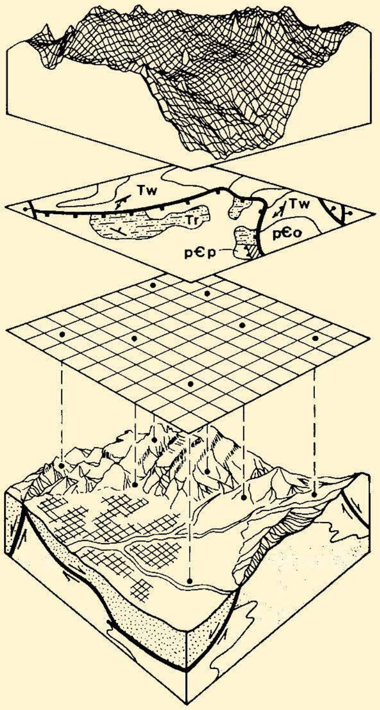
FRONTIERS IN GEOLOGY AND ORE DEPOSITS OF ARIZONA AND THE SOUTHWEST

Arizona Geological Society and the University of Arizona 1986 Symposium



FIELD TRIP GUIDEBOOK
1

Proterozoic Geology of the Sierra Ancha-Tonto Basin-Mazatzal Mountains Area, Central Arizona

March 17-19, 1986

Leaders: C. Conway and
C. Wrucke (U.S.G.S.)

Coordinators: P. Swift

ARIZONA GEOLOGICAL SOCIETY
TUCSON, ARIZONA

Cover preparation by Beverly Morgan, modified from J. Mehulka
and P. Mirocha, AGS Digest Volume XVI

ARIZONA GEOLOGICAL SOCIETY
P.O. BOX 40952, UNIVERSITY STATION
TUCSON, ARIZONA 85719

To: Field Trip Participants

Welcome to Arizona and the 1986 Arizona Geological Society Symposium "Frontiers in Geology and Ore Deposits of Arizona and the Southwest." As field trip chairman I would like to wish you an enjoyable and informative conference and a worthwhile field trip experience.

The field trip committee set out many months ago to provide field exposure to a broad spectrum of geological disciplines. The results include trips to recent precious-metal discoveries, areas of new and developing stratigraphic and structure concepts, industrial mineral resources, lithologic features significant to the petroleum potential in the Southwest, geologic hazards in the community, and an opportunity to attend trips from previous Arizona Geological Society meetings. We hope you find your chosen field trip as exciting as we intended.

At this time of very limited support from industry, it is especially important to acknowledge the personal efforts of so many. I include in those the planning and follow through of the field trip committee, the many hours of preparation by the trip leaders, and the commitment of the trip coordinators to a smooth-running trip. A special thanks goes to Maggie Morris of the University of Arizona Conference Department for the transportation, lodging, and meal arrangements.

Please enjoy the Southwest and remember this week of field trips and meetings as a step toward the frontiers of the future.

Best regards,

Parry D. Willard

Parry D. Willard
Field Trip Chairman

Field Trip Committee

Annon Cook
Norm Lehman
Beverly Morgan
Jon Spencer
Erick Weiland
Joe Wilkins Jr.
Jan Wilt

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FIELD TRIP 1

PROTEROZOIC GEOLOGY OF THE SIERRA ANCHA–TONTO BASIN–MAZATZAL MOUNTAINS AREA, CENTRAL ARIZONA

Leaders:	Clay M. Conway and Chester T. Wrucke (USGS)
Coordinators:	Peter Swift (U of A)

Monday, March 17, 1986

5:00 pm	Meet at University of Arizona, in front of Student Union
5:00 pm	Depart for Copper Manor Motel,* Globe, Ariz. (602-425-7124). Check in
7:00 pm	Dinner (on your own)
8:00 pm	Orientation meeting, Sundowner Room, Copper Manor Motel

Tuesday, March 18, 1986

8:00 am	Check out and depart Copper Manor Motel
8:00-12:00 noon	Geology of the Sierra Ancha Mountains
12:30 pm	Lunch* at Winter Camp near Diamond Butte
1:00-7:00 pm	Geology of Diamond Butte area; travel to Payson
7:00 pm	Arrive at Swiss Village Lodge,* Payson, Ariz., (602-474-3241)
7:30 pm	Dinner at Swiss Village Inn*

Wednesday, March 19, 1986

8:00 am	Depart Swiss Village Lodge
8:00-12:00 noon	Natural Bridge stop
12:00 noon	Lunch* at Sycamore Creek, Mazatzal Mountains
1:00 pm	McFarland Canyon stop
3:30 pm	Conclusion of trip—Depart Mazatzal Mountains
7:00 pm	Arrive in Tucson; stops at Holiday Inn (Broadway) and University of Arizona Campus.

*Included in fees.

Drivers:	Peter Swift Richard Orr

FRONTIERS IN GEOLOGY
1. Precambrian-Sierra Ancha Tonto Basin-Mazatzal Mountains
(March 17, 18, and 19)

March 11, 1

Rec#:	Name:	Pre Cam 1. $130:
126	Paul E. Damon	1
77	Tom Foster	1
85	Robert C. Greene	1
15	Michael R. Pawlowski	1
32	John Petersen	1
146	G. Todd Ririe	1
251	Gordon W. Weir	1
130	Gordon Wieduwilt	1
209	Chet Wrucke	1
	Grand Total	9

Clay Conway

Peter Swift

Richard Orr

FIELD TRIP 1

PROTEROZOIC GEOLOGY OF THE SIERRA ANCHA–TONTO BASIN–MAZATZAL MOUNTAINS AREA, CENTRAL ARIZONA

March 17–18, 1986

Leaders:	Clay M. Conway (U.S. Geological Survey) Chester T. Wrucke (U.S. Geological Survey)
Coordinators:	Peter Swift (University of Arizona)

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Arizona Geological Society Digest Volume XVI, 1986

PROTEROZOIC GEOLOGY OF THE SIERRA ANCHA-TONTO BASIN-MAZATZAL MOUNTAINS AREA,

ROAD LOG AND FIELD TRIP GUIDE

Clay M. Conway[1] and Chester T. Wrucke[2]

INTRODUCTION

The purpose of this trip is, first, to examine some of the major rock units in the Middle Proterozoic Apache Group and geographically and stratigraphically associated rocks that were intruded by Middle Proterozoic diabase, and, second, to study the layered sequences of Early Proterozoic sedimentary and volcanic rocks that underlie the Apache Group. Asbestos and uranium deposits will be visited in the Sierra Ancha and altered and mineralized Early Proterozoic strata will be examined in the Mazatzal Mountains.

The trip begins at Globe (Fig. 1) and proceeds northwest along Pinal Creek, past exposures of the Apache Group and Ruin Granite, then over the divide into the southeastern end of the basin of Roosevelt Lake. From there the route turns north and follows Arizona Highway 288 across the Salt River to the Sierra Ancha, where the Apache Group, the Troy Quartzite, and diabase are found in many magnificent exposures from the high desert to pine forest. The Apache Group, widely exposed in central and southern Arizona, is more completely represented and has fewer structural complexities in the Sierra Ancha region than elsewhere in the state. The Sierra Ancha is underlain almost wholly by these rocks, which nearly everywhere are approximately flat-laying, reflecting the location of the Sierra Ancha as structurally in the Colorado Plateau province. Paleozoic cover, except in the vicinity of Aztec Peak at the crest of the Sierra Ancha and one locality west of the crest, has been eroded back to the Mogollon Rim far to the north. From the forested uplands of the Sierra Ancha, the route descends northward to Young, in Pleasant Valley.

The broad Pleasant Valley depression owes its presence to deep weathering and erosion of the Early Proterozoic granite of Young. Westward from Young the route leads into the Diamond Butte area of the upper Tonto Creek drainage basin. Exposures here of volcanic and volcaniclastc rocks of the Early Proterozoic Alder and Red Rock Groups are among the best in the Tonto Basin-Mazatzal Mountains region.

The second part of the trip loops from Young around the upper Tonto Creek drainage by ascending the Mogollon Rim then dropping down to the west to Payson and Pine Creek. This portion of the trip affords exposures of interesting stratigraphic and structural relations between the Proterozoic rocks and Paleozoic and Tertiary strata. A Proterozoic silicic volcano-hypabyssal complex, centered in the Tonto Basin area, includes volcanic rocks of the Alder and Red Rock Groups, several hypabyssal rhyolite and granophyre units and the Payson Granite. Most of the hypabyssal units of this complex will not be visited on this trip, though one alternate stop is in granophyre. A similar complex which underlies most of the northern Mazatzal Mountains will also not be visited. Superb exposures of Early Proterozoic Mazatzal Quartzite and intertonguing relation with the underlying Red Rock Rhyolite will be seen near Tonto Natural Bridge (travertine) at Pine Creek on the third segment of the trip.

The fourth part of the trip is from Payson across the valley of Rye Creek into the central Mazatzal Mountains. A major Tertiary fault system bounding the east side of the Mazatzal Mountains and a number of stepped faults below the Mogollon rim define an asymmetric graben. South of Payson, valley-fill sediments lie unconformably on the Early Proterozoic Gibson Creek batholith, a plutonic suite which is intruded by Payson Granite and which hosts a small gold-mining district. Stops in the central Mazatzal Mountains will be to examine volcanic and volcaniclastic strata of the middle and upper parts of the Alder Formation and Red Rock Rhyolite. Of interest will be hydrothermally altered strata, exhalative rocks, and spatially associated mineral deposits of several types.

Some isotopic ages reported in this paper are 20 to 30 m.y. younger than reported in the literature in order to give a very approximate correction for recent changes in decay constants. Metric units are used herein except that route road distances are in miles and elevations are in feet. Geologic names in this report are from literature cited and from a revision in preparation by the authors.

PART I. GLOBE TO DIAMOND BUTTE

Mileage
Seg. Cum.

