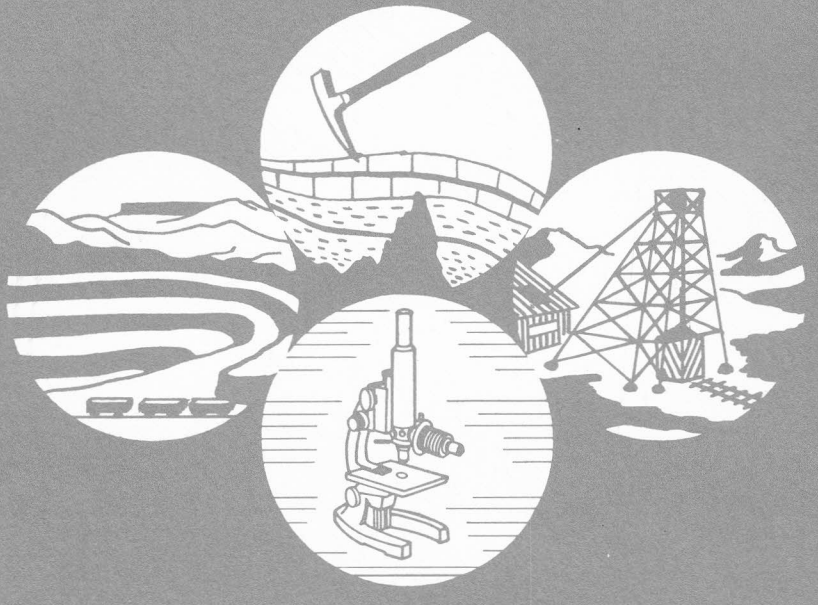
GUIDEBOOK 1—HIGHWAYS OF ARIZONA
U.S. HIGHWAY 666

by

Eldred D. Wilson, Geologist

THE ARIZONA BUREAU OF MINES

Bulletin 174
1965



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FOREWORD

The Arizona Bureau of Mines of the University of Arizona, at Tucson, believes that much salient information about the resources and related environments of Arizona can be obtained while the highways which criss-cross the State are being traversed. This being true, this journal, titled, GUIDEBOOK 1 — HIGHWAYS OF ARIZONA, has been prepared to assist a traveler in gaining knowledge about the natural phenomena and man-made features that can be observed along the route, in Arizona, of U.S. Highway 666. It will be noted that the bulletin presents the location and character of features by means of descriptive text material and, also, through the media of maps, charts, and photographs.

It is planned that all of the major highways of Arizona will be eventually treated in much the same manner as has been done in the case of U.S. Highway 666 and, then, this GUIDEBOOK 1 will become a separate component of an entire series of similar publications to be issued in the future by the Arizona Bureau of Mines.

The Arizona Bureau of Mines is pleased to have this opportunity to present a service to the people of Arizona by making the observations of Dr. Eldred D. Wilson, which he has made along U.S. Highway 666, available for general study.

J. D. Forrester, Director
Arizona Bureau of Mines

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INTRODUCTION

Purpose and Scope

The appreciation and value of a highway tour may be enhanced remarkably by an understanding of how the scenery, climate, vegetation, water supply, animals, and industries are related fundamentally to the geology and physiography of the land over which a given road exists. A convenient way of conveying such information is by means of a so-called "road log" which describes the various phenomena along a highway in sequential manner.

This road log is meant to be educational. Its text, illustrations, and glossary are designed for the general public rather than solely for the earth scientist or engineer.

Location and Extent

U.S. Highway 666 extends for some 381 miles through eastern Arizona. At its southern end, it begins at the Mexican boundary south of Douglas, Arizona. It crosses Cochise, Graham, Greenlee, and Apache Counties, and its northern terminus in Arizona is at the New Mexico boundary, east of Lupton (Fig. 1).

Geologic Features

The rocks seen along U.S. Highway 666 are cited in the Detailed Log according to type and geologic age; the types are defined in the appended Glossary, and the geologic ages are tabulated in Fig. 2.

For additional information regarding the geology of Arizona, reference may be made to the maps listed on p. 68 and to the literature (**1**; **2**; **3**)*.

Physiographic Environment

U.S. Highway 666 displays the spectacular, contrasting scenery of two major physiographic provinces (Fig. 3). These are, namely, the

*Bold-face numbers in parentheses refer to literature cited in Appendix.

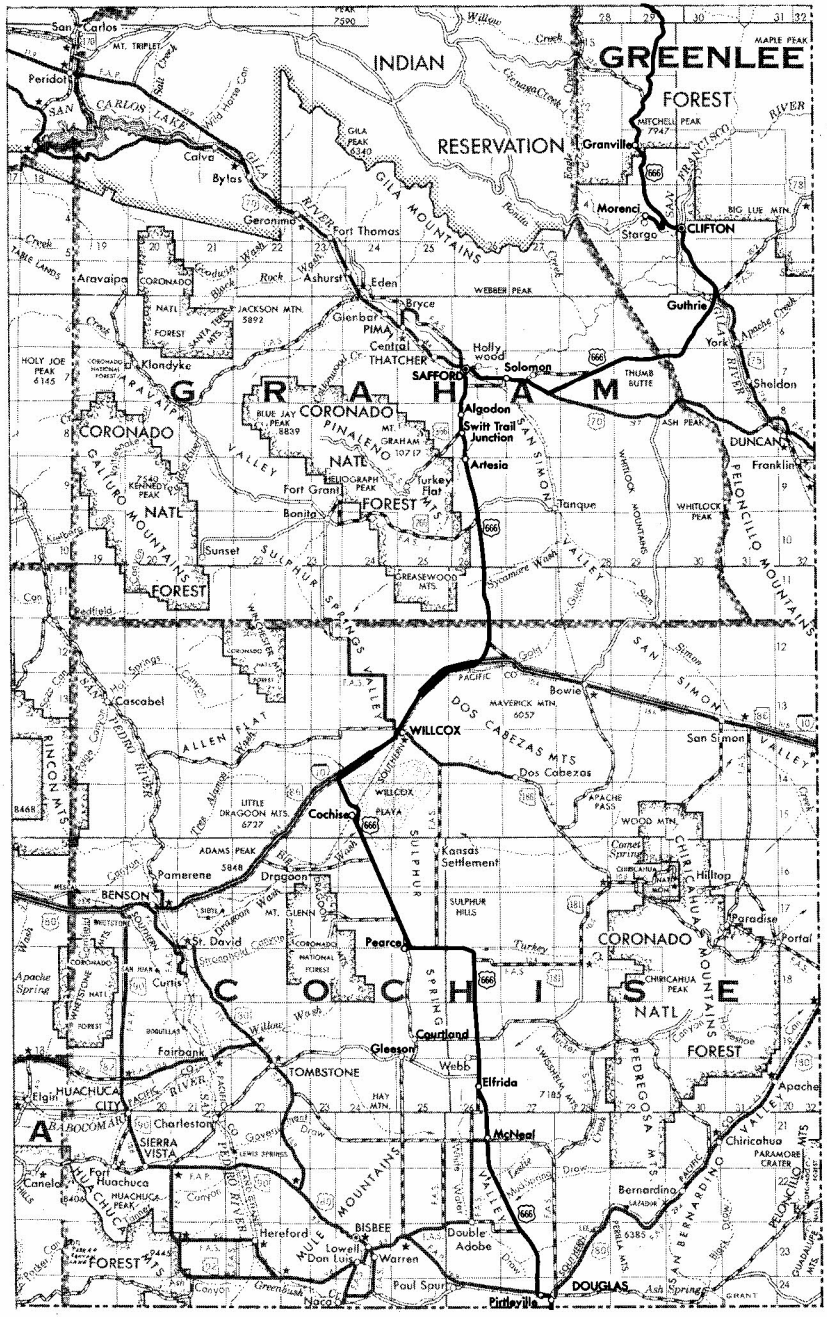


Figure 1-A. Index map of part of eastern Arizona showing location of southern portion of U.S. Highway 666. Profile views, looking westerly, are shown in Figures 4 and 5.

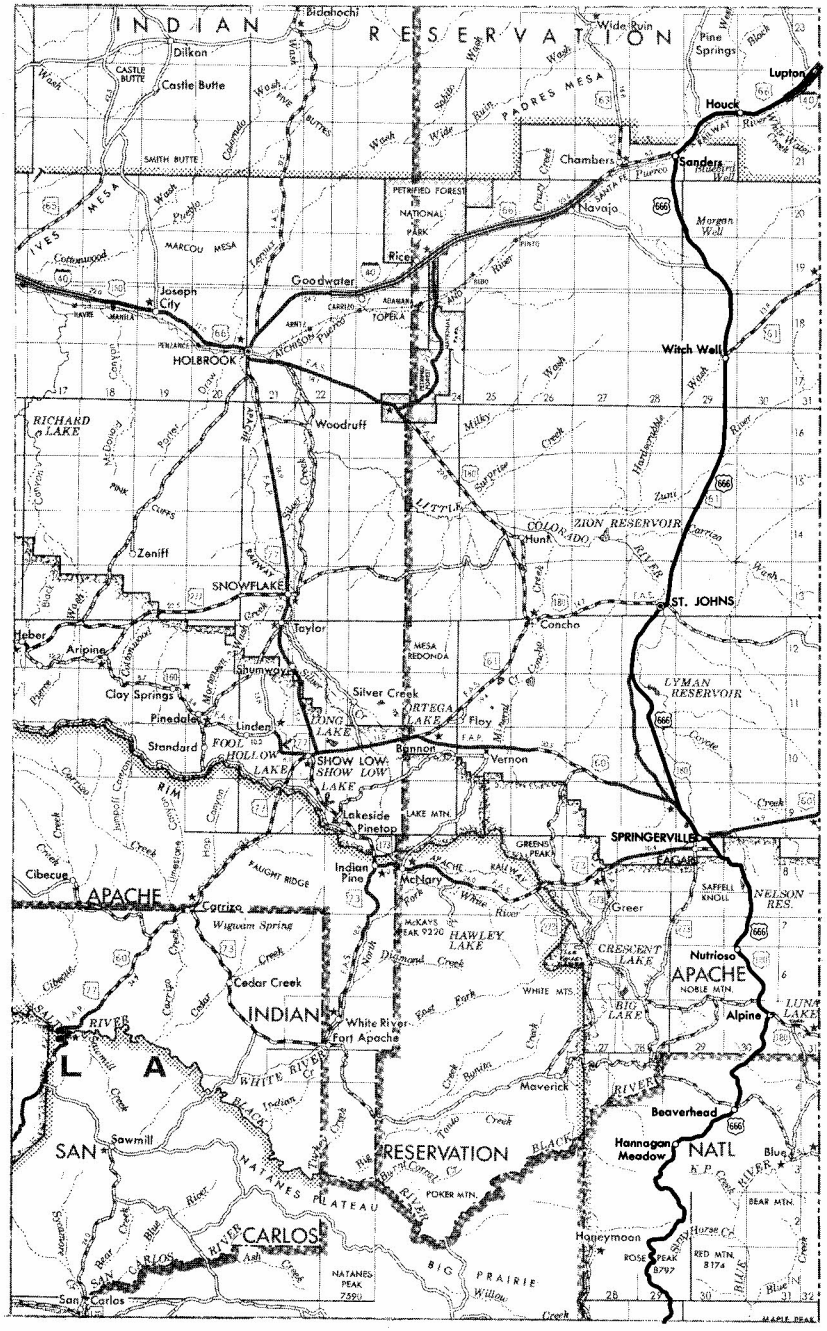


Figure 1-B. Index map of part of eastern Arizona showing location of northern portion of U.S. Highway 666. Profile views, looking westerly, are shown in Figures 7 and 8.

Basin and Range Province and the Colorado Plateau Province. They are separated by a comparatively narrow Transition Zone. The Basin and Range Province is further divided into the Mountain Region and the Desert Region.

From Douglas to upper Chase Creek, north of Clifton, the route lies within the Mountain Region of the Basin and Range Province. The Clifton-Alpine segment, known as the Coronado Trail through the White Mountains, crosses the Transition Zone (Fig. 3) and surmounts the Mogollon Rim of the Colorado Plateau at a point 6.4 miles south of Hannagan Meadow. North of the Mogollon Rim, the highway is on the Plateau.

The Basin and Range Province is characterized by numerous mountain ranges that rise abruptly from broad plain-like valleys or basins. These mountain masses attain altitudes of a few hundred feet to more than 10,000 feet above sea level and measure from a few miles to 100 miles in length by less than a mile to more than 20 miles in breadth. They represent deformed strips or blocks of the earth's crust that have been uplifted, in relation to the intervening valley troughs, and intensely sculptured by erosion. The intermont bedrock troughs have been filled by loosely to firmly consolidated silt, sand, gravel, and clay, which range from a few feet to more than 3,000 feet in thickness; their general plain-like surfaces were formed through combined deposition and erosion by sheet floods, meandering streams, and wind action.

In the Colorado Plateau Province, the strata above the Precambrian basement prevailingly lie almost flat or are inclined (dip) only at low angles.

In the Transition Zone, deformation has been stronger than in the Plateau, but less intense than in the Basin and Range Province.

Altitudes of the terrain on the route range from a minimum of near 2,900 feet above sea level at Safford to a maximum of 9,300 feet on the Mogollon Rim. Profiles of the highway are given in Figs. 4, 5, 7, 8. Topographic details for this part of Arizona are shown on quadrangle map sheets, published by the U.S. Geological Survey (see p. 67).

Except for the Sulphur Spring Valley, the region of U.S. Highway 666 is drained by the Gila and Little Colorado river systems (Fig. 1). In the Sulphur Spring Valley, the run-off flows partly into the closed basin of Willcox Playa, and partly via Whitewater Draw to the Yaqui River of Mexico. The washes on the valley plains south of the Gila River tend to be dry throughout most of the year, although they may be subject to flash floods during rainy seasons. On the other hand, many of the streams originating in the White Mountains are more or less perennial, as fed by melting snow and summer rains.

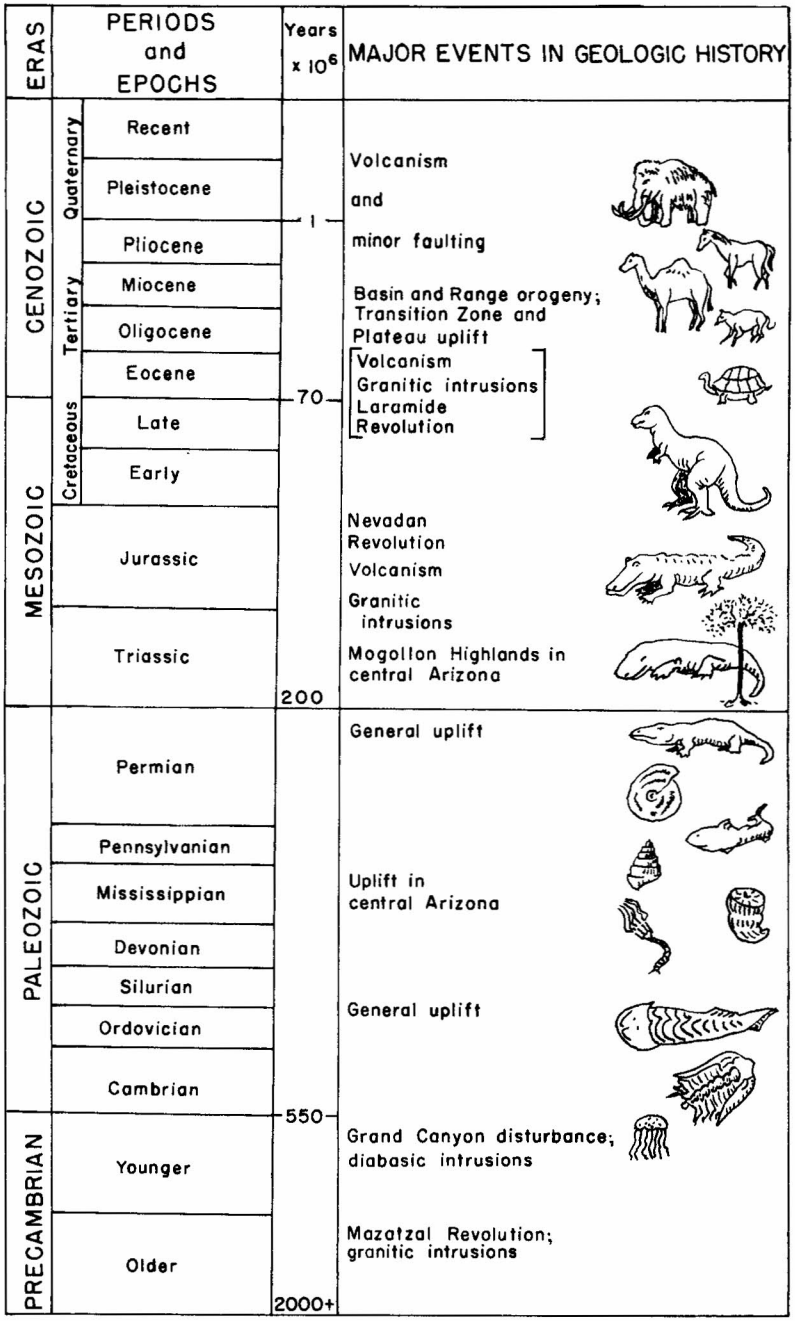


Figure 2. Geologic time scale.

