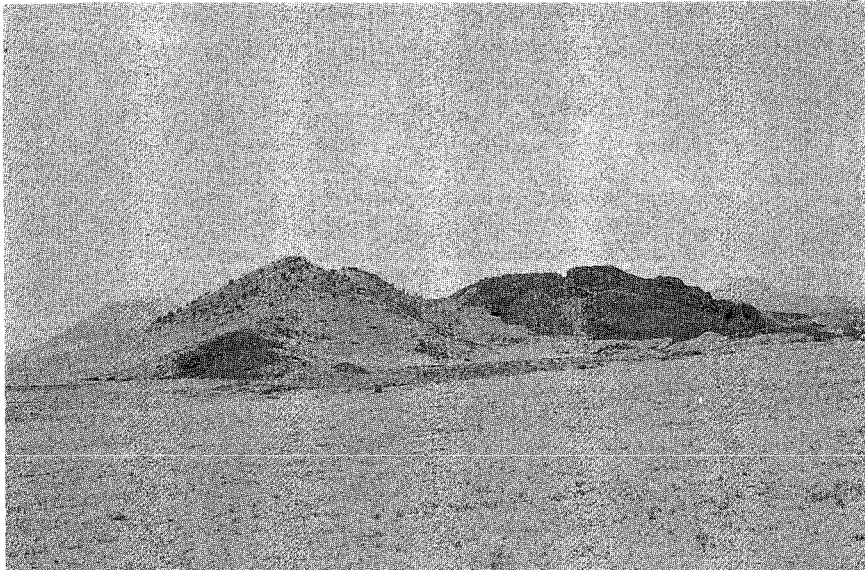


Looking east along fissure vent of Purvine Hills. Lava flowed east from trough.

On the distant skyline, in gap between the middle and right vents of the Purvine Hills fissures, is Emery Peak (7,350 ft.), a Clayton-age volcano that is the key to the volcanic history of this region because basalt from it flowed down into the Dry Cimarron River and dammed it. Into the lake that formed behind the basalt dam flowed basalt from other Clayton-age volcanoes as well as the much younger Capulin-age sequences, (for details see Log 1 mileage point 38.7). Emery Peak and East Emery Peak (behind the right fissure of the Purvine Hills) rest on a Raton-basalt cap that extends eastward (forested skyline ridge) behind Gaylord Mountain.

- 2.4 Gaylord Mountain on right skyline at 3 o'clock. Material for this road came from pits in the north side of Gaylord Mountain.

- 2.5 On left is the highest point on the Colorado and Southern Railway line between Denver, Colorado, and Fort Worth, Texas You are now higher than downtown Raton, Trinidad, Walsenburg, Colorado Springs, and Denver! 6,678 feet above sea level.
- 3.2 Purvine Hills fissure volcanoes on skyline between 12:30 o'clock and 2:30 o'clock. Their elongate shape can be seen fairly well from here
- 3.4 Ranch road enters on right. Between 7 o'clock and 11 o'clock to left at least 14 volcanoes (each mountain peak) can be seen.
- 3.8 Ranch road enters at left.
- 4.1 Crossing basalt from the westernmost Purvine Hills fissure (red hill at 3 o'clock). The flow moved toward Twin Mountain (11 o'clock with large cinder pit in north flank), buried the near edge of the cone and then flowed northward into the Dry Cimarron River east of Folsom.
- 4.5 Twin Mountain at 9 o'clock. The source of lava was in the groove (you're looking along it) between the two flanks of the cone. The north flank is being hauled away for railroad ballast by the Colorado and Southern Railway and is being used to make concrete cinder blocks for houses, acoustical insulation, etc.
- 4.6 Roadcuts are in the upper part of the Cretaceous Dakota formation. This forms the upper mesa edge to the right as well as the mesa margin down the Dry Cimarron Canyon into Oklahoma.
- 4.9 Ranch road enters from left and right. We are now crossing basalt from west Purvine Hills fissure.
- 5.0 Road enters on left from Colorado and Southern Railway cinder pit on Twin Mountain. The red color of some of the mountain is iron oxide, (rusty iron) stains in the cinders.
- 5.3 Flat surface ahead for next mile is underlain by basalt from Twin Mountain. At right, just beyond old road, are Purvine Hills basalt outcrops.



Twin Mountain fissure vent. Colorado and Southern Railway ballast pit on right. Capulin Mountain in left background

On left (9 o'clock), nearly a mile away is a low ridge , a volcano called Augite Vent, after its characteristic mineral, augite, which stands out in relief as little tablets on weathered surfaces. It is a Clayton-age vent that flowed into the lake behind the Emery Peak basalt dam.

- 5.8 The entire skyline ahead is Johnson Mesa (in distance at 11 o'clock) and Oak Canyon Mesa (11:30 to 2 o'clock), which are capped by the earlier sequence of Raton basalts that extends westward to Raton. The cliff-forming basalt under Emery Peak (3 o'clock) is the continuation of this Raton basalt cap.
- 6.1 Outcrop of Twin Mountain basalt on both sides of road.

- 6.3 Stream between walls of basalt from Baby Capulin, the small bare mountain at 9:30 o'clock to right and in front of tree-covered Mud Hill, which in turn is to right and in front of Capulin Mountain (on skyline with road', circling up it).

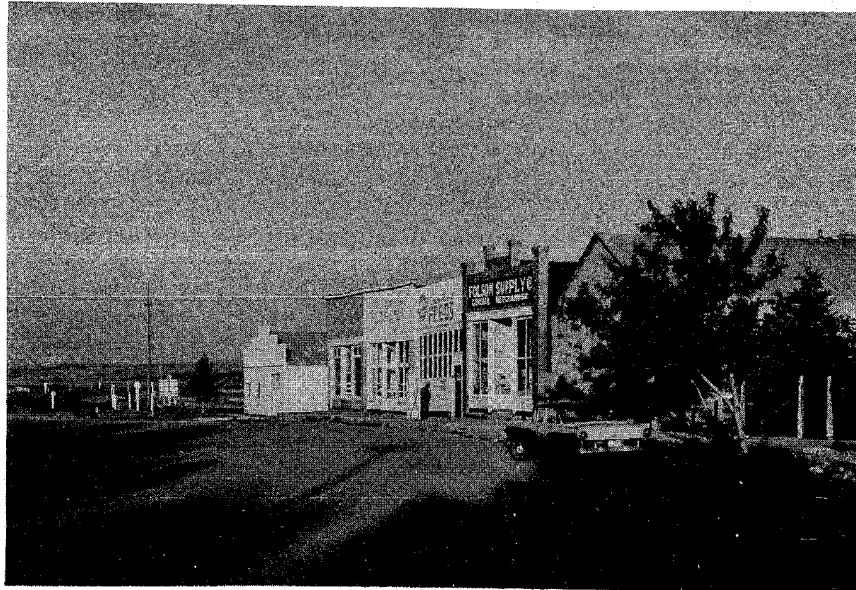


Capulin Mountain in background. Mud Hill in front of right base of Capulin Mountain and Baby Capulin to right and in front of Mud Hill. Twin Mountain-Purvine Hills basalt in foreground. Mesa to left is capped by Dakota sandstone.

- 6.4 Ranch road enters on right. Both the Ft. Union—Ft. Dodge military wagon road of Santa Fe Trail days and the Goodnight Cattle Trail passed across this flat.
- 6.5 Road goes off edge of Baby Capulin basalt.

Middle distance at 1 o'clock: Big Hill, a Clayton-age volcano that erupted at the same time as Emery Peak volcano.

- 6.6 Road cuts in uppermost Morrison formation, Dry Cimarron River valley ahead. Buffalo Head, Raton basalt-capped butte, on skyline ahead.
- 7.0 Road cuts in uppermost Morrison formation.
- 7.3 Railroad cuts at left in uppermost Morrison and basal Purgatoire formation. Ridge behind is capped by Dakota sandstone.
- 7.5 Folsom. Junction with N. Mex. 325. (Turn right for 0.2 miles and cross bridge over Dry Cimarron River to join. Log 1 at mileage point 37.4 for trip down Dry Cimarron Canyon or to go to Raton via N. Mex. 72.)



Folsom, New Mexico.

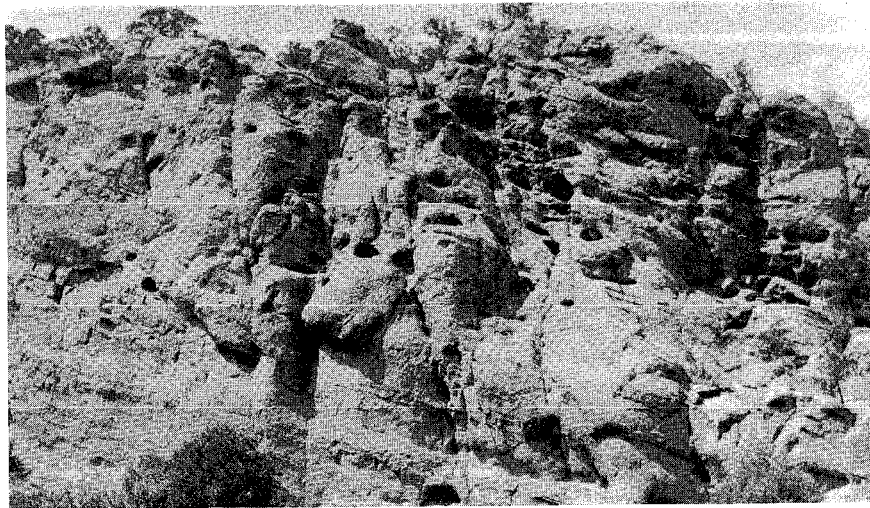
- 7.8 Road turns sharp left.
- 7.9 Cross tracks of Colorado and Southern Railway.
- 8.0 Road turns sharp right.

- 8.2 Embankment on right is for flood protection. On west (far) side of flood channel is the end of the basalt flow that moved north from Capulin Mountain.
- 8.3 Shrub-covered slope on left is underlain by Purgatoire sandstone. At 11 o'clock on skyline is José Butte, last Clayton-age volcano to pour lava into the lake behind the Emery Peak lava dam.
- 8.5 Road turns sharp left. Capulin Mountain basalt continues ahead and then turns sharp left about one-quarter mile on other side of this little valley.
- 8.8 Road climbs over Dakota sandstone rim.
- 8.9 Road zigs left, then zags right around top ledge of Dakota sandstone.
- 9.0 Road turns sharp right around corner of cemetery. Here is large dark granite boulder with a bronze plaque, which reads -
- "In honored memory of Sarah J. Rooke, telephone operator, who perished in the flood waters of the Dry Cimarron at Folsom, New Mexico, August 27, 1908, while at her switchboard warning others of their danger. With heroic devotion she glorified her calling by sacrificing her own life that others might live. 'Greater love hath no man than this.' Erected by her fellow workers."
- 9.2 Highway turns sharp left. Road ahead to Cornay Ranch.
- 9.3 Road drops off Dakota sandstone rim into valley flanked by basalt from tree-covered Capulin Mountain on right and Baby Capulin on left. Baby Capulin Mountain, the most recent volcano in this region, straight ahead.
- Sierra Grande, (8,720 ft.) the largest volcano in northeastern New Mexico, at 11 o'clock. Sierra Grande is reputed to be the largest lone mountain in North America, if not the world.
- 10.1 Road turns right, paralleling edge of Baby Capulin basalt.

- 10.2 Road turns sharp right.
- 10.3 Cattleguard. Across valley on right can be seen the blocky, broken edges of a Capulin Mountain lava flow.
- 10.6 Baby Capulin Mountain at 9 o'clock. Excellent example of a cinder cone. Test pits at right edge of cone were made to determine the quality of cinders for road foundations, etc.

Near the small juniper bushes in middle ground is where Baby Capulin lava flowed over edge of Capulin Mountain lava. By this we know that Baby Capulin lava is younger than Capulin Mountain lava. Down the Dry Cimarron Valley from Folsom, Baby Capulin lava rests on Twin Mountain-Purvine Hills-type lava. Baby Capulin is thus the youngest of the volcanoes in this region. A few other vents are of this youngest cycle of eruptions (Capulin-age basalts), but their position in the sequence has not been determined because broad areas of alluvial cover separate these outlying vents in this locality.

- 10.7 Road between Capulin Mountain basalt on left and small hill on right covered with basalt from Mud Hill-Great Wall (ahead and in front of Capulin Mountain).



Stratified pyroclastic material on north flank of Mud Hill.

- 11.0 Mud Hill straight ahead. Layers of cinders in its walls can be easily seen. It must have been violent in its eruption because most of this side is missing—presumably blown away.

This valley had Mud Hill basalt covering it as shown by the remnant preserved on the tiny butte in the valley to the right. It was eroded away, however, before the eruption of Capulin Mountain. Capulin Mountain basalt on left ahead and to right. Jose Butte on skyline at 2:30 o'clock.

- 11.4 Road climbs onto Capulin Mountain basalt. We will drive on top of this basalt for the next 5 miles until only 0.7 miles from U. S. 64-87 in the village of Capulin.

- 11.5 Extending left from Mud Hill is a series of hills along a fissure volcano (Great Wall). Some of the lava from this fissure caps the low mesas in the middle distance at 9 o'clock.

- 11.7 Road skirts base of Mud Hill.

