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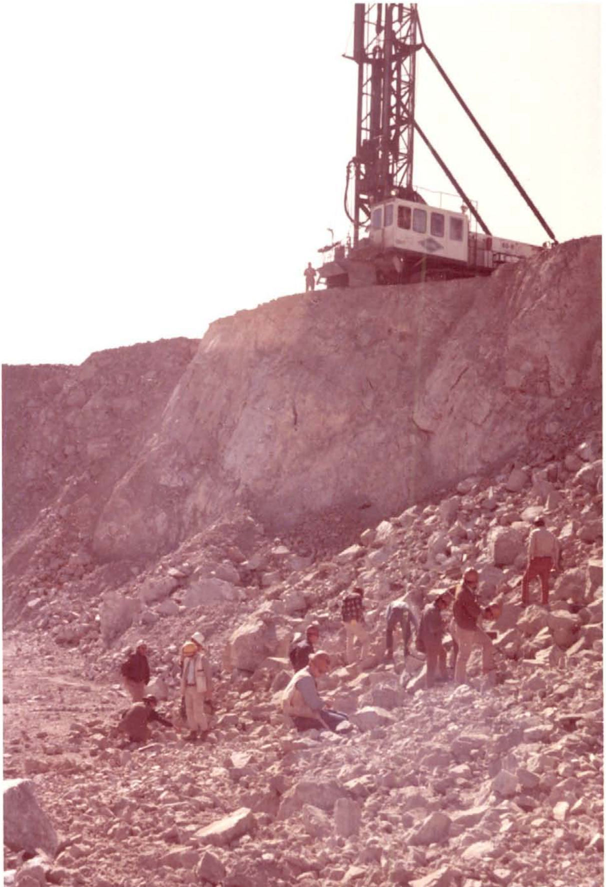

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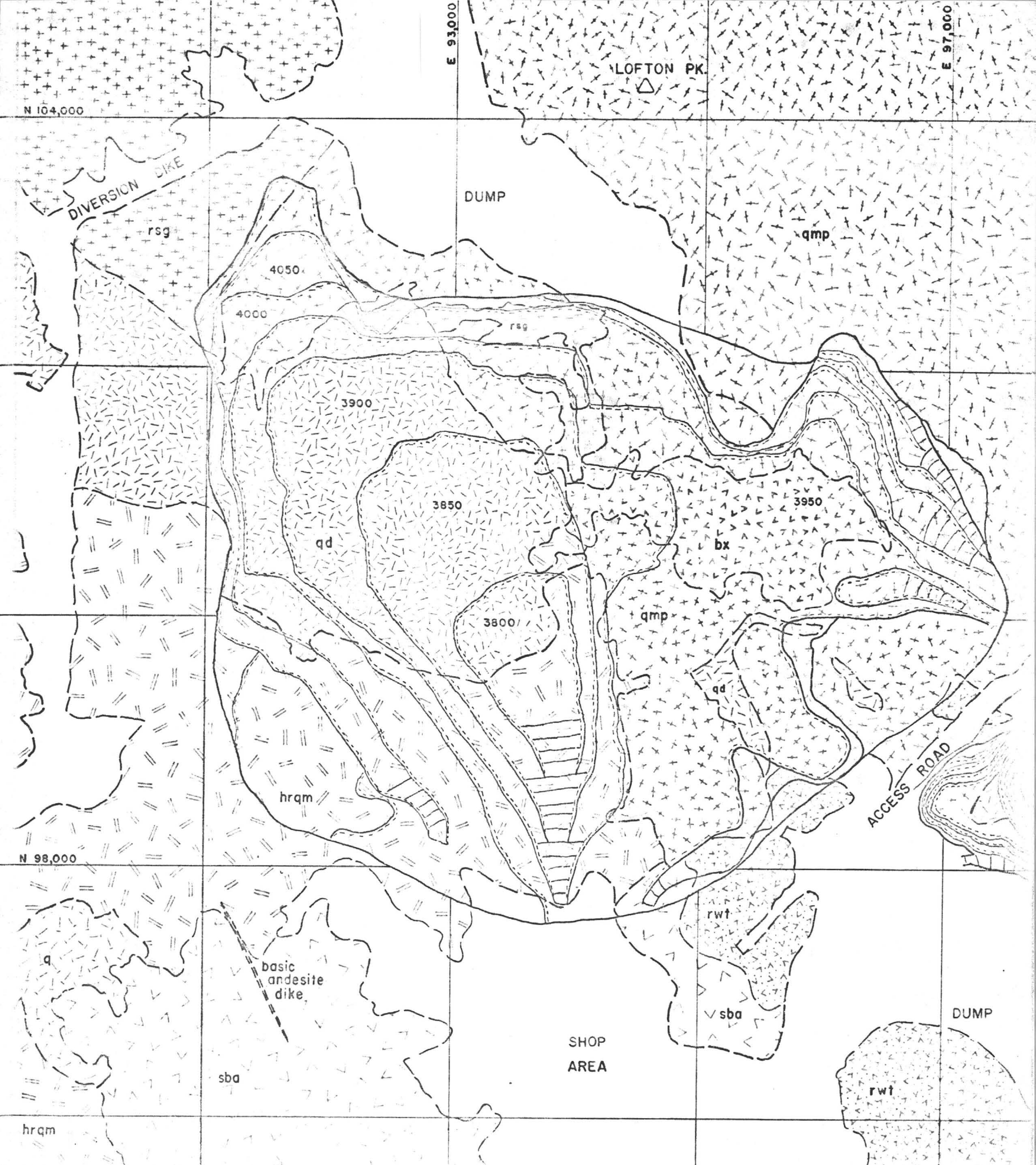


EXPLANATION

Qal — Alluvium, waste dumps, etc.	sba — Silver Bell (Demetrie) andesite
— Aplite	qd — Biotite quartz diorite
bx — Breccia Pipe	hrqm — Harris Ranch quartz monzonite
qlp — Quartz latite porphyry	rwt — Oxframe rhyolite welded tuff
qmp — Quartz monzonite porphyry	q — Quartzite
rsg — Ruby Star granodiorite	

DUVAL SIERRITA CORPORATION

SIERRITA PIT GEOLOGY

SCALE : 1" = 1000'	DATE : 11-30-71
GEOLOGY BY: RAM, AHJ, BLW, DWL, FWM, CAO, CDI	DRAWN BY : RLL , ATD

ARIZ - PIMA CO. - Esperanza dist. E
Sierrita Mine

[redacted]

PAY DIRT

A PUBLICATION DEVOTED TO THE INTERESTS OF THE ARIZONA SMALL MINE OPERATORS

Number 372 | **P. O. Box 13384, Phoenix, Arizona 85002** | **June 22, 1970**

Pima Co.

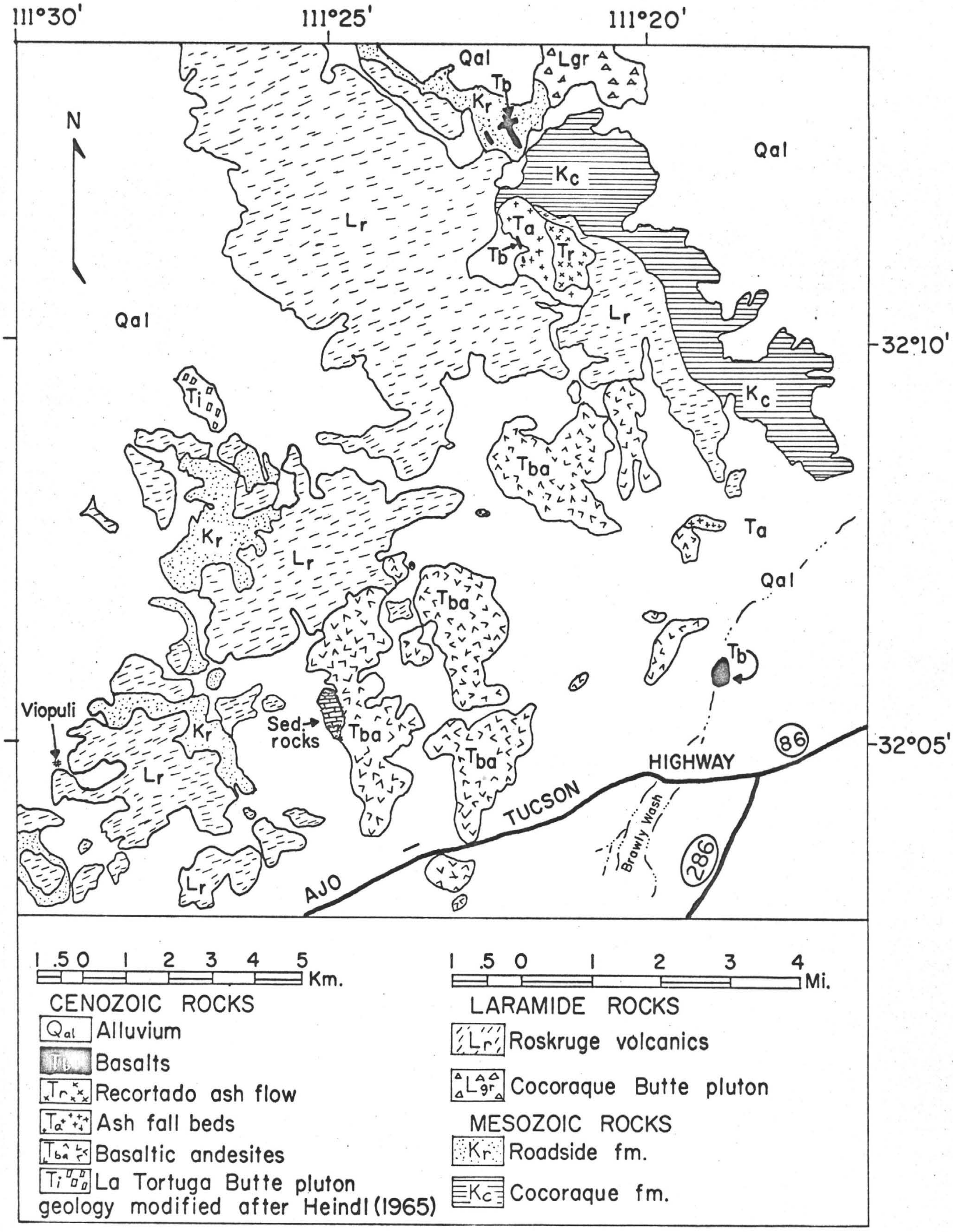


Figure 2 – Geologic map of the Roskruge Mountains, Arizona

Ariz. Bur. Mines Bull 183

Pima Co.

DETAILED LOG

Arizona Highway 86

This log, although recorded in an east to west direction, that is, from Tucson to Why, is designed to be used equally well from Why to Tucson.

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

Cumulative mileage for the eastbound trip is tabulated in the right hand margin, starting at the end of the log and reading upward.

MILES WEST-WARD Total	MILEAGE INTERVALS	MILES EAST-WARD Total

0.0

0.0 East end of State Highway 86 (Ajo Way) at Junction with 6th Avenue (U.S. Highway 89-State Highway 93, Tucson to Nogales). Elevation 2,460 feet. 119.2

0.6

0.6 Cross 12th Avenue. 118.6

0.4

1.0 Overpass across U.S. Interstate Highway 19 (Tucson-Nogales). To the north, Sentinel Peak ("A" Mountain) and Tumamoc Hill stand out as eastern erosional outliers of the Tucson Mountains. They form a faulted and slightly tilted block of rhyolitic agglomerate, tuff, and ash flows capped by basaltic andesite, all of Tertiary age (Figure 6, Section D-D'). 118.2

Sentinel Peak was used by the Papago Indians and early settlers as a look-out point for hostile Indian raids. Tumamoc is a Papago name for "horned toad" and the hill was the site of the Carnegie Desert Botanical Laboratory in the early 1900's. The buildings now are used by the Department of Geochronology of the University of Arizona.