Climate

The climate of Arizona is influenced by many variable factors (4; 5), the results of which often may be difficult to predict in detail. Nevertheless, past records indicate that the temperature and precipitation depend to a considerable extent upon the regional and local physiography.

Table 1. Some climatic data (4) for stations along U.S. Highway 666

Station	Altitude	Max. Temp.	Min. Temp.	Precipitation Av. per yr.	Snow, sleet, hail Av. per yr.
Alpine	8,000 Ft.	92° F.	−29° F.	20.73 in.	64.9 in.
Clifton	3,465	114	10	12.54	1.3
Cochise	4,180	108	− 4	13.35	4.4
Douglas	3,937	111	6	12.25	2.3
Safford	2,900	114	7	8.95	1.3
St. Johns	5,730	104	−22	11.59	21.6
Springerville	6,964	100	−20	12.11	26.3
Willcox	4,200	110	2	11.76	3.6

The temperatures (4) during summer commonly decrease by an average of 1° F. for each additional 235 feet of altitude. During winter (Table 1), such influences of altitude may be modified considerably by latitude and by the physiographic conditions that affect regional air flowage. Also, throughout the year, relatively cool air tends to drain downslope at night.

The precipitation in eastern Arizona occurs mainly during July-September and to a less extent during the winter. The factors (4; 5) favoring precipitation are moisture in the upper air, mountainous terrain, convergance of air flow from the south, and thermal heating. Consequently, the mountain areas receive more moisture than the valleys. On the other hand, the relatively high northeastern portion of the Plateau is somewhat dry because higher lands surround it; thus St. Johns (Table 1) is more arid than the lower areas of Clifton, Willcox, Cochise, and Douglas.

Some local features of climate are mentioned in the Detailed Log.

Vegetation

The main factors that determine the types and distribution of native vegetation in Arizona are altitude, topography, climate, soil, bed rock, and the works of man. For a discussion of these influences, as well as for descriptions of the numerous plant species, reference may be made to an extensive literature (6; 7; 8; 9).

The principal kinds of vegetation at various altitudes along U.S. Highway 666 are plotted in Figs. 4, 5, 7, 8.

Water Supply

In eastern Arizona, a large portion of the water used for domestic, irrigation, industrial, and stock-raising purposes comes from wells. In addition, the run-off from rains and melting snow furnishes large quantities of water to mountain streams and lakes, to reservoirs and dirt tanks, and to the Gila, San Francisco, Blue, Little Colorado, Puerco, and other rivers.

The supply and uses of water in Arizona have been discussed in numerous publications (3; 10).

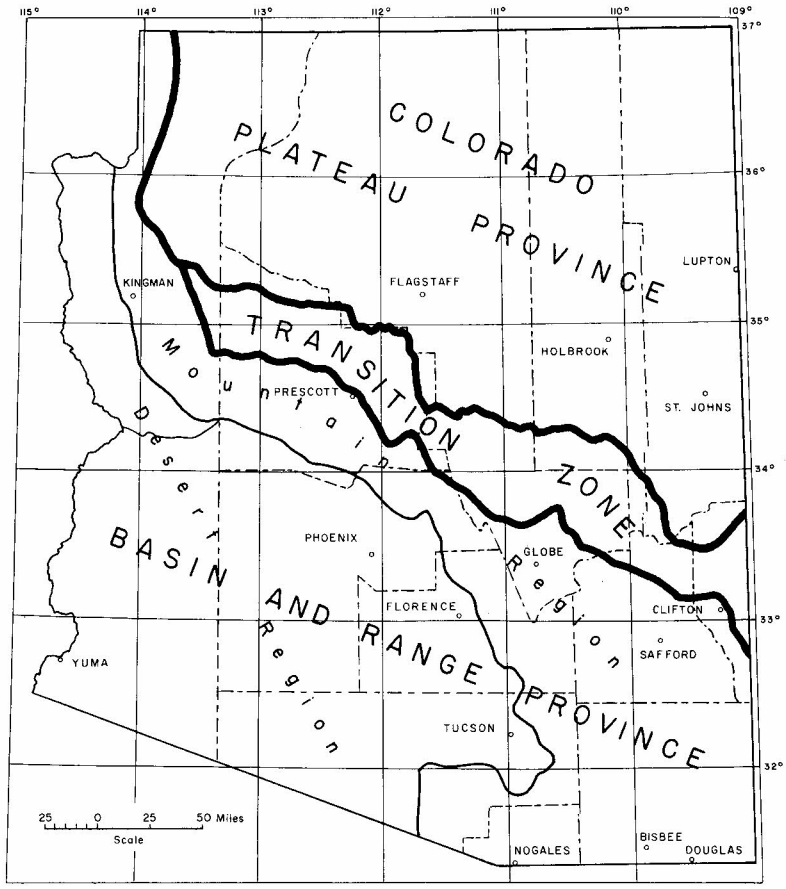


Figure 3. Physiographic provinces in Arizona.

Animals (11)

Owing to wide differences in physiography, climate, vegetation, and water supply, the fauna of Arizona are extremely diversified. Their variations, according to the general life-zones of Desert, Grassland, and Forest, are fairly distinct in some localities but widely gradational in others. The kinds of animals in the State have been estimated in numbers as shown in Table 2, and some of them are mentioned in the Detailed Log.

Table 2. Animals found in Arizona (11)

Fauna	Different Kinds
Insects and other invertebrates	15,000–20,000
Fishes	
Native	28
Introduced	33
Amphibians	
Frogs, toads	19
Salamanders	3
Reptiles	
Snakes	45
Lizards	37
Turtles	5
Game Birds	
Wild Turkey	1
Quail	3
Migratory species	numerous
Mammals	200

Industries

The principal industries along U.S. Highway 666 are mineral, livestock, agriculture, forest, and tourism.

Of primary importance are the production and resources of copper, molybdenum, gold, silver, lead, zinc, and many nonmetallic materials.

Cattle and other livestock are grown throughout much of the region and most extensively on the Grassland areas.

Agriculture is carried on in portions of the valleys, where favored by conditions of soil and water supply.

Lumber is produced in the White Mountains.

Acknowledgments

In the preparation of this Guidebook, much help was obtained from other members of the Arizona Bureau of Mines. Dr. J. D. Forrester planned the framework and critically read the manuscript. R. T. Moore edited the work for publication and contributed many important suggestions. F. L. Stubbs prepared the line drawings.

DETAILED LOG

This log, although recorded in a south to north direction, that is, from Douglas to Lupton, is designed to be used equally well from Lupton to Douglas.

Mileages for the north-bound trip are given in the left-hand margin and include a cumulative mileage from the point of origin to the point being discussed (Total), as well as the mileage from the last point of interest (Interval).

Mileages for the south-bound trip are similarly tabulated in the right-hand margin, and cumulate from bottom to top; that is, the user should start at the end of the log and read upward.

MILES NORTHWARD Total	Interval		MILES SOUTHWARD Total	Interval
0.0	0.0	U.S. port of entry; Agua Prieta, Sonora, on the south; Douglas, Arizona, on the north. Highway 666 lies north-south on Pan American Avenue. Parallel on the west is a railroad that leads to Nacozari, Cananea, and Nogales, Sonora.	380.7	0.3
		Douglas. Altitude 3,990 feet above sea level. Population (1960) 11,925. Founded during 1900-1902 as a smelter town, it grew also as a commercial center for southern Cochise County and northern Sonora, Mexico. Named for Dr. James Douglas, an eminent pioneer in the copper mining industry.		
0.3	0.3	Old smelter slag dumps on the west.	380.4	0.7
1.0	0.7	Intersection of Pan American Avenue and 14th Street.	379.7	0.1
1.1	0.1	Intersection of 14th Street and G Avenue (U.S. Highway 80).	379.6	0.1
1.2	0.1	Underpass.	379.5	0.1
1.3	0.1	Southern Pacific depot on the south.	379.4	0.4
		This branch of the Southern Pacific Railroad was completed in 1902, as the El Paso and Southwestern, to connect Bisbee and Douglas with El Paso, Texas. Now it joins the main Southern Pacific line at Benson, and its Douglas-El Paso segment has been dismantled.		
1.7	0.4	Road to Pirtleville branches northward.	379.0	0.3

2.0	0.3	Slag dump of old Copper Queen smelter, 0.8 miles to the southwest. The mountains behind it are in Mexico.	378.7	0.5
2.5	0.5	Phelps Dodge smelter (Pl. I) on the southwest. Paul Lime plant to the west, 9.5 miles distant, with Mule Mountains in the background.	378.2	0.1
2.6	0.1	Junction with U.S. Highway 80. To the west, 0.4 mile, is Whitewater Draw, the axial drainage channel for the southern portion of Sulphur Spring Valley.	378.1	0.4

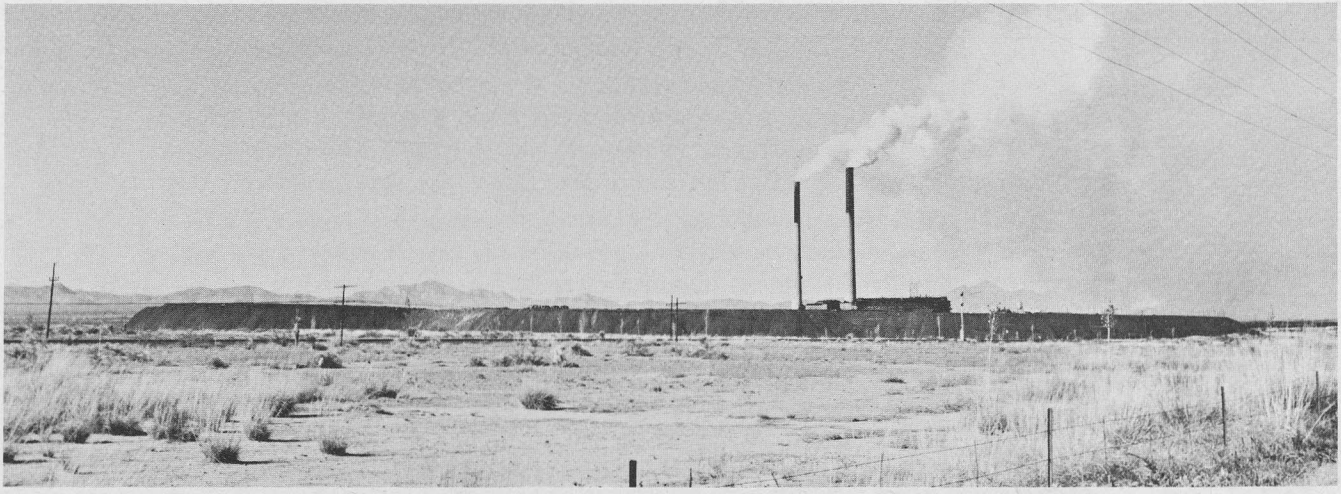


Plate I. Phelps Dodge smelter, Douglas. View southwestward.
The mountains on the horizon are in Mexico.

This valley extends northwesterly-southeasterly for approximately 90 miles, and it ranges from 10 to 30 miles in width. It represents a structural trough, filled to variable depths with loosely to firmly consolidated silt, clay, sand, and gravel. In places, as determined by exploratory wells, the alluvial fill is 2,000 feet or more thick. The principal kinds of native vegetation are indicated on Fig. 4.

During 1872-1876, much of the Sulphur Spring Valley was included in the Chiricahua Indian Reservation, and many cattle ranches were established on the non-reserved area. After 1880, some farming was done, mainly to supply agricultural and dairy products for the near-by mining centers. Large-scale agriculture developed mostly after 1910. Currently, extensive acreages (**12**) of the lower plain are under irrigation by ground water pumped from shallow wells, but the greater part of the valley as a whole is used for grazing of livestock (Pl. II).

As of 1952, the depth in feet of the water table below the surface of Sulphur Spring Valley at various points along Highway 666 was approximately as follows (**13**): Douglas, 100-160; Whitewater Draw, 20-40; McNeal, 100; Elfrida, 40; two miles east of Pearce, 160; six miles northwest of Pearce, 40; Cochise Overpass, 30; Willcox, 20; five miles northeast of Willcox, 100.

The crops grown include many different kinds, notably cotton, feed grains, alfalfa, and lettuce.

3.0	0.4	Road to Pirtleville branches east.	377.7	1.6
4.6	1.6	Perilla Mountains on the eastern skyline.	376.1	2.5
7.1	2.5	Railroad on the northeast extends from Douglas to the airport.	373.6	2.3
9.4	2.3	Entrance to Douglas-Bisbee International Airport on the northeast.	371.3	0.6
10.0	0.6	Road to Double Adobe and Bisbee branches west.	370.7	1.3
11.3	1.3	On the northeast, embankment of old El Paso and Southwestern railroad, which extended from Douglas to McNeal, Elfrida, and Courtland.	369.4	6.6

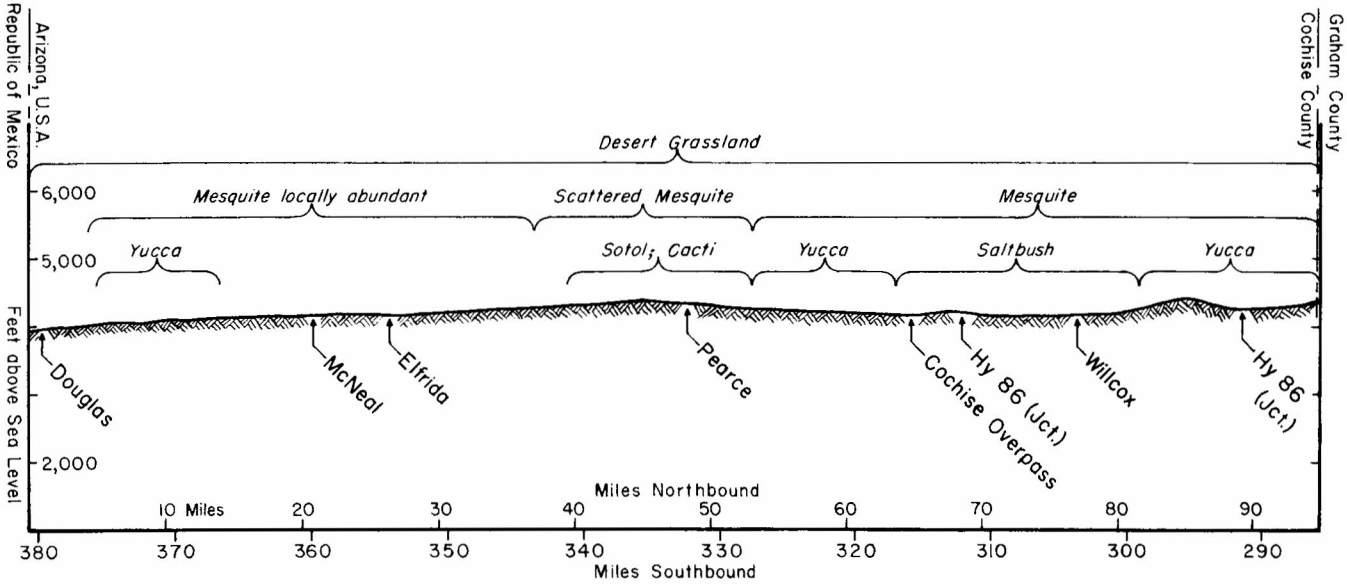


Figure 4. Profile and principal kinds of vegetation, U.S. Highway 666, between Mexican boundary and Cochise-Graham County line. View looking westerly.

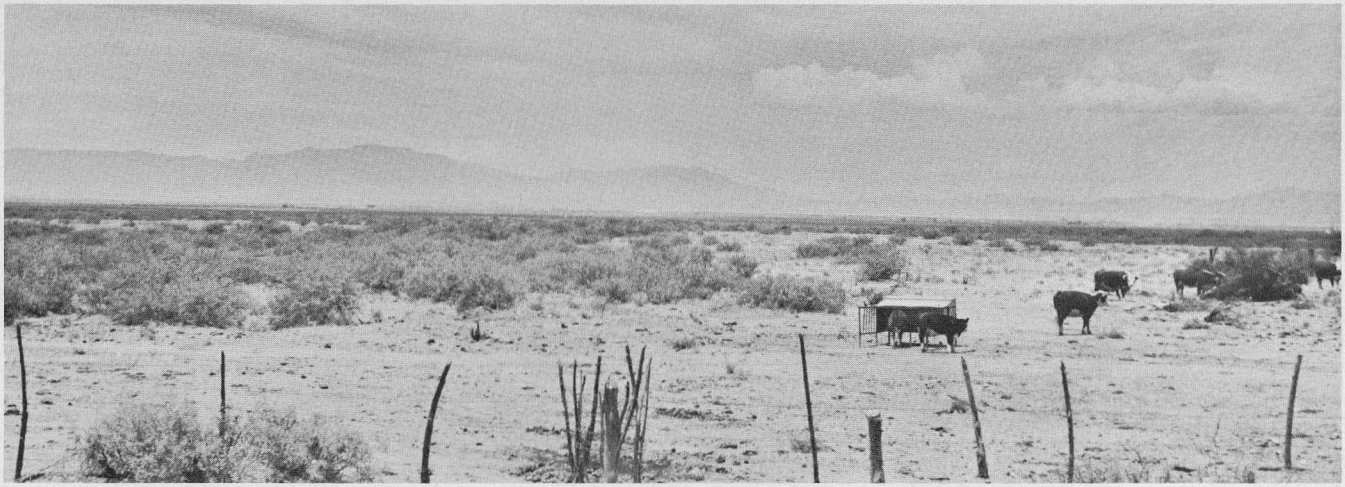


Plate II. Grazing land in Sulphur Spring Valley.