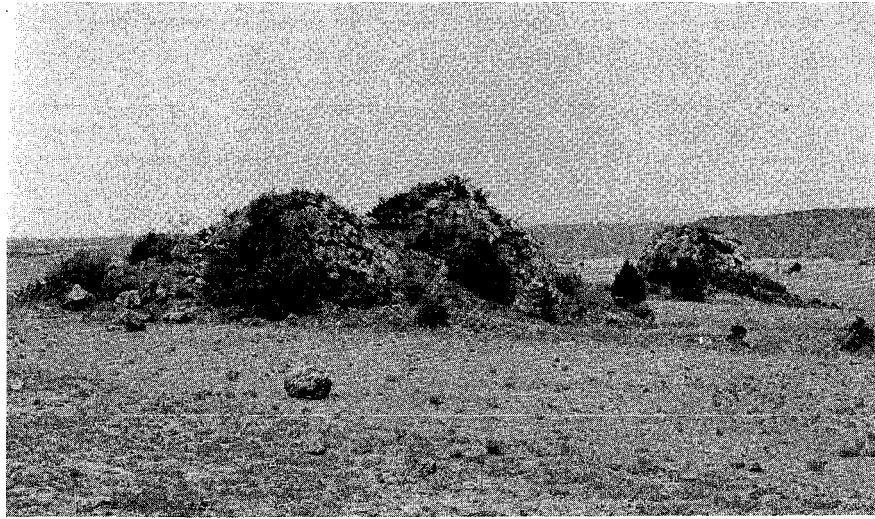
- 12.6 Low open side of Mud Hill to the left rear is where the lava poured out.

- 12.7 Hump near right base of Capulin Mountain is a minor vent of pasty lava from the volcano. Nearly all of the liquid lava flowed out from a vent behind the flat-topped ridge to the right of the hump. Capulin Mountain itself was where the gases escaped, throwing lava into the air in small pieces which solidified by the time they landed on the cone.

We are still climbing up lava from Capulin Mountain.

- 13.1 Cattleguard. Jose Butte at 2:30 o'clock on Raton basalt cap.

- 13.6 Beside road on right are 4 round balls of lava called "squeeze-ups." They formed when the top of the lava flow solidified and cracked, allowing the pasty lava below to squeeze up through the cracks like toothpaste.



Squeeze ups.

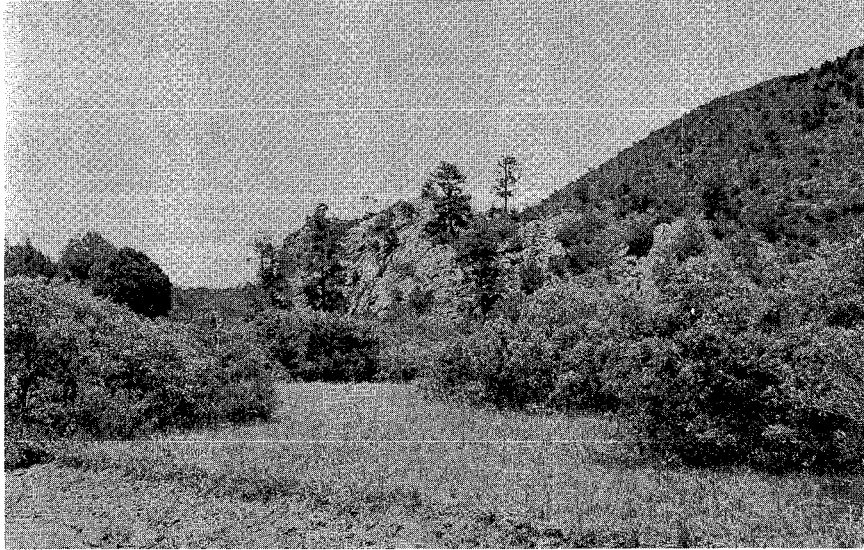
- 13.7 Road to Cornay Ranch enters on right. On left, about 100 yards from road, is a brush- and tree-covered wall of basalt. Behind it was the pool of lava which poured through cracks in the wall to make the big flows we have been driving on.
- 13.8 Capulin Mountain basalt extends to the far edge of valley on right. Basalt cliffs rimming the side of the valley are Raton basalt of the earlier sequence. José Butte on the skyline at 3 o'clock, and Robinson Mountain at 2:30 o'clock are both Clayton-age volcanoes.
- 14.0 We are now about 7,200 feet above sea level. We have climbed 450 feet since the road started up the Capulin Mountain lava.
- 14.1 Cattleguard.
- 14.3 Many volcanoes ahead. Horseshoe Mountain at 11:45 o'clock (Capulin-age; barren; grooves down it); Palo Blanco Mountain (behind it on right); Timber Buttes at 12:30 o'clock; Laughlin Peak (8,820 ft.) at 1 o'clock; Larga Mesa at 2 o'clock.

Village of Capulin at 11 o'clock below is 6,868 feet above sea level.

- 14.4 Junction. TURN LEFT on road to Capulin Mountain National Monument. To continue to village of Capulin without making side trip to crater rim turn to mileage point 19.8 which is at the same place as mileage point 14.4. The round trip to the rim is 5.4 miles.
- 14.5 Road turns sharp right. Then left. Tree-covered ridge at left is the outer wall of a former lava pool. Basalt lava broke through this wall and flowed down 6

the slopes to the valleys below.
- 14.7 Road turns sharp right. On left is grassy valley flanked with walls of basalt. These walls are natural levees for the lava which poured out of the big central pool (these pools are known to geologists as "bocas").
- 14.8 Entrance to Capulin Mountain National Monument. The Monument was established in 1916 by Presidential proclamation (Woodrow Wilson) and is under the jurisdiction of the National Park Service, U. S. Department of the Interior. Ridge beyond grassy flat is wall of natural levee.
Group of 3 squeeze-ups next to road on left.
- 14.9 Road turns left through natural levee .
- 15.0 Road to picnic area and rest rooms on right. Picnic area is between the natural levees for many of the large flows that moved south through here toward the village of Capulin.
- 15.1 Bare hill ahead is vent for lava from Capulin Mountain. Capulin itself was the escape hatch for gases which blew the lava into the air in fragments. The fragments then solidified in the air, although they were still red hot when they landed on the cone.
- 15.2 Road turns right passing end of natural levee. Road now skirts lava vent on left and natural levee on right.
- 15.3 Road turns right and begins spiral climb up Capulin Mountain. Please drive carefully. The road is well maintained and is wide enough to allow cars to pass easily at most places.

The road log and the view from here to the top will probably be enjoyed most by the passengers



Natural levee.

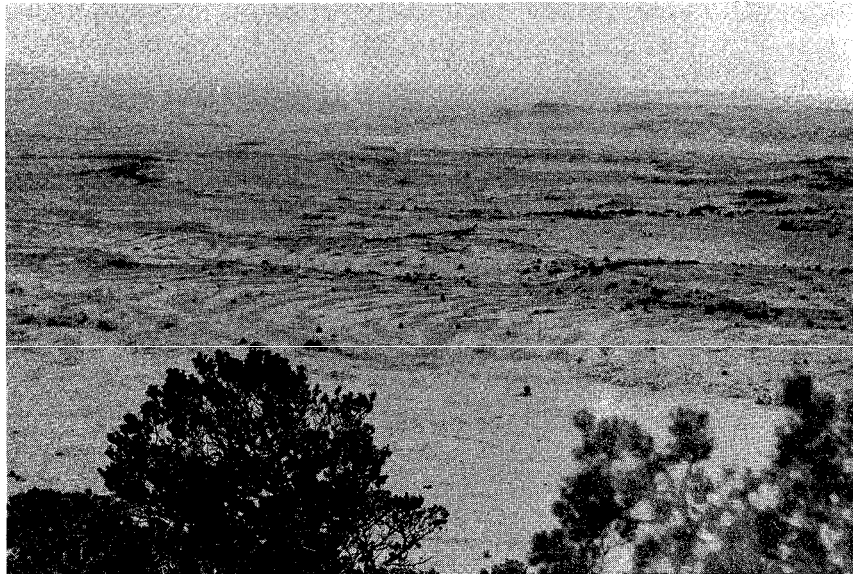
15.5 At 1:30 o'clock on skyline is Capulin-age volcano called Malpie Mountain or Mt. Marcy. To the left of it on the distant skyline are the Don Carlos Hills, a string of 14 Clayton-age volcanoes.

15.6 All of the area between us and Capulin village is covered with basalt from Capulin Mountain.

From here up the roadcuts will show the layering of cinders on the flanks of the cone. These cinders rained down onto the cone and built it up just as you build a sand pile by letting sand trickle through your fingers.

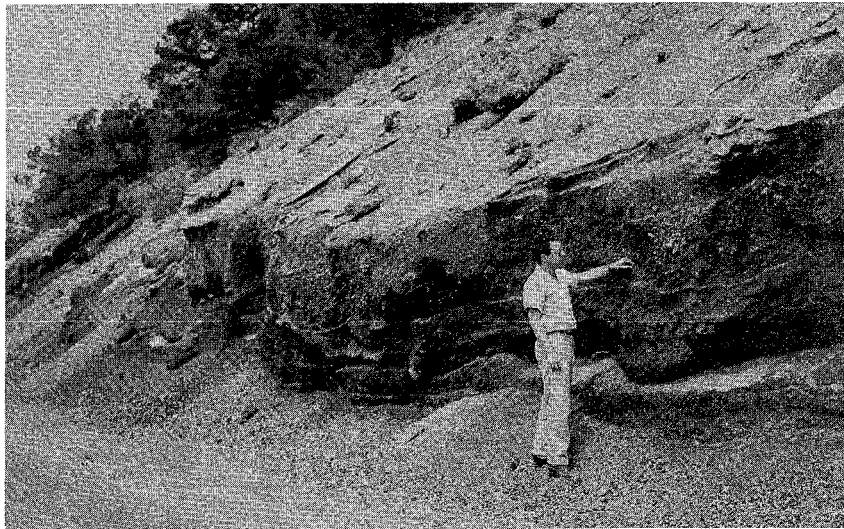
15.7 Lava flow about 100 yards beyond base of mountain below has prominent pressure ridges. These are formed when the upper surface gets stiff while the liquid lava underneath keeps moving and folds the upper part. Asphalt forms similar ridges as it slides off the high central parts of a highway.

15.8 Sierra Grande at 1:30 o'clock. Outer edges of Capulin



Pressure ridges

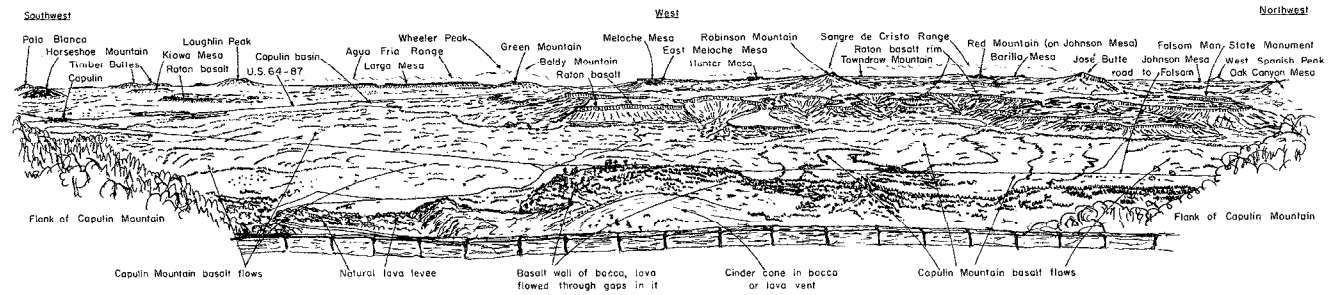
Mountain basalt, about one mile out, are marked by lines of bushes. In the roadcuts can be seen large bombs from Capulin that were dropped during the constant rain of cinders .



Cinders along flank of Capulin Mountain.

- 16.2 Village of Des Moines can be seen at north (left) base of Sierra Grande. On a clear day over the edge of Sierra Grande, Rabbit Ears Mountain (5,940 ft.) can be seen 40 miles away, north of Clayton.
- 16.4 At 3 o'clock about 5 miles away, with red and black scars, is Twin Mountain, a volcano younger than Capulin Mountain.
- 16.5 Big volcano about one mile north of us (with trees on far side) is Mud Hill (a Clayton-age volcano). Behind it another mile is Baby Capulin Mountain (bare cone into whose crater we can see). Baby Capulin is the youngest volcano in this region. Two miles ahead and slightly to the left is the village of Folsom.
- On skyline to north are broad mesas capped by the earlier Raton basalt sequence.
- 16.6 Tree-covered flats, beyond road below us and extending almost to Folsom, are underlain by basalt from Capulin Mountain.
- 16.7 José Butte, Clayton-age volcano, about 4 miles to west northwest. (Cone with shoulder humps on both sides).
- 16.8 Robinson Mountain, Clayton-age volcano, about 5 miles to west. O. K. Let's get to the top so we can stop and everyone can enjoy the view.
- 17.1 Parking area. STOP. Highest point on the other side of the rim is 8,215 feet. The panoramic sketch that follows identifies the major physiographic features of the region that can be seen to the west. This is a good time to review the geologic history of northeastern New Mexico near the beginning of this guidebook.

Below the viewpoint, near the base of the mountain, is the vent out of which the basalt lava flowed. The tree-covered rim that surrounds the vent is part of the wall that formerly enclosed the lava pool. On the other side of the parking area (east) is the crater of the volcano from which gases escaped and blew molten lava into the air, where it cooled, and dropped back to build up the present cone. The rim is higher on the other side because it was the downwind



Panorama from parking lot on rim of Capulin Mountain.

side during the eruption. The crater bottom is about 415 feet below the highest point on the rim.

At the information booth just below the parking area on the crater side are booklets that include a discussion of the geology, wildlife, trees, and flowers of the Monument area as well as a guide to the trail along the crater rim. In addition to the rim trail, a trail from the information shelter leads to the bottom of the crater. Both trails are fairly short and are well worth the walk.

Retrace route to junction of Monument road and N. Mex. 325.