0.3

1.3 Bridge over Santa Cruz River. This ephemeral stream heads in southern Arizona and drains the Santa Cruz Valley northward through Tucson to the Gila River Valley. Near Tucson the Santa Cruz Valley is a relatively flat, undissected flood plain covered by several hundred feet of unconsolidated alluvium which in turn rests on up to 2,000 feet of moderately consolidated alluvium consisting of lenses of sand, gravel, silt, and clay. There is strong evidence that the valley in the Tucson area is a downthrown fault block with the fault on the western side buried under the alluvium. 117.9

Historical records show that the Santa Cruz River was a permanent stream meandering on the surface as far north as Tucson as late as the early 1900's and that the ground water level was close enough to the surface of the plain to support a good grass cover and large stands of mesquite and cottonwood. Since that time the increased pumping from wells in the valley for irrigation, and for domestic and industrial use in Tucson have lowered the average groundwater level several hundred feet. The lowering of the water table has resulted in the loss of much of the original vegetation and the incision of the channel into the alluvium. The Santa Cruz River now flows only after occasional and seasonal heavy rains.

0.8

2.1 Cross Mission Road. To the north, Mission Road passes around the eastern foot of Sentinel Peak. To the south, Mission Road leads to the San Xavier del Bac Mission and to the open pit copper mines farther south. The Mission was originally founded in the early 1700's by the celebrated Jesuit missionary and explorer, Father Kino, who was the first European to extensively travel through the area covered by Highway 86. 117.1

0.2

2.3 Local headquarters of the U.S. Border Patrol. 116.9

0.1

2.4 Highway Mileage Marker 170. These markers indicate the road distance from Gila Bend and serve as useful orientation points along the logged route. Due to changes in the road location they may not always reflect the correct distance. 116.8

0.4

2.8 The surface cuts and dumps to the north result from an old clay quarry and, more recently, from the extraction of aggregate for road building. The hilly ridge to the south is composed largely of welded and unwelded, pyroclastic quartz-latite tuff (Cat Mountain Rhyolite). Some of this light-gray rock was quarried for building stone. 116.4

0.4 to 1.4

3.2 to 4.2 Road cuts are in Cat Mountain Rhyolite of Cretaceous age, dated radiometrically as about 68 million years old. This formation is the bottom member of a thick volcanic series capping a large part of the Tucson Mountains. 116.3 to 115.0

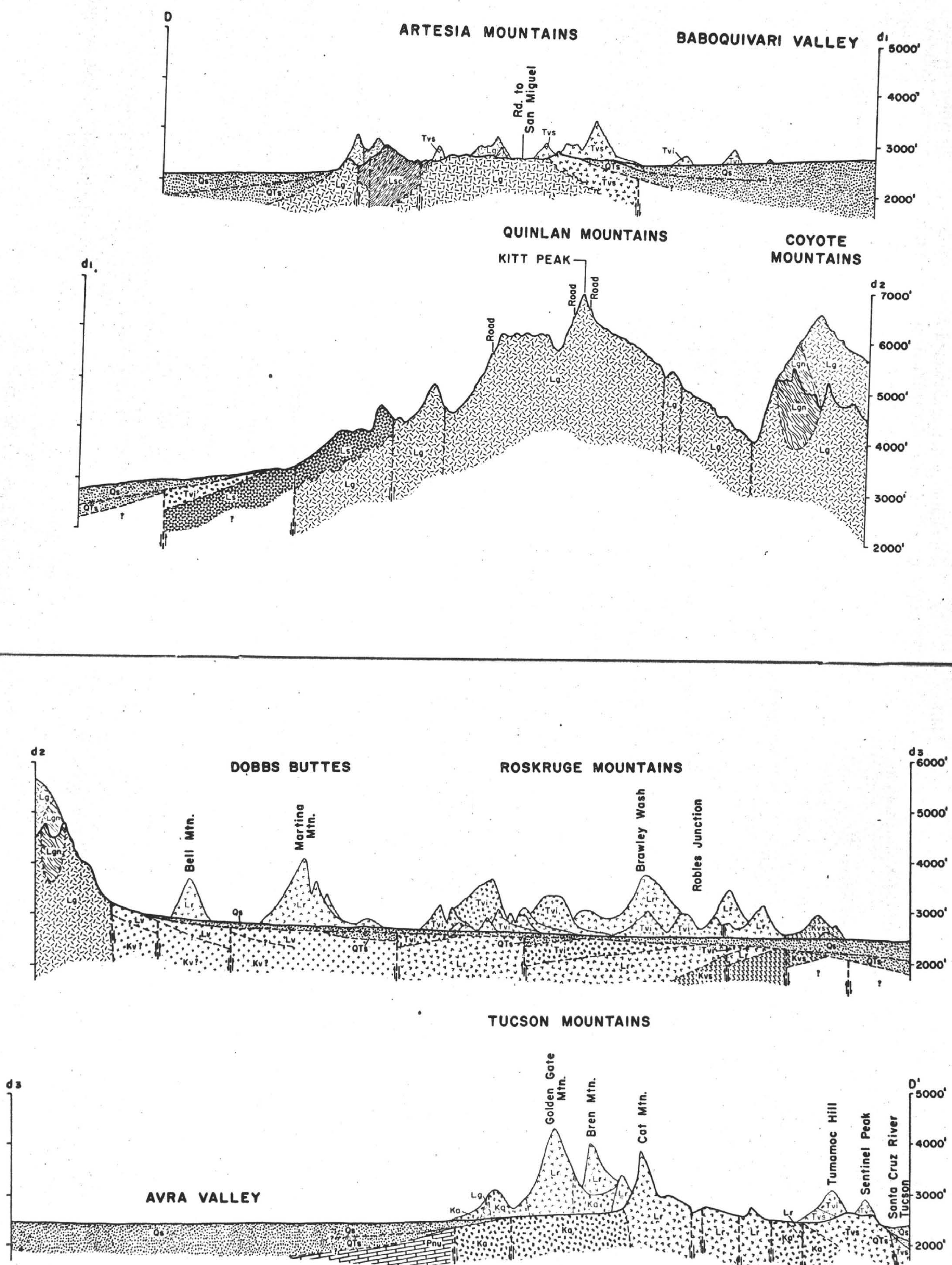


Figure 6. Generalized geologic cross-section D-D′.

0.3

4.5 Robles Pass. Elevation 2,654 feet. This pass, through the southern part of the Tucson Mountains, was named after Bernard Robles who, around 1884, ran stage lines from Tucson to the booming mining camps at Quijotoa and Gunsight. 114.7

The main mass of the Tucson Mountains extends northwest for about 16.5 miles and is a block-faulted and uplifted range composed of a structurally complex, thick sequence of sedimentary, volcanic and intrusive rocks ranging from Paleozoic through Tertiary in age. The steep-sided, 3,854-foot peak to the north is Cat Mountain which lends its name to the pyroclastics of which it is composed.

To the west, from this pass, the traveler overlooks the Altar and Avra Valleys, extending from south to north, respectively. These valleys form a wide trough or basin between the bordering mountain ranges. On the east side, southward from the Tucson Mountains, are the Black Hills and Black Mountain, composed of basaltic rocks; and the Sierrita Mountains, a large circular mass of Laramide granitic rock that intrudes older intrusive, sedimentary, and metamorphic formations and in turn is intruded and partly covered by later rocks. A broad pediment and bajada (alluvial slope) extends outward into the basin area from this sierra-type range (Plate 12). On the western side, to the south, is the long, steep-walled, serrated ridge of the Baboquivari Mountains with the blocky tower of Baboquivari Peak near the center. At the north end of this range are the Quinlan Mountains, at the top of

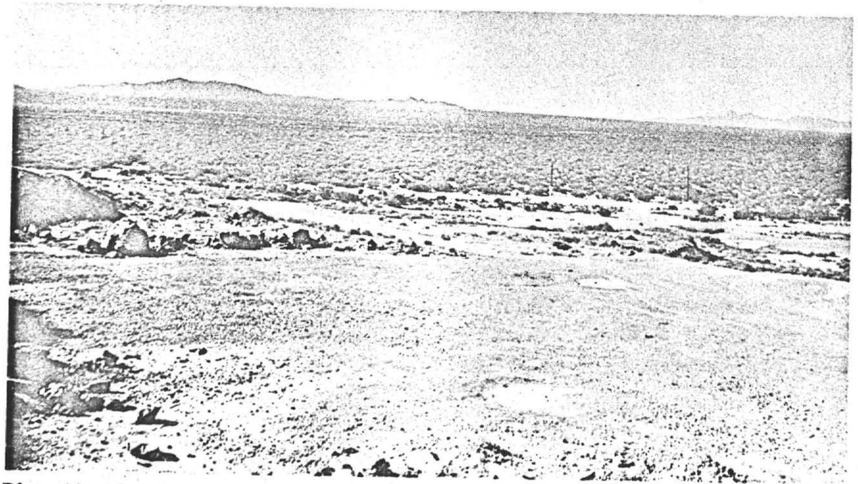


Plate 12. Altar Valley, looking south from the rock quarry on Snyder Hill. An even, gently sloping pediment extends outward from the Sierrita Mountains on the left. The Baboquivari Mountains, with Baboquivari Peak, border the valley on the right. The vegetation is mainly creosote bush.

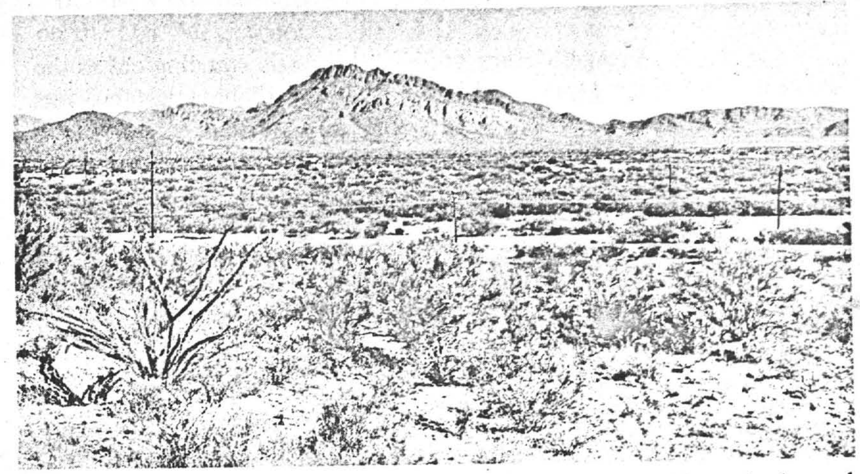


Plate 13. Golden Gate Mountain from the south with the Tucson Mountains beyond. Note that the layered eastward dipping rhyolitic flow and pyroclastics are well marked by differential erosion. The smaller hill to the left, Sedimentary Hills, is an upthrown block of arkose.

which are the white astronomical observatory installations at Kitt Peak. In front of the Quinlan Mountains are the Coyote Mountains. The ranges farther north, in sequence, are the Roskruge, Waterman, and Silver Bell Mountains. Altar Valley, in the southern part of the basin, is largely undeveloped and contains only scattered ranches. The northern part of Avra Valley is extensively developed by irrigated cotton farms.