0.0 0.0 Intersection of US Highway 60 and Arizona Highway 88. Tailings ponds from the Inspiration Consolidated Copper Co. Mine lie to the west. The mountains to the east consist mostly of Middle Proterozoic rocks of the Apache Group, Troy Quartzite, and diabase (Table 1), locally overlain by Paleozoic strata. These same rocks are

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[1] U.S. Geological Survey, 2255 Gemini Drive, Flagstaff, AZ 86001

[2] U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025

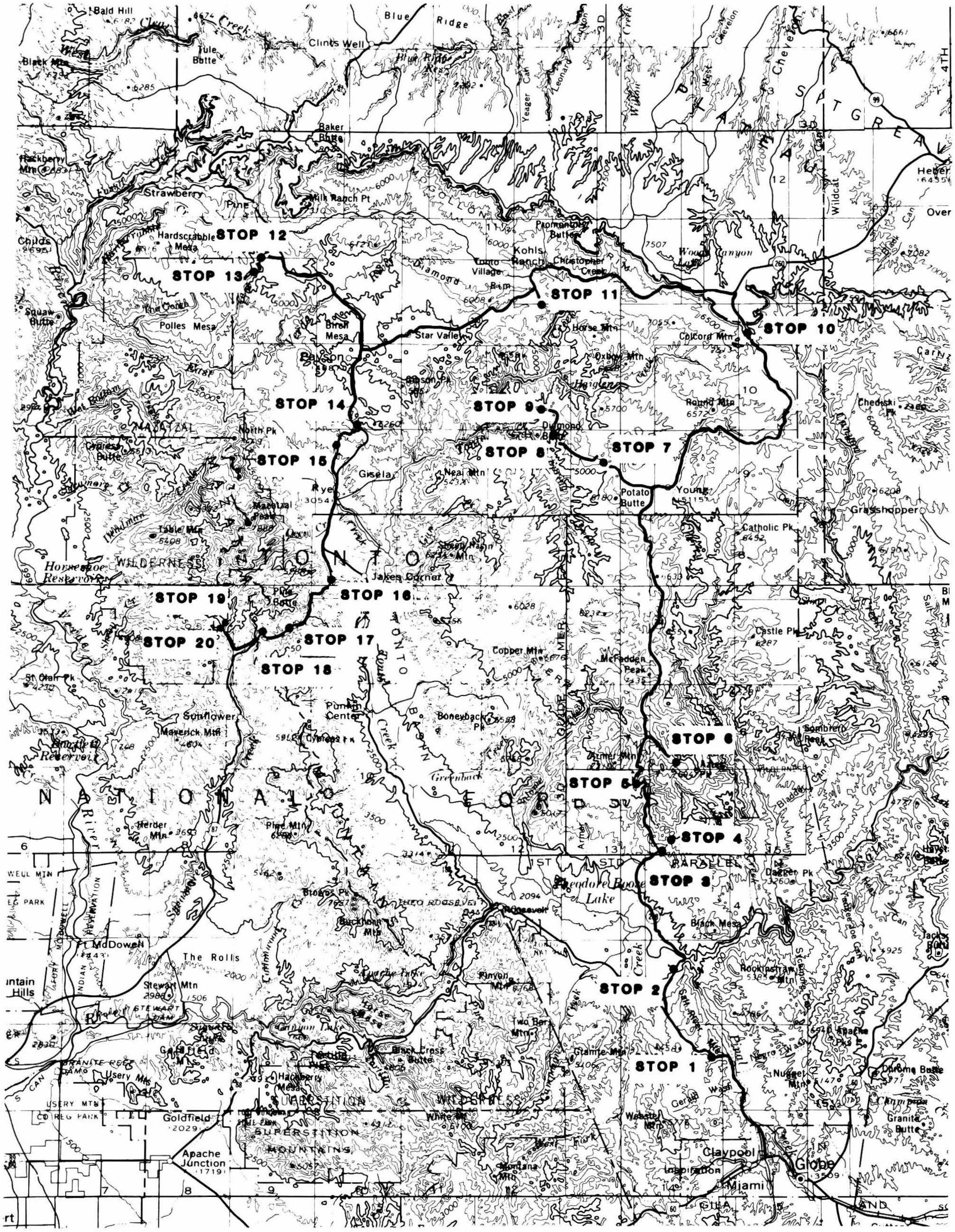

Figure 1. Topographic map of the region between Globe and the Mogollon Rim showing field trip route and stops.

exposed in the mountains to the west as are Early Proterozoic granite, early Tertiary porphyries, and Miocene ash-flows. Rocks in the Globe area were mapped by Peterson (1962) during a study of the mineral deposits in this famous old mining district.

2.7 2.7 Exposures on the west side of the road are of Proterozoic diabase that intruded poorly exposed strata of the Apache Group. Silver (1963), using samples collected in the Sierra Ancha, determined the age of the diabase by U-Pb methods as 1,130 m.y., and Livingston and Damon (1968) obtained the same age using K-Ar techniques. This date provides an upper limit for the age of the Apache Group and Troy Quartzite.

6.1 8.8 Arkose member of the Dripping Spring Quartzite intruded by diabase.

3.5 9.6 STOP 1. Turn left onto gravel road, park cars, and walk west across the wash to exposures of generally maroon-colored strata of the Pioneer Shale. This is the basal formation of the Apache Group. Throughout most of the region around Globe and in the Sierra Ancha, the Pioneer rests on granitic rocks, primarily the Middle Proterozoic Ruin Granite. At this locality diabase was emplaced beneath the Pioneer, and granite is not seen. The Scanlan Conglomerate Member, which is the lower member of the Pioneer, can be seen along the northern exposures of the formation. Here the conglomerate contains conspicuous well-rounded pebbles of white quartz, purplish quartzite, and jasper. The overlying Pioneer is not a shale but instead consists of deep brownish-red to dusky red-purple, thin-bedded siltstone and tuffaceous mudstone dotted with brownish-orange reduction spots. Some of the rock spalls into small chips that can give the appearance of a shale. Local greenish clots a few millimeters across formed during metamorphism by the underlying diabase.

The Ruin Granite (about 1.43 b.y.) is exposed for many miles along the highway northwest of Stop 1. Note that the granite, red-brown beneath exposures of the Pioneer Shale, becomes grayer to the northwest away from and farther below exposures of the Apache Group. The age of the Ruin provides a lower limit for the age of the Apache Group.

5.6 15.2 Junction Arizona Highway 288, which leads north to the Sierra Ancha and Young. Turn right.

1.2 16.4 Apache Leap Tuff, 20 m.y. old, caps the ridge to the right. The tuff is a rhyodacite widely exposed in the Superstition Mountains, around Superior, and as far northeast as the southern Sierra Ancha.

0.7 17.1 STOP 2. Overview of the south end of the Sierra Ancha. Cliff-forming strata of the Apache Group and the Troy Quartzite in the Sierra Ancha are interspersed with slope-forming diabase sills, which in aggregate at this end of the range exceed the thickness of the host sedimentary section. The prominent cliff and bench low on the west flank of the range expose the Dripping Spring Quartzite. Above the bench a broad concave slope is developed on a thick diabase sill that split strata in the siltstone (upper) member of the Dripping Spring, lifting the uppermost beds of the formation, along with overlying strata, almost 400 m. Dark-colored strata above the diabase belong to the Dripping Spring Quartzite and the overlying light-colored beds are in the metamorphosed lower member of the Mescal Limestone. Above is another diabase sill that splits strata of the Mescal a few meters below the algal member. Long-fiber chrysotile asbestos that developed upon diabase intrusion in the algal member was worked at the American Ores Mine, located at the top of the long white dumps near the top of the range. Troy Quartzite caps Asbestos Peak a short distance west of the mine dumps and also the higher peak to the east at Zimmerman Point. Relative to exposures on Asbestos Peak, Troy Quartzite that caps the low, red-colored hill west of the prominent cliff and bench underlain by the Dripping Spring on the west side of the range was dropped nearly 1,000 m along the Armer Mountain fault, which trends northwest along the base of the Dripping Spring cliff.

2.4 19.5 Salt River crossing. Apache Leap Tuff crops out in the cliffs along the river.

8.0 27.5 Junction road around the north side of Roosevelt Lake to the abandoned A-Cross ranger station and Punkin Center. Keep right. The Tertiary gravels that the road is on thin rapidly as the mountains are approached. Although outcrops are sparse for the next 1.8 mi, abundant exposures of the upper member of the Mescal Limestone, Troy Quartzite, and diabase on the downdropped side of the Armer Mountain fault are only a short distance north, and a few exposures of the rocks are south of the road.

1.8 29.3 Armer Mountain fault crosses the road. In road cuts to the east, the siltstone member of the Dripping Spring Quartzite is exposed for 150 m in a fault sliver, beyond which are typical strata of the arkose (middle) member of the Dripping Spring.

The basal Barnes Conglomerate Member of the Dripping Spring, not exposed in this cut, closely resembles the Scanlan Conglomerate Member of the Pioneer Shale in thickness and composition. The overlying arkose member exposed here is a cliff-forming unit of pale-brown to light-gray fine- to medium-grained, cross-bedded arkose, feldspathic quartzite, and quartzite. Arkose dominates the lower two-

Table 1. Middle Proterozoic stratified rocks and associated diabase of the Sierra Ancha region (modified from Shride, 1967)

Group	Formation or rock unit	Member	Thickness (meters)	Lithology
	Diabase			Dark-green olivine diabase consisting chiefly of ophitically intergrown calcic plagioclase and augite and in part of varietal amounts of olivine. Forms laterally extensive sills and sheets as thick as 400 m.
	Troy Quartzite	Quartzite member	0-150	Light-colored, medium- to coarse-grained, thin- to thick-bedded well-sorted quartzite.
		Chediski Sandstone Member	0-215	Commonly light-gray, grayish-red to grayish red-purple, poorly sorted pebbly sandstone, cross bedded in upper part and layers having convoluted laminations in central part. Has basal conglomerate locally.
		Arkose member	0-135	Pale-red to pale-brown, fine-grained, well-sorted arkose, typically cross-bedded on a large scale.
	Basalt flows		0-115	One or more dark red-brown flows, conspicuously hematitic
Apache Group	Mescal Limestone	Argillite member	0-30	Reddish-orange to black siliceous argillite and mudstone, locally containing thin beds of limestone.
		Basalt member	0-35	Basalt flow similar to flows above the Mescal.
		Algal member	12-40	Commonly light-gray limestone silicated from metamorphism. Thin-bedded and partly cherty in upper part, stromatolitic in lower part. Pale brown to red dolomite where unmetamorphosed.
		Lower member	45-80	In most places light-gray, thin- to thick-bedded limestone silicated from metamorphism. Locally silicified and brecciated during pre-Troy weathering. Pale-brown to red dolomite where unmetamorphosed. Basal unit is limestone breccia 5-30 m thick.
	Dripping Spring Quartzite	Siltstone member	60-110	Gray, grayish orange-pink, and yellow-brown, platy, feldspathic siltstone and arkosic sandstone, locally black from carbonaceous material.
		Arkose member	60-105	Pale brown to orangish-gray, thin- to thick-bedded, cross bedded, and feldspathic quartzite.
		Barnes Conglomerate Member	0-12	Well rounded pebbles and cobbles of quartzite, quartz, jasper, and volcanic rocks in sandstone matrix.
	Pioneer Shale	Siltstone, mudstone, and arkose	45-150	Deep reddish-brown to purplish-red tuffaceous siltstone and silty mudstone containing light-colored spots. Lower half locally has thin- to thick-bedded, cross bedded arkose.
		Scanlan Conglomerate Member	0-10	Pebbles and cobbles of quartzite, quartz, jasper, and volcanic rocks in matrix of fine- to coarse-grained sandstone.

member from the overlying dominantly thin-bedded siltstone member.

0.3 29.6 The contact between the generally medium-bedded arkose member of the Dripping Spring and the overlying thin-bedded siltstone member is at the curve where the road changes trend from northeasterly to northwesterly.

The siltstone member of the Dripping Spring consists of flaggy to slabby, fine-grained arkosic sandstone and highly feldspathic siltstone. Lenticular bedding, stylolites, ripple marks, and channel-like structures resulting from the compaction of sandstone lenses in siltstone are common features of the member. Shride (1967) and Granger and Raup (1964) subdivided the member into various units having contrasting light and dark hues resulting from variations in the concentration of feldspar and, in some units, from disseminated pyrite and carbon. The member is anomalously radioactive, in part from uranium, notably in carbon-rich units, but also from an unusually high potassium content reported as high as 14.6 percent K_2O (Granger and Raup, 1959). Diagenetic alteration of detrital clay (Granger and Raup, 1964) and the reconstitution of tuffs (Desborough, oral commun., 1985) have been suggested as the source of the abundant potassium. Potassium enrichment of underlying Early Proterozoic rocks (see Part I, mile 65.0) suggests that fluids were involved in an alteration process that may have affected both Apache rocks and substrate. The member has the oldest strata in North America reported to contain hydrocarbons (Desborough and others, 1984).

