GEOLOGIC GUIDEBOOK 2 – HIGHWAYS OF ARIZONA
ARIZONA HIGHWAYS 77 AND 177

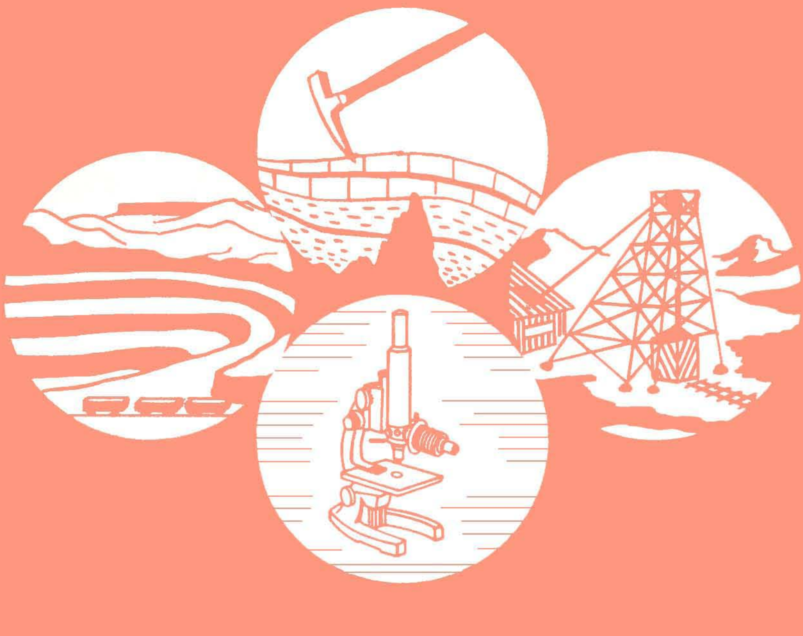
by

H. Wesley Peirce

THE ARIZONA BUREAU OF MINES

Bulletin 176

Reprinted 1975



THE UNIVERSITY OF ARIZONA

TUCSON

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FOREWORD

As one of its contributions for service about geologic matters and other related phenomena in Arizona, the Arizona Bureau of Mines is pleased to present this bulletin; titled GEOLOGIC GUIDEBOOK 2 — HIGHWAYS OF ARIZONA, by Dr. H. Wesley Peirce, Associate Geologist.

The work is issued as Bulletin 176 of the Arizona Bureau of Mines series and it is a comprehensive coverage of the routes of travel along Arizona Highways 77 and 177. It will be informative and useful to the general public of the State and to visitors who traverse these highways of Arizona.

J. D. Forrester, Director
Arizona Bureau of Mines

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

INTRODUCTION

Purpose and Scope

The kaleidoscopic nature of Arizona's scenery, climate, vegetation, water supply, wild life, and industry is due fundamentally to contrasting geologic circumstances. Highway travel provides an opportunity for the interested spectator to observe and to question. This road guide, emphasizing geologic and related observations, will assist travelers in developing an additional awareness and appreciation for a part of our natural environment.

The text, illustrations, and appendix are designed to accommodate varying degrees of interest ranging from those of the general reader to those of professional geologists desiring a brief account of the geologic framework of a portion of Arizona.

Location and Extent

State Highway 77 has its southern terminus at Oracle Junction located 21 miles north of Tucson on U.S. Highway 80–89. The northern terminus is on the Navajo Indian Reservation 60 miles north of Holbrook. The overall highway distance is about 272 miles (Fig. 1). Going north it passes through or near the towns of Oracle, Mammoth, Winkelman, Show Low, Taylor, Snowflake, Holbrook, and Bita Hoches. It traverses part of the San Pedro Valley, part of the canyon of the Gila River, crosses the Salt River in Salt River Canyon, passes into the pine forests of the Fort Apache Indian Reservation and over the Mogollon Rim into the Sitgreaves National Forest and then gradually descends the Mogollon Slope to the Little Colorado River at Holbrook. From Holbrook, State Highway 77 follows U.S. Highway 66 northeastward a short distance before turning north to enter the vast open spaces of the Navajo Indian Reservation. It terminates at its junction with Navajo-Hopi Route 3 (State 264).

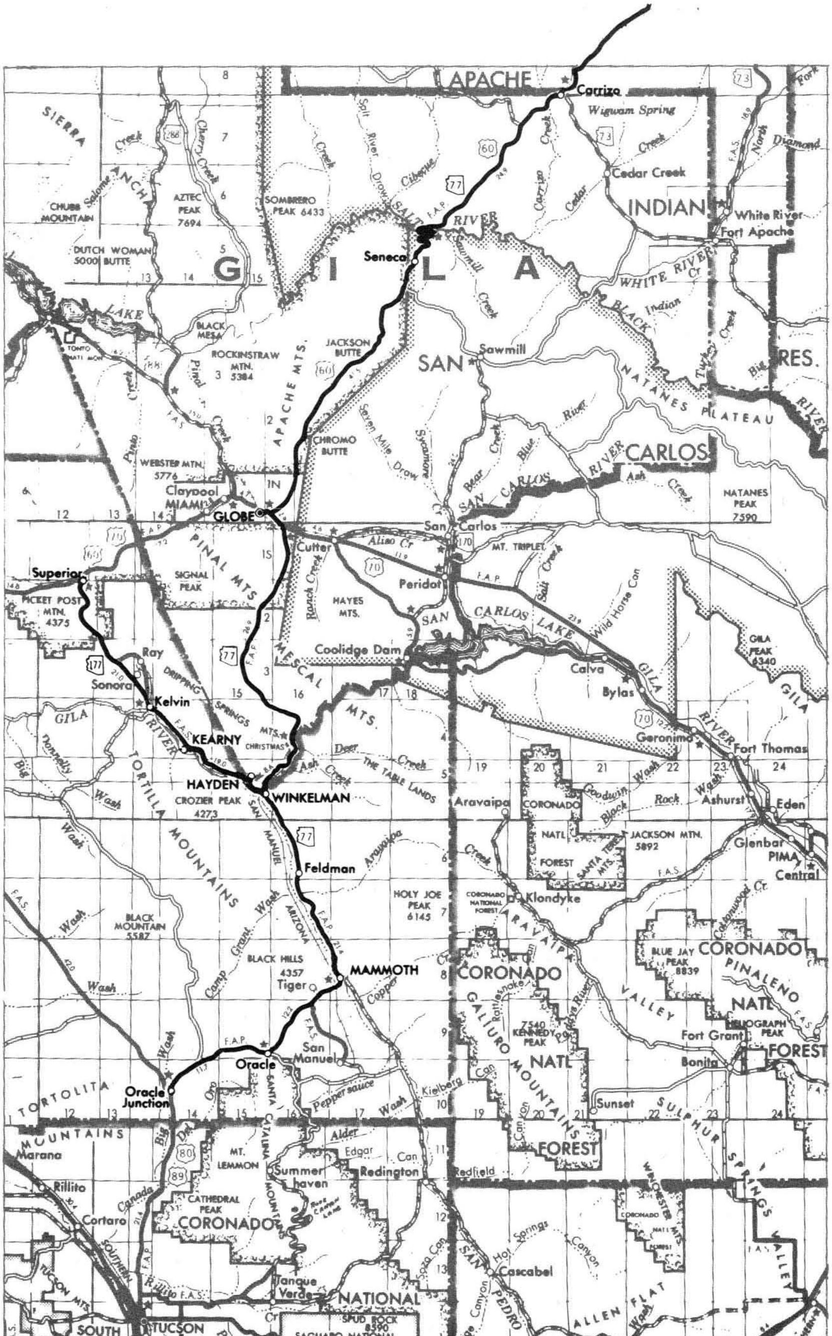

Figure 1–A. Index map showing the locations of Arizona Highway 177 and the southern portion of Arizona Highway 77.

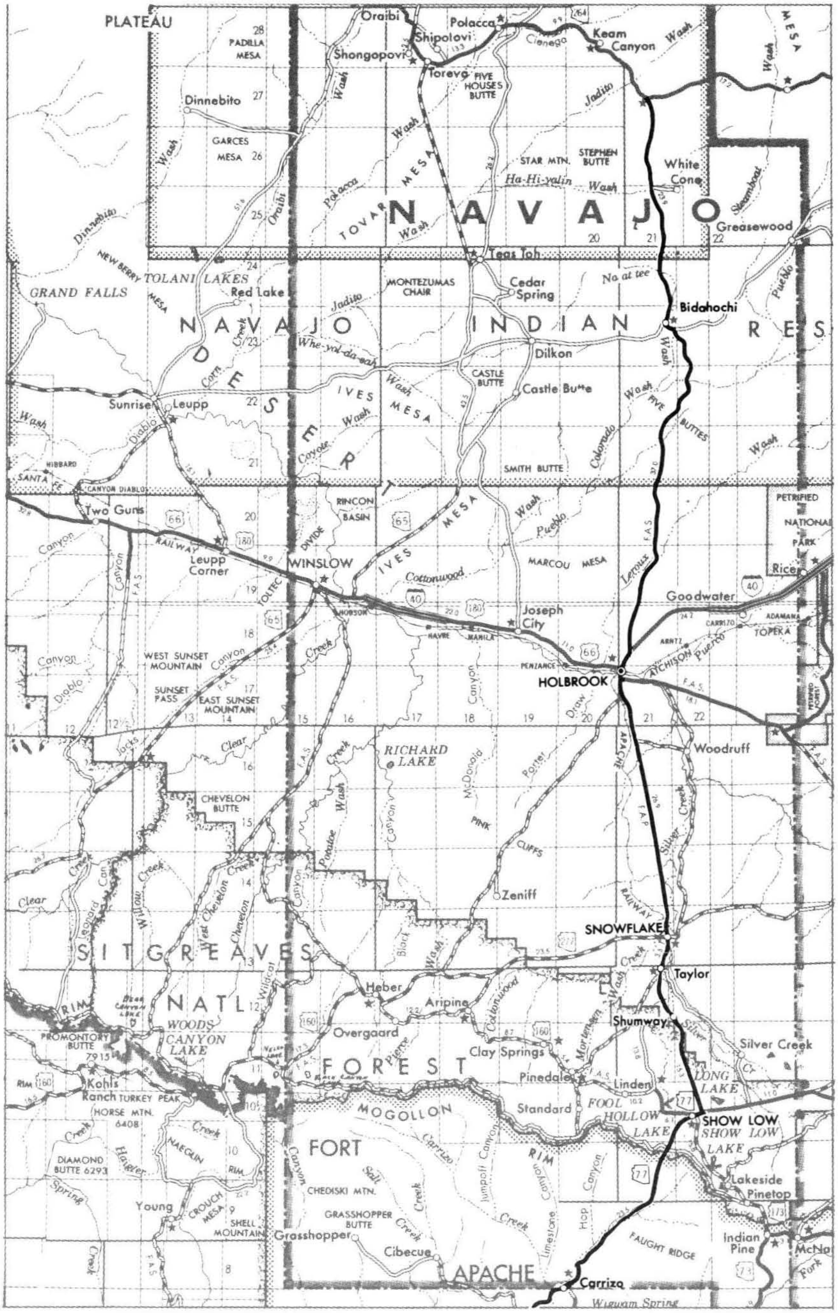

Figure 1–B. Index map showing the location of the northern portion of Arizona Highway 77.

State Highway 177, approximately 32 miles in length, junctions with U.S. Highway 60–70 to the north at Superior and to the south with State Highway 77 at Winkelman (Fig. 1). Going north the highway passes through or near the towns of Winkelman, Hayden, Kearny, and Kelvin in the valley of the Gila River. It ascends the west side of Mineral Creek Valley where the Kennecott Copper Corporation operates a large copper mine, crosses the northern end of the Tortilla Mountains, descends to lower country at the foot of the Apache Leap escarpment, and continues to its intersection with U.S. Highway 60–70 at Superior.

Although the accompanying road logs were recorded from south to north, they are arranged so that they can be read also from north to south.

Physiographic Setting

Arizona is divided into two, principal, physiographic provinces. The northeastern part of the State lies in the Plateau province, a portion of the larger Colorado Plateau province that also embraces parts of Utah, Colorado, and New Mexico. The southwestern part of Arizona belongs in the Basin and Range province that also embraces parts of Nevada, Utah, New Mexico, and California. The Basin and Range province in Arizona is further sub-divided into Mountain and Desert regions. The mountains in the Mountain region are noticeably longer and broader and the valleys longer and narrower than in the Desert region. Some general Arizona characteristics of these two provinces are listed in Figure 2. Although the two physiographic provinces are generally distinct, there is a problem in drawing a precise line of separation between them. With this in mind, Wilson and Moore (**1**)* introduced the concept of a "Transition Zone." This zone occupies the canyon country of central Arizona between the two major provinces (Fig. 2). The Mogollon Rim marks the southern edge of the Plateau province, is a major drainage divide, and is irregular in detail because of canyons that cut into it from the south. The southern boundary of the Transition Zone is less precisely defined but generally marks the northern limit of typical Basin and Range topography.

Although some of the geological characteristics of each of the two principal provinces have been listed (Fig. 2), it is interesting to inquire further into how these provinces might control certain socio-economic aspects of Arizona. Table 1 shows that over 90 per cent of each of the categories of population, value of mineral production, and agricultural acreage, is in the Basin and Range province, whereas, the principal scenic attractions, as measured by numbers of visitors, are in the Plateau province.

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

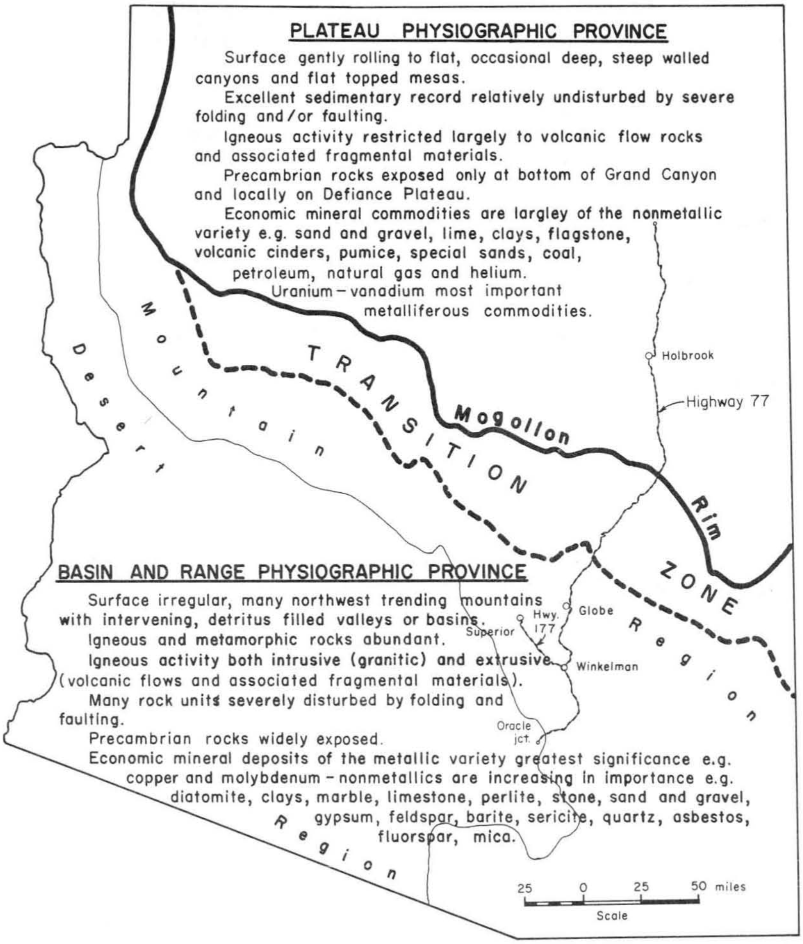

Figure 2. Physiographic subdivisions of Arizona.

The southern terminus of Highway 77 is approximately on the boundary between the Desert region to the southwest and the Mountain region to the northeast in the Basin and Range province (Fig. 2). The Transition Zone is entered north of Globe, and the Mogollon Rim is crossed at the north boundary of the Ft. Apache Indian Reservation, 5 miles south of Show Low. From this point to the northern terminus of Highway 77 the road is in the Plateau province. Highway 177 is confined to the Mountain region subdivision of the Basin and Range province (Fig. 2).

Altitudes along Highway 77 range from near 1928 feet at Winkelman on the Gila River to 6594 feet at the Mogollon Rim, a maximum relief of 5666 feet. Altitudes along Highway 177 range from the 1928 feet at Winkelman to about 3800 feet at the northern end of the Tortilla

Table 1. Some comparisons between the Plateau and Basin and Range portions of Arizona (**2**)

POPULATION (July 1966 estimate)		
		per cent
Plateau	132,000	8.0
Basin-Range	1,523,000	92.0
Total State	1,655,000	100.0
VALUE MINERAL PRODUCTION — 1964		
		per cent
Plateau	$ 13,855,348	2.6
Basin-Range	520,220,381	97.3
Undistributed	288,271	0.05
Total State	$534,364,000	99.95
AGRICULTURAL ACREAGE — 1965		
		per cent
Plateau	31,630 acres	2.7
Basin-Range	1,122,370 acres	97.3
Total State	1,154,000 acres	100.0
NUMBER OF VISITORS TO NATIONAL PARKS AND MONUMENTS IN ARIZONA (1965)		
		per cent
Plateau	3,692,700	80.00
Basin-Range (excluding Lake Mead)	897,000	20.00
Total	4,589,700	100.00
Lake Mead	3,594,100	
Total State	8,183,800	

Mountains, a relief of about 1870 feet. Topographic profiles of Highway 77 and 177 are shown in Figures 4 (fold out), and 5 respectively. The region as a whole is drained by the Gila and Little Colorado River systems, the Mogollon Rim being the divide between the two.

Climate

Because of the variable topographic aspects of Arizona, the climate is also widely variable. According to Smith (3) many climates found in other parts of the United States may be found here. Large areas on the Plateau have an average annual temperature betwen 20 and 25 degrees lower than those prevailing in some of the desert plains of the Basin and Range province. Annual precipitation in the Plateau country normally exceeds that on the southern deserts by 15 or 20 inches. Throughout the State, July and August are the rainiest months of the year (**4**).

Table 2. Climatic data for stations along or near Arizona State Highway 77 (**4**)

Station	*Altitude*	*Av. Ann'l Max. Temp.*	*Av. Ann'l Min. Temp.*	*Av. Pcpt. per year*	*Av. snow, sleet, hail per year*
Tucson	2410	82.9	51.6	10.91	0.9
Oracle	4450	74.8	49.3	19.35	11.6
Dudleyville	2120	80.4	48.5	14.74	1.1
Globe	3540	77.6	47.2	15.75	4.4
Cibecue	5300	72.6	36.3	18.61	19.9
Pinedale	6500	65.0	32.9	18.84	47.5
Snowflake	5644	69.6	33.4	12.25	19.8
Holbrook	5069	71.9	37.8	8.64	9.9

Table 2 presents some basic climatic data for weather stations in the vicinity of Highway 77. It might be noted that Cibecue, situated south of the high area of the Mogollon Rim, and Holbrook, situated to the north of the Rim, contrast markedly in average annual precipitation, even though there is little difference in elevations. Moisture being carried by southwest winds is precipitated in the higher country to the south leaving Holbrook in a rain shadow.

Vegetation

The native vegetation in Arizona varies as influenced by climate, topography, soil, bed rock, and man. The lower regions support various combinations of grasses, cacti, mesquite, palo verde, creosote bush, and yucca; the intermediate regions support various grasses, some cacti, oaks, pinyons, junipers, and chapparal; and the higher elevations are characterized by evergreens, especially the ponderosa pine. For details, the reader is referred to the literature (**5;6;7**). The distribution of the principal vegetation types along Highway 77 is shown in Figure 4. Vegetation along Highway 177 is of the desert type characteristic of the lower regions.

