Bulletin 184

GEOLOGIC GUIDEBOOK 4 - HIGHWAYS OF ARIZONA
ARIZONA HIGHWAYS 87, 88 AND 188

by

Chester F. Royse, Michael F. Sheridan, and H. Wesley Peirce

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GEOLOGIC GUIDEBOOK 4 - HIGHWAYS OF ARIZONA
ARIZONA HIGHWAYS 87, 88 AND 188

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INTRODUCTION

Purpose and Scope

Arizona is truly a land of scenic beauty and geologic marvels. The arid climate and great relief combine to expose geology in a dramatic fashion equaled by few other places in North America. This guidebook is the fourth of a series being issued by the Arizona Bureau of Mines to acquaint tourists and residents of this state with its geology. It is hoped that the text will appeal to the amateur and layman as well as professional geologists and engineers. This is not a textbook, however, and the conceptual aspects of geologic phenomena are not treated in detail. The reader should consult introductory textbooks to learn such things as why volcanoes erupt and mountain ranges rise. What we have attempted to do is to call to the attention of the public specific examples of geology which occur along our highways. We hope this will make your trip a little more satisfying.

Location and Extent

State Highway 88 originates at Apache Junction, east of Phoenix and terminates between the towns of Globe and Miami about 50 miles to the east. The portion of the highway between Apache Junction and Roosevelt Dam is known as the Apache Trail, and is a noted tourist route. Highway 188 begins at Roosevelt Dam and extends northward through the Tonto Basin for 40 miles where it joins Highway 87 (Fig. 1). The latter is the main route between Mesa and Payson and is locally known as the Beeline Highway. The overall distance covered by this roadguide is about 140 miles. Highways 88 and 188 are unsurfaced throughout their greater extent, but are well maintained and are generally serviceable in all weather. Highway 87 is paved the entire way from Payson to Mesa. No towns and only a few villages exist along this route. Food, gas and other services are available at only two localities along the lower part of the Apache Trail and at Punkin Center in the northern Tonto Basin. The village of Sunflower and a gas station at the Verde River provide the only services along the portion of the Beeline Highway covered by this guide.

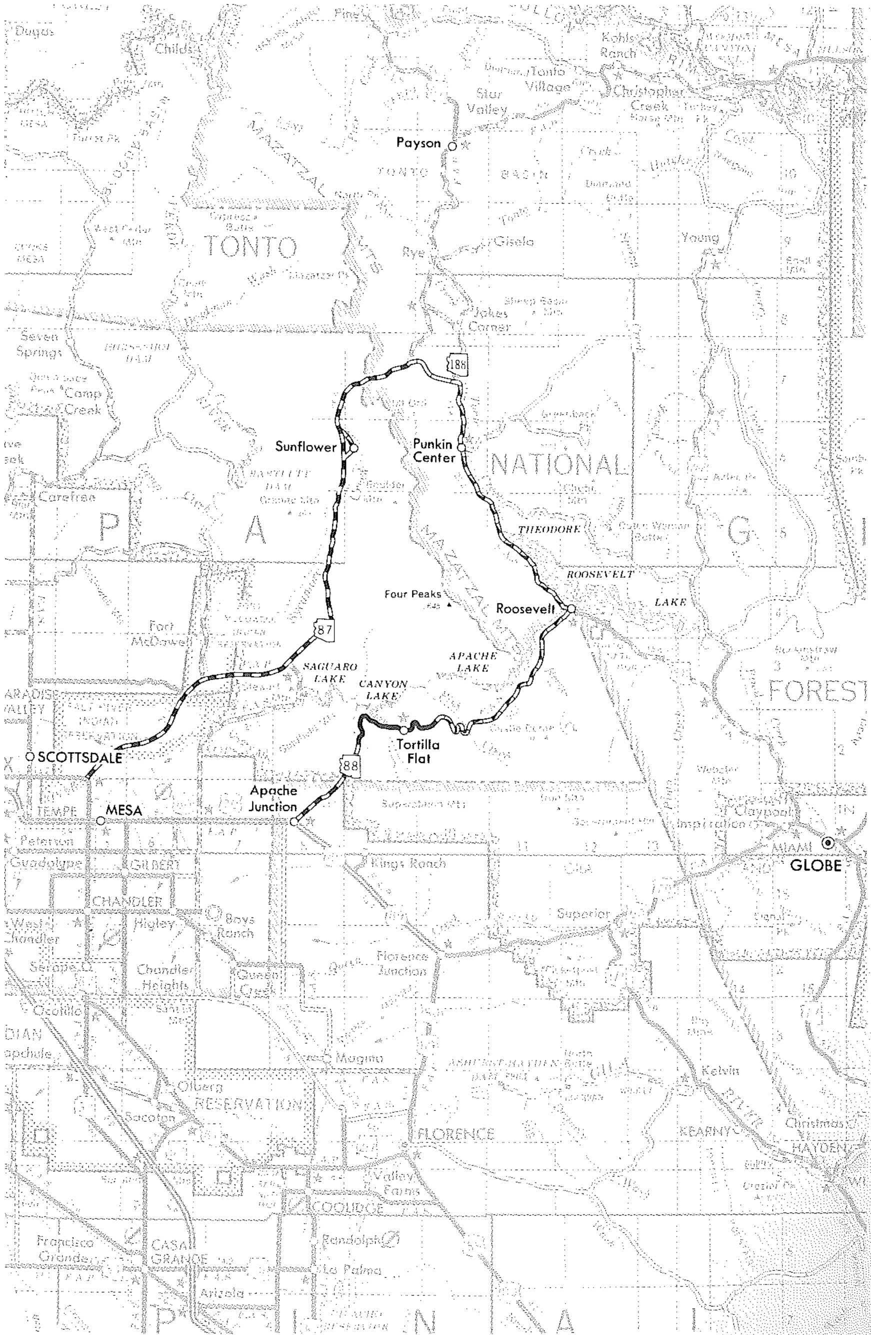

Figure 1. Index map showing route of the portions of Highways 87, 88 and 188 covered in this guidebook.

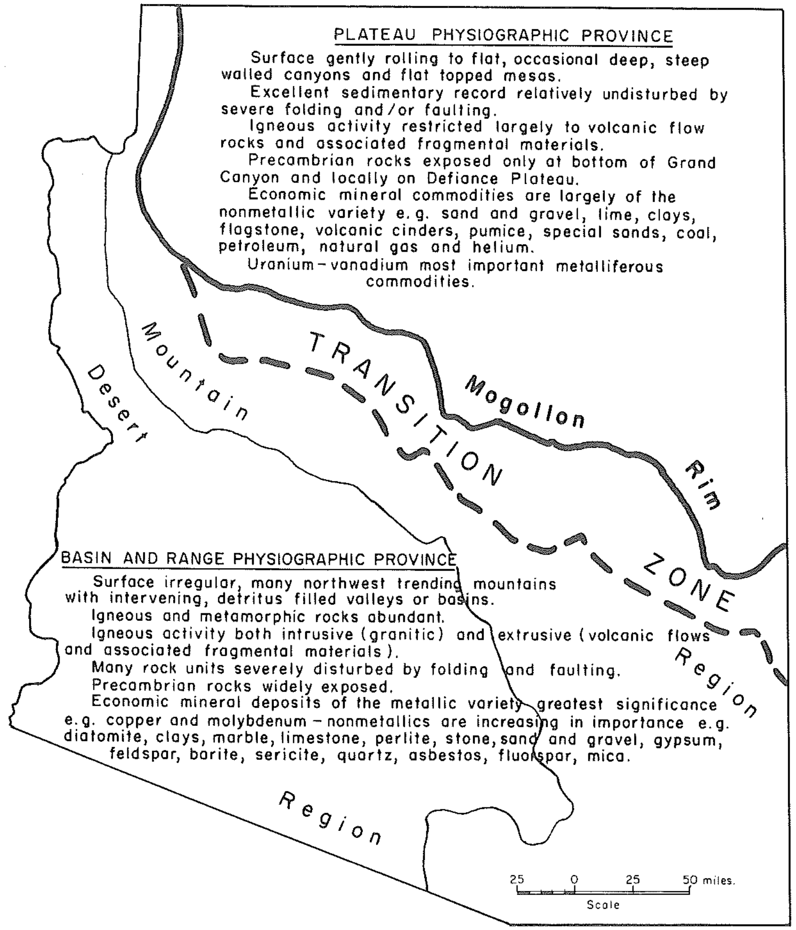

Figure 2. Physiographic subdivisions of Arizona.

Physiographic Setting

Arizona is divided into two main physiographic provinces, the Colorado Plateau province on the north and the Basin-and-Range province in the south (Fig. 2). The Plateau province is bounded on the south by the Mogollon Rim, a striking escarpment which trends southeastward across the state. Wilson and Moore (1959) defined a Transition Zone between the two major provinces which is characterized by canyons and large structural troughs, such as the Tonto Basin. The Basin-and-Range province is subdivided into a desert region and a mountain region. The boundaries between these subdivisions are not sharply defined, but they are useful generalities for describing the physiography of Arizona.

This guidebook begins and ends in the desert region near Phoenix, but most of its extent lies within the mountain region and the Transition Zone. The principal ranges encountered are the Superstition-Goldfield complex, and the Mazatzal and Sierra Ancha mountains. The major depression is the Tonto Basin, although smaller, deformed basins along the western flank of the Mazatzal Mountains are traversed by the Beeline Highway.

Most of this route is within the Tonto National Forest and is essentially a wilderness area. No industries or large mines are present along the route, but the economic value of the area is clearly manifested by the dams and reservoirs along the Salt River and its tributaries. Although a few irrigated hay fields can be seen along the way, agriculture is not a principal livelihood. Most residents are cattle ranchers or employees of the Forest Service, Park Service, or State Highway Department. In recent years, land development in the Tonto Basin has attracted many people, and rural communities are springing up along Tonto Creek.

Climate

The climate of Arizona varies markedly between the desert, mountain and plateau regions. Although average values of precipitation and temperature may appear quite moderate, daily, monthly and annual values all fluctuate enormously. Representative climatic data are given in Table 1.

Table 1. Climatic data for stations along the route of this road guide (from Green and Sellers, 1964)

Station	*Elevation (feet)*	*Average Annual*			
		Max. Temp. (°F)	*Min. Temp. (°F)*	*Precip. (in.)*	*Snow-Hail (in.)*
Payson	4,848	70.9	34.8	21.48	25.0
Reno Rng. Sta.	2,350	80.9	48.9	18.73	0.6
Roosevelt	2,205	80.7	54.6	15.99	0.3
Mormon Flat	1,715	84.3	59.5	13.21	0.3
Bartlett Dam	1,650	84.6	56.5	11.55	Trace
Mesa	1,225	84.6	51.6	8.06	0.1
Globe	3,540	77.6	47.2	15.7	4.4

The Tonto Basin has a semi-arid climate. Average annual precipitation is about twice that of the desert region to the southwest, but significantly less than that of the adjacent mountains and along the Mogollon

Rim to the north. The principal rainfalls occur during the summer months and are associated with surges of moist tropical air which originate in the Gulf of Mexico. Storms from the Pacific bring in moist air during the winter months of December and January.

Most of the summer precipitation is turbulent and accompanied by high winds. Thunderstorms develop almost daily over the mountains and along the Mogollon Rim. Despite these frequent storms, rainfall in the basin is light due to high rate of evaporation of the rain as it falls; the weather station at the Reno Ranger Station, near Punkin Center, generally records heavy rain only once or twice during the summer months. Winter precipitation is usually of longer duration and more widespread than that in summer. It is also less reliable, and total winter rainfall varies greatly from year to year.

Midsummer temperatures in the Tonto Basin are only slightly cooler than those of the desert region. Daytime maxima are usually close to 100°F and frequently approach 110°F. Nights are somewhat cooler than in the desert, and the temperature normally falls into the sixties before daybreak. Winter temperatures are generally mild from December through February although mild freezes frequently occur at night. Temperatures below 10°F have never been recorded in Tonto Basin, and from the end of March until the second week in November the minimum temperatures are usually above freezing. Afternoon temperatures are generally in the fifties and sixties although readings in the eighties have been recorded even in the coldest months.

Phoenix has a very dry climate and receives less than 7 inches of rain in most years. The weather pattern is much the same as described for the Tonto Basin, and December through February, and July and August are the wettest months. Summer temperatures in Phoenix are among the highest recorded in the State. Afternoon maxima commonly exceed 110°F in mid-summer and night temperatures in the eighties are common. Winter temperatures compensate nicely for the summer extremes. Daily temperatures in the sixties and seventies are common and nights are usually in the high thirties and low forties. Subfreezing temperatures are rare and are generally recorded only between the first week in December and the end of January.

Visitors to the mountain region should be particularly alert to the possibility of torrential downpours with high rates of surface runoff. Cloudbursts not only promote erosion but also pose a real threat of flashflooding. Tourists should keep their campsites well above the floors of small canyons and gullies, particularly during the summer months. Arizonans recall how the extended "Labor Day" rains of 1970 washed out roads and highway bridges and took the lives of many people within the area of this road guide.

Vegetation

The semi-arid to arid climate of Arizona greatly influences vegetation and only species adapted to long dry periods are able to survive. In many parts of the desert region, only sparse stands of creosote bush (greasewood) occur, but in the lower foothills palo verde trees and cacti such as saguaro and jumping cholla are abundant. Prickly-pear cactus thrives on well-drained slopes throughout a wide range of elevation. Along drainages of major streams, thick stands (chaparral) of mesquite, catclaw and mimosa occur. Despite the extreme scarcity of grasses, the Forest Service refers to this vegetation type as "semi-arid grassland." According to the nomenclature of Merriam (1890), this vegetation occurs within the Sonoran life zone.

The upper slopes of the Tonto Basin, the lower slopes of the Sierra Ancha and Mazatzal mountains, and other areas above about 1,100 meters (3,600 feet) are covered by juniper, oak and piñon. This flora occurs within the upper Sonoran life zone of Merriam. The highest elevations of the mountain ranges are within the Transition life zone and support forests of ponderosa pine. Most of this route is within the upper Sonoran life zone, and a varied flora can be studied.

Water Supply

There is very little surface water in the desert region, and the streams flowing into this province from the mountains are quickly lost by evaporation or by infiltration into the permeable sediments of the desert floor. Both the Salt River and its principal tributary, the Verde, have been harnessed by man to provide water and power for much of central Arizona. They provide a striking example of man's ability to modify and control his environment to his benefit. This extensive system of dams, reservoirs and canals (Fig. 3), known as the Salt River Project, is administered by the Salt River Water Users' Association.

The earliest settlers in the Phoenix valley recognized both the need and the feasibility of water control, but it was not until the United States enacted the Federal Reclamation Program in 1902 that financing became possible. This act, championed by Theodore Roosevelt, provided that money from the sale of western public lands could be made available for reclamation projects. To unite the people in a common effort, the Water Users' Association was incorporated in 1903 and represented some four thousand individual landowners. Under this leadership, an agreement was signed with the Federal Government in 1904 providing for the construction of Roosevelt Dam. The estimated cost was $2.7 million which amounted to $15 per acre for the land then involved in the reclamation. Actual construction began in 1905.

During construction of the dam, costs mounted and far exceeded the

Figure 3. Distribution of dams, reservoirs, and canals of the Salt River Project (courtesy of the Salt River Project).

original estimates. By June 30, 1912, expenditures exceeded $9.5 million and were still climbing. Considerable controversy arose between members of the Association and the Reclamation Service. Ultimately, the dam and related facilities cost nearly $10.2 million or $60 per acre for the water user. Despite the fact that costs exceeded estimates four-fold, the landowners completed payment of the Federal loan in 1955.

In addition to regulation of surface water, the Salt River Project owns and operates 243 deep wells in the greater Phoenix area which provide 35–40 percent of the one million acre-feet distributed each year. Communities served by the Project include Phoenix, Glendale, Tempe, Peoria and Gilbert.

GEOLOGIC HISTORY

The vast panorama of geologic history is well represented within the state of Arizona. Rocks ranging in age from Older Precambrian to recent are widely exposed. Along the route of this guidebook, the traveler can see rocks representing each of the principal geologic eras except the Mesozoic. The history depicted by these rocks is, of course, somewhat sketchy and one would have to travel beyond the limits of this guide to get the total picture. The highlights of the geologic history of Arizona have been summarized in Figure 4. Because the greatest extent of this guide traverses the volcanic rocks of the Superstition Mountains and ancient lake beds of the Tonto Basin, a brief summary of the geology of these areas is given below.

The Tonto and Related Basins

No comprehensive study has been made of the Tonto Basin and its origin and history are only vaguely defined. It is a typical down-faulted, sediment-filled, basin-and-range trough lying between uplifted mountain ranges. It is one of several large basins which lie just south of, and parallel to the Mogollon Rim in central Arizona (Fig. 5). To the northwest of the Tonto Basin are the Payson, Verde, and Chino valleys, and to the southeast is the Safford (or San Carlos) Valley. All of these basins are middle to late Tertiary in age and have many common characteristics; the Tonto Basin is best discussed with reference to these related basins.

Preceding tectonic formation of the basins, volcanism appears to have been widespread in central Arizona. Gradual tilting of large fault blocks then produced several major and many minor depressions bordered by elevated ranges (Twenter, 1961). The volcanics, which were severely dislocated by this tectonism, consist largely of basalt, vitric tuff and other pyroclastics, and are imperfectly correlated and dated; collectively they have been referred to as the Hickey Formation and appear to be of Miocene or Pliocene age (Anderson and Creasey, 1958; Sables, 1962; Twenter, 1962). According to Twenter (1962), volcanic rocks equivalent to

Geological Highlights of Arizona

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.
	Quaternary: Pleistocene	1	Stream, river, and lake deposits; Volcanics; Glaciation on San Francisco Peaks near Flagstaff and in White Mountains.		
	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.
	Tertiary: Miocene	23	S. Ariz.— Sediments and Volcanics.	Plateau uplift Volcanism Basin and Range orogeny	
	Tertiary: Oligocene		S. Ariz.— Locally several thousands of feet of non–marine sediments; volcanics.	Local erosion and sedimentation	
	Tertiary: Eocene			Laramide Revolution: Folding and Faulting. Granitic intrusions. Volcanism. Widespread mineral–ization.	
	Tertiary: Paleocene	70			
MESOZOIC	Cretaceous	135	Unconformity 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.
	Jurassic	180	N. Ariz.–2,000 feet largely non-marine sediments. S. Ariz.– Igneous activity.	Nevadan Revolution: Granitic intrusions. Volcanic activity. Some mineralization.	
	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.
	Pennsylvanian	320	Up to 2,500 feet marine sediments. Some oil produced in NE. Arizona.		
	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.	
	Devonian	400	Up to 1,000 feet marine sediments. Some oil produced in NE. Arizona.		
	Silurian		Not known in Arizona.	General Emergence.	
	Ordovician	490	Marine sediments in extreme NW. and SE. corners of Arizona.		
	Cambrian	600	Up to 2,000 feet marine sediments.	First record of abundant life.	
YOUNGER PRECAMBRIAN		1600	Unconformity 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 metamor–phism. Faulted and folded but not severely metamorphosed.	Grand Canyon disturbance.	Primitive Plant Life.
OLDER PRECAMBRIAN		2000 +	Unconformity Several thousands of feet of metamorphosed sediments and volcanics intruded by granite. Severely faulted and folded. Local mineralization e.g. Jerome.	Mazatzal Revolution.	