17.9	6.6	On the southern skyline may be seen the stacks of the Phelps Dodge smelter, with Mexican mountains in background.	362.8	1.0
18.9	1.0	Irrigated farm lands at intervals northward for 17.4 miles.	361.8	2.0
20.9	2.0	McNeal Post Office. Altitude 4,169 feet. Town established in 1909 and named for Judge Miles McNeal, an early settler here.	359.8	3.7
24.6	3.7	Irrigated fields on the west. Embankment of old El Paso and Southwestern Railroad, Douglas to Courtland, on the east.	356.1	2.0
26.6	2.0	Branch road to Bisbee on the southwest.	354.1	0.1

26.7	0.1	Elfrida Post Office. Altitude 4,139 feet. Town established in 1915 as a station on the Douglas-Courtland railroad, and named for the mother of G. I. Van Meter who donated land for the right-of-way.	354.0	1.1
27.8	1.1	Road branching to the west; Gleeson, 8.9 miles, Courtland, 11.6 miles.	352.9	4.0
		View of Swisshelm Mountains on the east. This range was named in 1878 for John Swisshelm, a prospector. Rising to an altitude of 7,185 feet, its western flank exposes Precambrian granite, Paleozoic quartzite and limestone, and Mesozoic quartzite and shale, in complex structural relations (3). A mass of younger granite, distinguishable from a distance by its light color, intrudes these older rocks. Ore deposits in the Swisshelm Mountains (3) have been worked intermittently since 1885; their output during 1918-1956 amounted to approximately 11,632,000 pounds of lead, 71,000 pounds of copper, 209,100 pounds of zinc, 323,800 ounces of silver, and 5,021 ounces of gold, in all valued at $1,938,000.		
31.8	4.0	Cross-road: East, to Rucker Canyon; west, 7.3 miles to Courtland, 12.4 miles to Gleeson.	348.9	0.5
		On the west is the southeastern portion of the Dragoon Mountains (3), which consist of a structurally complex assemblage of Precambrian metamorphic rocks; Paleozoic and Mesozoic quartzite, limestone, sandstone, and shale; younger granite; and Tertiary-Quaternary volcanic rocks.		
		Within this area, ore deposits of the Courtland-Gleeson or Turquoise district (3) have been worked intermittently since the late seventies of the past century and have yielded copper, lead, zinc, silver, and gold valued on the order of $12,000,000. Turquoise deposits, one mile northwest of Courtland, have been mined in a small way. During recent years, quartzite for use as flux in the Douglas smelter has been quarried from the eastern base of the ridge south of Courtland; this quarry is visible from Highway 666.		

The settlements of Courtland and Gleeson, which for some time had contained several hundred inhabitants, gradually diminished after 1929 and now are essentially ghost towns.

32.3	0.5	To the east, Whitehead Ridge of Tertiary rhyolite in the foreground; Chiricahua Mountains on the distant skyline.	348.4	4.0

Plate III. Pearce Hill. Southwestward view of the old Commonwealth mine, mill foundations, and dumps.

36.3	4.0	Southward, irrigated farm lands appear at intervals for 17.4 miles.	344.4	2.5
		On the east, 3-6 miles distant, are the Squaretop Hills, mainly of rhyolite, rising to an altitude of 5,500 feet.		
38.8	2.5	On the west, 1.5 miles distant, are low hills of Tertiary rhyolite.	341.9	1.5
40.3	1.5	Road branches east to Chiricahua National Monument, 15 miles.	340.4	0.6
		On the southeast, low hills of Paleozoic quartzite and limestone.		
40.9	0.6	On the northeast is the Turkey Creek Ridge of Tertiary andesite and rhyolite.	339.8	1.7
42.6	1.7	Highway curve. On the north, 1.5-5 miles distant, are the Sulphur Hills, of Tertiary rhyolite, with an altitude of 5,080 feet.	338.1	1.7
44.3	1.7	On the south are hills of Tertiary andesite and rhyolite.	336.4	0.8
45.1	0.8	Road branching north to Kansas settlement, an extensive area of irrigated farm lands, and Willcox. Hills of Tertiary rhyolite and andesite on the north and south.	335.6	1.2
46.3	1.2	On the north and south, hills of Tertiary rhyolite.	334.4	0.7
47.0	0.7	On the north, Tertiary rhyolite hill.	333.7	0.7
47.7	0.7	Road branching west, 0.5 mile to Pearce. On the south is Pearce Hill, of Tertiary rhyolite.	333.0	1.4

In Pearce Hill is the old Commonwealth mine (3) (Pl. III), which operated on a quartz vein containing silver and gold. This vein was discovered about 1895 by J. Pearce. Quoting from Barnes (**14**),

> Pearce and his wife had worked hard for some years at Tombstone, he as a hard-rock miner, she managing a miner's boarding house. They had saved considerable money. Their two sons were crazy to invest in cattle. They started a ranch in Sulphur Spring Valley. One day the old man scouting round on the range got off his horse on top of a small hill. Sitting there he idly hammered a rock against a nearby ledge. The break showed gold. An assay proved it to be very rich. He and his wife and the three children all filed claims and worked it for a time as a family affair. This was too slow for the boys.

John Brockman of Silver City coaxed an agreement of sale from Pearce. Brockman was to have 90 days to work the mine. At the end he was to pay Pearce $250,000 cash, or leave all the work and ore as it was. Inside of 60 days Brockman took out enough to pay the $250,000 and some still left on the dump. Money was divided into five equal shares, a fifth for each. The old lady however refused to sign for her fifth until the new owners had signed an agreement giving her sole right to run the only miner's boarding house in camp for ten years. She didn't propose to be without a job.

Shafts were sunk to the water level, 270 feet below the surface, and ore was hauled to Cochise for rail shipment to the El Paso Smelter. A concentrating plant was built in 1898, and a railroad from Cochise to Pearce was completed about 1903. The total production of silver and gold from the Commonwealth mine, 1875-1929, amounted to approximately $10,525,000, of which one-half was profit.

49.1 1.4 Road branching south, 1.2 miles to Pearce (Altitude 4,375 feet); also to Courtland and Gleeson. Highway 666 is near the grade of the former railroad to Cochise. 331.6 1.0

Six miles to the west is the northern segment of the Dragoon Mountains, with a maximum altitude of 7,512 feet. Extending westward from Pearce is the Middle Pass road, with branches that lead to the old Middlemarch, Black Diamond, Abril, and San Juan (Gordon) mines (3) in the Dragoon Mountains.

The Middlemarch mine during 1898-1920 yielded approximately 265,000 pounds of copper which, together with 1,600 ounces of by-product silver, was valued at $85,000. The Black Diamond for 1903-1929 was credited with an output of 1,100,000 pounds of copper and 5,000 ounces of silver, with a total value of $150,000. The Abril during 1945-1953 produced chiefly zinc, together with some copper, lead, and silver. The San Juan (Gordon) was worked mainly in 1913-1915, 1925, and 1947-1953 for zinc and lead.

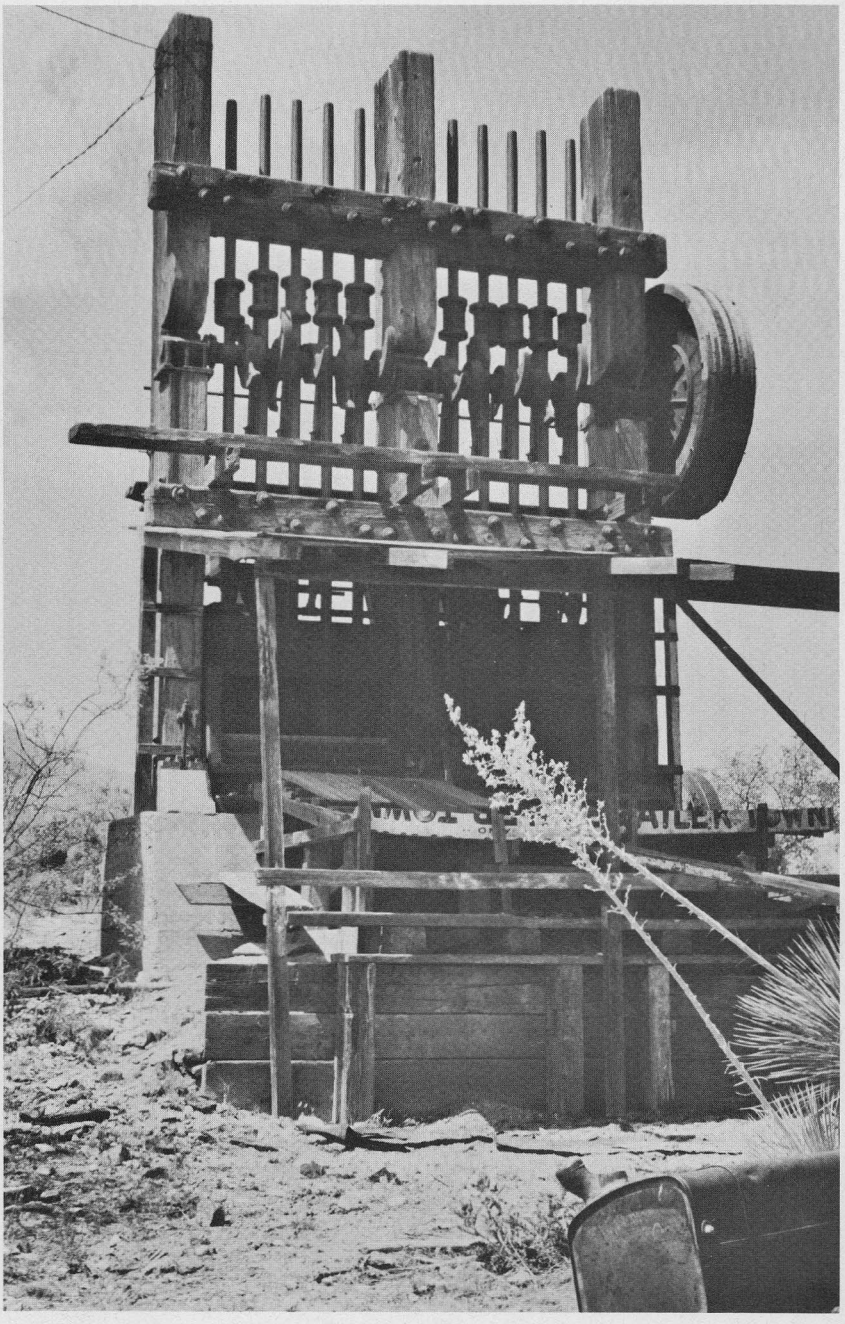


Plate IV. Old stamp mill north of the Golden Rule mine.

50.1	1.0	Arizona Sun Sites settlement; irrigated farm lands at intervals northwestward to mile 61.0. Road branching west, 10.5 miles to Stronghold Canyon, in the Dragoon Mountains. This canyon, ruggedly eroded in younger granite, forms a secluded greenwood basin which now contains a well-appointed Recreation Site administered by the Coronado National Forest. Some 90 or more years ago, the famous Chiricahua Apache, Chief Cochise, and his band used the area as a secure hide-out. He died here in 1874 and was buried at the mouth of the Canyon; after burial, the Apaches rode their ponies back and forth over the ground until all evidence of the grave's existence was obliterated (**14**).	330.6	4.9
55.0	4.9	Due east, 3.5 miles, are the two Sulphur Springs for which this valley was named. With bad-tasting water but good grass, their locality became a favored camping place in the early days, and also was the site of the agency for the Chiricahua Indian Reservation during 1872-1876. According to Meinzer (**15**), the mud surrounding the Sulphur Springs is black, contains sulfides, and has an odor of hydrogen sulfide.	325.7	2.6
57.6	2.6	Road branching west extends through Dragoon Pass, which separates the Dragoon Mountains on the south from the Gunnison Hills and Little Dragoon Mountains on the north; Dragoon, a town on the Southern Pacific railway, is at 9.5 miles. Marble deposits in the Gunnison Hills and in the northern portion of the Dragoon Mountains have been worked for many years; the stone now is being processed by a plant east of Dragoon. At the northeastern foot of the Dragoon Mountains, some 6 miles west of Highway 666, is an old gold mine (**3**) known as the Golden Rule, Old Terrible, or Manzoro. Worked mainly during 1883-1908 and intermittently from 1916 through	323.1	1.9

1929, its veins yielded approximately 10,000 ounces of gold and 320,000 pounds of lead, valued in all at $225,000. North of the mine, 0.5 mile, is an old stamp mill (Pl. IV) of the type that commonly was used in the early days for extracting gold from free-milling ores.

59.5	1.9	Electric generating plant on the west.	321.2	1.5
61.0	1.5	Southeastward, irrigated farm lands to mile 330.6.	319.7	1.8
62.8	1.8	Branch road northwestward, 0.6 mile to Cochise.	317.9	0.5
63.3	0.5	Road west, 0.5 mile to Cochise, altitude 4,225. This town, named for the Apache chief, was established in 1887; here the branch railroad, built in 1903 to Pearce, joined the main line of the Southern Pacific.	317.4	1.4

Plate V. Irrigated tract in San Simon Valley.

On the east is the Willcox Playa, altitude 4,135-4,137 feet. This feature occupies an irregular area, approximately 9.5 miles long by 9.25 miles wide, floored with alkaline clay soil that supports no vegetation. As the closed basin that catches the run-off from the northern portion of the Sulphur Spring Valley, its flat becomes inundated during rainy seasons; throughout most of the year, however, it is a "dry lake," subject to amazing mirages that often may be mistaken for water. The Willcox Playa of today represents the mid-portion of an ancient body of water, termed Lake Cochise, whose old beaches fringe an area 20 miles long from north to south by 11 miles wide (**15**). From mile 63.3 to 78.3, Highway 666 passes over the bed of old Lake Cochise.

64.7	1.4	Cochise Overpass. Main line of the Southern Pacific railroad, which was built across the northern end of Sulphur Spring Valley in 1880.	316.0	1.7
66.4	1.7	On the west, Red Bird Hills of Paleozoic and Cretaceous sedimentary strata, rising to an altitude of 7,043 feet.	314.3	2.3
68.7	2.3	Junction with Arizona Highway 86-U.S. Interstate 10. On the west, 3.5 miles distant, are the Steele Hills, which attain an altitude of 5,270 feet; they consist of Cretaceous strata and Tertiary andesite. On the north, about 6 miles away, are the Winchester Mountains, 7,631 feet in maximum altitude. Their principal mass consists of Cenozoic lavas, beneath which on the south are exposed small areas of Precambrian granite and Paleozoic-Mesozoic beds.	312.0	5.6
74.3	5.6	On the northern skyline, the high Graham Mountains. On the south, the Willcox Playa.	306.4	2.9
77.2	2.9	Willcox; Altitude 4,167 feet. Population (1960) 2,441. Established in 1880 and named for Gen. O. B. Willcox. Since the early days, an important commercial center for the cattle-growing industry. During recent years, large acreages (**12**)	303.5	4.2

northwest and southwest of the town have been farmed with irrigation from shallow wells.

On the northwest, roads to Bonita, Ft. Grant, and Aravaipa Valley; on the southeast, Arizona Highway 186 to Dos Cabezas and Chiricahua National Monument.

On the eastern skyline are the Dos Cabezas (Spanish "Two Heads") Mountains (3). This range, which rises steeply to a maximum altitude of 8,363 feet, consists of Precambrian granite and metamorphic rocks, Paleozoic-Mesozoic sedimentary beds, and Cretaceous-Tertiary lavas and intrusives. The Dos Cabezas and Tevis districts, in the northern part of the range, are credited with a production during 1884-1955 of approximately 4,000,000 pounds of copper, 1,414 pounds of lead, 5,200 pounds of zinc, 429,000 ounces of silver, and 18,000 ounces of gold, in all valued at $1,762,000.

81.4	4.2	Roadside Rest Area on the south, Circle I Hills of schist, granite, and andesite, on the north.	299.3	1.9
83.3	1.9	Roadside Rest Area on the south.	297.4	2.6
85.9	2.6	Railroad Pass, altitude 4,407 feet; divide between Sulphur Spring Valley on the west and San Simon Valley on the east. On the eastern skyline are the Peloncillo Mountains of volcanic rocks.	294.8	0.1

The San Simon Valley extends northwestward from New Mexico to the Safford Valley of the Gila River. As with other valleys in the Basin and Range Province, its bedrock forms a structural trough which is filled to present levels with loosely to firmly consolidated sand, gravel, clay, and silt, of Cenozoic age. The depth and character of this "valley fill" at many places have been determined by well-log (**16**) data.

The principal ground-water supply for the San Simon Valley occurs confined under artesian pressure, within the alluvium beneath a blue-clay zone.