Water Supply

Water used by man is stored either on the earth's surface or underground. Circumstances that control the distribution and habit of water in Arizona are directly affected by the geological environment. There is very little surface water in the Basin and Range province. Domestic water is supplied largely by wells drilled into the sediments that fill the valleys or basins. Intermittent surface water is trapped in small earth tanks for stock use. With the exception of the Colorado River, most of the perennial streams in Arizona are fed by precipitation associated with the higher elevations in the central and east-central parts of the State.

Animals

The wide variations that exist in climate, physiography and vegetation create many habitats and the fauna of Arizona is very diversified. Table 3 shows the numbers of animals belonging to certain groups.

Table 3. Animals found in Arizona (8)

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

Industries in the vicinity of Highway 77 include mining, stock raising, some agriculture, forest products, and tourism. The copper industry, involving the mining, milling, and smelting of copper ores, is monetarily the most significant. Cattle and other livestock are grown throughout much of the region; agriculture is not extensively developed but is carried on in portions of the valleys and locally on the Plateau. Lumber is produced from the forests in the vicinity of the Mogollon Rim and a pulp and paper plant in in operation west of Snowflake (9). Recreational opportunities are numerous and varied and they include hunting (quail, doves, ducks, geese, wild turkey, mule and whitetail deer, elk, javelina, bear, and numerous small game such as squirrels & rabbits), fishing (warm and cold water species), camping, and rock and mineral collecting. With the contrasts in climatic zones, it is possible to pursue varying recreational activities throughout the year.

Along Highway 177 the copper industry, consisting of the mining, milling and smelting of copper ores, is of principal importance. Agriculture is only locally developed and some livestock is grazed. Recreational opportunities are those naturally afforded by the environment such as hunting (quail, doves, deer, javelina, and small game animals), fishing for certain warm water species in the Gila River, camping, and rock and mineral collecting.

Geology

Geological history is subdivided into increments of varying magnitudes of time analogous to subdivisions of a book, e.g., chapter, paragraph, and sentence. Such subdivisions are not arbitrary, but instead coincide with well-defined geological events. Detailed studies of rock units over a wide area lead to the establishment of a framework within which events can be properly related.

Details of the geology to be seen are cited in the Detailed Logs. Supplementary materials in the form of photographs, tables, figures, and an appendix are included to facilitate orientation and general understanding.

Figure 3 is an attempt to summarize Arizona's geological highlights in relation to a generally accepted world-wide time scale. Tables 4 and 5 summarize geological names of principal rock units encountered along State Highways 177 and 77, respectively. Figure 4, on the other hand, is designed to offer a visual picture of the general geologic framework as it exists along and below State Highway 77.

Rocks encountered along these two highways include the three basic types — igneous, sedimentary, and metamorphic — with rock ages thought to range in excess of one billion years. Liberal use of the figures provided should help to place observations given in the Detailed Logs into a more meaningful, relative, time-event perspective.

For additional information regarding the geology of Arizona, reference may be made to the maps listed in the appendix and to the literature (**10**; **11**; **12**; **13**).

Acknowledgements

This bulletin results from the cooperative efforts of members of the Arizona Bureau of Mines professional staff. Additional appreciation is extended to Mrs. Claudia Fisher, Stenographer, and to Mr. Joseph LaVoie, Draftsman and field assistant. Special help was given on State Highway 177 by Robert Metz, Geologist, Ray Mines Division, Kennecott Copper Corporation.

Suggestions for using the Detailed Logs

At a starting point it is desirable to have the odometer on a whole mile without any tenths. This can be accomplished by a little extra driving. From the starting point a ten-mile or so test will indicate the magnitude of discrepancy between the mileage cited and that indicated on another recording device. The correction factor thus established, if significant, can either be carried mentally or used to recalculate the mileages in the Detailed Log. On occasion orientation will be lost, but certain easily observed features such as side roads and mile posts serve as re-orientation points.

Eras	Periods and Epochs	Age-millions of years	Geological Highlights of Arizona		
Cenozoic	Quaternary — Recent	.011	Alluvial sediments; Volcanics.	Volcanism and minor faulting	Development of Man.
Cenozoic	Quaternary — Pleistocene	1	Stream, river, and lake deposits; Volcanics; Glaciation on San Francisco Peaks near Flagstaff and in White Mountains.		
Cenozoic	Tertiary — Pliocene	12	Accumulation of up to several thousands of feet of non-marine sediments that include salt deposits in NW. Arizona; Volcanics.		Rise of Mammals.
Cenozoic	Tertiary — Miocene	23	S. Ariz.— Sediments and Volcanics.	Plateau uplift Volcanism Basin and Range orogeny	
Cenozoic	Tertiary — Oligocene		S. Ariz.— Locally several thousands of feet of non-marine sediments.	Local erosion and sedimentation	
Cenozoic	Tertiary — Eocene			Laramide Revolution: Folding and Faulting. Granitic intrusions. Volcanism. Widespread mineralization.	
Cenozoic	Tertiary — Paleocene	70	Unconformity		
Mesozoic	Cretaceous	135	N. Ariz.— 2,000 feet marine and non-marine sediments containing important coal beds. S. Ariz.—15,000 feet of continental and marine sediments; Volcanic rocks; Granitic rocks.		Age of Dinosaurs.
Mesozoic	Jurassic	180	N. Ariz.—2,000 feet largely non-marine sediments. S. Ariz.— Igneous activity.	Nevadan Revolution: Granitic intrusions. Volcanic activity. Some mineralization.	
Mesozoic	Triassic	220	N. Ariz.— 1,500 feet non-marine sediments, some of which give rise to the Painted Desert and Petrified Forest National Park. S. Ariz.— Probable igneous activity.		
Paleozoic	Permian	270	N. Ariz.— 2,000-3,000 feet marine and non-marine sediments. Includes significant salt and gypsum. A source of helium and flagstone. S. Ariz.— 2,000-3,000 feet marine sediments. Some gypsum.	General Uplift.	Abundant Sea Life.
Paleozoic	Pennsylvanian	320	Up to 2,500 feet marine sediments. Some oil produced in NE. Arizona.		
Paleozoic	Mississippian	350	Up to 1,000 feet marine sediments. Some oil produced in NE. Arizona. Widely used in manufacture of portland cement and lime.	Uplift in central Arizona.	
Paleozoic	Devonian	400	Up to 1,000 feet marine sediments. Some oil produced in NE. Arizona.		
Paleozoic	Silurian		Not known in Arizona.	General Emergence.	
Paleozoic	Ordovician	490	Marine sediments in extreme NW. and SE. corners of Arizona.		
Paleozoic	Cambrian	600	Up to 2,000 feet marine sediments.	First record of abundant life.	
			Unconformity		
Younger Precambrian		1600	1,200 feet sediments forming the Apache Group of central Arizona and the Grand Canyon Series of N. Arizona. Both sequences are intruded by diabase. Asbestos developed by local metamorphism. Faulted and folded but not severely metamorphosed.	Grand Canyon disturbance.	Primitive Plant Life.
			Unconformity		
Older Precambrian		2000 +	Several thousands of feet of metamorphosed sediments and volcanics intruded by granite. Severely faulted and folded. Local mineralization e.g. Jerome.	Mazatzal Revolution.	

Figure 3. Geologic time scale.

Table 4. Ages and geologic names of rock units along State Highway 177

AGES	ROCK REPRESENTATIVES
CENOZOIC	
Quaternary	Not named sands, silts, clays and gravels
Tertiary	Not named sedimentary and local volcanic units; Dacite; Whitetail Conglomerate; Granite Mountain porphyry
MESOZOIC	
Cretaceous	Not recognized
Jurassic	Not recognized
Triassic	Not recognized
PALEOZOIC	
Permian	Not present
Pennsylvanian	Naco Limestone
Mississippian	Escabrosa Limestone
Devonian	Martin Formation
Silurian	Not present
Ordovician	Not present
Cambrian	Not encountered
PRECAMBRIAN	
Younger	Diabase; Troy Quartzite; Apache Group: Mescal Limestone, Dripping Spring Quartzite, Barnes Conglomerate, Pioneer Shale
Older	Not named granitic rocks; Pinal Schist

Table 5. Ages and geologic names of rock units encountered along State Highway 77

AGES	ROCK REPRESENTATIVES
CENOZOIC	
Quaternary	Not named sands, silts, clays, gravels and volcanics
Tertiary	Not named sedimentary and volcanic rocks; Dacite; Andesite; Bidahochi Formation; Not named high elevation gravels
MESOZOIC	
Cretaceous	Not named sedimentary rocks and, locally, volcanic rocks
Jurassic	Not present
Triassic	Wingate Sandstone; Chinle Formation; Moenkopi Formation
PALEOZOIC	
Permian	Kaibab Formation; Coconino Sandstone; Supai Formation
Pennsylvanian	Possibly basal Supai Formation; Naco Limestone
Mississippian	Redwall Limestone and Escabrosa Limestone
Devonian	Martin Formation
Silurian	None
Ordovician	None
Cambrian	Bolsa Quartzite
PRECAMBRIAN	
Younger	Diabase; Troy Quartzite; Apache Group: Mescal Limestone, Dripping Spring Quartzite, Barnes Conglomerate, Pioneer Shale
Older	Granitic rocks locally named, e.g., Oracle Granite; Pinal Schist

Plate 1. Typical mile post sign west of Oracle. These are used in the Detailed Log to help provide specific orientation of position. Looking west toward the Tortolita Mountains.

DETAILED LOG

Arizona Highway 77

This log, although recorded in a south to north direction, that is, from Oracle Junction to the Navajo Reservation, is designed to be used equally well from the Navajo Reservation to Oracle Junction.

Mileage for the northbound trip is given in the left hand margin as a cumulative mileage from the point of beginning to the point being discussed (Total). The Mileage Interval between each point of discussion is recorded in the center of the page.

Cumulative mileage for the southbound trip is tabulated in the right-hand margin, for which the user should start at the end of the log and read upward.

MILES NORTHWARD Total | Mileage Intervals | **MILES SOUTHWARD Total**

0.0

0.0 Oracle Junction. Elevation 3308 feet. Junction of State Highway 77 with U.S. Highway 80–89. This is the southern terminus of Highway 77. **272.4**

0.9

0.9 On the south side of the road is a water tank that is a part of the water supply system of the town of Oracle, located ten miles to the east on granitic rock. All domestic water in this southern region of Arizona is pumped from wells drilled into water-bearing sands and gravels that fill the valleys between the mountains. **271.5**

Numerous washes flow from the mountain fronts into a main drainage that occupies an axial position in most valleys. Some runoff penetrates the sandy wash bottoms and sinks downward to recharge water-bearing materials or zones beneath the valley floors. The overall potential of a valley to supply water is a function of many interrelated geologic factors, the gathering and evaluation of which require considerable effort.

Local vegetation is composed largely of mesquite, cholla, prickly pear, and yucca with small desert shrubs and grasses.

2.9

3.8 On the north side of the road is a missile site, one of eighteen such built in the Tucson region by the Federal Government. **268.6**

The highway is traversing an erosional slope developed on the relatively unconsolidated Cenozoic sediments that occupy the valley.

To the west are the Tortolita Mountains, consisting largely of granitic rocks as does Black Mountain to the north. To the east and southeast are the geologically complex Santa Catalina Mountains, one of the largest ranges in the Basin and Range province. The highest point, Mt. Lemmon, reaches an elevation of 9,157 feet. On a clear day the white domes of an Air Force radar facility mark the summit. The sharp relief of about 5800 feet on the west face of the mountain was caused, fundamentally, by movement along a northeast-to-north trending fault at the base of the mountain.

The Santa Catalina Mountains provide popular summer and winter recreational conditions.

1.1

4.9 Willow Springs Ranch road to the north. **267.5**

0.7

5.6 Little Hills Mine road to the south. Fluxing ore (copper with high silica content) from the Little Hills Mine has been shipped to one of the Hayden smelters. **266.8**

2.5

8.1 Rancho Linda Vista road to the south. **264.3**

0.9

9.0 Typical mile post sign. Mile post 100 (Plate 1) represents the road distance from the Mexican border. Western edge of exposures of Precambrian Oracle Granite at the north end of the Santa Catalina Mountain rock complex. The Cenozoic sediments lap up against the granite. It is customary to give geographic names to important rock units; thus, this granite was named "Oracle" from the town of Oracle just to the east. This granite has been dated at about 1450 million years. **263.4**

2.3

11.3 Oracle, Arizona. Elevation 4500 feet. Founded in 1873, post office established in 1880. Oracle, situated approximately on the divide that separates drainage to the San Pedro River from drainage to the Santa Cruz River, owes its name to a ship in which a local mining man traveled around Cape Horn enroute to the western United States (14). The town has served as a half-way point between various mining camps and Tucson. A relatively mild climate attracts residents. **261.1**

0.3

11.6 Side road to the south (paved only a short distance) leads to the summit of the Santa Catalina Mountains via the Peppersauce Canyon picnic area. **260.8**

0.7

12.3 Western edge of the San Pedro Valley. Road cuts expose Precambrian Oracle Granite. The Galliuro Mountains, composed largely **260.1**

of Tertiary volcanic rocks, are in the distance to the east. The valley is an excellent example of a basin in the Basin and Range province.

1.8

14.1 The contact zone between Precambrian Oracle Granite and Cenozoic sedimentary rocks occupying the San Pedro Valley between the mountain blocks lies between mile posts 105 and 106. The immediate presence of granite is reflected in the high percentage of granite fragments in the gravels. This relationship shows that the granite is older than the sediments. (Plate 2). **258.3**

1.7

15.8 Mile post 107. To the southeast is the smelter and mill area of the San Manuel Division of the Magma Copper Company. The Galliuro Mountains are well displayed along the east side of the valley. **256.6**

1.5

17.3 Head frames to the north are above shafts that service the San Manuel Mine, one of the largest underground block caving mines in the world. This mine is in the Mammoth Mining District. For a discussion of the geology of the San Manuel ore body, the reader is referred to the literature (**15**). **255.1**

Plate 2. Bedded Cenozoic gravels between mile posts 105 and 106 containing an abundance of Precambrian granitic rock. Looking northwest.

MAMMOTH MINING DISTRICT

The Mammoth Mining District includes principally the currently inactive mines of the Mammoth Mining Camp located three miles southwest of the present town of Mammoth, and the San Manuel Mine operated by the Magma Copper Company. Production history goes back to 1881 at which time gold stimulated mining activity in the district. In later years, ores containing gold, silver, lead, zinc, molybdenum, vanadium, and copper were mined. Copper production was initiated at the San Manuel Mine in 1956 with by-products consisting of molybdenum, gold, and silver.

Approximate recorded quantities and values of constituents produced from this district are shown below:

	Production		*Value*
MAMMOTH MINING CAMP (1881–1952)			
Copper	6,605,610 pounds		$ 1,237,094
Gold	369,192 ounces		10,478,901
Silver	1,165,093 ounces		955,656
Lead	118,847,056 pounds		13,997,119
Zinc	77,011,100 pounds		10,194,256
Vanadium	Not available		
		TOTAL	$ 36,863,026
SAN MANUEL MINE (1956–1964)			
Copper	1,299,037,900 pounds		$408,541,048
Gold (1956 & '57 only)	23,313 ounces		815,955
Silver (1956 & '57 only)	337,459 ounces		305,417
Molybdenum	Not available		
		TOTAL	$409,662,420
		DISTRICT TOTAL	$446,525,446

0.5

17.8 Side roads to the San Manuel Mine to the north, and the San Manuel smelter, mill, and townsite to the south. **254.6**

1.2

19.0 On the south side, steeply-tilted gravels reflect deformation. These Cenozoic gravels cover the ore body of the San Manuel Mine. **253.4**

0.4

19.4 On the north side, there is a fault contact between granite and gravels, thus proving that these gravels have been involved in structural disturbance. **253.0**

0.4

19.8 Younger gravels that are flat-lying, gray, and fine-grained. **252.6**

0.8

20.6 The east side of the San Pedro Valley contains excellent exposures of intricately eroded, fine-grained sediments of Pliocene-Pleistocene age. Diatomaceous earth and gypsum deposits are locally associated with these quiet, lake water deposits. **251.8**

0.5

21.1 Railroad crossing for the industrial railroad serving the San Manuel mining operation. It connects with the Southern Pacific at Winkelman, Arizona. Younger sediments are present nearer the center of the valley. There are many sedimentary units along the valley axis **251.3**

that record some of the more recent depositional history of the San Pedro River.

1.5

22.6 Dense mesquite along the valley floor to the east. **249.8**

1.0

23.6 Mammoth, Arizona. Elevation 2353 feet. Post office established in 1887. Named from Mammoth Mine, a gold mine located about 3 miles southwest of town. The Mammoth claim was first located in 1882. In 1885, a mill for recovery of gold was erected at the future town site on the west bank of the San Pedro River. A cable and bucket tramway brought ore to the mill and carried water on the return trip (**14**). **248.8**

0.2

23.8 To the west a cliff face exposes an erosional unconformity (see glossary) between two Cenozoic sedimentary units. **248.6**

0.7

24.5 Bridge over north-flowing San Pedro River. The San Pedro River heads in Mexico over one hundred miles to the south and flows northward to its confluence with the Gila River about twenty miles to the north, near Winkelman. **247.9**

0.3

24.8 The proximity of water to the ground surface supports a dense growth of mesquite trees. **247.6**

0.3

25.1 The side road along the east side of the San Pedro Valley continues to Benson to the south. **247.3**

2.1

27.2 Local agricultural development along the San Pedro River (Plate 3). Cotton is the principal crop. **245.2**

0.7

27.9 Bridge. **244.5**

1.4

29.3 Side road to the west. **243.1**

0.4

29.7 Mile post 121. **242.7**

0.5

30.2 Side road to the east. For several miles in both directions highway cuts afford exposures of Cenozoic sediments associated with the more recent drainage history of the valley. The contrast in the grain sizes of the various strata is a notable feature. The coarser gravels represent deposition in comparatively fast-moving water, whereas the finer sediments were deposited in less vigorous, stream-related environments. **242.2**

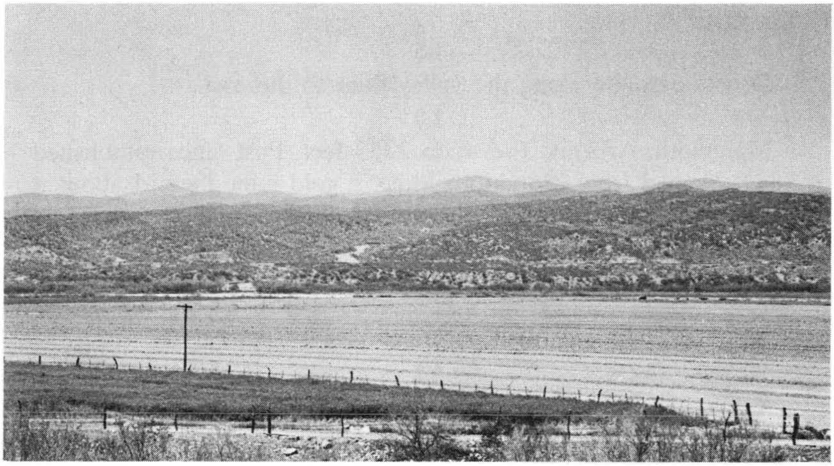

Plate 3. Local agricultural development on bottom land of the San Pedro River. The Black Hills are in the distant background. Looking southwest.