Figure 4. Geologic time scale.

the Hickey are overlain by fluvial-lacustrine sediments in the Verde, Chino, Lonesome, Walnut Grove, Peeples, and Skull valleys and in the Tonto Basin. He also suggests that no major break occurred between deposition of the volcanics and the basinfill sediments. Evidence within the Tonto Basin indicates that volcanism in that area preceded structural formation of the trough. No volcanic flows are interbedded with the Tonto beds (although ash layers do occur) but basalt is present in older conglomerates along the basin margin which dip steeply beneath the Tonto beds.

Fault displacement appears to be greatest along the southwestern margin of the major structural troughs. Anderson and Creasey (1958) demonstrated 360 meters (1,200 feet) of post-Hickey movement along the southern margin of the Verde Basin; maximum displacement probably

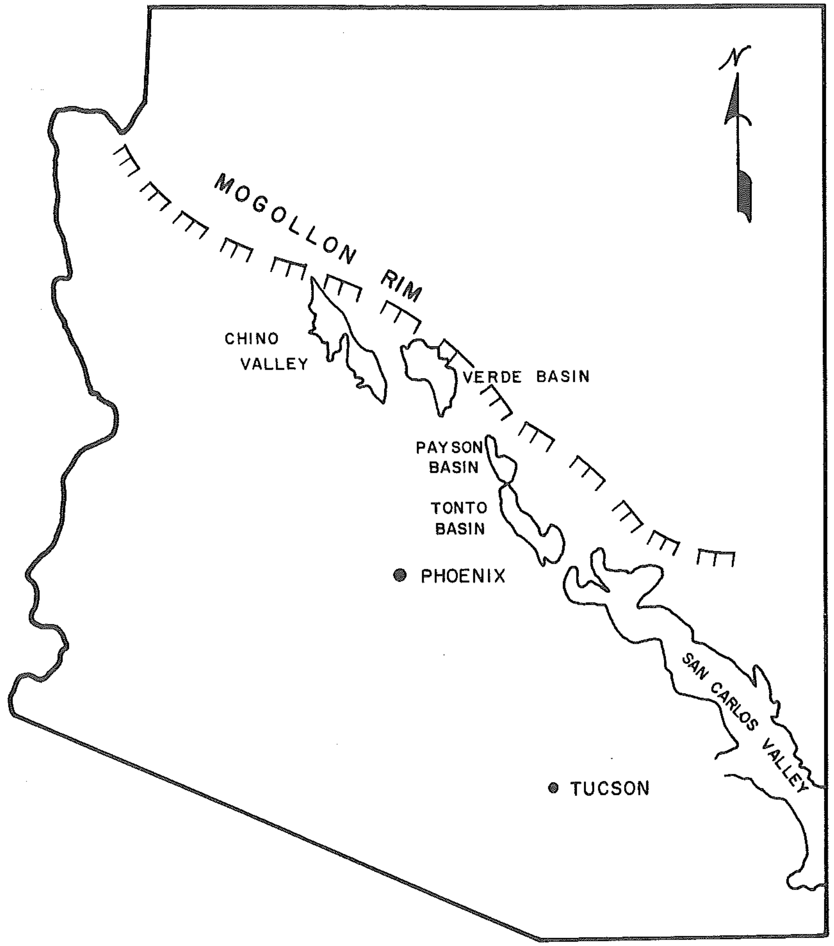

Figure 5. Distribution of major structural troughs along the southern margin of the Mogollon Rim in Arizona.

exceeds 900 meters (3,000 feet) (Twenter and Metzger, 1963). E. P. Pederson (1969, oral communication) also concluded that the major displacement in the Payson Basin was along the southwest flank, with minor step-faulting along the northeast margin. Barsch and Royse (1971) conclude a similar structural framework for the Tonto Basin with major tectonic displacement along the base of the Mazatzal Mountains and minor rupture along the base of the Sierra Ancha. This interpretation is supported by the observation (Lance and others, 1962) that the basinfill deposits generally dip gently toward the Mazatzals with a reversal of dip near the mountain front, the inference being that the structural axis and thickest fill occur along the southwest margin of the basin. This is consistent with the second observation that islands of bedrock protrude through the basinfill at many places along the northeast margin of the basin, suggesting a shallow and irregular basement, whereas such outcrops are absent along the southwest margin.

The Sierra Ancha and Mazatzal mountains are composed largely of Precambrian granite, gneiss, schist and metasediments. Mesozoic rocks are absent, but Tertiary flows and dikes are exposed locally, primarily along the lower mountain flanks. Basinfill lithologies consist of sandstone, siltstone, claystone, conglomerate, marl and limestone, gypsum, diatomite, caliche, and pyroclastics. Fluvial, lacustrine, colluvial and alluvial-fan facies are represented. The maximum thickness of the fill in the various basins is unknown, but Davidson (1961) reports they exceed 1,140 meters (3,800 feet) in the Safford Basin, and Gray (1967) cites a minimum thickness of 540 meters (1,800 feet) for fill in the San Pedro Valley near Saint David. The thickness of the Verde Formation is estimated to exceed 600 meters (2,000 feet) (Jenkins, 1923; Twenter and Metzger, 1963) and sediments within the Payson Basin are presumed to exceed 360–420 meters (1,200–1,400 feet) (Pederson and Royse, 1970). Total exposed sediments in the Tonto Basin exceed 300 meters (1,000 feet) and it is probable that they extend several times this distance into the subsurface.

Stratigraphic relationships within the Tonto Basin are only vaguely defined, but complex facies relationships among coarse conglomerate, sandstone, siltstone, claystone, limestone, gypsum and volcanic ash are apparent. In general, basinfill sediments are finer grained toward the axial and southern portions of the basin. Evaporite beds of gypsum thicken and become more numerous toward the lower end of the basin. Basin-marginal conglomerate of two types exist: an older (Gila-type) conglomerate which dips beneath the Tonto beds, and a coarse marginal facies of basinfill sediments. The first of these contain basaltic lava flows, the second apparently does not. The greatest bulk of the basinfill material consists of pink and red gypsiferous siltstone, but prominent beds of limestone occur in the upper third of the exposed section. Several ash beds are present, the thickest of which is referred to as the Haystack Butte bed (C. F. Royse, in progress) and constitutes a useful marker throughout the northern half of the basin.

Structural deformation of sediments in the Tonto Basin appears to be minor. Lance and others (1962) noted faults displacing sediments in the northern part of the Tonto Basin and along the base of the Mazatzals, but the magnitude of displacement was slight. No fault displacement is evident within the basinfill along the east side of the basin, although an exhumed fault-scarp contact can be traced on air photos along the northeast margin of the basin. The only evidence for structural movement between the basinfill and adjacent mountain blocks seems to be along the eastern side of the Mazatzal Mountains, and although the extent of this movement is uncertain, it is apparently slight. Pederson and Royse (1970) observed no displacement within sediments of the Payson Basin and assumed all stratal dips to be primary with little or no structural modifications; Gray (1967) reached a similar conclusion with regard to sediments in the San Pedro Valley. Although faulting in sedimentary fill can be demonstrated in the Verde Basin (Lehner, 1962, p. 97) and Safford Basin, it too is minor, and can largely be accounted for as the result of differential compaction or post-depositional slumping. Morrison (1965) deduced that post-basinfill fault movement, in excess of 90 meters (300 feet), has modified the elevation of the uppermost "lake" terrace above the Gila River near Duncan, Arizona. No evidence of such tectonic modification of terraces is apparent within the Tonto Basin.

The age of basinfill deposits along the Mogollon Rim is generally regarded as Pliocene-Pleistocene. Thus Davidson (1961) cites an age of Pliocene-Pleistocene for sediments in the Safford Basin based on reports of earlier workers (Knechtel, 1938; Wood, 1960; Lance, 1960); Taylor (1968) notes that the age may be Blancan (late Pliocene-early Pleistocene). Invertebrate fossils from Table Mountain in the Payson Basin (Feth and Hem, 1963) indicate a post-Blancan age for those deposits (Taylor, 1968). Fossil occurrences in the Verde Basin have been cited by several workers (Jenkins, 1923; Nininger, 1941; Mahard, 1949; Anderson and Creasey, 1958; Lehner, 1958; and Brady and Seff, 1959) and include vertebrate, invertebrate and plant remains. Known fossil localities in the Verde were summarized by Twenter (1962). On the basis of the similarity of the mollusks to those of the Benson local fauna, Taylor (1968) restricted the age of the Verde to Blancan and suggested that it is probably early Pleistocene. This assignment is probably too young. Lehner (1962) reports that remains of a mammoth and horse excavated from a gravel lens in the Verde beds north of Clarkdale indicate a Pliocene age for the formation and states that a Miocene age cannot be precluded. Age dates (not formally released) of basalts in the northern part of the Verde

Basin indicate that the upper strata of the Verde Formation are Middle Pliocene. It appears reasonable that the lower (subsurface) portion of the formation may be somewhat older than the generally accepted Pliocene age. A similar relationship, in which the "Milk Creek" formation contains fossils diagnostic of lower Pliocene age, was reported in the Walnut Grove Basin (Lance, 1960, p. 156) which is not far southwest of the Verde Basin.

Fossils within beds of the Tonto Basin include vertebrate, invertebrate, and plant remains (Lance and others, 1962). The known vertebrate fauna consist of camel (*Procamelus* sp.), dog (*Canis* sp.), and horse (*Pliohippus* sp.). Based on the stage of evolution of a horse tooth, Lance placed the age of the upper Tonto beds as definitely Pliocene and suggests that they are not late Pliocene (Lance and others, 1962; Twenter, 1961). Dr. Lindsay of the University of Arizona (written communication) confirms the conclusion that the vertebrate fauna of the Tonto Basin should be considered middle Pliocene, but adds that there is a remote possibility that additional evidence could necessitate revision of age assignment to early Pliocene. As in the Verde Basin, the possibility appears implicit that a Miocene age for the earliest basinfill cannot be discounted on the basis of available data. Invertebrate and plant fossils from the Tonto Basin resemble those found in other late Cenozoic lake beds in Arizona, but they have not been studied in detail. Gray (1960) concluded from study of pollen from samples taken with the horse tooth that the Pliocene vegetation of this area (now semi-desert grassland) comprised a woodland savanna community dominated by pine.

According to Barsch and Royse (1971) the post-basinfill history of the Tonto Basin was characterized by erosion and the formation of terraces and pediment-terraces (Figs. 6 and 7). They suggest that climatic changes have been largely responsible for erosional episodes and that these appear to have occurred from latest Pliocene time through the Quaternary Epoch. Detailed comments are made at mile 27.1 on the road log for Highway 188.

The Superstition Volcanic Field

Throughout the Basin-and-Range province, the mid-Tertiary (35 to 15 million years before present) was a time of great volcanic and tectonic activity (Damon and Bikerman, 1964). Thick sheets of volcanic ash spread from several centers to cover much of southern Arizona. The area directly above the intruding magma chambers swelled, then collapsed to form huge cauldrons tens of kilometers in diameter. The term *cauldron* is used in the sense of Smith and Bailey (1968) to mean a large irregularly-shaped volcanic depression. The term *caldera* is restricted to nearly circular volcanic depressions. These depressions sometimes were filled with hot

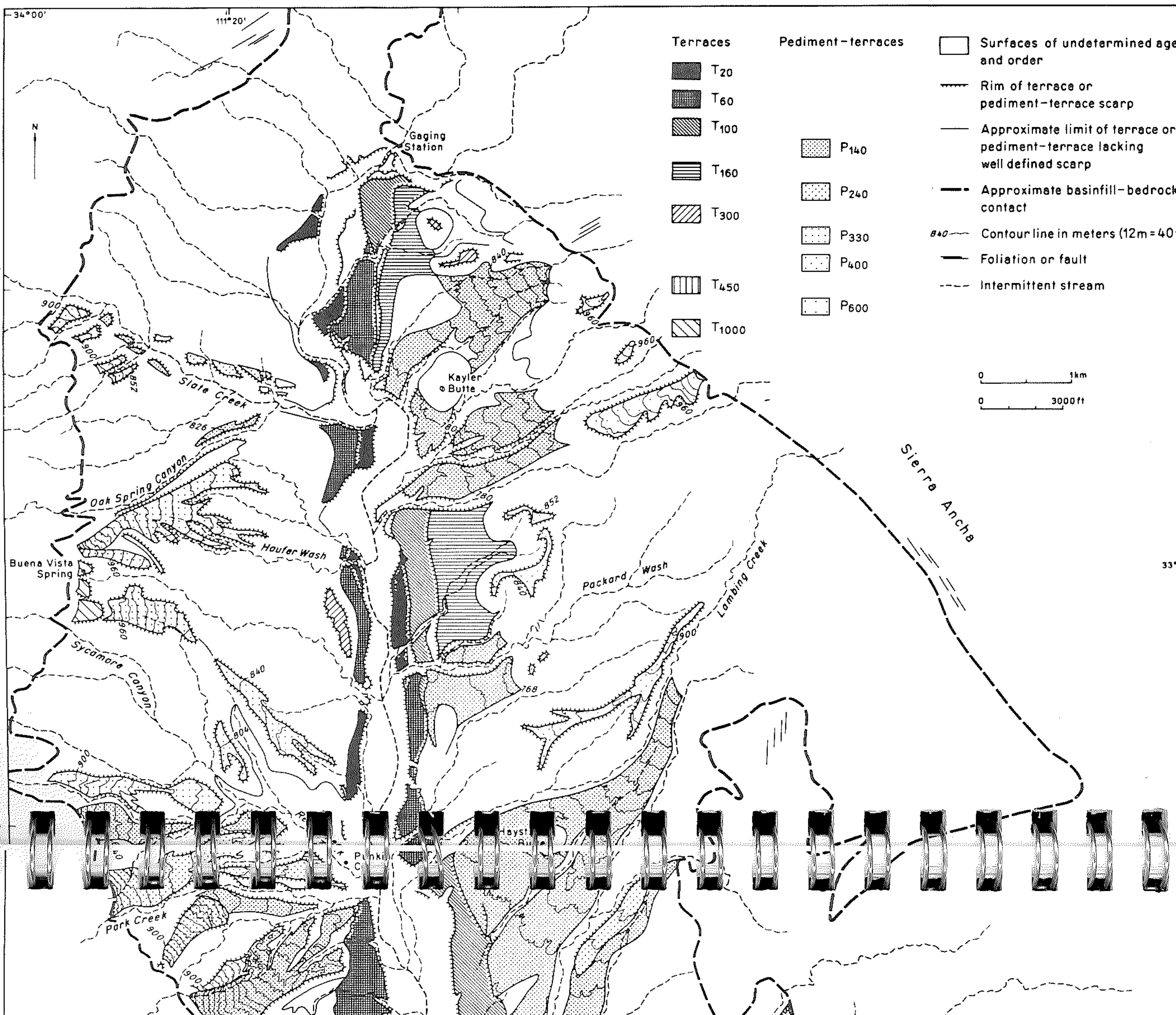

Figure 6. Map indicating the distribution of terraces and pediment-terraces in the northern part of the Tonto Basin (from Barsch and Royse, 1971).

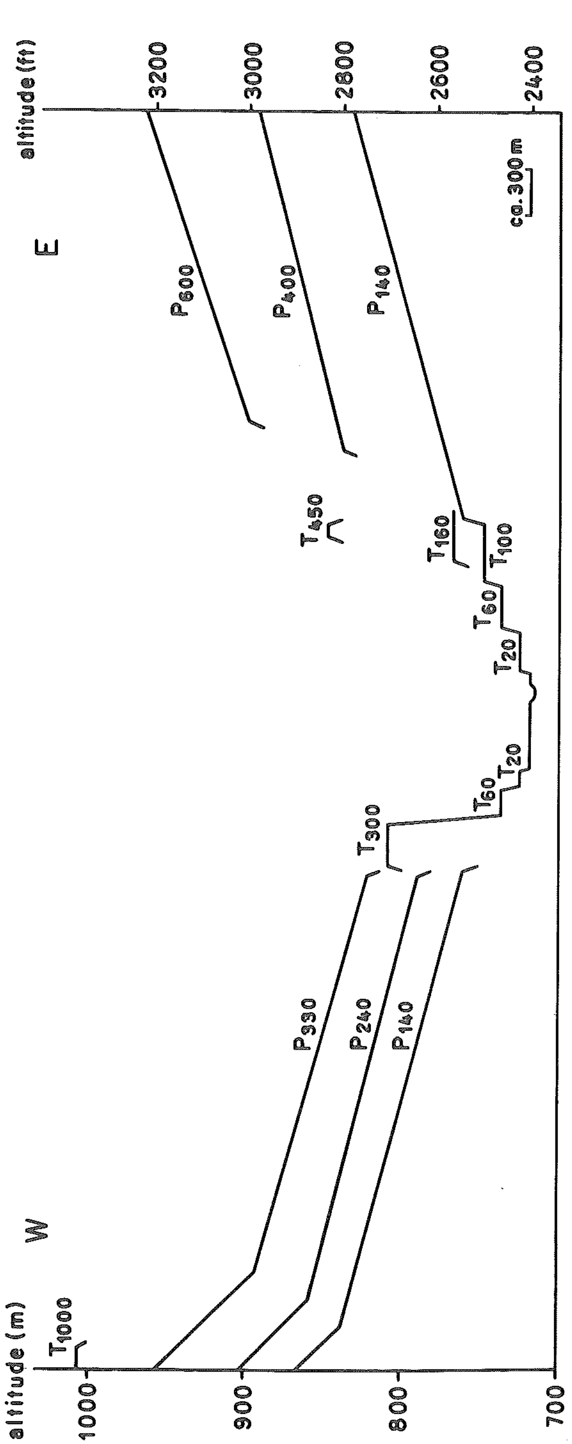

Figure 7. Schematic diagram indicating the relative position of terrace and pediment-terrace surfaces on the east and west sides of the northern part of Tonto Basin (after Barsch and Royse, 1971).

ash that compacted while hot to form welded tuffs. Renewed activity thrust up the central dome of some cauldrons causing dikes to intrude into ring fractures, and lavas to issue at the surface.