- 19.8 JUNCTION. Monument road and N. Mex. 325. TURN LEFT.
- 19.9 Road starts down 400-foot drop to Capulin village. We'll be on top of Capulin Mountain lava nearly the entire distance.
- 20.2 Cattle guard, Road drops off the end of one lava flow onto the one under it.
- 20.7 Horseshoe Mountain on skyline ahead is another Capulin volcano. Humps around base are basalt lava masses.
- 21.3 Cattleguard
- 21.6 The valley on our right drained east (left), somewhere under us, before Capulin. Mountain erupted and stopped the drainage. The valley to the right is now a closed basin, the Capulin basin, containing large amounts of artesian water.
- 21.9 We have now driven off the end of the Capulin Mountain basalt. The southern rim of lava can be seen as brush-covered knobs to the left and right.
- 22.4 Cattle guard.
- 22.6 Capulin. Junction with U. S. 64-87. Join Log 4 at mileage point 54.5 to go to Raton or east to Clayton via 64-87.

LOG 3: CLAYTON-DRY CIMARRON CANYON-THREE
CORNERS-CLAYTON LAKE

(151.3 miles)

From Clayton to the canyon of the Dry Cimarron River the route is over gently rolling plains cut by some small valleys such as those of the Cieneguilla and North Canadian Rivers, and the ruts of the Santa Fe Trail. The divides between streams are capped by the tan sands and gravels of the Tertiary Ogallala formation. Along the valley walls are scattered exposures of the Cretaceous Graneros shale, Dakota sandstone, and Purgatoire formation. At approximately mileage point 31.8, the road (N. Mex. 18) begins the descent into the colorful canyon of the Dry Cimarron River, paralleling the New Mexico—Colorado border for almost 50 miles. Descending onto the floor of the canyon, we also descend into the geologic past as the road crosses over successively older rock units such as the Cretaceous Dakota and Purgatoire formations, Jurassic Morrison formation and Exeter sandstone, and Triassic Sheep Pen sandstone, the Sloan Canyon, and Travesser formations. Thus in a few brief moments we have passed over rock units that represent about 100 million years of time. From the junction of N. Mex. 18 and 325 in the canyon bottom, we include a short side trip to the monument that marks the common boundary between New Mexico, Colorado, and Oklahoma. Retracing the route back to the junction, the log continues up the Dry Cimarron Canyon past numerous copper- and iron-stained sandstone plugs to outcrops of the oldest rocks exposed in northeastern New Mexico the purple sands and muds of the Triassic Baldy Hill formation deposited some 180 million years ago. Leaving N. Mex. 325 (formerly U. S. 64) we continue on N. Mex. 370 as it winds back up out of the canyon over the interesting "agate bed" in the Morrison formation and returns to Clayton via Clayton Lake and Rabbit Ear Mountain. Altitudes along the route vary from 5,500 feet on the mesa above the Dry Cimarron Canyon to 4,500 feet at the Three Corners Monument.

This log connects with Log 1 at mileage point 95.8, and if preferred Log 1 may be followed to Raton via Johnson Mesa or to Raton via Logs 1, 2, and 4 past Capulin Mountain National Monument.

Clayton (altitude 5,050 feet; population about 4,100), the county seat of Union County, was named after the son of Senator Stephen W. Dorsey, of Arkansas. Senator Dorsey had a vast cattle

ranch that extended well into the present area of Union County from its headquarters in the Chico Hills. Clayton was surveyed in 1887 along the route of the Denver and Fort Worth (Colorado and Southern) Railway, then under construction. The site was one of the few along the route that was level and broad enough for the proposed division point between Trinidad, Colorado, and Amarillo, Texas. The first train was operated in March 1888, and Clayton rapidly assumed an important position as a shipping and supply center. For some years, cattle were driven to Clayton from as far south as Roswell and Capitan.

Union County historically has been an agricultural area with closer ties to Colorado and Texas than to New Mexico. It was settled when the Sangre de Cristo Mountains were still a formidable barrier to communications with central and western New Mexico. Development of the area began in the 1820's with the first wagon train across the Cimarron Cutoff of the Santa Fe Trail. Trading along this route was particularly hazardous. As late as 1868-69, Plains Indians killed 160 men in 5 months.

- 0.0 Begin at traffic light at center of Clayton; intersection of U. S. 64 and 87. Drive east on U. S. 64 toward Boise City. Route for next 1-1/2, miles is on basalt (commonly called malpais).

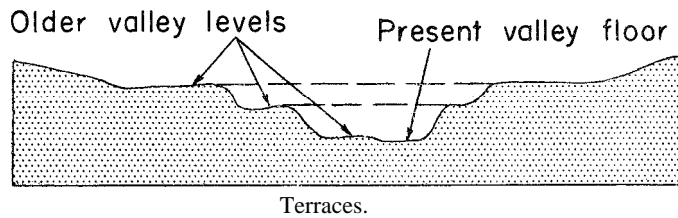
- 0.5 At 8 o'clock, Rabbit Ear Mountain, a prominent landmark along the Cimarron cutoff of the Santa Fe Trail, is one of about 80 extinct volcanoes present in Union County. The round-topped butte just to the right of Rabbit Ear Mountain and the low double hill at 10 o'clock are also extinct volcanoes. The three volcanoes are in a line that trends north of west. Apache Canyon (Rabbit Ear Creek) is in the middle distance of the road.

- 1.5 Descend hill from the east end of the basalt flow onto the poorly consolidated tan sandy clay and gravel of the Ogallala formation.

- 2.7 Cross abandoned road grade of the Atchison, Topeka & Santa Fe Railway from Felt, Oklahoma, to Clayton; the tracks were laid in 1931 and were taken up again early in World War II.

- 3.5 Turn left (north) off U. S. 64 on to N. Mex. 18.

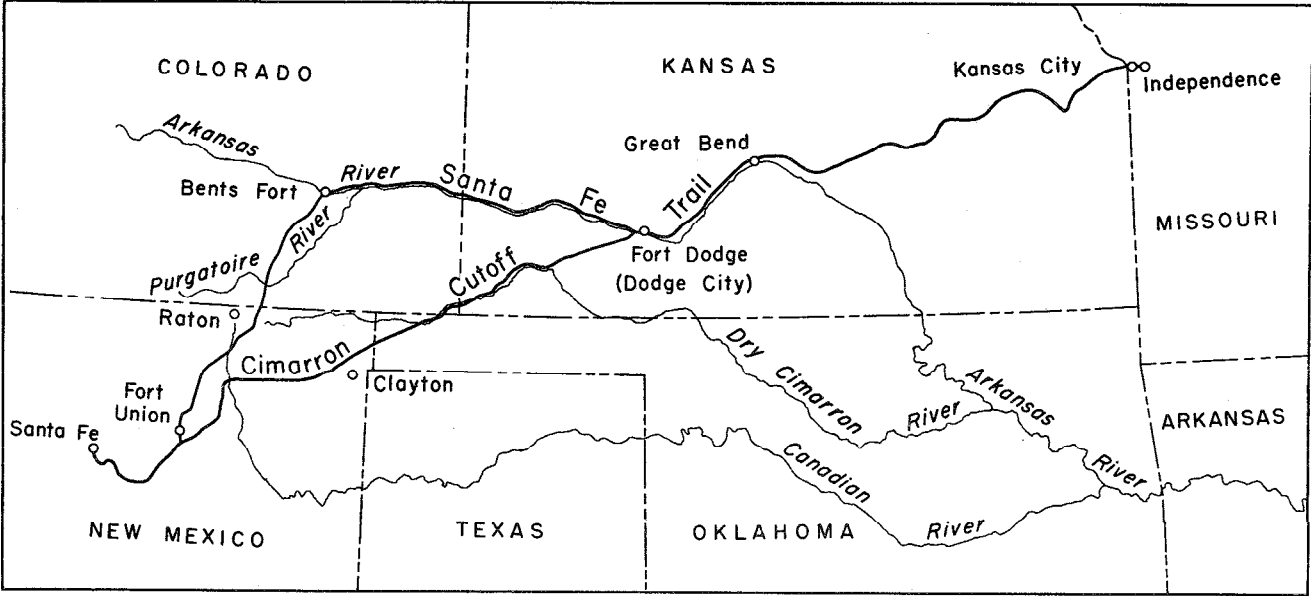
- 3.9 At 2 o'clock the Clayton Compressor Station of the Colorado Interstate Gas Company. The 22-inch pipeline extends from the gas fields at Borger, Texas, to Pueblo, Colorado. Rabbit Ear Mountain at 11 o'clock. Road continues on the Ogallala formation.
- 9.1 Ascend hill. In roadcut on the left basalt rests on sandy clay of the Ogallala formation, the upper foot of which is here turned to a brick-red color because of baking by the lava flow.
- 9.5 Trail to right leads to windmill; the lava flow extends east of the well.
- 9.8 Descend from basalt flow onto the Ogallala formation. The highway levels off on a high terrace; the same level is also present on the north side of the valley, 2 miles ahead.



- 10.5 Pipeline crossing.
- 11.0 Trail to right leads to an irrigation well that yields 1,000 gallons of water a minute from sand and gravel of the Ogallala formation.
- 11.4 Bridge across Cieneguilla Creek (commonly called Seneca Creek).
- 12.0 At top of hill, intersection with dirt road. Route from here to the nearest farmhouse is on the high terrace.
- 15.0 Seneca School on right.
- 16.0 SLOW. Highway turns right.
- 17.0 The base of the Ogallala formation is about at road

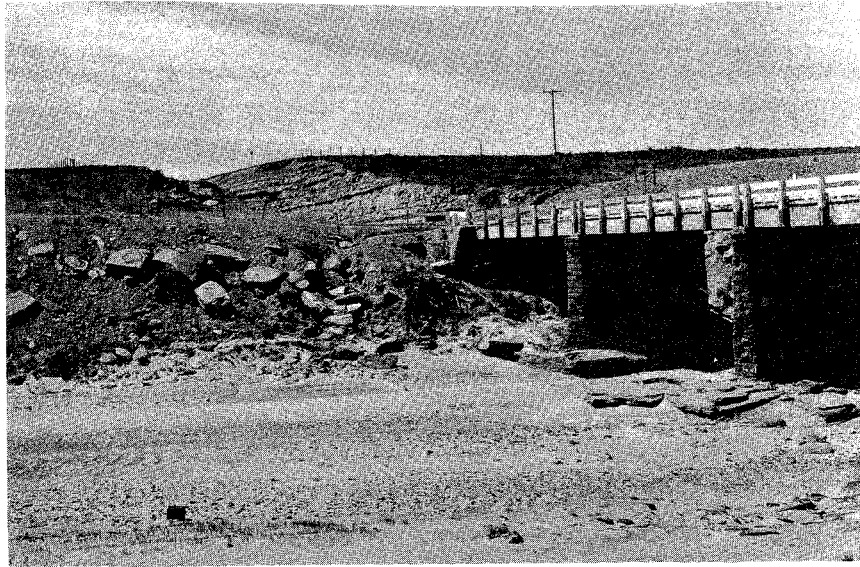
level. The highway, even with all its bends, is following section lines!

- 17.9 The tan Ogallala formation is exposed at 9 o'clock on the hill top.
- 19.0 SLOW. Highway turns left (north).
- 20.4 At 1 to 2 o'clock, valley of the North Canadian River (commonly called Corrumpa Creek in Union County, and Beaver Creek in Oklahoma).
- 21.8 Top of hill; slow down for first stop.
- 22.1 STOP. 200 feet beyond road to left leading to the old Moses Church. Hill at 9 o'clock rises westward on a surface stripped on the Dakota formation; Graneros shale is exposed this side of the valley. In cut to right of road, the felted limestone of the Graneros shale forms slabs; the limestone is about 15 feet above the highest sandstone of the Dakota formation and is characterized by tiny needles of calcite shell fragments. The scar just above the flat at 10 o'clock is a remnant of the Santa Fe Trail.
- 22.3 At 2 o'clock, the white pillar a mile away in front of steep bank is a monument to the days of the Santa Fe Trail.
- 22.5 Route crosses the Santa Fe Trail; the ruts can be seen dimly to the right of the road. The Cimarron Cutoff of the Santa Fe Trail was first used about 1822; it saved many miles since the main trail went west to the base of the mountains following the Arkansas River and then south across Raton Pass (see map); however, the Cimarron route had water holes spaced as much as 30 miles apart; this meant several dry camps. Fort Union, now a National Monument, was built in 1851 at the junction of the two routes to afford protection from Indian raids.
- 23.1 Highway descends hill. The roadcut is in the thin-bedded sandstone and siltstone of the upper part of the Dakota formation. The dark gray beds are plant-bearing coaly shales.



Santa Fe Trail

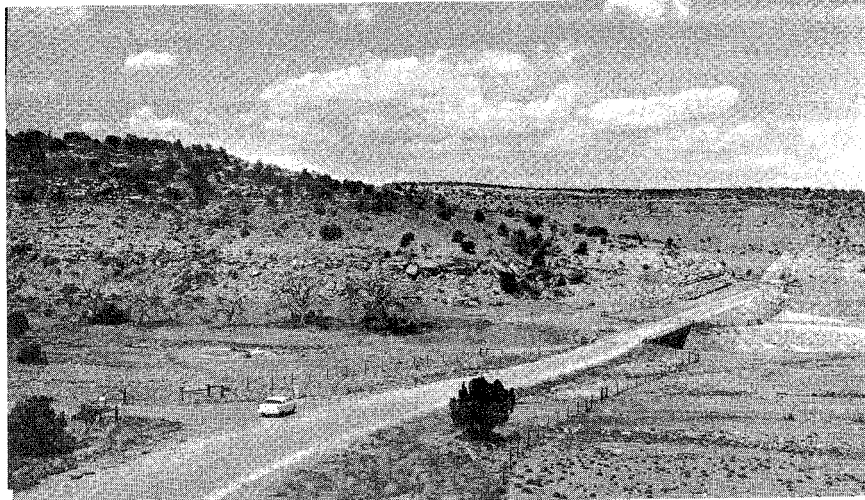
- 23.3 Narrow bridge across the North Canadian River (Corrumpa Creek). The massive sandstone at 10 o'clock is in the upper part of the Dakota formation.