0.2 29.8 Junction of road to Red Bluff Mine and Warm Creek. Turn right, then, after 0.1 miles, turn right again to the mine area. STOP 3 at Red Bluff Mine.

The Red Bluff Mine is developed in a uranium deposit in the siltstone member of the Dripping Spring Quartzite. Uranium in the Sierra Ancha region was discovered here in 1950, and the discovery lead to a flurry in uranium prospecting in Gila County in the mid-1950s. The mine was one of five that produced more than 2,000 tons of ore during that period (Granger and Raup, 1969). Production of uranium in the Sierra Ancha ceased in 1957 when the U.S. Atomic Energy Commission stopped the purchase of ore at a buying station established by the Commission at Cutter, 13 km east of Globe. Uranium ore from the Dripping Spring proved to be low in grade (generally less than 0.25 percent U_3O_8) and too expensive to mill economically. Exploration drilling at Red Bluff and elsewhere in the Sierra Ancha in the 1970s did not result in new mining.

As described by Kaiser (1951) and Granger and Raup (1959, 1969), mineralized rock at the Red Bluff Mine occurs in two stratigraphic intervals centered about 25 and 45 m above the base of the siltstone member of the Dripping Spring Quartzite. Each zone is about 6 m thick, and both contain one or more beds of carbonaceous siltstone. Only the lower of these favorable intervals is found in the workings on the west side of Warm Creek Canyon at Stop 3. Both favorable zones occur on the east side of the canyon. Ore on the west side was mined from zones a few centimeters to a meter or so thick in black carbonaceous rock containing limonite-filled fractures. Uraninite, pyrite, chalcopyrite, and galena are primary minerals at the deposit.

Uranium ore zones throughout the Sierra Ancha region are in veins in and adjacent to stratabound uranium-bearing carbonaceous zones that lie either above massive diabase sills or, as here, adjacent to diabase feeder dikes. According to Otton and others (1981), the ore probably was derived from syngenetic uranium in the carbonaceous siltstone, was mobilized by hydrothermal fluids from the adjacent diabase, and was redeposited in nearby fractures and faults.

The conspicuous piles of black rock on the nearly flat ground a few tens of meters north of the workings at the Red Bluff Mine consist of magnetite that was mined from small deposits in Mescal Limestone on the knoll 1.6 km to the north. Additional magnetite deposits have been reported on the southern and eastern flanks of Zimmerman Point, which is 4 km to the northeast of the Red Bluff Mine. The magnetite may have formed by contact-metamorphic replacement of carbonate rock in the Mescal Limestone during intrusion of diabase. Evaluation of the magnetite deposits by the Cerro de Pasco Corporation in the late 1950s indicated about 15 million tons of rock averaging 26.5 percent iron (Otton and others, 1981).

Return to the Warm Creek road, turn right, and drive about 1.0 mi to a road that takes off to the left along a creek in diabase. Follow this road about 0.3 mi as it climbs the east wall of the canyon to a broad bench developed on the diabase. STOP 4 at asbestos deposit in the white beds above the bench. Climb above the bench to the adit at the base of the white beds, which belong to the Mescal Limestone. Low in the portal of the adit, multiple veins of long-fiber chrysotile asbestos are developed in serpentine that replaced thin beds of cherty carbonate rock. Prior to metamorphism by the diabase, the carbonate rock was dolomite, a fact that eluded Ransome when he named the Mescal Limestone for exposures in the Ray quadrangle in 1915.

Although this deposit has not been studied in detail, it probably originated in the same manner as most asbestos deposits in the Sierra Ancha region. These deposits formed where carbonate members of the Mescal were partly silicified during the development of karst features prior to deposition of the Proterozoic Troy Quartzite (Otton and others, 1981; Shride, 1967). Serpentine containing asbestos veins replaced the karst-modified carbonate rocks near diabase intrusions that shouldered aside the host strata, causing the development of small-scale thrust and bedding-plane faults and abundant fractures. These faults and fractures are common near discordant contacts of the diabase, such as those at the margin of the Mescal in this area. Note the step-like contact between the Mescal and the underlying diabase in the vicinity of the adit. Most asbestos deposits, like this one, are within 8 m of a diabase contact. Typically the deposits are flat lying and elliptical in plan, reflecting the broad, commonly subtle, doming caused by the shouldering action during emplacement of the diabase.

The argillite, basalt, and algal members of the Mescal are exposed 180 to 300 m southeast of the Asbestos Mine. Stromatolite-bearing beds in the lower part of the algal member at this locality rest unconformably on the lower member. Although the carbonate rocks have been strongly metamorphosed by the adjacent diabase, the striking appearance of the stromatolites is preserved. Most of the stromatolites in the Sierra Ancha are the Collenia type of the older literature and have been classified in form genera by McConnell (1975). A characteristic of the algal member is that the stromatolites are found in biostromes having great lateral continuity throughout central Arizona, where little variation exists in the 15 to 28 m thickness of the stromatolite unit of the algal member.

Subaerial erosion of the Mescal after deposition of the algal member led to the development of cavities, local silicification of the dolomite, and ultimately to sink holes and the collapse of strata. Evidence of collapse is not found here. Beeunas and Knauth (1985) concluded from a study of carbon isotopes that a cover of vegetation (algal?) existed during the subaerial alteration.

Basalt overlying the algal member here is unusual in that at few localities in the Sierra Ancha is basalt found stratigraphically between the algal and argillite members. In the region north of Globe, basalt more commonly lies above the argillite member. Flows at both stratigraphic positions are similar in consisting of secondary minerals and in having abundant hematite as a result of deep weathering in the Proterozoic.

The argillite member rests unconformably on the basalt, although its usual position in the region is directly on the algal member. Generally the argillite member consists of siliceous argillite and shale, and locally it has chert or chert breccia at the base and sparse thin lenses of silicated limestone at higher positions. The argillite member everywhere is metamorphosed because upper and lower contacts were favorable horizons for diabase intrusion.

29.8 Return to the Young Highway and turn right. Resume the mileage log at the junction. From here to the next stop, the road climbs slowly in the thick diabase sill emplaced high in the Dripping Spring.

Diabase crops out in nearly every exposure of the Apache Group and Troy Quartzite in Arizona. Typically the diabase occurs as sills tens of meters thick emplaced at or near stratigraphic horizons between rocks of contrasting competency. The maximum known thickness of the diabase is 400 m at Aztec Peak, 10 km to the northeast. All of the diabase bodies locally have discordant contacts at low to high angles to the host strata. At Stop 5 a high-angle discordant contact will be seen.

The diabase in the Sierra Ancha is composed principally of labradorite and augite, varietal amounts of olivine and accessory minerals typical of dolerites. Biotite is an accessory mineral in the sill along this road. Most of the Arizona diabase is olivine tholeiite containing normative olivine and hypersthene and 2 to 4 percent total alkalies. Quartz normative diabase has been reported at localities near Globe and south to the Catalina Mountains. Detailed descriptions of the diabase have been given by Shride (1967), Granger and Raup (1969), Nehru and Prinz (1970), Smith (1970) and Fouts (1974). Significantly, the most detailed studies of the diabase in the Sierra Ancha have concentrated on a single sill--the one followed by the road between Stops 4 and 5.

A characteristic feature of the Arizona diabase is an unusually coarse grain size of the ophitically intergrown plagioclase and pyroxene in central parts of sills. Plagioclase laths commonly are 4 mm long; some are twice that length. Pyroxene crystals commonly are 20 to 50 mm in size and some reach 80 mm in length. These dimensions contrast with plagioclase laths generally 1/4 to 2 mm long and pyroxene grains less than 5 mm long in well known dolerite, such as in the Karoo sills in South Africa and the Palisade sill in New York. Knobby weathering surfaces of outcrops along roads in the Sierra Ancha result from the large pyroxene crystals.

0.6 30.4 The American Ores Mine, whose prominent dumps are near the skyline to the northeast, was opened prior to World War I and was one of the first mines in the region to produce asbestos. The ore was mined high in the thin-bedded upper part of the algal member of the Mescal, above the stromatalite-bearing beds. Asbestos fibers from the mine were of a harsh variety lacking the silky softness of more desirable ore. Although early miners attributed the harshness to the closeness of diabase, the igneous rock that lies less than a meter above the ore actually is basalt beneath the argillite member of the Mescal. The cause of the harshness is not understood. Uses were found for harsh ore, and the American Ore Mine became the largest producer of asbestos in the Sierra Ancha. The last production was in the 1950s (A. F. Shride, oral commun., 1985).

3.1 33.5 Good view to the north of Troy Quartzite in cliffs near the range crest. Strata down section from the Troy consist of unnamed basalt, Mescal Limestone, and Dripping Spring Quartzite.

0.3 33.8 Pocket Creek

0.3 34.1 To the left is a spectacular canyon eroded into the Dripping Spring and the underlying Pioneer Shale. The canyon is best seen from a road that meets Highway 288, 0.3 mi ahead.

2.3 36.4 STOP 5. The diabase sill along the Young highway north of Stop 4 becomes sharply discordant at a vertical, east-west contact that extends from immediately northwest of Stop 5 easterly about 3 km. South of the vertical contact the diabase is mostly high in the siltstone (upper) member of the Dripping Spring, but about 1-1.5 km from the vertical contact the diabase climbs into the Mescal Limestone. North of the vertical contact the diabase drops into the arkose (middle) member of the Dripping Spring. The vertical contact where the diabase steps down to the north is not a post-diabase fault. It is the chilled igneous margin of diabase against sedimentary rocks. The intruding magma split the strata, moved vertically, and lifted the beds north and south of the break as a single mass above the thickening, stepped sill whose northern and southern segments were interconnected along the vertical contact. Numerous examples of similar steeply dipping contacts between diabase and host strata exist in the Sierra Ancha.

On the south side of Parker Creek, about 2 km east of Stop 5, knobby outcrops can be seen near the top of the diabase. These outcrops consists of quartz-bearing aplite, granophyre, and hornblende granite that formed high in the sill near the vertical contact. Xenoliths of siltstone country rock in various stages of digestion in the granitic bodies suggest the possible importance of assimilation in the formation of felsic magma. Although opinions differ regarding the origin of the granitic rocks (Granger and Raup, 1969; Shride, 1967; Smith and Silver, 1975), a reasonable interpretation is that they formed where residual fluids migrating upward in the cooling and differentiating diabase reacted with feldspathic xenoliths, producing quartz-bearing differentiates, and that variations in composition of the differentiates may be related to the abundance of assimilated material. Quartz-bearing differentiates are rare in the Sierra Ancha. Extensive bodies occur only at the tops of thick sills that invaded the siltstone member of the Dripping Spring.