The Superstition Wilderness is the location of a typical volcanic center — the Superstition cauldron complex (Sheridan and others, 1970). This center produced about 4,000 cubic kilometers (2,500 cubic miles) of volcanic ash and lava that covers an area of 8,000 square kilometers (5,000 square miles). The extent of the Superior volcanic field is thought to be somewhat greater than the limit proposed by Peterson (1968), and is shown in Figure 8. Several interconnected cauldrons have been identified. The Willow Springs cauldron, the Black Mesa cauldron, and the Florence Junction cauldron lie along a northwest fracture zone that cuts through the larger Superstition cauldron.

The Superstition cauldron complex is on the northern margin of the southern Basin-and-Range province where the north striking block-fault mountains change their trend to the northwest (Fig. 9). Near Globe, Ransome (1903) proposed a three-fold Tertiary volcanic stratigraphy of andesites overlain by rhyolites which in turn are overlain by basalts. This simple succession is applicable to most volcanic areas of Arizona within

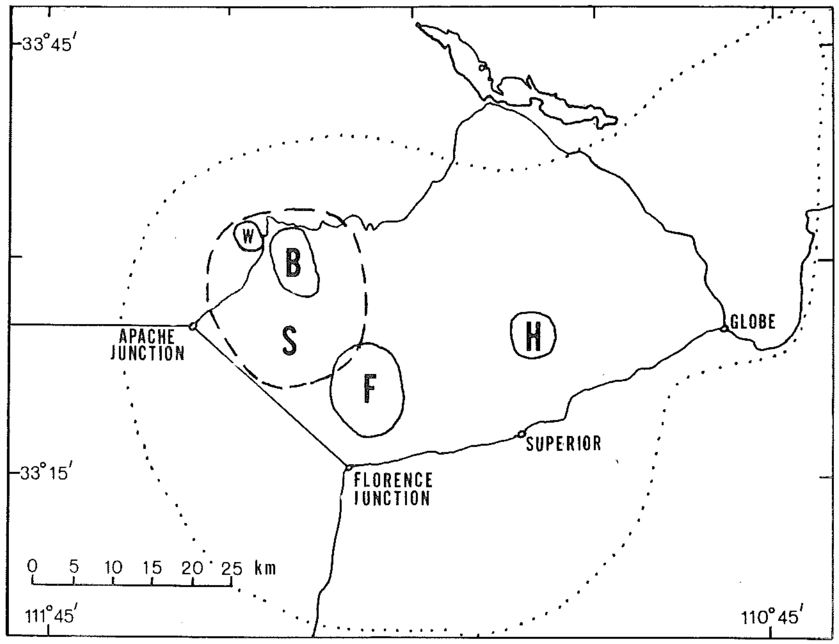

Figure 8. Map showing distribution of cauldrons within the Superior volcanic field. The limit of the field is shown by the dotted line. The cauldrons are: Black Mesa (B), Florence Junction (F), Haunted Canyon (H), Superstition (S), and Willow Springs (W).

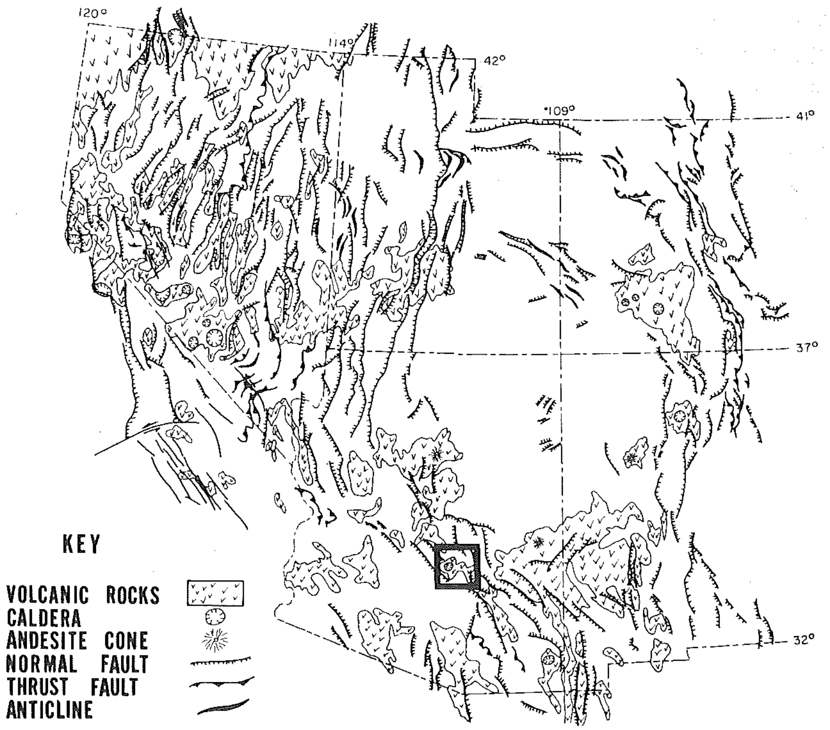

Figure 9. Index map of southwestern United States showing the location of the Superior volcanic field (dark square) in central Arizona. (From P. B. King, 1969, Tectonic Map of North America).

the Basin-and-Range province. Several mountain ranges in central Arizona have Tertiary volcanic rocks (Sell, 1968) that have a similar stratigraphy to those found in the Goldfield and Superstition mountains (Sheridan, 1968; Fodor, 1968; Sheridan and Stuckless, 1969). Welded tuffs in Nevada have been shown to extend hundreds of miles from their source (Mackin, 1960) and hence are useful for correlation from one mountain range to the next.

Five volcanic centers are now known in the Superior volcanic field (Fig. 8): 1. Haunted Canyon caldera (Peterson, 1968); 2. Superstition cauldron (Sheridan and others, 1970); 3. Willow Springs cauldron (Sheridan, 1968); 4. Black Mesa cauldron (Sheridan, 1968; Sheridan and Stuckless, 1969); and 5. Florence Junction cauldron (Sheridan and others, 1970). Deformation and eruption followed a similar pattern in each case. Because of excellent outcrop exposure and a relief of 1,200 meters (4,000 feet), considerable detail has been mapped within the Superstition region (Fodor, 1968; Stuckless, 1969). The important features defined include the resurgent central dome of the Superstition Mountains, the subsequent cauldron of Black Mesa, the ring fracture zone of

closely-spaced antithetic fault blocks, the inner ring of early dacite centers, the outer ring of late silicic domes and the peripheral flat-lying volcanic plateau of rhyolitic breccias.

Table 2. Stratigraphic Sequence in the Goldfield and Superstition Mountains

Rock Units	*Maximum Thickness in Meters*	*Age m.y.*
Rhyolite breccia	100	Late Miocene
Quartz-latite welded tuff	300	†15
Basalt and basanite lavas	25	*17.8 ±3.1
Dacite and rhyolite domes	170	*20.1 ±1.2
Rhyolite tuff, breccia, and lava	430	*21.3 ±0.8
Quartz-latite welded tuff	670	†25
Andesite to dacite breccia and lava	1000	†29
Alkali olivine basalt	40	Oligocene?
Arkosic conglomerate redbeds	75	Oligocene?
Quartz monzonite	——	Precambrian

† Unpublished radiometric ages from Stuckless (oral comm., 1970).
* Radiometric dates from Damon (1969, p. 49).

The stratigraphic sequence and age of the major rock units of the western part of the volcanic field are given in Table 2. The trend in rock types progresses from an early intermediate composition dome-and-lava stage through a silicic composition ash-flow stage to a late mafic composition lava stage. This succession is generally similar to Ransome's (1903) three-fold stratigraphy. However, in the Superstition Mountains the early rocks are basalts and dacites; andesites are rare. The most voluminous rock units are welded tuffs similar to the Apache Leap Formation (Peterson, 1969) near Superior that was formerly called the Superior Dacite (Ransome, 1903; Peterson, 1961). Over a dozen radiometric dates (Stuckless, oral comm., 1970) support the hypothesis that there are actually several welded-tuff sheets in this region. The history of the entire volcanic field is thus more complex than the pattern presented here for the Superstition cauldron.

The history of the volcanic center can be outlined as follows: An early ring of dacite domes (29 m.y.) of up to 1 kilometer (3,300 feet) in relief formed a semi-circular arc 7 kilometers (4 miles) in diameter on the western margin of the caldera (Fig. 10-A). The last phases of dome building were contemporaneous with the extrusion of a vast quartz-latite welded tuff (24 m.y.). The plateau formed by the welded tuff collapsed to a maximum depth of 800 meters (2,600 feet) along a northwest-trending graben which is the locus of three small cauldrons (Fig. 10-B).

These late cauldrons were the source of rhyolitic magma which produced nonwelded ash flows, lava (21 m.y.), and a thick sequence of epiclastic breccias during the period of 21 to 18 m.y. (million years before present). The rhyolitic volcanism was accompanied by resurgence within the cauldron (Fig. 10-C), intrusion of domes and extrusion of glassy lavas of quartz-latite composition in a 16 kilometer (10 mile) arc concentric with older dacite domes. Some of the cauldrons were flooded with basalts dated at 18 m.y. that are nearly contemporaneous with the Apache Leap Tuff (Peterson, 1968, 1969) near Superior. A later welded tuff (15 m.y.) that filled low places in the topography near the present Canyon Lake is covered by rhyolitic breccias.

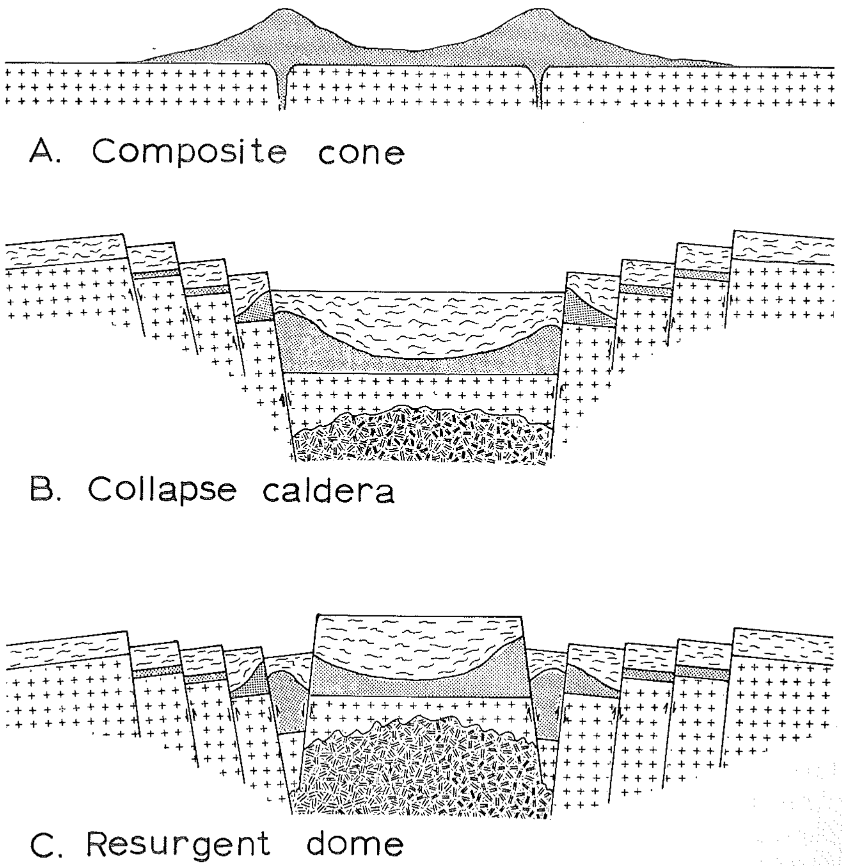

Figure 10. Schematic cross sections of a typical caldera development. A. Formation of early intermediate to mafic domes and composite volcanoes. B. Caldera collapse with formation of welded tuffs. C. Resurgence of central dome and intrusion of ring dikes.

Acknowledgements

This bulletin is the result of the efforts of its writers combined with the cooperation and courtesy of the institutions for which they work. In this regard we thank Arizona State University, the University of Arizona and the Arizona Bureau of Mines. Special thanks are extended to R.T. Moore for his encouragement and assistance in bringing our individual efforts together in this guidebook.

DETAILED LOG

Arizona Highway 88

The following road log progresses east on State 88 from Apache Junction to Roosevelt Dam.

MILES CUMULATIVE — MILEAGE INTERVALS

0.0

0.0 Turn left onto the Apache Trail (Highway 88). Before initial excavation could begin on Roosevelt Dam, it was necessary to build roads to the site. The most important of these was the Apache Trail over which all machinery was freighted from the town of Mesa, 60 miles from the dam site. It is an extraordinary engineering feat in itself, and was completed in 1904 at a cost of more than a half-million dollars.

0.7

0.7 Directly east of the road rise the Superstition Mountains (Plate 1). The flat-lying, bedded units at the top comprise the Superstition Formation, a welded tuff. Massive dacite domes make up the vertical-faced cliffs on the western end of the mountain range. To the west of the road are the Goldfield Mountains which are composed mainly of rhyolite lavas and ash-flow tuffs of the Geronimo Head Formation. The rocks of the Goldfield Mountains dip moderately to the northeast at the edge of the range, but become more steeply inclined in a northeasterly direction.

2.4

3.1 Gently-dipping arkose is exposed on the left side of the road. The road curves to the east and passes through a deep wash. Many chain fruit cholla cactus are present along this stretch of the road.

0.6

3.7 The stratigraphic sequence of granite, arkose, basalt, and andesite breccia is repeated several times in the next few miles due to displacement along the closely spaced faults of the caldera ring-fracture zone (Fig. 10-C).

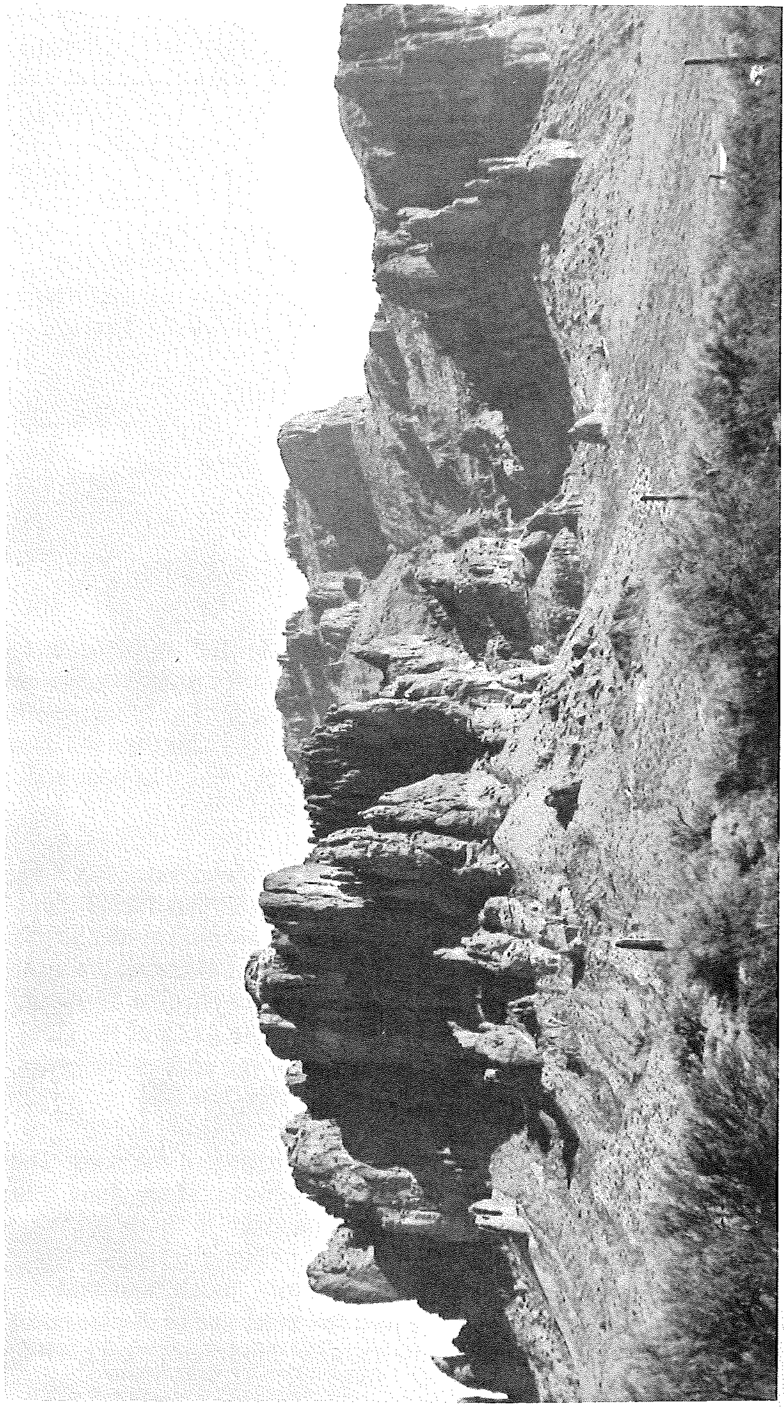

Plate 1. Superstition Mountains. Two early dacite domes make up the bold cliffs at the western end of the resurgent dome.

0.4

4.1 Turn-off for Mining Camp Restaurant. Good exposure of basalt occurs just beyond this point in a small quarry.

0.2

4.3 Goldfield. A snack-bar is on the right side of the road. The old Bluebird mine is located just behind the snack-bar. A dirt jeep-trail that takes off to the east behind the snack-bar leads up to Siphon Draw. A trail up this canyon provides a rigorous 3 to 4 hour climb to the top of the Superstition Mountains, 5,024 feet above sea level.

0.8

5.1 Weeks Wash along the west side of the road provides water to support the abundant vegetation present in this area.

0.2

5.3 Maricopa County Line.

0.1

5.4 Turn-off. First Water Ranch is to the east. This is the take-off point for many hiking trails into the Superstition Wilderness Area.

0.4

5.8 Good view of the up-thrust Superstition Mountains is provided here. A graben, or down-faulted wedge, on the northern side of the mountains is clearly visible. Massacre Grouds is an erosional remnant composed of the yellow Geronimo Head Formation within this graben.

0.6

6.4 Tonto National Forest sign. Granite basement crops out on both sides of the road. Northward from here for several miles the stratigraphic sequence exposed is unbroken.