2.0

32.2 Bridge over Aravaipa Creek. To the west, across the San Pedro River are exposures of steeply-tilted sedimentary rocks belonging to the Younger Precambrian Apache Group and to the lower Paleozoic formations. Quarry operations are conducted by the San Manuel Division of the Magma Copper Company. Both quartzite (high silica) and limestone (high lime) are quarried and shipped by railroad for use in their milling and smelting operations, located to the south (**16**). **240.2**

0.6

32.8 To the east is the Aravaipa Canyon Road. Road cuts are in Quaternary sediments. **239.6**

1.3

34.1 Saguaro cactus. These tall cacti grow exclusively in Arizona. **238.3**

0.3

34.4 Side road to the east leads to the mine plant of the Arizona Gypsum Corporation. **238.0**

0.4

34.8 On the east is a side road to the National Gypsum Company mining operations. **237.6**

Gypsum (calcium sulfate with water) occurs as beds or layers in the Cenozoic sedimentary units that were deposited in lakes subjected to evaporation. Gypsum is used as a retarder in portland cement, as a soil conditioner for certain soils, and in the manufacturing of wallboard and lath in Phoenix. It is trucked to a railroad siding at Winkelman.

1.5

36.3 Side road. **236.1**

1.2

37.5 The hill to the west across the San Pedro River is composed of Tertiary volcanic rock. **234.9**

0.2

37.7 Mile post 129. **234.7**

1.3

39.0 Bridge. **233.4**

1.1

40.1 To the west, Tertiary andesitic volcanic rocks occur which are similar to those that make up the northern half of the Galliuro Mountains to the east. **232.3**

0.5 **231.8**

40.6 To the west, the Tortilla Mountains are composed of Precambrian rocks. Saddle Mountain, capped by volcanic rocks, is prominent in the distance to the east.

0.4

41.0 Bridge. **231.4**

1.2

42.2 Fine-grained and coarse-grained Cenozoic sediments in road cuts. **230.2**

1.1

43.3 Bridge over west-flowing Gila River. Boundary between Pinal County to the south and Gila County to the north. **229.1**

0.2

43.5 Junction of Highway 177 to Superior. **228.9**

For the Detailed Log of Highway 177, between Winkelman and Superior, please turn to page 55.

0.9

44.4 The three stacks to the northwest are associated with two copper smelters at Hayden. The Kennecott Copper Corporation facilities are used to treat the copper ore mined at Ray about 19 miles to the north. **228.0**

The American Smelting and Refining Company treats copper concentrates from several copper mines in southern Arizona.

The black material in the foreground is slag, the waste material from smelting operations.

0.1

44.5 A quarry on the north side of the road is developed in the Naco Limestone of Pennsylvanian age. Certain zones are very fossiliferous. These Paleozoic limestone exposures occur at the southern end of the Dripping Spring Mountains where the Gila River has cut its gorge. **227.9**

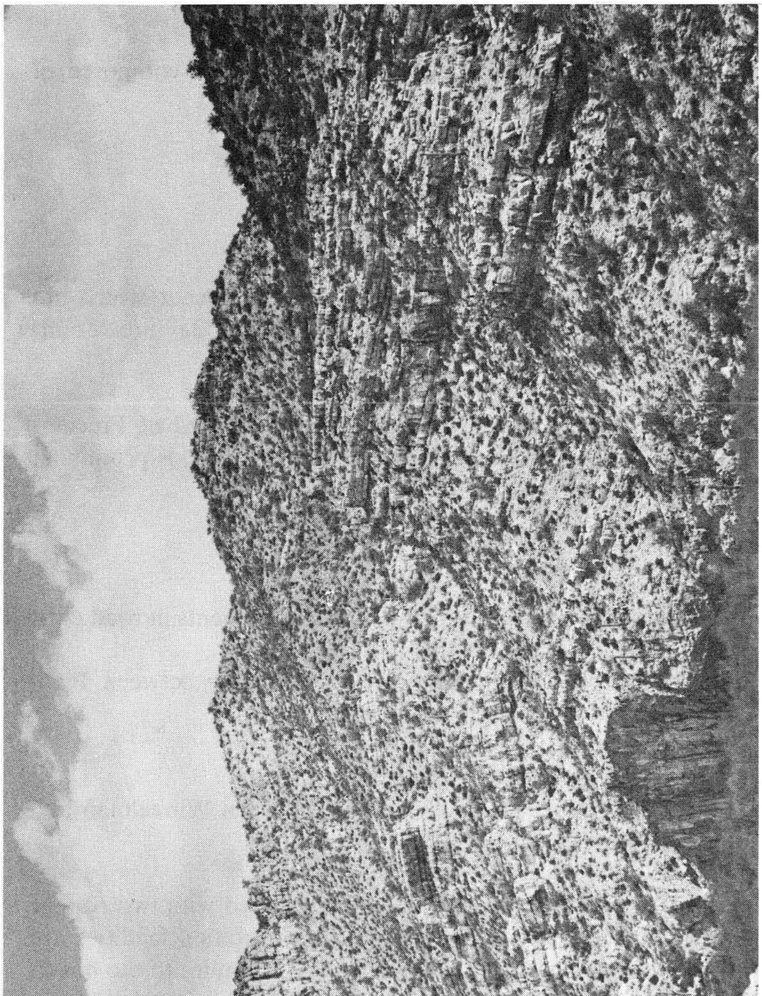

Plate 4. Anticlinal fold (arch-like) in strata of the Pennsylvanian Naco Limestone, Gila River Canyon. Looking east.

0.7

45.2 An anticlinal fold, forming an arch, is on the south wall of the canyon (Plate 4). Smaller folds and some faulting can be seen, also. 227.2

0.3

45.5 To the south, vertically dipping beds of Naco Limestone. 226.9

0.3

45.8 Contact of light-colored carbonate rocks of the Paleozoic Naco Limestone with a dark-colored volcanic rock complex of Cretaceous age. Although these andesitic volcanics directly overlie Paleozoic rocks at this point, further to the east Cretaceous sediments occupy a position between the Paleozoic limestones and the andesitic complex. This establishes the age of the volcanics as being no older than Cretaceous. 226.6

The reason for the absence of the Cretaceous sediments in this area involves two major possibilities: They were not deposited here, or they were deposited here but were eroded away prior to the accumulation of the volcanics. A conglomerate at the base of the volcanics in some areas proves that some erosion did take place before their accumulation. In the Deer Creek area to the east the andesitic volcanics are reported to be about 1000 feet thick (17).

1.0

46.8 The water in the Gila River is regulated to supply irrigation water for projects to the west. 225.6

0.4

47.2 Gravel deposits along the Gila River drainage system. 225.2

2.9

50.1 Gravels deposited during an earlier phase of the development of the canyon of the Gila River are plastered against older rocks above the present river level. 222.3

0.2

50.3 To the north is a road to copper mining operations conducted by the Christmas Mine Division of the Inspiration Consolidated Copper Company. 222.1

1.1

51.4 The light-colored rock is diorite, an intrusive igneous rock of Laramide age. Related intrusives seem to be closely associated with the mineralization of this region. This rock intrudes the volcanics and older rocks seen to the west along the highway. 221.0

0.4

51.8 To the north, side road to the Christmas Mine. 220.6

0.5

52.3 Tertiary-Quaternary coarse sediments (gravels) exposed at the southern end of Dripping Spring Valley. 220.1

0.7

53.0 Bridge over Dripping Spring Wash. 219.4

0.7

53.7 Christmas Mine area, one mile to the west. 218.7

0.6

54.3 A few saguaro cacti. 218.1

1.0

55.3 Green palo verde trees and cholla (jumping) cacti are prominent. 217.1

2.4

57.7 Dripping Spring Mountains are to the west and the Mescal Mountains are to the east. This is a good example of two northwest-trending ranges with a similarly trending valley (basin) in between. The basin or valley contains Tertiary-Quaternary sediments that thin and coarsen toward the mountain fronts while becoming finer and thicker nearer the valley axis. 214.7

The beautiful pattern exhibited on the west flank of the Mescal Mountains to the east is that developed through erosion of the southwest-dipping (tilted) bedded carbonate units belonging to the Paleozoic formations, especially the Naco Limestone of Pennsylvanian age.

0.2

57.9 Road cuts expose fine-grained Tertiary sediments. Certain zones are very firmly cemented and form resistant ledges. 214.5

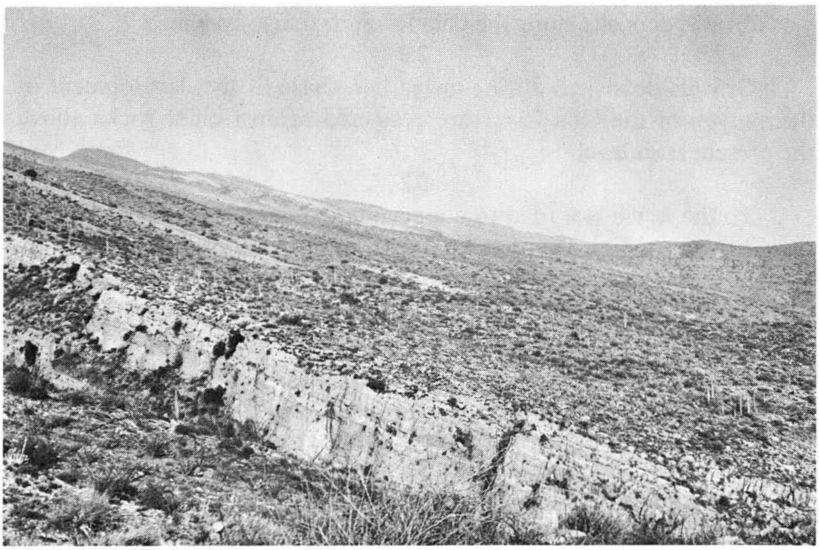

Plate 5. View looking south along the west slope of the Mescal Mountains. Paleozoic limestone strata have been tilted to the west.

1.2

59.1 Base of the grade that ascends the west slope of the Mescal Mountains. Side road to the west. **213.3**

1.2

60.3 Tertiary-Quaternary valley fill sediments coarsen toward the source area of the Mescal Mountains. **212.1**

0.9

61.2 Contact area between the valley fill deposits and the Paleozoic sedimentary rocks. The latter are tilted about 20 degrees toward the southwest (Plate 5). The Dripping Spring Mountains form the skyline to the west. **211.2**

0.3

61.5 Mile post 156 — Paleozoic limestones. **210.9**

0.3

61.8 High erosional remnant of coarse gravels. Much of the mountain was once covered by these gravels and subsequently removed by erosion. **210.6**

0.1

61.9 To the south, lower Paleozoic formations are well exposed. The Cambrian Bolsa Quartzite forms a dip slope ledge 100 yards to the south. The distant slope is on the Devonian Martin Formation. The high cliff is formed by the Mississippian Escabrosa Limestone (Plate 6). **210.5**

0.3

62.2 Mescal Limestone, a formation within the Younger Precambrian Apache Group. The Apache Group underlies the Paleozoic formations. A dark, igneous rock of Precambrian age, diabase, intrudes the various components of the Apache Group. **210.2**

0.3

62.5 Road cuts expose portions of the tannish Dripping Spring Quartzite, purplish Pioneer Shale, and diabase. **209.9**

0.7

63.2 Diabase. **209.2**

0.3

63.5 To the east, above the house, and in the upper half of the hill, there is a ledge of Barnes Conglomerate that underlies the Dripping Spring Quartzite and overlies the darker Pioneer Shale. This conglomerate is an excellent "marker" unit. It is not thick, but it persists over an extensive region in Arizona. In faulted areas, its distinctiveness serves to provide geological orientation. (See Plate 7). **208.9**

0.3

63.8 North side road cut, Barnes Conglomerate. **208.6**

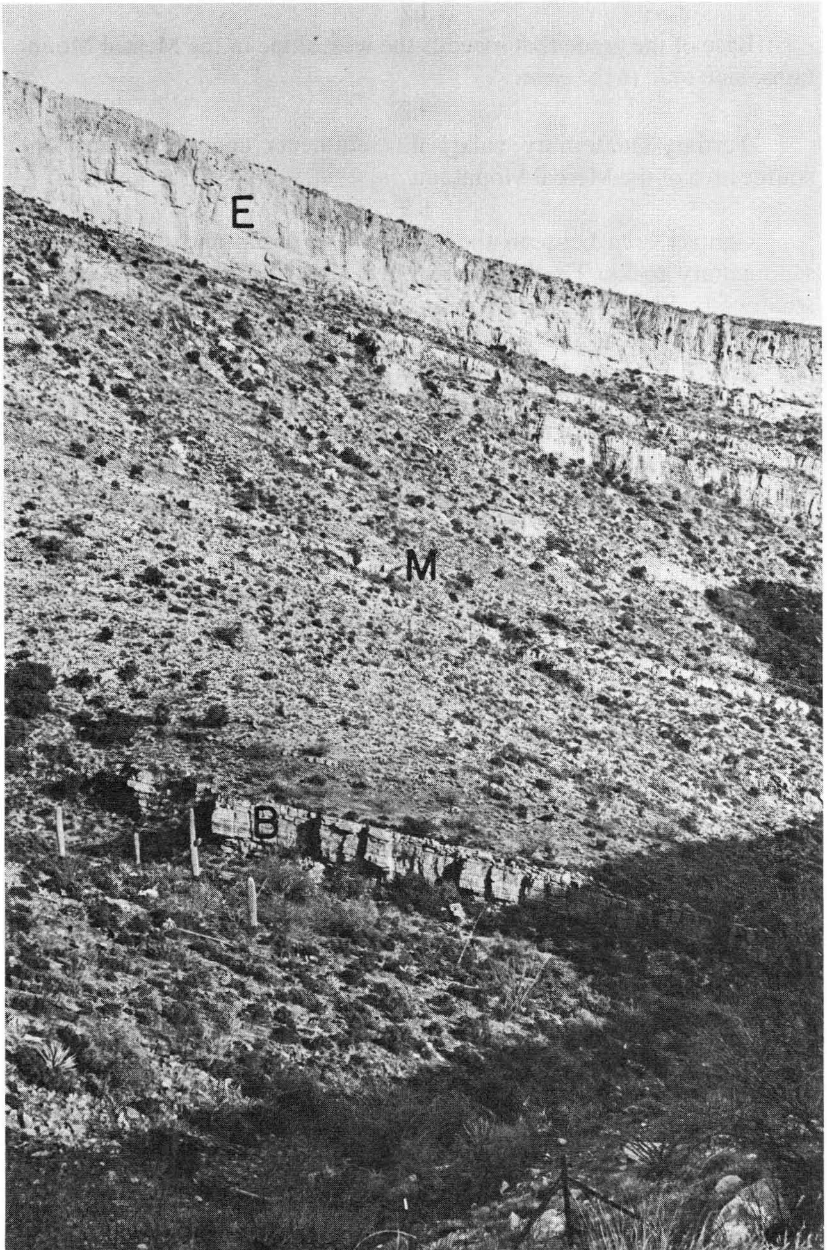

Plate 6. Excellent section of lower Paleozoic strata including the Cambrian Bolsa Quartzite (B), Devonian Martin Formation (M — slope maker), and Mississippian Escabrosa Limestone (E — cliff maker). Mescal Mountains looking south.

Plate 7. Close-up of rounded pebbles in the Precambrian Barnes Conglomerate, an important marker unit. Looking west.

0.6

64.4 Cuts expose Dripping Spring Quartzite. **208.0**

0.5

64.9 The local oak woodland vegetation is developed on weathered granitic rock. The setting, both vegetational and geological, is similar to that at Oracle, Arizona, further to the south on Highway 77. **207.5**

1.1

66.0 Granite, Older Precambrian in age, and upon which the Younger Precambrian Apache Group of sedimentary rocks was deposited. **206.4**

Van Winkle road is to the east.

0.5

66.5 Historical marker and picnic table to the east. El Capitan Pass, used in 1846 by Kearny's army during the march to California. Kit Carson was a guide on this expedition. Road cuts in Older Precambrian granite. **205.9**

1.3

67.8 Summit elevation is 4983 feet. The Pinal Mountains are to the northwest and the Mescal Mountains are to the southeast. The higher elevations are in the Pinal Mountains with Pinal Peak the highest point (7850 feet, note signal towers). The latter mountains are composed largely of Older Precambrian granite and Pinal Schist, whereas the Mescals are composed of the Younger Precambrian Apache Group sedimentary rocks and Paleozoic sedimentary rocks. **204.6**

0.1

67.9 Pull out point for view. Road cut to the north exposes weathered granite with a gravel gap. El Capitan Mountain is in the distance to the south with the Hayes Mountains to the east. The valley to the northeast contains drainage network of the Gila River system. The Gila River and Coolidge Dam are about 15 miles to the southeast. Most of the country that can be seen to the east and northeast in the distance is part of the San Carlos Indian Reservation (Apache). **204.5**

2.3

70.2 Occasional exposure of bluish schist. Schist, a metamorphic rock, is extensively exposed in the Pinal Mountains, the type area for the older Precambrian Pinal Schist. This schist has been dated at approximately 1600 million years (**18**). **202.2**

1.3

71.5 Mile post 166. **200.9**

0.4

71.9 Bluish schist in west road cut. **200.5**

0.6

72.5 Contact area of Tertiary-Quaternary sediments with the granite. **199.9**

The abundance of granitic fragments in the gravel reflects the proximity of the granitic mass and the fact that the gravels are younger than the granite. Gravels occupy the valleys to the north and east. The gentle surfaces sloping away from the mountains are formed upon these Cenozioc sediments.

3.0

75.5 Mile post 170. **196.9**

0.9

76.4 Junction of State Highway 77 with U.S. Highway 70. Northbound traffic turns left to the west for continuation of Highway 77. Two asbestos mills are located on the north side of the highway, and one is on the south. Asbestos is mined largely in the Salt River Canyon area and trucked to these mills near the railroad. **196.0**

0.4

76.8 Underpass — Southern Pacific Railroad. **195.6**

1.6

78.4 Junction of U.S. Highway 60-70 with State Highway 77. Northbound traffic turns right to the north. Southbound traffic turns left to the east for continuation of Highway 77. Tertiary-Quaternary coarse-grained sediments. **194.0**

1.2

79.6 East side road cut, Younger Precambrian Troy Quartzite. Light-colored boulders to the west represent a Tertiary volcanic flow of dacite. **192.8**

0.3

79.9 Tertiary coarse sediments, noticeably tilted and well cemented. **192.5**

0.2

80.1 Troy Quartzite. **192.3**

1.8

81.9 To the west are the Globe Hills consisting largely of diabase and sedimentary rocks of the Apache Group. Small pits and dumps are from prospecting for copper and other minerals. The road is traversing a surface eroded upon Cenozoic sediments. **190.5**

2.5

84.4 Mile post 258. This represents mileage from the California border via U. S. Highway 60 which here coincides with State Highway 77. **188.0**

0.4

84.8 Southern boundary of Tonto National Forest. This is also the approximate southern edge of a 35-mile (road distance) belt of exposures of Older Precambrian granite, Younger Precambrian Apache Group and Precambrian diabase. **187.6**

1.0

85.8 Diabase in east cut. **186.6**

1.2

87.0 Mile post 261. Vegetation, juniper and a few pinyons. 185.4

0.6

87.6 To the west, high road cut exposes north-tilted (20 degrees) Pioneer Shale, Barnes Conglomerate (25 feet thick, see Plate 7), and the basal portion of the overlying Dripping Spring Quartzite. Pinal Mountains are in the far distance to the south (Plate 8). 184.8

0.4

88.0 West side road cut, diabase exposed at the south end. Diabase frequently intrdues the weaker Pioneer Shale zone. 184.4

0.1

88.1 North end of cut exposes Pioneer Shale, Barnes Conglomerate, and Dripping Spring Quartzite. Many faults interrupt the lateral continuity of the Apache Group and account for finding the formations at different elevations. Every canyon may mark the position of a fault, because erosion progresses more rapidly in zones of fracturing. 184.3

1.5

89.6 Road cuts expose diabase (elevation near 5000 feet). Diabase is persistently found associated with the Apache Group. It is an igneous rock that is considered to be Precambrian in age yet younger than any 182.8

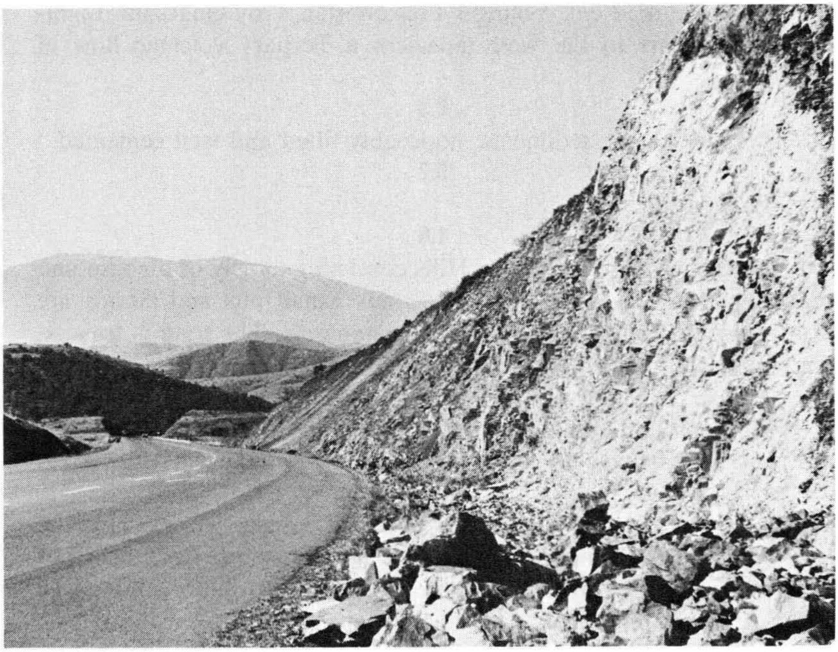

Plate 8. Pinal Mountains in distance (approx. 15 miles) with snow patches. Road cut exposes sedimentary units of the Precambrian Apache Group. Looking south.