To the east from the pass there is a restricted view of the Santa Cruz Valley and the Rincon Mountains.

The vegetation in the pass is typical of the succulent desert zone found in the higher, rocky areas of the Sonoran Desert. Saguaro, palo verde, acacia, cholla, and other small cacti and shrubs predominate.

0.7

5.2 The small hills and rocky slopes to the south are composed largely of Cat Mountain Rhyolite and Cretaceous and Tertiary volcanics and agglomerates that have been faulted and tilted. Saginaw Hill, the largest and most westerly hill, exposes a Tertiary porphyritic intrusive that has been prospected for copper. 114.0

0.8

6.0 Junction with Kinney Road which leads north to Old Tucson, the site for many western movies and television productions; the Arizona-Sonora Desert Museum, containing a collection of local fauna and flora; Tucson Mountain Park, a recreational area; and the western section of the Saguaro National Monument. 113.2

1.4

7.4 Highway Mileage Marker 165. To the north, standing out to the west of the Tucson Mountains, is Golden Gate Mountain, 4,288 feet in elevation, composed of Cat Mountain Rhyolite. The northward extension of the rugged Tucson Mountains is well seen from this point (Plate 13). 111.8

1.4

8.8 The highway skirts the north side of Snyder Hill, a low isolated hill exposing limestone and dolomite of Permian age. This outcrop probably resulted from faulting and folding of the bedrock. On the west side of the hill the carbonate rock was quarried for road construction material. 110.4

0.3

9.1 San Joaquin Road to the north. The vegetation has been changing to the mycrophyll type with evenly spaced creosote bush becoming the dominant shrub. 110.1

1.3

10.4 Bridge over wash. Mesquite and acacia line the washes where more moisture is available from the spotty rains. Drilling in this area down to about 500 feet, failed to find water or bedrock, suggesting a structural break between this point and the outcrops at Snyder Hill to the east. 108.8

0.2

10.6 Bridge over wash. Streams in such washes are ephemeral. 108.6

1.8

12.4 Highway Mileage Marker 160. Ryan Field, on the north side of the highway, was constructed as an air training base during World War II and is now used mainly as an auxiliary airfield for the Civil Air Patrol, Air National Guard and parachute jumping clubs. It is operated under the jurisdiction of the Tucson Municipal Airport. 106.8

0.4

12.8 West Valencia Road to the south. The highway is crossing the broad, gently-sloping bajada extending northward from the Sierrita Mountains. 106.4

3.0

15.8 Sandario Road leads northward into Avra Valley. 103.4

2.7

18.5 To the north of the highway is one of the missile sites built by the U.S. Department of Defense and serviced by the Air Force. 100.7

0.3

18.8 Sierrita Mountain Road goes south to ranching and mining areas. 100.4

3.0

21.8 Three Points (also called Robles Junction) at the junction with State Highway 286 which goes to Sasabe at the head of Altar Valley 97.4

on the U.S.-Mexico border. Father Kino and other early Spanish missionaries and explorers often used this route for access into Arizona territory. Bernard Robles sunk a deep well and established a ranch at Three Points in the 1880's. The ranch was a stage stop on the runs between Tucson and the mining camps to the west.

0.6

22.4 Highway Mileage Marker 150. The farms on each side of the road are irrigated by 700-foot wells penetrating permeable lenses of sand and gravel interbedded with clay and silt. The average ground water level is 200 feet below the surface and the depth to bedrock is believed to be about 2,000 feet. The relatively little pumping here has had small effect on the water table in contrast to the excessive pumping farther north in Avra Valley where the water table has been lowered critically by at least 70 feet in recent years. 96.8

0.6 to 1.1

23.0 to 23.5 Three bridges across branches of Brawley Wash, the corrupted name derived from Bowley or Bawley, which was the name of a ranch and stage station along the wash in the 1880's. Elevation 2,540 feet. This wash is the main drainage for Avra Valley, joining the Santa Cruz River to the north. The streams are ephemeral but can reach flood stage after heavy rainfall. The entrenchment of the stream bed is due to the channeling of the rapid flow when the streams are active. Mesquite trees favor the banks of such washes (Plate 14). 96.2 to 95.7

1.0

24.5 The Tucson Rifle Club firing range is to the north. 94.7

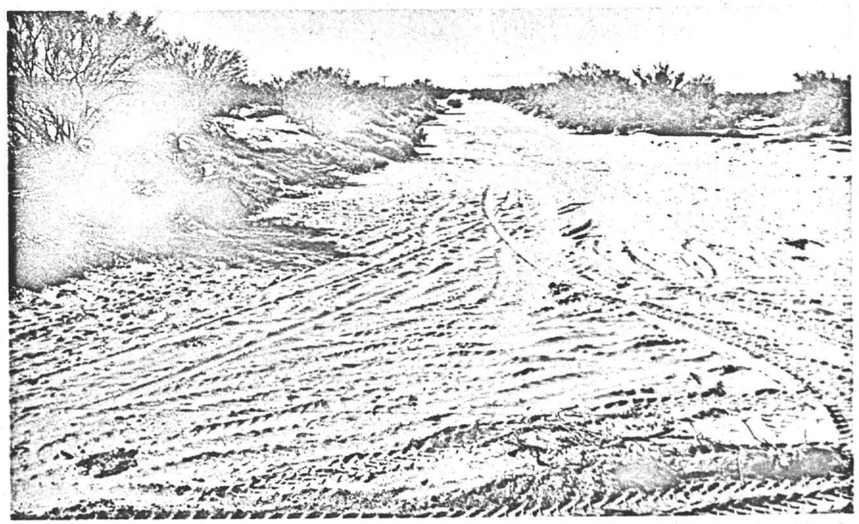


Plate 14. Looking south along the slightly-incised, main channel of Brawley Wash, filled with fine alluvium and lined by mesquite trees. Baboquivari Peak and Mountains in the distance.

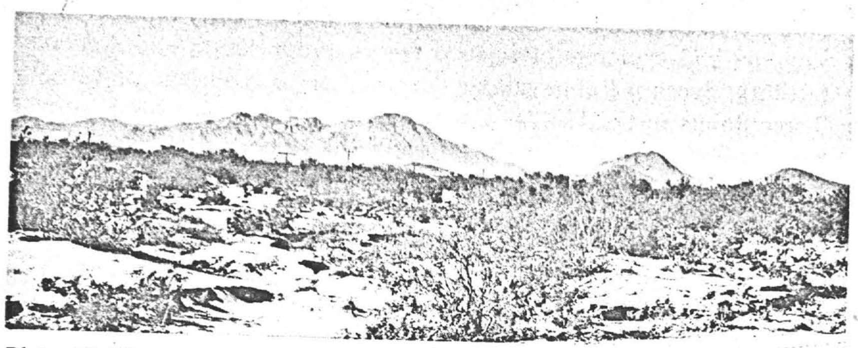


Plate 15. The Coyote Mountains, with the Quinlan Mountains and Baboquivari Range behind, looking west from Brawley Wash. The peaks to the right are Martina Mountain and other volcanic hills. Note the difference in erosion between the jagged topography of the granitic and metamorphic mountain ranges and the smoother surface of the volcanic hills.

1.7

26.2 Highway passes the southern end of the Roskruge Mountains at an elevation of 2,644 feet. This range consists mainly of colorful volcanic flows and pyroclastic rocks of Laramide age which rest on folded and interbedded Cretaceous sedimentary and volcanic rocks. The Laramide rocks are capped in part by Tertiary basaltic andesite. The formations have been faulted, warped, and tilted. The rounded hills near the highway are outcrops of the basaltic andesite (Figure 6, Section D-D′). 93.0

1.1

27.3 Highway Mileage Marker 145. The cattle guard and fence mark the eastern boundary of the main Papago Indian Reservation. In this area there is a mixture of the microphyll-type desert vegetation (principally creosote bush and bur-sage), which is typical of the low-lying broad alluvial plains, and the succulent-type desert varieties (various cacti such as saguaro, cholla, and barrel; ocotillo; and palo verde) where there is more moisture and a rocky soil. 91.9

0.4

27.7 Bridge over small wash. 91.5

3.0

30.7 Coleman Road goes south to ranches along the east side of the Coyote Mountains. To the north is the conical, 4,041-foot peak called Martina Mountain, formed by erosion from a thick sequence of pyroclastic ash flows and volcanic breccia of Laramide age. This peak and others farther north and west are collectively called Dobbs Buttes, after a local stage driver and ranch owner of the 1800's. Most of these buttes are eroded, tilted, fault blocks displaying the light-colored ash bands interbedded with darker volcanic flows and breccia (Plate 15). 88.5

1.1

31.8 Road north to Viopuli (also called San Pedro), a long established Papago winter rancheria where a good water supply is available. The Indian name means "wild tobacco," which was grown and used by the Indians. 87.4

1.0

32.8 Road south to Nawt Vaya (Papago for "pampas grass well" and also called Alamo), a winter rancheria established at a well dug by early prospectors. Prior to having this well, travelers obtained water from Aqua la Vara, a small spring in the fractured granitic rock higher up on the north slope of the Coyote Mountains. 86.4

Bell Mountain, one of Dobbs Buttes, lies to the north and displays the tilted, interbedded ash flows and volcanics of Laramide age (Plate 16).

0.1

32.9 An old section of the Tucson-Ajo road veers off to the northwest. It passed the Roadside Mine, a low grade copper prospect in interbedded clastic sediments and andesitic volcanics of Cretaceous age. Considerable underground development from a 800-foot shaft and several subsequent surface exploration programs failed to disclose economic mineralization. The mine camp, when operating, was a source of water and supplies for travelers in the early 1900's. 86.3

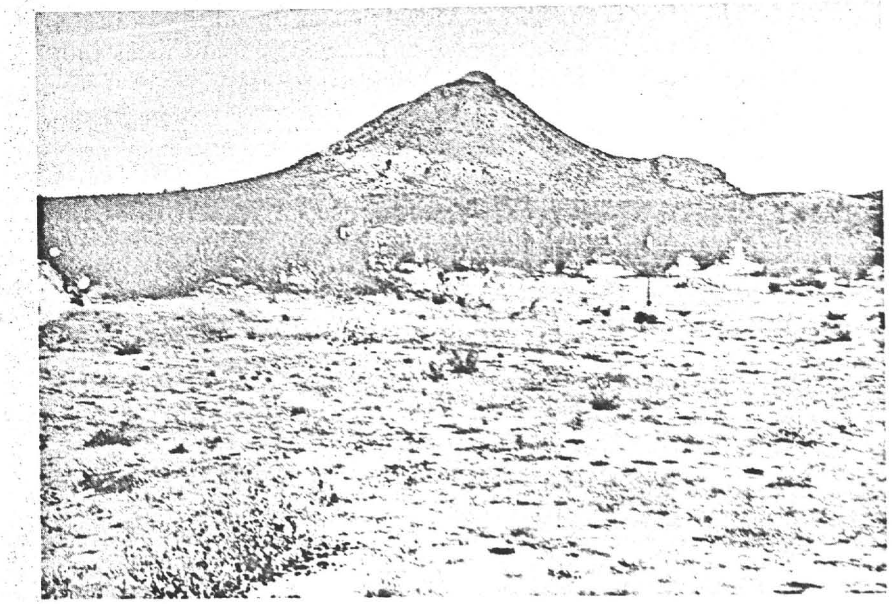


Plate 16. Bell Mountain from the south, showing the tilted, interbedded, light-colored ash beds and darker lava flows of Laramide age.