Nearly the entire route of this field guide is contained within the Tonto National Forest. This Forest embraces 2,900,000 acres (an area nearly as large as the state of Connecticut) which ranges from pine-clad mountains to cactus-studded desert. About 40,000 cattle and 14,000 sheep, owned by 108 local ranchers, graze within this area. Wildlife includes Rocky Mountain mule deer, white-tailed deer, elk, black bear, javelina, rabbit, squirrel and beaver, wild turkey, quail, dove, band-tailed pigeon, duck and geese. Predators include mountain lion, coyote, fox, bobcat, skunk, weasel, racoon and porcupine. Timber from the higher elevations to the north and east supplies material for the pulp and paper mill at Snowflake and sawmills at Payson and Heber.

0.6

7.0 Weavers Needle Vista. Weavers Needle is the prominent pinnacle due east from here. As the road winds down toward Government Well, stark cliffs of Geronimo Head Formation resting on andesite are seen to the west. The sharp line separating the Geronimo Head Formation from the granite basement is a fault along which the west side has dropped some 3,000 feet into the Willow Springs caldera.

0.5

7.5 Arizona State Highway District sign. The road intersects a contact at which arkose rests on granite. The arkose is a distinctive red rock in this area making the name "red-bed" appropriate. This rock unit extends to the northwest where both it and the underlying granite are cut off by the main bounding fault of the Willow Springs caldera.

0.2

7.7 Here the road intersects a contact at which basalt overlies the arkose. A prominent white ash layer is present in the middle of the black basalt sequence.

0.2

7.9 The road begins a tortuous climb up through a section of andesite and dacite lavas and breccias that overlie basalt. The boundary fault of the Willow Springs caldera is clearly visible to the west where the yellow, inward-dipping rocks of the Geronimo Head Formation are enclosed on three sides by older rocks.

1.2

9.1 Where the road begins to descend, it cuts a dike of black glassy rhyolite that is exposed after a sharp turn to the right.

0.5

9.6 Apache Gap lookout. The nose of a dacite dome can be seen to the north where flow-banding forms elbow-like folds (Plate 2). This dome extends across the highway where it broke to the surface forming a glassy lava flow that spilled toward the present site of Canyon Lake. This dome has been dated by K-Ar methods at 20.5 million years before present.

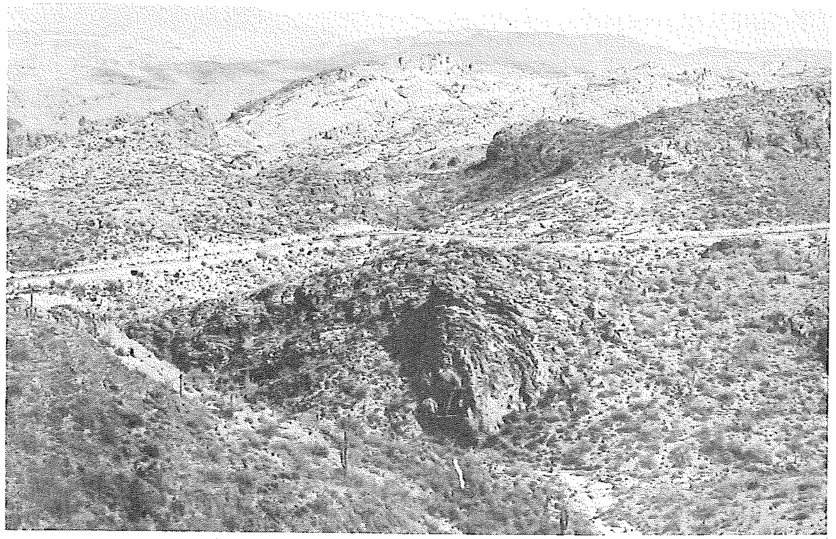

Plate 2. Dome at Apache Gap. The viscous magma formed elbow-like folds that plunge to the right.

0.4

10.0 The road winds down toward Canyon Lake. To the west, beds of Geronimo Head Formation have been uptilted by the intrusion of the dome of dark, viscous dacite. Resting on top of these tilted beds to the west of the dome is a black basalt lava that dips slightly to the southwest. The rhyolite ash below this lava is reddened due to oxidation and leaching of iron from the basalt. This basalt once filled a depression within the Willow Springs caldera. Later it was uplifted and tilted to its present position.

0.3

10.3 The glassy lava that parallels the road is part of the flow that issued from the Apache Gap dome and spilled over tilted beds of the Geronimo Head Formation.

0.3

10.6 The bedding of the Geronimo Head Formation can be seen for great distances along strike. These beds are the product of subaerial deposition of volcanic ash.

0.3

10.9 The road intersects a flow-banded rhyolite dike. The devitrified matrix of this rhyolite is dull reddish-gray.

0.3

11.2 The deep canyon of First Water Creek incises the Geronimo Head Formation to the east of the road. The matrix of the dike intersected at this point is composed of glass that has been hydrated to milky perlite containing small reddish spherulites of feldspar.

0.3

11.5 The bedding of the Geronimo Head Formation is clearly visible in the yellow rock escarpment ahead. The steepness of this bedding on the far side of the outcrop should be noted.

0.3

11.8 Canyon Lake overlook. This is an ideal spot to view the surrounding geology. A rhyolite dike with perlite matrix and reddish feldspar spherulites cuts the road at this location. Directly to the north are two large blocks of rock tilted to the northeast. Across Canyon Lake, the bedding of the rhyolitic breccia is horizontal. This region is outside the chaotic structure of the caldera ring-fracture zone, and Canyon Lake lies on the northern boundary of the caldera. A fresh landslide scarp on the north side of the lake marks the place where a mass of rubble has recently tumbled into the lake.

From here the road winds down to lake level. Leaving this lookout, and looking back to the south, the contorted beds of the Geronimo Head Formation are exposed on the dip slope.

0.3

12.1 Turn-off to Mormon Flat Dam. This is a private road maintained by the Salt River Project. Mormon Flat Dam was constructed primarily for hydroelectric power, but it also aids significantly in regulating water usage. Prior to its completion in 1925, water from Roosevelt had to be released to meet farmers' irrigation needs and this pattern did not always coincide with the demands for electricity. Mormon Flat provided a means of regulating water usage while still allowing optimum generation of electricity at Roosevelt. Its reservoir, Canyon Lake, has a storage capacity of 57,852 acre-feet.

Apache Trail, from here to the bridge across First Water Creek, closely follows the course of a fault with displacement such that the densely-welded Superstition Formation is exposed in road cuts.

0.7

12.8 A one-way bridge here crosses the gorge of First Water Creek leading to Canyon Lake. South of the bridge a rhyolite dike, intruded along a fault, runs more or less parallel to the road. Along the road, near lake level, the Superstition Formation is exposed in road cuts and the overlying Geronimo Head Formation crops out in the cliffs north of the road.

2.8

15.6 Beyond a short rise, the road descends toward Tortilla Flat. The Superstition Formation crops out in the road cuts. Downgrade, toward Tortilla Flat, a flat-lying basalt lava visible to the north separates the lower Superstition Formation from the overlying Geronimo Head Formation. Because this contact is below road level north of Tortilla Creek and above it south of the Creek, a fault essentially following the creek must have dropped the rocks to the north to their present position.

0.8

16.4 Tortilla Flat Restaurant. Food and gasoline are available here. The 29 miles from this point to Roosevelt Lake have no other services.

0.1

16.5 Tortilla Creek. From here the road rises through the upper part of the Superstition Formation and into the overlying Geronimo Head Formation that forms the cliffs.

0.5

17.0 Glassy dikes of dacite cut the road. These dikes contain large, pink feldspar crystals, and locally have well-developed gas cavities filled with radiating quartz crystals. To the east is a small intrusive dome that was probably the source for the dikes.

0.5

17.5 Mesquite Creek. A few hundred yards downstream one can see the contorted flow banding and brecciation of the dome. For the next few miles the terrain is markedly different. The beds of the surrounding Geronimo Head Formation are flat-lying which is typical of the volcanic plateau surrounding the caldera. Jumbled blocks of steeply-dipping rocks lie

about one-half mile to the south beyond the caldera boundary fault. The road from here to Fish Creek traverses the flat beds of the Geronimo Head Formation.

0.5

18.0 Typical boulder-bearing beds of the flat-lying Geronimo Head Formation are well exposed in roadcuts.

0.5

18.5 The prominant summit to the north, in the Mazatzal range, is Four Peaks. It is probable that the ash from the Superstition volcanic field spread northward onto the Mazatzal range. Alluvial fans from these mountains have since formed a thick blanket on the volcanic rocks.

0.7

19.2 Turn-off to scenic viewpoint to the south. The rocks at the view point are flat-lying beds of the Geronimo Head Formation. These are cut by the deep canyon of Tortilla Creek.

0.4

19.6 End of the paved highway. The dirt road to Roosevelt Lake is well maintained, but does traverse a steep cliff at Fish Creek.

0.4

20.0 The series of topographic highs south of the road are domes related to the Superstition cauldron complex. The gravels and breccias at the surface are warped up by the protrusion of the domes. In some places they yielded by faulting, in other places by folding. To the west are vertical beds where a rhyolite dome has protruded through these breccias near Canyon Lake.

0.4

20.4 Turn-off to Horse Mesa Dam.

0.1

20.5 Rhyolitic dome cuts flat-lying rhyolitic breccias.

0.7

21.2 To the north, Fish Creek Canyon provides an excellent view of the yellow, rhyolitic breccias and tuffs of the Geronimo Head Formation which are intruded by dark rhyolite domes. At some places the flat-lying beds have been folded into a nearly vertical attitude.

0.2

21.4 At this point, the road crosses a rhyolite dome.

1.0

22.4 Turn-off to Tortilla Ranch. Cattle pen for this ranch is visible about one half mile to the west. The winding road through this section traverses flat-lying rhyolitic gravels amenable to prickly pear cactus and ocotillo vegetation.

0.9

23.3 Flat-topped hill to the north is Horse Mesa. Four Peaks of the Mazatzal range is in the background.

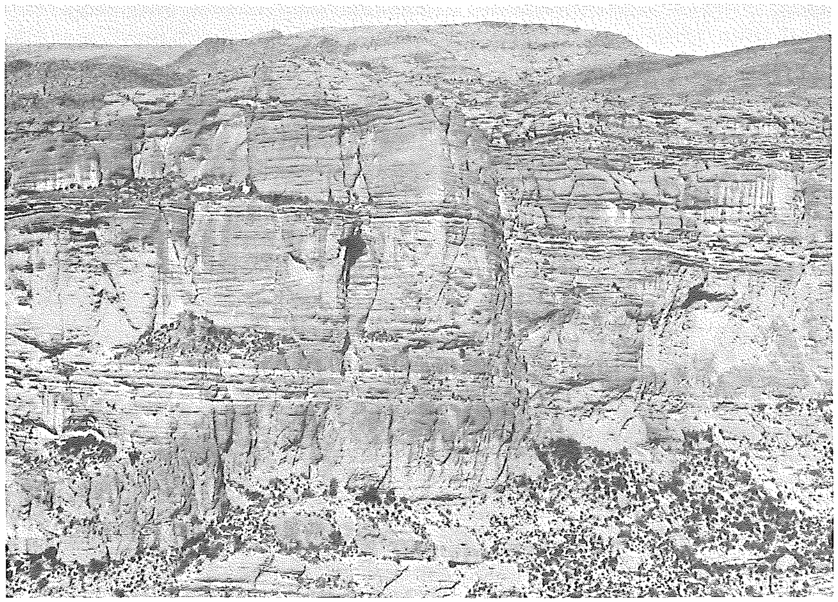

Plate 3. Rhyolitic breccias of the Geronimo Head Formation at Fish Creek.

0.5

23.8 Top of the Fish Creek scarp. Horse Mesa to the north is underlain by yellow tuffs and breccias of the Geronimo Head Formation (Plate 3) and dark welded tuffs, lavas, and intrusions. Two closely spaced faults parallel the road and are loci for dark rhyolitic domes.

0.4

24.2 Road traverses Fish Creek scarp. A fault occurs just above the road.

0.6

24.8 One-lane bridge over Fish Creek. The fault zone extends south up Fish Creek Canyon where numerous dark rhyolitic domes can be seen.

0.6

25.4 Turn-off for Fish Creek Campground. One of the major fault zones in this area trends parallel to Fish Creek. A hair-line fault can be seen in the cliffs to the north where yellow tuffs of the Geronimo Head Formation rest next to darker lavas and welded tuffs to the east. Parallel faults occur to the west above the road along Fish Creek scarp.

0.5

25.9 One-lane bridge across Lewis and Pranty Creek.

0.6

26.5 Narrow bridge over an arroyo. Mafic lavas exposed are the uppermost layers of olivine basalt (Table 2). These underlie silicic tuffs and lavas exposed at road level to the west.

0.5

27.0 Outcrops of basalt along the north side of the road mark the base of the Tertiary volcanic pile. The many cottonwood trees along this stretch suggest subsurface flow of water in Lewis and Pranty Creek.

0.5

27.5 Outcrops of granite in the road mark the top of the Precambrian rocks. The contact with the overlying volcanic rocks is a profound unconformity. This erosion surface seems to be tilted about 25° to the north, and the present eastern boundary of the volcanic field is an erosional scarp.

0.2

27.7 Arizona Highway Department Maintenance Yard.

2.5

30.2 Apache Lake viewpoint and turn-off. Camping and picnic facilities are available at this Tonto National Forest campground. Rocks of the Superstition volcanic field make up the bold cliff face of Bronco Butte to the west. The lowest exposed rocks are Precambrian porphyritic granites. Above the granites are dark basalt layers that are in turn overlain by yellowish, rhyolitic tuffs and breccias of the Geronimo Head Formation. Above these nonwelded tuffs are darker welded tuffs and lavas. To the north, across Apache Lake, the cliffs of Goat Mountain are capped by a dark welded tuff (Plate 4). The columnar joints of this unit are typical cooling features of densely welded tuffs. The volcanic sequence here dips gently northward at 20° to 30°. In the background stand Four Peaks in the Mazatzal range. From here the road winds through gently rounded hills of Precambrian granites that provide an incipient soil for stands of saguaro cactus and yucca.

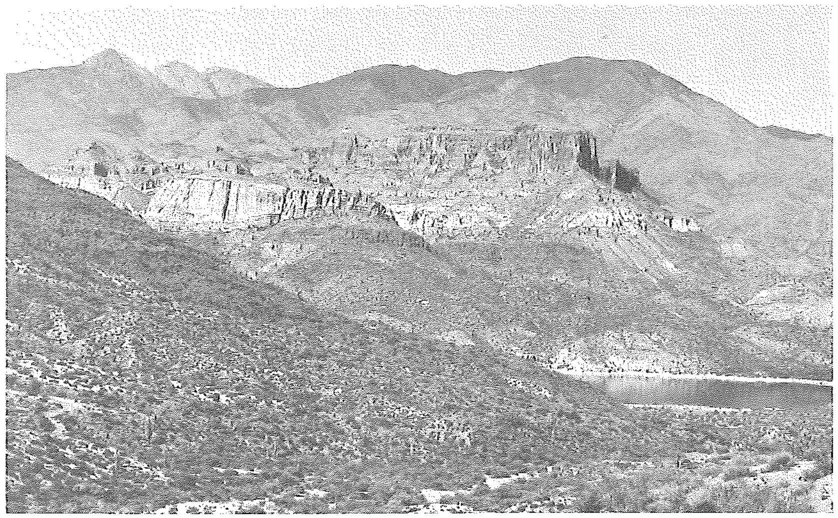

Plate 4. Goat Mountain. A welded tuff caps the cliffs that are underlain by the yellow tuffs and breccias of the Geronimo Head Formation. Four Peaks of the Mazatzal Range is in the background.

Apache Lake is the third of four reservoirs on the Salt River constructed by the Salt River Project. It is formed by Horse Mesa Dam located about halfway between Mormon Flat and Roosevelt Dams (Fig. 3), and was completed in 1927. It was constructed primarily to provide hydroelectric power for the Inspiration Consolidated Copper Company, located at Miami, 30 miles to the southeast.

2.5

32.7 Davis Wash.

3.0

35.7 Basic dike in granite.

0.3 - 2.3

36.0 - 38.0 Granite terrane. Note the thick dike swarms weathered in relief, and sparse occurrences of bedded caprock of the Precambrian Apache Group. K-Ar dates on this granite indicate an age between 1,500 and 1,700 million years before present.

3.3

39.0 The road parallels the upper reaches of Apache Lake for about three miles through the canyon of Salt River to Roosevelt Dam.

0.8

39.8 Diabase dike in road cut. The dike is about 60 feet thick and dips nearly due north at 30°

1.0

40.8 Mafic rock crops out in road cut.

0.1

40.9 Younger Precambrian rocks of the Apache Group are well exposed in the canyon wall across the river (Plate 5).

The Apache Group consists of highly altered sedimentary rocks of several types. The basal unit is the Scanlan Conglomerate which is overlain in succession by the Pioneer Shale, Barnes Conglomerate, Dripping Spring Quartzite and Mescal Limestone. These formations are of Younger Precambrian age and are roughly correlative with the Unkar and Chuar Groups of the Grand Canyon series. With the exception of the Mescal, which contains abundant fossil algae or stromatolites, these rocks are unfossiliferous. The Mescal was used extensively in the construction of Roosevelt Dam. K-Ar dates on granite beneath the Apache Group and on dikes which intrude it, indicate that the Apache Group was deposited between 1,140 and 1,300 million years ago.

3.4

44.3 Scanlan Conglomerate crops out in road cut. The unit is well exposed but thin at this locality. It consists of about 20 feet of well-rounded, well-cemented quartzite-cobble conglomerate with a coarse sand matrix. The base is a non-conformable, erosional contact (Plate 6) with moderate relief. Thin sandstone stringers of Dripping Spring lithology occur locally

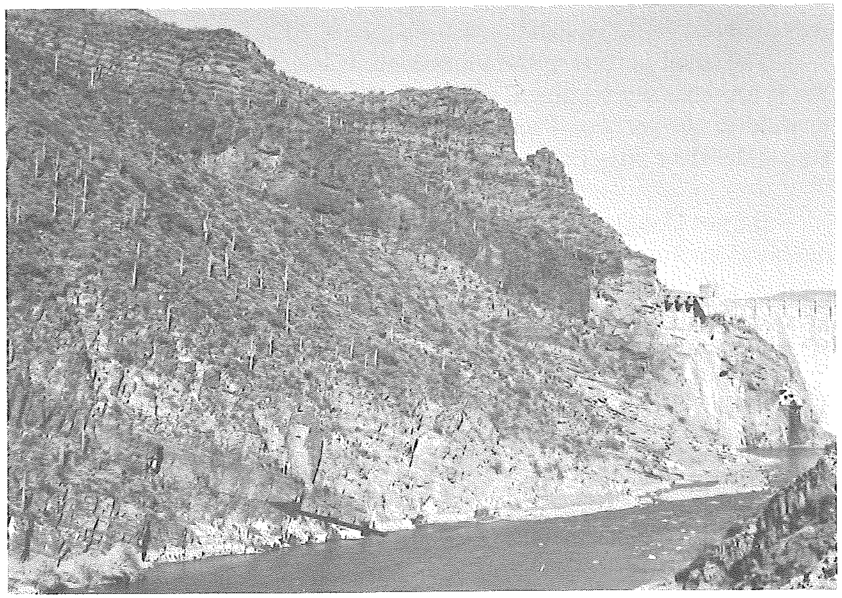

Plate 5. Stratigraphic section of the Apache Group (Younger Precambrian) below Roosevelt Dam. The arrow marks the base of the prominent Barnes Conglomerate, the thin beds near the skyline are Martin Limestone.