Plate 9. Historical marker.

of the known units assigned to the Apache Group, because it intrudes these and all older rocks. It occurs as sills and dikes.

0.3

89.9 Diabase in large cuts. **182.5**

0.7

90.6 To the west, Richmond Mountain with Apache Group rocks overlying granite. **181.8**

0.3

90.9 Older Precambrian granite with cross-cutting bodies known as aplite dikes. **181.5**

0.3

91.2 Diabase. **181.2**

0.4

91.6 To the west, a historical marker describing McMillenville, a ghost mining camp. It is said that the old community once had a population of 1000 persons, not counting the hostile Apaches that waited in the surrounding country (Plate 9). Silver mineralization occurred in veins cutting the diabase. **180.8**

0.2

91.8 To the west an old adobe building with a mine dump on the hill in back. Road cuts are in a coarse crystalline phase of the diabase. **180.6**

0.6

92.4 Mile post 266. **180.0**

0.9

93.3 Gravels and volcanic materials. To the east is a white, volcanic **179.1**

tuff, a light-weight rock composed of volcanic glass particles and rock fragments that were explosively ejected from a volcanic vent.

0.6

93.9 Tertiary basalt, a volcanic flow rock. **178.5**

0.6

94.5 Gravels overlying basalt. **177.9**

0.2

94.7 Seven Mile Wash. Basalt is in road cut. **177.7**

0.1

94.8 To the east, Jones Water Forest Camp and picnic grounds. **177.6**

1.9

96.7 Road cuts expose Older Precambrian granite. **175.7**

1.3

98.0 Jackson Butte to the North. High ledges are Dripping Spring Quartzite. Rock Springs Butte is to the south. **174.4**

0.5

98.5 Mile post 272. Granite. **173.9**

0.2

98.7 Aplite dike in granite. These are characteristically light-colored and finely crystalline. **173.7**

0.2

98.9 Diabase. **173.5**

0.1

99.0 Picnic area. **173.4**

0.2

99.2 Road cuts expose granite. **173.2**

1.5

100.7 Diabase in road cut. In far distance to the west (about 55 miles) are Four Peaks in the Mazatzal Mountains west of Roosevelt Lake. **171.7**

0.8

101.5 Granite cut by light-colored, aplite dikes. **170.9**

0.2

101.7 View Point. Rock Springs Butte is due south in the middle distance. To the southeast in the far distance, the high mountains are the Graham Mountains in Graham County. To the southwest the rounded, humped skyline is formed by the Pinal Mountains in Gila County. **170.7**

0.2

101.9 Diabase. **170.5**

0.3

102.2 Apache Group rocks overlying granite. **170.2**

0.2

102.4 Summit of Timber Camp Mountains approximately 6000 feet in **170.0**

elevation. The shrub growth a short distance to the south contrasts markedly with the timber growth on this plateau-like surface. Juniper, pine and oak are predominate.

0.6

103.0 Mogollon Rim country can be seen in the far distance to the north. **169.4**

1.3

104.3 Highway maintenance camp — radio facilities. **168.1**

0.6

104.9 Diabase. **167.5**

0.1

105.0 To the east, Barnes Conglomerate at the base of road cut exposure. Here the Barnes Conglomerate is over 1000 feet higher in elevation than where it is seen in highway exposures to the south. This is indicative of structural disruption, in this case faulting. **167.4**

2.3

107.3 Side road to the west. **165.1**

0.2

107.5 North boundary of Tonto National Forest. **164.9**

1.3

108.8 To the east, quarry in Precambrian Troy Quartzite. **163.6**

0.6

109.4 Excellent exposures of the Troy Quartzite. **163.0**

0.2

109.6 Quarry in diabase, a material often used in local highway construction. **162.8**

0.9

110.5 Mile post 287. **161.9**

0.2

110.7 To the west, side road to Seneca Lake. **161.7**

0.6

111.3 To the west, side road provides access to asbestos mines. **161.1**

0.4

111.7 Southwest edge of Salt River Canyon. Summit of five-mile grade from the bottom of the canyon. **160.7**

0.4

112.1 Diabase. **160.3**

0.1

112.2 Brownish cliffs to the east (high above the road) are basal Paleozoic sandstones that fill channels cut into the underlying Precambrian rocks. They are not continuous laterally and are not present along the highway. **160.2**

Plate 10. Salt River Canyon region. White debris slope is waste from asbestos mining. Light-colored strata belong to the Mescal Limestone of the Precambrian Apache Group of sedimentary rocks. Dark bands are diabase sills that are closely associated with the formation of asbestos. Looking west.

0.9

113.1 Harder, unfractured portions of the dark diabase weather into rounded knobs. **159.3**

0.2

113.3 To the west, asbestos mining area. (Plate 10). **159.1**

ASBESTOS IN ARIZONA — (19)

Arizona is the only source on the American continent of naturally iron-free chrysotile spinning fiber used for electrical cable covering. Mines are usually located in rugged canyon country. In the average mine one ton of commercial asbestos requires the removal of 30 to 40 tons of waste rock. Mining costs are necessarily high and prices must be high if the product is to be produced at a profit. The type of mining required is not conducive to mass production methods; therefore, relatively small quantities are obtained annually. Production ranges from more to less than 1000 short tons per year. Individual asbestos fiber is thinner than hair, wool, cotton, or rayon.

Arizona asbestos deposits are controlled, consistently, by certain geologic circumstances. Its occurrence is limited to certain units within the Mescal Limestone of the Precambrian Apache Group. The limestone is the host rock, but the diabase that intrudes it is responsible for the formation of chrysotile asbestos veins and lenses in the limestone.

0.5

113.8 Hieroglyphic Point Overlook. **158.6**

The Salt River is the largest tributary to the Gila River. It flows southwesterly for over 200 miles and joins the Gila River about 12 miles southwest of Phoenix. Salt springs occur along a part of the river, thus accounting for its name.

The walls of the canyon at this point consist principally of units of the Younger Precambrian Apache Group, and the ever present Precambrian diabase. Paleozoic formations occur in the upper part of the canyon walls. Especially well displayed here is the manner in which the diabase sills have intruded and vertically expanded the Mescal Limestone. The light-colored segments are of the Mescal Limestone, and the darker segments are diabase that have been forcefully injected between layers of the limestone (Plate 11).

0.1

113.9 Sliver of light-colored Mescal Limestone surrounded by diabase. **158.5**

0.6

114.5 Mile post 291 — diabase road cut. **157.9**

1.3

115.8 Mescal Limestone in road cut. **156.6**

0.4

116.2 Contact area (specific contact not well exposed along highway) between the light-colored Mescal Limestone and the dark-colored, underlying Dripping Spring Quartzite. **156.2**

0.2

116.4 Bridge over Salt River. South boundary of the Ft. Apache Indian Reservation. North abutment is in Dripping Spring Quartzite which underlies the Mescal Limestone. **156.0**

0.3

116.7 Service facilities. **155.7**

0.2

116.9 Cenozoic gravels associated with an earlier stage in the formation of Salt River Canyon. **155.5**

0.2

117.1 Mescal Limestone (light-colored) under diabase. **155.3**

0.1

117.2 View point — diabase in road cut, exposure of Mescal Limestone is just below overlook. **155.2**

2.3

119.5 Quarry in diabase. Material used in highway construction. **152.9**

0.6

120.1 Sedimentary contact of Paleozoic rocks (Devonian Martin Formation) with Precambrian diabase, an intrusive igneous rock (Plate 12). It is estimated that a time lapse of over 200 million years is represented in this contact. Locally, the basal, dark, siliceous, shaly Devonian beds contain plant remains. This contact proves that the diabase existed prior to the deposition of the Martin Formation. **152.3**

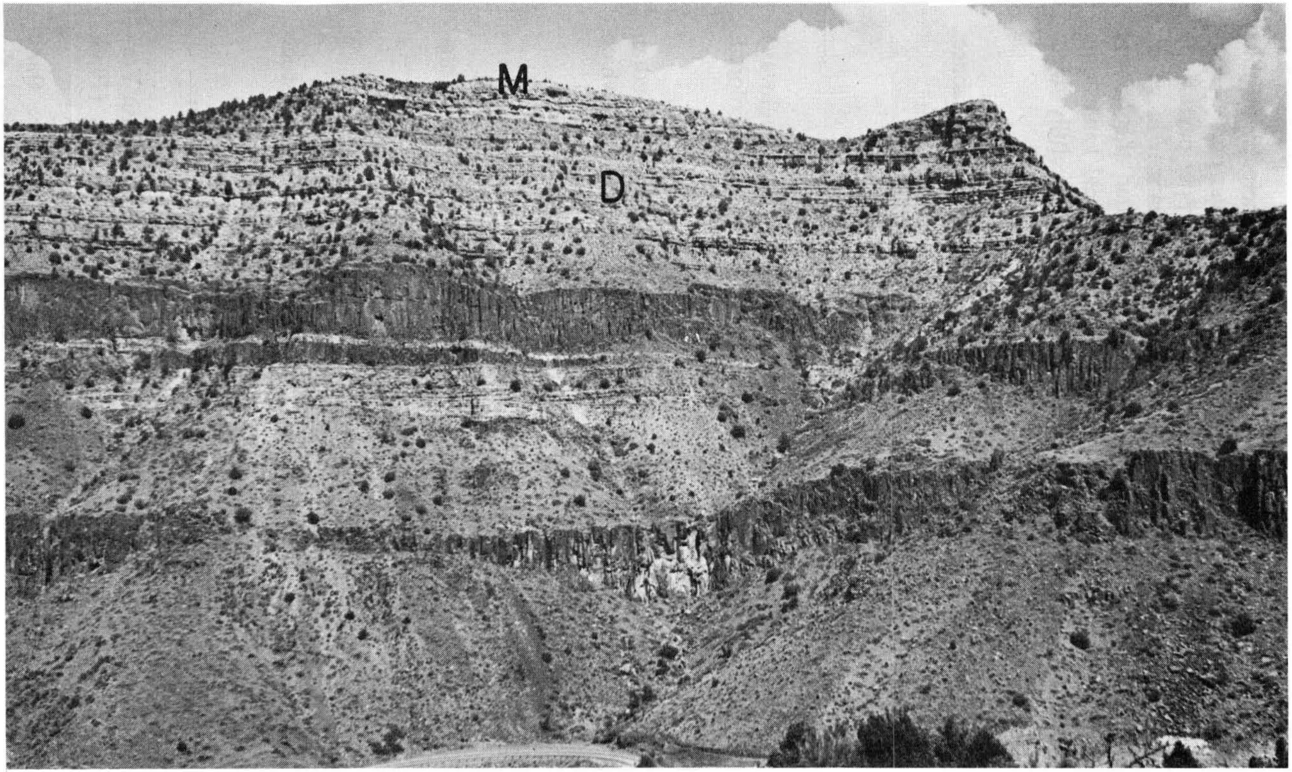

Plate 11. View from Hieroglyphic Point in Salt River Canyon. Dark sills of Precambrian diabase intrude the light-colored Mescal Limestone. Limestones of Paleozoic age (Devonian (D) and Mississippian (M) form the upper wall above the highest dark diabase). Looking northeast

Plate 12. Sedimentary contact (arrow) between Paleozoic (Devonian) strata (D) and Precambrian diabase (P). It is estimated that the disparity in the ages of the rocks on either side of this contact is at least 200 million years. Salt River Canyon area looking north.

Plate 13. Tertiary gravels at high elevation. The elongate boulders (arrows) are oriented so as to offer the least resistance to a current that once flowed from left to right. Looking northwest.

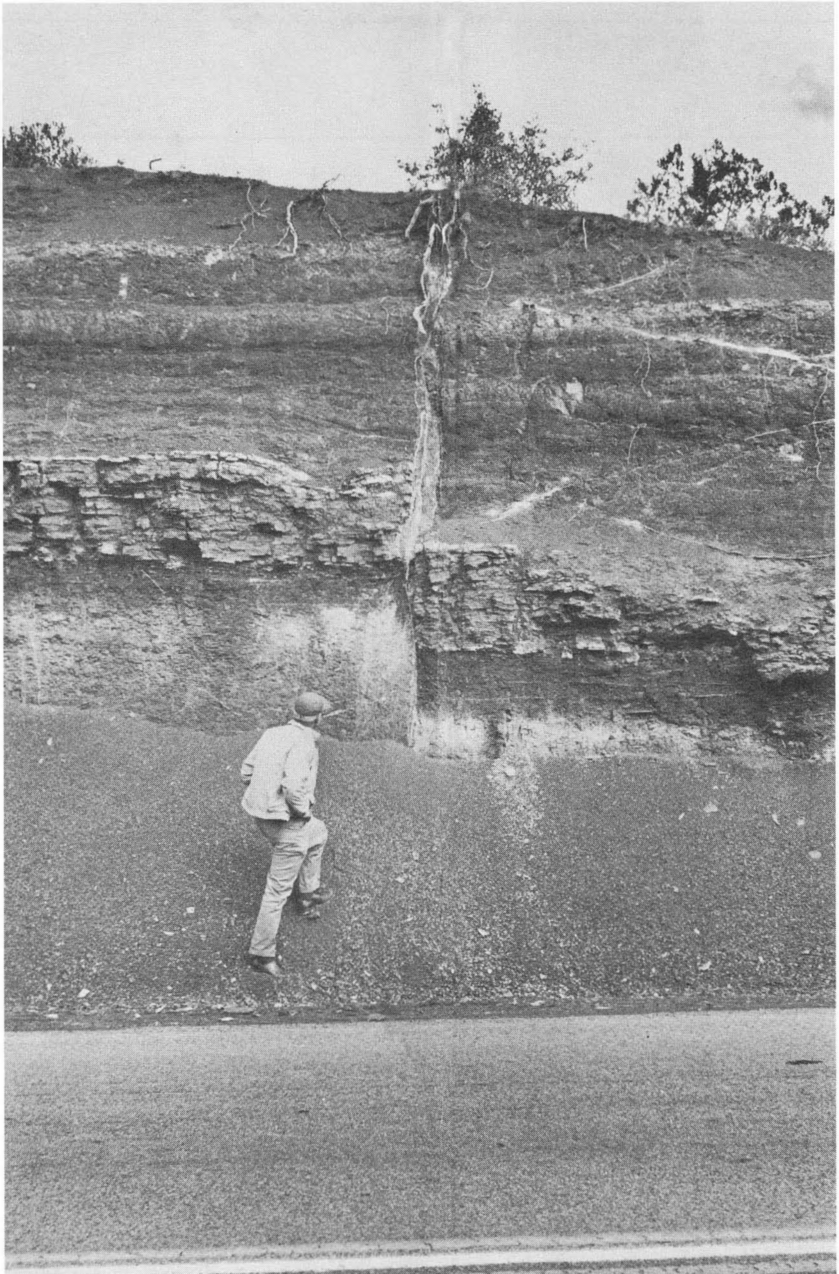

Plate 14. Small vertical fault in strata of the Permian Supai Formation. Right, or north, side is down relative to the left, or south, side. A root follows fracture zone. Looking west.

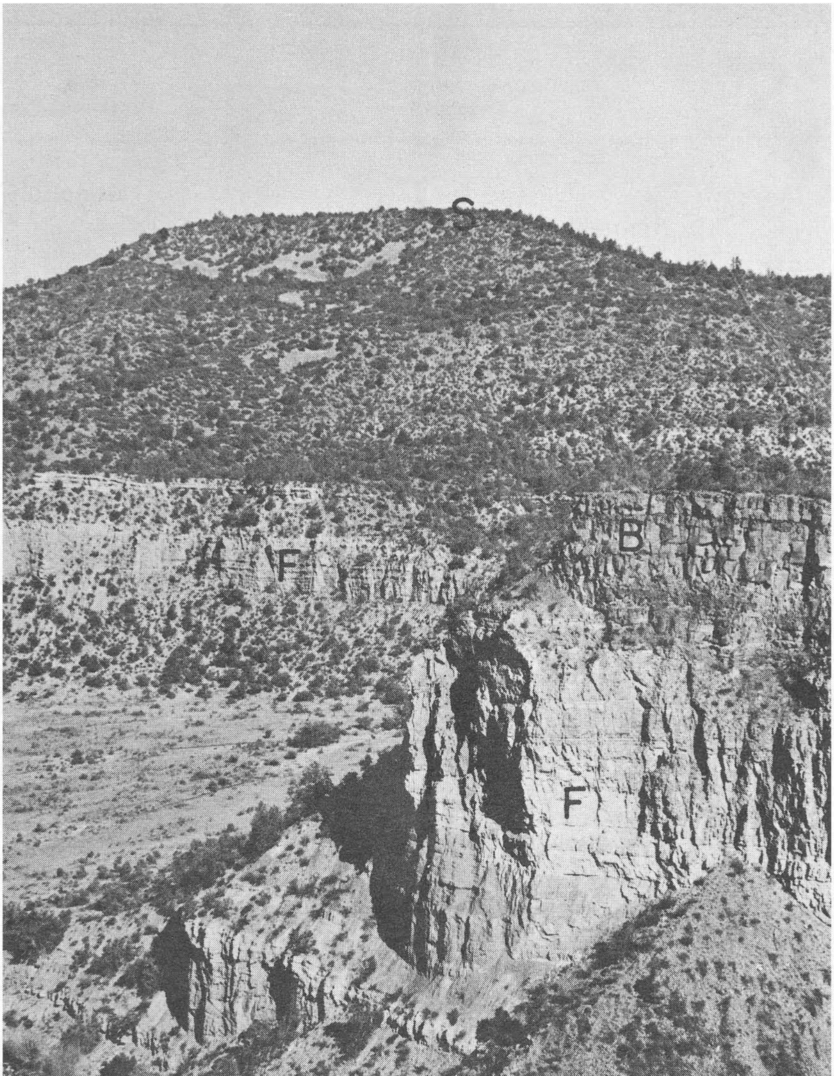

Plate 15. Canyon of Corduroy Creek. Strata of the Permian Supai Formation including the cliff-making limestones of the Fort Apache Member (F), other thinner limestone ledges, and soft beds of sandstone and siltstone. A hard Permian sandstone above the Supai forms the skyline (S). Basalt overlies Supai strata at right center (B). Fort Apache Indian Reservation. Looking west.