0.8

33.7 Highway Mileage Marker 139. Road cuts show Cretaceous pyroclastics with interfingering conglomerates and abundant caliche. Palo verde, cholla, ocotillo, and some yucca thrive in the rocky terrain. Sharp eyes may spot the top of the headframe of the old Roadside Mine above the vegetation about one-half mile to the north. 85.5

1.1

34.8 Road cuts in Cretaceous volcanic agglomerate. 84.4

0.2

35.0 Bridge. Reddish purple agglomerate and conglomerate are exposed in the deep wash. 84.2

1.3

36.3 Roadside rest area. From here there is a good view of the Coyote Mountains to the southeast. They are composed mainly of Laramide granitic and gneissic rocks with some engulfed metamorphosed limy and sandy Paleozoic(?) and Mesozoic sediments. The intrusive mass is cut by swarms of quartz pegmatite dikes and by strong faults. The trace of one fault passes along the north face of the mountains accounting for the steep erosional wall and the sharp break between the intrusive mass and the Cretaceous volcanic rocks to the north. Another fault marks the sheer western wall of the mountain mass. 82.9

To the southwest are the Quinlan Mountains marked by the large white dome housing the 150-inch astronomical telescope on Kitt Peak, elevation 6,875 feet. The Quinlan Mountains, at the north end of the Baboquivari Range, also are made up of Laramide granitic rocks with some scattered pegmatite and black lamprophyre dikes and dark segregations and inclusions. James Quinlan had a stage station at the northern base of the Quinlan Mountains. Kitt Peak may have been named after an Indian or after the relative of an early surveyor.

The amount of rainfall is somewhat greater in this area, accounting for the increase in vegetation.

0.1

36.4 Bridge over wash. 82.8

0.5

36.9 Road north to Pan Tak (Papago for "coyote sits" and often called "Coyote"), an Indian winter rancheria below a spring in fractured granitic rock on the west flank of the Coyote Mountains. This watering place was known to travelers as early as 1864. 82.3

1.2

38.1 Junction with State Highway 386, the road to Kitt Peak. This well-maintained, paved road climbs and circles the Quinlan Mountains for 12 miles at a maximum grade of 6 percent, from an elevation of 3,220 feet at the highway junction to about 6,800 feet where the Kitt 81.1

Peak National Observatory installations are located. (See detailed log of Arizona Highway 386 and Plate 17.)

The Kitt Peak National Observatory is operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under a contract with the National Science Foundation. AURA was created in 1957 as a non-profit organization of seven universities, now increased to nine. Kitt Peak, a sacred Papago Indian spot, was selected and leased from the Papago Tribe after a thorough investigation. Except for restricted areas, the road, observatory grounds, Astronomical Museum, and picnic area, are open to the public daily from 10:00 A.M. to 4:00 P.M.

0.4 to 1.1

38.5 to 39.2 Road cuts in reddish-brown Tertiary rhyolite. The low hills to the south were prospected for soft manganese oxides which occur as thin coatings and in narrow fractures in the shattered rock. The hills to the north display granitic rocks. 80.7 to 80.0

The small dirt basin just south of the road is a typical "charco" where run-off rain water is collected for watering livestock.

0.7

39.9 Bridge over wash. From the highway in this section there is a good view to the north of the Aguirre Valley (named after Pedro Aguirre, a rancher and stage line operator in the mid-1800's). This valley is flanked on the west by the South and North Comobabi Mountains and further north by the Santa Rosa Mountains with Gu Achi Peak (Papago for "big narrow ridge"). The distant low, dark, basaltic 79.3

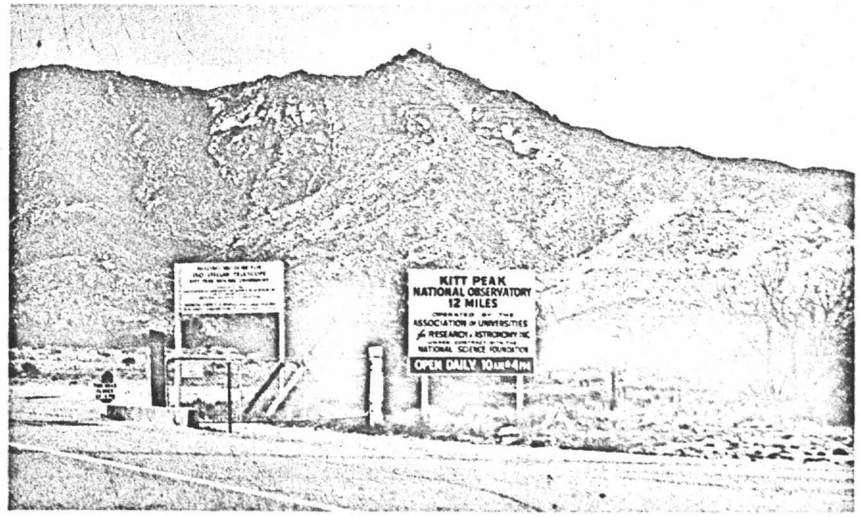


Plate 17. Kitt Peak at north end of the Quinlan Mountains from the intersection of State Highways 86 and 386. The white dome of the 150-inch astronomical telescope building surmounts the mass of eroded, Laramide, granitic batholith.

andesite hills rising out of the valley floor are the Vaca Hills. The east side of the valley is bordered by the Roskruge, Waterman and Silverbell Mountains.

1.7

41.6 Road north to Schuchk, (Papago for "black"), the Santa Rosa School, the old Santa Rosa Ranch, and the Indian settlement of Sil Nakya (Papago for "saddle hanging"). The latter is located at the north end of the North Comobabi Mountains. Father Kino reportedly visited this area in 1693. **77.6**

The dirt road to the south was a part of the old Tucson-Ajo road, leading to San Vicente, an old settlement where early-day travelers could obtain water and supplies.

2.1

43.7 Highway skirts the northwest extension of the Quinlan Mountains. The granitic rocks of Laramide age intrude the Cretaceous volcanics and coarse arkosic sediments. All the formations are block-faulted. **75.5**

1.6

45.3 Road cuts in Quaternary gravel. **73.9**

0.6

45.9 Cross roads. The road north leads to Haivana Nakya (Papago for "crow hanging"), an Indian village on the drainage divide between the Santa Cruz-Gila basin to the north and the San Simon-Sonoyta basin to the southwest. The depth to water here is over 400 feet. This road also goes to Comobabi (also spelled Comobavi, a Papago term for "hackberry tree well"), one of the oldest Indian rancherias known. The old route through the pass between the North and South Comobabi Mountains was a recommended alternate road between Tucson and Ajo in the early 1900's, avoiding the difficult desert washes of more southerly routes. **73.3**

The road south is a foothill truck trail along the western flank of the Quinlan and Baboquivari Mountains, serving numerous Papago rancherias and mining prospects.

1.0

46.9 Bridge over Sells Wash. **72.3**

0.5

47.4 Highway Mileage Marker 125. **71.8**

2.6

50.0 The well visible to the north of the highway is in Sells Wash and the depth to water is reported to be about 300 feet. **69.2**

2.2

52.2 Highway Mileage Marker 120. The Indian settlement of Chiawuli Tak (Papago for "barrel cactus sits"), extends along the north side of the highway. From this area there is a good view to the **67.0**

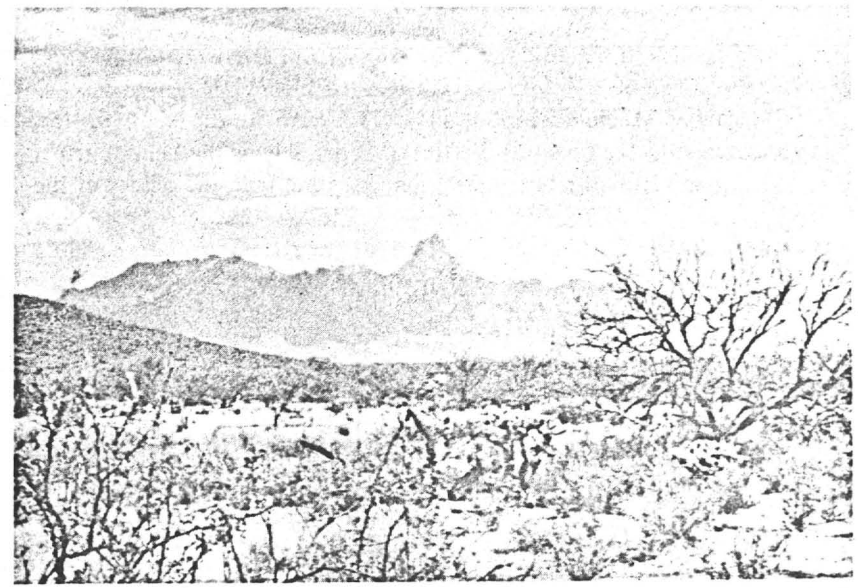


Plate 18. View of the Baboquivari Mountains from the west, showing Kitt Peak in the Quinlan Mountains with the road cuts and white observatory towers to the left, and towering Baboquivari Peak in the center.

east of the Quinlan Mountains with the white observatory towers on Kitt Peak and the road cuts leading to the top. Extending south from Kitt Peak is the steep-sided Baboquivari Range capped by box-like Baboquivari Peak, elevation 7,730 feet, believed by the Indians to be the sacred home of a Papago god. The peak has long been an important landmark. The sharp break from the steep rock slope of the mountain to the gentle westward sloping bajada of Baboquivari Valley is well marked.

The Baboquivari Mountains form a sinuous, elongated, narrow, high, rugged range. Block-faulted Laramide granitic and metamorphic rocks make up most of the mountain mass (Plate 18; Figure 6, Section D-D').

1.0

53.2 The road south leads to Ali Chuk Shon (Papago for "foot of little black hills") and to other small Papago settlements. The dark-colored hills are a northeast extension of the Artesia Mountains and have been eroded out of Tertiary andestic lava flows. **66.0**

3.5

56.7 A large charco, a collecting basin for run-off surface water, is on the north side of the road. **62.5**

0.1

56.8 Road cut in Tertiary basaltic andesite. **62.4**

0.5

57.3 Old road into Sells veers to the south from Highway 86. 61.9

0.9

58.2 Highway Mileage Marker 114. The road to the south is the eastern access to the business district of Sells. Sells is the headquarters for the Papago Indian Reservation. The meeting hall, the offices of the tribal council, the offices of the Bureau of Indian Affairs, a school, and the tribal Rodeo Grounds are located there. Also there are Trading Posts and a Post Office. 61.0

Sells, originally called Indian Oasis, had its beginning in the early 1900's when Joseph Meneger dug a well and established a trading post at this location. An Indian settlement grew around the post and in 1918, after the selection of Indian Oasis as the tribal headquarters, the name of the Post Office was changed to Sells, after the then Commissioner of Indian Affairs. In spite of local opposition at the time, the new name persisted.

From Sells, a road leads south through the Artesia Mountains into the Baboquivari Valley, and on to the Mexican border. The Artesia Mountains, as well as the Comobabi Mountains to the north, are composed of Laramide intrusive granitic rocks that invaded Cretaceous rocks, and later were largely covered by Tertiary volcanics and sediments. Block faulting and erosion have produced their present shape. Several small mines and prospects were opened up around the south end of the Comobabi Mountains but none became sustained economic operations.