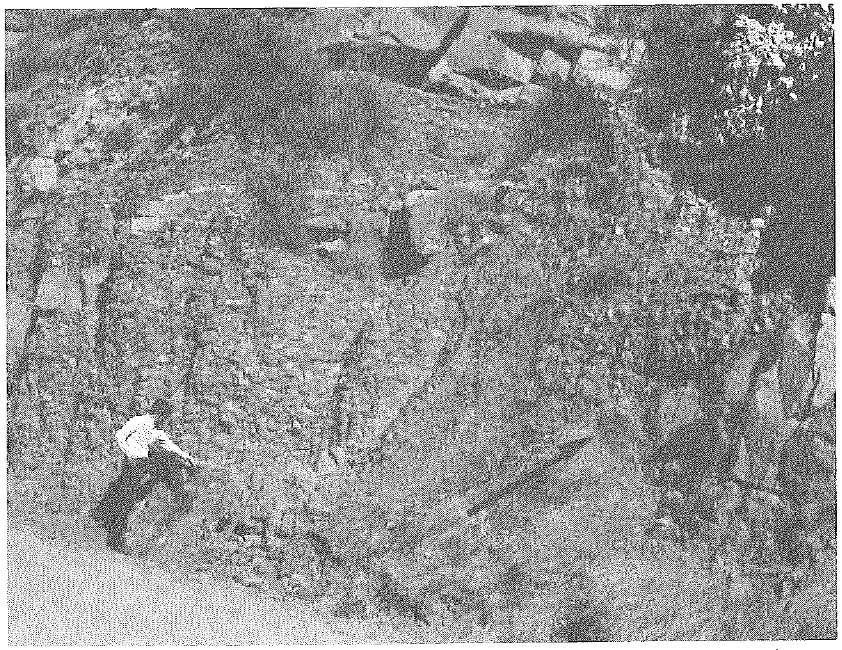

Plate 6. The Scanlan Conglomerate, basal unit of the Apache Group, resting on Precambrian granite at mile 44.3. The arrow marks the base of the Scanlan.

within the conglomerate. This outcrop is part of a large fault block which strikes about N. 22°W. and dips at about 34°NE.

The basal portion of the Pioneer Shale is quite sandy at this locality, but it becomes finer grained, thinner bedded, lighter colored and mottled upward in the section. These same beds can be seen in the canyon wall across the river adjacent to mile 44.8.

0.5

44.8 Barnes Conglomerate at road down to river. The Barnes is a quartzitic conglomerate which is very similar to the Scanlan but somewhat finer grained and better sorted. The basal contact (Plate 7) is gradational, but the upper contact with the Dripping Spring Quartzite is sharp.

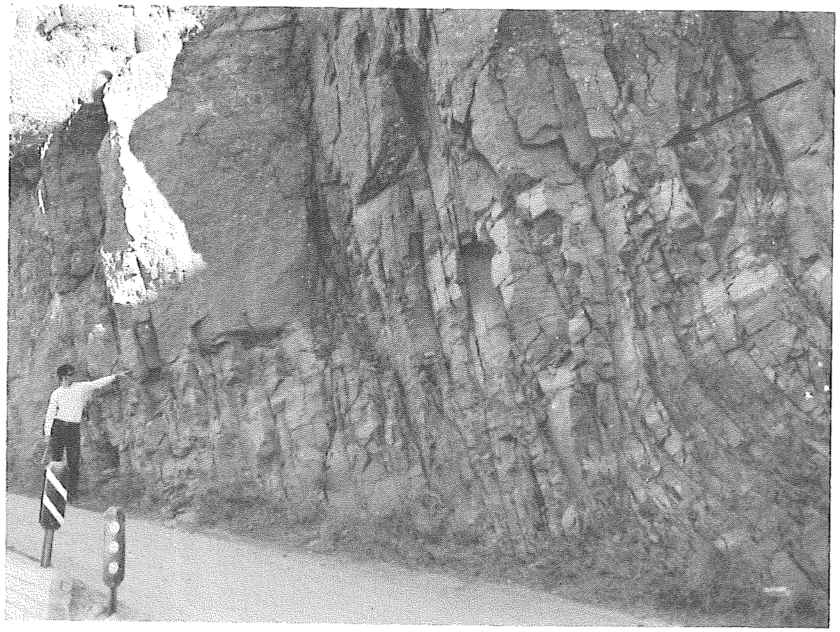

Plate 7. Barnes Conglomerate overlying the Pioneer Shale at mile 44.8, just below Roosevelt Dam. The arrow marks the base of the Barnes.

0.4

45.2 First occurrence of Mescal Limestone in road cut. The basal contact with the Dripping Spring is concealed by slope wash, but it can be readily observed near the top of the northwest abutment of the dam (Plate 8). Watch for this after we round the final switchback in the road and approach Roosevelt Dam.

0.5

45.7 Contact of Mescal and Tapeats Sandstone in road cut. This contact is better observed from the southeast approach to the dam.

0.2

45.9 Contact of Tapeats Sandstone and Mescal Limestone.

0.2

46.1 Junction of Route 88 and 188.

DETAILED LOG

Arizona Highway 188

The following road log progresses north on State 188 from Roosevelt Dam to State 87 via Slate Creek Road.

CUMULATIVE MILES — MILEAGE INTERVALS

0.0

0.0 Junction of State Highways 88 and 188.

The Tapeats Sandstone (Cambrian) and the Martin Limestone (Devonian) crop out at this locality (Plate 8), and the disconformity between the two is well exposed as a dip-slope just above the quarry floor. Younger Precambrian rocks of the Apache Group form mesa-like caps on older rocks of the Sierra Ancha Mountains along the sky-line on the east side of the lake.

The quarry adjacent to the junction is one of several excavations from which stone was removed for dam construction. The volume of stone used (350,000 cubic yards) in construction can better be visualized by the dimensions of the dam; it is 184 feet thick at the base, 18 feet thick at the crest, towers 284 feet above bedrock and stretches (including the spillway) more than 1,000 feet across the canyon.

0.2

0.2 Theodore Roosevelt Dam (Plate 9) is the world's highest masonry dam and its reservoir, Roosevelt Lake, has a capacity of 1,381,580 acre-feet. It took Italian stone masons 5 years to complete the project and the dam was dedicated by Theodore Roosevelt in March, 1911. This dam was the first multi-purpose reclamation development in the United States and has been designated a Registered National Historic Landmark.

Below Roosevelt Dam are three other storage dams and reservoirs: Horse Mesa Dam on Apache Lake, Mormon Flat Dam on Canyon Lake and Stewart Mountain Dam on Saguaro Lake. Two additional dams have been constructed on the Verde River; Horseshoe and Bartlett. At the confluence of the Salt and Verde Rivers, Granite Reef Diversion Dam channels water into two main canal systems (Fig. 3) which provide the greater Phoenix area with about one million acre-feet of water each year.

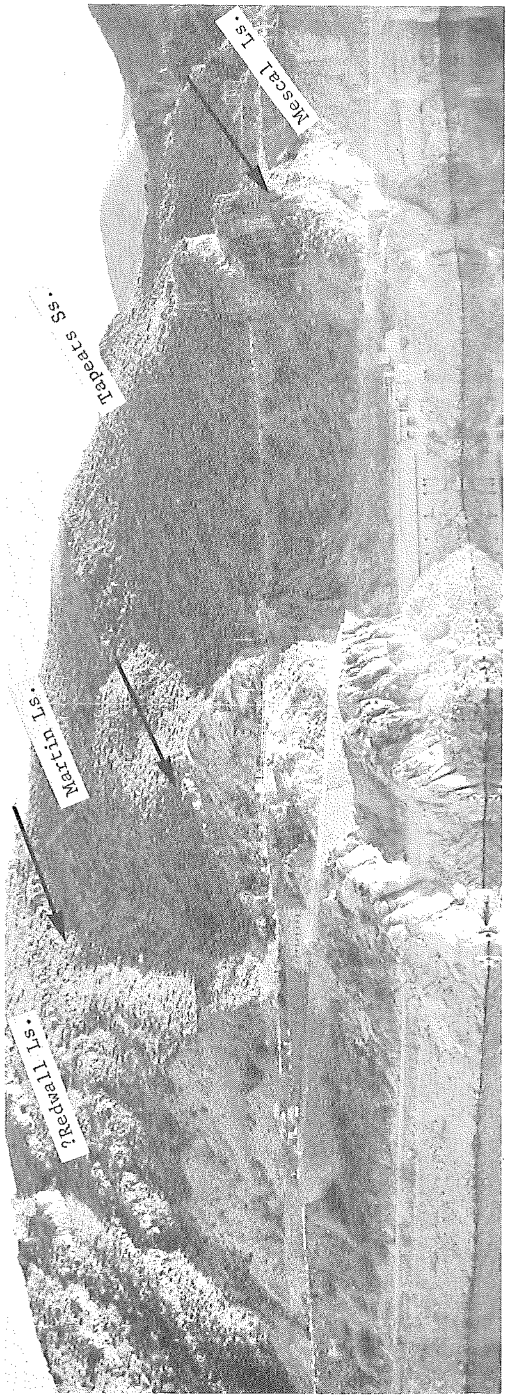

Plate 8. Panoramic view of the southeast abutment of Roosevelt Dam. Approximate contacts of rock units are indicated by arrow.

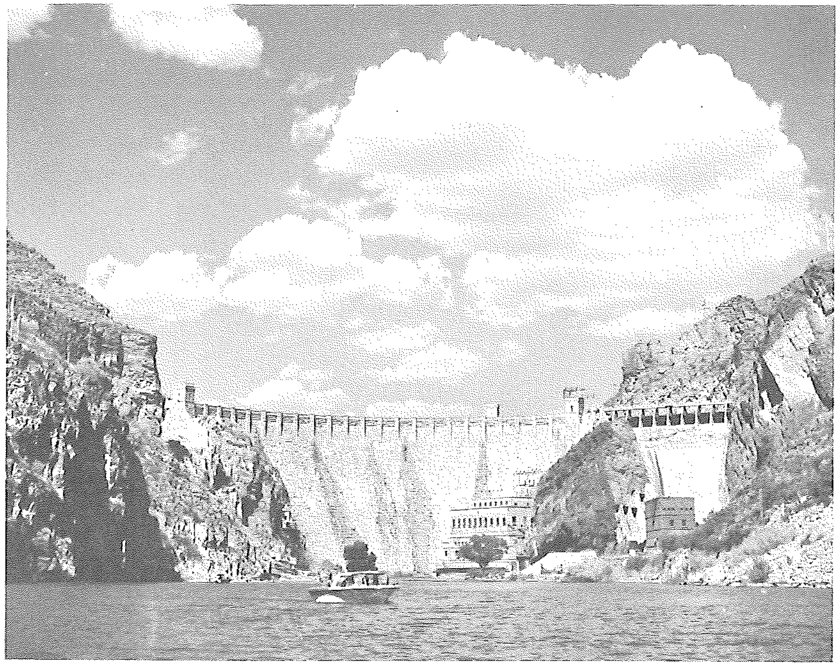
Plate 9. Roosevelt Dam, the world's highest masonry dam. (Photo by Ed Toliver, courtesy of the Salt River Project).

This multi-purpose system, known as the Salt River Project, is owned and administered by some four thousand landowners on a non-profit basis. The ownership of the dams and canals themselves resides with the Federal Government.

Cross Dam.

0.2

0.4 Contact of Mescal Limestone and Tapeats Sandstone (Plate 10) is marked by three feet of dark shale (? paleosol) just beyond the dam. The Tapeats Sandstone is about 300 feet thick.

0.1

0.5 Contact of Tapeats Sandstone and Martin Limestone (Plate 10). The upper Tapeats is quite shaly, and the lower Martin is thin bedded at the contact.

0.3

0.7 Redwall Limestone crops out at picnic ground. The contact of the Martin and Redwall is poorly defined at this locality.

0.1

0.8 Most outcrops and road cuts expose Devonian Martin Limestone. The attitude of the beds changes several times and the section is repeated.

Lake Roosevelt, a major recreational area in central Arizona, is nearly 23 miles long, has a surface area of 14,000 acres and contains 2.2

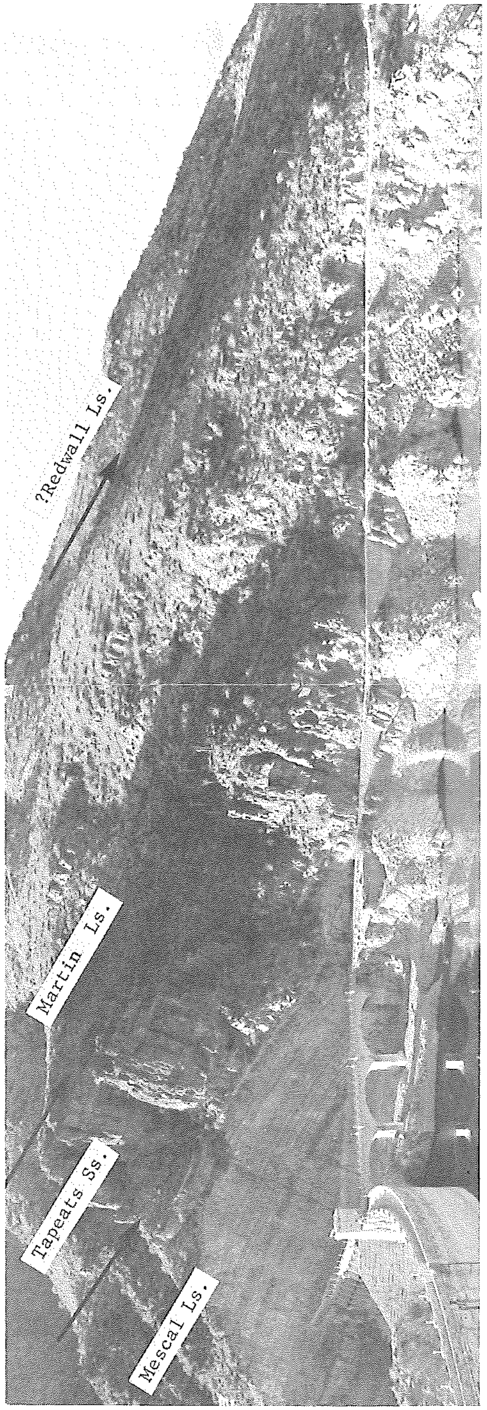

Plate 10. Rock exposure at the northwest abutment of Roosevelt Dam. Arrows indicate approximate contacts of major rock units.

billion cubic yards of water at full capacity. It occupies portions of the drainages of both the Salt River and Tonto Creek, and is stocked with a wide range of pan fish, bass, catfish, walleye pike and crappie.

1.3

2.1 Good view of Paleozoic limestone in road cuts and hills ahead. Much of the exposed rock is probably Redwall Limestone, but it has not been differentiated from the Martin.

0.4

2.5 Shaly interval in Martin Limestone.

0.2

2.7 Caliche developed on basinfill sediments in road cut.

0.1

2.8 Purple shale in road cut. This bed is similar to a lavender shale near Superior which marks the top of the Devonian section.

0.2

3.0 Limestone, possibly Redwall.

0.1

3.1 Tapeats Sandstone in road cut at small bend in road.

0.3

3.4 Basinfill.

0.1

3.5 Mills Ridge Road.

0.3

3.8 Approaching Mills Canyon. Good exposures of coarse-grained basinfill in road cuts. Bedrock crops out up the canyon and includes dioritic volcanics.

1.2

5.0 Road turns sharply to right. Good views of the Sierra Ancha Mountains here and for next few miles. The prominent butte across the lake is Dutch Woman Butte and the central cliffs are formed of Dripping Spring Quartzite.

0.5

5.5 Bottom of small canyon. The attitude of the coarse-grained basinfill is primary, and dips toward the axis of the basin.

0.6

6.1 Obvious disconformable contact of coarse-grained basinfill and overlying terrace alluvium.

1.0

7.1 Near the head of this small canyon, rock of the Apache Group (probably Dripping Spring) has been intruded by diorite.

0.15

7.25 Dark granitic intrusive in road cut.

0.55

7.8 Campground below at right is built on a recent fan at the head of an unnamed canyon. Note the beach ridges formed during higher stands of Lake Roosevelt. These ridges can be studied at many localities along the 88 miles of lake shoreline.

0.4

8.2 Note outcrop of basinfill extending above road level to the left of the road. Good exposures of fine-grained basinfill can be seen across the lake ahead and to the east.

0.2

8.4 Good view across the lake to the mouth of Salt Gulch. A thick ash bed (see mile 23.0) crops out at the head of the gulch and constitutes an important marker bed throughout the northern half of the Tonto Basin.

0.4

8.8 Rock Creek. Finer-grained lacustrine (lake-bed) sediments dip toward the basin axis (N.45°E. at 17°).

0.7

9.5 Basinfill lithologies include sandstone, siltstone, claystone, conglomerate, marl and limestone, gypsum, diatomite, caliche and volcanic ash. These sediments were deposited by several mechanisms in several types of environments; river, lake, alluvial fan, and talus (colluvial) deposits are all recognized. The maximum thickness of the basinfill is unknown, but nearly 1,000 feet has been exposed by erosion and exploratory wells have penetrated nearly twice that thickness in the subsurface. The total thickness of sedimentary fill may well approach 4,000 feet.

The age of sediments in the Tonto Basin has not been precisely determined. Fossils within these strata include vertebrate, invertebrate and plant remains, none of which are very abundant or well preserved. Species of camel (*Procamelus* sp.), dog (*Canis* sp.), and horse (*Pliohippus* sp.) have been found in the basinfill. According to Everett Lindsay of the University of Arizona (written communication), this fauna should be considered middle Pliocene with the remote possibility that it is early Pliocene.

0.6

10.1 Approaching the head of Lake Roosevelt. The lower erosional terraces are fairly well developed at this locality (Fig. 6).

0.5

10.6 Three-bar road to the left. The two low hills (in the basin) to the right are Twin Buttes. A 1,400-foot hole was drilled here some years ago in search of uranium.