Plate 16. Northern boundary of the Fort Apache Indian Reservation. This boundary is coincident with the Mogollon Rim which marks the southern edge of the Plateau province in Arizona. The Rim is also a major drainage divide. Looking south.

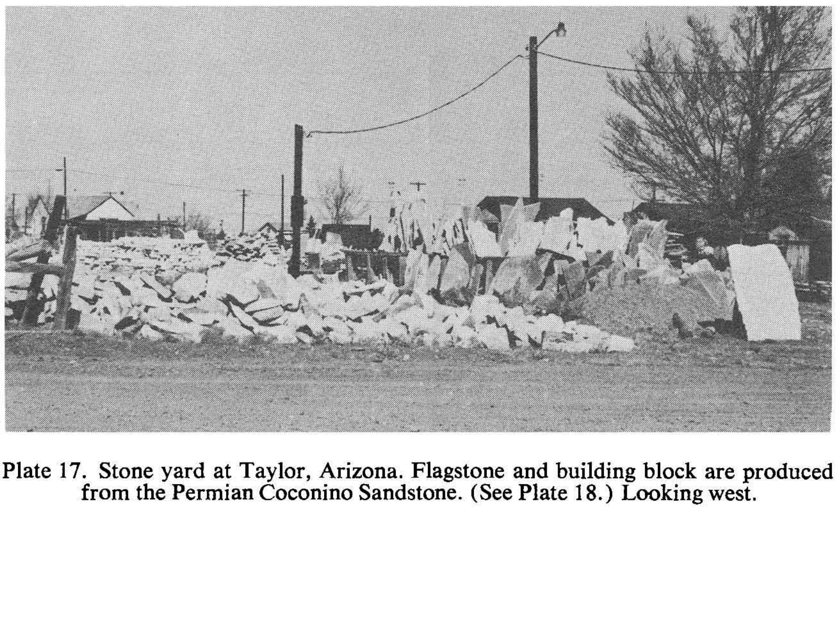

Plate 17. Stone yard at Taylor, Arizona. Flagstone and building block are produced from the Permian Coconino Sandstone. (See Plate 18.) Looking west.

0.6

120.7 Becker Butte Overlook. Martin Formation is exposed in road cut. The top cliff in this vicinity is the Mississippian Redwall Limestone, an equivalent of the Escabrosa Limestone seen in the Mescal Mountains to the south. To the east on the opposite side of the canyon, the slope-forming Martin Formation rests unconformably upon the Precambrian Troy Quartzite, whereas, on the highway, the Martin Formation overlies diabase. This reflects structural disruption and erosion prior to the deposition of the Martin Formation. 151.7

0.3

121.0 Green shale to the north is near the top of the Devonian Martin Formation. 151.4

0.2

121.2 Rubbly-looking, marine Redwall Limestone in north side road cut. This limestone was fractured and weathered prior to the deposition of the overlying Pennsylvanian Naco Limestone. Resistant chert from the Redwall accumulated at the erosion surface and was then incorporated into basal, coarse phase of the Naco Limestone. This surface indicates a sea withdrawal, erosion, and a re-invasion of the sea to allow deposition of the marine Naco Limestone. 151.2

0.3

121.5 North road cut is in shales and clays of the Naco Limestone of Pennsylvanian age. The south cut is in basal Naco Limestone containing a chert pebble conglomerate surrounded by a purplish mud matrix. 150.9

0.8

122.3 Naco Limestone. Small flexures give undulating appearance. There is minor faulting, also. 150.1

0.3

122.6 Small anticline (an arch-like fold). 149.8

2.7

125.3 Interbedded gray to reddish shales and harder limestone zones in the Naco Limestone. 147.1

1.6

126.9 Mile post 304. Vegetation consists largely of pinyon, juniper, and oak. 145.5

2.8

129.7 Flying V Highway maintenance yard. 142.7

1.0

130.7 High road cuts are in conglomeratic Tertiary sediments. Boulders are largely of Precambrian rocks that were derived from the southwest and deposited by northeasterly-flowing streams. (See Plate 13.) The streams today are flowing toward the south and west. 141.7

1.1

131.8 Red beds of the Permian Supai Formation overlain by Tertiary sediments. To the north along the Mogollon Rim these Tertiary sediments overlie Cretaceous sedimentary rocks. Such a relationship indicates that the erosion surface beneath these Tertiary rocks cuts older rocks toward the south. 140.6

2.5

134.3 Supai Formation, the same formation that makes the red cliffs in Oak Creek Canyon and in the upper part of the Grand Canyon. Small faults are exposed in road cuts (Plate 14). The light-colored zones are where passing solutions have altered the iron compound that makes the red color. 138.1

0.3

134.6 To the west, side road to Cibecue. 137.8

1.9

136.5 Road is traversing red sedimentary rocks of the Permian Supai Formation. 135.9

2.0

138.5 Bridge over Carrizo Creek. Fossil-bearing limestones near the top of the Pennsylvanian Naco Limestone are at creek level. 133.9

0.5

139.0 Apache Indian town of Carrizo. Lumbering is the principal local industry. 133.4

FORT APACHE INDIAN RESERVATION

The Ft. Apache Indian Reservation was established by executive order issued by President Grant November 9, 1871. The reservation contains 1,664,872 acres and a population of about 6000 persons. Elevations range from 2700 feet at Salt River to 11,459 feet at Mt. Baldy in the heart of the White Mountains. The White Mountain Apache people are making the reservation an all year around recreational center. There are about 300 miles of streams and many lakes stocked with trout.

0.3

139.3 Navajo and Gila Counties boundary. 133.1

0.8

140.1 Dark, Quaternary basalt flow caps Paleozoic rocks. 132.3

0.8

140.9 Short road cuts expose Supai Formation strata that are tilted to the north. The tilted nature of the strata is one manifestation of a northwest-southeast trending fault that uplifts the strata on the south side and depresses them on the north side of the fault. The volcanic flow to the west covers a segment of the fault but is unaffected by it; therefore, the volcanics are younger than this faulting. 131.5

0.1

141.0 Junction of State Highway 73 to White River (Indian Agency Headquarters) and McNary. 131.4

1.8

142.8 Quaternary basalt caps the Supai Formation to the west. The marine, fossiliferous, Ft. Apache Member (principally limestone) of the Supai Formation caps the red beds to the east. Several thinner limestones form ledges in the Supai Formation. Such variations in rock types reflect the shifting of depositional environments. 129.6

1.2

144.0 Basalt overlies gravels. 128.4

0.3

144.3 To the north, prominent cliff is composed of the Ft. Apache Member of the Supai Formation. 128.1

0.4

144.7 The picnic area on the west side overlooks Corduroy Creek. The hills are Supai Formation capped by a hard Permian sandstone that forms the high, rock-strewn slopes. (Plate 15.) 127.7

0.8

145.5 The basalt follows valleys much like streams of water do. The present streams have deepened these older valleys and thus have cut through the basalt. 126.9

0.8

146.3 Cedar Canyon is cut in basalt. 126.1

1.4

147.7 Quaternary basalt over the Permian Supai Formation. 124.7

0.3

148.0 To the west — Snake Ridge. 124.4

0.9

148.9 Notch, or saddle, in the ridge to the west marks the location of a northwest-southeast trending fault that drops the south side down, placing Cretaceous sedimentary rocks on the south against those of the Supai Formation on the north. The vertical component of displacement is at least 600 feet, and the fault is known to have a length of at least twenty miles. This feature has considerably influenced the topography or surface land form in this segment of the Mogollon Rim region. (See Fig. 4.) 123.5

0.4

149.3 Thin limestone unit in the upper part (Corduroy Creek Member) of the Supai Formation. 123.1

1.1

150.4 Dark, vesicular basalt (numerous holes created at time of escape of contained gasses). 122.0

0.7

151.1 Bridge over Corduroy Creek — basalt forms the canyon walls. **121.3**

1.2

152.3 Faught Ridge in the distance to the southeast. The ridge is capped by Tertiary conglomerate that rests unconformably on Cretaceous rocks. **120.1**

2.8

155.1 Forestdale Trading Post. **117.3**

0.2

155.3 In the west side road cut is a contact zone between the dark Supai Formation below and light-colored sandstones above, all dipping (tilted) northward at about 6 degrees. These light-colored sandstones have been called the "Coconino" Sandstone. However it should be pointed out that whereas these sandstones are largely flat-bedded, typical Coconino Sandstone is cross-stratified on a large scale. Typical Coconino Sandstone is well exposed along Highway 77 between Taylor and Holbrook (Plate 19). It seems clear that the depositional environment of the typical Coconino Sandstone, found to the west and north, did not persist in this area. **117.1**

0.8

156.1 Permian Kaibab Formation forms the cliff to the east. Road cuts in highly-fractured, light to rust colored, "Coconino" Sandstone. **116.3**

1.0

157.1 Kaibab Formation is above the road to the west. **115.3**

0.4

157.5 Kaibab Formation to the east. Here the Kaibab Formation contains impure carbonate rocks and sandstones. Many of the carbonate rocks contain marine fossils. These strata are continuous with the Kaibab Formation of the Grand Canyon region where it forms the rim, or cap rock. Between this locality and Snowflake to the north the Kaibab Formation pinches out (disappears), which suggests the proximity of the ancient shore line of the Kaibab Sea. **114.9**

0.8

158.3 Occasional outcrop of buff to yellowish Cretaceous sandstone, and pink to white siltstone. In the Rim area, the Cretaceous sedimentary rocks rest unconformably on Permian rocks. The erosion surface beneath the Cretaceous rocks cuts older rocks southward. The Cretaceous here contains marine fossils, especially types of clams, including oysters. One hundred miles to the north there are over 3000 feet of Mesozoic (Triassic, Jurassic, and Cretaceous) sedimentary rocks that are not present here. It is thought that southern and central Arizona were parts of a highland existent during much of Mesozoic time, a **114.1**

highland that was a source of the sediments that filled basins of accumulation north of the Rim area.

1.3

159.6 Mogollon Rim. Elevation 6594. Highest point on Highway 77 (Plate 16). The Rim road to the east and west follows the north boundary of the Ft. Apache Indian Reservation. The Rim road follows the Mogollon Rim (see Fig. 5) which forms the drainage divide between the Little Colorado River to the north and the Salt River to the south. Waters separated by this divide come together again near Yuma, Arizona. where the Gila River flows into the Colorado River. The road is on Cretaceous rocks that are largely mantled with soil. Rounded pebbles and boulders come from Tertiary sediments that cap the higher elevations along the Rim. **112.8**

0.3

159.9 South boundary of Sitgreaves National Forest. **112.5**

1.2

161.1 Ponderosa pines. The stand of Ponderosa pines on the Mogollon Slope to the west is the largest in the United States. **111.3**

1.4

162.5 Junction of Highway 160 to the west to Heber and Young . **109.9**

0.2

162.7 Show Low city park to the north offers camping and picnicking facilities. **109.7**

1.4

164.1 U.S. Post Office, Show Low, Arizona. Elevation 6432 feet. Post office established in 1880. In about 1875, two men settled in this area but decided that there was room for only one. They played cards and the one who could "show low" would remain. There was a store for travelers and in 1890 land was purchased by a man who wished to establish a Mormon settlement (14). Show Low is currently a business center serving ranchers, lumbermen, and tourists. **108.3**

0.4

164.5 Junction of Highway 173 to the south to Lakeside and McNary. **107.9**

0.5

165.0 Junction of Highways 77 & 60. Highway 77 turns north toward Holbrook for northbound traffic and west toward Show Low for southbound traffic. Highway 60 continues eastward toward Springerville. **107.4**

0.4

165.4 Low rounded hills to the east and southeast are volcanic hills called cinder cones. The White Mountains consist of a complex of volcanic phenomena. The highway is on top of a volcanic flow of Quaternary age. Juniper is the predominate vegetation along with **107.0**

grasses that support cattle and a mule deer population. The higher timber country to the southwest is the Mogollon Rim region.

2.6

168.0 To the west a juniper eradication program is in progress to promote better grass range for stock grazing. **104.4**

4.1

172.1 Side road to the west. **100.3**

0.2

172.3 North boundary of Sitgreaves National Forest. **100.1**

0.5

172.8 Quaternary basalt (lava) in road cuts. **99.6**

1.2

174.0 Little Valley, occupied by Silver Creek. Flat-topped land forms represent a Quaternary lava flow (basalt) that rests upon sedimentary rocks of the Triassic Moenkopi Formation. **98.4**

0.7

174.7 Road cuts are in red sedimentary rocks of the Triassic Moenkopi Formation. **97.7**

1.4

176.1 Side road to the east leads to Shumway. **96.3**

0.8

176.9 The light-colored sandstone ledge to the east is part of the Moenkopi Formation. **95.5**

0.1

177.0 Bridge over Show Low Creek, a tributary of Silver Creek to the east. **95.4**

0.9

177.9 Rounded hills to the immediate east are erosional remnants of Tertiary-Quaternary deposits. Sediments such as these provide basic information that aids in developing the Cenozoic history of the Colorado River drainage system. Fossils collected in this vicinity have included those of plants, fish (a four- to six-foot long squaw fish, related to the squaw fish presently found in the Colorado River), horse, camel, mastodon, and a small rodent. Available data suggest that these deposits are late Pliocene to early Pleistocene in age (**20**). **94.5**

1.2

179.1 The light-colored sandstone ledges are part of the Triassic Moenkopi Formation. **93.3**

0.9

180.0 Side road to the west. **92.4**

0.3

180.3 Stone yard on the west (Plate 17). Stone is derived from the Permian Coconino Sandstone and is quarried near the highway about **92.1**

25 miles to the north (Plate 18). Much of the stone is shipped eastward to markets in New Mexico.

0.1

180.4 Taylor, Arizona. Elevation 5640. Post office established in 1881. Settlers along Silver Creek decided to name this community after John Taylor, a leader of the Mormon Church who was wounded in 1884 at the time Joseph Smith was killed (**14**). Cucumbers have been the main commercial crop grown along Silver Creek. **92.0**

1.3

181.7 Bottom land. Local farming. **90.7**

0.5

182.2 High school to the west, outcrops are of the Triassic Moenkopi Formation. **90.2**

0.8

183.0 Railroad Crossing. Apache Railroad operated by the Southwest Forest Industries, Inc. This 140-mile line runs between Holbrook to the north and Maverick to the south. A spur line serves the company's pulp and paper mill 15 miles west of Snowflake. **89.4**

0.5

183.5 U.S. Post Office, Snowflake, Arizona. Elevation 5630, established in 1881. Named by combining the names of two founders, Snow and Flake (1878) (**14**). It is mainly a farm, ranch, and industrial community. The majority of the more than 400 persons employed by the pulp and paper mill reside in Snowflake. The plant, opened in 1961, was located with special regard for wood sources, water, and waste disposal (**9**). The mill requires approximately eight million gallons of water per day, and this is pumped from wells located about four miles southwest of Snowflake. The wells are developed in the Permian Coconino Sandstone, the top of which is approximately 200 feet below the land surface in that area. **88.9**

0.4

183.9 Highway 277 to the west leads to the paper mill, Heber, and Payson. **88.5**

0.6

184.5 Bridge over Cottonwood Creek, a tributary to Silver Creek immediately to the east. Red sediments to the west are Cenozoic (Pliocene-Pleistocene) in age. **87.9**

0.3

184.8 To the northeast, the Permian Coconino Sandstone forms the canyon walls of Silver Creek. It has been brought to the surface by an anticlinal fold frequently termed the "Holbrook" or "Snowflake" anticline. This fold extends for over 40 miles in a northwest- southeast direction, and it has been drilled in several places in search of oil **87.6**

Plate 18. Quarry in the Permian Coconino Sandstone. The large scale cross-stratification (deposition at an angle) makes it possible to produce excellent flagstone (see Plate 17). Looking east.

and gas. The Coconino Sandstone here is approximately 500 feet thick and is underlain by about 3000 feet of other Paleozoic rocks before Precambrian basement rock (granite here) is reached. In the subsurface, the upper Supai Formation contains salt. (See Fig. 5). To the northeast, several million dollars have been spent in a search for potassium-bearing salts.

0.3

185.1 South edge of Permian Coconino Sandstone outcrops. **87.3**

0.5

185.6 Basal, thin-bedded, light-colored unit of the Triassic Moenkopi Formation which overlies the Coconino Sandstone in this region. **86.8**

1.2

186.8 Red sedimentary rocks of the Moenkopi Formation are to the west in the distance. **85.6**

0.5

187.3 Thin-bedded, basal Moenkopi strata. **85.1**

0.6

187.9 Near the top of the Coconino Sandstone. To the south and west the Kaibab Formation is between the Coconino Sandstone and the Moenkopi Formation. It is not present here, however. Its absence is explained by a combination of two factors: 1, The Kaibab Sea did not encroach to this point, and 2, if some Kaibab was deposited, it was eroded away before the Moenkopi was deposited. The Kaibab thickens gradually northwest to about 400 feet at the Grand Canyon and continues to thicken into Utah. **84.5**

0.8

188.7 Mile post 366. Extensive juniper eradication program to improve the growth of range grasses. **83.7**

0.6

189.3 Bridge over a gully that exposes the cross-stratified, Coconino Sandstone. The Coconino Sandstone is a most versatile and important sedimentary rock. Forty miles to the northeast, helium is produced from it. It supports a major stone industry in northern Arizona, and it is an invaluable source of pumped water to many communities and industries. **83.1**

1.0

190.3 Basal Moenkopi in low east side road cut. **82.1**

0.5

190.8 Bridge, Coconino Sandstone at the surface. **81.6**

0.5

191.3 Moenkopi Formation. **81.1**

0.6

191.9 Coconino Sandstone at the surface. **80.5**

1.0

192.9 Moenkopi Formation in a road cut. 79.5

0.1

193.0 Picnic table to the east. 79.4

The highway between Snowflake and Holbrook traverses what is called the Mogollon Slope, a northward, gently-sloping surface developed close to the Permian Coconino Sandstone-Triassic Moenkopi Formation contact. (See Fig. 4). It is a slope controlled by a gentle northward tilt of the strata, a tilt amounting to approximately 20 feet per mile along the highway.

0.5

193.5 Bridge. 78.9

2.6

196.1 Small isloated buttes are remnants of the Triassic Moenkopi Formation. To the east, a thin gravel cap can be seen on the butte nearest the highway. 76.3

1.6

197.7 Mile post 375. 74.7

0.2

197.9 Small gully exposes the Coconino Sandstone and the overlying Moenkopi Formation. 74.5

1.3

199.2 Wind mill to the west pumps water from the underlying Coconino Sandstone. 73.2

0.9

200.1 To the west, remnant of the Moenkopi Formation. 72.3

1.6

201.7 To the west, dark Triassic Moenkopi Formation in contact with underlying light-colored Permian Coconino Sandstone. 70.7

0.2

201.9 Bridge over Washboard Creek. 70.5

0.2

202.1 To the east five miles is Woodruff Butte, an igneous, intrusive plug (see glossary) of Tertiary age. 70.3

1.6

203.7 Side road to the east. 68.7

2.1

205.8 Thin remnant of gravels. 66.6

0.5

206.3 To the east, the upper part of the Permian Coconino Sandstone is well exposed in a canyon. Small, isloated, darker buttes are remnants of the Triassic Moenkopi Formation. The Coconino Sandstone is quarried (Plate 18) here to supply a stone yard in Taylor to the south 66.1

(Plate 17). The cross-stratification (deposition at an angle with the horizontal) is well developed in the Coconino Sandstone and is characteristic of it. The sandstone represents "fossil" sand dunes. The sloping thin beds represent deposition on the steep fronts of dunes that migrated toward the southeast. In some localities reptile tracks are frequently found on the inclined surfaces (**21**). The slope direction is the direction in which the depositing wind was blowing (Plate 19).