Dakota sandstone; north Canadian River

- 23.7 The gully at end of curve to the right is the result of the heavy traffic over the Santa Fe Trail.
- 24.3 Moses store and gasoline station; curve right. The highway is now back on the Ogallala formation; the contact with the underlying Dakota formation is a few hundred feet south of the store.
- 25.7 Curve left. The road to the right is paved to the Oklahoma State line. The Santa Fe Trail extends northeast at 1 o'clock.
- 26.5 Cattleguard.
- 27.3 Cattleguard. From 10 to 11 o'clock, the shrub-covered mesas are capped with sandstones of the Dakota formation. About 20 feet of Graneros shale rests on the Dakota formation near the base of the ridge. The ridge along the route is formed by the Ogallala formation. Sierra Grande (8, 720 ft.) an extinct volcano, is the high peak at 8:30 o'clock.

- 28.9 Cattleguard. Route follows a ridge that is capped by the Ogallala formation. Sandstone of the Dakota formation is exposed in valleys on either side; but the Graneros shale, which here lies between the Dakota and Ogallala formations, is mostly covered.
- 29.6 Cattleguard.
- 30.5 Windmill on right. On the skyline from 11 to 12:30 o'clock is Black Mesa, which is capped with a narrow tongue of basalt that extends southeast from Mesa de Maya in Colorado.
- 31.3 At 9 o'clock the bare benches a mile to the west are on the top of the Dakota formation.
- 31.8 Descend from Ogallala formation onto the Dakota formation; the Graneros shale is absent here as a result of erosion before the deposition of the Ogallala formation.
- 33.9 Road curves to the left. The route is in the upper part of the Dakota formation, which here has been eroded into many small sandstone knobs.
- 34.8 SLOW. Top of Riff Hill; road turns left. Thinbedded sandstone and shale of Dakota formation in roadcuts.
- 35.0 Top of the massive sandstone that is the basal, cliff-forming unit of the Dakota formation. The sandstone is well exposed as the rimrock on either side of the road.
- 35.3 Highway curves right. The few feet of light-brown sandstone at the top of the roadcut is the bottom of the sandstone member of the Purgatoire formation. It rests on light-gray siltstone and greenish and maroon mudstone of the Morrison formation. The thick sandstone at the lower end of the cut is part of the Morrison formation.
- 35.5 Bridge across Road Canyon.
- 35.6 Morrison formation in roadcut. Most of the uranium produced in the United States is obtained from this formation.



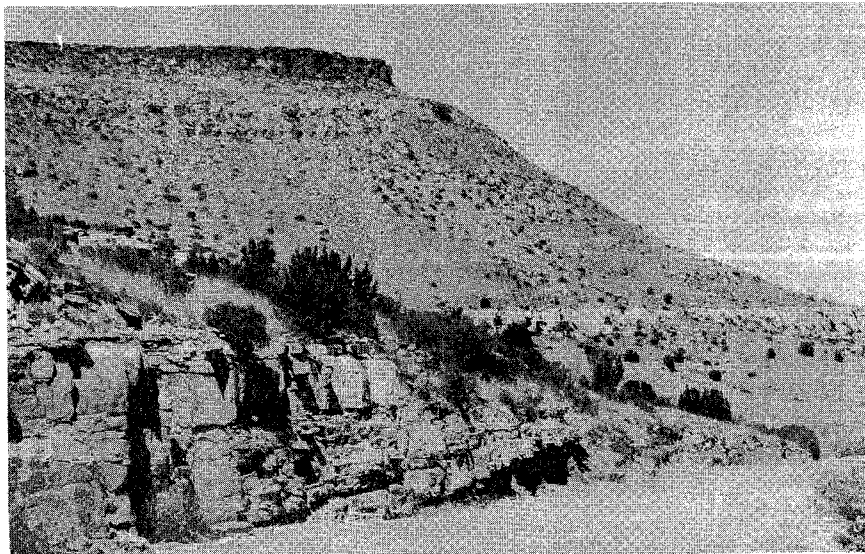
Morrison formation in roadcut just beyond bridge.
 Purgatoire sandstone at top of roadcut can be traced to
 the left. Dakota sandstone caps ridge in left fore-
 ground and mesa in background.

- 35.8 Cattle guard.
- 36.0 At 3 o'clock, the Dakota sandstone caps mesa; the sandstone member of the Purgatoire formation is half way down the slope. It is overlain by a medium- to dark-gray shale member that is generally covered by debris from overlying Dakota sandstone.
- 36.7 The butte to the right of the road is capped with a thin sandstone that is at the top of the Purgatoire formation; the shale member is covered, but the lower Purgatoire sandstone is exposed half way down the side of the hill.
- 37.5 Remains of slush pit of the Pure Black Mesa #2 oil test just to left of road. No oil was found. At 3 o'clock, the Purgatoire sandstone is exposed only at the left and right ends of the mesa below the Dakota sandstone cap. The sandstones exposed in the lower third of the slope are in the Morrison formation.
- 38.6 Bridge across Carrizozo Creek.

- 38.8 Road to left goes up valley of Carrizozo Creek. At 11 o'clock the knob is a clastic plug of sandstone.
- 39.8 Junction of N. Mex. 18 and 325. To continue on this log for a short side trip to the monument marking the point common to New Mexico, Oklahoma, and Colorado, turn right on N. Mex. 325. Round trip distance to the Three Corners Monument from this junction is 27.0 miles. To continue west up the Dry Cimarron Canyon turn left onto N. Mex. 325 and follow this log from mileage point 66.8.
- 40.7 Bridge across Carrizozo Creek; New Mexico Oklahoma State line.
- 41.1 The butte to the right of the road is capped with a brown sandstone, uppermost part of the Purgatoire formation or the lowermost part of the Dakota formation.
- 42.8 Bridge. Kenton, Oklahoma, is just ahead. The mesa from 12 to 3 o'clock, is capped by Dakota sandstone; the Purgatoire sandstone is the thick white sandstone below. At 8:30 o'clock, the east end of the hill is faulted.
- 42.9 Kenton, Oklahoma. Filling station, grocery store.
- 43.3 Turn left onto dirt road. The paved road continues east to Boise City, about 35 miles. A dinosaur quarry, from which several skeletons were collected from the upper part of the Morrison formation, is 7 miles east of this turnoff, on the north side of the road; a large concrete cast of a legbone marks the locality. Black Mesa extending from 10 to 12 o'clock is the highest point in Oklahoma, at about 5,000 feet above sea level.
- 45.2 Bridge across Dry Cimarron River. For the next 2 miles, the Dakota sandstone is exposed nearly continuously half way up the slope below Black Mesa. The underlying Purgatoire sandstone is exposed in a few places. The covered interval between the Dakota sandstone and the lava cap is sand and gravel of the Ogallala formation.
- 47.4 Cattleguard. North Carrizo Creek is on the right of the road. The Dakota and Purgatoire sandstones are

exposed in the spur to the left of the road.

- 48.3 Tate (Labrier) Butte at 12 o'clock is capped with Dakota sandstone; Exeter sandstone is exposed near the base.
- 48.9 Sheep Pen sandstone and Sloan Canyon formation of Triassic age exposed on both sides of road.
- 49.1 Top of hill. The Exeter sandstone is at road level; note the crossbedding.
- 49.3 (Picture point). Descend hill. The road cut at the left exposes the Sheep Pen sandstone, which is a thin bedded light-brown sandstone with streaks of red and green mudstone. The Sheep Pen sandstone is here underlain by vividly colored maroon and green mud stone of the Sloan Canyon formation.

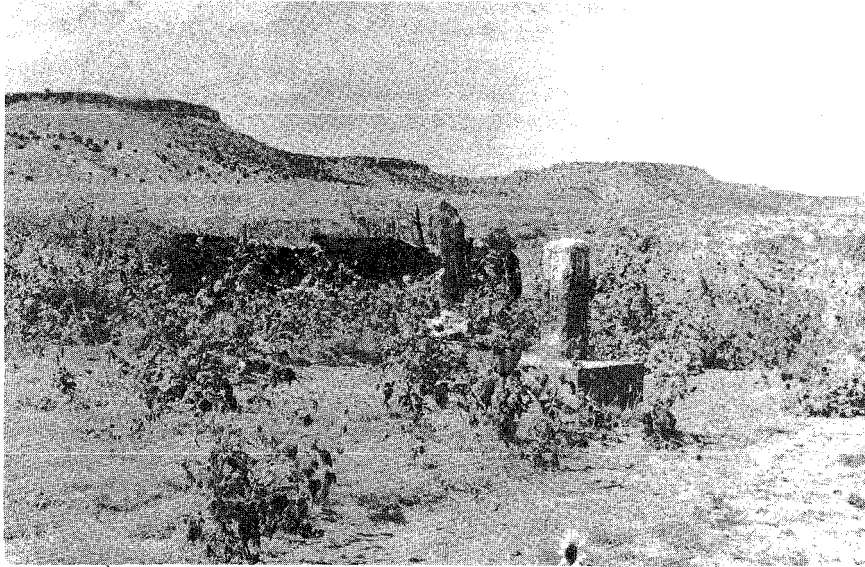


Sheep Pen sandstone above Sloan Canyon formation in roadcut. White cliff near base of slope in background is Exeter sandstone overlain by slope of Morrison formation. Lower cliff near top of mesa is Purgatoire sandstone and Dakota sandstone caps mesa.

- 50.7 Cattle guard. At 3 o'clock, the butte is capped with the Dakota sandstone, and the Exeter sandstone forms the

cliff just above the creek. At 8 o'clock, the Sheep Pen sandstone caps the low bench.

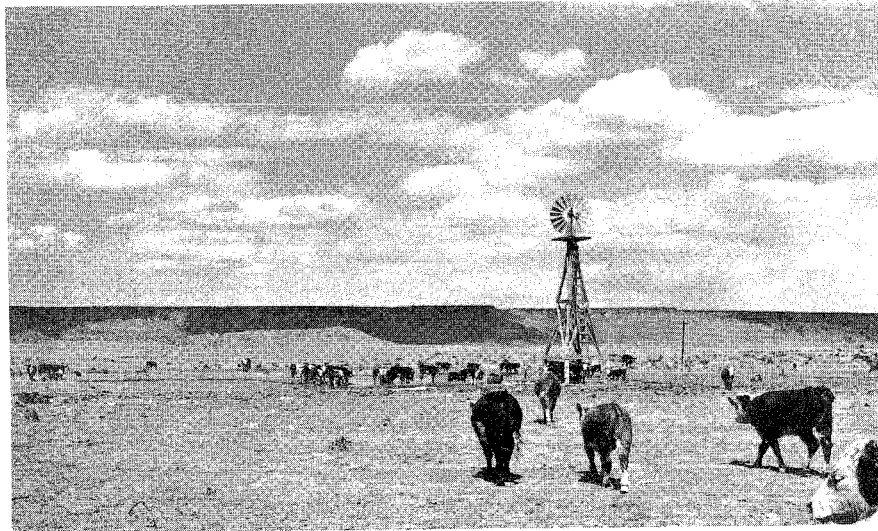
- 51.1 Cattleguard.
- 51.2 SLOW; sharp dip.
- 51.4 Cattleguard. Ranch road to left.
- 52.1 Cattleguard.
- 52.6 Cattle guard. Turn left onto ranch road.
- 53.3 Cattleguard. The monument that marks the northeast corner of New Mexico, with Colorado on the north and Oklahoma on the east, is 200 feet to the north. The mesas at 10 to 11 o'clock are capped with the Dakota sandstone. The Exeter sandstone forms the shrub covered knob just to the southeast. Turn around and retrace route.



Three corners monument. Standing in Colorado and looking southwest across corner of Oklahoma into New Mexico.

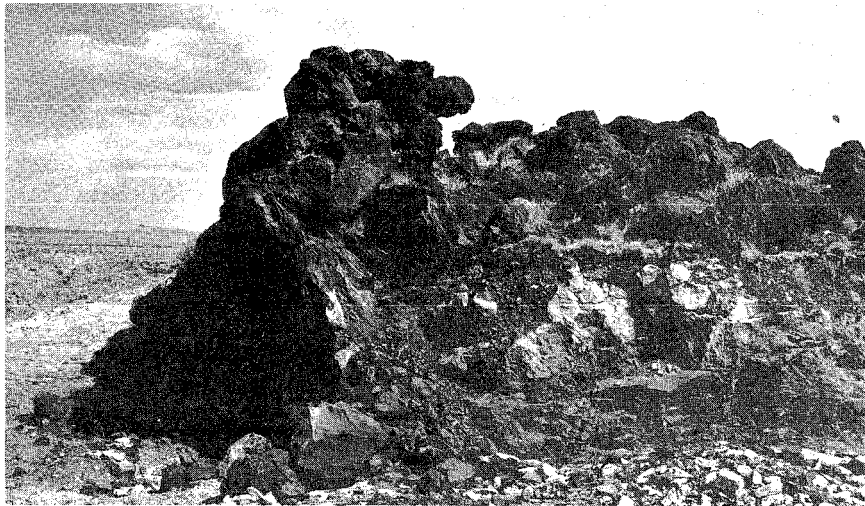
- 63.7 Kenton Post Office on left.

- 64.6 At 10 o'clock, the Purgatoire sandstone rests on a tilted sandstone of the Morrison formation.
- 65.7 Bridge across Carrizozo Creek. Re-enter New Mexico.
- 66.8 Junction of N. Mex. 18 and 325. Continue straight ahead. At 3 o'clock in the slopes below basalt capped Black Mesa, the Dakota sandstone near the top and the Exeter sandstone near the base are fairly continuously exposed; the remainder of the slopes are covered by talus and landslides. Pavement ends.
- 67.8 Clastic plug forms a knob on the right of the road.
- 68.7 STOP on hilltop. The bench is capped with the Sheep Pen sandstone, and the Sloan Canyon formation is exposed in the left side of the roadcut. On the right, a clastic plug. Note the many blocks of sandstone and mudstone that are tilted out of position. On the right side of the roadcut, at the east end, there is a dike of light-gray sandstone.
- 70.0 Narrow bridge. At 10 o'clock, the low bench is underlain by the Sloan Canyon formation.