0.1

58.3 Bridge over Sells Wash. 60.9

0.3

58.6 Hill with water tank on the south side of highway is composed of Tertiary andesitic volcanics. 60.6

0.2

58.5 The road to the south is the western entrance to the Sells business district. Elevation 2,360 feet. The offices of the Indian health service and the hospital of the U.S. Public Health Service can be seen to the south. The road to the north is an old alternate route of the Tucson-Ajo highway, which passed through the old Cobabi mining district in the Ko Vaya Hills, on the west side of the South Comobabi Mountains. 60.4

1.5

60.3 Highway Mileage Marker 112. The graded road to the west descends the broad, alluvium-covered, westward sloping bajada into the "Great Plain," drained by San Simon Wash. One of the early routes from Sells to Ajo crossed this valley through several Indian summer rancherias. The predominant vegetation is creosote bush and cholla with occasional saguaro and palo verde. 58.9

3.0

63.3 Highway Mileage Marker 109. Highway passes through the Etoi-Ki Hills (derivation unknown) which are erosional remnants of andesitic volcanic flows, agglomerate, and some welded tuff of Tertiary age. 55.9

1.0

64.3 The erosional hills to the east are made up of basaltic agglomerates, tuffs, and flows. 54.9

1.3

65.6 Highway skirts the western foot of a basaltic volcanic hill. To the far west the gneissic Kupk Hills (Papago for "dike"), rise out of the Great Plain with the ragged ridge of the volcanic Mesquite Mountains behind them. 53.6

0.9

66.5 Road east to Nolia (corruption of "novia," a Spanish word for "well"), Ko Vaya (Papago for "badger well"), Comobabi, and Sil Nakya; all of which are Indian settlements. 52.7

The Ko Vaya Hills to the east consist predominantly of strongly faulted andesitic flows and tuffs. On their eastern side is one of the oldest mining districts in southwestern Arizona. The Picacho (Cobabi) mine was worked for silver by the Indians and early Spaniards in the 1700's, and in the mid 1800's produced about $40,000 in silver ore. There has been no active mining in recent years.

3.5

70.0 Road east to Nolia, Ko Vaya, Comobabi, and Sil Nakya. 49.2

0.2

70.2 Highway Mileage Marker 102. Picnic area on west side of the highway under a large blue palo verde tree just south of the bridge. Relatively thick vegetation occurs in this area with mesquite, palo verde, acacia, and other trees along the numerous washes. Creosote bush, bur-sage, and cactus are also seen, mainly in the alluvial soil between washes. 49.0

The dirt road to the west leads to Vainom Kug (derivation unknown), a small Indian summer rancheria in Gu Oidak (Papago for "big field") Valley. Beyond the valley are a series of mountains named from south to north, South Mountain, Ben Nevis Mountain, and the Quijotoa Mountains. South Mountain rises to an elevation of 4,158 feet and has been carved by erosion from thick flows of andesitic lava showing strong horizontal parting and vertical columnar jointing. Ben Nevis Mountain even more strikingly rises sharply in a narrow, cliff-bordered ridge to an elevation of 4,013 feet. It is an eroded fault-block mountain made up of Cretaceous to Tertiary rhyolitic to andesitic volcanic flows, tuffs, and agglomerates, with intercalated sediments (Plate 19). Several short-lived mines around this ridge —

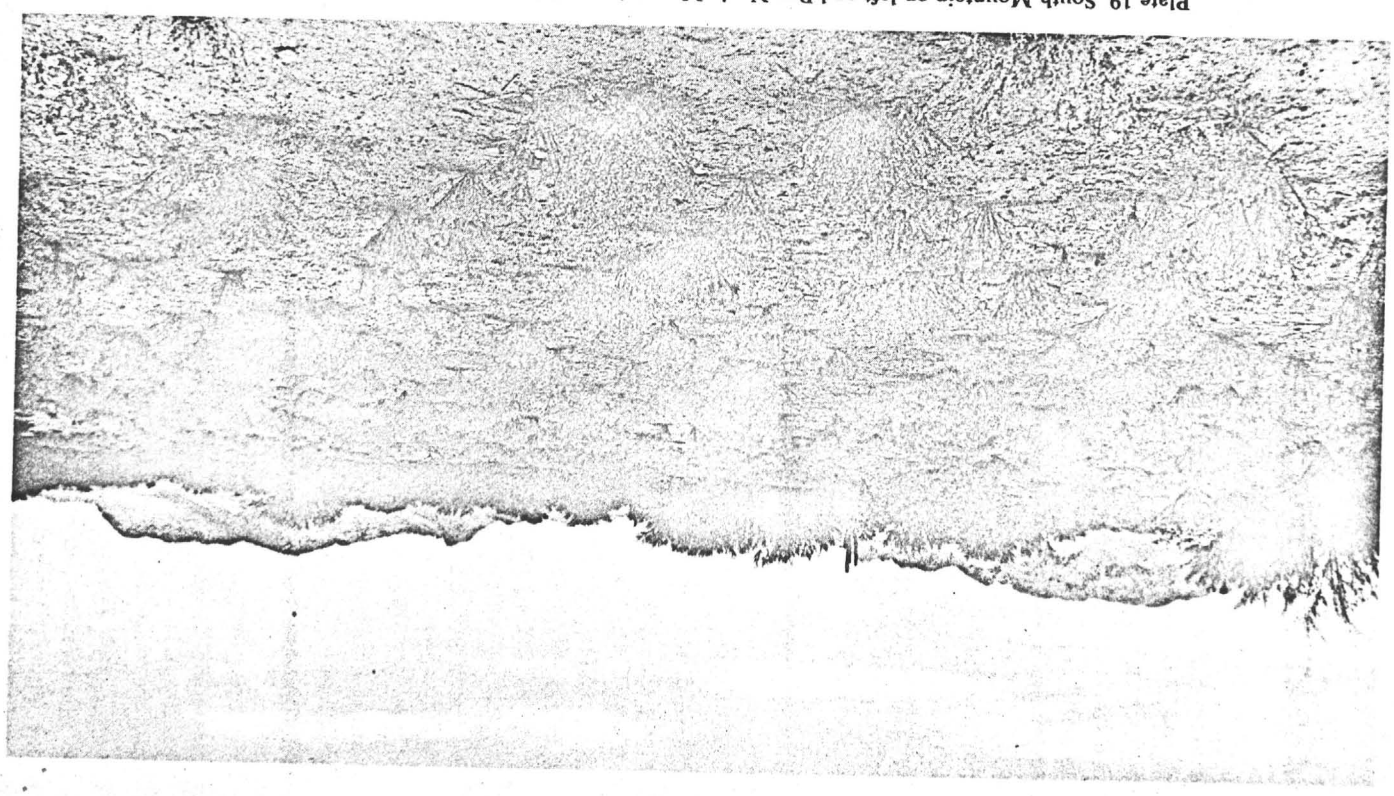


Plate 19. South Mountain on left and Ben Nevis Mountain on right, looking west from the picnic area at Highway Mileage Marker 102. Note mixed microphyll and succulent types of vegetation.

the Weldon, Ben Lomond, and Quijotoa — were worked in the late 1800's and early 1900's for gold and silver. The rich ore pockets were discovered by Albert Weldon, J. A. Roark, and Alex McKay and optioned to the same capitalists who made fortunes in the Comstock Lode in Nevada. The "boom" led to the construction of stamp mills, a tramway, a 1,000-foot deep well, and several townsites grouped under the name Quijotoa. The population grew to some 1,500 persons and stage lines between Quijotoa and Tucson were kept busy. After the initial mining of small rich pockets in quartz veins and hematite breccia zones near the surface, the development results were very disappointing and within two years the "boom" was over. A small production was made in 1887 and from 1891 to 1892 from the mines and from the dry placers in the consolidated gravel beds below the deposits. The total production and returns were small, up to $500,000, while an estimated several million dollars were invested or spent. As late as 1932, attempts to mine gold and silver ore in the district were still being made.

0.8 to 3.6

71.0 to 73.8 Highway crosses numerous dry washes draining westward on the broad gently-sloping bajada extending out from the Comobabi Mountains. **48.2 to 45.4**

0.7

74.5 Highway crosses Sikul Himatk Wash (Papago for "whirlpool"), elevation 2,111 feet, that drains southward through Gu Oidak Valley. A short distance to the north is the drainage divide between northward and southward flow at an area where the bajadas from the mountains to east and west coalesce. The valley alluvium at the wash is at least 1,000 feet thick and the depth to ground water is estimated at 400 feet. **44.7**

1.0

75.5 Cattle guard. **43.7**

0.5

76.0 Inactive radar station. **43.2**

2.0

78.0 Historical Marker "Quijotoa" on west side of highway. The dirt road to the west leads to the old mining areas in the Quijotoa Mountains and Ben Nevis Mountain (Plate 20). **41.2**

The Quijotoa Mountains are a large fault-block range of Laramide granitic rock. The lighter color of these rocks contrasts sharply with the dark volcanics of the mountains farther south.

0.4

78.4 Graded road running southeast is the old Tucson-Ajo road through the Comobabi Mountain area, either to Sells or to the north end of the Baboquivari Range. **40.8**

1.1

79.5 Road to west leads to Indian settlements and mining prospects in the northeastern foothills of the Quijotoa Mountains. To the east the bajada slopes into the Santa Rosa Valley. 39.7

0.2

79.7 Tertiary rhyolitic volcanic hills are east of the highway. 39.5

0.2

79.9 Junction of Highway 86 with a paved, unnumbered road running north to Casa Grande, a distance of 61 miles. Elevation 2,430 feet. An excellent stand of saguaros can be seen in the rocky terrain to the south of the highway. 39.3

0.5

80.4 Cross Quijotoa Wash. Papago Indian settlements are scattered along both sides of the highway. 38.8

0.5

80.9 Indian cemetery on south side of highway. 38.3

0.2

81.1 One of the main Indian settlements, Maish Vaya (Papago for "Covered Wells") is to the south. The townsite and wells were originally planned and constructed by early American miners to service their activities in the area. When mining declined, the Indians took over the facilities. The bedrock on both sides of the highway is Laramide granitic intrusive. 38.1

Plate 20. Historical marker for "Quijotoa," the short-lived mining boom camp. The granitic Quijotoa Mountains are in the background.

0.4

81.5 Remains of an old trading post on north side. 37.7

0.5

82.0 Andesitic volcanics are exposed in the road cuts. 37.2

0.4

82.4 Highway crosses Quijotoa Wash. 36.8

0.3

82.7 Western settlement of Maish Vaya (Covered Wells) with mission school and church to the south. To the north are two of the original wells. 36.5

The Quijotoa Mountains to the south are composed mostly of Laramide granitic rocks that intruded older rocks that are no longer present. Some overlying Tertiary rhyolitic volcanics crop out near the highway. The Brownell Mountains to the north are a complex fault block showing Laramide granitic intrusives along the east side and Cretaceous and Tertiary volcanics in the western half (Figure 5, Section C-C′). Brownell Valley to the west of the mountains has been eroded out of Tertiary sediments interbedded with andesite flows, producing a dissected mountain pediment with little alluvial cover. Several short-lived gold and silver mines and prospects were active in the past in the Brownell Mountains.