The ground surface is strewn with pebbles consisting in part of colorful petrified wood and chert, materials that Indians made tools from.

0.5

206.8 Gravels in the east road cut are over the Moenkopi Formation. **65.6**
In the far distance to the north and northeast are the Hopi Buttes on the Navajo Indian Reservation approximately 35 road miles distant via Highway 77.

1.7

208.5 To the east, Moenkopi Formation with basal Chinle Formation **63.9**
(Shinarump Conglomerate) cap. The lighter-colored Shinarump Conglomerate is an important source of uranium ore in northeastern Arizona on the Navajo Reservation. Most of this unit has been eroded away from this part of Arizona.

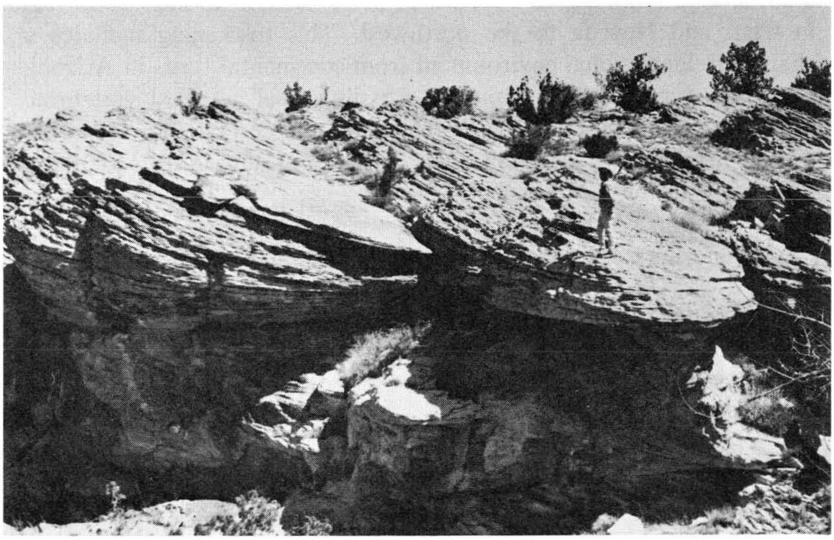

Plate 19. Exposure of the cross-stratified Permian Coconino Sandstone. This sand accumulated originally as sand dunes. The direction of dip of the cross strata reflects the direction in which the depositing winds were blowing (southeast). The formation, as a whole, is nearly flat lying. Looking northeast.

208.8 **0.3** 63.6

To the west, side road to Heber and Young.

209.3 **0.5** 63.1

Road cuts expose red beds of the Triassic Moenkopi Formation.

210.4 **1.1** 62.0

Junction with Highway 180 to the Petrified Forest National Park.

210.8 **0.4** 61.6

Bridge over the Little Colorado River.

211.2 **0.4** 61.2

Santa Fe Railroad crossing.

211.3 **0.1** 61.1

Major intersection of U.S. 66, 180, and State 77. Highway 77 continues straight ahead.

0.2

211.5 Holbrook, Arizona. Elevation 5080 feet. Post office established in 1882. The name is after H. R. Holbrook, first chief engineer of the Atlantic & Pacific Railroad. Tracks were first laid in 1881 (14). Holbrook is a supply point for ranches, trading posts on the Navajo Reservation, and serves as the distribution point for mail to 76 post offices off the Santa Fe Railroad. Highway 66 is the main tourist route in northern Arizona. 60.9

Dark sandstones of the Triassic Moenkopi Formation. This formation, approximately 200 feet thick here, thickens to near 2000 feet in Utah and Nevada to the northwest. This thickening includes a change in depositional environment from continental types in Arizona to marine types to the northwest. Fossils reveal a varied vertebrate fauna which includes reptiles, amphibians, and certain fish. This contrasts markedly with invertebrate marine shells found in the Moenkopi Formation to the northwest.

0.7

212.2 Quaternary sediments overlie the Moenkopi Formation. 60.2

1.5

213.7 State Highway Department office on the north side of the highway. 58.7

3.3

217.0 Soft beds in the Triassic Chinle Formation form rolling hills and knobs to the south. 55.4

0.8

217.8 Junction of Highway 77 to the north with U.S. Highway 66. It is approximately 56 miles to the northern terminus of Highway 77 where it joins Navajo-Hopi Route 3 (State Highway 264). 54.6

1.6

219.4 Cattle guard, open range. 53.0

0.4

219.8 Wind-blown sand. 52.6

1.5

221.3 To the west, banded Chinle Formation underlies Marcou Mesa. To the north in the distance are the Hopi Buttes. To the northeast is dune sand "climbing" Hennessey Buttes. 51.1

2.8

224.1 Leroux Wash. 48.3

1.4

225.5 Cattle guard. Hennessey Buttes to the east are intrusive volcanic features. 46.9

2.9

228.4 Mitten Peak to the east is an intrusive volcanic feature. 44.0

2.6

231.0 Transmission line running from northwest New Mexico to Mesa, Arizona, near Phoenix. 41.4

0.6

231.6 Cattle guard is the south boundary of the Navajo Indian Reservation. The Navajo Reservation, the largest Indian reservation in the United States, embraces parts of New Mexico and Utah as well as northeastern Arizona. The reservation, approximately 25,000 square miles in area, was established in 1868. The population is now approximately 80,000 whereas it was initially 7000. Principal industries are lumber, uranium mining, and tourism. The only oil and natural gas production in Arizona is from this reservation. Exploration on these lands should continue, with varying intensity, into the future. 40.8

2.1

233.7 Buttes and plateaus to the west and north are composed of both sedimentary and igneous rocks. The volcanic rocks and some of the associated sediments belong to the Pliocene Bidahochi Formation. 38.7

6.8

240.5 Five Buttes area. To the north and northeast, the dark caps are volcanics belonging to the Middle Member of the Bidahochi Formation. In the distance to the north, white sediments, constituting the Lower Member, underlie the volcanics. The red sedimentary rocks belong to the Triassic Wingate Sandstone, and these in turn overlie the variegated shales of the Triassic Chinle Formation. 31.9

1.1

241.6 Chinle Formation to the east. Occasional thin, hard sandstone ledges protect the underlying, soft clays from rapid erosion. 30.8

0.8

242.4 Pueblo Colorado Wash. 30.0

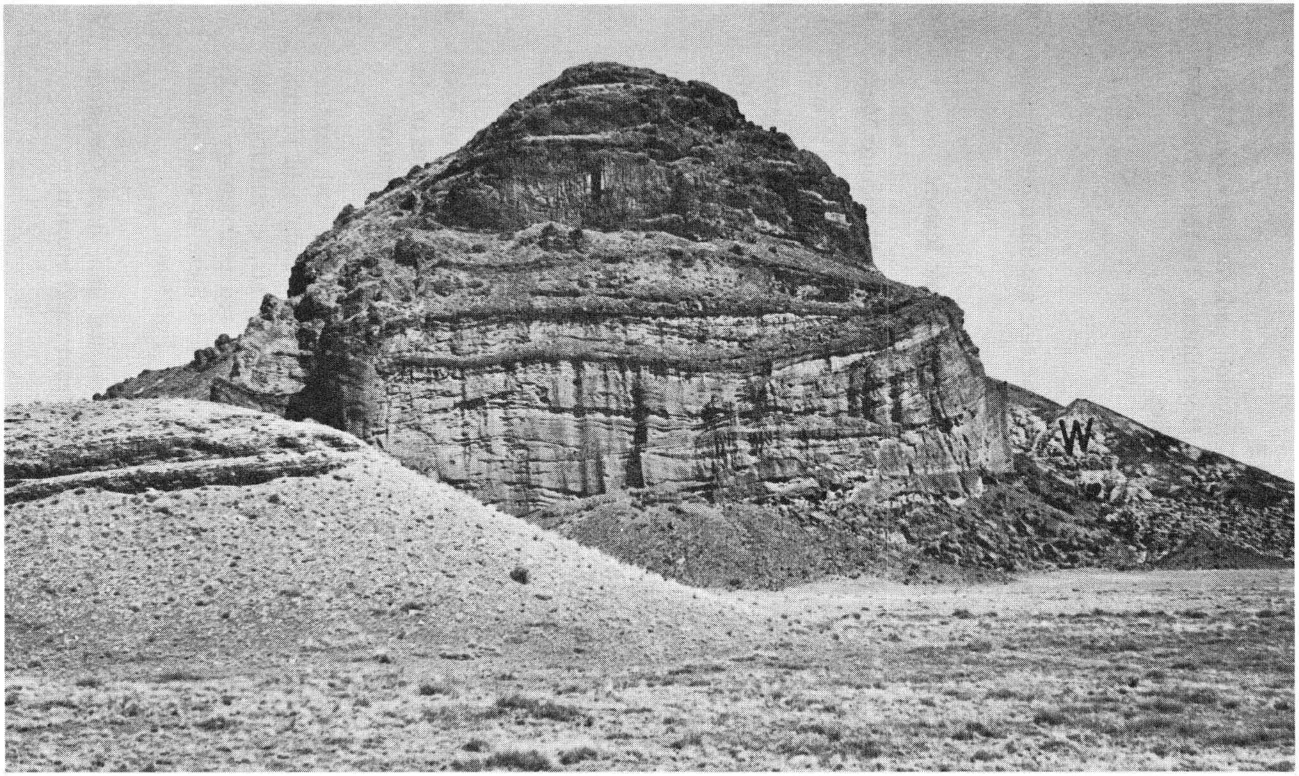

Plate 20. A butte in the Hopi Buttes volcanic field. The butte, consisting of a complex of volcanic materials that intrude the Wingate Sandstone (W), probably represents the throat of a volcanic vent. Looking east.

1.3

243.7 To the east, red Triassic Wingate Sandstone overlain by volcanic rocks of the Bidahochi Formation. Notice the vertical structures in the capping volcanics. 28.7

2.3

246.0 Volcanics cut through the red Wingate Sandstone (Plate 20). 26.4

0.4

246.4 Road cut exposes an interesting sequence of rocks belonging to the Bidahochi Formation (Plate 21). 26.0

0.1

246.5 The platy sedimentary rocks are a phase included within the Bidahochi Formation. In other localities fresh-water fish fossils have been found in similar Bidahochi sediments. 25.9

1.7

248.2 Turnoff to the west to Indian Wells Trading Post, two miles distant. 24.2

0.2

248.4 "Bita Hochee" Trading Post. Spelling on local signs is not in agreement with that indicated on certain maps (Plate 22). 24.0

1.2

249.6 One half mile to the east is a circular collapse structure. Such features are common in the Hopi Buttes volcanic field. They are believed to represent inward collapse of volcanic ejecta into a dormant volcanic vent. 22.8

0.6

250.2 Tertiary Bidahochi Formation overlying red Triassic Wingate Sandstone. 22.2

1.0

251.2 Wingate Sandstone along road on east side. 21.2

2.5

253.7 Side road to the west to Na-ah-tee Trading Post. 18.7

2.2

255.9 Bidahochi Formation to the east and west along the side of the road. 16.5

4.5

260.4 To the east, sediments belonging to the Bidahochi Formation form the erosional feature known as White Cone. The light-colored cliffs to the north are carved from the Bidahochi Formation. Fossils found at White Cone include those of beaver, horned beaver, rabbit, wolverine, camel, large cat, and a marten-like animal. In addition, reptiles, amphibians, birds, fish, plants, and pollen are represented. Such fossils make it possible to date the sediments forming the upper part of White Cone as late middle Pliocene in age (**20**). 12.0

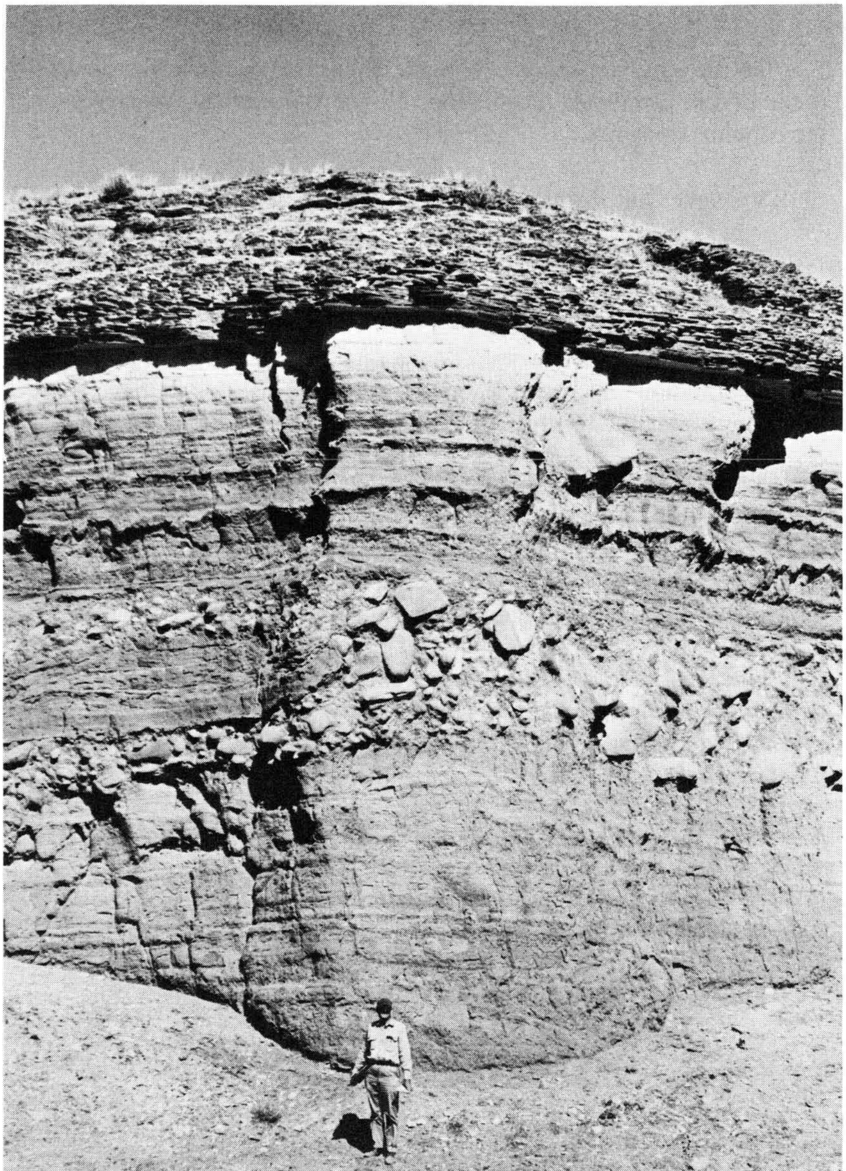

Plate 21. Volcanic ejecta of varying sizes capped by water-laid shaly weathering strata. A phase of the Pliocene Bidahochi Formation. Looking east.

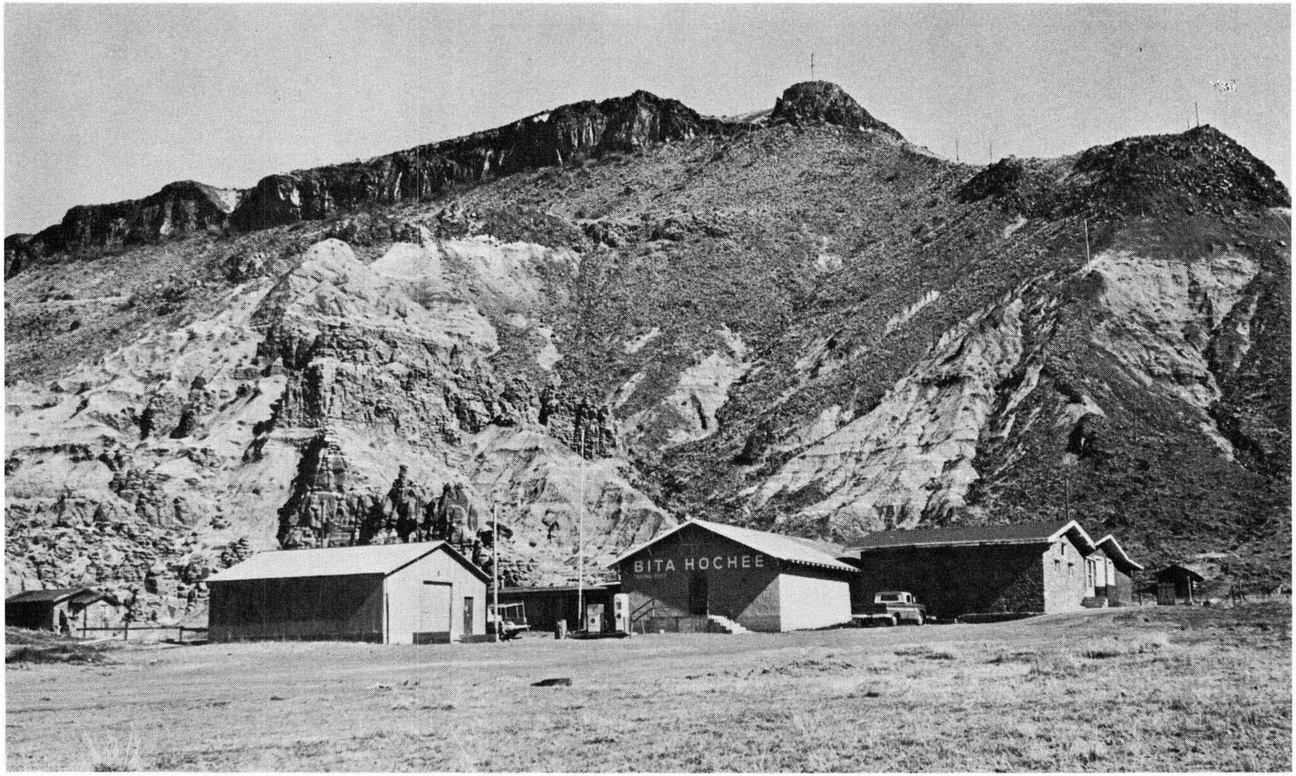

Plate 22. Bidahochi Butte behind the trading post. Lower exposures are of the Triassic Wingate Formation. The dark, resistant cap rock is the volcanic Middle Member of the Pliocene Bidahochi Formation. The Lower Member of the Bidahochi Formation is inconspicuous. Looking southeast.

All domestic water in this region is pumped from wells. Some stock water is caught in earth tanks.

2.2

262.6 Side roads. 9.8

3.9

266.5 Cliffs are the Upper Member of the Tertiary Bidahochi Formation. 5.9

3.3

269.8 The plateau surface is cut upon the Bidahochi Formation and is known as Roberts Mesa (Plate 23). 2.6

2.6

272.4 Northern terminus of State Highway 77. Junction with Navajo-Hopi Route 3 (State Highway 264). Elevation approximately 6600 feet. Keams Canyon and Tuba City to the west; Window Rock and Gallup to the east. 0.0

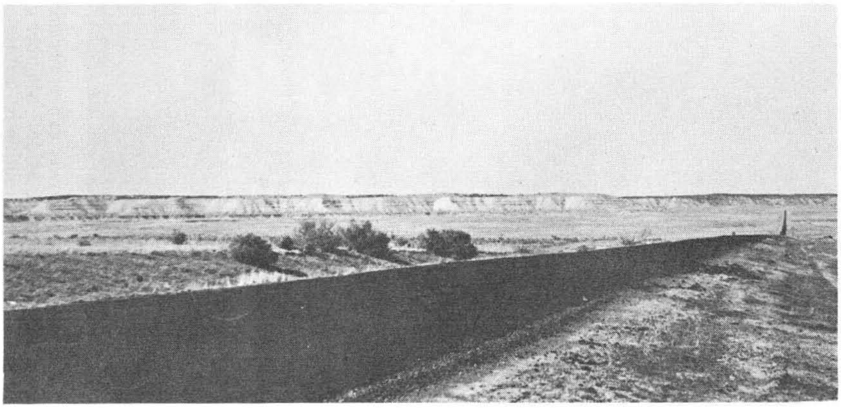

Plate 23. Light-colored cliffs of Roberts Mesa are formed by sedimentary rocks of the Tertiary (Pliocene) Bidahochi Formation. Navajo Indian Reservation. Looking north.