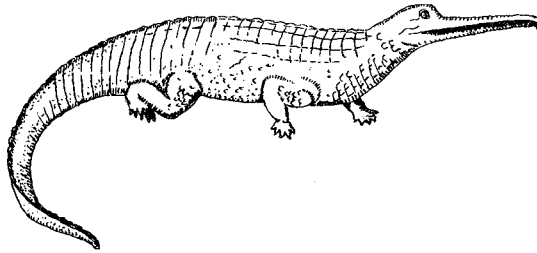
Windmill and stock tank; Dry Cimarron Valley.

- 71.2 Goodson School at 2 o'clock. In the hill at 3 o'clock, part of the Morrison formation and the underlying white Exeter sandstone are faulted down against the mud stones of the Sloan Canyon formation, which forms the knob to the right.
- 72.1 Ranch road to left. Knob at 3 o'clock is capped with white sandstone, probably Sheep Pen. At 9 o'clock, the mesa is capped by the Dakota sandstone; the next sandstone down is Purgatoire, and the lower two sand stones are in the Morrison formation.
- 72.7 At 9 o'clock, the low hill is capped with the lower part of the Morrison formation, with the white Exeter sandstone at the base. At 1 o'clock, the dark-brown knob is a clastic plug mineralized with hematite.
- 73.3 Narrow bridge. The clastic plug at 2 o'clock is reported to have been mined for copper in the early 1900's. Development reportedly included a shaft 380 feet deep with several tunnels.
- 74.3 Clastic plug on right of road. Another plug, just ahead at 11 o'clock, has been worked on a small scale for copper. The surrounding rock is the Sheep Pen sandstone, which holds up the bench above the road to the left.



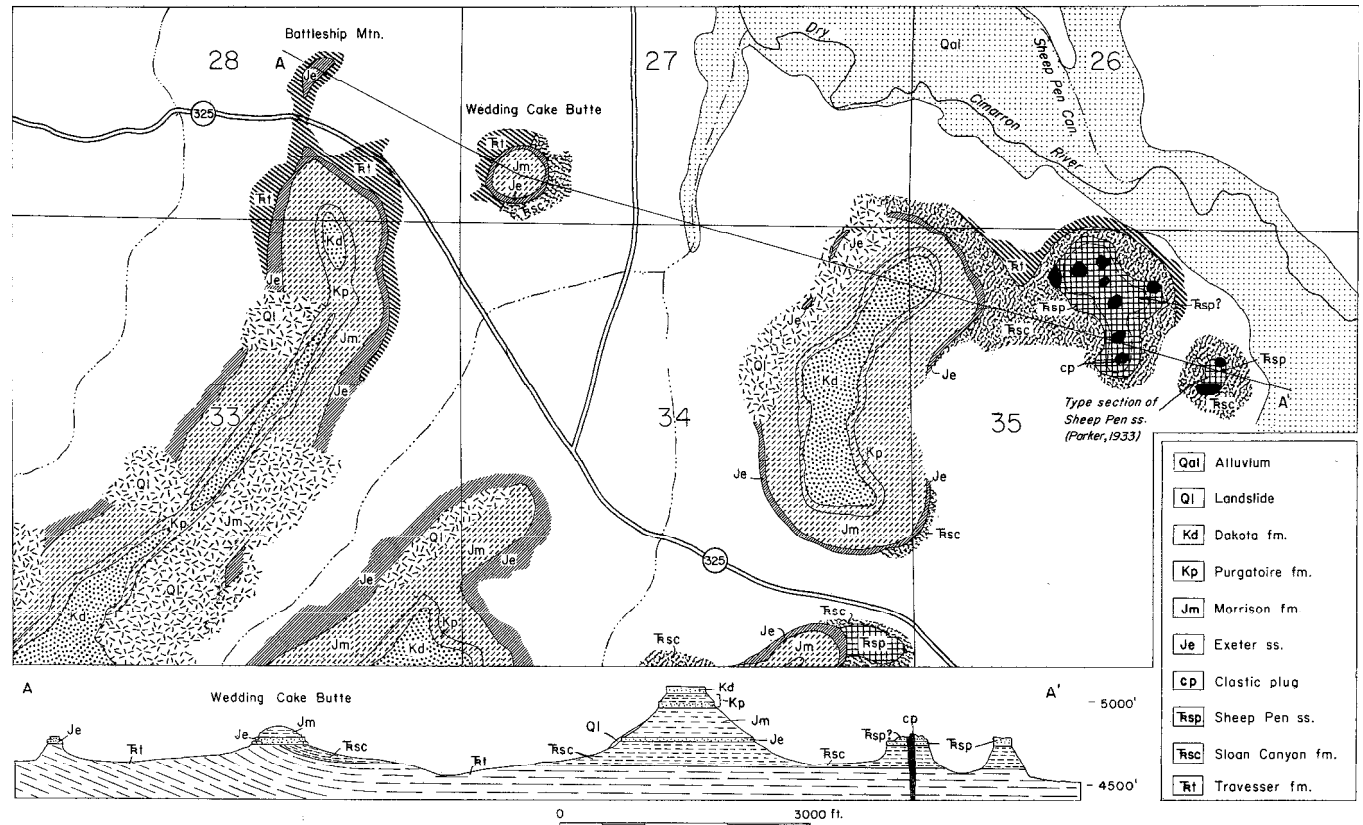
Clastic plug.

- 75.0 SLOW. Turn right and cross bridge over Sloan Canyon creek. Just downstream are sandstone dikes cutting the Sloan Canyon formation. About 500 feet downstream, the fossil remains of a phytosaur -- a crocodile-like Triassic reptile -- were collected.

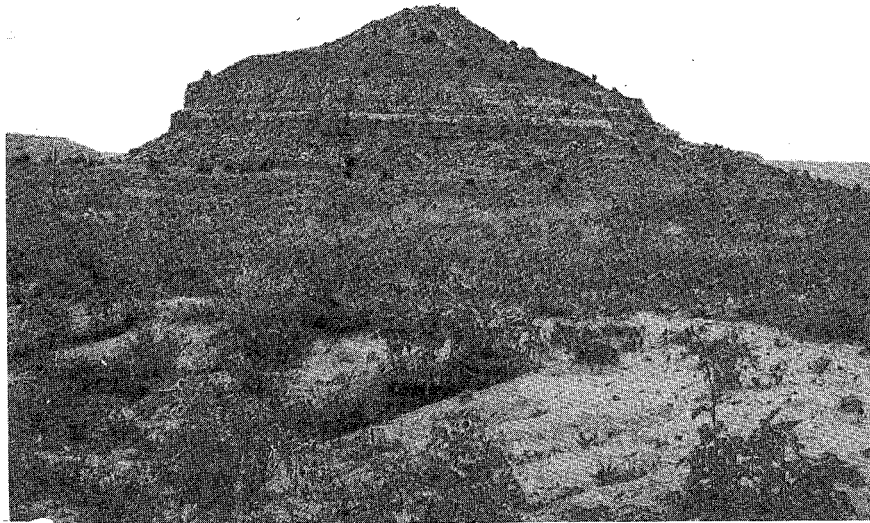


Phytosaur.

- 75.3 Road bends left. At 3 o'clock and 10 o'clock the Sloan Canyon forms low mesas. This is the type locality for the Sloan Canyon formation of the Dockum group.
- 75.9 Mailbox and ranch road to right; continue straight ahead. At 1 o'clock the small butte is the type locality of the Sheep Pen sandstone. At the butte, the sandstone is 68 feet thick and rests on the Sloan Canyon formation. Observe that in the next 3 miles, both the Sheep Pen sandstone and the underlying Sloan Canyon formation are cut out beneath the Exeter sandstone because of pre-Exeter folding and erosion.
- 76.3 At 9 o'clock, the massive white Exeter sandstone overlies about 10 feet of thinbedded Sheep Pen sandstone.
- 77.7 Top of hill; Wedding Cake Butte at 1:30 o'clock is capped by the Morrison formation; a lower brown-silt part of the Morrison forms the steeper slope just above the white cliffs of the Exeter sandstone.
- 78.3 Keep straight; road to right leads to Mesa de Maya in Colorado. Wedding Cake Butte at 1 o'clock; Battleship Mountain at 12 o'clock. For the next 3 miles, the Exeter sandstone has an extra, lower cliff and is as much as 80 feet thick.



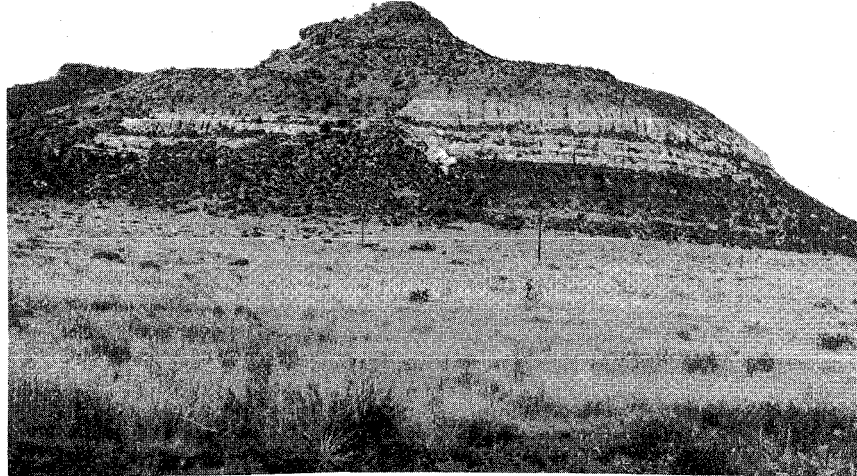
Geologic map and section of Wedding Cake Butte area.



Wedding Cake Butte. Slope of Morrison formation at top; double Exeter sandstone cliff; Sheep Pen sandstone cliff.

- 79.4 Top of hill. Battleship Mountain is on right, note the tilted sandstone and red-brown mudstone of the Travesser formation at the base of Battleship Mountain. The best view of this angular unconformity is about 0.2 miles farther along the road (see frontispiece).
- 80.1 At 11 o'clock, there is a south-trending fault that offsets the Exeter sandstone about 40 feet. At 3 o'clock, across the valley, the Exeter rests on the red beds of the Travesser formation.
- 81.1 The Exeter sandstone, as can be seen at 9 o'clock, thins abruptly. This is the westernmost extent of the lower sandstone bed in the Exeter. At 2 o'clock, the west-dipping red beds are on the far side of the pre-Exeter folding that resulted in the removal of the Sheep Pen sandstone and Sloan Canyon formation over the crest of the anticline.
- 82.9 STOP where road curves to right; ranch road to left. To the south, the Sheep Pen sandstone forms the 20-foot ledge on the bench that projects from the main mesa; the ledge is overlain by nearly 90 feet of sand-

stone that projects above the level of the lower brown-silt part of the Morrison; evidently this was a residual hill of Sheep Pen sandstone that was not buried until after the lower brown silty interval was deposited. From a point half a mile south, along the ranch road, there is a good view of the Exeter resting unconformably on the Sloan Canyon formation and the lower part of the Sheep Pen sandstone. Continue on main road.



Fault with left (east) side downthrown by about 40 feet as shown by Exeter sandstone cliff.

- 83.1 Bridge across Dry Cimarron River.
- 84.3 Cattleguard. From 9 to 10:30 o'clock, the Sheep Pen sandstone forms the persistent ledge half way up the side of the mesa. The orange-colored Exeter sandstone appears to be absent in places above the Sheep Pen sandstone. At 1:30 o'clock the reentrant in the valley walls at 11 o'clock is Peacock Canyon. The Exeter sandstone rests on the Sloan Canyon formation, and the Sheep Pen sandstone is absent.
- 85.8 Top of hill. Clastic plug at 3 o'clock at base of steep slope. The Exeter sandstone is mostly covered by landslides.

- 87.6 Mailbox and ranch road at left. At 4 o'clock, a clastic plug stands above the bench of red beds. The Exeter sandstone is probably absent at the base of the main steep slope at 2 o'clock. From 9 to 10 o'clock, many clastic plugs dot the valley floor. For the next 3 miles, outcrops along the road are red beds of the Travesser formation.
- 88.4 Road curves down hill to left. Valley School (abandoned) on left. At 1 o'clock, several flows of basalt cap the mesa, resting on the eroded surface of the Dakota sandstone.
- 90.1 Valley Post Office (abandoned) in building to left. At 9 o'clock, red beds dip east. The Exeter sandstone in the vicinity is only about 20 feet thick.
- 90.6 Bridge across Dry Cimarron River.
- 90.9 Top of hill. Observe the variations in thickness of the Exeter sandstone. At 3 o'clock, the basalt flows rest on tilted beds of the Dakota formation. The Colorado-New Mexico state, line is about where the Exeter sandstone crops out at 3 o'clock.
- 91.6 On the right, above road level, massive red beds of the Travesser formation are overlain by less than 10 feet of Exeter sandstone. For the next 2-1/2 miles the route follows Travesser Creek southwestward along the lower side of the Guy monocline.
- 92.6 To left most of the bedrock is covered by landslide.
- 94.4 Road bends to the right. Route for the next 2 Miles is westward across the Guy monocline. Travesser Creek reaches southward. At 11 o'clock, the brown-silt part of the Morrison formation, the Exeter sandstone, and the Travesser formation make a small nose on the steep slope.
- 95.8 Junction of N. Mex. 325 and 370, altitude, 5,042 feet. Continue straight ahead. At 3 o'clock, Baldy Hill is capped by the Morrison formation, which rests on the Exeter sandstone, which in turn rests on the Travesser formation. The resistant ledge at road level is the basal unit of the Travesser formation, which overlies

purple mottled mudstones of the Baldy Hill formation.