As stated by White (**16**), stock raising was the chief industry in the valley from about 1870, when the first white settlers came into the area, until about 1910, when artesian water was discovered. Before this time, ground water was obtained locally from shallow wells. In 1910, a well several hundred feet deep, drilled for the Southern Pacific Railroad at San Simon, produced flowing water and led to the development of agriculture in the valley. Since 1910, the amount of water used and the acreage under cultivation have fluctuated with economic conditions.

Large tracts (Pl. V), mainly in the southeastern, central, and northern portions of the valley (**12**), now are irrigated from artesian wells, many of which flow at the surface. Among the various crops raised, cotton, feed grains, alfalfa, and lettuce are particularly important.

86.0	0.1	Road cuts for next 2.7 miles show coarse sandy silt together with angular gravel and boulders.	294.7	2.7
88.7	2.7	Roadside Rest Area on the north.	292.0	0.4
		In the northern background is the southeastern tip of the Pinaleno Mountains, of Precambrian granite overlain by steeply westward-dipping adesite.		
		On the south and southeast is the northern end of the Dos Cabezas Mountains, where prospects and small mines have been worked for placer gold, lode gold, and tungsten.		
89.1	0.4	Junction with Arizona Highway 86-U.S. Interstate 10.	291.6	2.8
91.9	2.8	Southeast fork to Arizona Highway 86-U.S. Interstate 10. On the east are the Fisher Hills, composed of Tertiary andesite.	288.8	1.0
92.9	1.0	Andesite crops out from beneath the valley fill.	287.8	1.8
94.7	1.8	Cochise-Graham County boundary.	286.0	1.2

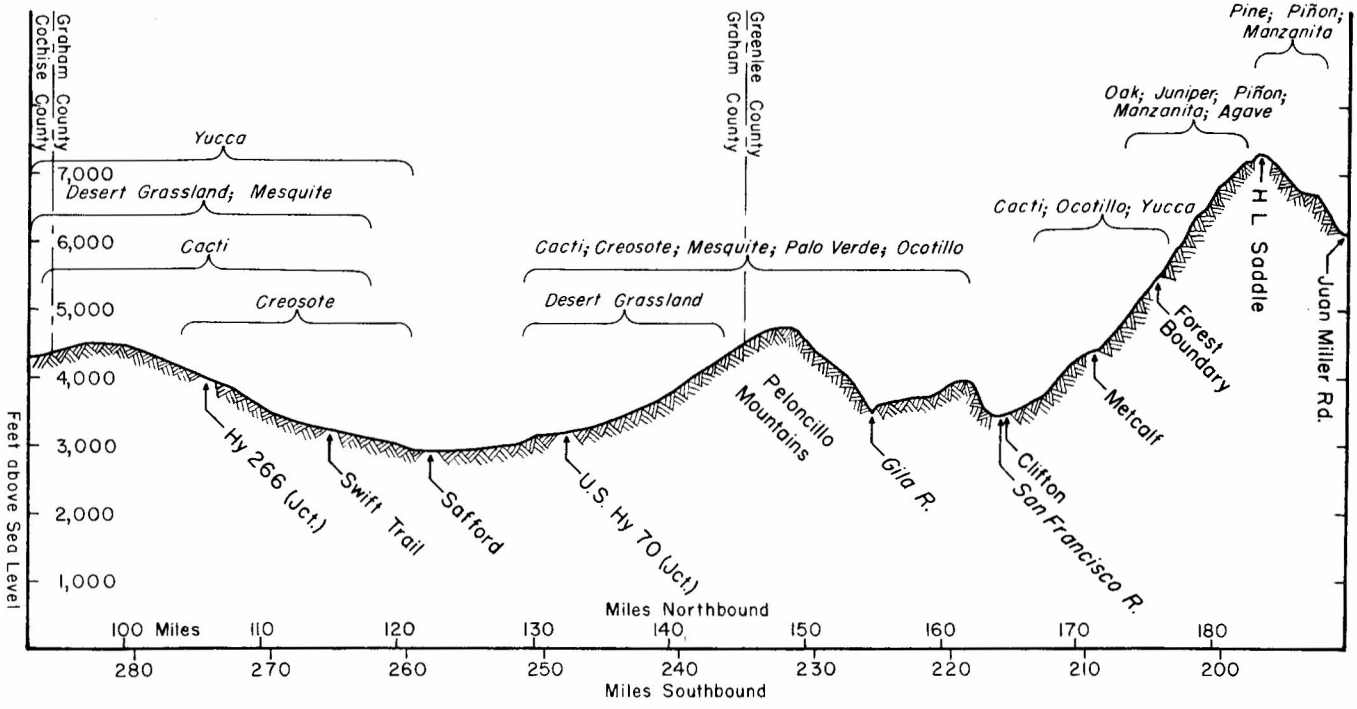


Figure 5. Profile and principal kinds of vegetation, U.S. Highway 666, between Cochise-Graham County line and Juan Miller road. View looking westerly.

95.9	1.2	Tertiary andesite. Outcrops of Precambrian granite at intervals for 5.6 miles northward.	284.8	5.6
101.5	5.6	Outcrops of Precambrian granite at intervals for 5.6 miles southward.	279.2	2.9
104.4	2.9	Road cuts in fine sandy silt and clay.	276.3	1.6
106.0	1.6	On the west, Arizona Highway 266 leads to Ft. Grant, Bonita, and other points in the Aravaipa Valley. Ft. Grant, 22 miles distant, at the southwestern base of the Graham Mountains, was a military post during 1872-1905. The State Industrial School for boys has been located there since 1912.	274.7	0.3
106.3	0.3	Road eastward to ranches in the San Simon Valley. The Whitlock and Peloncillo ranges, of volcanic rocks, appear on the eastern skyline.	274.4	1.6
107.9	1.6	Roadside Rest Area on the east. Dominating the landscape on the west is the Graham Range, a high, forested segment of the Pinaleno Mountains, composed of Precambrian granite, gneiss, and schist. In allusion to its scenery, this range originally was called Sierra Bonita (Beautiful Mountain).	272.8	0.1
108.0	0.1	Northern edge of upper bench on alluvial valley floor; a few miles northwest are spectacular erosional cliffs of the upper benchland.	272.7	4.6
112.6	4.6	Artesia settlement, irrigated farms.	268.1	1.2
113.8	1.2	Highway crosses tongue of higher benchland.	266.9	1.3
115.1	1.3	On the west, Swift Trail road to several recreational areas in Coronado National Forest; to Heliograph Peak (altitude 10,028 feet) and Mount Graham (altitude 10,713).	265.6	1.5
116.6	1.5	Irrigated tracts at intervals.	264.1	2.4
119.0	2.4	County Fairgrounds and Safford Country Club on the east.	261.7	1.1
120.1	1.1	Sand and gravel plant on the east.	260.6	0.1
120.2	0.1	Cement block plant on the west.	260.5	0.1

120.3	0.1	Highline canal, north of which is the Safford irrigated area in the Gila Valley.	260.4	1.8
122.1	1.8	Cross the Bowie-Miami branch of the Southern Pacific Railroad.	258.6	0.2
122.3	0.2	Junction with U.S. Highway 70.	258.4	2.0

Safford. Altitude 2,906 feet. Population (1960) 4,648. Established in 1874 and named after Governor A. P. K. Safford. The Graham County Seat from 1874 to 1883 and from 1915 to present time. Essentially a commercial center of agricultural and livestock industries.

In this valley, approximately 32,500 acres are irrigated (**12**), mainly by gravity flow from the Gila River and to a less extent by wells. The principal crops grown are cotton, feed grains, and alfalfa. Considerable acreages are planted to safflower, the seeds from which yield oil. Also, the culture of sugar beets, depending upon future allotments, may be regarded as potentially important.

124.3	2.0	On the south, the Bowie-Miami branch of the Southern Pacific Railroad. Highway 666 extends eastward along the Gila Valley floor, which here is limited on the north and south by steeply eroded bluffs of older alluvium.	256.4	1.9
126.2	1.9	Channel of the San Simon River, which drains north to the Gila River.	254.5	1.0
127.2	1.0	On the south, Solomonville. Altitude 2,970 feet. Established in 1878 and named after I. E. Solomon, a merchant who, as a side-line, operated mesquite-charcoal pits to supply fuel for the early Clifton smelters (**14**). The Post Office and railway station are named Solomon.	253.5	1.0

Branch road north, 3 miles to Safford municipal airport.

On the north, 9 miles distant, is Weber Peak, altitude 6,100 feet, in the Gila Mountains. The southern portion of this range consists of Mesozoic-Cenozoic volcanic and intrusive rocks. On its southwestern flank is the Lone Star mining district, where ore deposits have been worked intermittently since the late seventies of the past centry; they are credited with an output during 1907-1944 of 319,200

pounds of copper, 47,600 pounds of lead, 1,151 ounces of silver, and 81 ounces of gold, in all valued at approximately $79,000.

During recent years, large low-grade copper deposits were discovered and developed in the Lone Star district, but mining of them is not anticipated for the near future.

128.9	1.7	Agricultural Inspection Station.	251.8	0.3
129.2	0.3	Road branching northeast to San José and Buena Vista settlements.	251.5	0.2
		As early as 1873, according to Granger (14), Mormon farmers near San José used prehistoric irrigation canals to supply water for irrigation.		
129.4	0.2	Western edge of a dissected bench of Cenozoic gravel, sand, and silt. The rounded shapes of the cobbles indicated them to have been transported by river action.	251.3	0.6
130.0	0.6	Roadside Rest Area on the north. Peloncillo Mountains on the eastern skyline.	250.7	2.2
132.2	2.2	Junction with U.S. Highway 70.	248.5	1.8
134.0	1.8	Cenozoic basalt in low hill on the left and cropping out from beneath valley fill for the next mile.	246.7	6.3
140.3	6.3	Old Clifton dirt road branches northeastward and leads to volcanic pumiceous cinder deposits, 3-4 miles distant, that have been worked to some extent for light-weight concrete aggregate.	240.4	0.3
140.6	0.3	Tertiary rhyolite hill on the north.	240.1	1.2
141.8	1.2	Highway is on outwash gravel in Tollgate Gulch with Tertiary rhyolite on both sides.	238.9	3.0
144.8	3.0	Tertiary rhyolite, overlain by andesite.	235.9	0.7
145.5	0.7	Graham-Greenlee County boundary.	235.2	1.8
147.3	1.8	Cenozoic basalt, overlying andesite.	233.4	0.5
147.8	0.5	Summit of pass through Peloncillo Mountains. Altitude 4,803 feet.	232.9	0.6

		Highway leads down Tollhouse Canyon, through basalt locally floored with outwash gravel.		
148.4	0.6	Roadside Rest Area on the west. Rounded summits of basalt on both sides.	232.3	3.5
151.9	3.5	Northeastern edge of basalt. Highway extends onto the sharply dissected southwestern flank of the Gila Valley, which here is floored with loosely to firmly cemented gravel, sand, and silt. The mountains 12 or more miles to the east are in New Mexico.	228.8	2.8
154.7	2.8	Bridge across the Gila River. In the gorge below, is the railroad that extends from Lordsburg, New Mexico to Clifton and Morenci. Exposures of cemented gravel.	226.0	1.1
155.8	1.1	Three Way Junction. Arizona Highway 75 southeast; Arizona Highway 78 northeast.	224.9	0.4
		In this vicinity, numerous road cuts and deep, steep-sided gulches expose Cenozoic cemented gravel and interbedded sandy silt; the rounded cobbles are characteristic of river deposits.		
156.2	0.4	Cold Creek Canyon.	224.5	0.8
157.0	0.8	Buzzard Roost Canyon.	223.7	0.3
157.3	0.3	Road southwest to Guthrie Station.	223.4	0.3
157.6	0.3	Rattlesnake Canyon.	223.1	3.6
161.2	3.6	Cross road; old Safford road to the southwest. Highway 666 descends northwestward, through cuts in cemented gravel, into the valley of San Francisco River. Views of Morenci tailings pond and smelter stacks on the northwest.	219.5	1.7
162.9	1.7	Stack and remains of the old Arizona Copper Company smelter (Pl. VI) on the west; the entrenched, meandering channel of San Francisco River, lined with cottonwoods, on the southwest.	217.8	0.8
163.7	0.8	Above slag dump on the west are some foundations of the old Shannon smelter and concentrator, which were operated during 1902-1918, approximately.	217.0	0.1

Plate VI. Stack and foundations of the Arizona Copper Company smelter, built south of Clifton about 1914. View southwestward. The bluffs are of cemented Cenozoic gravel, eroded along the meandering channel of San Francisco River.

163.8	0.1	Ward Canyon and southern edge of Clifton. Bluffs of cemented Cenozoic gravel.	216.9	0.8
164.6	0.8	Bridge over San Francisco River. Altitude 3,468 feet.	216.1	0.4
		This stream, rising south of Nutrioso (Fig. 1) and draining a large mountainous area, is perennial and at times subject to large floods.		
165.0	0.4	Old railway depot. Bluffs of Tertiary rhyolite and basalt on both sides of the canyon.	215.7	0.1
		A hot spring (temperature 160° F.) formerly issued near the river, 300 feet south of the Clifton depot. This spring no longer exists, but a shallow well on the east bank of the river supplies hot water for a bath house and a swimming pool.		
165.1	0.1	On the west, near Post Office, is the Old Clifton Cliff jail. On the east, Plaza featuring early locomotive (Pl. VII) . Northwest, 0.2 mile, the intermittent Chase Creek joins the San Francisco River.	215.6	0.3

Clifton, population (1960) 4,191, is the Greenlee County Seat. The history of this community is mutually related to that of Metcalf and Morenci; for orientation, reference should be made to Figure 6.

Evidences of gold, silver, and copper deposits, along lower Chase Creek, were discovered by scouts about 1866; this region, then relatively inaccessible and remote from military posts, was strictly Apache domain. In 1872, a group of men prospecting these discoveries established the camp of Clifton near the river at the mouth of Chase Creek and located numerous claims within an area extending for several miles northwest. As certain of these locations developed into promising copper mines, their centers of population evolved into the towns of Morenci and Metcalf (Fig. 6). At the same time, placer gold deposits along Chase Creek, San Francisco River, and gulches southwest of Morenci were discovered and worked to a minor extent.

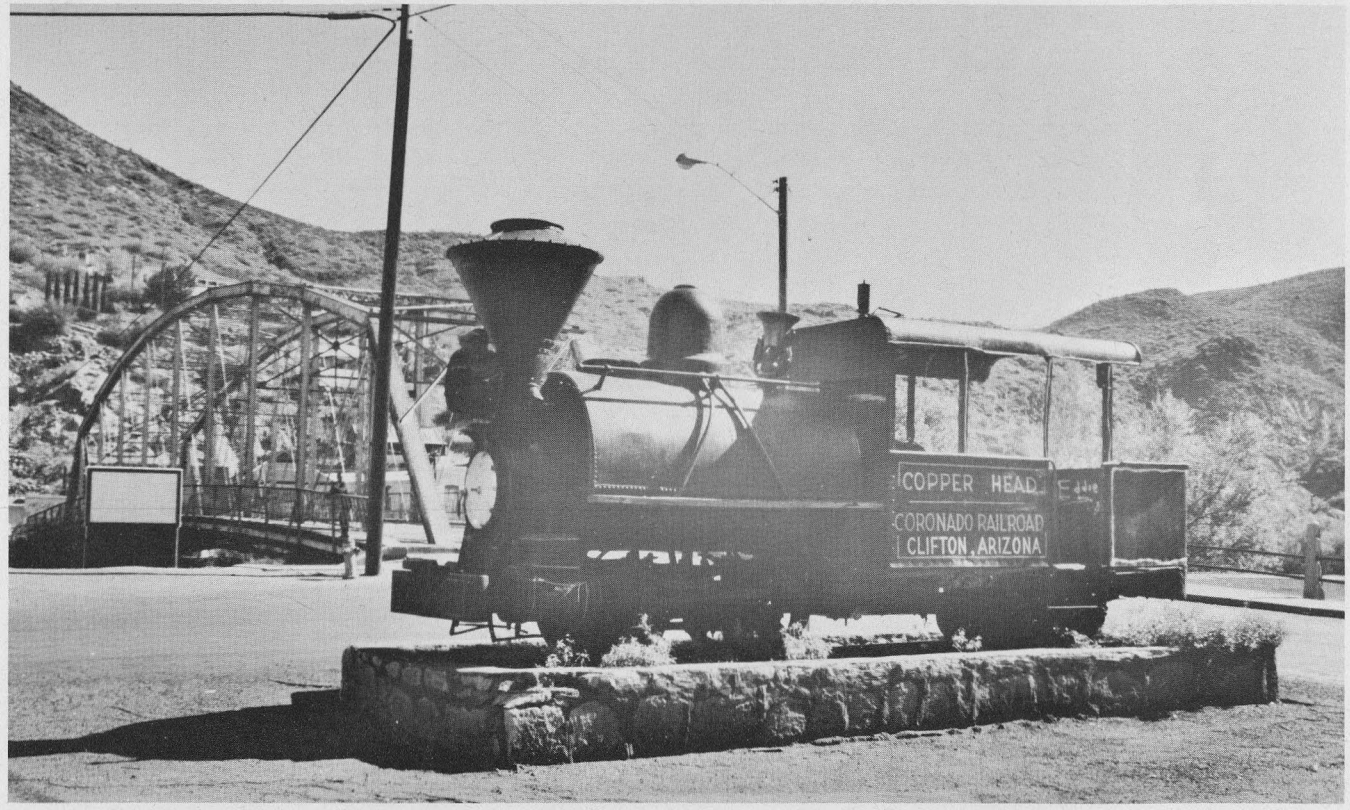


Plate VII. Locomotive used on the first mine railroad in Arizona.