Strata above the diabase differentiates on Parker Creek consist up section of carbonate rocks and overlying siltstone of the Mescal Limestone, unnamed basalt, and Troy Quartzite. The Troy is about 240 m thick here. Note the sparse vegetation on the Dripping Spring. The sparseness probably results from a high pyrite content in the siltstone.

For about 8 mi north of Stop 5, the Young highway is almost entirely on diabase. The upper contact of the diabase east of the highway is in the Dripping Spring. To the west, under Armer Mountain, located 3 km northwest of Stop 5, the upper contact is in the Pioneer Shale and is at a higher altitude then the contact to the east in the Dripping Spring. The differences in altitude and stratigraphic position of the diabase reflect complications resulting from the north-trending Sierra Ancha monocline, which trends approximately along the route of the highway and flexes down to the east. The monocline developed prior to or during emplacement of the diabase (see Bergquist and others, 1981).

4.3 40.7 Workman Creek. Turn right to ALTERNATIVE STOP 6 at Workman Creek Falls. About 3 km east of Highway 288 is the upper contact of diabase against the siltstone member of the Dripping Spring. Extensive exploration for uranium has been conducted in the Dripping Spring in this area. One km farther upstream the road cuts into carbonate beds of the Mescal. Just below the falls, another km up Workman Creek, the road crosses the algal member of the Mescal, about 12 m thick, and the overlying argillite member, about 35 m thick. The falls, one of the major scenic attractions of the Sierra Ancha, occur where Workman Creek drops abruptly across a cliff developed in the basalt that overlies the Mescal. Troy Quartzite rests on the basalt.

The basalt consists of albite and other alteration minerals. No primary minerals remain. A vague intergranular texture is suggestive of an original basaltic composition. Abundant hematite introduced during pre-Troy weathering accounts for the deep red color of the basalt. No genetic connection has been established between the basalt and the diabase.

The road continues east from the falls, across the Troy Quartzite and an extensive diabase sill that invaded the Troy, and ends at Aztec Peak. Cambrian Tapeats Sandstone, which overlies Troy Quartzite above the diabase sill, caps Aztec Peak. The peak affords sweeping views of eastern and central Arizona.

Return to Highway 288 and resume odometer readings.

2.0 42.7 Reynolds Creek. An alternate side trip would be to follow the road to the right to the crest of the Sierra Ancha, where excellent exposures can be found of all three members of the Troy Quartzite. The Troy Quartzite was defined by Ransome (1915a) for exposures in the Ray quadrangle, centered about 80 km south of Reynolds Creek. Ransome considered the Troy to be Cambrian and part of the Apache Group, but Darton (1932), believing that the Apache Group was Precambrian, removed the Troy from the group after finding Cambrian fossils in rocks misidentified as Troy. However, Shride (1967) reported that all but the uppermost beds that Ransome measured as Troy at the type locality are in fact Precambrian because they correlate with strata in the Sierra Ancha that have been intruded by diabase. Despite this evidence of a Precambrian origin, the Troy today is not included in the Apache Group.

Ransome (1916) recognized that a 275-m-thick section of Troy on Baker Mountain, high in the Sierra Ancha south of Reynolds Creek, is much thicker than it is near Ray, where he measured a section 110 m thick. Because the Troy in the Sierra Ancha is more complete than farther south, Shride (1967) designated the well exposed section at Center Mountain, 3 km northeast of Baker Mountain, as a reference section, which he found by careful measurement to be 365 m thick. Center Mountain is immediately south of the point where this road tops out on the crest of the range.

As defined by Shride (1967), the Troy Quartzite is divided from the base upward, into an arkose member, the Chediski Sandstone Member, and a quartzite member. The arkose member, confined to the central Sierra Ancha, consists of well sorted arkose that has very large-scale cross strata in sets as long as tens of meters. The Chediski Sandstone Member is of regional extent. It has units of poorly sorted pebbly, sericitic sandstone that enclose a middle unit containing laminations highly contorted from soft sediment deformation. The quartzite member, also regional in distribution, consists almost wholly of clean quartzite in tabular beds.

2.5 45.2 Beds of the siltstone member of the Dripping Spring in road cuts are tilted east on the Sierra Ancha monocline. Note stains from the alteration of syngenetic pyrite.

0.6 45.8 East-west fault at tight bend in the road. Troy Quartzite crops out to the north, Dripping Spring to the south, both east-dipping on the Sierra Ancha moncline.

Strata in the Troy Quartzite and underlying Mescal Limestone change in attitude from flat-lying beneath McFadden Peak (topped with a lookout tower), 1.5 km northwest of the sharp bend in the road, to steeply east-dipping in the Sierra Ancha monocline 1 km east of the Peak. For at least 10 mi north of McFadden Peak, the road follows the east flank of the monocline, locally exposing diabase and east-dipping strata of the Mescal Limestone and Troy Quartzite in road cuts.

Fluorspar has been produced at the Big Mack Mine from the east-west-trending fault 2 km west of the tight bend in the road. Approximately 30,000 tons of ore containing 60 to 90 percent CaF_2 were produced from 1976 to 1978 (Otton and others, 1981) and milled near Punkin Center. The age of the fluorspar is uncertain.

9.9 55.7 East-dipping, hematite-rich, cherty carbonate beds of the Mescal Limestone

6.5 62.2 Valley Store in Young

0.4 62.6 Junction road to Marsh Creek and Spring Creek. Turn left.

2.4 65.0 Exposures approximately 50 m before crossing Walnut Creek of the granite of Young overlain by gently westward-dipping basal conglomerate of the Dripping Spring Quartzite of the Apache Group. Granite from this site was dated at about 1,620 m.y. (Silver, 1967; Conway, 1976). An unusually high K_2O content (nearly 10%) in granite at this site (Conway, 1976) may be due to alteration related to saline(?) water in the basin of deposition of the Apache Group. The Apache Group, which overlies the granite unconformably only a few m above the sample site, is known elsewhere to be unusually K-rich and to contain probable authigenic K-feldspar. Early Proterozoic rhyolite of the Haigler Formation several kilometers northward, also a few meters below the unconformity, was similarly found to be enriched in K_2O.

Granite, presumably equivalent to the dated mass, underlies a broad area in and around Pleasant Valley. It intruded Early Proterozoic strata of the Alder Group several kilometers west of Young (Gastil, 1958).

The next mile or so will be mostly in diabase. Look for cliffs to the right of Dripping Spring Quartzite and its basal conglomerate member.

2.1 67.1 Junction Flying W Ranch and Marsh Ranch roads. Turn right on Marsh Ranch road (FS 129).

0.5 67.6 Exposures of conglomeratic facies of undivided Houdon Formation of the Early Proterozoic Alder Group on climb northward up rim of mesa.

0.4 68.0 Junction. Take Board Cabin Draw road (FS 133, primitive road) to the left. This road leads generally westward for about 3 mi across Colcord Mesa, which is capped with Dripping Spring Quartzite. (Note:

Table 2. Early Proterozoic stratified rocks of the Tonto Basin (from Conway, 1976, and Gastil, 1958)

Group	Formation	Thickness (meters)	Lithology
	Mazatzal Quartzite	700-1,000	Red-brown to maroon, cross-bedded, medium- to coarse-grained quartz arenite. Sparse pebble conglomerate and siltstone. Maroon shale or shaly rhyolite clast breccia locally at base.
Red Rock Group	Oxbow Mountain Rhyolite	0-400	Tan, massive to weakly laminated (flattened pumice fragments), crystal-rich (25%) rhyolite. Contains 2-6 mm quartz and alkali feldspar phenocrysts. Probably a dome.
	Haigler Formation	1,000-1,500	Tan to red-brown rhyolite: mostly ash-flows but also flows, tuff, breccia, and conglomerate. Minor mafic volcanic rocks, dark shale, and graywacke.
	Winter Camp Formation	300	Dark gray to brown rhyodacite flows and breccias, and conglomerate composed of similar rhyodacite and clasts derived from the Board Cabin Formation.
Alder Group	Board Cabin Formation	300-600	Green to gray, porphyritic and aphyric andesite and basalt. Andesite porphyry with 20-30% clustered plagioclase phenocrysts is most abundant. Conglomerate and agglomerate composed of mostly mafic clasts.
	Houdon Formation	400-600	White to gray, cross-bedded quartz arenite and lithic arenite, and black to brown shale and siltstone. In most places the formation is divisible into a thin basal conglomerate member and lower quartzite, middle shale, and upper quartzite members.
	Flying W Formation	400-600	Basalt flows and pillows, rhyodacite flows and ash-flows; minor conglomerate, graywacke, sandstone, and shale. Highly variable along strike.
	Breadpan Formation	1,300-1,800	In type locality, the lower three-fourths is shale, siltstone, graded lithic arenite, and conglomerate. This is overlain by cross-bedded lithic arenite and quartz arenite and then by shale, graywacke, and conglomerate.
	Pendants at Gisela	>200	Feldspathic graywacke, rhyodacite and rhyolite, and mafic volcanic rocks.

mileages from here to Alternate Stop 9 are approximate.)

2.5 70.5 ALTERNATE STOP 7. Exposures of Houdon Formation quartzite (Table 2). Excellent exposures of basal conglomerate, quartzite, shale, and quartzite members of the Houdon Formation are located 100 m to the south on the southwest slopes of Colcord Mesa.

1.0 71.5 Rim of mesa. Excellent overview to the west where Diamond Butte, capped by the Apache Group, is the most prominent feature in sight. The view is basically into the upper Tonto Creek drainage basin, which is underlain by Early Proterozoic stratified and hypabyssal rocks (Fig. 2). In the next few hundred meters, the road cut affords excellent exposures of the Pioneer Shale (with numerous drill holes where samples for paleomagnetic measurements were extracted). The basal Scanlan Conglomerate Member, locally beneath the Pioneer here, caps a small ridge to the right.

0.3 71.8 From a small saddle a road departs to the left and in about 200 m reaches a small gold mine developed on a quartz vein (Ellison mine), anomalous in the Spring Creek mining district, which has only a few small base metal mines and several beryllium occurrences (Conway and others, 1983).