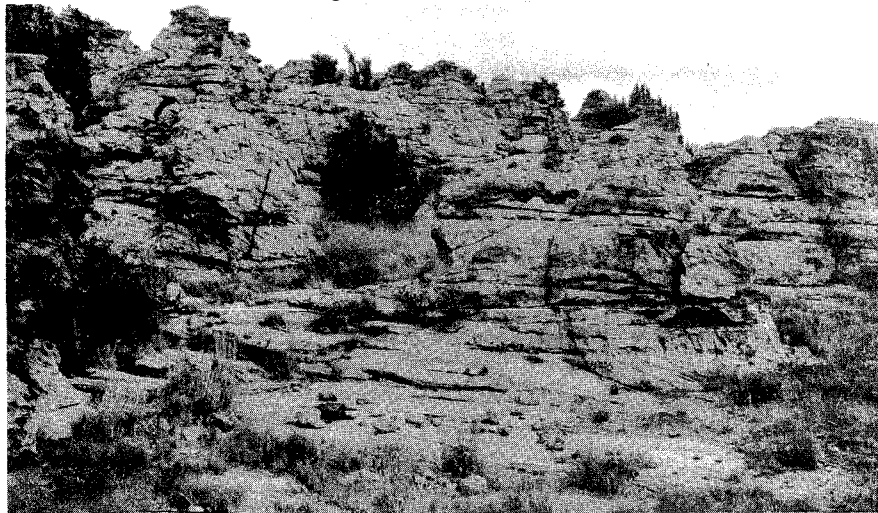
- 97.1 STOP on top of hill. Road continues to Folsom and Capulin. Face east down valley. Using Baldy Hill as the 12 o'clock direction, the Baldy Hill formation is exposed from 7 to 12 o'clock beneath the ledge-forming basal unit of the Travesser formation. The Triassic Baldy Hill formation is the oldest formation exposed in Union County. The Dry Cimarron River has here cut down below the top of the formation, but the Guy monocline depresses the Baldy Hill formation below river level only 3 miles to the northeast. To continue west on this road to Folsom, Capulin Mountain National Monument, Johnson Mesa, and Raton, see Log 1 at mileage point 67.8 and reverse the log. To return to Clayton via this log retrace route 1.3 miles to junction of N. Mex. 325 and 370,
- 98.4 Junction of N. Mex. 325 and 370; turn right.
- 99.2 At 1 o'clock, the best continuous exposures from the Exeter sandstone up to the Dakota sandstone can be seen. In this vicinity, the Travesser formation has its type locality but is only 250 feet thick, whereas it is commonly more than 400 feet thick. The yellow band is the Exeter sandstone; the white immediately above is a gypsum cement in the lower part of the Morrison formation and in the upper few feet of the Exeter sandstone. At 12 o'clock, the Dakota sandstone on the skyline is on the west, or upper side of the Guy monocline .
- 100.6 Cattleguard. The Dakota sandstone from 9 to 1 o'clock is on the monocline .
- 102.2 Road to right leads to Colorado Interstate Gas Company's Cimarron Compressor Station.
- 103.6 At left, the yellow sandstone is Exeter; nodules of white gypsum are probably from the lower part of the Morrison formation.
- 103.9 STOP at pipeline crossing. The agate bed is exposed in the roadcut. Pieces of the red-orange agate are strewn along the road, from the outcrop down. The agate consists of chalcedony and calcite and breaks

apart readily. The agate bed of the Morrison formation has been recognized in much of the Rocky Mountain region and western Plains. It may represent an ancient soil developed in volcanic ash. Continue up hill; the Morrison formation is thinbedded and in the upper part is maroon.

- 104.2 Top of hill. The route is on the west, upper side of the Guy monocline; the Dakota sand stone to the left dips eastward.
- 104.9 Second cattle guard. Maintenance camp for the pipeline at 9 o'clock.
- 105.6 Bridge. Triassic redbeds and Jurassic Exeter sandstone in cutbank.
- 106.6 Top of hill. Route is on the upper part of the Morrison formation; the Purgatoire formation is not readily recognized, but Dakota sandstone caps the ridge at 9 o'clock.
- 108.0 Road to right. At 7:30 o'clock the creek drains eastward through a "V"-notch in the Dakota sandstone which dips east.
- 108.7 Road on Morrison formation. At 1 o'clock, Carrizozo Creek drains eastward through a V-notch in the east-dipping Dakota sandstone.
- 110.0 Slab crossing of Carrizozo Creek; Guy Post Office (abandoned) on left.
- 111.5 Top of hill. Road is probably on Purgatoire formation. The broad valley 3 miles ahead is along Corrupa Creek, in the headwaters of the North Canadian River. Sierra Grande to right in distance; Rabbit Ear Peak at 11 o'clock.
- 112.1 Road turns left, across the east-dipping beds of the Dakota formation on the steeper part of the Guy monocline. Road to right leads west toward Des Moines.
- 112.5 Top of hill. Road on gravel of Ogallala formation for the next 2 miles. At 2 o'clock, glimpses of the Dakota sandstone, in the valley of Corrupa Creek, on the

east, lower side of the Guy monocline.

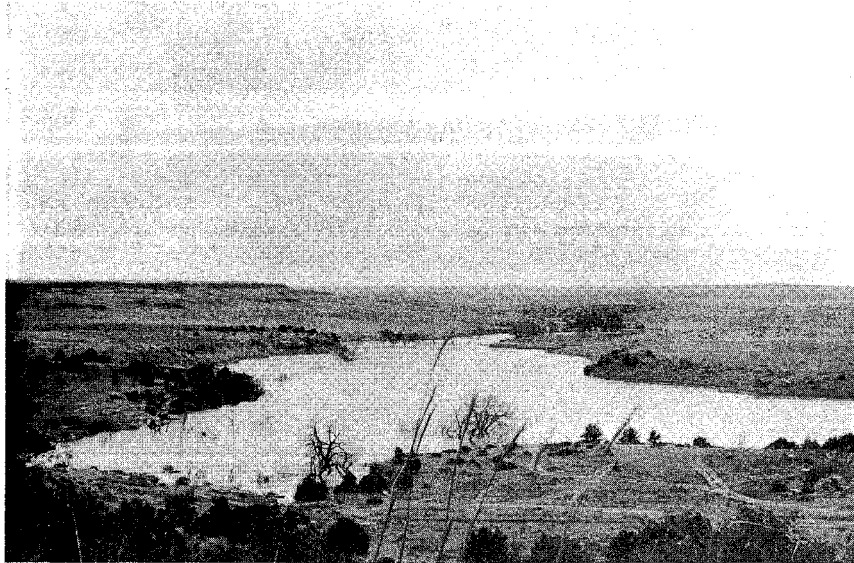
- 115.2 Pipeline crossing. Road is on the upland surface, developed on the Ogallala formation
- 116.5 Dry lake at right. The hill at 11 o'clock consists of the Ogallala formation with a caliche cap
- 117.2 Road turns right (south).
- 118.2 Road turns left (east).
- 120.2 Road turns right (south).
- 122.6 Top of hill. Several of the more prominent volcanoes can be seen from here: Rabbit Ear Mountain (6,070 feet) at 11 o'clock; Bible Top at 12; Mt. Dora (Burro Mountain) 6,295 feet, at 1; Sierra Clayton (Round Mountain), 6,665 feet at 1:30; Sierra Grande, 8,720 feet, at 3; and Capulin Mountain, 8,215 feet, at 3:30. Altitudes are approximate.
- 125.0 Outcrop of castellate-weathering Dakota sandstone on right. At 12 o'clock, in cutbank of North Canadian River, about 15 feet of black shale of the Purgatoire formation underlies the Dakota sandstone.



Castellate Dakota.

- 125.2 Bridge across North Canadian River.
- 126.2 SLOW for winding road. Dakota sandstone at road level.
- 127.1 Top of hill. From 1 to 3 o'clock, there are east-dipping beds of the Graneros shale and Dakota formation, on the southern extension of the Guy monocline
- 128.7 Road intersection; continue straight. Grandview School (abandoned) on right. For the next 4 miles, the route is on the Ogallala formation, except for the valleys, which are cut into the upper part of the Dakota formation.
- 130.4 Cross the Santa Fe Trail, which is not distinct here.
- 130.9 Bridge over Alamos Creek. Thinbedded shaly sandstone of the upper part of the Dakota formation in the cutbank.
- 131.6 Top of hill. At 11 o'clock, view southeast into the elongate crater of Rabbit Ear Mountain.
- 132.8 Road turns left. Road is on the upper part of the Dakota formation for the next 1.2 miles.
- 133.0 At 11 o'clock caliche-capped buttes of Ogallala formation.
- 134.6 Road curves right; road on Ogallala formation for a short distance.
- 135.1 At 12 o'clock the mesa is capped with basalt, which is underlain by less than 20 feet of the Ogallala formation, and in turn is underlain by the Dakota formation.
- 135.8 Bridge across Seneca (Cieneguilla) Creek. Clayton Lake is a mile upstream. The field at 1 o'clock is irrigated from a storage tank fed by water seeping from the Dakota sandstone. At 3 o'clock the green grass marks a seep at the base of the Dakota sandstone, one of the good water-bearing units of Union County.
- 136.3 On the hill, the Ogallala is thin, and the top foot is red because of baking by the overlying lava flow.

- 136.4 Road on Rabbit Ear Mesa, which is capped by several long, narrow tongues of basalt that issued from Mt. Dora or some other volcano to the west. These tongues are in turn buried in places by later sheets of basalt from Rabbit Ear Mountain, Mt. Dora, and other nearby volcanoes.
- 137.2 Turn right onto road to Clayton Lake.
- 138.0 SLOW, turn right (north).
- 138.5 SLOW. Descend hill from rimrock of basalt onto Dakota formation.
- 138.7 STOP in parking area. The earth-fill dam for Clayton Lake was constructed in 1955 for the New Mexico Game and Fish Department. Although Seneca Creek has a modest base flow, the lake is fed primarily by flood water from rainstorms. The reservoir has a capacity of about 4,000 acre feet, and the dam is about 75 feet high. The Dakota sandstone forms the walls of the valley. Turn around and retrace route.



Clayton Lake.

- 140.3 Turn right onto N. Mex. 370.

- 141.8 Curve left. Ascend hill onto flows from Rabbit Ear Mountain.
- 142.5 Road turns right. The plate on the southwest side of Rabbit Ear Mountain is probably all that remains of the outside surface of the volcano. The rest is evidently the coating on the inside of the crater.
- 143.5 Descend hill onto an older basalt flow that may have come from Mt. Dora or farther west.
- 146.5 Road turns left. Apache Canyon ahead.
- 146.9 Descend hill from basalt cap onto Ogallala formation, which is exposed in pit on left,
- 147.4 Road curves to the left. The contact between the Ogallala formation and the underlying Graneros shale is marked by seeps and green grass.
- 148.6 SLOW. Slab crossing of Rabbit Ear Creek. The walls of Apache Canyon are covered by landslides.
- 149.2 Ascend hill. The top 5 feet of the Ogallala formation was turned red by the heat of the overlying basalt flow.
- 149.5 Top of Clayton Mesa; turn right.
- 150.9 STOP. Intersection of N. Mex. 370 with U. S. 64 and 87. Fort Jordan, a museum and zoo, with buffaloes, is half a mile to the right, across the overpass.
- 151.3 Traffic light, center of Clayton.

LOG 4: CLAYTON SIERRA GRANDE-CAPULIN MOUNTAIN-RATON

(82.0 miles)

For the first 66 miles along U. S. 64-87 we travel over gently rolling grassy plains, broken only by the numerous extinct volcanoes that dot the landscape in every direction. Near Des Moines the road skirts the base of the huge Sierra Grande volcano. In this area we again see the three major subdivisions of basaltic lava flows that cover much of northeastern New Mexico, the Raton- Clayton- and Capulin-age flows. Although the flows are not as well exposed as they are east of Johnson Mesa along the route of Log 1, there is perhaps a greater opportunity to understand more fully the complexities of the numerous flows that make up these three great rock units. In the last 25 miles of this trip we cross the highly dissected country of the Canadian River drainage system. Here are seen the Pierre shale and Trinidad sandstone of Cretaceous age and remnants of recent higher levels of the Canadian River and its tributaries that are now preserved as terraces. Altitudes along the route vary from a low of 5,050 feet at Clayton to between 6,500 and 7,000 feet from Des Moines to Raton.

From the village of Des Moines a very interesting and scenic loop drive of 22.6 miles, via Log 2, to Folsom and Capulin Mountain National Monument will give a close look at the most recent sequence of eruptions known as the Capulin-age flows.

- 0.0 Start at traffic light in Clayton at junction of Main and First Street. Travel on U. S. 64-87 toward Raton.
- 0.4 Turn left over Colorado and Southern Railway overpass. Road straight ahead, N. Mex. 370 to Clayton Lake, Guy and the Dry Cimarron Valley, is covered on Log 1. Rabbit Ear Mountain, largest peak at 11:30 o'clock, is named for Chief Rabbit Ears.
- 0.7 Straight ahead on the skyline is Mt. Dora (Cienguilla del Burro Mountain), a huge extinct volcano. To the right and far behind it is Sierra Grande, the largest volcano in this region. It is 40 miles from here.

Between 1 and 3 o'clock are 4 prominent volcanoes along the northern skyline. These large vents furnished the lava that caps the mesa on which

they rest. Most of the lower hills along the skyline are small volcanoes.