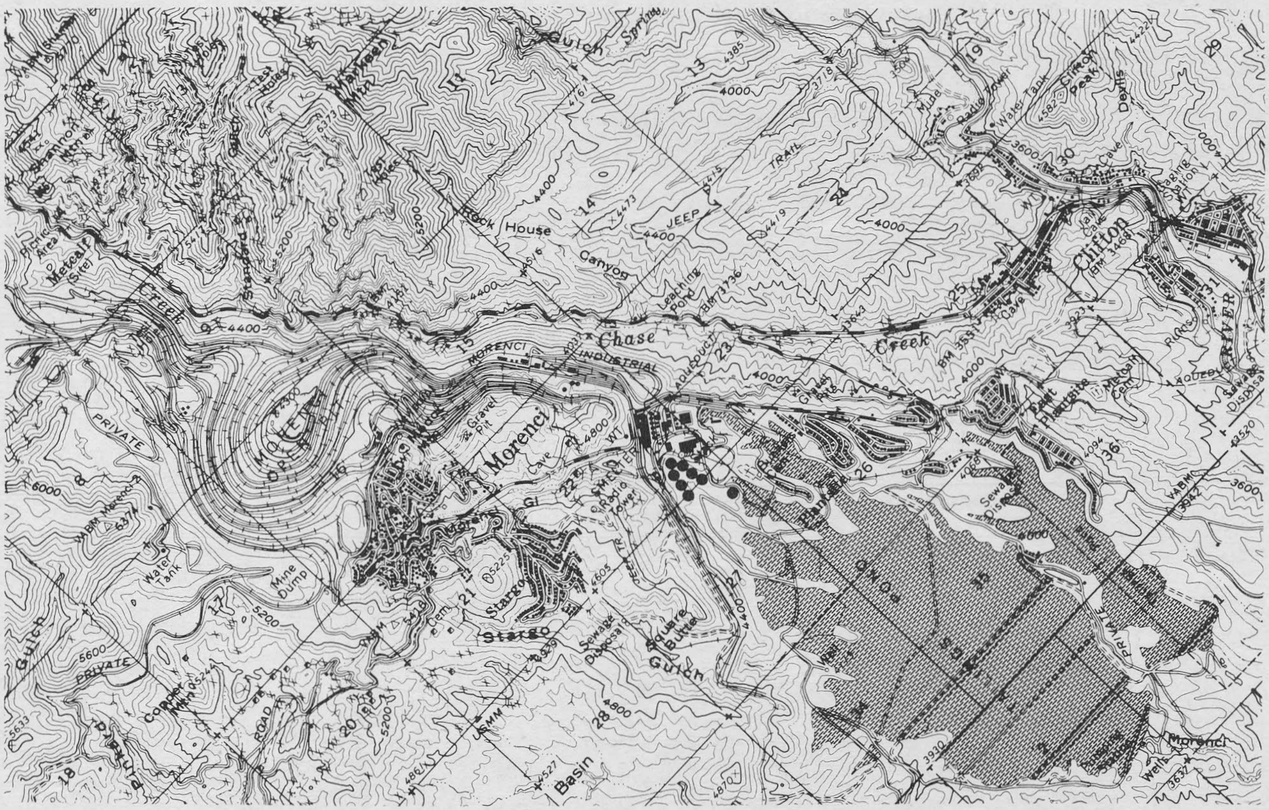


Figure 6. Map of the Clifton-Morenci-Metcalf area.

In 1873, the principal copper claims in the district were acquired by the Lezinsky brothers, merchants of Silver City, New Mexico. They organized the Longfellow Copper Company and began direct-smelting operations, at first near Morenci with an adobe furnace blown by hand-bellows, and subsequently at Clifton with water-jacket furnaces powered by water wheel.

In 1879, the Lezinskys built the first mine railroad in Arizona, a 20-inch-gage line extending up Chase Creek for 7 miles from Clifton to the Metcalf area. Until a locomotive (Pl. VII) was obtained, mules pulled the train on the up-grade and reportedly rode it back on the down-grade gravity run.

Before the coming of the Southern Pacific Railway to Lordsburg, New Mexico in 1881 and the completion of a branch line from there to Clifton in 1884, freight transportation to and from the district was by wagons, mostly drawn by oxen. The best shipping point for copper during the early seventies was Kansas City, some 1,200 miles distant. As aptly stated by Lindgren, this earlier period teemed with stirring episodes of frontier life at places far distant from lines of communication, where the pioneers were exposed under a burning southern sun to many privations and to dangers from hostile Apaches and from the lawless element. No wagon road was as yet built; provisions and supplies were very high, and the communications frequently interrupted. Indian raids continued at intervals, rendering the country unsafe until about 1885. These unfavorable conditions, however, produced a courageous self-reliance, no doubt contributing to the later and rapid advancement of the country (**20**).

Following the advent of railroad transportation, the mining industry here expanded rapidly. Various companies, working the Morenci and Metcalf mines, built concentrators and smelters at Clifton (Pls. VI,VIII) and Morenci. In 1942,

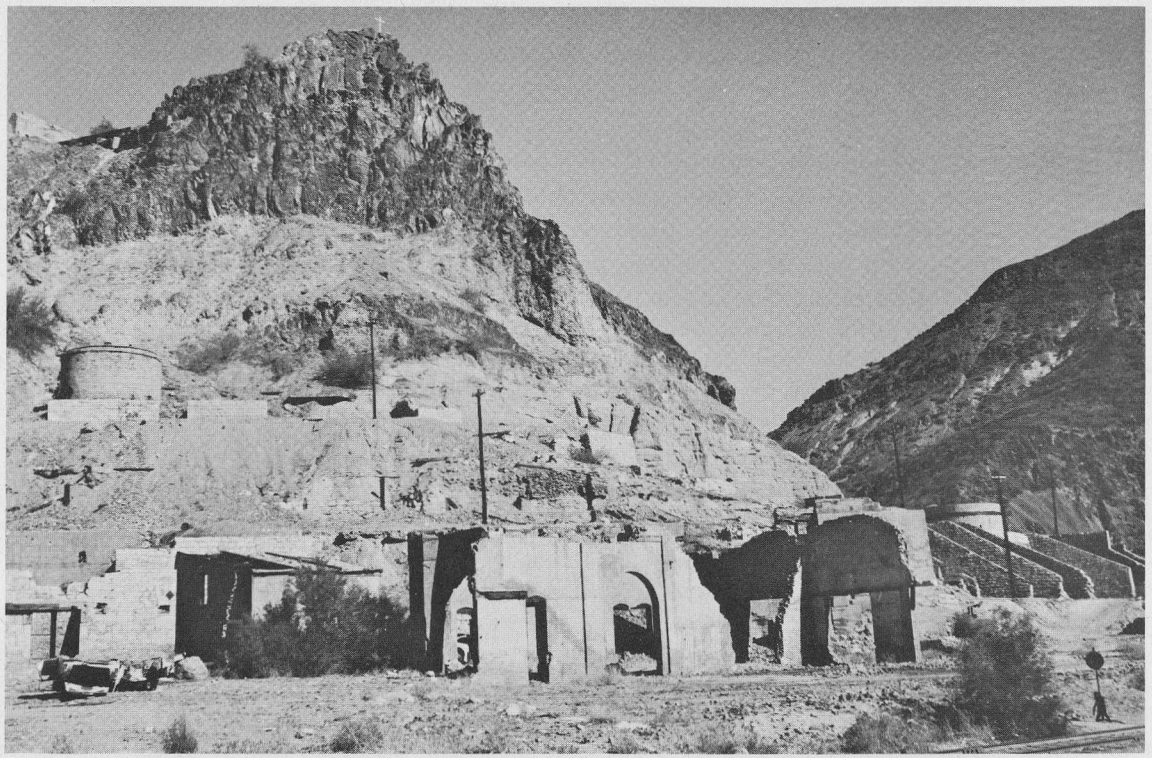


Plate VIII. Ruins of the Arizona Copper Company concentrator, which was operated from 1890 until about 1917. Immediately east of this concentrator was a smelter, which ran during 1884-1914. View northward from near the mouth of Chase Creek.

Phelps Dodge Corporation began large-scale production from the Morenci open pit mine.

The total production of copper, silver, and gold from the Morenci-Metcalf mines during 1873-1963 was approximately as follows:

Copper	7,190,000,000 pounds, valued at	$1,610,000,000
Silver	13,900,000 ounces, valued at	11,900,000
Gold	247,000 ounces, valued at	7,575,000
Total value		$1,629,475,000

Of this total, approximately 80 per cent was won from relatively low-grade ores after 1941. Also, considerable by-product molybdenum has been recovered during the past decade.

Currently, the Morenci open-pit mine is the largest producer of copper in Arizona and the second largest in the Nation.

165.4	0.3	Bluffs of Tertiary rhyolite and basalt on the north and south.	215.3	2.0
		On the north are foundations of the old Arizona Copper Company concentrator; the smelter, east of the concentrator, operated during 1884-1914.		
		Highway continues over Cenozoic gravels. Large pipeline on the southwest is aqueduct, from wells at the river, to Morenci.		
167.4	2.0	Road to Morenci on the west. Log continued on p. 40.	213.3	0.2

Morenci Side-Trip

0.0	0.0	Leave Highway 666 at mile 167.4 north or 213.3 south. Road to Morenci (Fig. 6) swings westerly up grade, onto ridge of Cenozoic gravels.	5.5	1.2
1.2	1.2	Road south, to East Plantsite.	4.3	0.9
2.1	0.9	Turn-out; views of Chase Creek Canyon to the east and Clifton to the southeast. Plantsite on the southwest.	3.4	0.3

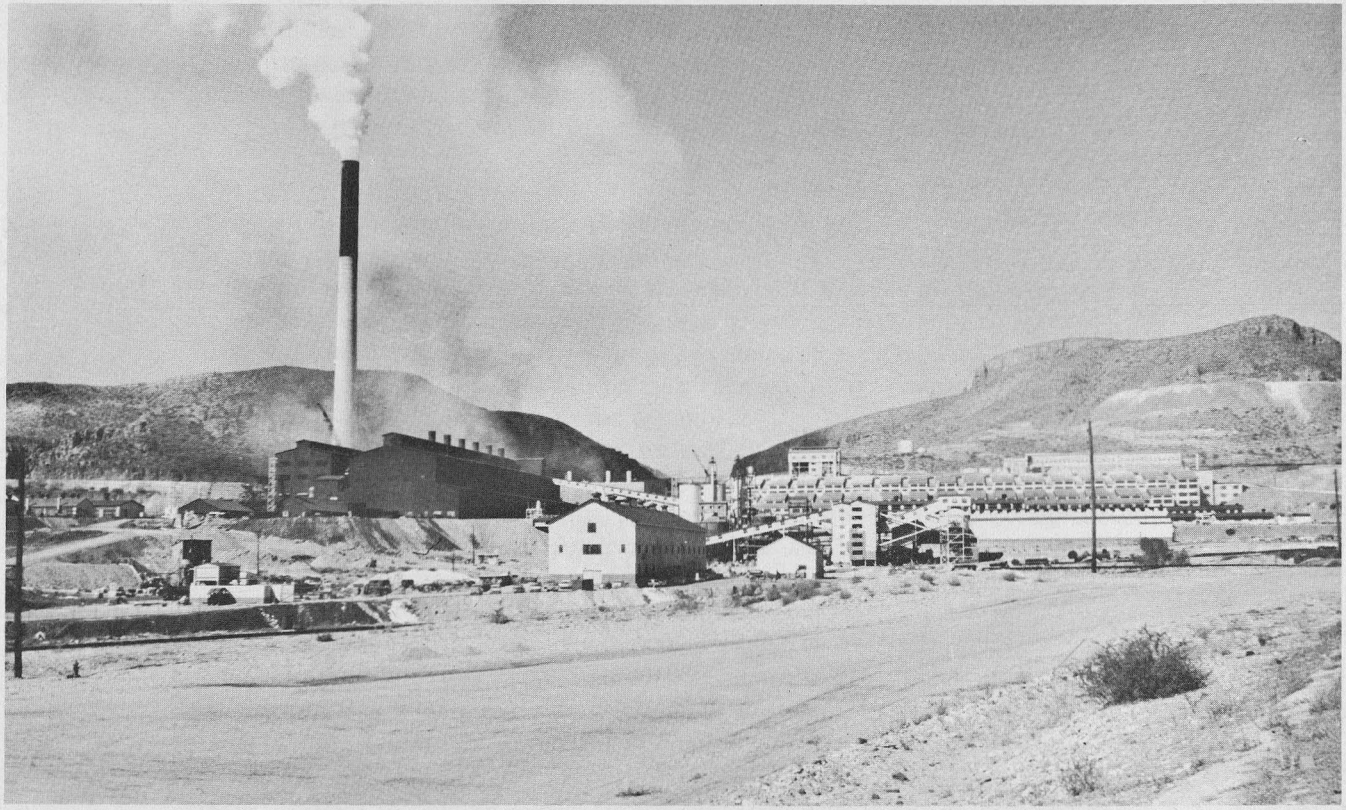


Plate IX. Phelps Dodge reduction plant, Morenci. View northwestward.
Smelter on the left, concentrator on the right.

2.4	0.3	Turn-out; Phelps Dodge Morenci smelter, concentrator, and mine dump on the northwest (Pl. IX).	3.1	0.5
2.9	0.5	Concentrator and smelter.	2.6	0.1
3.0	0.1	Underpass.	2.5	0.1
3.1	0.1	Westward-dipping Cambrian quartzite.	2.4	0.2
3.3	0.2	Across gulch on the southwest, bluff of Cambrian quartzite. On the north, Ordovician limestone.	2.2	0.3
3.6	0.3	Tunnel in limestone.	1.9	0.6
4.2	0.6	On the north, slag dump of the old Detroit Copper Company smelter, which was in operation during 1884-1921. On the southeast, road to Stargo.	1.3	0.5
4.7	0.5	Sharp curve; road to Eagle Creek, southwest. Metamorphosed limestone in road cut.	0.8	0.1
4.8	0.1	Morenci business area.	0.7	0.1
		Morenci. Population (1960): Town 2,431; Plantsite 1,552; Stargo 1,075. Originally known as Joys Camp, the town was renamed about 1884 after Morenci, Mich. The general history of the Morenci-Metcalf district is outlined on p. 30-35.		
4.9	0.1	Limestone on the north.	0.6	0.2
5.1	0.2	On the east, old Arizona Copper Company concentrator, built in 1900.	0.4	0.2
5.3	0.2	Gate, open from 6 AM to 8 PM.	0.2	0.2
5.5	0.2	Visitor's Viewpoint, altitude approximately 5,040 feet. Morenci open-pit mine (Pls. Xand XI) in porphyry; on northern background is the Canyon of Chase Creek.	0.0	0.0

For descriptions of the geology, ore deposits, and mining in the Morenci district, reference may be made to the literature (3).

Plate X. Morenci open-pit mine in September, 1964. View northwestward.

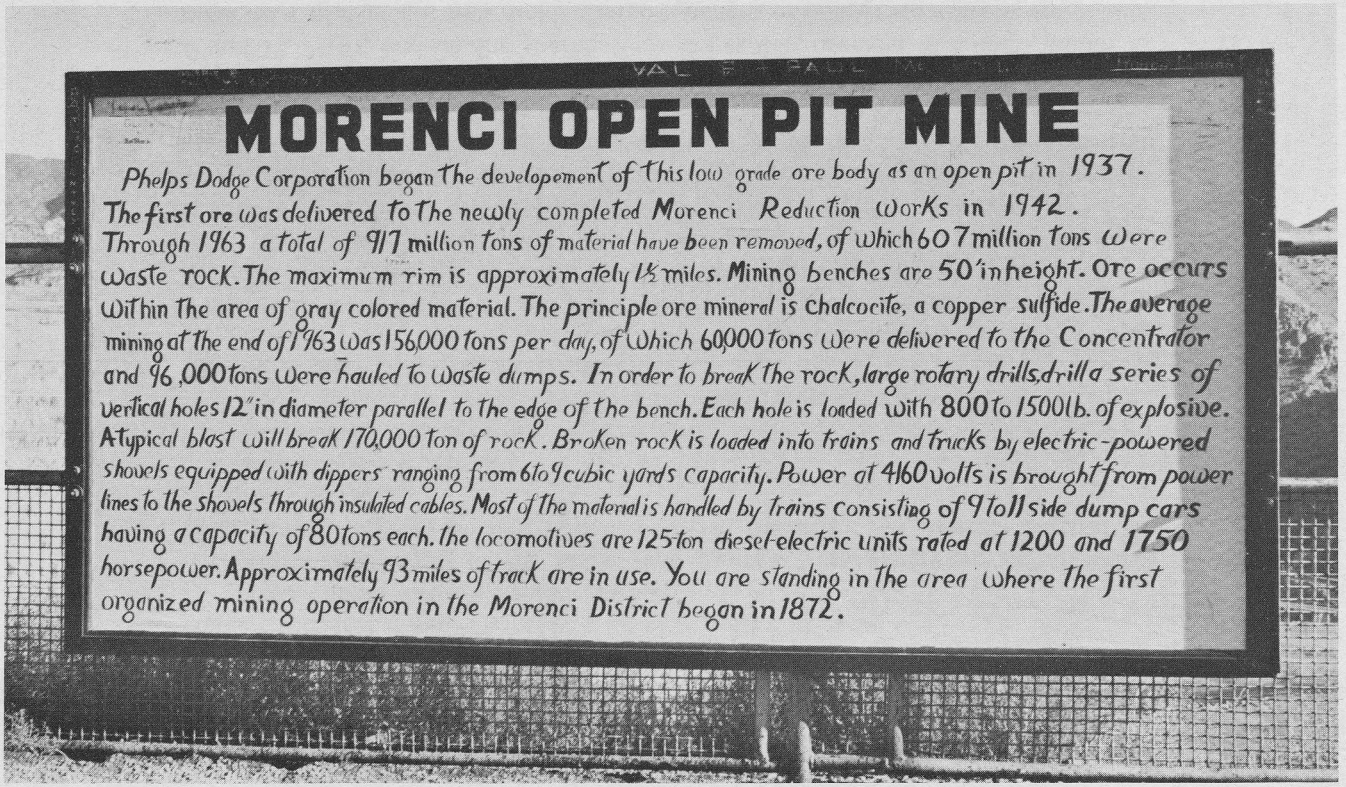


Plate XI. Information regarding Pl. X.