1.5

12.1 Coarse-grained basinfill. This area is very near the southwest margin of the basin and the sediments are quite coarse; this condition persists to Ash Creek (mile 15.1).

1.7

13.8 Note the prominent white outcrop to the right across the basin. This

is a thick sequence of light colored sand and fine gravel capped by an 11-foot thick ash bed at the head of Salt Gulch. (See comments for mile 23.0.)

1.0

14.8 El Oso road (Spanish for "the Bear") to the left. This trail crosses the Mazatzal Mountains along the north flank of Four Peaks and meets the Beeline Highway a few miles north of Saguaro Lake turnoff. The A-Cross road crosses Tonto Creek to the east and joins State Highway 288 (Young Road) near the south end of the basin.

Four Peaks lies slightly to the southwest. These craggy peaks are said to have ended the westward migration from Mexico of an ancient Indian tribe. These people considered the number "four" sacred — a sign of finality and the end of life. Purportedly, when the tribe reached Salt River Canyon, the Indians gazed in awe across the lower Tonto to these four magnificent peaks and concluded that they must mark the edge of the world.

0.3

15.1 Ash Creek. This creek is fault controlled and follows an offset in the basin margin. From here northward the basin margin is about 2 miles to the west of the road and the road passes through finer-grained types of basinfill sediments.

1.2

16.3 Good exposure of gypsum beds in cut bank near abandoned road bridge. It is apparently the occurrence of normal faults such as the one in this outcrop that have prompted people to say that the Tonto beds have been tectonically disturbed. However, this fault is probably the result of slumping due to solution of salts (evaporites) in the subsurface, or due to differential compaction of silts and clays.

0.2

16.5 Light colored gypsum beds are well exposed for the next mile.

0.6

17.1 Good view to the north end of the basin. Haystack Butte, slightly to the right, is partially masked by a long pediment-terrace surface in the background.

The high, rounded peak slightly to the left, in the Mazatzals, is Mt. Ord. It is composed of Older Precambrian pyroxinite which intruded schists of the Alder Series and was subsequently itself intruded by an older Precambrian granite.

Note that, in the distance along the road, the beds dip gently (Plate 11) toward the Mazatzals. Between Roosevelt Dam and Ash Creek the dip of all units is toward the basin axis. The change in direction is probably the result of crossing the basin-marginal fault. South of Ash Creek the road is on the west side of the fault and beds show a primary dip toward the axis of the basin. North of the creek, beds have been tilted

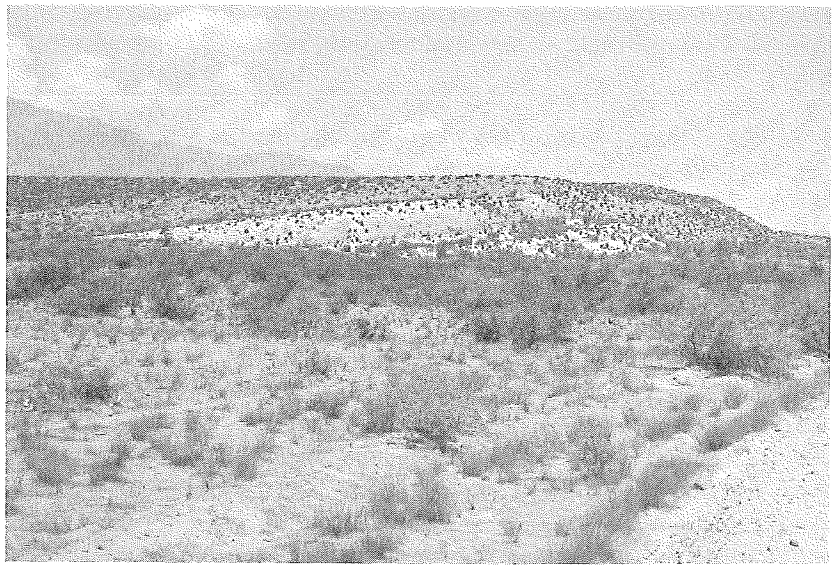

Plate 11. White gypsum beds near mile 20 dipping gently toward the Mazatzal Mountain front.

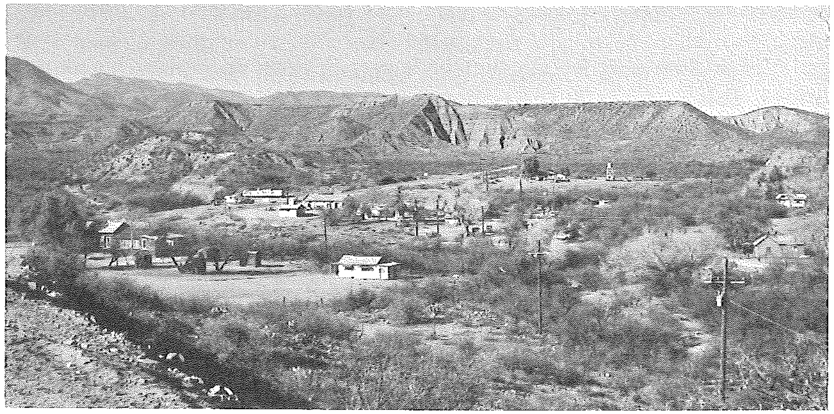

Plate 12. Village of Punkin Center with outcrops of fine-grained basinfill sediments in the background.

by faulting (contemporaneous with filling of the basin) toward the Mazatzal Mountains. This same phenomenon can be observed in the Payson and Verde basins to the northwest.

0.5

17.6 Sycamore Creek.

0.5

18.1 Gypsum outcrops occur on the left for the next mile.

0.7

18.8 Walnut Spring Canyon. The Haystack Butte ash bed is well exposed

halfway up the head-wall of the canyon. At this locality it is about seven feet thick.

0.1

18.9 Tonto Basin. This is the site of the Howells Ranch and the old Seven-Cross Cattle Company. A Post Office was established here in 1884 which operated until 1929 when it was moved to Punkin Center a few miles north.

0.1

19.0 The white beds to the right, along the far side of the basin, were the site of considerable exploration during the uranium boom between 1950 and 1960. No rich deposits were discovered, but there was enough "show" to tempt the local ranchers into staking claims and selling their stock to pay for drilling and blasting. As one old timer in the basin declared, "I was a millionaire half a dozen times in those days." Exploration died out after a few years, and the pits and shafts were closed to prevent cattle from falling in. Recently, nearly this entire basin has been staked by a Phoenix firm, and a modern program of exploration is underway for uranium.

0.1

19.1 Gypsum beds thin and are interstratified with red clay. These beds are highly oxidized and apparently accumulated very slowly in an ancient lake.

0.6

19.7 Note dip (6°-8° nearly due east) of pink and white beds (Plate 11) straight ahead. This attitude is characteristic of sediments along this portion of the basin.

2.3

22.0 Haystack Butte to the right. The white beds of the old uranium prospects are visible beyond, and south of the butte. The white slash on the north side of the butte is a highway quarry in the Haystack Butte ash bed.

0.2

22.2 Park Creek.

0.3

22.5 Tonto Basin Ranger Station. Good exposure of fluvial terrace cap-gravels occur in road cut. This road leads through the Ranger Station to the site of old Fort Reno near the base of the Mazatzal Mountains.

0.5

23.0 Punkin Center. This picturesque little community (Plate 12) centers about a general store, schoolhouse, Ranger Station and highway maintenance yard. The general store, established in the late 1800's, was formerly known as Packard's Store after its original owner. The present proprietors, Jip and Frankie Tort, have operated the store since 1944. The general store is the hub of activity up and down the basin. Frankie

Tort can tell a stranger which ford to use in Tonto Creek, where the Joy Slash X outfit is branding or what the current price of beef is. The store offers everything from horseshoe nails to a cup of coffee and as Henry Simmons (a local personality) observed, it serves as Punkin Town's waterin'-hole.

Side-trip. A brief side-trip east of Punkin Center, along the Greenback Road, crosses Tonto Creek and leads toward the east side of the basin. Haystack Butte is a prominent erosional remnant just south of the road about 2.5 miles from Punkin Center; a dirt trail leads from the county road to a quarry at the base of the butte. A 12-foot thick ash bed, informally referred to as the Haystack Butte bed, crops out here and has been excavated by the county for use on roads throughout the Tonto Basin. The basal foot or more of the bed is very pure and apparently represents the "air-fall" deposit of the original volcanic eruption that produced the ash. The remainder of the unit is less pure and displays thin horizontal- and cross-bedding which indicates that it was washed into this site of accumulation from the surrounding area. The lower contact of the bed is very sharp, whereas the upper boundary is gradational. This is evidence for the abrupt initiation of this volcanic event and the gradual decrease in deposition as the adjacent highlands were washed clean. This same ash bed crops out in the long ridge (bench) just north of Haystack Butte (Plate 13).

The environment of deposition within which the ash accumulated was a lake. The extent of this lake can be approximated by the extent of the ash layer which is widespread along both margins of the northern half of the basin. Apparently, the basin was dammed at its lower end and water backed up to, and beyond, this locality. Whether the lake maintained these dimensions during the entire depositional history of the basin is questionable, but it is not unlikely.

Return to Punkin Center.

1.0

24.0 Prominent beds in the cut bank of Tonto Creek contain the Haystack Butte ash. The term Tonto derives from the Spanish for foolish. The word was applied indiscriminately and broadly in reference to the Tonto Apache of central Arizona. The original Spanish explorers considered the Apaches to be somewhat imbicilic, an error of judgment which the Indians later made apparent. The name was later used for the Tonto Basin (known to the Spanish as Apacheria) and to Tonto Creek. The term is appropriately applied to this creek — although it is nearly perennial, its flow can vary from nearly nothing to a raging torrent in a very short time. Its average annual discharge between 1941 and 1967, measured at the upper end of the basin, was 105 cubic-feet per second. The maximum discharge for the same period was 45,400 cubic-feet per second recorded on January 18, 1952.

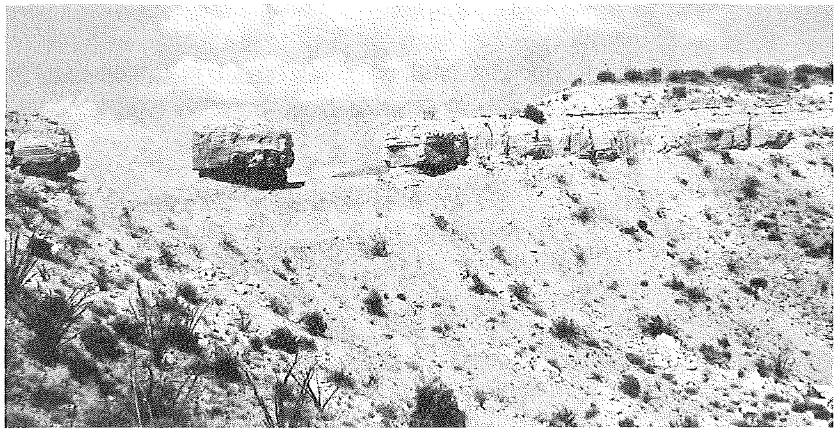

Plate 13. Thick bed of Haystack Butte ash in wind gap just north of Haystack Butte.

1.5

5.5 Note the terrace development along Tonto Creek. Kayler Butte is visible slightly to the right of the road.

1.0

26.5 Haufer Wash road. The Haystack Butte ash crops out at road level about 0.7 mile up this road (Plate 14) and has a thickness of about 7 feet.

Plate 14. Outcrop of the Haystack Butte ash in Haufer Wash; thickness of the ash exceeds seven feet.

0.6

27.1 First outcrop of "older" (Gila-type) conglomerate in cut-bank of Tonto Creek dipping down-basin. Also note the erosional surfaces which can be seen throughout the upper portion of the Tonto Basin (Plate 15).

Two types of erosional surfaces form "benches" in the Tonto Basin; these are river terraces and pediment-terraces. Terraces are formed as a result of down-cutting of the main stream and its tributaries which leaves the old floodplain elevated above the new channel. These old surfaces parallel the present course of Tonto Creek and slope gently down-valley at about the same gradient as the stream. Pediment-terraces are defined as pediment-like features cut in the soft basinfill. They are fan-like surfaces across which sediment was transported from the mountain fronts to the axis of the basin to be removed by Tonto Creek. They slope at angles varying from 7° near the mountain front to about 0.5° near Tonto Creek. As was the case with the river terraces, pediment-terraces have also been left elevated many times as a result of successive down-cutting of the drainage system. Terraces and pediment-terraces are surficially similar, but they differ in their pattern of areal extent (Fig. 6), in their angle of slope, and in the conditions of their origin. The few studies that have been made of their surfaces have led to different (and opposing) theories regarding their origin. Some geologists explain the downcutting as a result of periodic regional uplift, and others claim that cyclical changes in climate caused changes in stream discharge and slope stability which resulted in downcutting. It is probable that both of these factors have induced downcutting in North America, but Barsch and Royse (1971) suggest that climatic changes associated with Pleistocene glaciations are the principal cause in the Southwest. They have defined

Plate 15. View southward from a locality near the mouth of Slate Creek Canyon. The small conical hill in the background is Haystack Butte and the surface to the left of it is the P_{400} pediment-terrace surface. Several terrace surfaces are apparent in the foreground above the cut-bank of Tonto Creek.

seven distinct and persistent terrace levels which parallel Tonto Creek and five widespread pediment-terraces in the Tonto Basin (Fig. 7). Because these two types of surface do not grade into one another, they postulate that they are products of separate climatic and erosional episodes. An argument is advanced that pediment-terraces are products of processes active under arid and semiarid conditions whereas terraces formed during times of more humid climate. If this postulate is correct, the logical interpretation is that terraces were formed during glacial (or pluvial) times and pediment-terraces were formed during interglacial (or interpluvial) times. It would appear that, in the Tonto Basin, the entire glacial epoch was characterized by erosion which removed tremendous volumes of basinfill sediment and produced the striking series of erosional surfaces which today characterize the topography of the basin.

1.0

28.1 Older conglomerate (dark gray) is unconformably overlain by coarse facies of basinfill sediments. The reddish channel-fill material is also coarse-grained and is apparently related to (contemporaneous with) the terrace gravels of the T_{160} stage (Plate 16).

0.2

28.3 Junction of Slate Creek road and Highway 188. Turn left up Slate Creek Canyon. Note the thick caliche layer interstratified with Tonto beds in the north wall near the canyon mouth, and the exposures of terrace gravels.

2.8

31.1 Small canyon. An unconformity (Plate 17) between two different coarse-grained basinfill sediments is evident in the section exposed in this canyon. The lower conglomerate (Gila-type facies) dips S. 65° E. at about 15°, whereas the younger, basin-marginal facies of the Tonto beds dips about N.70°E. at 10°. The angular discordance is not extremely marked from the road, but a short climb up the canyon demonstrates its reality.

0.1

31.2 Outcrops of basalt in Slate Creek. This basalt is interbedded with the older (Gila-type) gravels and has been tilted by faulting toward the axis of the basin.

0.8

32.0 Steeply dipping older conglomerate at bend in road.

0.6

32.6 View to right (Plate 18) shows dark colored basalt interbedded with older conglomerate. Both of these rock types dip with increasing steepness toward the Tonto Basin.

1.4

34.0 Junction of Slate Creek Road and State Highway 87 (Beeline Highway). To the west of the highway is an old mercury mine; the old retorts can still be seen from a vantage point just south of this junction. End of Highway 188 log.

Plate 16. Thick fluvial gravel capping an erosional remnant near the junction of Highway 188 and Slate Creek Road.

Plate 17. Unconformity between older (Gila-type) and younger conglomeratic facies of coarse-grained basinfill at mile 31.1 in Slate Creek Canyon.

DETAILED ROAD LOG

Arizona Highway 87

Intersection of Slate Creek Road and State Highway 87.
The following road log progresses south on State 87.

CUMULATIVE MILES — MILEAGE INTERVALS

0.0

0.0 The mountainous region to the west and south belongs to the central section of the Mazatzal Mountains of central Arizona. Its crest marks the boundary between Gila and Maricopa counties and is a divide between the Verde River drainage to the west and the Salt River drainage to the east. Ahead, the highway follows Slate Creek, which is cut along the northeast structural grain that is so well manifested in older Precambrian rocks in Arizona.

For the most part, only older Precambrian and Cenozoic rocks are preserved in this central section of the range. There is no record of the history of younger Precambrian, Paleozoic, or Mesozoic sedimentary rocks in this region. Apache Group strata of the Roosevelt area probably did not extend much to the northwest of the present site of the Mazatzals, and Paleozoic and Mesozoic strata generally are absent between Payson to the north and Silver Bell to the south in Pima County, a distance of about 130 miles.

Hayes (1969) includes the central Mazatzals in a newly defined "Tonto Section" of the Colorado Plateau province whereas other workers prefer to include it in the Basin-and-Range province or in a Transition Zone.

0.1

0.1 The network of roads on the flank of Mt. Ord, ahead, is testimony to the interest in the mineral potential of this area.

0.5

0.6 Mile post 229. In west side of road-cut, Cenozoic gravels on the south are faulted against rocks of the older Precambrian Alder Series on the north (Plate 19).

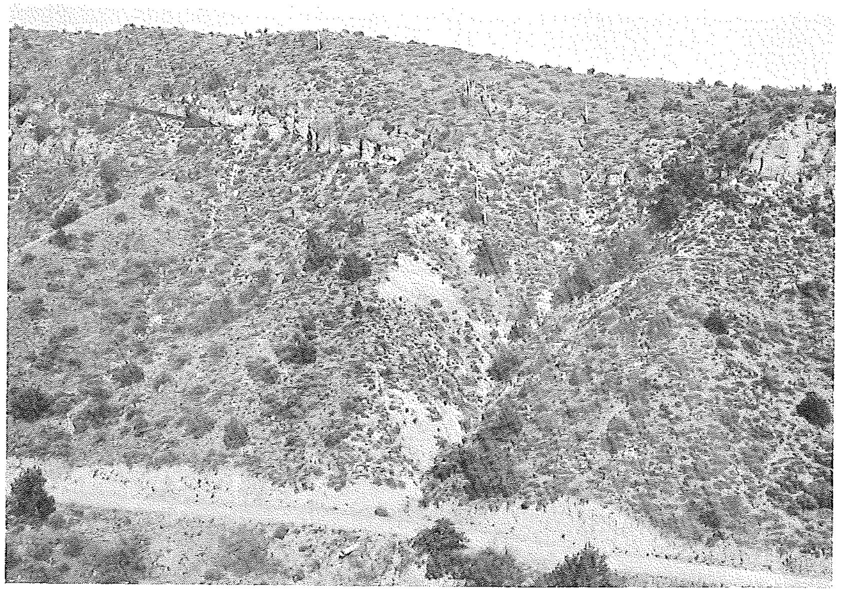

Plate 18. Basalt (arrow) interbedded with older (Gila-type) conglomerate in Slate Creek Canyon.