0.7 72.5 STOP 8. Winter Camp, a line camp on Board Cabin Draw at the east foot of Diamond Butte. Park here and walk down Board Cabin Draw examining first outcrops of the Winter Camp Formation (Conway and Wrucke, in prep.) of the Red Rock Group and then

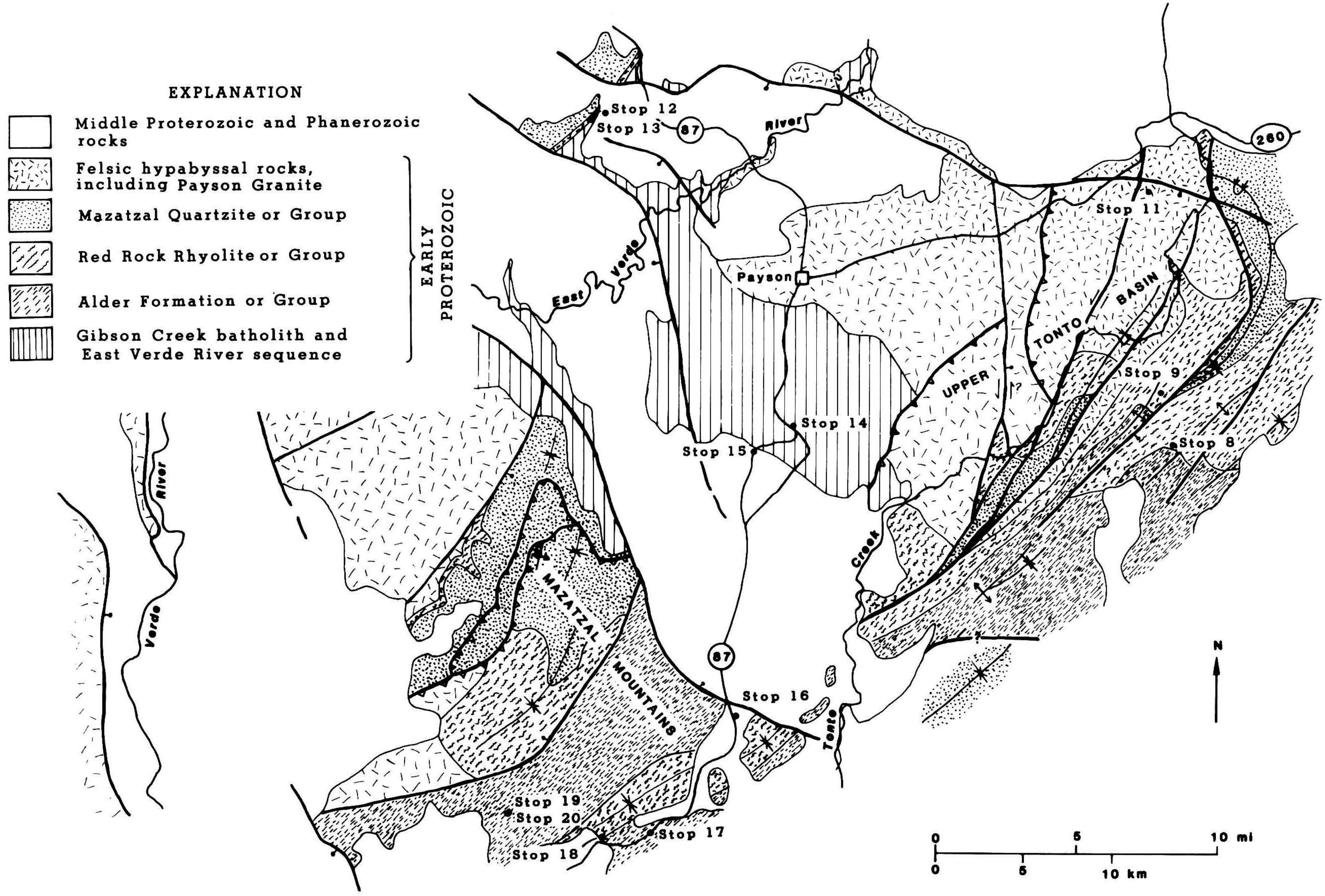

Figure 2. Simplified geologic map showing major groups of Early Proterozoic rocks in the Tonto Basin-Mazatzal Mountains region.

of the underlying Board Cabin Formation, uppermost formation of the Alder Group (Gastil, 1958; Conway, 1976). Exposures of these units and underlying strata are superb in the area between here and the Flying W Ranch 5 km to the south on Spring Creek. The strata are broadly folded near Diamond Butte, dipping gently northwest to northeast, but elsewhere in the region are generally isoclinally folded and strongly foliated. Gastil's (1958) pioneering work in the Diamond Butte area resulted in the first subdivision of Early Proterozoic stratified rocks in Tonto Basin.

The Winter Camp Formation is composed mostly of dark gray to brown rhyodacite flows and breccias, and conglomerate. The conglomerate contains clasts of both rhyodacite and underlying Board Cabin Formation. The Board Cabin Formation is comprised of a variety of mafic volcanic rock types including aphyric basalt and porphyritic andesite flows, basalt and andesite agglomerate and/or pillows, breccia, and conglomerate. It is interbedded at its base with sandstone of the Houdon Formation. Coarse glomeroporphyritic (clustered slabby plagioclase phenocrysts) andesite is a distinctive lithology of the Board Cabin Formation which can be followed intermittently westward into the central Mazatzal Mountains.

Return to Young or proceed north from Winter Camp for Alternate Stop 9.

0.5 73.0 Contact of Tertiary gravel on Early Proterozoic rocks. Continue uphill to north on the gravel. Such gravel deposits are common in the region and contain mostly locally derived material. They are probably related to an ancestral Tonto Creek drainage system.

0.7 73.7 Intersection on ridge crest. Turn left going westward on ridge capped by gravel.

1.4 75.1 ALTERNATE STOP 9. (East slope of hill elevation 5741 at about contour 5600, Diamond Butte 7.5' quadrangle, 1973). Rhyolite ash-flow tuff of the Haigler Formation is well-preserved at this locality and displays a variety of textures suggesting stages of welding and vapor exsolution indicative of a cooling unit. The Haigler Formation is predominantly rhyolite, and most exposures are of ash-flow origin. This unit and other rhyolite and rhyodacite units in the upper part of the Alder Group and Red Rock Group are products of continental ash-flow caldera complexes (Conway, 1976; Conway and Silver, 1976). They are stratigraphically interbedded with quartz arenite sequences (Houdon Formation, Mazatzal Quartzite) in the region (Tables 2, 3). which are of cratonic provenance (Conway and Silver, 1984). A few kilometers to the west, and on strike several kilometers to the northeast (at Lost Camp Mountain), the Haigler Formation is overlain by Mazatzal Quartzite. Both rhyolite of the Haigler Formation and rhyolite of the Flying W Formation, downsection in the Alder Group have been dated at about 1,700 m.y. (Silver, 1964; Conway, 1976).

Return 12.5 mi to Young and begin road log at 0.

PART II. YOUNG TO PAYSON

0 0 Intersection of Arizona Highway 288 and Marsh and Spring Creek road in Young. Drive east then north out of Young. Leave the paved road at about mile 3. The only mapping done in this area (Young 15' quadrangle) is that of the state geologic map. The granite of Young, cropping out on either side of the valley, is overlain by Apache Group and diabase over a broad area east and southeast of Young. Troy Quartzite resting on a thin Apache section in cliffs of the Naegelin Rim is seen straight up the road several kilometers to the north.

5.2 5.2 The Chamberlain Trail, the old route from Young to Kohl's Ranch, takes off to the left. This alternate road, best used in good weather, has exposures on Haigler Creek and Turkey Mountain of Oxbow Mountain Rhyolite (Conway and Wrucke, in prep.), Mazatzal Quartzite, Apache Group, Troy Quartzite, and Paleozoic rocks.

0.6 5.8 Cherry Creek bridge. About here the road crosses a probable north-south fault bounding Pleasant Valley on the east.

0.7 6.5 Granite of Young. Straight ahead a little dark brown basal conglomerate of the Apache Group can be seen on the cliff top.

0.8 7.3 A variety of unstudied Early Proterozic rocks, probably intruded by the granite of Young, are exposed over the next 1.1 mi.

1.1 8.4 Top of grade. Dripping Spring Quartzite rests on the Early Proterozic rocks. The next 5.3 mi has poor exposure of the Apache Group, diabase, and possibly some Troy Quartzite. The road follows the ridge to southeast, paralleling Cherry Creek on the north.

5.2 13.6 Next 4.7 mi has intermittent exposures along the road of Troy Quartzite and overlying dolomite of the Devonian Martin Formation and limestone of the Mississippian Redwall Limestone. Northernmost exposures are mostly Redwall Limestone. Local lag from Tertiary gravel deposits is also present.

4.7 18.3 A crossing of Cherry Creek. From here to the top of the Mogollon Rim (6.7 mi, a climb of 230 m), a blanket of Tertiary gravel unconformably rests progressively upsection on Redwall Limestone, Naco Formation, Supai Formation, and Coconino Sandstone.

4.6 22.9 STOP 10. Excellent road-cut exposures of Tertiary boulder conglomerate. This stop is for the dual purposes of discussing the

Table 3. General framework of Early Proterozoic geology in the Tonto Basin-Mazatzal Mountains region

MAZATZAL MOUNTAINS		TONTO BASIN	
Stratified Rocks	Intrusive Rocks		Stratified Rocks
		Bear Flat Alaskite Green Valley Hills Granophyre Hells Gate Rhyolite	
Mazatzal Group Mazatzal Peak Quartzite Maverick Shale Deadman Quartzite	Granophyre, intrusive rhyolite, Pine Mountain Porphyry Payson Granite	Payson Granite	Mazatzal Quartzite
Red Rock Rhyolite			Red Rock Group Oxbow Mountain Rhyolite Haigler Formation Winter Camp Formation
Alder Formation (Informal members of Ludwig, 1974)			Alder Group Board Cabin Formation Houdon Formation Flying W Formation Breadpan Formation
	Gibson Creek batholith (diorite, gabbro, granodiorite)		
East Verde River sequence			Pendants at Gisela

source of the clasts and pointing out some important Proterozoic lithologies in the conglomerate which will not be seen elsewhere on the trip. Common clast types are of Mazatzal Quartzite, Hells Gate Rhyolite (Conway and Wrucke, in prep.), Payson Granite, Green Valley Hills Granophyre, rhyolite of the Red Rock Group, and Dripping Spring Quartzite. Sparse clasts also exist of other Proterozoic lithologies, including porphyritic andesite of the Board Cabin Formation.

Clearly the clasts were derived from the south and west, probably mostly west. The distinctive Hells Gate Rhyolite (red-brown, quartz and alkali feldspar rhyolite porphyry with two kinds of mafic inclusions) crops out only in a 50 square km area 20 km to the west along Tonto Creek (Fig. 2). This rhyolite is a compound sill, a hypabyssal member of the silicic alkalic caldera suite (Table 3) (Conway, 1976).

The various Early Proterozoic source bodies for the clasts are now exposed at elevations less than 6,000 ft, and most of the source terrane was overlain by Paleozoic rocks, remnants of which stand at 5,000 to 6,000 ft. This source terrane once stood high relative to the 7,500 ft elevation where the clasts are now found and has since been lowered. Thus the southward dip of the base of the gravels may be structural; these gravels need not have been reworked down from the rim, but may have been simply tilted southward after primary deposition on a slope that dipped northward. Regionally, Tertiary gravels were initially deposited on a north-dipping slope (Wrucke and Conway, in prep.; Conway and others, 1986; Peirce and others, 1979).

2.1	25.0	Northern limit of Tertiary gravel which here rests on Coconino Sandstone.
1.7	26.7	Intersection Arizona Highways 288 and 260. Turn left toward Payson. From here to mile 44.8 the highway is almost entirely on Paleozoic rocks.
2.9	29.6	Mogollon Rim capped with Coconino Sandstone.
0.4	30	Coconino resting on red beds of the Supai Formation.
1.1	31.1	Gray limestone about 15 m thick is probably the Fort Apache Member of the Supai Formation. Supai and Naco Formations are exposed in the next few miles.
2.9	34.0	Intersection Chamberlain Trail. Base of Naco near here; Redwall Limestone exposed for next few miles. Turkey Mountain to the left is capped with Paleozoic rocks.
3.2	37.2	Christopher Creek bridge.