Highway 666, log continued from p. 35

167.4	2.0	Road to Morenci on the west. Highway 666 continues over Cenozoic gravels.	213.3	0.2
167.6	0.2	On the southwest, waste dump of the Morenci open-pit mine.	213.1	0.4
168.0	0.4	Drab, altered Precambrian granite. Along Chase Creek to southeast and northwest, are several vats wherein copper is precipitated from solution by means of contact with iron scrap.	212.7	1.4
169.4	1.4	Short tunnel through altered granite.	211.3	0.3
		An interpretation of the subsurface geology from southwest to northeast through here is given on Cross-Section No. 8, issued by the Arizona Bureau of Mines (p. 68).		
169.7	0.3	Adit tunnel on the east.	211.0	0.6
170.3	0.6	Old railway tunnel on the west.	210.4	1.3
		Approximate contact between Precambrian granite on the southeast and Cretaceous-Tertiary porphyry on the northwest.		
171.6	1.3	Roadside Monument to Metcalf. Altitude approximately 4,480 feet. Picnic area on the northeast. Foundations and ruins of old buildings extend approximately 0.6 mile south and 0.2 mile north. Creek water is green with copper sulfate.	209.1	0.6

Among the prospectors on Chase Creek in 1872 (p. 30) were the Metcalf brothers. Their name was given to this settlement of miners who came to work properties in the vicinity. By 1901, Metcalf had a population of about 1,000; after 1918, however, activity in the local mines ceased, and the town gradually passed out of existence.

The principal mines were on Shannon Mountain, northeast of Metcalf (Fig. 6 and Pl. XII), and on the southeastern slopes of Coronado Mountain, about 2 miles west of Metcalf; they yielded large tonnages of high-grade copper ore. Their

FRANK P. KNIGHT.

Plate XII. Some of the Metcalf mines, southwest of Shannon Mountain, about the year 1900. View southeastward.

Plate XIII. Forest along U.S. Highway 666, approximately 4.5 miles south of Hannagan Meadow. Aspen (with white bark) among spruce, fir, and pine trees.

workings were linked to the railway on Chase Creek (p. 33) partly by means of spectacular inclines, of which the Shannon had a total drop of 800 feet in a horizontal distance of 1,000 feet, and the Coronado, 1,200 feet in less than half a mile.

172.2	0.6	East of the highway, old inclines and mine dumps on the slope of Shannon Mountain.	208.5	1.0
		Highway cuts on the west show iron and copper stains.		
		Approximate contact between Cretaceous-Tertiary prophyry on the west and Precambrian granite on the east.		
		The high country between the Metcalf area and Springerville commonly is regarded as part of the White Mountains (p. 50).		
173.2	1.0	On the east, a road leads up Garfield Gulch, where several copper mines and prospects formerly were worked.	207.5	0.3
173.5	0.3	Cambrian quartzite, overlain in places by Paleozoic limestones.	207.2	0.1
173.6	0.1	Old silica quarry on the northeast.	207.1	0.2
173.8	0.2	On the east, Cenozoic basalt, cut at intervals by black glassy dikes, and overlain by rhyolite. On the west side of canyon, Precambrian granite.	206.9	1.1
174.9	1.1	Ranch buildings; Chesser Gulch on the east.	205.8	1.0
175.9	1.0	South boundary of Apache National Forest (p. 50).	204.8	0.1
176.0	0.1	Coronado Spring, at west edge of Highway.	204.7	0.2
176.2	0.2	Sharp curve.	204.5	0.5
176.7	0.5	Sharp curve.	204.0	0.6
177.3	0.6	Small outcrop of Ordovician limestone.	203.4	0.1
177.4	0.1	On the west, southwest, and north, Precambrian quartzitic schist, steeply dipping and faulted.	203.3	0.9
		View to the south, down Chase Creek Canyon.		
		On the north, 0.5 mile distant, is Pinal Point, altitude 7,242 feet.		

178.3	0.9	Paleozoic limestone and shale.	202.4	0.4
178.7	0.4	Cenozoic basalt and rhyolite on the southwest, Precambrian schist on the northeast.	202.0	0.8
179.5	0.8	Cherry Lodge on the west. Road north to Granville Recreation Area, old Granville silver prospects, and small manganese mines.	201.2	0.2
179.7	0.2	Paleozoic limestones.	201.0	2.7
182.4	2.7	Roadside Park, Sardine Saddle. Cenozoic basalt overlaps Paleozoic limestone.	198.3	0.9
183.3	0.9	HL Saddle turn-out; altitude approximately 7,370 feet. View west across Eagle Creek, and southwest to Graham Mountains on the skyline.	197.4	1.5
184.8	1.5	On the west, Grey Peak; also road to Tule Springs.	195.9	2.1
186.9	2.1	Roadside Rest Area on the east, Highway maintenance camp on the west.	193.8	2.1
189.0	2.1	On the west, road to Eagle Creek and to Honeymoon Recreation Area.	191.7	0.7
189.7	0.7	Road east to Juan Miller Picnic areas and to Blue River.	191.0	3.2
192.9	3.2	Treeless, grassy area of Four Bar Mesa.	187.8	5.7
198.6	5.7	Tertiary andesite on the north, overlain by Cenozoic basalt on the south.	182.1	1.5
200.1	1.5	AD Bar trail to the east.	180.6	4.8
204.9	4.8	Cenozoic basalt on the north, underlain by Tertiary andesite on the south.	175.8	1.7
206.6	1.7	To the west, Bear Canyon trail; to the east, Rose Peak (altitude 8,789 feet), named for the wild roses on its northern slope (14).	174.1	0.6
207.2	0.6	Roadside stop. View into canyon of Blue River, 11 miles east. Road to Rose Peak Lookout on the south.	173.5	1.4
208.6	1.4	Small groves of aspen among pines (Fig. 7).	172.1	3.3
211.9	3.3	Sheep Saddle; Roadside Rest Area.	168.8	0.4

An interpretation of the subsurface geology from southwest to northeast through here is given on Geologic Cross-Section No. 7, issued by the Arizona Bureau of Mines (p. 68).

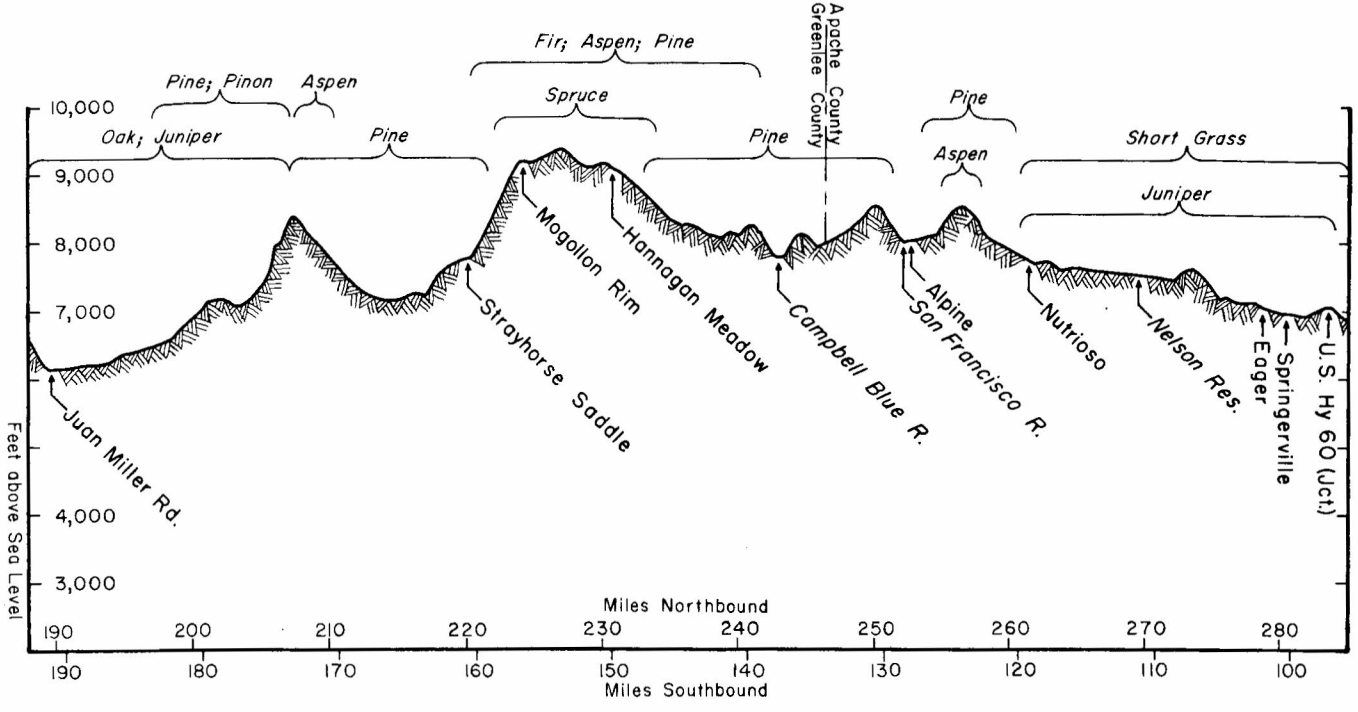


Figure 7. Profile and principal kinds of vegetation, U.S. Highway 666 between Juan Miller road and junction with U.S. Highway 60. View looking westerly.

212.3	0.4	Red Mountain on the southeast; Rose Peak on the south.	168.4	1.6
213.9	1.6	Burnt-over area.	166.8	3.4
217.3	3.4	Sawmill road on the west.	163.4	0.9
218.2	0.9	Jeep trail crossing, altitude 7,586 feet.	162.5	1.9
		Movement on the east-west Strayhorse fault in this locality has depressed the country on the south some 2,000 feet in reference to that on the north.		
220.1	1.9	Strayhorse Saddle; Roadside Camp Area. Exposures of basaltic agglomerate and tuff. View of Mogollon Rim on the north.	160.6	0.2
220.3	0.2	Highway maintenance camp to the northeast. Road cuts on the grade provide fresh exposures of basalt flows and agglomerates.	160.4	3.9
224.2	3.9	Summit of Strayhorse grade; Mogollon Rim, altitude 9,200 feet. Flows of basalt.	156.5	0.1
224.3	0.1	Road south, 0.2 mile to a Rest Area that affords grand, long-distance views, such as eastward across Blue River to Bear Mountain and into New Mexico; southwestward across Eagle Creek, Big Prairie, and the Gila Mountains, to Mount Turnbull, 63 miles; and south-southwestward to Mount Graham, 67 miles distant.	156.4	0.1
224.4	0.1	To the northeast, road to KP Cienega Forest Camp, 0.5 mile.	156.3	1.4
		Over many square miles in all directions, the forest (Fig. 7) is particularly tall and dense (Pl. XIII.)		
225.8	1.4	Road north-northwest to Reno Lookout Tower and to Gobbler Point, which overlooks the canyon of Black River.	154.9	1.1
226.9	1.1	Highest area on Highway 666, altitude approximataely 9,365 feet.	153.8	3.5
230.4	3.5	Hannagan Meadow Forest Camp on the east, altitude 9,141 feet.	150.3	0.2
230.6	0.2	Hannagan Meadow.	150.1	0.3
230.9	0.3	Road northwest, 5 miles to Lost Lake.	149.8	1.0
231.9	1.0	Road north to Willow Creek. Highway 666 extends over Cenozoic basalt which in places is mantled by sand, gravel, and boulders.	148.8	7.1

239.0	7.1	Beaver Head Lodge. Altitude approximately 8,050 feet. Road west, 23 miles to Big Lake; on the southeast, Red Hill road to Blue River and the Blue Range Primitive Area.	141.7	3.0
242.0	3.0	Exposure of typical basalt.	138.7	0.7
242.7	0.7	Campbell Blue River.	138.0	2.0
244.7	2.0	Divide between Campbell Blue River and Coleman Creek. Altitude 8,170 feet.	136.0	1.3
246.0	1.3	Highway is in gulch of Coleman Creek, on basalt.	134.7	0.4
246.4	0.4	Greenlee-Apache County boundary.	134.3	2.9
249.3	2.9	Grayish-white Tertiary sandstone beneath basalt on the east.	131.4	0.5
249.8	0.5	Divide between Coleman Creek on south and San Francisco River on the north.	130.9	0.3
250.1	0.3	Trail northwest to Bear Spring.	130.6	0.1
250.2	0.1	Grayish-white Tertiary sandstone beneath basalt.	130.5	0.6
250.8	0.6	Road east to sawmill.	129.9	1.6
252.4	1.6	Valley of upper San Francisco River (Pl. XIV); named Bush Valley after Anderson Bush, who settled here in 1876 (14).	128.3	0.3
252.7	0.3	Junction with U.S. Highway 180 at west edge of Alpine; Luna Lake is 3.5 miles east.	128.0	0.2
		Alpine, altitude 8,000 feet. Named in 1882, presumably in allusion to its altitude, climate (p. 6), and natural vegetation (Fig. 7); earlier, it was called Fort Bush and also Frisco.		
		Although the growing season here averages only 91 days in length, some cold-resistant crops, such as oats, spring wheat, barley, and corn, are grown.		
252.9	0.2	Brownish outcrops of Tertiary sandstone.	127.8	1.6
254.5	1.6	Basalt mesas on the east and west. Road west, 17 miles to Big Lake.	126.2	1.2
255.7	1.2	Tal Wi Wi Lodge on the east. Quarry in sandstone on the northeast.	125.0	0.8

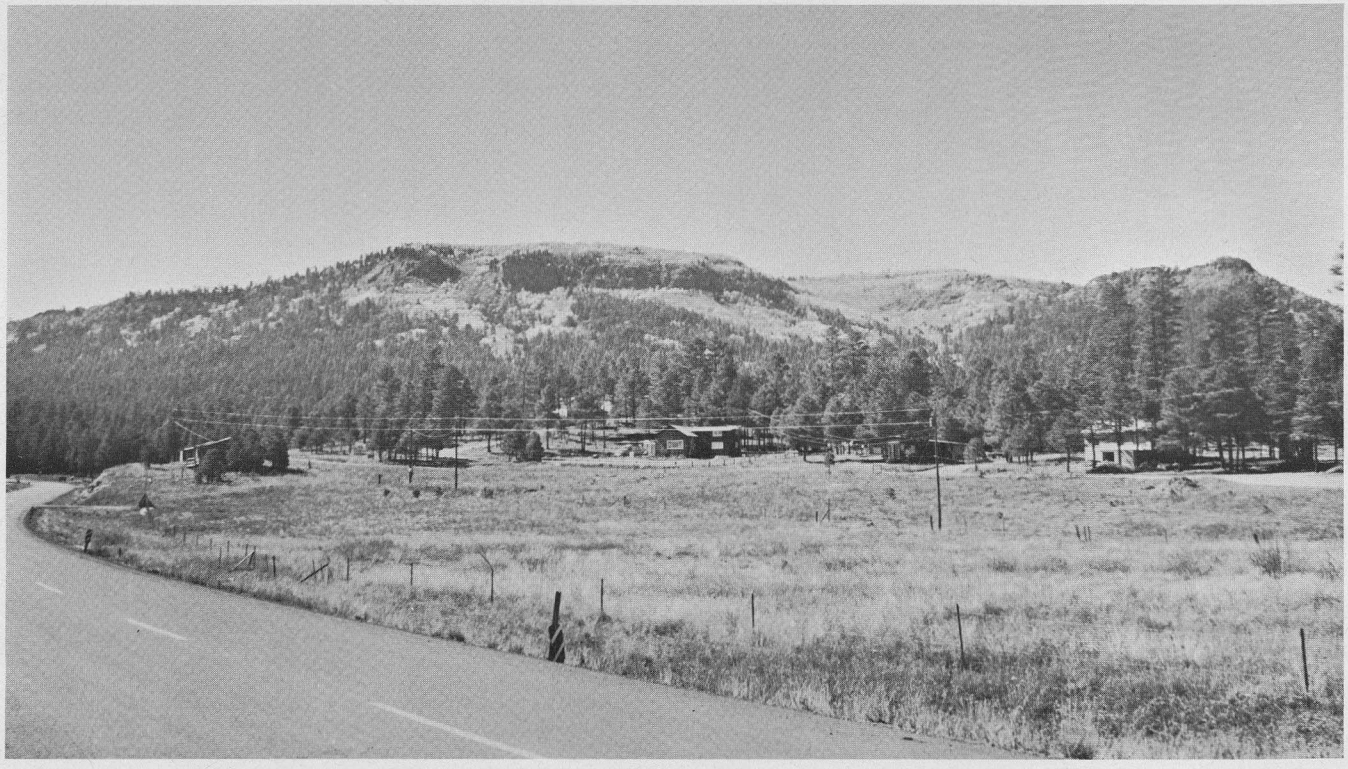


Plate XIV. Southwestern margin of Bush Valley. Mesas in background, rising some 1,500 feet above the valley, consist of Cenozoic basalt and underlying Tertiary sandstone. View southwestward from Alpine.