Plate 19. Normal fault. Tertiary sediments on the south are faulted against older Precambrian Alder Series. Looking north.

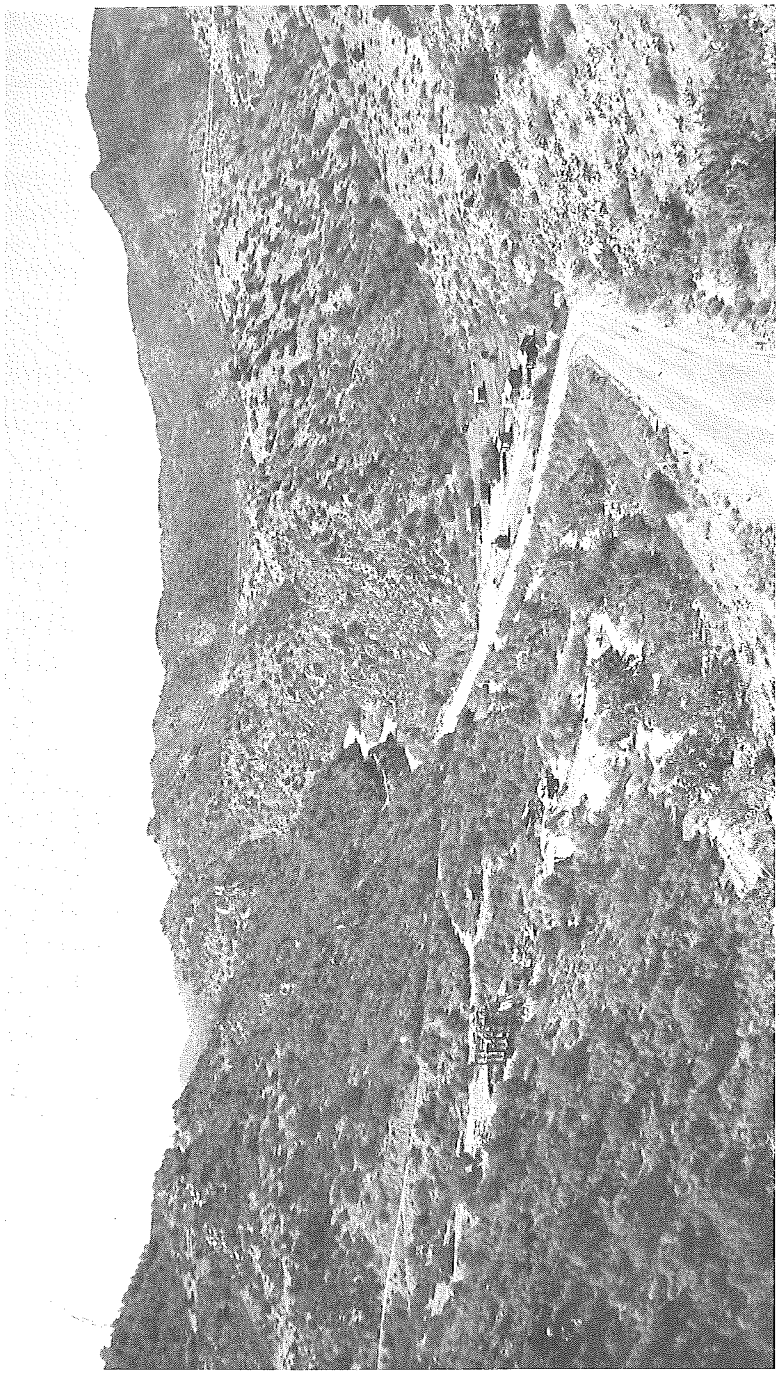

Plate 20. View to the southwest up Slate Creek with mercury mining and processing area in middle distance.

0.1

0.7 Road descends into drainage of Slate Creek. This creek gets its name from outcrops of slate and phyllite of the Alder Series along its upper reaches (Plate 20).

0.2

0.9 Ord mine area is in the Mazatzal Mountains mercury mining district, formerly the principal mercury producing area in Arizona. Old retorting site can be seen to the left of the highway.

0.4

1.3 Quartzitic unit in the Alder Series.

0.7

2.0 Slaty, locally schistose units in Alder Series. Light-colored zones mark high quartz content. Slate Creek is cut into the relatively nonresistant Alder Series along a northeast trend.

0.3

2.3 To west, siliceous zones stand above general ground surface.

0.4

2.7 Turn-off to left permits parking for close inspection of green and purple phyllite (shiny slate) of the Alder Series.

0.5

3.2 Intermixed slaty and quartzitic rocks of the Alder Series are cut by gray-green volcanic dike on the right.

0.6

3.8 Coarse Cenozoic gravels. Mt. Ord to the southeast is about 7,100 feet in elevation and is the type area for the Mt. Ord Pyroxenite, an older Precambrian rock that is intruded by the older Precambrian granitic rocks that are so extensively developed to the south.

0.2

4.0 Contact area to the north between the Red Rock Rhyolite of Wilson (1939) and the Alder Series. The contact cannot be readily distinguished from a moving vehicle but there is a general absence of slate in the road ahead. Red Rock Butte, a type area, is less than a mile to the north of the sharp bend in the highway.

0.3

4.3 In east side of road-cut, Cenozoic gravels are intruded by a narrow dike and a short sill.

0.3

4.6 The large road-cuts expose tilted and faulted Tertiary sediments that contain a large percentage of fragments derived from the Alder Series (Plate 21).

0.1

4.7 Slate Creek summit, crest of Mazatzal Mountains, and Gila-Maricopa County line (elev. 4,345 feet). Pine Mountain Road to the east leads to the Mercurio, Oneida, and Pine Mountain mines; a spur of this road

leads to the Jenella mine. To the west and south is a shallow intermontane basin, the first of several such basins along the route ahead. The age of sediments and volcanics within these basins is imperfectly known, but they are probably middle Tertiary. They may represent remnants of original accumulations associated with drainage diverted by volcanism in the Superstition area. These present valleys or basins may, in part, represent exhumation of previously existing valleys and, therefore, may not represent simple tectonic down drops of a traditional sort. Considerable mapping remains to be done.

0.4

5.1 Deformation of gravels in west cut may be related to the intrusion of the volcanic rocks that form the high points to the immediate east.

1.2

6.3 Light-colored Tertiary gravelly strata with a high content of Precambrian clasts, notably of granite composition.

0.1

6.4 Gray rocks to west are quartzites of the Alder Series.

0.9

7.3 East road cut contains granitic Tertiary gravels intruded by dark Cenozoic basaltic rock.

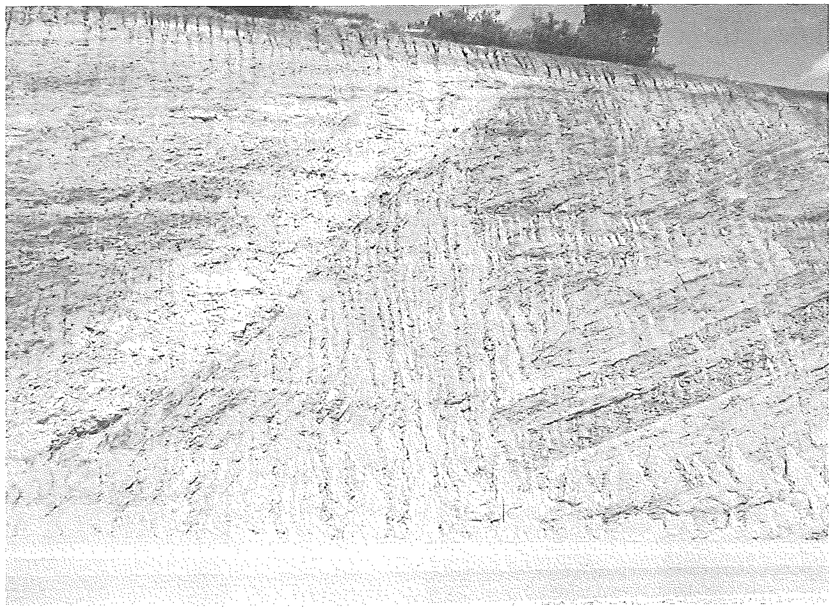

Plate 21. Faults in Tertiary sediments near Slate Creek summit (mile 4.6).

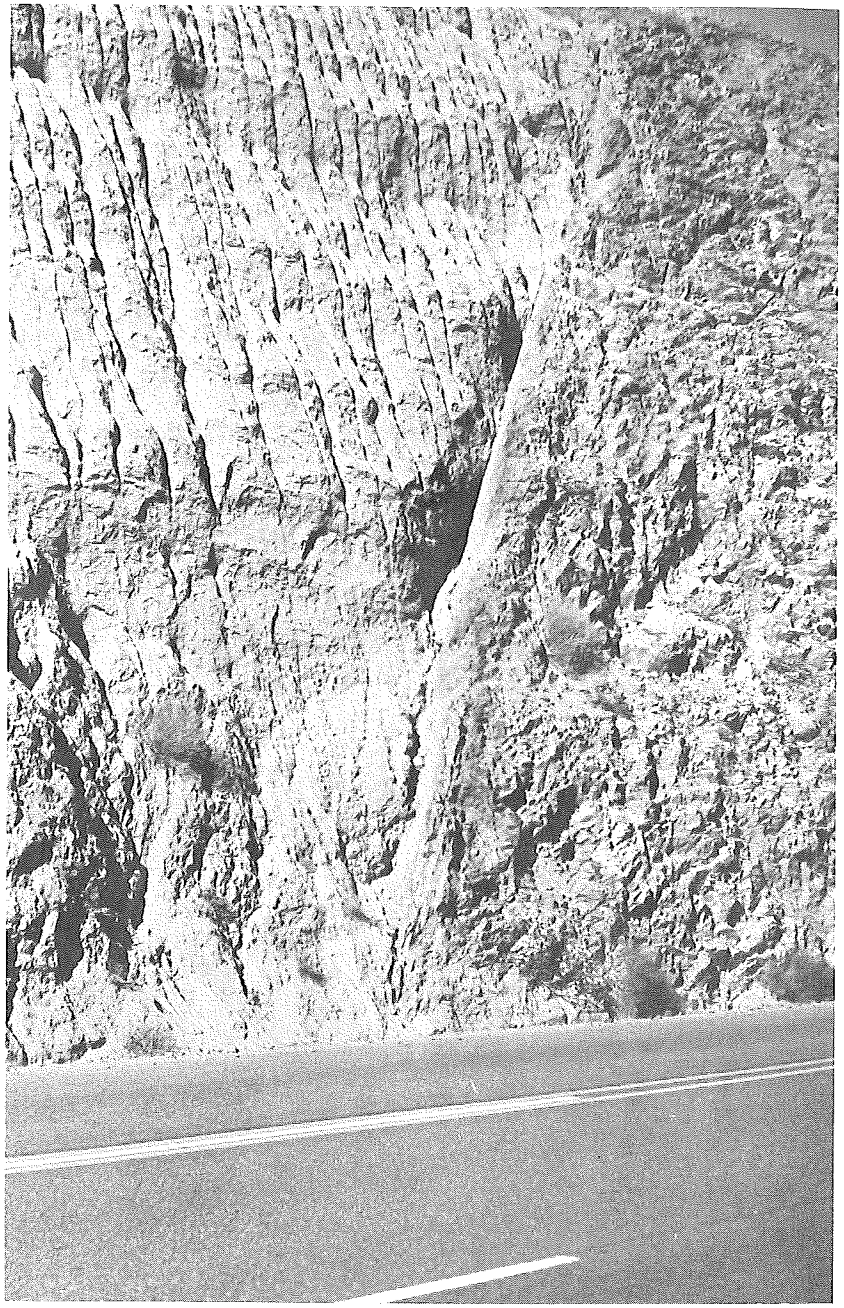

Plate 22. A pronounced fault at mile 15.4 which brings stratified Tertiary sediments into contact with Precambrian granite. The down-dropped block on the left consists of sediments unconformably overlying granite. Quaternary channel deposits overlie the Tertiary strata.

0.6

7.9 Canyon walls are a complex of volcanic flows and sediments containing volcanic debris. Road ahead follows Sycamore Creek.

0.5

8.4 Cenozoic basalt.

1.4

9.8 Sycamore Creek flows on hard volcanic rock for several miles. Outcrops can be studied at many places along the road and in the creek bed adjacent to the store in Sunflower, ahead. Younger stream gravels, through which the creek has cut, overlie the volcanics in some areas.

0.5

10.3 Entering the little valley of Sunflower.

0.9

11.2 Circle-Bar Ranch.

0.2

11.4 Red conglomerate of Tertiary age.

0.2

11.6 Mile post 218, turnoff to Sunflower to the east. This wayside stop provides services.

0.2

11.8 Tertiary basinfill in fault contact with granite in the small road-cut between the access roads to Sunflower.

0.2

12.0 Cenozoic gravels resting on granite (elevation 3,600 feet).

0.1

12.1 Dark-colored dikes cut Precambrian granite. Numerous dikes can be seen ahead as the highway descends through a granitic terrane into Sycamore basin.

2.5

14.6 Road cut in older Precambrian granite.

0.8

15.4 West side of road-cut. Fault contact of Tertiary sediments and older granite on the south with older Precambrian granite on the north (Plate 22). The upper surface of the sediments is channeled and filled with younger gravels. There is a wide shoulder on the left side of the highway which is suitable for parking if approached carefully.

0.3

15.7 Road cut in fractured granite.

0.3

16.0 The highway is descending into Sycamore valley, an example of an intermontane basin. The perimeter of the basin is formed by granite of the Mazatzal range and the central portion contains remnants of interbedded sand, gravel and basaltic lava flows. Faulting is manifested in westward tilted blocks throughout the basin. The basalt flows make good

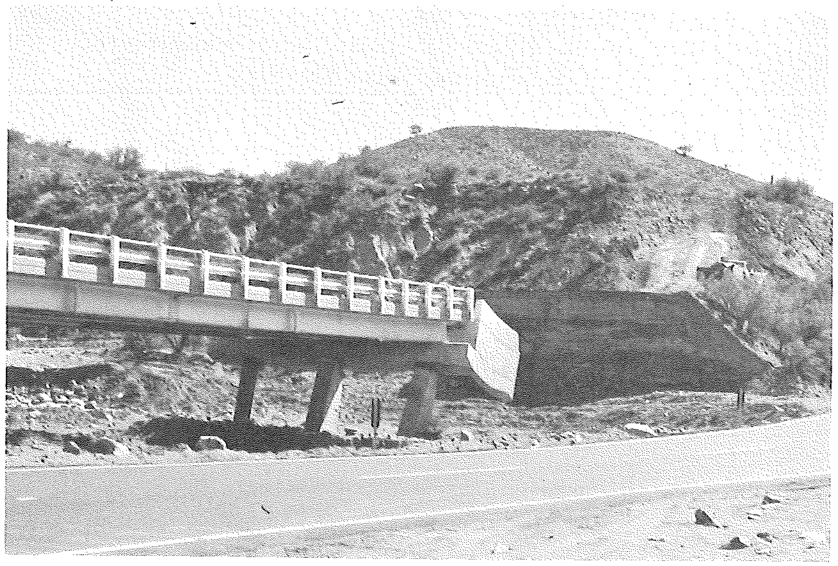

Plate 23. Bridge over Sycamore Creek at mile 17.1 which was washed out by floods in September, 1970.

Plate 24. Automobile fragments in the dry bed of Sycamore Creek below Highway 87 bear testimony to the strength of its flood-waters.

marker beds and are generally higher along the basin margins and lower in its center. The road cuts for the next few miles contain granite, sediments, and volcanics, and expose faults which moved these different rock units into juxtaposition.

1.1

17.1 Sycamore Creek (elevation 2,355 feet). The concrete bridge over

this small creek collapsed when its south abutment was washed out in a flood during the Labor Day weekend of 1970 (Plate 23). The flood accompanied four days of heavy rain which transformed Sycamore Creek into a raging torrent. Several people lost their lives here, including a State Highway Patrolman, before the highway was flagged with warnings. The torn and mangled wreckage of cars (Plate 24) can be found in the creek bed for miles downstream and bear testimony to the potential violence of the tranquil "gullies" of Arizona.

0.5

17.6 Mile post 212. Tertiary sediments.

1.0

18.6 Tertiary sediments and volcanics to the west.

0.1

18.7 The butte ahead is composed of sediments capped by basalt. The gentle westward dip of the summit manifests the general westward tilting of strata in this basin. These strata are but remnants, therefore it is possible that westward tilting is a regional phenomena and not necessarily confined simply to local basins.

0.2

18.9 Crossing Pine Creek. Mazatzal Mountains to the east are largely granitic, and the crestal elevations range near 6,000 feet.

0.7

19.6 Crossing Camp Creek. The hills straight ahead and to the right consist of well-lithified sediments which typify the basin. They are capped by basalt.

0.4

20.0 Cattle guard. Elevation of valley bottom is 2,181 feet.

0.4

20.4 Contact of west-tilted volcanics and sediments.

0.5

20.9 Cenozoic volcanics.

0.4

21.3 Mesquite wash, elevation 2,061 feet.

0.5

21.8 Sharp fault contact between basalt and sediment can be seen in road cut to right. Also, contact area of valley fill and topographically higher granite.

0.7

22.5 This grade provides a good panorama back across the basin and the features noted can be placed in better perspective. Note the basalt high on the north margin, the granite outcrops bounding the basin, and the westward dip of its contained sediments.

0.2

22.7 Light-colored dikes in Precambrian granite. The fine-grained rock in dikes of this type is often referred to as aplite.

0.8

23.5 Summit (elevation 2,636 feet). Periodically, a mound-like butte called Sugarloaf Mountain can be seen to the right as the road descends for the next mile. This butte is an erosional remnant of a basalt flow which has been down-dropped to its present position. Other remnants of this flow can be seen at various elevations throughout this vicinity.

0.2

23.7 Well developed fracture system in granite to east. K-Ar dates for this granite indicate that it is about 1,540 million years old.

0.3

24.0 The great boulder piles in this area are the result of a phenomenon referred to as spheroidal weathering. Granite commonly develops joints in several directions which effectively render it blocky. Weathering along these joints ultimately rounds the edges and corners of the blocks and forms a boulder-studded topography such as that seen along this flank of the Mazatzals.

0.6

24.6 At one time, the basin area ahead was a vast desert floor which must have resembled the present Phoenix valley. Since the time of deposition of the immense volume of sediments which filled this depression, the Verde River has eroded deeply and its tributary gullies have dissected the region into a bad-land topography. Erosion is still active, and desert rainfalls transport great quantities of desert soil into the Verde. This not only causes problems in land use, but tends to fill in the reservoirs downstream which act as great settling basins and trap the sediment. Measures are underway by the Forest Service to stabilize this surface, and the area is designated the Tonto Soil Conservation District.