DETAILED LOG

Arizona Highway 177

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

Mileage for the northbound trip is given in the left hand margin as a cumulative mileage from the point of beginning to the point being discussed (Total). The Mileage Interval between each point of discussion is recorded in the center of the page.

Cumulative mileage for the southbound trip is tabulated in the right-hand margin, for which the user should start at the end of the log and read upward.

MILES NORTH-WARD Total	Mileage Intervals	MILES SOUTH-WARD Total
	0.0	

0.0 Junction of State Highways 77 & 177. Highway 177 extends from Winkelman at its southern end to Superior, which lies 32 miles to the northwest. **32.6**

Winkelman, Arizona. Elevation 1928 feet. Post office established in 1905 and named after Peter Winkelman, a stockman. It was established along a branch of the Arizona and Eastern Railroad as a business center for local settlers (14).

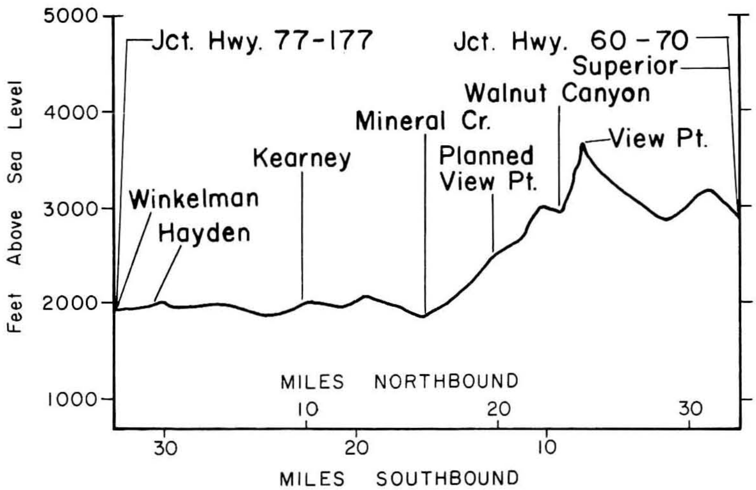

Figure 5. Profile along Arizona Highway 177 showing topographic and geographic highlights. View looking westerly.

0.3

0.3 Enter southern limits of Hayden, Arizona. Elevation 2051 feet. Post office established in 1910 and named after Charles Hayden, a principal of the mining company of Hayden, Stone and Company. A mill and smelter were built. Today, Hayden is the site of a mill and two smelters. A mill and smelter are operated by the Kennecott Copper Corporation to handle ore from its mining operations at Ray, north of Hayden. The other smelter is operated by the American Smelting & Refining Company (ASARCO), which treats copper-bearing concentrates produced from several mine-mill complexes in southern Arizona. **32.3**

1.0

1.3 Side road to the northeast to the smelter-mill area. To the west is a dam that surrounds a large tailings disposal pond. **31.3**

0.1

1.4 The large building east of the road houses a crushing plant that handles Kennecott Copper Corporation ore that is dumped along the railroad immediately to the west. From the crushing plant, the ore is transferred to the concentrator via a conveyor belt that is one-fourth mile in length. **31.2**

0.1

1.5 Side road to the northeast leads to the Hayden business area. **31.1**

0.2

1.7 Overhead pipe system carries tailings (waste material) from the concentrator to the tailings pond for disposal. **30.9**

0.1

1.8 Side road to the northeast. Cliffs in the Dripping Spring Mountains to the east are formed by the Mississippian Escabrosa Limestone. The overlying Naco Limestone of Pennsylvanian age is noticeably thin bedded, which contrasts with the more massive Escabrosa Limestone. **30.8**

0.4

2.2 Boundary between Gila County to the south and Pinal County to the north. **30.4**

0.8

3.0 Southern Pacific Railroad crossing. Embankment to the southwest confines a tailings disposal pond. **29.6**

1.7

4.7 The highway is traversing the valley of the Gila River that lies between the Tortilla Mountains to the southwest and the Dripping Spring Mountains to the northeast. Whereas the Dripping Spring Mountains are composed largely of Paleozoic rocks with some Precambrian units, the Tortilla Mountains consist largely of rock units **27.9**

of Precambrian age that have been steeply tilted. Road cuts expose Cenozoic valley fill gravel deposits that are relatively undeformed. Vegetation consists largely of palo verde, cholla cactus, creosote bush, saguaro cactus, and small shrubs and grasses (See Plate 24).

3.3

8.0 To the east are excellent exposures of cliffs carved from Cenozoic deposits. In deposits of this type, it is frequently instructive to make a statistical study of the arrangement of and the rock types that make up the pebbles, cobbles, and boulders. If the deposits are younger than the adjacent mountains, then they should contain the same rock types that make up the mountains. Such studies help lead to a reconstruction of source areas and drainage directions. Locally, the bottomland of the valley supports agriculture. **24.6**

0.6

8.6 Abundant mesquite is an indication of near surface moisture. **24.0**

0.4

9.0 One half mile to the south are steeply tilted, light-colored, Cenozoic gravel deposits (Plate 24). This is an interesting geological occurrence in that it is indicative of relatively recent earth movements. **23.6**

0.7

9.7 Side road to the south to Kearny. Elevation 2070 feet. Founded in 1958 as a modern town for persons working in the local mineral industry. **22.9**

0.8

10.5 High school to the west. **22.1**

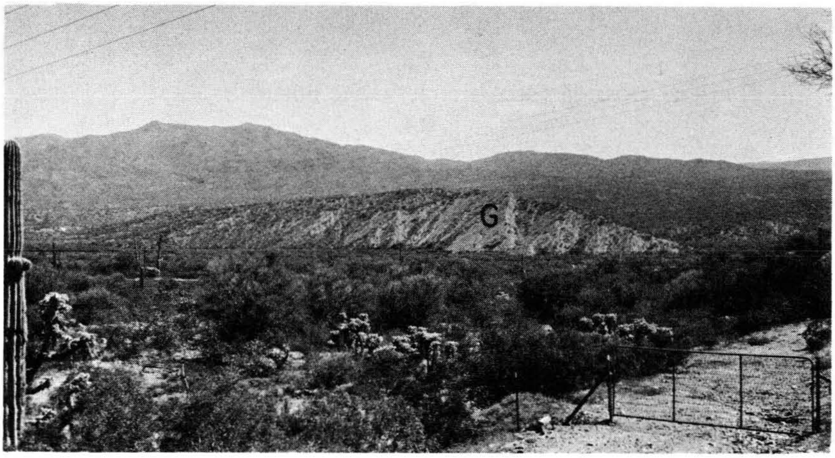

Plate 24. Tilted Cenozoic gravels (G) form a hogback along west side of the Gila River. Tortilla Mountains in distance. Saguaro cactus at extreme left edge and in middle distance. Looking southwest.

1.0

11.5 To the southwest, across the river, the light-colored ridge in the foreground is severely fractured, Paleozoic limestone. Precambrian and younger granitic rocks form the high skyline of the Tortilla Mountains. 21.1

1.7

13.2 Side road to Kelvin to the south. 19.4

0.1

13.3 The Dripping Spring Mountains to the north consist principally of Paeozoic limestones. The light-colored cliffs are characteristic of the Mississippian Escabrosa Limestone. 19.3

1.0

14.3 Community to the southwest is Kelvin, an old mining town. A post office and stage station at Riverside (changed to Kelvin in 1900) were established in 1877 (14). The old town area now serves as home sites for local families. 18.3

The Gila River turns to the west at this point and cuts across the trend of the mountains. The Southern Pacific Railroad follows the path cut by the river.

0.7

15.0 The abandoned concrete structure to the west is an ore bin that accompanied a mill used in the early 1900's. It was served by a narrow gauge railroad. 17.6

0.4

15.4 Contact area (actual contact not well exposed) between Cenozoic valley fill deposits to the south and Precambrian granitic rock to the north. 17.2

0.6

16.0 Railroad crossing (serves mine to the north). 16.6

0.1

16.1 Bridge over Mineral Creek. The creek was named by Major Emory in 1846 when he and his Boundary Survey party noted "indications of gold and copper ores" (14). 16.5

The discoloration along the creek is caused by iron salts.

0.3

16.4 Side road to the east leads to Kennecott Copper Corporation's Ray Mines Division mine and headquarters area. Paleozoic carbonate rocks are exposed in th Dripping Spring Mountains to the east. 16.2

0.6

17.0 Road cut is in diorite of Laramide age. 15.6

0.2

17.2 To the west, the Tortilla Mountains are composed of Precambrian granitic rock which is locally cut by light-colored dikes of Lara- 15.4

mide age. The extensive mineralization of this region was developed largely in Laramide time.

To the east, in the center of the valley, are Cenozoic gravel cliffs and isolated peaks and buttes. The tops of these gravel features are at similar elevations suggesting the existence of a former surface that has been dissected as a down cutting response to uplift of the region. The remaining gravels are probably about 2000 feet thick as they extend at least 1500 feet (as determined by drilling) below the level of Mineral Creek (22).

0.3

17.5 Road cut exposes Precambrian granitic rock. **15.1**

0.5

18.0 Light-colored coarsely crystalline Precambrian granitic rock. The mining area of the Ray Mines Division, Kennecott Copper Corporation, is to the east in the valley of Mineral Creek. **14.6**

0.7

18.7 Road cuts are in Precambrian granite. **13.9**

0.3

19.0 The fill material (dump) to the east is mine waste. Some of this is treated to remove soluble copper. **13.6**

0.3

19.3 The Pearl Handle Pit is in the valley to the east. **13.3**

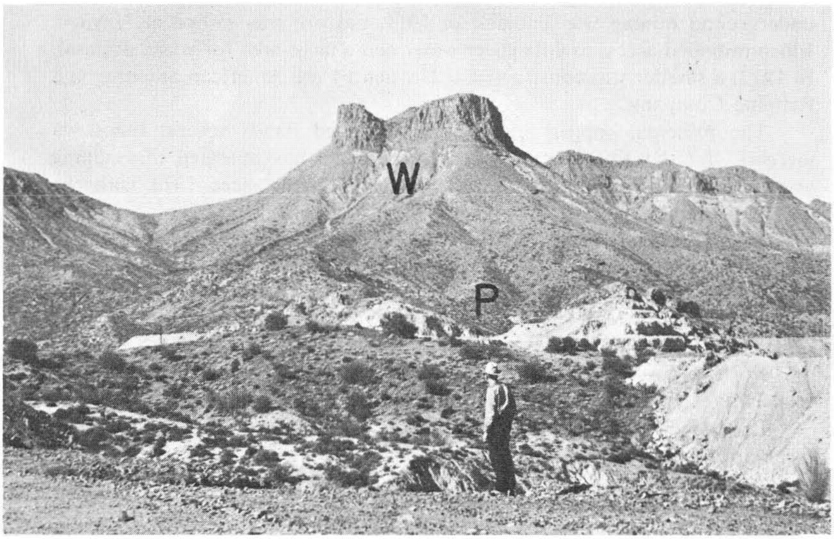

Plate 25. Teapot Mountain at center is capped by Tertiary dacite that overlies the light-colored Tertiary Whitetail Conglomerate (W). Lower slopes are Precambrian Pinal Schist (P). Mining activity is that of the Ray Division, Kennecott Copper Corporation. Looking north.

0.1

19.4 Side road to Sonora, a largely abandoned town founded in 1912 by Mexican employees of the now defunct Ray Consolidated Copper Company. 13.2

Teapot Mountain is the high peak to the north (Plate 25). The cap rock is Tertiary dacite which overlies the Tertiary Whitetail Conglomerate. Here the Tertiary rocks unconformly overlie Precambrian Pinal Schist.

0.3

19.7 The approximate location of a turnoff to a proposed observation point overlooking the open pit mine situated in the valley to the east. To the west is Granite Mountain. It consists partly of a Laramide granitic rock (quartz monzonite porphyry) that intrudes the Pinal Schist. The prophyry is thought to be intimately related to the copper mineralization in this district. Ore is currently being mined from two pits, the Pearl Handle and the West Pit. In 1964, about 35,000,000 short tons of material were handled to produce in excess of 116,000,000 pounds of copper valued at close to $19,000,000. 12.9

Some of the dumps are being treated (leached) to remove and recover soluble copper.

MINERAL CREEK DISTRICT (23)

Production from the Mineral Creek District is attributed largely to mining at Ray, Arizona. Attempts at copper mining in the district were initiated in 1880, but silver prospectors were on the scene even earlier. Large scale underground mining was initiated in 1911 and ore was milled at Hayden, which provided access to Gila River water and a large area for waste disposal. In 1912, a smelter was constructed at Hayden by the American Smelting and Refining Company.

The principal copper property has changed hands several times via mergers, but the Kennecott Copper Corporation has operated this mining venture since 1933. Production has been continuous since 1911 with the exception of but one year.

In 1948, it was decided to convert the mine from an underground to an open pit operation, and this was completed in 1955. Copper is the principal metal produced, but the by-products gold and silver are significant. Facilities have recently been installed at Hayden to produce also a molybdenite concentrate.

For a discussion of the geology of the Ray copper deposit, the interested reader is referred to the literature (**15**).

Following is the recorded production for the Mineral Creek District through the year 1964:

Commodity	*Production*	*Value*
Copper	2,984,646,331 pounds	$638,748,537
Gold (1911–1957)	35,253 ounces	1,032,771
Silver (1911–1957)	2,941,760 ounces	2,421,110
Lead (1911–1957)	11,634,270 pounds	1,165,756
Zinc (1911–1957)	260,000 pounds	30,995
	Total of public record	$643,399,169

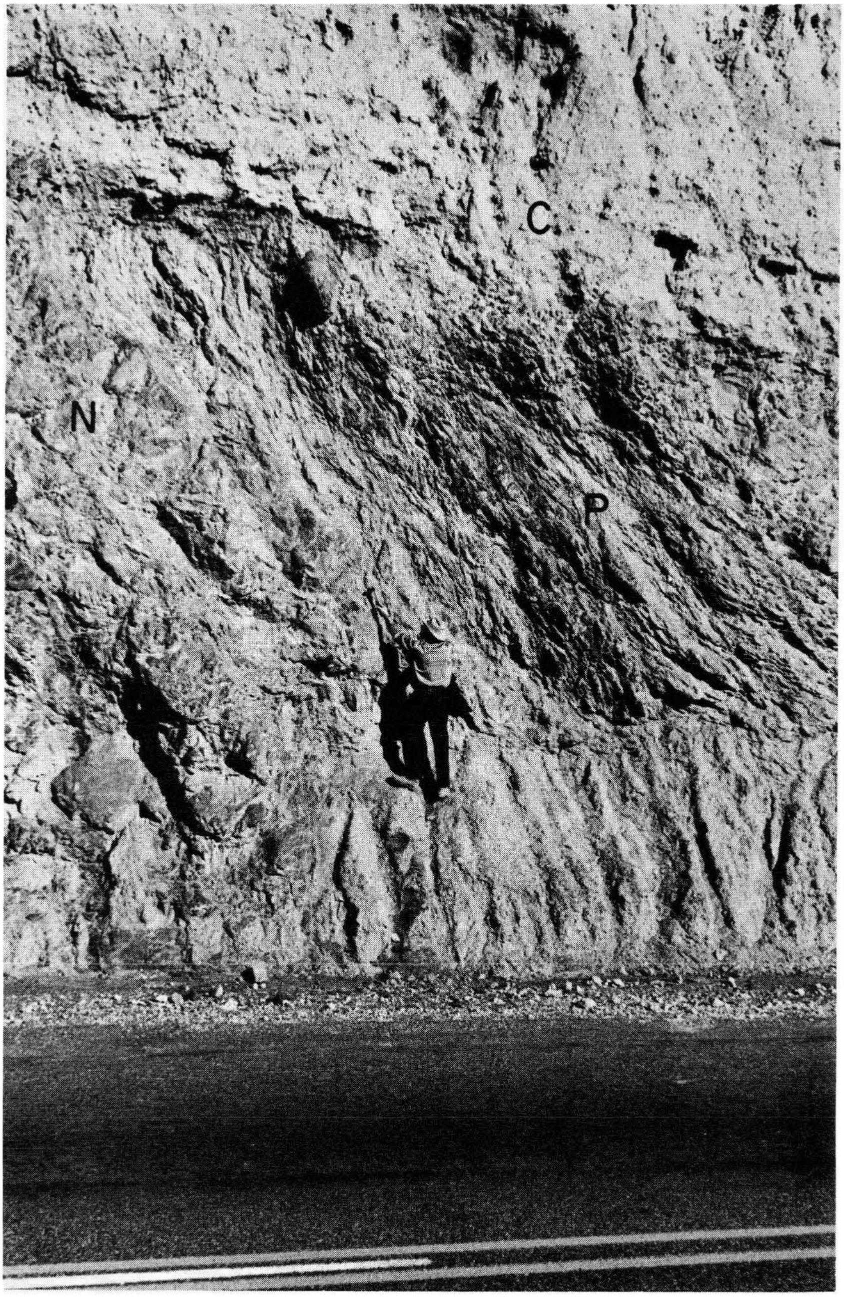

Plate 26. Walnut fault zone. Precambrian Pinal Schist (P) is against broken Pennsylvanian strata of the Naco Limestone (N). Cenozoic deposits (C) unconformably overlie both units. Looking east.