0.6 37.8 Quaternary gravel composed of Coconino Sandstone resting on Redwall Limestone on the right.

0.7 38.5 Good exposures of gray limestone and shale of the Pennsylvanian Naco Formation. Redwall and Naco are exposed on the highway from here to mile 44.6.

0.8 39.3 Low exposures of purplish-brown Mazatzal Quartzite overlain by the Naco can be seen for a few hundred meters along the road. Christopher Mountain, a few kilometers to the left, is underlain largely by Mazatzal Quartzite capped by Dripping Spring Quartzite. Mazatzal Quartzite and other Early Proterozoic rocks of an ancestral Christopher Mountain stood as a monadnock on a peneplaned late Precambrian terrane. Paleozoic rocks onlap the ancient mountain from the west, with strata from the Tapeats Sandstone upward as high in the section as the Naco, and possibly the Supai, resting directly on the Precambrian.

3.3 42.6 Bridge over Tonto Creek at Kohl's Ranch.

1.6 44.2 Tonto Village turn off on the right. Near this area the Redwall rests on light gray to tan dolomite of the Martin Formation.

0.4 44.6 Martin resting on red-brown to tan sandstone and pebble conglomerate beds of the Tapeats Sandstone.

0.2 44.8 Tapeats Sandstone here rests on Payson Granite. Turn left on the Bear Flat road for Alternate Stop 11. For about 1.3 mi the drive is in Payson Granite (Conway and Wrucke, in prep.) and there are three crossings, the first on concrete, of Thompson Draw. At the third crossing, turn right and drive for about 0.4 mi down the wash on the jeep trail.

1.7 46.5 ALTERNATE STOP 11. This stop is to examine granophyre of the Green Valley Hills Granophyre (Conway and Wrucke, in prep.), a sill complex which intrudes the upper semi-planar, south-dipping contact of the Payson Granite. The contact with Payson Granite is near the third crossing of Thompson Draw. The Payson Granite, Green Valley Hills Granophyre, and higher level Hells Gate Rhyolite constitute a hypabyssal suite many kilometers thick that is comagmatic with the extrusive rhyolite of the Red Rock Group (Conway, 1976).

The granophyre is porphyritic, miarolitic felsic rock with a groundmass of micrographically intergrown alkali feldspar and quartz. Micrographic texture easily can be seen with a hand lens and locally with the unaided eye. The micrographic domains, which surround quartz or feldspar phenocrysts on which they nucleated, are texturally gradational upward in one sill (King Ridge phase) into spherulites. Thus, spherulitic texture in upper parts of these sills is of magmatic origin (Conway, 1976, 1981). Good outcrops in the wash in the inside corner of the sharp bend in Thompson Draw at this locality show spherical shaped micrographic domains (coarse "spherulites") in anastamosing aplitic segregations. The aplite may represent residual interstitial melt which segregated and formed dikes (one in this outcrop) and selvages, usually at upper margins of the large granophyre sills.

Return to highway.

1.7 48.2 Intersection of Bear Flat road and Arizona Highway 260. The drive from here to Payson (mile 62.4) is all in Payson Granite.

4.6 52.8 Preacher Canyon bridge. In the next few miles, the Green Valley Hills can be seen several kilometers to the left, and Diamond Rim, capped by Tapeats Sandstone, can be seen to the right. The Green Valley Hills are underlain by the Green Valley Hills Granophyre and by Bear Flat Alaskite (Conway and Wrucke, in prep.) a unit of local leucogranite sills between the Payson Granite and the granophyre. The upper part of the Payson Granite and overlying granophyre sills over a broad region generally south of here, and similar granitic rocks in the Mazatzal Mountains, have low potential for tin (Conway and others, 1983; Wrucke and others, 1983). Analyses of drainage sediments, bedrock, and mineralized areas indicate that these felsic intrusive rocks and, to a lesser degree, the comagmatic overlying extrusive rhyolite, are enriched in large-ion lithophile elements such as Sn, Be, Nb, La, and Y. Cassiterite was identified in drainage sediments but not in outcrop. Only small weakly developed greisen zones have been found.

5.8 58.6 Bridge in Star Valley.

0.6 59.2 Roadcut at the sample site for Payson Granite dated at about 1,700 m.y. (Conway and Silver, 1976, 1984). Such semi-fresh outcrops are uncommon as the granite is deeply decomposed.

1.4 60.6 Granite grus pit on the right. Grus is used as light gravel for paving and landscaping.

1.8 62.4 Intersection Arizona Highways 260 and 87 in Payson.

(OVERNIGHT STAY IN PAYSON)

Part III. PAYSON TO PINE CREEK

0 0 Intersection Arizona Highways 260 and 87 in Payson. Proceed north on Highway 87.

2.4 2.4 Just before the road makes a bend to the left, dark iron-stained Tapeats Sandstone rests on Payson Granite. Tapeats is also seen northward across the drainage at a higher altitude. For the next 2 mi or so the road closely follows a Tertiary fault that has dropped the Tapeats down on the southwest.

2.8 5.2 Bridge on the East Verde River. The unconformity at the base of the Paleozoic section and underlying Payson Granite are well exposed in this vicinity. The road crosses the unconformity about 0.2 mi ahead and progresses up section through the Tapeats, Martin, Redwall, and Naco over the next 3.2 mi.

3.2 8.4 Tertiary gravel rests unconformably on the Naco Formation.

1.0 9.4 Tertiary basalt flows lie above the gravel and cap Buckhead Mesa.

1.0 10.4 Turn left on the Tonto Natural Bridge road. Approaching this turn, notice tan low cliffs in the hills less than a kilometer ahead on the right and a large reddish-brown hill 1-2 kilometer ahead on the west side of the highway. The cliffs on the right are Tapeats overlain by Martin; westward these Paleozoic units lap out against Mazatzal Quartzite, which sustains the reddish-brown hill. The basalt of Buckhead Mesa (12 m.y., Peirce and others, 1979) is downfaulted against the Early Proterozoic and Paleozoic rocks (Conway, unpublished mapping). This fault is a westward continuation of the Diamond Rim fault (Titley, 1962, Conway, 1976).

1.5 11.9 QUICK STOP 12. Rim of Buckhead Mesa overlooking Pine Creek. Purplish-brown strata (nearly 2 km thick) across the creek are Mazatzal Quartzite dipping moderately westward. These are onlapped by Paleozoic strata from the north and from the east. The eastern onlap relation is not clearly seen because of dissection of the landscape by Pine Creek. The highest Paleozoic unit resting directly on the quartzite is probably the Naco Formation. As at Christopher Mountain, the quartzite was a ridge on a relatively smooth plain prior to deposition of the Tapeats. North a few kilometers, the Paleozoic and Tertiary strata are seen juxtaposed against Mazatzal Quartzite on the Diamond Rim fault.

North Peak of the Mazatzal Mountains is seen in the distance looking down Pine Creek.

0.5 12.4 Unfaulted Tertiary strata (gravel and basalt) rest on faulted Naco Formation (Laramide? faulting). Southward the Tertiary section rests on progressively older Paleozoic rocks, including every formation, until in the northern Mazatzal Mountains it rests on the Precambrian. Clasts in the gravel of the Buckhead Mesa area include many of the Proterozoic lithologies found in the Mazatzal Mountains. As at Stop 10, the source is from the southerly Proterozoic complex.

The road cuts downsection through Naco, Redwall, and Martin from here to the lodge. South of the lodge, the upper part of the Martin Formation rests on the Precambrian.

0.9 13.3 Tonto Natural Bridge Lodge. Stop to clear entry; brochures are available on travertine bridge and history of lodge. Note this is private property.

0.5 13.8 STOP 13. Tonto Natural Bridge. A geologic wonder, the travertine bridge is a huge partly eroded structure which probably dammed the creek in drier times. Our primary interest on this trip, however, is the Early Proterozoic section. At the northern base of the bridge, Mazatzal Quartzite coarsens in the lower few meters and grades into a cobble conglomerate 50 m thick composed entirely of rhyolite clasts. This conglomerate overlies at least two rhyolite flows (about 30 m), one of which contains pyrophyllite(?)-filled vesicles and is virtually identical to a 30 m-thick rhyolite flow up section several hundred meters in the quartzite. The flow interbedded in quartzite yielded a zircon age of about 1,700 m.y. (Silver, 1967). These rhyolite flows and conglomerate are equivalent to the Red Rock Rhyolite.

These units all extend for several miles downstream where the section overlies a massive coarse rhyolite porphyry containing enigmatic mafic clots. The coarse rhyolite porphyry is exposed at the south base of the natural bridge. Near its western contact with the rhyolite and quartzite layers, this rhyolite porphyry is strongly altered, but eastward is well-preserved. It may intrude on the south rim of Buckhead Mesa a newly defined section (Wrucke and Conway, in prep.) widespread in the northern Mazatzal region referred to informally as the East Verde River sequence (Table 4). A current working hypothesis is that the westward alteration in the rhyolite porphyry was caused by weathering and that the porphyry and East Verde River sequence are unconformably overlain by Red Rock Rhyolite and Mazatzal Quartzite at Natural Bridge.

Return to Payson.

PART IV. PAYSON TO MCFARLAND CANYON

0 0 The intersection of South McLane and West Phoenix streets. To find this intersection drive south through Payson on Arizona Highway 87 and turn right on West Phoenix a few blocks before leaving town. The turn is near (just before?) Mario's Restaurant and Super 8 Motel. Drive a few blocks west on West Phoenix to the intersection then drive south on South McLane.

0.1 0.1 Contact exposed in roadcut: Payson Granite intrudes and dips beneath diorite of the Gibson Creek batholith. The upper surface of the Payson Granite in the Tonto Basin region dips gently to moderately southward beneath all the units it intrudes. From here to mile 7.2 we will be in the Gibson Creek batholith, which is composed of several intrusive units ranging from

Table 4. Early Proterozoic East Verde River sequence[1]
(from Wrucke and Conway, in prep.)

Unit	Thickness (meters)	Lithology[2]
Upper graywacke	900	Gray to maroon, thin- to thick-bedded, fine- to coarse-grained, graded feldspathic to lithic graywacke. Minor mudstone and conglomerate. Contains more quartz than lower graywacke.
Upper mudstone	70	Dark bluish gray, thin-bedded mudstone and minor graywacke. Contains more quartz than lower mudstone.
Conglomerate	600	Gray to green, granule to boulder conglomerate and breccia, and gray to tan graywacke and mudstone. Conglomerate and breccia clasts are mostly of graywacke but also of jasper and various types of volcanic rocks.
Lower mudstone	800	Dark bluish-gray, thin-bedded mudstone and subordinate graywacke.
Lower graywacke	2,500	Bluish-gray to maroon and brown, thin- to thick-bedded feldspathic to lithic graywacke, pebble conglomerate, and mudstone. Consists entirely of graded beds several centimeters to several meters in thickness.
Siltstone and shale	20-200	Red, maroon, tan, and green, thin-bedded siltstone and shale, and minor resistant beds (up to 20 cm) of green to tan, mafic to felsic tuff and tuffaceous sandstone. City Creek Series of Wilson (1939).
Rhyodacite and jasper	40-200	Gray to greenish-gray rhyodacite or dacite pumice breccia and massive to laminated jasper. Slightly flattened, granule- to cobble-sized pumice clasts in the breccia are irregularly oriented. Jasper lenses are discontinuous and up to 20 m thick. Unit contains rhyolite or rhyodacite flows at City Creek.
Mafic volcanic rocks	3,000-6,000	Green to greenish-brown andesitic and basaltic massive amygdaloidal flows, pillow flows, agglomerate, breccia, conglomerate, and volcanic sandstone. Andesite with plagioclase or pyroxene phenocrysts is common. Unit contains minor graywacke, siliceous shale, jasper, and felsic flows and tuffs.