- 0.8 Road drops off edge of basalt-capped mesa on which Clayton is situated. Broad depression ahead (1.2 miles across) is rimmed by Clayton basalt, except for the south margin, and is floored by Ogallala sand and gravel. The south rim is part of the ancient uplands into which the valley was cut. Later the Clayton basalt flowed down this valley. The Ogallala formation extends east and south for several hundred miles and underlies the High Plains that extend from Texas to Nebraska. The porous sands of the Ogallala make excellent reservoirs for water and because of this, ranching and some irrigation is possible on the plains.
- 1.2 Fort Jordan, a replica of an early western fort, contains a museum of relics of the early West, a zoo (including a herd of buffalo) and a cafe.
- 2.1 Climb back onto Clayton basalt mesa. Basalt boulders can be seen cropping out on both sides of the road. The basalt that filled the ancient stream valleys is more resistant to erosion than are the surrounding softer rocks. These softer rocks have since been washed away, leaving what had been a stream valley now forming the high mesas between the present stream valleys.
- 2.7 Stop. Rabbit Ear Mountain historic sign marker. 10 miles to north. (actually about 5) Reads,: "Famous landmark on the alternate Santa Fe Trail over which the commerce of the prairies moved between 1822 and 1880. Caravans passed on both sides of the mountain, 860 miles out from Independence, Kansas, their starting point, and 230 miles from the end of the trail in Santa Fe."
- 3.1 Once again we drop off the edge of the Clayton basalt onto the Ogallala sands and gravels.
- 3.7 Back up onto the Clayton basalt cap. The tree and brush-covered rim, visible many miles to the south, is held up by the Dakota sandstone.
- 4.2 Excellent view north to Apache Canyon, showing the

basalt rim on both sides and the line of volcanoes and their lava flows on top of the mesa beyond.

At 1:30 o'clock Bible Top is the tilted flat-topped mountain. Rabbit Ear Mountain at 3 o'clock.



Rabbit Ear Mountain and unnamed vent to right (east). Looking across Apache Canyon.

- 6.0 At 10 o'clock, about 5 miles distant, is edge of Clayton basalt tongue (black rim) that caps the mesa which, 6 miles to the west, joins the one we are now riding across. On skyline from 8-10 o'clock is Dakota sandstone-capped mesa.
- 7.6 Mile 330 on Burlington Route (Colorado and Southern Railway). Beyond railroad on skyline is Bible Top (at 3 o'clock). The peak is flat-topped and has a crease parallel to the highway so that the basalt cap resembles an open book, hence the name.
- 8.3 Road enters from north. At 1 o'clock the enormous size of Mt. Dora (Cieneguilla del Burro Mountain) can now be seen. In shape and probable habit when it erupted (one million? --two million? years ago) it resembles the broad shield volcano type of the Hawaiian Islands. Nearly all the material from the volcano was

a very fluid lava which flowed very rapidly away from the peak, forming the broad low volcano.

- 9.8 Windmill on south side of road. This windmill is typical of hundreds in northeastern New Mexico that must penetrate the hard basalt cap before entering porous sands which, the driller and land owner hope, will be full of good water.
- 10.3 In the abandoned borrow pits on the left, wind blown sand and caliche ("hard pan") was scraped off the Clayton basalt and used as fill for the highway.
- 12.1 At 1 o'clock, the head of Apache Canyon can be seen at the foot of Mt. Dora. At that point, the basalt mesa forming the north rim of Apache Canyon (and underlying Rabbit Ear Mountain at 5 o'clock) joins the Clayton basalt mesa upon which we are still driving.
- 15.3 Gravel pits along south side of road.
- Mt. Dora (Cieneguilla del Burro Mountain) at 3 o'clock. At 12:30 o'clock is Sierra Clayton, another extinct volcano. In this region nearly any peak rising above the level of the plains and mesas is an extinct volcano.
- 17.2 At 9 o'clock on skyline is another line of extinct volcanoes. At 10 o'clock on distant skyline is yet another line of extinct volcanoes. At 12 o'clock the great bulk of Sierra Grande can be seen on the distant skyline.
- 18.0 Mt. Dora, stock-shipping station for Colorado and Southern Railway.
- 19.0 Junction with N. Mex. 426 to Sofia.
- 20.3 At 3 o'clock, low hill on skyline is a small volcano along line of volcanoes that includes Mt. Dora. At 10:30 o'clock is Sierra Clayton. Steeply dipping layers of volcanic cinders can be seen on the flanks of the cone.
- 23.6 Stop. Concrete Monument, "First wagons on Santa Fe

Trail crossed here in 1822." Sign erected by Colorado and Southern Railway. No ruts are visible at this point. Ruts from the Santa Fe Trail can be best seen north of Clayton near Moses (see Log 3).

25.6 Roadcut through Clayton basalt cap. This is still the same lava flow we have been on since leaving Clayton.

27.0 Grenville, altitude 5,990 feet. Stock shipping station along Colorado and Southern Railway. Junction with N. Mex. 120 to Pasamonte.

28.0 Stop at Colorado and Southern Mile Marker 310.

Straight ahead (west) is Sierra Grande (8,720 ft.), the largest volcano in this region, with Little Grande at the base (right down highway). Straight behind us (east) is Mt. Dora (Cieneguilla del Burro Mountain), the second largest. The large broad dome (an unnamed feature) south of Sierra Grande (about 11 o'clock) rates among the top 5 volcanoes in size in this region and appears to be the source of the lava on which we are driving.

Sierra Clayton at 8 o'clock. At 9 o'clock a few peaks of the 14 alined volcanoes of the Don Carlos Hills are on the distant skyline. At 4 o'clock is an Ogallala-capped mesa that was never covered by lava flows. The edges of a Clayton basalt-capped mesa can be seen at 3 o'clock. On the far horizon (10 or more miles away) is another basalt-capped mesa (called the Gaps flow one gap in it can be seen at about 3 o'clock) which appears to be another tongue of the Clayton basalt.

30.7 Staunton. Cuts along railroad are into top of the Clayton basalt.

31.5 Abandoned sand and caliche pits on south side of highway.

31.6 Bridge.

33.9 At 10 o'clock on far distant skyline are Palo Blanco Mountain (left) and 8,820 ft. Laughlin Peak right behind Mt. Marcy (Malpie Mountain) on near skyline.

The unnamed large broad volcano at 9 o'clock is composed of basalt identical with that on which we have been driving from Clayton. It probably supplied much of the lava that formed this wide basalt covered flat. Other volcanoes also supplied this same type of lava, as for example, the unnamed volcano at 11 o'clock.

37.3

Little Grande on south side of road. Layers visible are eroded edges of lava flows interlayered with cinders. The small, steep-sided volcanoes, like this one, have a large proportion of cinders in contrast to the broad shield volcanoes, like Sierra Grande (ahead), which are mostly formed of fluid lava with only a small amount of cinders. Complex cross-layering was formed because the vent changed its shape and direction during formation of the volcano.

To the north, the plains are mostly covered by sands of the Ogallala formation. On the remote sky line, at 3 o'clock the Seven-L Buttes, part of Mesa de Maya in southern Colorado, can be seen on a clear day. In the middle distance at 4 o'clock is the north rim of the great Clayton basalt sheet on which we have been riding.



Cross-layering of cinders on Little Grande.

38.5 At right in gully are outcrops of basalt that exhibit crudely developed columnar jointing, caused by contraction during cooling of the basalt.

38.6 At 2 o'clock, the south edge of a basalt flow (Van Cleve flow), similar in composition to that in the gully we just passed through (but slightly different from the Clayton basalt whose northwest rim can be seen at 3 o'clock) extends east for 14 miles.

At 9 o'clock is a basaltic volcano which may have supplied the lava for the Van Cleve flow.

39.6 Ranch road enters from left. At 11 o'clock on near skyline is a small volcano which also may have supplied lava to form the Van Cleve flow.

41.4 Ranch road enters from left. Gaylord Mountain can be seen in distance by sighting along railroad at 12:30 o'clock. Some of the basalt from this vent contains beautiful (but worthless) tiny blue crystals of the rare mineral haiynite, one of the sodalite-lazurite group of minerals.

42.3 Now a clear view of Gaylord Mountain can be had at 1 o'clock. Behind it and to the left of it is a tree-covered mesa capped by Raton basalt, the southeast end of the basalt rim that rises slowly westward until at Raton it is more than 1,000 feet above the city. On the mesa at 12 o'clock is a Clayton-age volcano, Emery Peak (7,350 ft.), an important key in the volcanic history of this region because lava from it blocked the Dry Cimarron River (behind it from us). Into the lake that formed behind the lava dam poured basalt and stream deposits from many other volcanoes so that the sequence of 11 different volcanoes could be determined. This sequence is discussed in Log 1 at mileage point 38.7.

We are still skirting the east base of Sierra Grande. The main bulk of the mountain is composed of pyroxene andesite, a lighter-colored rock than the basalt we have seen because it contains more silica.

43.0 Ranch road enters from left. Sierra Grande is high enough (elevation 8,720 feet) to intercept the summer

rain clouds, so that the grass on it is wet and green even if the surrounding plains are dry and brown.



Sierra Grande.

- 43.4 Gully on left with concrete slab across bottom is abandoned early route of this highway.
- 44.9 Des Moines village limit, altitude 6,622 ft. At 2:30 o'clock on near skyline is Dunchee Hill, the eroded remnant of another volcano.

Des Moines is a trading and shipping point for an extensive dry farming and ranching area. Although the Colorado Southern Railway erected a station here when it extended its lines through New Mexico in 1887-88, no town grew until 1907 when two townsites were surveyed and both were occupied. About 1916, the two towns grew together and the name Des Moines was used for both. Drought and depression caused the population to decline after its peak of about 800 people in 1920.

- 45.7 Junction with N. Mex. 72 to Folsom. See Log 2 that covers the trip on this road to Folsom and Capulin Mountain National Monument and rejoins this log on U. S. 64-87 at Capulin. Continue straight ahead on this

log to Raton, if you cannot take the scenic loop.

46.4 STOP. Historic Marker - Goodnight Trail

Read: "This famous old trail, up which more than 250,000 head of cattle were trailed to market, was blazed by Charles Goodnight in 1866. Most of the herds originated on the plains of Texas and were trailed by lean cowboys up the Pecos River to Ft. Sumner then north to Colorado, Wyoming and Montana. U. S. 87 crosses trail here." This trail skirted the east base of Sierra Grande and headed north from here around east end of Oak Canyon Mesa.

This sign is also near the crest of the Sierra Grande arch. The underlying bedrock here forms a broad northerly-trending arch with the westward-sloping side extending to the center of the Raton basin (just west of Raton) before turning up again along the foot of the Sangre de Cristo Mountains. The eastward-sloping side continues with only gentle warps into Texas.

At 1 o'clock is Capulin Mountain (8,215 ft.), a nearly perfectly preserved cinder cone. Behind it and at its right base is Robinson Mountain. To its right and slightly nearer on the mesa top is Jose Butte. In front of José Butte and low in the valley is the ruddy-colored Mud Hill. All three of these poured volcanic material, lava and cinders, into the lake behind the Emery Peak lava dam. Only the top of Emery Peak is visible at 3 o'clock.

At 1:30 o'clock on the distant skyline is tree covered Red Mountain, a volcano similar in composition to Sierra Grande. It is on top of Johnson Mesa, which in turn is held up by the Raton basalt, that forms the forested skyline from Red Mountain to 2 o'clock. For details of this area see Log 1.

46.8 Large depression on right (meadow in dry years and lake in wet) was formed in much the same manner as were the oases of Africa. Wind removed the cap of uncemented sand (Dakota formation) down to a muddy layer which is always damp and thus adheres together. This dampness stopped the downcutting by the wind

(deflation). Along the east rim are sand dunes (mostly covered with vegetation) formed by the deposition of the sand blown out of the depression. The oases of northern Africa are bottomed at the natural ground-water level. This keeps the sand moist and sticking together. The big sand "seas" of the Sahara Desert are downwind from the giant depressions (oases).

Abandoned railroad grade from Des Moines to Raton parallels road to right. It can be seen at many places near the highway.

48.0 Ranch road enters from left. Small juniper trees cover much of lower slopes of Sierra Grande. Higher on the slopes are Ponderosa pine and spruce.

48.2 Approximate crest of Sierra Grande arch. West from here the Cretaceous and older rocks slope westward, and east from here they slope eastward.

Along northern skyline are the forested mesas held up by Raton basalt.

49.1 Ranch road enters from left. At 11 o'clock is barren, round, humped shape of Horseshoe Mountain, a volcano of the same general age as Capulin Mountain. Behind it and to the left is Palo Blanco Mountain. To the right and behind Horseshoe is Laughlin Peak.

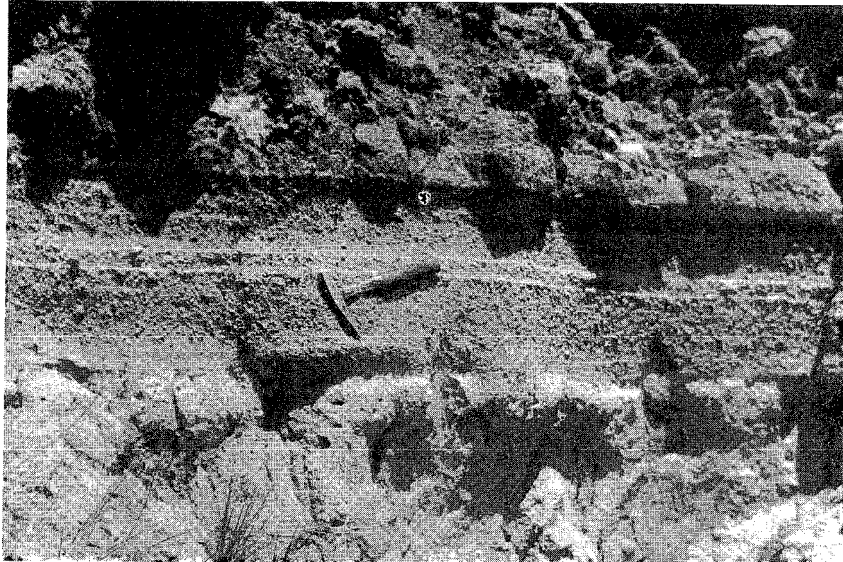
49.4 Road crosses abandoned railroad grade. Gravel pit in the Ogallala formation at 3 o'clock.