1.3

84.0 Quijotoa Pass, elevation 2,800 feet. The road cuts are in weathered Laramide granitic rocks. Just east of here the highway crosses a strong northwest striking normal fault which marks a contact between the Laramide granitic rocks to the west and the Tertiary sediments and interbedded volcanics to the east. 35.2

1.3

85.3 Cattle guard. 33.9

1.9

87.2 Highway Mileage Marker 85. About here the alluvium of the valley laps up onto the granitic bedrock. The Sierra Blanca Mountains to the north are a fault block extension of the Quijotoa Mountains and consist of granitic gneiss of Laramide age. The Black Prince Mine, along a fault zone on the eastern side, has been prospected sporadically for copper, lead, and silver since the mid-1800's. 32.0

2.0

89.2 Road south to Pisinimo (Papago for "bison head"), a large and long established Indian summer rancheria in San Simon Valley. The dark outlying hills to the south are erosional remnants of Tertiary to Quaternary basaltic flows, tuffs, and agglomerates that formerly covered a much larger area. 30.0

1.2

90.4 Road north to silica quarry in Paleozoic quartzite, possibly 28.8

Abrigo Formation, in a small fault sliver on the western edge of the Sierra Blanca Mountains. Paleozoic limestone also crops out in the fault zone. The workings and dumps of this operation, which furnished smelter flux for Ajo, can be seen in the saddle between the outlying hills and the main mountain mass.

1.7

92.1 Highway Mileage Marker 80. 27.1

0.2

92.3 Picnic area on south side of highway along a small wash lined with large palo verde trees and mesquite. The highway is descending a broad dissected bajada extending westward to San Simon Wash. 26.9

0.2

92.5 Highway crosses the Gila and Salt River Meridian, the main north-south base line precisely surveyed by the U.S. Coast and Geodetic Survey in order to establish the land divisions (township and range) in Arizona. Elevation 2,051 feet. 26.7

1.0

93.5 Abandoned radar station to the south. 25.7

1.4

94.9 Road south into San Simon Valley. Creosote bush is the principal type of vegetation. 24.3

0.4

95.3 Indian Village of Wahak Hotrontk (Papago for "road dip"), or more commonly called San Simon, which is located in San Simon Wash. The alluvium, consisting of fine sand with lenses of gravel, silt, and clay is more than 800 feet deep. This broad basin, formed by the coalescing bajadas extending out from the bordering mountains, has numerous intersecting and shifting washes and often becomes very wet and muddy after the occasional hard rain. Because of the retained moisture in the soil, the wash has been an important summer farming area for the Indians (Plate 21). 23.9

To the north, the volcano-shaped Cimarron Peak, elevation 3,376 feet, is an erosional remnant of a mound of thick basaltic volcanics.

0.3

95.6 A trading post and Highway Maintenance yard are on the south side of the highway. 23.6

1.6

97.2 Highway Mileage Marker 75. Due to the construction of the highway, which was first laid out prior to 1920, stream drainage is held to the north side of the road, accounting for the dense stand of mesquite trees and brush on that side. 22.0

2.4

99.6 Cattle guard. In the distance to the south are the Mesquite Mountains with a distinctive corrugated crest. This range is composed 19.6

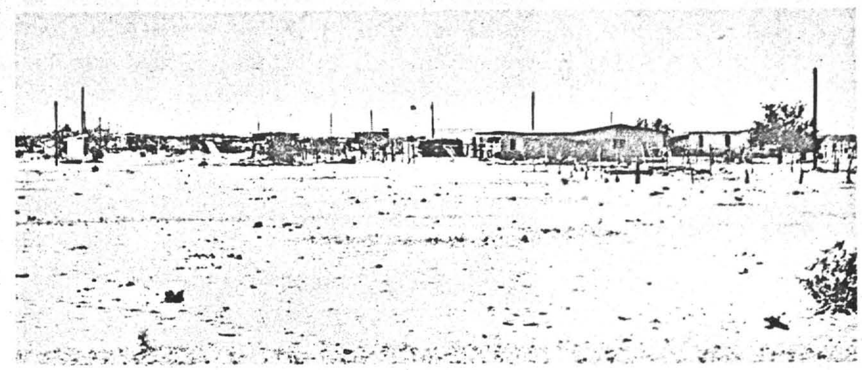


Plate 21. Indian village of Wahak Hotrontk (San Simon), a farming community in the broad, flat basin of San Simon Wash.

mainly of eroded, folded and faulted Tertiary rhyolitic flows, tuffs, and agglomerates. More to the southwest are the basaltic Gu Vo (Papago for "big charco") Hills and behind them the higher and more rugged Ajo Mountains.

1.6

101.2 The east-west ridge to the south of the highway is an eroded outcrop of Laramide granitic rock. The alluvial cover is relatively thin in this area, forming a veneer on the granitic bedrock pediment which slopes eastward. 18.0

2.2

103.4 The white patches in front of the hills to the south are the dumps of the Little Chief Mine where quartz veins cutting granitic and gneissic rocks are quarried for silica flux used in the Ajo smelter. The hills to the north are outcrops of light-gray, gneissic rocks of Laramide age capped by dark-colored, Tertiary, basaltic andesite volcanics. 15.8

1.8

105.2 Highway Mileage Marker 67. The highway skirts the north side of Ninemile Peak, so named because it marks the eastern end of a nine mile straight stretch of the highway. It and other hills to the south are the erosional remnants of a thick series of late Tertiary basaltic andesite volcanics which rest on Laramide granitic basement rocks. 14.0

2.4

107.6 Road north to Hickiwan (Papago for "jagged cut") and other Indian settlements in upper San Simon Valley. Father Kino visited this area in 1699. 11.6

The road to the south goes to Gu Vo (Papago for "big charco"). This large and long established Indian settlement lies along Gu Vo Wash, where it cuts westward through the eroded Gu Vo hills of Laramide granitic rocks. It has been dammed up to form a large ephemeral

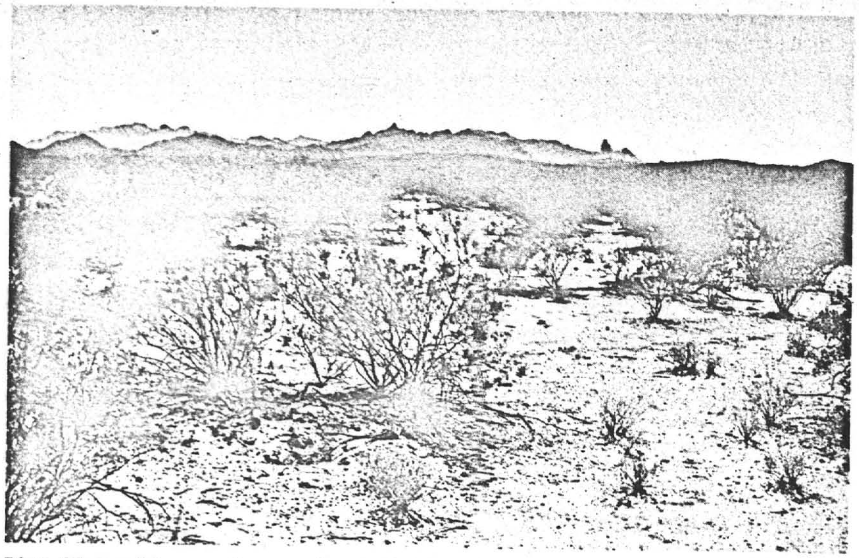


Plate 22. Looking south over the eroded, basaltic andesite Gu Vo hills to the Ajo Mountains, marked by Montezuma's Head at the north end.

pond. Father Kino visited Gu Vo in 1701 and the old southern route (from Tucson to Ajo) ran by this settlement.

The low discontinuous hills south of the highway are eroded remnants of basaltic andesite volcanics. Behind them are ragged ridges of Laramide granitic rocks and in the distance the high Ajo Range is marked at the north end by Montezuma's Head, a block-like peak sculptured out of volcanic flows and pyroclastics (Plate 22).

3.5

1.1 The road to the north goes to Hotason Vo (Papago for "rock base charco"), an Indian settlement at the south end of the Sikort Chuapo (Papago for "round spring") Mountains. This gently folded but sharply faulted range has been eroded out of basaltic andesite and basalt volcanics of Tertiary age. 8.1

2.7

3.8 The road south to Gu Vo is the route of the old southern Tucson-Ajo road of the 1910's and 1920's which passed through Gu Vo and Pisinimo to Sells. A branch of the road also goes south to Menager's Lake near the Mexican border. This lake was made by a dam across a wash in a divide between basaltic andesite hills. Joe Menager homesteaded some six square miles here about 1915 and completed the dam in 1920. The homestead was sold to the Papago Tribe in the 1930's. 5.4

The low, broken line of the Gunsight Hills to the south of the highway are erosional remnants of Laramide granitic rocks exposed by the stripping away of overlying Tertiary volcanics (Plate 23). The

origin of the name "Gunsight" is in dispute. One story relates that an early prospector noticed a hammered-silver gun sight on an Indian's rifle and learned that the silver came from this locality. Another story suggested the name originated because the main flat ridge reportedly resembled a gun barrel. Prospecting in the late 1800's disclosed some small pockets of lead-silver ore in these hills. Sporadic mining and prospecting continued until 1928 but the total production probably did not exceed $150,000. The dumps of the old Gunsight (Surprise) Mine, patented in 1874, can be seen on the northern slope of the main ridge. Farther south in the Laramide granitic rocks other small prospects and mines were worked for base and precious metals and tungsten.

The road north leads up Pozo Redondo Valley between the Sikort Chuapo and Pozo Redondo Mountains.

0.7

114.5 Road south to Schuchuli (Papago for "many chickens"). The old Gunsight Ranch was located here at a well dug in the 1800's and was one of the few available watering places for travelers between Sells and Ajo in the early 1900's. 4.7

0.9

115.4 The highway passes the south end of Pozo Redondo (Spanish for "round well") Mountains made up of westward-tilted basaltic andesite volcanics broken by faulting into ragged north-south trending ridges 3.8

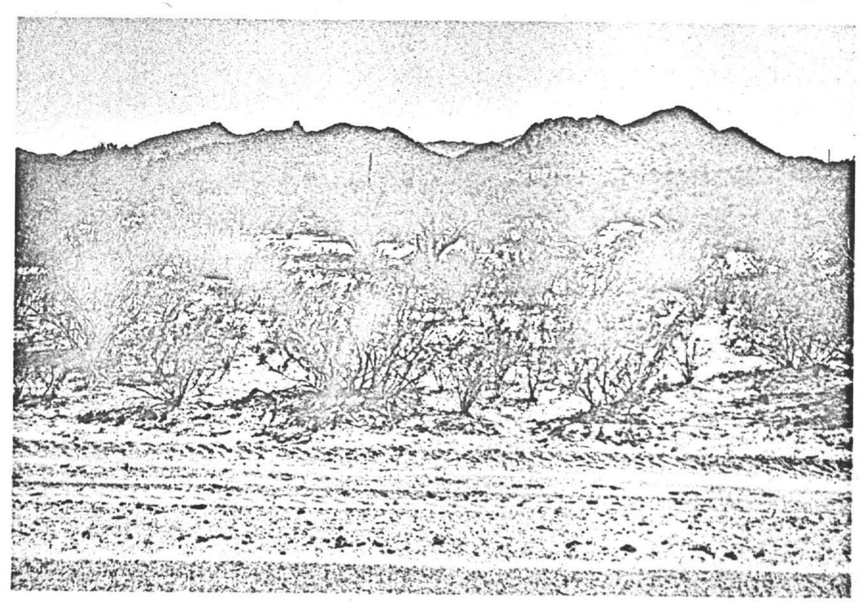


Plate 23. Gunsight Hills, erosional remnants of Laramide granitic rocks, with old mine dumps on the lower slopes. The north end of the volcanic Ajo Mountains, with Montezuma's Head, are behind.