[1] This table describes the section south of the East Verde River between City Creek and the Limestone Hills.

[2] Sandstone terminology is from Pettijohn and others, 1973.

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gabbro to granodiorite (Conway, 1976; Wrucke and Conway, in prep.). The plutonic suite is mostly diorite and underlies about 350 km^2 south and west of Payson.

0.2 0.3 Intersection South McLane with Highway 87. Drive south on the highway.

0.2 0.5 Tapeats Sandstone resting unconformably on the Gibson Creek.

0.6 1.1 The diorite or gabbro in the road cut on the left has a subtle layering defined by 1-2-cm-thick plagioclase-rich lamellae. A two pyroxene gabbro in the batholith a few kilometers to the east has well-developed compositional layering (cm to m in scale) and igneous lamination (Conway, 1976).

3.5 4.6 ALTERNATE STOP 14. Deep road cut in the Gibson Creek batholith on the north side of the divided highway. Pull off to the left into the median toward the end of the road cut. This stop is to look at fresh diorite in the cut and to examine the numerous and varied dikes. Some and possibly all of the reddish-tan leucocratic felsic dikes are derived from the Payson Granite or the Green Valley Hills Granophyre. Granitic, aplitic, and granophyric dikes and plugs increase in abundance northward near the granite where granophyre locally occupies the contact between the Payson and the Gibson Creek.

A small gold mining district is centered a few miles to the west primarily in Gibson Creek diorite (Lausen and Wilson, 1925). Gold bearing quartz veins trend primarily west to northwest and some apparently occupy Tertiary faults (Wrucke and others, 1983; Conway, unpublished mapping). Other veins trend northeast and may be related to Proterozoic faults. The source of the gold may be the mafic plutonic rocks because there is little gold mineralization in these faults outside the batholith. Tertiary faults eastward in the Payson Granite contain barite veins, the barium source possibly being the granite (Conway and others, 1983).

Volcanic and volcaniclastic rocks are caught up as pendants in diorite of the Gibson Creek batholith 4 km to the southeast near Gisela (Table 3, and Conway, 1976). These rocks may be correlative with the East Verde River sequence.

2.6 7.2 STOP 15. Viewpoint at the contact between the Gibson Creek batholith and unconformably overlying Tertiary gravel. Pull off to the right atop a little knob where there is room to park 4-5 vehicles. Prominent geographic features seen from this spot are Table Mountain (Tapeats cap on Gibson Creek rocks; 70°), Gisela and Neal Mountains eastward across Tonto Creek (115°), Sheep Basin Mountain and the Sierra Ancha beyond (135°), Black Mountain, a knob a few kilometers to the southeast of Haigler Formation rhyolite surrounded by valley fill (165°), Four Peaks in the southern Mazatzal Mountains and the Rye Creek drainage basin in the foreground (180°), Mount Ord in the central Mazatzal Mountains (190°), and Mazatzal Peak (230°) and North Peak (280°) in the northern Mazatzal Mountains. (Note: azimuths only approximate because the higher elevations were partly cloud covered the day this log was made).

This spot affords an excellent view of the steep east face of the Mazatzal Mountains. A number of thrust faults are present in the Mazatzal Group (Table 5) which caps the range between Mazatzal Peak and North Peak (Wilson, 1939; Wrucke and Conway, in prep.). A southeast-dipping ramp, centrally located in this scene, is the easiest of the thrusts to see. The basal fault from which this ramp rises is more difficult to see; it dips very gently southward largely within the Maverick Shale of the Mazatzal Group and rises northward up through the Mazatzal Peak Quartzite of the Mazatzal Group to break the surface about midway between the ramp and North Peak. Thrusting is to the northwest (Wrucke and Conway, in prep.; Karlstrom and Puls, 1984), similar in vergence to thrust and reverse faults in Tonto Basin shown to pre-date deposition of the Apache Group (Conway, 1976; Conway and others, 1982). Wilson (1939) assigned the thrusting to a Precambrian deformational event he named the Mazatzal revolution, now generally referred to as the Mazatzal orogeny. Wilson (1939) suggested thrust movement on the order of 20 km and Conway (1976) estimated up to 10 km displacement. From an analysis of fault geometry involving a new postulated uppermost thrust, Karlstrom and Puls (1984) place the minimum displacement in the Mazatzal Mountains at 20 km.

The north-trending prominent rib near the base of the Mountains is the Deadman Quartzite, the basal unit of the Mazatzal Group in the Mazatzal Mountains. The Deadman is flat-lying to gently-dipping beneath most of the range but is warped upward and locally folded back on itself on the east flank of the mountains, thus forming the rib. The Deadman rests in angular unconformity on the East Verde River sequence (Table 4) from North Peak south nearly to Barnhardt Canyon just north of Mazatzal Peak. Southward and westward it rests, both conformably and unconformably to layering, on Red Rock Rhyolite.

Conglomerates of the Mazatzal Group/Quartzite, Alder Group/Formation, and Apache Group of the Tonto Basin-Mazatzal Mountains region were recently evaluated for uranium and gold potential (Anderson and Wirth, 1981). From extensive reconnaissance mapping and chemical analysis, no evidence was found for significant potential.

A late Miocene fault system at the flank of the mountains has dropped the valley block down 1-2 km. A number of old base and precious metal mines at the base of the mountain are either in or close to faults of this system, suggesting a Tertiary age of the mineralization (Wrucke and others, 1983). Weak expression of stratabound copper in strata of the East Verde River sequence west of North Peak suggests a potential for volcanogenic base metal deposits.

The highway from here to mile 19.3 is on late Miocene sedimentary rocks.

4.5 11.7 Rye Creek

3.0 14.7 View to the right of the northward-dipping Deadman Quartzite resting on Red Rock Rhyolite on Cactus Ridge.

0.6 15.3 Intersection Arizona Highway 188 to Roosevelt Lake and Globe.

0.5 15.8 Late Miocene limestone along the road.

1.0 16.8 Approximately here the highway crosses a major Tertiary range-bounding fault which, at the site of the highway, juxtaposes Tertiary gravel against Tertiary gravel, or is covered with gravel, or both.

0.6 17.4 ALTERNATE STOP 16. Pull off to the left. From this site a huge northeast-trending, near-vertical quartz vein can be seen a kilometer or more to the northwest. The quartz vein occupies the contact between Red Rock Rhyolite on the northwest and Tertiary gravel on the southeast (Ludwig, 1974). Because Proterozoic faults of this trend throughout the Mazatzal Mountains-Tonto Basin region commonly host large quartz veins, it is likely the fault at this site is Proterozoic and that Tertiary gravel has been deposited against the fault surface.

Looking to the north, one can see the dissected remnant of a pediment from an earlier stage of valley floor construction.

1.9 19.3 Road cut in the hill top exposes Red Rock Rhyolite which is overlain by Tertiary gravel on the east and faulted against Tertiary gravel on the west. Thus, not all faults bounding the range on the east are east side down.

0.6 19.9 Highway becomes divided. Hills on the right are underlain by Red Rock Rhyolite. Mount Ord is straight ahead. The road lies on Tertiary gravel for the next few miles, but outcrops of Alder Formation (Table 5) will be seen to the left, particularly approaching mile 22.1. Conspicuous in the Alder exposures are white to light gray northeast-trending ribs of quartzite which are interbedded with purple shale and siltstone and felsic volcaniclastic rocks. These are strata of the upper part of the Alder Formation exposed in the southeast limb of a major northeast-trending syncline, which Ludwig (1974) identified and named the Red Rock syncline. The quartzite beds extend intermittently northeastward into Tonto Basin and appear to thicken to become the Houdon Formation (Conway, 1976). Sparse andesite porphyry beds higher in the Alder section a few kilometers to the west may be correlative with the Board Cabin Formation (Conway, 1976).

2.2 22.1 Tertiary gravel resting on steep Alder beds. In the next few hundred meters, note some old roads and mine portals to the left across Slate Creek. These are workings of the Ord Mine, one of several mercury mines in the central Mazatzal Mountains, which together constitute the major mercury producing district in Arizona (Bailey, 1969). The entire district produced about 4,700 flasks between 1911 and 1946 (Faick, 1958; Wilson, 1941). The mercury in this area occurs almost exclusively in shaly strata, possibly localized in zones of greatest shear. Ransome (1915b), who made the first geological report on the district, proposed the mineralization was due to Tertiary magmatic activity in the area. A recent mineral resource assessment of the area (Wrucke and others, 1983) supports this model. Faick (1958) suggested the ultimate source of mercury in the major mineral, cinnabar, may be breakdown of mercurian tennantite found in deep levels of the Ord Mine. Anderson and Guilbert (1979) considered the tennantite to be evidence for the existence of Proterozoic massive sulfides.

In the next 2.7 mi the road closely follows the strike of the Proterozoic strata. The deep road cuts provide excellent exposures of tan to gray quartz arenite and lithic arenite, purple shale and felsic volcaniclastic rocks, and minor conglomerate, white shale, and mafic flows(?) of the upper part of the Alder Formation. ALTERNATE STOP 17 at one of these roadcut exposures.

2.7 24.8 The road turns right here and crosses upsection to the Red Rock Rhyolite at the next stop. Unfortunately several hundred meters of the uppermost Alder Formation is covered with Tertiary gravel.

0.6 25.4 STOP 18. Road cut in Red Rock Rhyolite. Vehicles may park on the right where there is little shoulder space or slightly past the road cut, where there is a pull-off on the left but where visibility is poor for highway re-entry.

Red Rock Rhyolite is a 1-km-thick section of dominantly ash-flow rhyolite. Here in the central Mazatzal Mountains it occupies the axis of the Red Rock syncline, a major shallowly plunging isoclinal fold which apparently affects all the Alder Formation as well (Ludwig, 1974). The rhyolite in this road cut has a variety of flow textures, including classical welded ash-pumice textures. A little basalt or andesite here is apparently interbedded with the rhyolite. This is representative of the regional Red Rock lithologic association; it is a highly skewed bimodal suite of mafic and felsic volcanic rocks.

0.3 25.7 Basalt dikes intrude Tertiary gravel in road cut on the left.

0.4 26.1 Slate Creek divide, entering Maricopa County. Turn off highway to the right then turn immediately left onto FS Road 25 leading to the West Fork of Sycamore Creek. The next mile will be in Tertiary basalt. Notice the large basalt hill called Iron Dike to the left across the highway; this may be a basalt plug. An extensive evolved Tertiary volcanic center (about 5 m.y. old) is found a few miles to the west in the Saddle Mountain-Lion Mountain area (Wrucke and Conway, in prep.). There is abundant evidence of Tertiary magmatic activity in the area to support the model of Tertiary mercury mineralization.