0.5

20.2 To the east is the Kennecott Copper Corporation's West Pit. 12.4

0.2

20.4 To the north is reddish, mineralized, Precambrian Pinal Schist. The red color is iron oxide that results from the oxidation of iron pyrite. 12.2

0.3

20.7 Road cut is an example of unmineralized Pinal Schist. 11.9

0.2

20.9 The two peaks to the north are capped by Tertiary dacite, a volcanic rock. The Tertiary Whitetail Conglomerate underlies the dacite. Mile post 157. 11.7

0.5

21.4 Side road to Ray. 11.2

0.2

21.6 Road cuts are in bluish grey Pinal Schist. 11.0

0.4

22.0 Limited exposure of the Laramide age Granite Mountain Porphyry, a quartz monzonite that gives an age of 63 million years by the potassium-argon method on biotite mica (24). This intrusive igneous rock is closely related to mineralization in the Mineral Creek District. 10.6

0.1

22.1 Schist. Side road to Copper Butte. Grade summit. 10.5

0.4

22.5 In distance to the west is Hell's Peak, a Tertiary rhyolite plug. 10.1

0.7

23.2 Walnut Canyon. The canyon to the east of the road marks the position of the Walnut Canyon fault. The effect of the fault is to place the Precambrian Pinal Schist on the south against the carbonate rocks of the Pennsylvanian Naco Limestone on the north, a relative vertical displacement of at least 4000 feet (25). 9.4

0.5

23.7 Whitish material is a travertine spring deposit resulting from springs which are now inactive. 8.9

0.1

23.8 Walnut Creek fault zone is exposed in east road cut (Plate 26). 8.8

0.1

23.9 Light-colored carbonate strata belong to the Pennsylvanian Naco Limestone. 8.7

0.3

24.2 West road cut exposes shattered quartzite, probably Precambrian Troy Quartzite. 8.4

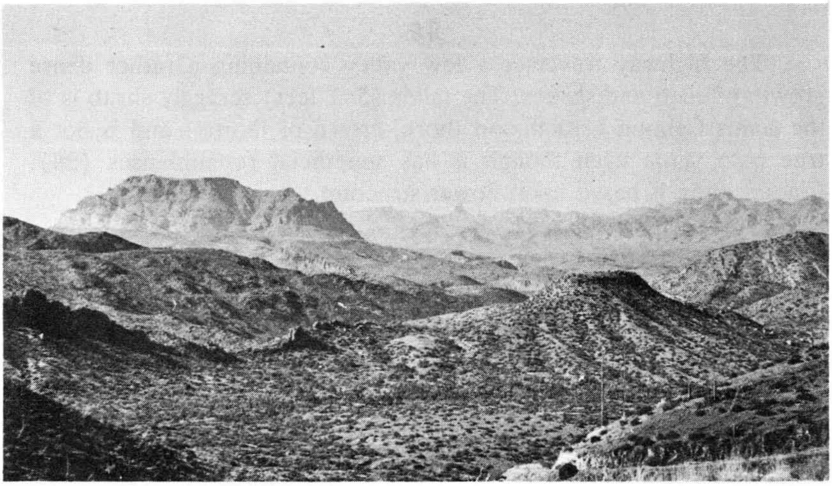

Plate 27. Pickett Post Mountain (an igneous plug) at left center with Weavers Needle (at center) in the Superstition Mountains approximately twenty-five miles distant. Looking northwest.

0.3

24.5 Summit. High cuts are in the Mescal Limestone of the Precambrian Apache Group. Two faults are well exposed by the cut and each is occupied by a fine-grained, relatively dark, igneous rock. **8.1**

0.1

24.6 Excellent view to the north toward Pickett Post Mountain and the Superstition Mountains. The distant, high spine to the right of Pickett Post Mountain is Weaver's Needle in the Superstition Mountains (Plate 27). Both are volcanic features. **8.0**

0.2

24.8 Mile post 161. Diabase is exposed in road cuts. The diabase is a Younger Precambrian intrusive igneous rock that is intimately associated with the Apache Group throughout central Arizona. **7.8**

0.1

24.9 West side road cut exposes ripple-marked surfaces of steeply dipping Dripping Spring Quartzite. These ripples are products of wave or current action at the time of deposition when the sand was loose and uncemented. Earth movements have subsequently tilted these strata to their present position. **7.7**

Barnes Conglomerate in east road cut. This conglomerate at the base of the Dripping Spring Quartzite, though thin, is widespread and is an invaluable marker or reference unit in central Arizona (See Plate 7). It is underlain by the dark-colored Pioneer Shale of the Apache Group.

0.6

25.5 The highway traverses a low valley containing a rather dense growth of cacti and shrubs. The taller (5–7 feet) scraggly shrub is of the genus Canotia (crucifixion thorn, crown of thorns) and is not a true palo verde even though it has superficial resemblances (**26**). Classification is based upon flower structure. **7.1**

0.3

25.8 Mile post 162. **6.8**

1.0

26.8 To the east along the road Tertiary dacite overlies pink to tan sediments of the Tertiary Whitetail Conglomerate. **5.8**

The north-south trending Concentrator fault zone lies east of the highway which, at this point, is traversing the western down dropped block. This fault zone has been mapped for a length of at least 15 miles and effects a vertical displacement of at least 2000 feet (**25**). The fault is younger than the copper mineralization in the region. Its most obvious manifestation is the displacement of the Apache Leap dacite down to road level.

0.5

27.3 Dacite exposed in road cuts. **5.3**

1.5

28.8 Devonian Martin Limestone is exposed in the north road cut. Mile post 165. **3.8**

0.3

29.1 Brown knob to the west is dacite overlying the Mississippian Escabrosa Limestone. **3.5**

1.0

30.1 To the east is Apache Leap, a cliff of Paleozoic carbonate rocks capped by Tertiary dacite. Darker-colored quartzites are in the foreground whereas the highway is in Precambrian diabase. **2.5**

0.2

30.3 Diabase road cut. **2.3**

0.4

30.7 Precambrian diabase in road cut. Mile post 167. **1.9**

0.9

31.6 Cattle guard. **1.0**

0.2

31.8 The light-colored scars near the base of Pickett Post Mountain (an eroded, rhyolitic volcanic vent) to the west are perlite quarry sites. Perlite is a volcanic glass that "pops" (expands) like popcorn when heated. The resulting material is used as light-weight aggregate in building materials, and as a soil conditioner. **0.8**

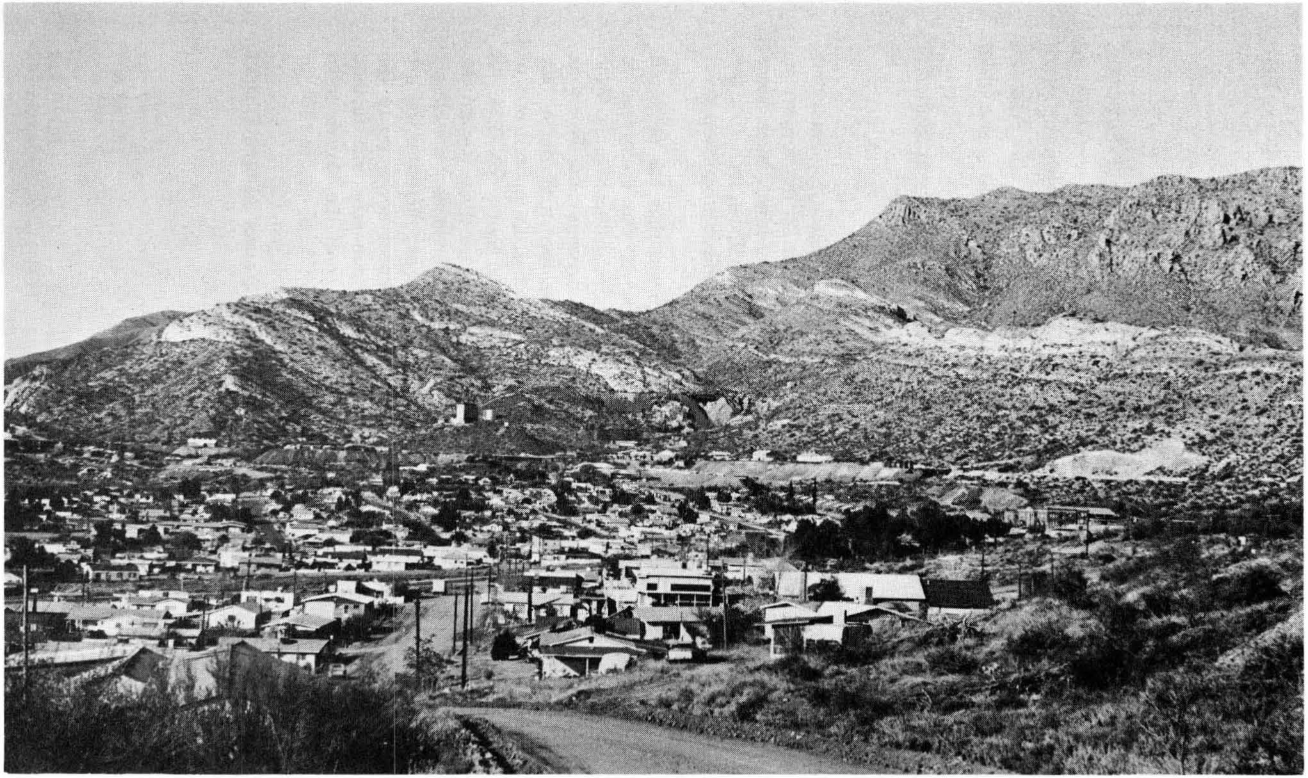

Plate 28. Superior, Arizona, is a mining town centered around the Magma underground mine operated by the Magma Copper Corporation. The light-colored strata are Paleozoic units that have been tilted towards the east. Looking north.

0.3

32.1 The cross to the east above the road is on slabby, light gray, Precambrian Troy Quartzite. **0.5**

0.4

32.5 Overpass over U.S. Highway 60–70. **0.1**

0.1

32.6 Mile post 169. North end of State Highway 177 at Superior. **0.0**

Superior, Arizona. Elevation 2888 feet (Plate 28). Although the post office was founded in 1902, there was a community here prior to 1882. The name "Superior" was derived from the Arizona and Lake Superior Mining Company upon whose operations the town depended (14).

Apache Leap is a prominent feature to be seen near Superior (Plate 29).

PIONEER MINING DISTRICT

The Pioneer Mining District embraces a region around Superior that has a long history of mining activity. Although at least 20 mines were in operation in 1937, only one, the Magma Mine, now is active. Other mines within the district have been relatively small and shortlived such that the districts production figures, presented below, largely reflect production from the Magma Mine.

The Magma Mine is an underground development that has produced continually since 1910, although the original prospect was discovered in 1875 and was known as the Silver Queen. Copper ore in the Magma Mine occurs in two principal ways, fault-related vein deposits and limestone replacement bodies. The vein deposits have been developed from the surface to a depth of 4900 feet whereas the replacement bodies, at the east end of the property, are developed between the 2000 and 3600 foot levels (27). As can be seen at the surface, the Paleozoic limestones are tilted toward the east approximately 30 degrees (Plate 28). The replacement deposits closely follow certain strata in the Devonian Martin Limestone; therefore the ore bodies become progressively deeper as they are followd down dip to the east. How far they can be followed is dependent upon economic factors. Additional ore has been discovered replacing portions of the Mississippian Escabrosa Limestone and it is hoped it will materially increase the life of the Magma Mine at which over 700 persons are employed (28).

Following is the estimated production for the Pioneer Mining District through the year 1964:

Commodity	*Production (1875–1964)*		*Value*
Copper	1,490,377,259 pounds		$301,957,591
Gold	477,433 ounces		15,142,607
Silver	34,668,406 ounces		27,865,653
Lead[1]	3,928,520 pounds		357,380
Zinc[1]	74,503,000 pounds		8,710,511
		TOTAL	$354,033,742

[1] Not currently being produced

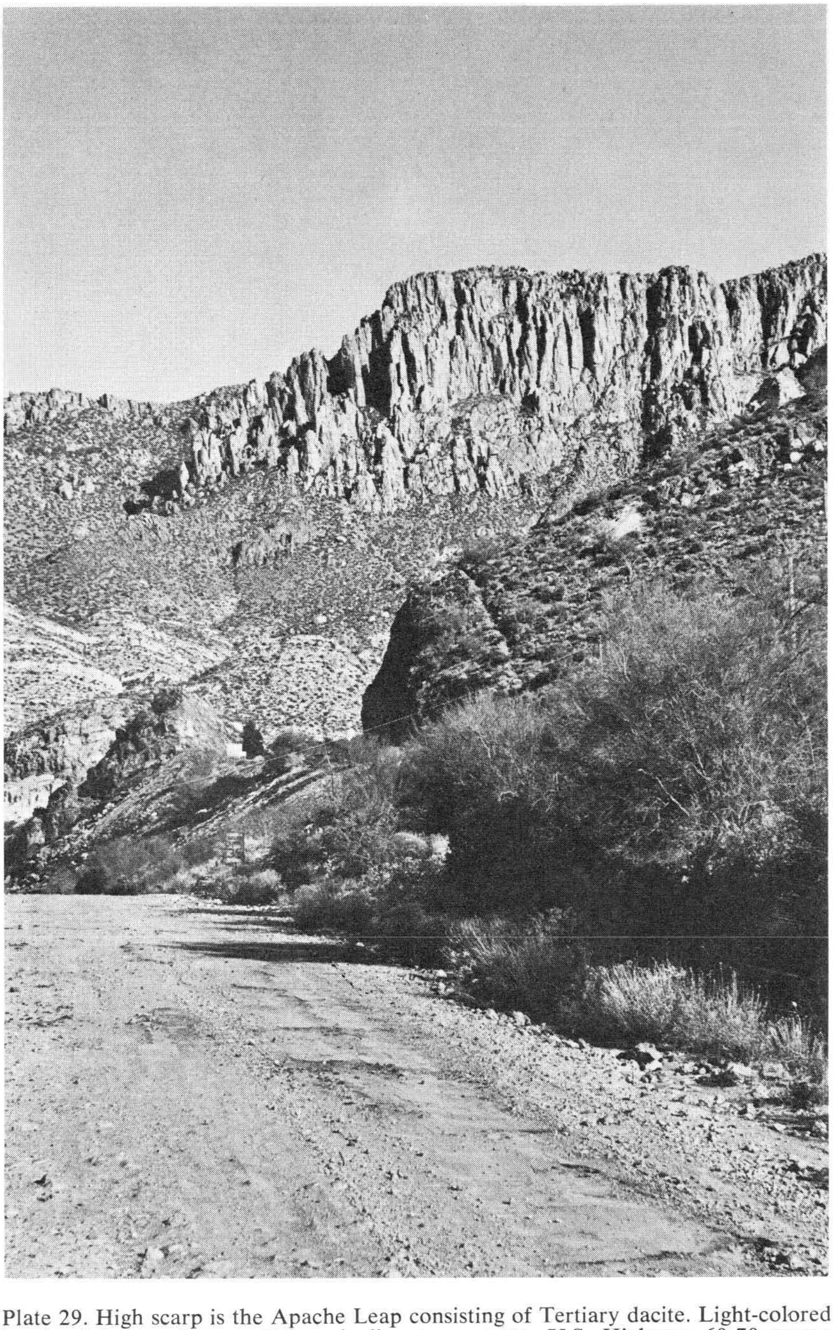

Plate 29. High scarp is the Apache Leap consisting of Tertiary dacite. Light-colored bands at left center are Paleozoic limestone strata. U.S. Highway 60-70 passes through deep road cut in middle foreground. Looking east.

APPENDIX

GLOSSARY OF SELECTED TERMS

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

Anticline. An upfold or arch in layered rocks.

Apache Group. A name given to a conformable and closely related group of formations of Younger Precambrian age.

Aplite. Finely crystalline, light-colored igneous rock that usually occurs as dikes in granitic rocks.

Asbestos. From the Greek for incombustible. Applied to fibrous varieties of amphibole low in alumina and, popularly, to fibrous serpentine (chrysotile) in Arizona.

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. 3) is divided; approximate age, 490 million to 600 million years.

Cenozoic. The youngest of the geologic eras (Fig. 3); approximate age, 0–70 million years.

Chert. A dense, siliceous rock frequently found in limestone.

Cinder Cone. A volcanic cone composed of vesicular lava, clinker-like material, or ash.

Conglomerate. A sedimentary rock made up in part of large rounded fragments of other rocks.

Cretaceous. The latest geologic period within the Mesozoic era (Fig. 3); approximate age, 70 million to 135 million years.

Cross-stratification. Stratification inclined to the true bedding or attitude of the formation as a whole.

Dacite. A generally light-colored volcanic rock containing plagioclase feldspar and quartz as essential minerals.

Diabase. A dark-colored basic igneous rock that usually occurs as dikes or sills and has a particular mineralogical composition characterized by augite and laths of plagioclase feldspar.

Diatomaceous earth. A fine-grained siliceous deposit consisting of a high proportion of the microscopic sized skeletons of diatoms.

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

Diorite. A granitic rock having a particular composition range more basic than granite.

Extrusive. Usually applied to a volcanic rock that has accumulated at the earth's surface.

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.

Fold. A bend in layered rocks.

Formation. A stratigraphic term applied to a set of strata having certain similar characteristics.

Fossil. A record or an indication of ancient life.

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

Granitic. Granite-like in texture.

Gypsum. A substance composed of calcium, sulfur, oxygen, and water, that usually accumulates in response to evaporation of standing water.

Igneous. Literally, "fire-formed." Igneous rocks form by the cooling of molten rock material.

Intrusive. An igneous rock that invades other rocks but cools below the surface of the earth.

Jurassic. The second period in the Mesozoic era (Fig. 3); approximate age, 135 million to 180 million years.

Laramide. A time embracing the latter part of the Mesozoic and the early part of the Cenozoic (Fig. 3), characterized by extensive igneous intrusion, extrusion, earth movements, and mineralization in the Rocky Mountain region.

Limestone. A sedimentary rock composed largely of calcium carbonate (calcite).

Mesozoic. The geologic era between the Paleozoic and Cenozoic (Fig. 3); approximate age, 70 million to 200 million years.

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

Mineralization. The process or processes by which minerals of economic interest are added to rocks.

Mississippian. A period in the Paleozoic era (Fig. 3); approximate age, 320 million to 350 million years.

Ore. Mineralized rock from which a substance of value can be economically extracted.

Paleozoic. An era (Fig. 3); approximate age, 220 million to 600 million years.

Pennsylvanian. A period in the Paleozoic era (Fig. 3); approximate age, 270 million to 320 million years.

Period. In geology, the next lesser subdivision of an era (Fig. 3).

Permian. The last period in the Paleozoic era (Fig. 3); approximate age, 200 million to 270 million years.

Pleistocene. The first epoch of the Quaternary period (Fig. 3); approximate age, 11 thousand to 1 million years.

Pliocene. Last epoch in the Tertiary period (Fig. 3); approximate age, 1 million to 12 million years.

Plug. Solidified core of igneous material in the throat of an old, eroded outlet.

Porphyry. An igneous rock in which certain well-developed crystals (phenocrysts) are enclosed in a fine-grained matrix.

Precambrian. The oldest geological time division that is variously (Fig. 3) subdivided; approximate age, 600 million years to some point in excess of 2 billion years (origin of the earth).

Quartz monzonite. A granitic igneous rock having a particular composition range and is frequently associated with Arizona's large copper deposits.

Quartzite. A dense, hard quartz-rich rock produced from a sandstone by various processes.

Quaternary. The last period in the Cenozoic era that includes the present (Fig. 3); approximate age, the last 1 million years.

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 metamorphic rock characterized by a platy structure.

Sill. A sheet of igneous rock that has solidified between layers of conformable strata.

Tertiary. The first period in the Cenozoic era (Fig. 3); approximate age, 1 million to 20 million years.

Triassic. The earliest geologic period within the Mesozoic era (Fig. 3); approximate age, 150 million to 220 million years.

Unconformity. An erosional break or hiatus in the continuity of sedimentation, a significant missing record between two rock units.

Volcanic. Pertaining to features or rocks resulting from the surface or near surface eruption and cooling of once molten material.

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THE ARIZONA BUREAU OF MINES

The Arizona Bureau of Mines was created in 1915 and placed under the authority of the Arizona Board of Regents by an act of the State legislature. Under the functions mandated by the enabling legislation, the Bureau regularly provides wide ranging service in the fields of geology, metallurgy, and mining in response to both public inquiries and requirements of the management agencies of State government. In order to carry out these diverse functions, two basic operational subdivisions have been established in the Bureau.

GEOLOGICAL SURVEY BRANCH

This branch is charged with the responsibility of acquiring, disseminating, and applying basic geologic data that are designed to (a) enhance our understanding of Arizona's general geologic and mineralogic history and to assist in determining the short and long range influence these have on human activity and the relative merits of alternative land use plans, and (b) assist in developing an understanding of the important controls influencing the location of both metallic and nonmetallic mineral resources and mineral fuels in Arizona.

MINERAL TECHNOLOGY BRANCH

This branch conducts research and investigations into, and provides information about the development of Arizona's mineral resources, including the extraction, refinement, and utilization of metallic and nonmetallic mineral deposits. These activities are directed toward the efficient recovery of Arizona's mineral resources as well as insuring that the recovery methods will be compatible with the environmental aspects of the state.

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