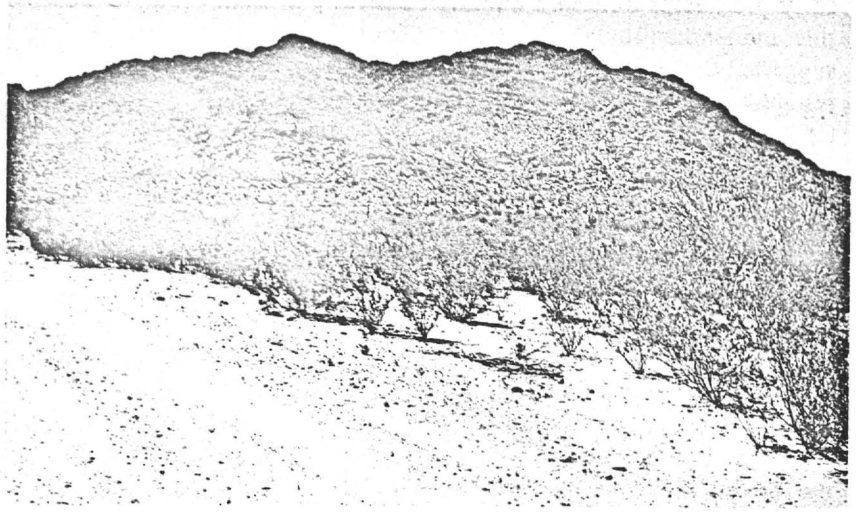


Plate 24. South end of the Pozo Redondo Mountains showing tilted and broken basaltic andesite flows.

(Plate 24). To the southwest there is a twisting, narrow ridge with a horizontal top. Basaltic flows rest unconformably on tilted and discontinuous andesite flows. The road cuts along the highway are in andesitic volcanics.

1.9

117.3 Cattle guard and fence marking the western boundary of the Papago Indian Reservation. To the northwest, the mining and metallurgical complex at Ajo can be seen on the eastern side of the Little Ajo Mountains. To the west, in the distance across the Valley of the Ajo, are the Growler Mountains. 1.9

1.6

118.9 Highway Mileage Marker 53. A branching road curves to the west to join State Highway 85. The small settlement is Why (Rocky Point Junction), named because of the shape of this road junction. 0.3

0.3

119.2 Western end of State Highway 86 at the junction with State Highway 85 which runs from Gila Bend to Lukeville. (See detailed log of Arizona Highway 85.) 0.0

go to p. 33

DETAILED LOG

Arizona Highway 386

This log is recorded from the junction with Arizona State Highway 86 southward to the end of the highway at the Kitt Peak National Observatory at the top of the Quinlan Mountains. However, it is designed to be used equally well for the descent.

Mileage for the upbound trip is given in the left hand margin as a cumulative mileage from Highway 86. The Mileage Interval between each point discussed is recorded in the center of the page.

Cumulative mileage for the descent is tabulated in the right hand margin, starting at the end of the log and reading upward.

MILES ASCENT Total — MILEAGE INTERVALS — **MILES DESCENT Total**

0.0

0.0 Junction of Arizona Highway 386 (Kitt Peak Road) with Arizona Highway 86 at 38 miles west of Tucson. Elevation 3,220 feet. This road is open to the public from 10:00 A.M. to 4:00 P.M. daily It climbs some 3,580 feet in 12 miles with a maximum grade of six percent. It is a good paved road, but the traveler is advised to drive carefully, observing all road signs and stopping only at the frequent, well-spaced, designated turn-outs and view-points. 12.0

Kitt Peak, elevation 6875, is the highest point in the Quinlan Mountains, at the northern end of the Baboquivari Mountain Range. The large, white, observatory tower visible at the top of the mountain houses the 150-inch telescope (Plate 25).

1.0

1.0 Pan Tak (Papago for "coyote sits" and also frequently called Coyote) lies to the east at the foot of the Coyote Mountains. This old Indian rancheria acquired water from natural springs on the steep slope above. These springs probably lie along the trace of a north-south, high angle, reverse fault which is responsible for the steep mountain wall and the divide between the Coyote and Quinlan mountains. The watering place was known to travelers in the 1850's. 11.0

The northern section of the Coyote Mountains is composed

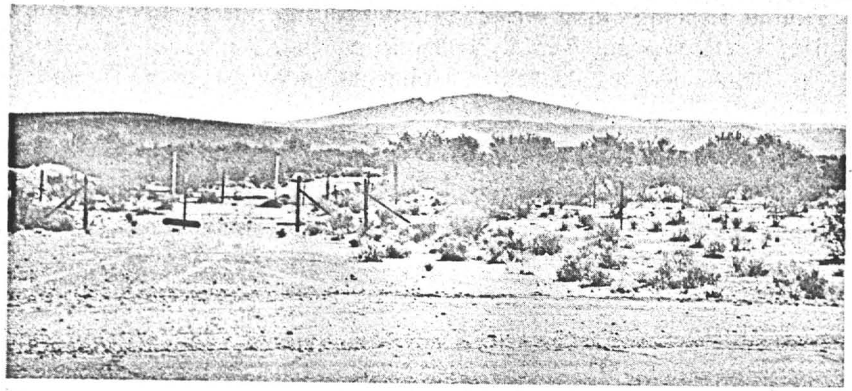


Plate 4. Looking east at the Batamote Mountains surmounted by the eroded Tertiary basaltic volcanic cone, one of the sources of the widespread volcanics of this area.

ing cattle until about 1919, when overgrazing denuded the available forage.

2.9

32.7 Bridge over Rio Cornez Wash, the main drainage to the northwest from the northern part of the Valley of the Ajo and from Childs Valley. 47.8

0.1

32.8 Border between Maricopa County to the north and Pima County to the south. The line of the Tucson, Cornelia, and Gila Bend Railroad veers to the northeast through Deadman Gap. The highway passes the western end of the Batamote Mountains which show a thick series of slightly dipping late Tertiary to early Quaternary basaltic volcanic beds. 47.7

1.0

33.8 The site of the Childs Ranch is to the east in the Rio Cornez Wash. Here the Batamote Well, named after a local, dense, green bush, encountered water at a relatively shallow depth in the veneer of alluvium covering volcanic bedrock. The well was an important watering place for travelers in earlier days. 46.7

1.3

35.1 Airport Road, to the east, leads to the Ajo Airport, the small settlement of Childs, and the shaft wells and pumping plant supplying the needs of the New Cornelia mining and metallurgical operations and the community at Ajo. 45.4

The Batamote Mountains to the east were a center of Tertiary-Quaternary volcanic activity. The dissected plateau of basaltic lavas and tuffs is surmounted by an eroded volcanic cone with a central intrusive plug. The original gentle slope of the volcanic beds has been modified by later warping, faulting, and erosion (Plate 4).

1.2

36.3 The road west leads to the facilities of the U.S. Air Force Ajo Station, part of which can be seen along the top of Childs Mountain. The latter is an eroded, asymetrical, faulted and tilted ridge of Tertiary-Quaternary basaltic flows and tuffs. The western ridge rises abruptly some 2,000 feet above the valley floor. The broad prong extending northeastward forms a dissected plateau. 44.2

The highway is passing over a gentle, north-sloping bajada extending out from the Little Ajo Mountains.

1.0

37.3 Southern boundary of the Luke Air Force Range, a military reservation in which public travel is restricted to the main highways and roads. 43.2

0.1

37.4 Bridge over a wash draining northward from the Little Ajo Mountains. 43.1

0.3

37.7 Northern edge of the city of Ajo. 42.8

3.0

40.7 The old site of Gibson, now a suburb of Ajo, is to the west. 39.8

1.4

42.1 Main Plaza of Ajo, an unincorporated city of about 7,000 inhabitants and the location of the open pit copper mine and metallurgical works of the New Cornelia Division of the Phelps Dodge Corporation. Elevation 1,750 feet. The name of the city may have originated from the Papago words "au auho" meaning paint since the Indians reportedly used the red iron-oxide over the copper deposit as a decorative paint, or it may have acquired the name from the Spanish word "ajo" meaning garlic since the ajo lily, having an edible onion-like root bulb, grows in the area. 38.4

The original settlement of Ajo was located on the site of the present open pit mine. Largely destroyed by fire in the early 1910's, when the New Cornelia Company was planning the pit operations, the company built a new town at the present site, which it proposed to call Cornelia. The latter name was not accepted and the older name "Ajo" persisted. However, objections to a company-controlled town led to the establishment of the privately owned settlements of Clarkstown (or Clarkston) to the east, and Gibson to the north. In these locations the house lots were rented and each of these settlements established independent water supplies from local wells or shafts. In 1917, the inhabitants of Clarkstown tried unsuccessfully to change the name to Woodrow after President Woodrow Wilson and eventually the Post Office in Clarkstown bore the name "Rowood," an inversion of Woodrow. That name subsequently was often used for the settle-

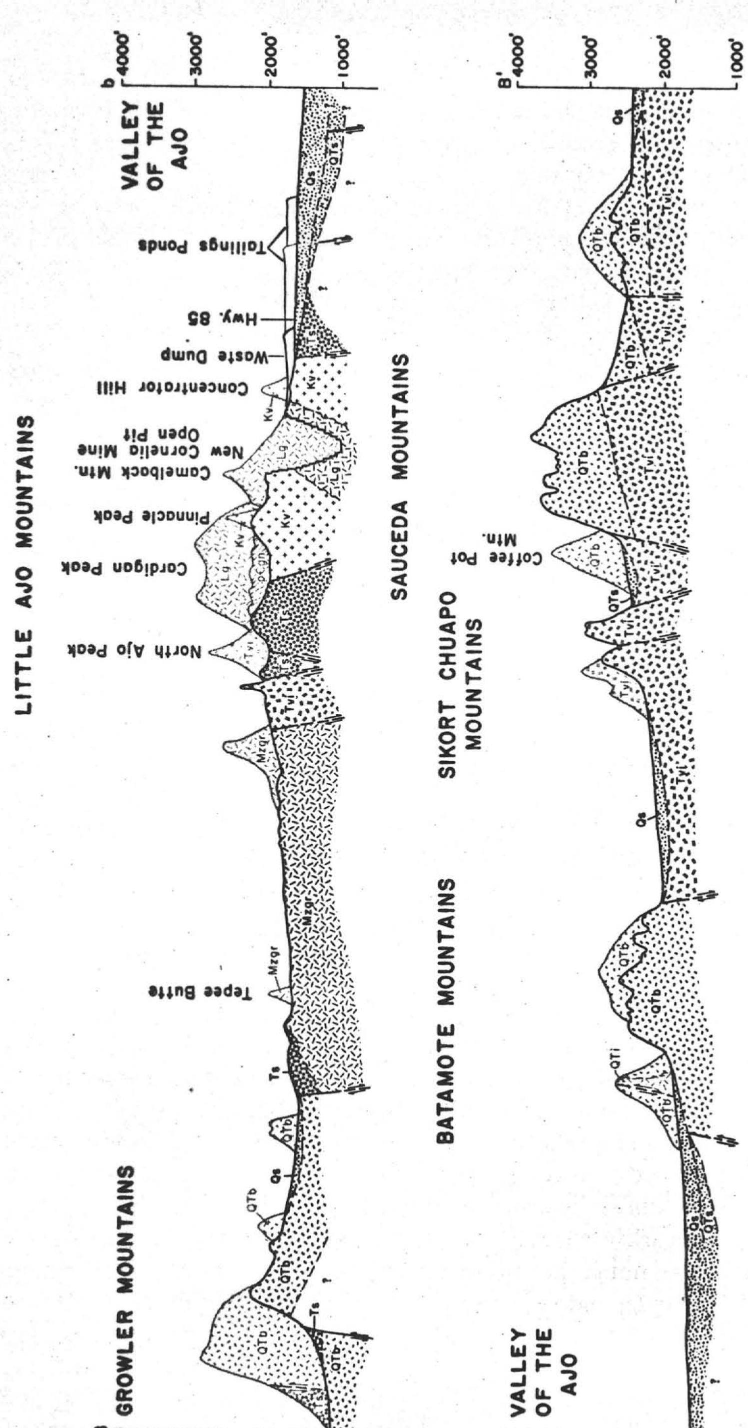


Figure 4. Generalized geologic cross-section B-B′.

ment. More recently a destructive fire and the encroachment of tailings ponds and waste dumps led to the abandonment of Clarkstown as a townsite. Gibson has survived and is now a northern suburb of Ajo.