1.4 27.5 East Fork of Sycamore Creek. A few hundred meters to the right is a gold milling operation of American International Mining, Payson.

0.5 28.0 This stretch is in Tertiary sediments and volcaniclastics. To the left across the East Fork of Sycamore Creek is a hill of purplish-brown quartzite similar to that of the Mazatzal Group surrounded by Tertiary sediments. Facings are entirely to the southeast in this 200 m-thick quartzite, in contrast to northwest facings in the thin tan to gray quartzite ribs in the upper part of the Alder Formation on strike to the northeast in Slate Creek. A possible explanation for this anomaly is that the quartzite indeed belongs to the Mazatzal Group and has been thrust into this position.

0.2 28.2 Sharp right turn upon reaching the West Fork of Sycamore Creek. Looking north up the West Fork drainage one can see Alder Formation rocks in the foreground. The large rounded hill a kilometer or more

Table 5. Early Proterozoic stratified rocks of the Mazatzal Mountains[1]
(modified from Ludwig, 1974, and Wrucke and Conway, 1986)

Group	Formation or lithology	Thickness (meters)	Lithology
Mazatzal Group	Mazatzal Peak Quartzite	480-740	Reddish-brown to white, fine- to coarse-grained, thin- to thick-bedded cross-bedded quartz arenite with sparse pebble lenses. Upper half is light gray or pink to white; lower half is reddish-brown.
	Maverick Shale	120-230	Drab olive-brown to reddish-brown laminated to thin-bedded siltstone, silty and sandy shale, and minor cross-bedded sandstone.
	Deadman Quartzite	25-450	Reddish-brown, fine- to coarse-grained, thin- to thick-bedded, cross-bedded quartz arenite with sparse pebble beds. Basal pebble to cobble conglomerate (0-100 m) contains mostly rhyolite clasts.
	Red Rock Rhyolite	1,000-2,000	Light to moderate brown rhyolite ash-flow tuff, flows, and breccia. Several well-preserved cooling units on Mt. Peeley. Minor conglomerate, sandstone, shale, and mafic volcanic rocks.
	Alder Formation (northwest limb of Red Rock syncline)		
	Sandstone	600-1,000	Tan, gray, white, and purplish-brown lithic arenite, granule to pebble conglomerate, graywacke, and quartz arenite. Minor shale, felsic tuff, and mafic and felsic flows. (Telephone Canyon unit of Ludwig, 1974)
	Lapilli tuff	800-900	Bluish-gray, felsic lapilli tuff and crystal tuff, white to purple tuffaceous shale, and minor tan to purple conglomerate. Clasts of felsic volcanic rock and jasper in the conglomerate. All lithologies are slaty. (Oneida unit of Ludwig, 1974)
	Shale	500-800	Maroon tuffaceous(?) shale and siltstone containing minor interbeds of limestone and lithic graywacke. Reddish-maroon, 15-m-thick limestone at base. (East Fork unit of Ludwig, 1974)
	Volcanics, jasper and dolomite	450-600	Upper light to dark gray-blue monolithologic dacite to rhyodacite breccia and cobble conglomerate. Middle dark bluish-gray to tan basalt flows, pillows, and volcaniclastics (partly dolomitized) and thinly interbedded jasper and tan dolomite. Lower blue-green to gray, massive, felsic crystal and vitric tuff. (Cornucopia unit of Ludwig, 1974)
	Shale	500-800	Purple to maroon laminated and thin-bedded shale with subordinate siltstone, green volcanic sandstone, and pebble conglomerate. (West Fork unit of Ludwig, 1974)
	Volcanic sandstone	500-1,000	Green to purplish-green, massive, unsorted, poorly bedded volcanic arenite, graywacke(?), and conglomerate. Minor purple shale. Basal one-third is mostly conglomerate with clasts of rhyodacite, jasper, and purple shale. (Crystal-lithic tuffs unit of Ludwig, 1974)
	Shale	50-300	Purple laminated to thin-bedded shale and sparse thin siltstone and sandstone interbeds.
	Volcanic rocks	400-500	Dark brownish-green, mostly aphyric, basaltic pillow lavas and breccia, and green porphyritic andesite in lower one-third of unit. Massive white to lavendar, phenocryst-poor rhyolite, brown volcanic breccia, white to red chert, and minor mafic volcanic rocks in upper two-thirds of the unit. The volcanic breccia is chaotic, with rhyodacite(?) and minor chert as clasts up to 4 m.
	Micaceous sandstone	600	Light gray and greenish-gray, fine- to medium-grained, intricately cross-bedded sandstone and minor basalt. Abundant chlorite and white mica (talc?) give the sandstone a slippery feel. Primary bedding features are pervasively disrupted by soft-sediment(?) deformation.
	Rhyolite	>200	Tan to bluish-gray rhyolite breccia and lappili tuff, and red to brown massive rhyolite porphyry. These rocks are in fault contact with the micaceous sandstone, but may be part of the Alder Formation.

[1] The sections from which these descriptions are taken occur between Slate Creek (Arizona Highway 87) in the central Mazatzal Mountains, and North Peak in the northern Mazatzal Mountains.

ahead on the right is underlain by the Pine Mountain Porphyry (Wilson, 1939), a thick Proterozoic rhyolite sill. The red-brown cliffs several kilometers farther on the left side of the creek are jasper-dolomite beds of the middle part of the Alder Formation which will be seen at Stop 19.

1.1 29.3 Alder Formation in the northwest limb of the Red Rock syncline is exposed from here to mile 29.6, except for local Tertiary gravel cover. These strata are largely gray slaty volcaniclastic and sedimentary rocks (Table 5; Oneida unit of Ludwig, 1974).

0.6 29.6 Contact of Alder strata with the highly foliated margin of the Pine Mountain Porphyry. This intrusive body may be a hypabyssal equivalent of the Red Rock Rhyolite; it is similar in composition and has been deformed with the host strata. The road bed is on the porphyry for the next 0.6 mi; note the dissipation of the foliation toward the interior.

0.6 30.2 Northern contact of the porphyry sill with purple slaty shale, sandstone, and pebble conglomerate (Table 5; East Fork unit of Ludwig, 1974) of the Alder Formation. A small satellite sill of the porphyry is about 30 m ahead. In the small flats of this area are old buildings of the Sunflower mercury mining operation, workings of which are 0.5-1.5 km up the drainage to the left.

0.4 30.6 STOP 19. Adit at road intersection. Park here and walk north downhill on the road for a hundred meters to McFarland Canyon, or drive to the canyon bottom, but there is little turn-around room at the creek. This stop, requiring a 1-km hike up McFarland Canyon, is to examine dolomitized pillow lavas and thinly interbedded jasper and dolomite (Table 5; Cornucopia unit of Ludwig, 1974) of the Alder Formation. The hike begins near the contact of the purple to maroon slaty unit with the underlying strata of interest.

Exposures for the first 0.5 km are largely of carbonate-rich sedimentary rocks, including conglomerate or breccia, and mafic volcanic rocks. An indeterminate, but possibly large part of this section, could be dolomitized volcanic sediments or flows. A variety of dolomite and calcite veins also are present. The next 0.5 km is underlain first by dolomitized pillow flows, then by spectacular, gaudy, interbedded and widely brecciated jasper and tan dolomite, and then by another section of dolomitized pillow flows. The structurally well-preserved pillows in both sections give stratigraphic tops to the southeast. We will walk a few hundred meters into the second pillow lava section then return to the vehicles.

Marsh's (1983) map explanation indicates this unit is composed of chert and dacite breccia. Dacite breccia is not an apparent lithology in McFarland Canyon but is common to the northeast (Ludwig, 1974) in this unit where alteration may be less extreme.

Ransome (1915) and Lausen (1926) considered the jasper-dolomite to be part of the Proterozoic section, whereas Wilson (1939), emphasizing the breccia texture, thought it was a Tertiary hydrothermal deposit. Ludwig (1974) confirmed the Proterozoic sedimentary character of the deposits and pointed out that the brecciation is internal to the jasper-dolomite unit and that breccia layers as thin as 0.3 m are conformable with the bedding. He suggested the brecciation might be penecontemporaneous with deposition (gravity sliding or current break up), or, less likely, of deformational origin (bedding-plane shearing). We suggest the extensive carbonate alteration in the section occurred in a hydrothermal regime that resulted also in the exhalative formation of the jasper-dolomite. We concur with Ludwig in the soft-sediment origin of the breccia. The distribution of the breccias and their internal fabric has no relation to the regional tectonic fabric.

It is intriguing that three areas of distinctly different mineral deposits lie close to the jasper-dolomite and dolomitized pillows in the McFarland Canyon area. The Au-Ag-Pb Story mine, the only mine in the northern Mazatzal Mountains to produce appreciable lead, lies 1.5 km to the west and several hundred meters stratigraphically beneath the jasper-dolomite-pillow unit. Alteration and stratiform character at the Story mine (Wrucke and others, 1983; Marsh, 1983) suggest to the senior author the possibility of volcanogenic mineralization. Volcanogenic mineralization was demonstrated to have occurred at a mineral deposit 6 km to the west and lower in the Alder section (Conway, 1983). In upper McFarland Canyon, several km to the northwest, gold and arsenic are associated with post-deformational pyrite- and arsenopyrite-bearing rhyolite sills and dikes. Mercury at the Sunflower mine is along and just above the upper contact of the jasper-dolomite-pillow unit. Local extensive chlorite alteration in this zone is not typically found with mercury mineralization in the region and may be suggestive of Proterozoic volcanogenic alteration.

Marsh (1983) found As, Cu, Pb, Sb, Au, Ag, Hg, Bi, and Te abundances at the Story mine and in mineralized rock associated with the sills in McFarland Canyon to be similar to those in mineralized zones in Payson Granite in the northern Mazatzal Mountains and in Tonto Basin. Finding these elements not to be anomalous in the jasper-dolomite, Marsh concluded that mineralization at both the Story mine and rhyolite sills was unrelated to volcanic activity and due to Payson Granite, hypothesized to be present at depth.

Wrucke and others (1983) and Marsh (1983) concur with Faick (1958) in suggesting that mercury in the district may have been derived during Tertiary heating from pre-existing sulfides, whatever their origin, in the Proterozoic strata. Anderson and Guilbert (1979) consider the original mineralization in the district to be volcanogenic. Clearly the gold in upper McFarland Canyon and the cinnabar are not volcanogenic, whereas metals at the Story mine may be (Wrucke and others, 1983). The ultimate source of metals and the extent of volcanic-related hydrothermal activity in processes which mineralized the middle and lower parts of the Alder Formation of this area is a promising topic of research.

Return to mile 30.6 where the trip will formally disband and those who wish may continue to Alternate Stop 20.

0.4 31 From mile 30.6 take the west fork of the road south and up the hill to ALTERNATE STOP 20, the Sunflower mercury mine. This road swings right after about 100 m and travels westward nearly horizontally past the retort downhill on the left and leads to a number of adits and a large open-face mine area. The mercury is in slaty fine-grained shales, felsic tuffs, and mafic(?) volcaniclastic rocks. Massive chlorite is abundant in the open-cut mine area and is probably of hydrothermal origin.

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FIELD NOTES AND SKETCHES

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