50.2 Ranch road enters from right. Ahead at 12 o'clock basalt from Capulin Mountain flowed southward as far as the highway. In doing so it buried a stream valley. Springs from gravels in that early valley issue forth near the grove of trees at 2:30 o'clock.

To right and a mile beyond the springs is a mesa capped with the southwesternmost extension of Raton basalt; it overlies the orange-stained sands of the Ogallala formation. Other extensions of Raton basalt can be seen ahead, capping the mesa between 11 o'clock and the highway and capping the south-sloping mesa (left) on the distant skyline at 12 o'clock.

The road spiraling up Capulin Mountain gives the visitor to the monument excellent views of the surrounding countryside as well as of the layering of cinders on the flanks of the cone.

At 9 o'clock another unnamed volcano.



Raton basalt overlying bedded cinders and Ogallala formation.

- 51.9 Abandoned railway grade in foreground on right. Beyond it across narrow valley is edge of Capulin Mountain basalt. Extending diagonally to the right rear from the foot of the basalt at 12 o'clock is a road now marked by old telephone lines that follow another route of the old Ft. Union-Ft. Dodge military wagon road of Santa Fe Trail days.
- 52.6 Roadcut in tip of basalt flow from Capulin Mountain. Road now between Capulin Mountain basalt on right (north) and Raton basalt (left).
- 53.4 Scenic Marker—"Capulin Mountain National Monument, 3 miles. Most perfect example of an extinct volcanic cone in America. Entrance 1 mile west."
- 53.5 Crushed rock quarry at 9 o'clock.

54.5 Capulin. Junction with N. Mex. 325 to Capulin Mountain and Folsom. See Log 2 at mileage point 22.6 and read log backward for trip to Capulin Mountain National Monument.

Sign at junction reads "Capulin Mountain National Monument, 3 miles. Regarded as the most perfect extinct volcano on the North American continent. The crater is 1,450 feet in diameter. Last violent eruption occurred about the beginning of the Christian era. Excellent road. View from summit is inspiring." We now know that Capulin Mountain erupted between 10,000 and 4,500 years ago.



Capulin Mountain.

55.0 Cross abandoned railroad grade. On skyline at 3 o'clock is José Butte. Robinson Mountain (at 2:30 o'clock) is partially hidden by the ruddy columns of Raton basalt which hold up the mesa. In the middle ground are basalt flows from Capulin Mountain. The low basin which the road crosses for the next mile is the Capulin basin. It drained eastward prior to the eruption of Capulin Mountain, and now no surface water escapes from this closed depression.

Horseshoe Mountain at 9:30 o'clock. Rain run-

ning down its slopes caused the grooves.

Clayton basalt-capped mesa from 11—12 o'clock.

55.3 Enter Colfax County.

56.5 STOP. Here is a good place to see the relative elevations of the 3 major groups of basalt in this region and thus determine the relative ages of the basalt flows. The ruddy, tree-covered cliffs at 2 and 3 o'clock are held up by the oldest group, named Raton basalt. Robinson Mountain, a Clayton-age volcano at 2:30 o'clock on skyline, erupted through the Raton basalt cap; lava flowed southward, over the Raton basalt edge (at 2:15 o'clock), to fill the valley that then existed. Removal of the surrounding softer rocks by erosion has left that valley standing as a low mesa between 1 and 2 o'clock (behind the red and white ranch building at 1:30 o'clock). The youngest volcanoes, the Capulin basalts, flowed into the present valley bottoms, and during the last few thousand years they have been partially buried by material blown or washed into the low areas.

57.5 Road crosses abandoned railroad grade.

58.1 Robinson Mountain at 3 o'clock. To the south are the large volcanoes, which, because of their light color and composition, are grouped with Sierra Grande into the Red Mountain dacites. At 8:30 o'clock Palo Blanco Peak; at 9 o'clock on the distant skyline are the pair known as Timber Buttes (mesa cap to left and in front of them is the Raton basalt capped Kiowa Mesa). At 10 o'clock, Laughlin Peak.

From 10-11 o'clock on the skyline is the high south-sloping narrow Raton basalt-capped Larga Mesa.

At 11:30 o'clock extending south is a Clayton basalt flow.

At 12:30 o'clock on far skyline is Raton basalt-capped Dry Mesa.

59.3 Road climbs onto basalt flow of Capulin age.

61.5 Still on lava from Capulin-age vents that are about 3 miles north but hidden behind grassy ridge at 2:30 o'clock. Basalt came around both sides of the ridge and moved toward us. At 3 o'clock, the grassy hill is an older Clayton-age volcano. The grassy meadow with the windmill in the middleground was not covered by the lava.

On distant skyline to north is Raton basalt-capped Johnson Mesa. On it at 2:30 o'clock is Bellisle Mountain (8,520 ft.), from which a lava flow went east as far as Emery Peak. At 3:30 o'clock is Red Mountain, the type for the volcanoes belonging to the Red Mountain dacites. The round knob on the skyline at 3 o'clock is an outlying remnant of Raton basalt no longer connected with Johnson Mesa.

Dry Mesa at 1 o'clock shows a double set of columnar joints; here each set represents one lava flow. Some basalt flows form 2 sets of joints, a short, stubby set on the bottom and tall, narrow ones on top. The upper ones are longer and narrower as a result of the more rapid cooling possible because of exposure to the air.

63.3 Hill off west edge of the Capulinage basalt. At right is gully undercutting columnar-jointed basalt. At left is abandoned railroad grade.

65.0 North end of Raton basalt capped Larga Mesa at 9 o'clock.

Unnamed Clayton age volcano at 10 o'clock. In gap at 9:30 o'clock is Laughlin Peak.

65.3 In roadcut on right are brown-weathering pieces of limy and sandy mud rocks in which a few extinct oysters and marine worm burrows can be found. These fossils show this area was under the sea during upper Cretaceous time.

65.5 The ridge on the left is held up by Clayton basalt. On right, ridge is held up by limy and sandy layers in the upper Cretaceous black shales. The right skyline is Dry Mesa, held up by columnar-jointed Raton basalt.

Straight ahead are the distant peaks of the Sangre de Cristo Mountains. In front of them in the middle distance are the mesa rims held up by the Trinidad sandstone, part of the Cretaceous coal-producing sequence that extends from Cimarron, New Mexico, northward to Pueblo, Colorado.

- 66.6 Roadcut on right (north) and stream valley on left expose sandy and limy beds of upper Cretaceous Pierre shale with fragments of oysters and clams.
- 66.9 Clear view ahead toward Cunningham Butte and Black Mesa in middle distance at 12 o'clock. Small knobs at 12:30 o'clock are Clayton basalt. High mesas at 1 o'clock are Meloche Mesa (Red Mountain dacite) and East Meloche Mesa. At 3 o'clock on skyline is Buck-horn Mesa, capped by Clayton-age basalt. Dry Mesa (Raton basalt) at 4 o'clock.
- 67.5 In distance on skyline at 10 o'clock is Green Mountain, composed of Red Mountain dacite. At 11 o'clock is outlying remnant of Clayton-age basalt.
- 69.3 Entrance to TO Ranch headquarters on right. Meloche Mesa at 2:30 o'clock, East Meloche Mesa at 3 o'clock. At 9 o'clock is tree-covered Green Mountain. At 8:30 o'clock is a grass-covered Clayton-age volcano with basalt flows extending nearly to Round Mesa at 11 o'clock. At 10 o'clock is Eagle Tail Mountain, a Clayton-age volcano. Another unnamed Clayton-age volcano is the flat-topped peak at 9:30 o'clock.

We now drive on flats cut across the upper Cretaceous Pierre shale for the remainder of the distance to Raton. In places the shale is covered by a thin veneer of gravel or soil.

- 72.2 Ranch roads enter from both sides. Hunter Mesa (skyline point at 2:30 o'clock) like Meloche Mesa (3 o'clock) is held up by Red Mountain dacite. Johnson Mesa at 1-2, o'clock on the distant skyline is held up by Raton basalt as is Bartlett Mesa north of Raton at 12:15 o'clock.

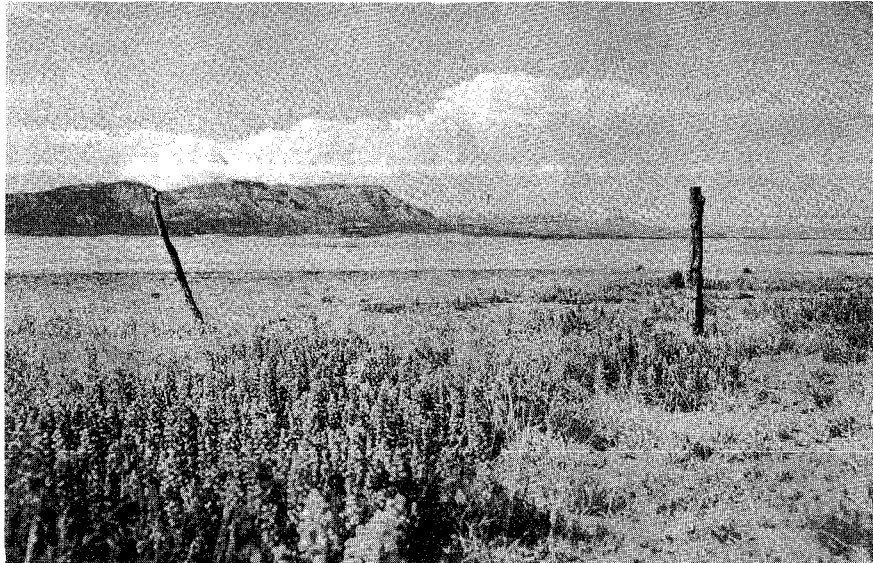
Clayton basalt-capped mesas at 9:30 o'clock frame Cunningham Butte (behind them) composed of

Red Mountain dacite.

73.2 At 10 o'clock is Black Mesa, capped with Clayton-age basalt. Straight ahead on distant skyline is one of the Spanish Peaks in Colorado.

73.9 At 1:30 o'clock is southwest point of Johnson Mesa. About half-way down is a point held up by an orangish-white layer, the Trinidad sandstone. This band of light-colored sand can be traced as patches sticking through the landslide cover and climbing slowly to the right until at 2:30 o'clock it nearly meets the Raton basalt cap. Coal is found with the Trinidad sandstone and associated formations. The region that has been mined extensively is west and north of Raton, although smaller workings are present in the flanks of Johnson Mesa.

The light-colored bands of the Trinidad sandstone can be seen on the bluffs beyond Raton where the belt can be traced by eye from 10:30 to 3 o'clock.



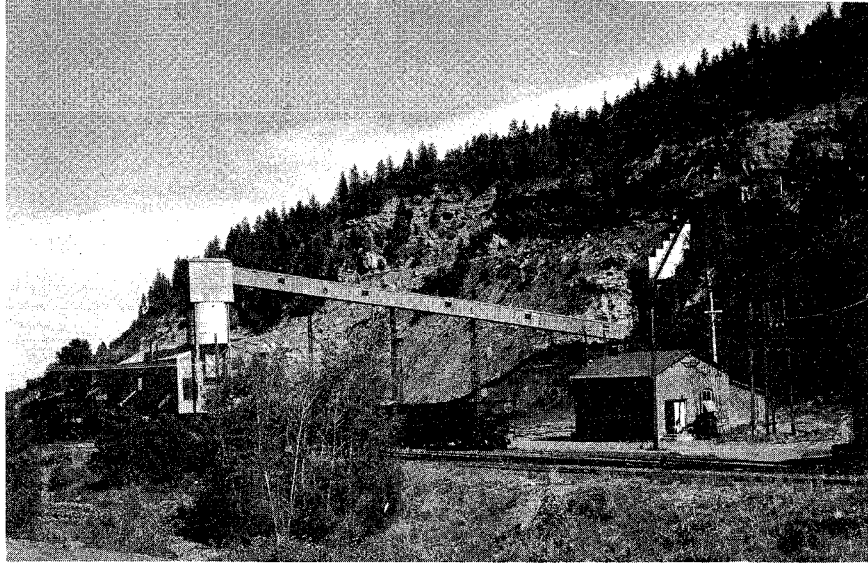
Raton Mesa from the south. Lupines In foreground

74.7 At this point the road drops off an earlier broad flat stream valley down to the level cut by the modern Canadian River. Remnants of another slightly younger

valley bottom can be seen ahead where the road is cut through the end of the terrace. Pierre shale in roadcut under stream gravel veneer.

- 75.0 Terrace at 9 o'clock is a remnant of the old valley we just left.
- 75.2 Black Mesa on skyline at 9 o'clock.
- 75.4 At 3 o'clock, eroded edge of old valley now above present valley.
- 76.3 Roadcut in "paper shale" of Pierre shale. Upper surface is gravel floor of abandoned valley.
- 76.4 In distance between 9 and 10 o'clock the difference in altitude between several remnants of the older stream valleys can be seen. Present stream valley (with trees and bridge) has 2 distinct benches (terraces) of older valleys beyond it.
- 77.2 Road drops off edge of older valley into modern valley of Chicorico Creek.
- 77.5 On right we can see the older valley floor rimming the present valley.
- 78.3 Bridge over Chicorico Creek.
- 78.6 Ranch road enters from right.
- At 10 o'clock is gravel pit in older valley fill.
- 78.8 Begin climb onto next older terrace. Note stream gravel in roadcuts.
- 79.0 Road continues up onto a still older terrace.
- 80.2 On distant skyline at 3 o'clock is Barilla Mesa capped by Raton basalt.
- 80.9 Bridge over Raton Creek.
- 81.5 Overpass over U. S. Interstate 25.
- 82.0 Raton. Junction with U. S. 85. End of road log. Log

1 begins after you turn right through Raton for 1.4 miles to junction of U. S. 87 and N. Mex. 72.



Operating coal mine southwest of Raton.

ADDITIONAL READING

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