Plate XV. Nelson Reservoir in December, 1964. View northwestward.

256.5	0.8	Forest Recreational Area on the east.	124.2	0.3
256.8	0.3	Alpine divide between San Francisco River on the south and Nutrioso Creek on the north. Altitude 8,540 feet.	123.9	1.6
258.4	1.6	Road east to trail leading up Escudilla Mountain.	122.3	2.8
261.2	2.8	Small sawmill on the south.	119.5	0.6
		On the northeast, 4.5 miles distant, may be seen Escudilla Mountain, of Cenozoic basalt, altitude 10,912 feet.		

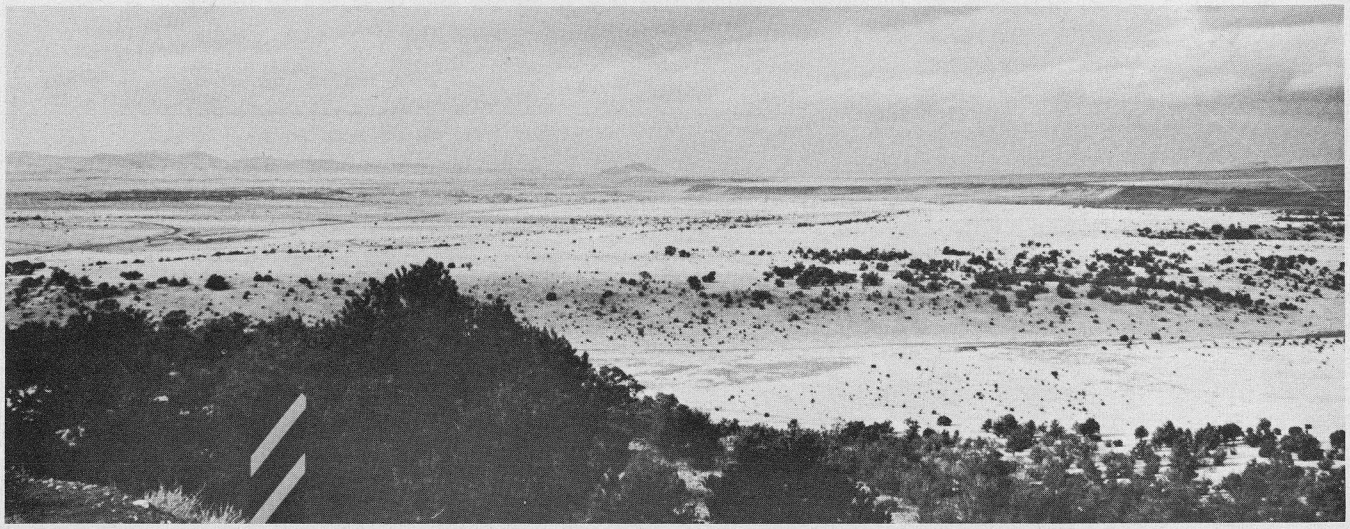


Plate XVI. Valley of the upper Little Colorado River, covered by snow, in December, 1964. View from boundary of Apache National Forest northwestward across part of Round Valley locality.

261.8	0.6	Nutrioso Post Office. Altitude approximately 7,700 feet. Established in 1883 and named (**14**) from Spanish words, "nutria" (beaver) and "oso" (bear).	118.9	0.2
262.0	0.2	Nutrioso Creek. Highway 666 extends northward for 10.2 miles down this valley, which is floored with Tertiary sandstone and lined with mesa bluffs of Cenozoic basalt above the sandstone.	118.7	5.5
267.5	5.5	Small sawmill on the east.	113.2	2.3
269.8	2.3	Dam, with Nelson Reservoir (Pl. XV) on the south. Escudilla Mountain on the southeastern skyline.	110.9	2.4
272.2	2.4	A gulch tributary to Nutrioso Creek. Tertiary sandstone beneath mesas of Quaternary basalt, on both sides. Highway 666 extends southward for 10.2 miles up this valley.	108.5	1.8
274.0	1.8	Northwestern edge of a basalt mesa. Boundary of Apache National Forest on the south. Valley of Little Colorado River on the northwest (Pl. XVI).	106.7	1.1

The Apache National Forest, with headquarters in Springerville, contains more than 677,000 acres in Arizona and extends into New Mexico. It covers that portion of the White Mountains area which lies east of the Apache Indian Reservations and is traversed by Highway 666 northward from mile 175.9 to mile 274.0 or southward from mile 106.7 to mile 204.8. Its arboreal growth (Figs. 5, 7) and included meadows are especially luxuriant and well-watered, owing to the relatively favorable character of the geology, physiography, soils, and climate in the range.

Geologically, the White Mountains represent a volcanic pile, 4,000 or more feet thick, which culminates with an altitude of 11,590 feet on Baldy Peak, 21 miles west of Nutrioso. Younger basalt flanks the range on the north as an extensive area containing more than 200 cinder cones of Recent aspect (P.. XVII). Weathering of the volcanic rocks in the White Mountains has formed soils very suitable for vegetation.

Plate XVII. Extinct volcanic cinder cones and Recent lava northwest of Springerville.

On Baldy Peak, the minimum temperatures probably reach 50° or more below zero (4; 5).

The range, as a whole, annually receives from 15 to well over 25 inches of precipitation, much of it in the form of snow, which feeds the numerous streams, reservoirs, and lakes and supports the natural plant life.

The streams and lakes contain trout and other fish. In the forest are found mule deer, while-tailed deer, pronghorn antelope, bear, javelina, wild turkey, quail, doves,

cottontail rabbits, mountain lion, coyote, fox, bobcat, skunk, porcupine, beaver, muskrat, and badger (**17**).

The principal industries are lumbering and stock raising. Also, tourism here has developed greatly during recent years.

275.1	1.1	Sharp bend in highway.	105.6	0.2
275.3	0.2	Picnic Creek, a tributary of Little Colorado River.	105.4	0.9
276.2	0.9	Rodeo grounds on the east.	104.5	2.0
278.2	2.0	On the north, a low knoll capped by alluvium. On the southeast, Table Top Mountain, a mesa of Quaternary basalt on Tertiary sandstone.	102.5	0.5
278.7	0.5	Intersection with Arizona Highways 73, west to McNary, and 273, south to Big Lake.	102.0	1.6

To the west, eroded edge of Quaternary basalt flow facing Little Colorado River. Cinder cones in the distance.

Eagar. Altitude 7,090 feet. Population (1960) 873. Established about 1880, on ground donated by the Eagar brothers, and settled largely by Mormons after 1884. Originally known as Union, later as Eagarville, and since 1892 by its present name.

280.3	1.6	Junction with U.S. Highway 60 from the east.	100.4	1.0

Springerville. Altitude 6,964 feet. Population (1960) 719.

Springerville and Eagar are in a locality known as Round Valley. Here, about 1870, W. R. Milligan and others settled and built a fort.

A store, established by Harry Springer in 1875 on the west side of the Little Colorado River, was the nucleus of the original Springerville, which served as the Apache County Seat during 1880-1882. The Round Valley area then was divided into two Mormon wards and, in 1885, Springerville was moved approximately two miles east, to its present site (**14**).

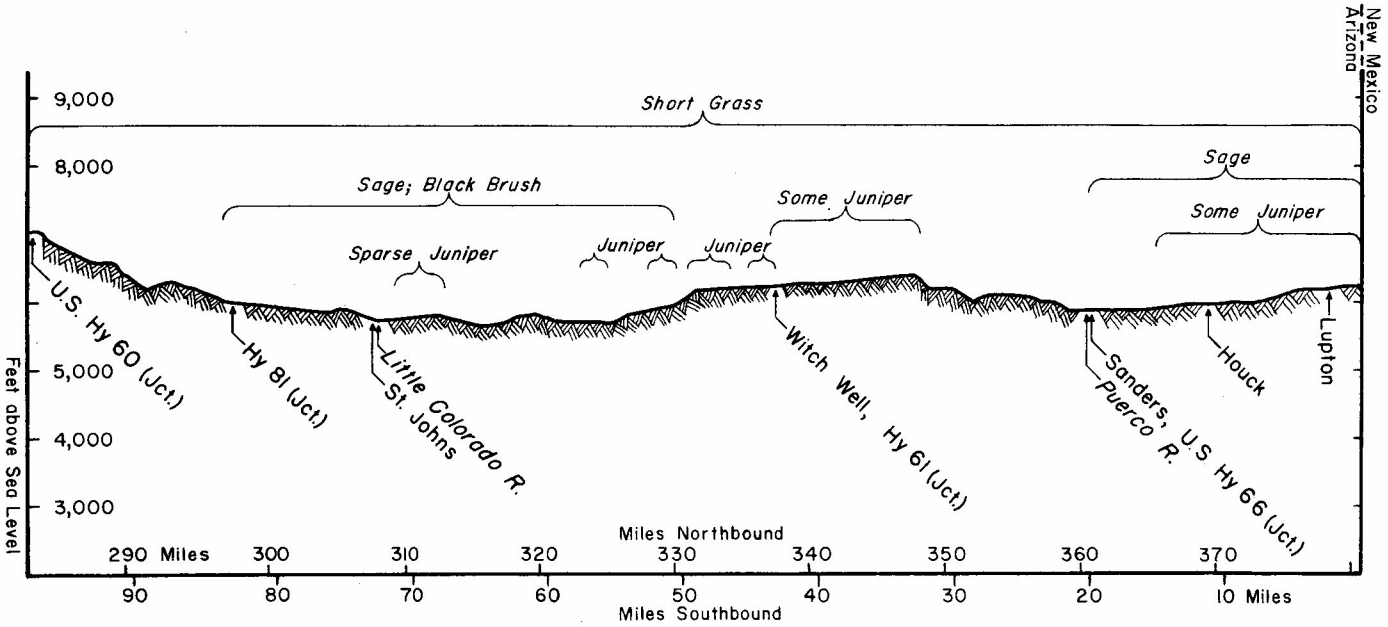


Figure 8. Profile and principal kinds of vegetation, U.S. Highway 666 between junction with U.S. Highway 60 and New Mexican boundary. View looking westerly.

Another store for the valley was founded in 1876, by Julius Becker. As stated by Granger (**14**), a nephew, J. W. Becker, actively sought to establish major highways here, and for many years Springerville lay on the only transcontinental automobile route. The first automobile to make the journey was a Pathfinder, driven in 1910 by A. L. Westgard.

Some irrigation farming is carried on in Round Valley (**12**). Large numbers of cattle and sheep are raised on the grasslands throughout the surrounding country.

281.3	1.0	Little Colorado River. This stream, a major tributary of the main Colorado, heads near Baldy Peak, 15 miles southwest of here, and is crossed again by Highway 666 near St. Johns. Early Spanish explorers called it the Rio de Lino (River of Flax) because flax grew abundantly at places on its bottom lands.	99.4	0.1
281.4	0.1	Agricultural Inspection Station.	99.3	0.8
282.2	0.8	Becker Lake on the west.	98.5	0.3
282.5	0.3	Roadside Rest Area on the west. On the northeast, outcrop of Cretaceous red shale and sandstone beneath Quaternary basalt. On the northwest, a basalt mesa.	98.2	1.0
283.5	1.0	Junction with U.S. Highway 60. Highway 666-180, north from here to mile 300.7, was relocated about 1963.	97.2	1.4
		Large area of Quaternary basalt. On the west, cinder cones in the distance.		
284.9	1.4	Road cuts in basalt (Pl. XVIII) for 0.6 mile north.	95.8	3.7
		On the northwest, cinder cone and Recent lava flow (Pl. XVII).		
288.6	3.7	Quarry in cinder cone on the east.	92.1	0.5
		Volcanic cinders find extensive use in road construction and as a light-weight aggregate for concrete.		
289.1	0.5	Cuts in recent basalt.	91.6	2.4
291.5	2.4	View of Little Colorado River Valley on the east.	89.2	1.1
292.6	1.1	Cinder cones on the west, southwest, and southeast.	88.1	2.5

Plate XVIII. Quaternary basalt flow, northwest of Springerville. The cellular cavaties were formed by gas bubbles while the rock was molten.

295.1	2.5	Cuts in Triassic Chinle formation variegated shale and coarse-grained, gray sandstone.	85.6	1.0
296.1	1.0	On the west and northeast, mesas of Quaternary basalt capping Chinle beds.	84.6	0.3
296.4	0.3	On the east, view of Lyman Lake.	84.3	1.1
297.5	1.1	Intersection of Arizona Highway 81; 0.5 mile east to Lyman Lake State Recreational Area (Pl. XIX).	83.2	1.4

Lyman Dam is an earth-fill structure on Little Colorado River. The original dam at this site was completed about 1903 and named for F. M. Lyman, a Mormon bishop; it washed out in 1915, with the loss of eight lives and severe damage to the farmlands. The present dam was built with loans from the State of Arizona.

As stated by Feth and others (18),

> At several places along the Little Colorado River in the reach between Lyman Reservoir and St. Johns, travertine cones have been built by deposition from warm, highly mineralized spring waters. These spring cones attain heights of more than 100 feet and, in extreme cases, diameters of nearly half a mile. The waters discharging from these springs add large amounts of mineral matter, principally common salt, to the Little Colorado River. The sources of the mineralized waters are believed to be artesian aquifers in older sedimentary rocks that occur at considerable depth below the land surface. The linear arrangement of the spring cones suggests that faulting may determine the paths along which the artesian waters rise.

298.9	1.4	Farms along Little Colorado bottom lands.	81.8	1.7
300.6	1.7	Exposures of Chinle formation on the south and west.	80.1	0.1
300.7	0.1	Paved road from the southwest is the former location of Highway 666.	80.0	1.0
301.7	1.0	Salado settlement, farms.	79.0	0.2
301.9	0.2	Valley alluvium; Chinle shale on the east.	78.8	2.1
304.0	2.1	Edge of low mesa of Chinle sandstone and shale.	76.7	2.2
306.2	2.2	Valley of Little Colorado River widens to the north.	74.5	1.0

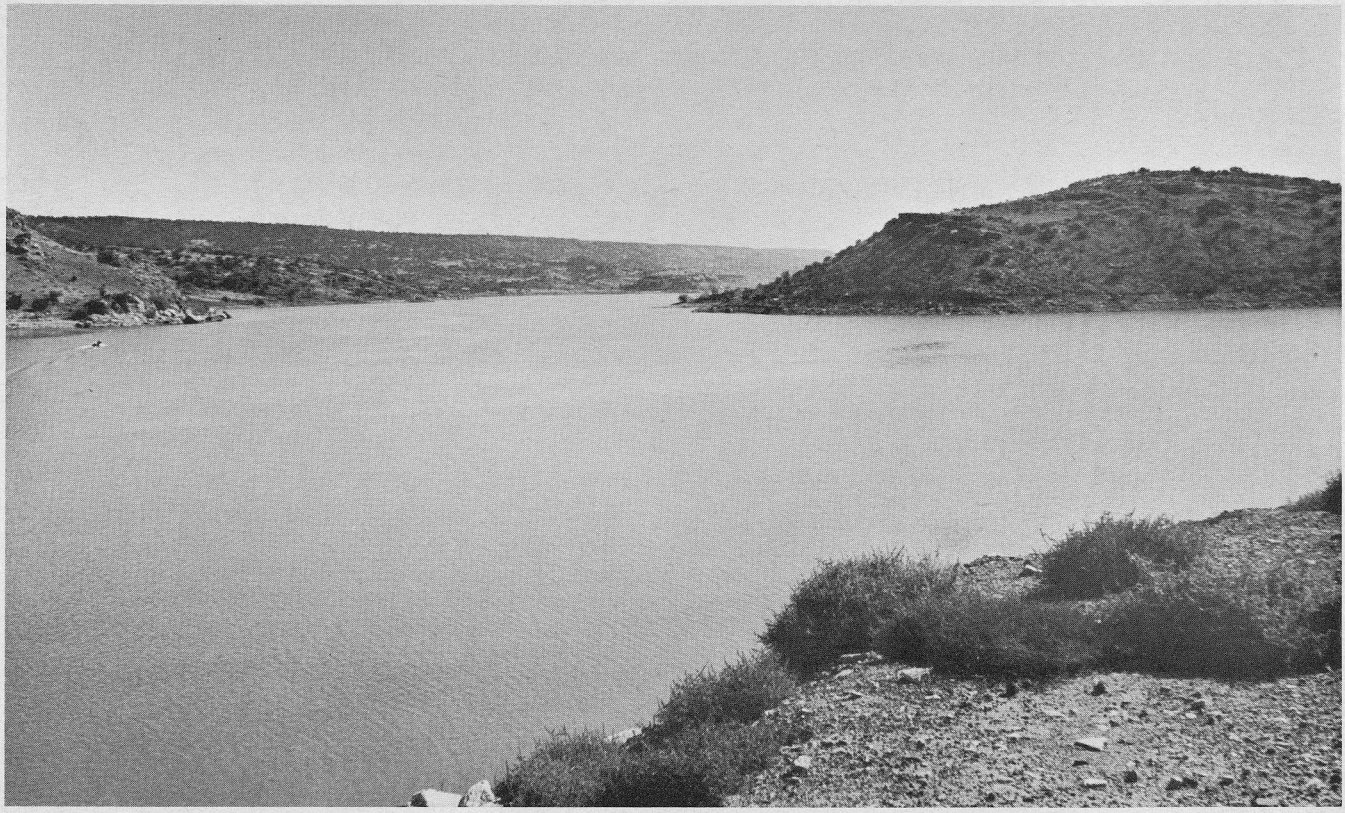


Plate XIX. Lyman Lake, on Little Colorado River.