0.4

25.0 Side-road to west leads to volcanic-capped Sugarloaf Mountain and Sycamore Creek, a popular, undeveloped camping ground.

1.0

26.0 Junction of El Oso Road and Beeline Highway.

0.6

26.6 Turn-off to Desert-Vista Viewpoint (restroom facilities). The panorama from northeast to southeast provides some of the most spectacular scenery in the Southwest and encompasses much of the region through which we have come. The Goldfield Mountains comprise the low, jagged hills to the southeast, and the Superstitions begin with the bold-cliffed rock on the skyline and extend eastward to the pinnacle called Weavers Needle and beyond into the distant middleground. To the northeast, the castellated summits of Four Peaks rise majestically. Between Four Peaks and the highway, granite knobs known as Mine Mountain, Pine Mountain and Boulder Mountain display a typical southwestern granitic terrane. An old mine road zig-zags up the flank of Mine Mountain.

Figure 11 illustrates the collapse structure which characterizes the Superstition Volcanic complex. Weavers Needle is an erosional remnant in the down-dropped central portion of the Black Mesa Caldera, and the Superstition block and Geronimo Head are uplifted blocks along its margin. Well developed desert caliche can be seen in the parking areas of this stop.

Four Peaks is a classic outcrop area in that it is here that granitic rocks of suspected older Precambrian age are seen to intrude the Mazatzal Quartzite. However, though the granite is younger than the quartzite, it also is believed to be older than the younger Precambrian Apache Group. These ideas served to bracket the principal intrusive event in Eldred Wilson's concept of the older Precambrian Mazatzal Revolution (1939).

At the time of this writing, a new southbound lane was under construction, and the readers of this guide will view different road cuts than those seen by the writers. Although we have omitted comments on specific road cuts, many good examples of stratified basinfill sediments with interbedded layers of resistant, light-colored caliche can be seen for the next 12 miles along the highway.

2.4

29.0 Rugged peaks straight ahead are Mt. McDowell, locally referred to as Red Mountain.

0.8

29.8 Turn-off to Saguaro Lake. A few miles to the east are Saguaro Lake and Stewart Mountain Dam, the lowest of the dams and reservoirs on the Salt River. A brief side-trip here provides good views of towering cliffs of bedded volcanic ash of the Superstition Volcanic complex. The Bush Highway provides an alternate route from the lake to east Mesa.

0.6

30.4 A small, craggy knob of basalt can be seen on the small hill to the east.

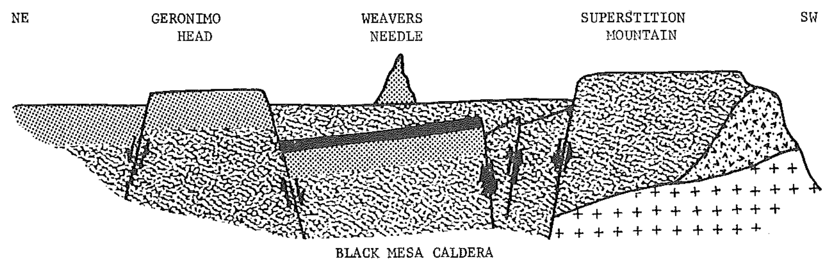

Figure 11. Schematic diagram indicating the general collapse structure of Black Mesa Caldera as seen from the Vista-Point at mile 26.6.

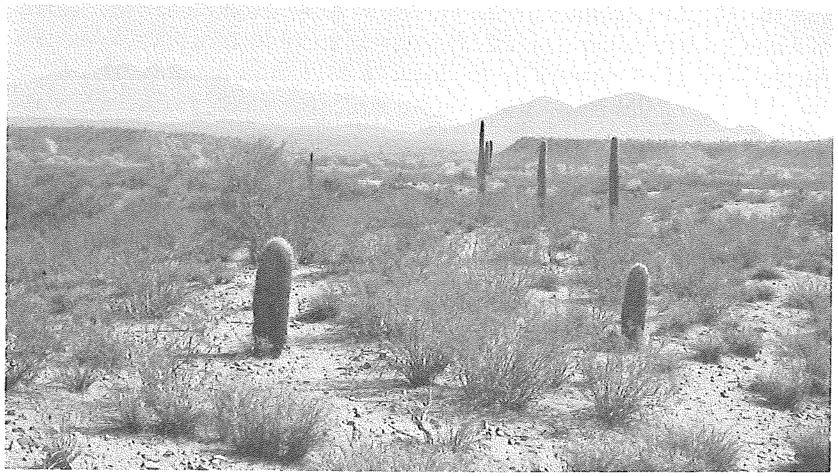

Plate 25. High terraces along the Verde River. View is northward from the vicinity of mile 38; Mt. Stewart rises in the middle-ground and Four Peaks is silhouetted on the skyline.

2.9

33.3 Road cuts in Tertiary sediments. To the east is Stewart Mountain, a granitic outcrop for which Stewart Mountain Dam was named.

1.2

34.5 To the southeast are rugged cliffs of the west margin of the Goldfield Mountains. These cliffs mark a fault contact between the light-colored volcanic beds and Precambrian granite along which the Salt River flows after leaving Saguaro Lake.

0.4

34.9 Note the expanse of the McDowell Mountains ahead and to the right. At their southeast end, this range terminates in a smooth erosional surface which slopes gently westward. This surface is a pediment and, because it separates this basin from the Salt River Valley, it can be called a pediment-pass. The erosional remnants on this surface are called inselbergs (island-mountain). The McDowells are a granite-cored range that have been intruded by many basalt dikes and veneered with Tertiary sediments.

0.8

35.7 Southern boundary of Tonto National Forest. The National Forest area has been extended into the desert to help protect against excessive erosion.

1.3

37.0 Flat-topped benches can be seen on both sides of the highway as we approach the Verde River. These benches or terraces (Plate 25) represent old surfaces across which the Verde flowed when its channel was at a higher elevation. These can be correlated with one of the higher terraces along the Salt River. The resistant beds in the upper part of the cut-face

of the benches is caliche, a cement formed by evaporation of water from this ancient floodplain. Several lower, mesquite-covered terraces can also be distinguished.

0.2

37.2 Abundant mesquite growth in this vicinity is an indication of proximity of ground water to the surface because mesquite thrives only where its roots can reach permanent water.

0.4

37.6 Bridge over Verde River (elevation 1,379 feet).

0.4

38.0 Turn-off to Fort McDowell. This old army post dates back to the 1870's and was set aside in 1903 as a reservation for the Yavapai Indians. Although they are commonly called the Mohave-Apache, these people belong to the Yuma tribe and are not related to the Apache. They are picturesque in their dress and in many of their habits and customs. Their woven baskets are among the finest made by Arizona tribes. The hardy Yavapai have become good stockmen and construction workers.

A view back toward the river best shows the development of the Verde River terrace surfaces.

1.4

39.4 Precambrian granite. Dates obtained by the K-Ar method indicate this granite to be about 1,370 million years old.

0.6

40.0 Junction with Shea Blvd. This road leads to north Scottsdale and north Phoenix. For several miles westward, road cuts contain red conglomerate of the same type as found in Mt. McDowell, but with overlying younger gravels. Both the red conglomerate and the younger sediments have been cut by many basaltic dikes which probably furnished the lava forming the basalt flows capping nearby buttes.

0.6

40.6 The highway crosses a low divide near the east end of the McDowell Mountains. Shallow road cuts ahead expose red, coarse-grained sandstone of Mesozoic or Tertiary age. It consists largely of granitic debris and includes many large boulders. The large butte to the east, Mt. McDowell (Plate 26), is composed of similar material. A knowledge of the age of this unit would aid in better understanding the erosional history of a large section of south central Arizona in which there is meager preservation of Paleozoic and/or Mesozoic rocks.

2.5

43.1 Milepost 188. Entering the Salt River Valley. Elevated terrace remnants of the Salt River occur to the southeast (left). Road cuts ahead are in Tertiary sediments and old stream gravels of the Salt River.

0.1

43.2 The low, crowded granitic knobs to the east are the Usery Mountains. Ahead, beyond the Salt River Valley, are the Salt River Mountains.

0.2

43.4 Cenozoic stream gravels.

0.3

43.7 A pediment, broken by inselbergs, slopes gently from the foot of the Usery Mountains to the floor of the Salt River Valley.

1.0

44.7 Arizona Canal.

1.0

45.7 Half a mile ahead the road rises on a step from a lower terrace of the Salt River to a higher terrace.

0.3

46.0 The highway parallels the Salt River channel for the next few miles. The stream bed is a source of sand and gravel for use in local construction. We cross the Salt River Indian Reservation from here to the end of the guide.

0.8

46.8 McDowell Mountains are to the northwest. The main mass is Precambrian granitic material, but the lower foothills are patches of basaltic volcanics that are younger than the red sandstones of Mt. McDowell.

2.5

49.3 Undeveloped roadside rest area.

1.7

51.0 Intersection with McDowell Avenue. Turn left for Mesa or right to Scottsdale, Tempe, and Phoenix. End of log.

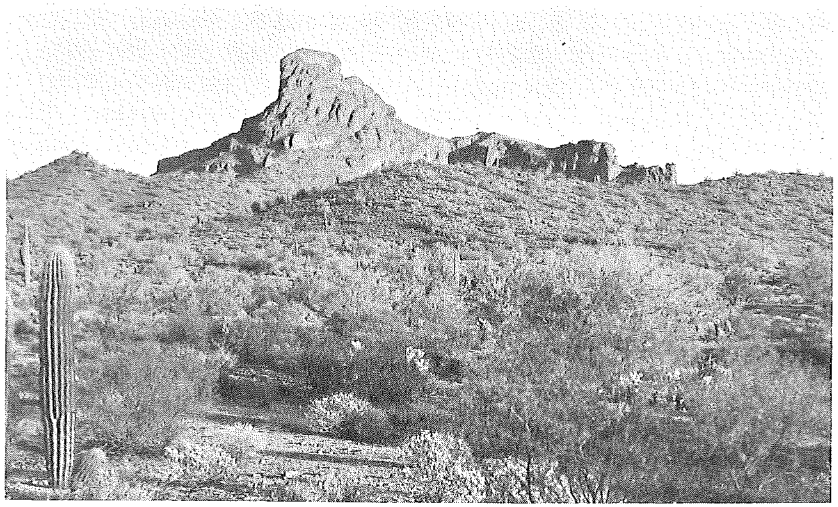

Plate 26. Mt. McDowell, to the east, consists of coarse, red sandstone and conglomerate of Mesozoic or early Tertiary age. This unit probably precedes Basin and Range tectonism and therefore may be protected in down-dropped valley blocks.

APPENDIX

GLOSSARY OF SELECTED TERMS

Acre-foot. A volume of water that would cover an area of one acre to a depth of one foot.

Andesite. A volcanic rock composed of plagioclase feldspar and hornblende or pyroxene. The gray lava has white patches of feldspar in a dark matrix.

Arkose. A sedimentary rock composed of 25 percent or more feldspar. It is usually derived from weathering and disintegration of granites. This reddish rock has well-developed bedding.

Ash. Volcanic fragments less than 4mm in diameter ejected into the air at the time of an eruption.

Ash flow. An avalanche of hot volcanic ash produced by an explosive eruption. This term also applies to the deposit resulting from such an eruption.

Attitude. The orientation of a bed or stratum as defined by its strike and dip.

Basalt. A volcanic rock composed of plagioclase feldspar and pyroxene, with or without olivine. A dark grey to black dense lava.

Bedding. Planar structures in sedimentary rocks. Bedding usually indicates the near horizontal original position of rock layers. Tilted bedding suggests deformation due to faulting or folding.

Biotite. A dark brown to black mineral of the mica group. It forms hexagonal plates that flake easily.

Caldera. A large basin-shaped volcanic depression which is more or less circular in form. Calderas range in size from one to 20 miles in diameter.

Cambrian. The oldest of the geologic periods in the Paleozoic Era (Fig. 2) which occurred 600-500 million years ago.

Cauldron. A large irregular-shaped volcanic depression, usually formed by collapse due to eruption of a large volume of ash.

Cenozoic. The latest of the four eras into which geological time is divided. This era extends from about 70 million years to the present.

Cinders. Porous volcanic fragments usually of basalt composition. Cinders are the result of explosive volcanic eruption.

Claim. The portion of mining ground held under Federal and local laws by one claimant or association, by virtue of location and record. Land claims have a maximum size of 600 by 1500 feet.

Composite Cone. A volcanic cone of large size composed of alternating layers of lava and cinders or ash.

Contact. The surface of juncture between two adjacent rock units.

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

Devonian. The fourth geologic period of the Paleozoic Era which occurred about 413-350 million years ago.

Dike. A tabular body of igneous rock that cuts across existing rocks. Dikes result from the intrusion of magma toward the surface.

Dip. The angle at which a stratum is inclined from the horizontal. The dip is at right angles to the strike.

Dip slope. A hillside that is inclined more or less parallel to the dip of the underlying strata.

Dome. A rounded mountain formed by the up-welling of material from below.

Extrusion. The emission of magma to the surface as lavas, volcanic domes, or ash.

Fault. A fracture in the earth along which there has been displacements of the sides relative to one another.

Fold. A bend in layered rocks.

Formation. The primary unit designating or describing rocks in geologic mapping. Formations are the formal names of rock units.

Gas cavity. The portion of a volcanic rock that has been forced open by expanding gases during or shortly after eruption.

Glacial epoch. Refers to the Pleistocene Epoch during which glaciers covered most of North America; about 3,000,000-10,000 years ago.

Glass. The rapidly chilled liquid portion of magma that does not have a crystalline structure. Volcanic glasses (obsidian) are generally of rhyolite composition.

Granite. A plutonic rock composed of quartz, K-feldspar, plagioclase and biotite. Granites are coarse-grained and light-colored rocks with even grain size.

Gypsum. A mineral, $CaSO_4 \cdot 2H_2O$, commonly formed by precipitation due to evaporation.

Hornblende. A brown to green pencil-shaped mineral. Hornblende is common in some andesites and quartz latites.

Hot spring. A thermal spring with water at a higher temperature than that of the human body. Hot springs are found in areas of recent volcanic activity.

Hydration. The combining of water with another substance. Volcanic glass often hydrates to form perlite.

Hydrothermal. Hot magmatic fluids which produce ore deposits, alterations, and hot springs.

Igneous. Rocks that have crystallized from molten magma. Volcanic rocks are ore categories of igneous rock.

Interglacial. Refers to the interval of time between successive glaciations when the climate was warmer and drier.

Intrusion. A body of igneous rock that invades an older rock.

Isotopes. Element having the same atomic number but different atomic weights.

K-Ar. A technique for measuring the age of rocks based on the radioactive decay of potassium-40 to argon-40.

Lava. Fluid rock material extruded from a volcano. Rock which results from solidification of the fluid material on cooling is also called lava.

Lode. A fissure in the earth that is filled with valuable minerals. Examples are the Comstock lode of Nevada or the Mother Lode of California.

Magma. Mobile, partly-molten rock material generated within the earth.

Mine. Subterranean excavations for minerals.

Mineralization. The process of replacing a body of rock with valuable minerals.

Miocene. An epoch of geologic time that existed from 30 to 15 million years ago.

Obsidian. Generally black volcanic glass. Obsidian has a low water content, whereas perlite is hydrated rhyolite glass.

Olivine. A green mineral with the formula (Mg, Fe) SiO_4. Olivine (peridote) is a common constituent of basalts.

Ore. A mineral or group of minerals that can be extracted from the earth for a profit. The material that is unprofitable to mine is called gangue.

Oxidation. The process of combining with oxygen. Many volcanic rocks undergo oxidation on eruption to the surface.

Paleosol. An ancient soil covered by younger rocks or deposits.

Pediments. Gently inclined erosional surfaces developed on bedrock along mountain fronts; they are generally covered with a thin blanket of gravel.

Perlite. Hydrated volcanic glass, having numerous concentric cracks. If suitable for expansion, it can be economically valuable.

Pleistocene. The epoch of geologic time from approximately 3 million years to 10,000 years age. The "ice age" is another name for this epoch.

Pliocene. The epoch of geologic time which preceded the glacial epoch (Pleistocene), about 12-3 million years ago.

Plutonic. Rocks of igneous origin that crystallize deep within the earth. Granite is one type of plutonic rock.

Pluvial. Refers to former climatic episodes of greater humidity and rainfall, sometimes equated in the Southwest to glaciations.

Precambrian. The vast span of geologic time which preceded the Cambrian Period (see Fig. 2).

Pumice. Frothy volcanic fragments thrown out at the time of eruption.

Pyroxene. A dark green black mineral with the formula Ca (Fe, Mg) Si_2O_6 or (Fe, Mg) SiO_3. Pyroxene is found in basalts or andesites.

Pyroxinite. A medium to coarse-grained igneous rock composed primarily of the mineral pyroxene.

Quartz. A white clear mineral with the formula SiO_2.

Quartz Latite. A volcanic rock that contains quartz, plagioclase, and biotite. Most tuffs in the Southwest are quartz latite or rhyolite in composition.

Ring dikes. A series of intrusive bodies surrounding a caldera.

Rhyolite. A volcanic rock composed of quartz, sanidine, and biotite generally with a glassy groundmass.

Sanidine. A milky mineral with the formula $KAlSi_3O_8$. Sanidine (moonstone) is found mainly in rocks of rhyolite composition.

Scarp. The cliff formed by movement of a fault. The position of many faults can be found by tracing the fault scarp.

Sedimentary. Rocks formed from fragments deposited by water.

Spherulite. A small spherical aggregate of radiating crystals formed by growth during cooling of volcanic glass.

Spring. A place where water flows to the surface through rock or silt.

Strike. The bearing of an inclined stratum or bedding on a level surface. The attitude of stratified rocks is given by the dip and strike.

Talus. An accumulation of coarse rock debris at the base of a steep slope or cliff.

Tectonic. Relates to major deformation of the crust of the earth.

Texture. The arrangement of components that make up a rock. Volcanic rocks have a fine-grained texture; plutonic rocks are coarse-grained.

Tuff. A rock composed of volcanic particles ejected through the air.

Volcanic. Igneous activity at the surface of the earth. When intruding magma breaks to the surface it forms lava or other types of volcanic rocks.

Volcanic breccia. A rock composed of large angular fragments of older volcanic rock in an ash matrix.

Welded Tuff. A rock composed of volcanic particles (ash and pumice) that were so hot at emplacement that they fused together to make a compact hard rock.

Zeolites. A group of minerals formed by the hydration of volcanic glass.

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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 the 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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