307.2	1.0	Reservoir on the east.	73.5	1.5
308.7	1.5	Commercial and Second Streets in St. Johns; junction with U.S. Highway 180 and Arizona Highway 61.	72.0	0.1

St. Johns. Altitude 5,730 feet. Population (1960) 1,310. The Apache County Seat in 1879 and again since 1882. Quoting from Barnes (14),

> José Seavedra and father, first settlers, arrived here in December, 1872, in a two-wheeled oxcart. They built first bridge across Little Colorado to cross a band of sheep. Road to Fort Apache from Zuni crossed here, and they made good money allowing freighters to use the bridge. Seavedra filed on a homestead and took out a ditch in 1875.
>
> Wilford Woodruff selected a location in 1880 for Mormon colonists about 1.5 miles below present St. Johns. Erastus Snow advised changing to higher ground adjoining the Mexican town on west and north, resulting in present townsite.

The surrounding region serves well for the grazing of cattle and sheep (Pl. XX).

Some irrigation farming is carried on in the vicinity of St. Johns, largely with surface water but partly with ground water from wells extending into the Permian Coconino sandstone.

308.8	0.1	Little Colorado River.	71.9	0.4
309.2	0.4	Highway turns; valley floor of Quaternary alluvium.	71.5	2.1
311.3	2.1	Variegated Chinle shale, capped by sandstone on the north and on the east.	69.4	2.7
314.0	2.7	Quaternary alluvium.	66.7	3.1
317.1	3.1	Carrizo Wash.	63.6	1.5
318.6	1.5	To the northwest is the road to St. Johns Stake Welfare Ranch. Chinle shale and sandstone.	62.1	3.6
322.2	3.6	Quaternary alluvium.	58.5	2.7

An interpretation of the subsurface geology from the southwest to the northeast through here is given on Geologic Cross-Section No. 6, issued by the Arizona Bureau of Mines (p. 68).

Plate XX. Grassland with scattered juniper trees, Zuni River area, northeast of St. Johns.

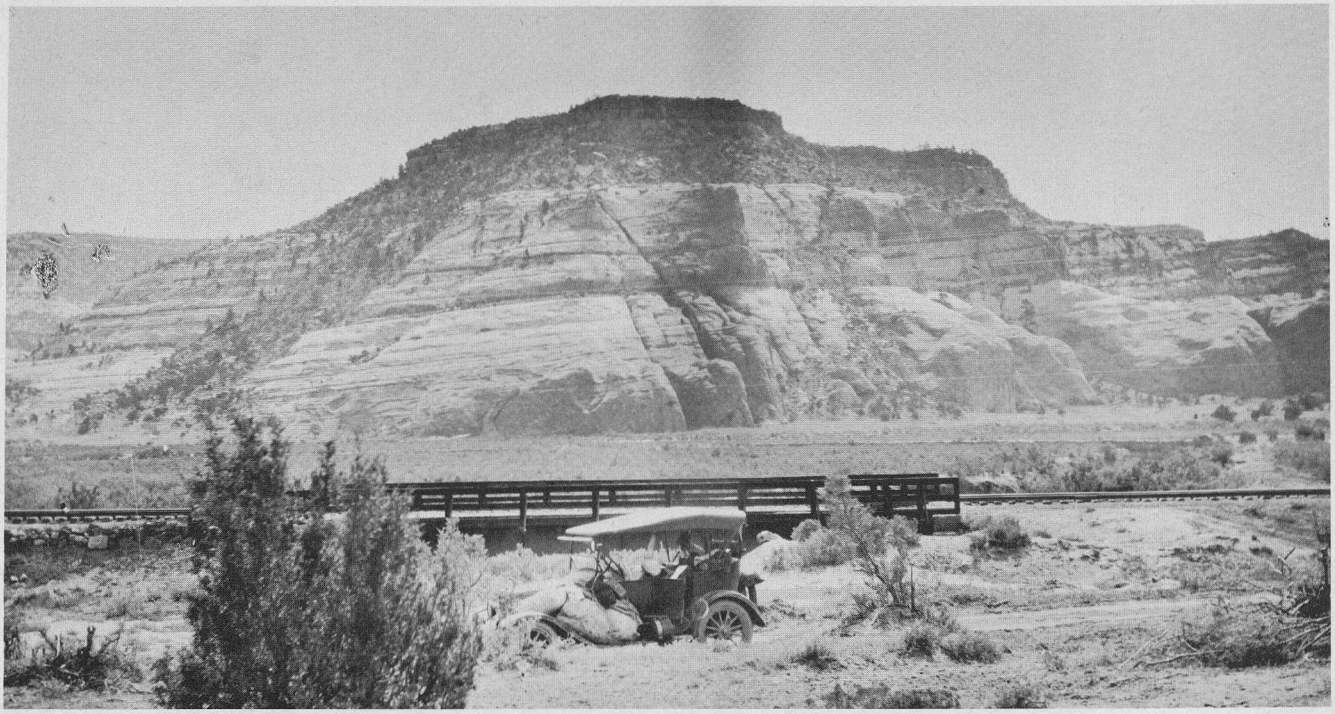
324.9	2.7	Zuni River.	55.8	1.9
326.8	1.9	Quaternary basalt on the east and west.	53.9	0.4
327.2	0.4	Quaternary basalt on the east; Chinle shale and sandstone on the west and south.	53.5	1.5
		Recently, considerable exploration for potash has been carried on within the area extending west from the Highway for several miles and northward for 15 miles, by means of wells sunk into the Permian Supai formation. The results of this prospecting have not been announced.		
328.7	1.5	Prominent low ridge of Quaternary basalt two miles to the east.	52.0	2.7
331.4	2.7	Bluffs of Tertiary sand and silt on the west.	49.3	0.9
332.3	0.9	Quaternary alluvium, sandy.	48.4	0.9
333.2	0.9	Roadside Rest Area on the west.	47.5	2.7
335.9	2.7	Roadside Rest Area on the west.	44.8	1.5
337.4	1.5	Witch Well ranch on the west. Arizona Highway 61 branches northeastward.	43.3	1.1
338.5	1.1	Hardscrabble Wash.	42.2	5.3
343.8	5.3	Lowry Well to the west.	36.9	0.6
344.4	0.6	Minor valleys of Quaternary sand and silt and ridges of Tertiary sand.	36.3	10.5
354.9	10.5	Roadside Rest Area on the west.	25.8	1.4
356.3	1.4	Indian hogans on the west.	24.4	1.2
357.5	1.2	Chinle shale and sandstone to the north and east.	23.2	3.1
360.6	3.1	Puerco River or Rio Puerco (Spanish, "dirty river"). This southwestward-flowing tributary of the Little Colorado is dry much of the year, but at times it is subject to abrupt floods.	20.1	0.2
360.8	0.2	Cheto Overpass. Main line of Atchison, Topeka, and Santa Fe Railroad.	19.9	0.9
		This line, originally the Atlantic and Pacific, was built through northern Arizona in 1883.		
		Town of Sanders on the northwest. Altitude about 5,900 feet.		

Important deposits of bentonitic clay occur within the Bidahochi sedimentary beds, of Tertiary age, in this general area. Since 1925, several million tons of the clay have been shipped to Los Angeles, mainly for use as a catalyst in petroleum refining. This output has come largely from the Cheto open-pit mines, six miles east-southeast of Sanders, since 1942; minor amounts were obtained earlier from the Chambers underground workings, three miles northwest of Sanders, and from the Allentown workings, 16 miles farther east.

Wells on the Pinta anticline, four miles southwest of Navajo or 16 miles southwest of Sanders, in 1963 produced gas which yielded approximately 36,200,000 cubic feet of helium, valued at (19) $1,300,000. This gas is obtained from the Permian Coconino sandstone and recovered in the Navajo Processing plant.

		Junction of U.S. Highway 666 with U.S. Highway 66-Interstate 40. On the north, bluffs of variegated Chinle sandstone and shale.		
361.7	0.9	Agricultural Inspection Station.	19.0	0.3
362.0	0.3	Southern boundary of Navajo Indian Reservation.	18.7	1.1
363.1	1.1	Cedar Point Interchange.	17.6	0.1
363.2	0.1	Cedar Point Trading Post.	17.5	0.5
363.7	0.5	Roadside Rest Areas.	17.0	0.3
364.0	0.3	To the north, Chinle sandstone, shale, and conglomerate. Road north, 12 miles to Pine Springs.	16.7	1.7
365.7	1.7	Puerco River on the southeast.	15.0	0.9
366.6	0.9	Bridge; Triassic Shinarump fine-grained conglomerate at ends.	14.1	0.7
367.3	0.7	Big Arrow Trading Post.	13.4	1.5
368.8	1.5	Roadside Rest Area on the north.	11.9	0.4
369.2	0.4	Black Creek Wash. To the south, Tegakwitha Mission.	11.5	0.4
369.6	0.4	Houck Post Office on the north. Chinle sandstone and shale.	11.1	0.3

Plate XXI. Cliffs of Mesozoic sandstone showing erosional arches and small caverns, west of Lupton. View northward across U.S. Highway 666-66.



N. H. DARTON.

Plate XXII. The road that preceded U.S. Highway 666-66, at the Arizona-New Mexico boundary. Photograph taken in 1922. View southeastward across the Santa Fe Railroad and the narrow valley of the Puerco River, with cliffs of Mesozoic sandstone and shale in background.

Total MILES NORTHWARD	Interval		Total MILES SOUTHWARD	Interval
369.9	0.3	Roadside Rest Areas on the north and south.	10.8	4.3
374.2	4.3	On the south, Roadside Rest Area, with Santa Fe Railroad and Puerco River beyond.	6.5	0.4
374.6	0.4	Yellowhorse Trading Post.	6.1	1.1
375.7	1.1	Hawthorne Road Overpass.	5.0	1.2
376.9	1.2	Eroded bluffs of gray, white, and pink Mesozoic sandstones and shales to the east.	3.8	0.3
377.2	0.3	Cuts in Triassic Chinle shale.	3.5	0.3
377.5	0.3	Indian huts on the north.	3.2	0.9
378.4	0.9	Eroded bluffs of colorful Mesozoic sandstone and shales to the southeast.	2.3	0.2
378.6	0.2	Overpass; the road to Lupton leads south; the road to the Window Rock Navajo Agency branches northward.	2.1	0.7
379.3	0.7	On the north, sandstone cliffs with erosional arches and small caverns (Pl. XXI).	1.4	0.6
379.9	0.6	Town of Lupton on the south.	0.8	0.3
380.2	0.3	Grant's Road and Lupton Overpass. Erosional arch in sandstone bluff to the north.	0.5	0.5
380.7	0.5	Boundary, McKinley County, New Mexico-Apache County, Arizona (Pl. XXII).	0.0	0.0

For information regarding the geology and mineral deposits of Apache County, reference may be made to the literature (2; 3).

APPENDIX

GLOSSARY OF SELECTED TERMS

Agglomerate. Volcanic fragments of coarse to fine texture, generally unsorted and more or less cemented.

Andesite. A volcanic rock, generally of dark-gray color and intermediate in composition between rhyolite and basalt.

Aquifer. Permeable rock or earth material that carries water.

Basalt. A common lava of dark color and of great fluidity when molten. It is less siliceous than rhyolite and contains much more iron, calcium, and magnesium.

Cambrian. The oldest of the geologic periods into which the Paleozoic era (Fig. 2) is divided; approximate age, 430,000,000-550,000,000 years.

Cenozoic. The youngest of the geologic eras (Fig. 2); approximate age, 0-70 million years.

Cienega. Marshy area.

Cinder Cone. A volcanic cone composed of scoriaceous lava, clinkerlike material, or ash.

Cretaceous. The latest geologic period within the Mesozoic era (Fig. 2); approximate age, 70,000,000-125,000,000 years.

Deformation. Any tectonic or structural change, such as folding, jointing, and faulting, in the original shape of rock masses.

Dike. An upright or steeply dipping sheet of igneous rock that has solidified in a crack or fissure in the earth's crust.

Era. A geologic-time division comprising one or more periods (Fig. 2).

Fault. A movement or displacement of the rock on one side of a fracture or break in the earth's crust past the rock on the other side.

Gneiss. A rock resembling granite but with its mineral constituents so arranged as to give it a banded appearance. Gneiss does not split as freely and evenly as schist.

Granite. A granular plutonic rock composed essentially of quartz, alkalic feldspar, and mica.

Mesozoic. The geologic era between the Paleozoic and Cenozoic (Fig. 2); approximate age, 70,000,000-200,000,000 years.

Metamorphic rock. Rock that has been changed in the earth by heat, pressure, solutions, or gases.

Nonmetallics. Mineral or rock substances that find industrial use, generally other than as sources for metals.

Ordovician. The second geologic period within the Paleozoic era (Fig. 2); approximate age, 350,000,000-430,000,000 years.

Paleozoic. The geologic era between the Precambrian and Mesozoic (Fig. 2); approximate age, 200,000,000-550,000,000 years.

Period. In geology, a division of an era (Fig. 2).

Physiography. Physical geography; land relief.

Playa. A central, relatively shallow basin, in which water gathers after a rain and evaporates.

Plutonic. A general term for those rocks that have crystallized in the depths of the earth.

Porphyry. Any igneous rock in which certain crystals (phenocrysts) are distinct from a fine-grained matrix.

Precambrian. That part of geologic time before the Cambrian (Fig. 2); approximate age, 550,000,000-2,000,000,000 years or more.

Quaternary. The later geologic period within the Cenozoic era (Fig. 2); approximate age, 0-1 million years.

Quartzite. A rock composed of sand grains cemented by silica into an extremely hard mass.

Recent. The later part of the Quaternary period.

Rhyolite. A siliceous lava, generally of light color.

Rock. Any naturally formed aggregate or mass of mineral matter, whether or not coherent, constituting part of the earth's crust.

Schist. A metamorphosed rock that splits more easily in certain directions than others. Schist splits more evenly and freely than gneiss.

Tertiary. The earlier geologic period within the Cenozoic era (Fig. 2); approximate age, 1,000,000-70,000,000 years.

Travertine. Essentially calcium carbonate, deposited from water solutions.

Triassic. The earliest geologic period within the Mesozoic era (Fig. 2); approximate age, 150,000,000-200,000,000 years.

Tuff. A rock consisting of small or fine-grained volcanic fragments.

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1. Prepare and publish bulletins and circulars containing authoritative information on a wide range of topics of interest to prospectors, miners, and others concerned with the development of Arizona's mineral resources and industries. The bulletins are distributed free of charge to residents and at cost to non-residents of Arizona upon request.

2. Classify mineral and rock specimens. Besides identifying rocks and giving the composition of minerals, the Bureau makes qualitative tests for important elements and answers inquiries concerning the probable market for and the economic value of material similar to samples submitted. This service is furnished free of charge providing the specimens originate within the State of Arizona; a charge of $1 per specimen is made for samples submitted from outside the State. When spectrographic analyses or detailed microscopic determinations are desired, they are furnished at established rates, a schedule of which will be submitted on request.

3. Conduct laboratory and pilot-plant metallurgical testing of mineral substances in cooperation with industries and individual mine operators in the State. Such tests are conducted on the basis of nominal charges to compensate for wear and depreciation of equipment needed in the experimentation.

4. Make geologic investigations of mining districts and counties and compile geologic maps and reports. Geologic maps of each county, on a scale of 1:375,000, have been issued. As a product that will result from the compilation of data for the county map issues, a new Geologic Map of the State, as a whole, will be established on a scale of 1:500,000.

5. Maintain a working file of statistical records of mineral production in Arizona.

6. Develop well-log storage facilities and a library of data pertaining to oil and water wells drilled in Arizona.

7. Conduct state-wide commodity studies as to modes of occurrence and potential industrial value of various mineral materials.

8. Collect and file items relating to Arizona mines and minerals that appear in Arizona newspapers and in many technical periodicals.

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