The city lies on the eastern edge of the Little Ajo Mountains, a maturely dissected and geologically complex mountain mass formed from tilted fault blocks of Precambrian gneiss, Mesozoic intrusive rocks, Cretaceous volcanics and Laramide intrusives (Figure 4, Section B-B′). This complex was eroded and later largely covered by alluvial conglomerate and andesite breccia, flows, and tuffs. Subsequent erosion has produced the present rough topography. The copper orebody occurs mainly in the mineralized apex of a prong of Laramide quartz monzonite which intruded the earlier rocks. The mineralized area is roughly oval, with an elongated northward dimension of 1¼ miles and a width of ¾ of a mile. Disseminated bornite and chalcopyrite are the primary copper minerals but the deposit was oxidized and enriched by weathering to a considerable depth. The upper part, and first ore mined, contained chalcocite, malachite, and chrysocolla.

There is evidence that early Spanish prospectors tried to mine high grade native copper from the deposit as early as 1750. American interests did not try to mine the deposit until after the Gadsden Purchase of 1852 made the area a part of the United States. Early production consisted of a few high grade ore shipments in the 1850's, which were hauled by pack animals and teams to either Yuma, Arizona, or San Diego, California, for transport in sailing vessels to Swansea, in Wales, England, for smelting. Prior to 1911, numerous unsuccessful attempts to exploit the deposit were made. Difficulties with high transportation costs, lack of water, and unsound and sometimes fraudulent metallurgical schemes brought about repeated failures. Except for the brief periods during these activities the population of Ajo seldom exceeded 50 inhabitants.

In 1911, a favorable preliminary examination by the prominent geologist Ira Joralemon, aroused the interest of John C. Greenway, manager of The Calumet and Arizona Mining Company. This company acquired rights to a large part of the orebody and carried out a thorough exploration program and study of the deposit. Several million tons of copper ore were outlined by drilling, ample water was found in shaft wells sunk 7 miles north of Ajo at Childs, and an economical and practical leaching process for extracting the copper from the oxidized carbonate ore was developed. The transportation problem was solved by building a railroad line to Gila Bend. As a result, the New Cornelia Company started open pit mining and leaching of the ore in 1917; it was the first such operation in Arizona and the second in southwestern United States. Adjoining properties were acquired and the company become the single operator on the orebody. The car-

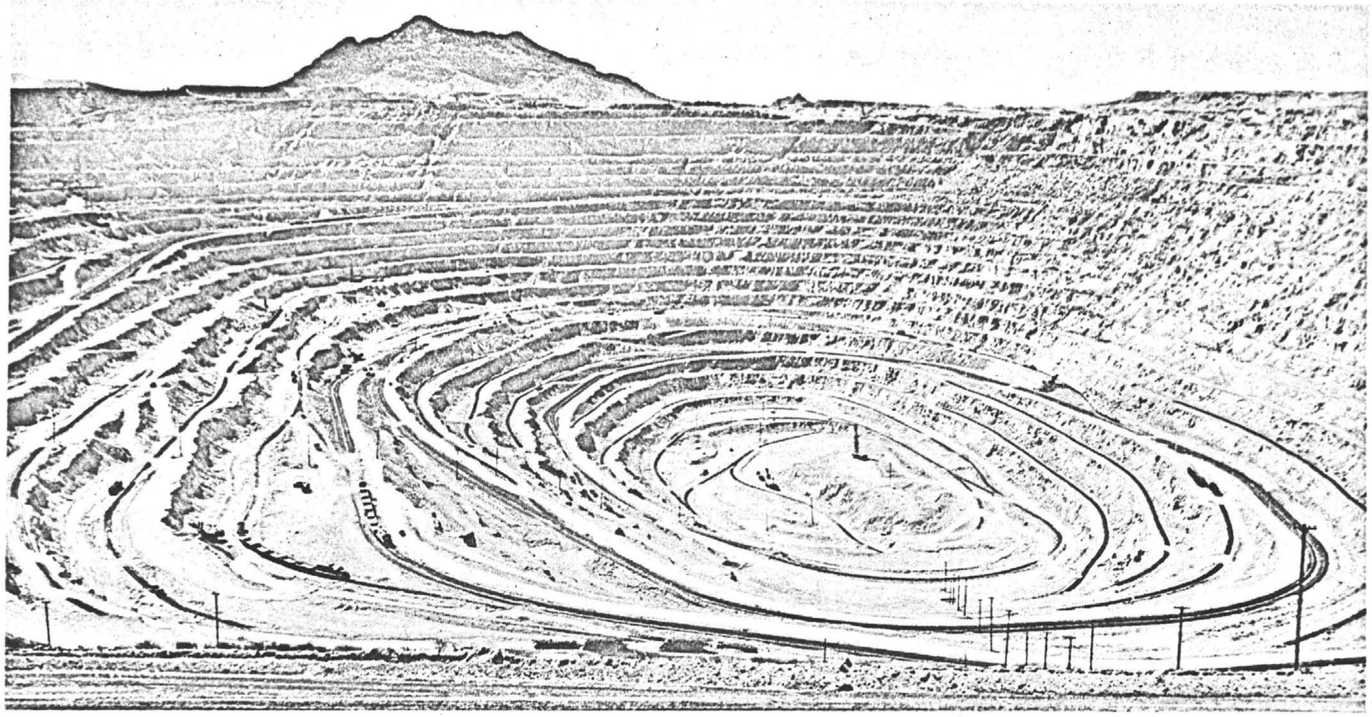


Plate 5. The open pit copper mine of the New Cornelia Division of the Phelps Dodge Corporation at Ajo, looking south from the visitor's view point. The central part of the pit is in mineralized, light-colored quartz-monzonite and quartz-diorite, the east and west walls in poorly mineralized Cretaceous rhyolite, and the south wall in darker, post-mineralized Tertiary conglomerate. The high peak to the south is Black Mountain, carved out of nearly horizontal basaltic flows of Tertiary age.

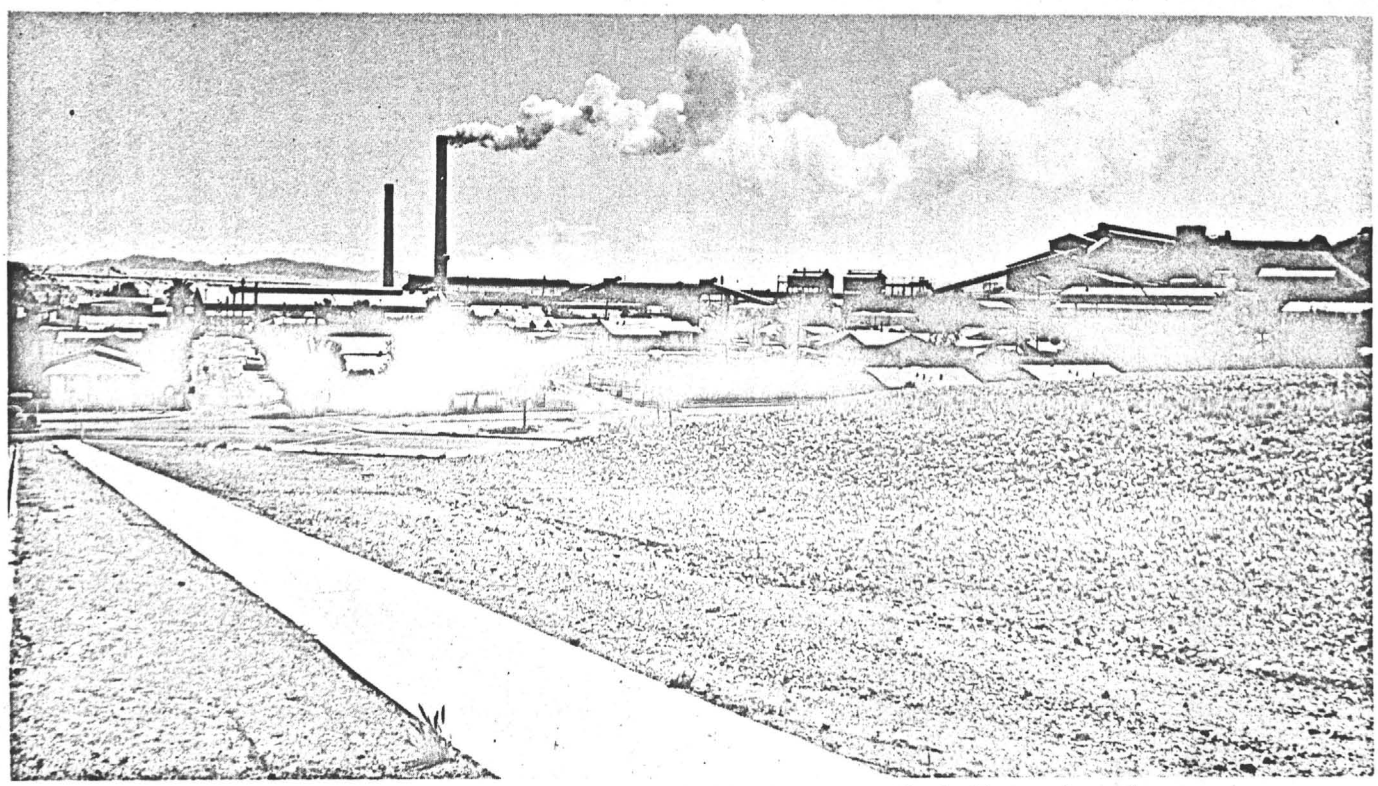


Plate 6. The New Cornelia Division metallurgical installations at Ajo, looking southeast from the road to the visitor's viewpoint. The flotation mill is to the right and the smelter, with tall stacks, is in the center.

bonate ore was mined out by 1930, but a flotation concentrator, originally built in 1924, was enlarged to permit continued operations on the deeper sulfide ore. The New Cornelia Company was acquired and made a division of the Phelps Dodge Corporation in 1931 and the present smelter was completed in 1950.

Production from Ajo has risen to over 15 million tons of ore per year with an average grade of about 0.7% copper (a content of 14 pounds of copper to one ton of ore). Nearly as much waste rock as ore has been removed. To date, over 337 million tons of ore containing more than 2.6 million pounds of copper (plus substantial amounts of by-product gold and silver) and some 374 million tons of waste have been mined from the pit, the bottom of which is now over 850 feet below the original surface.

Signs direct visitors to a viewpoint at the north end of the pit where the mining operation is described and can be observed (Plate 5).

0.1

42.2 Highway crosses railway tracks. **38.3**

0.1

42.3 Well Road, branching to the north, leads to Childs, the Ajo Airport, and the shaft wells and pumping station supplying the water needs of the New Cornelia Division and the city of Ajo. **38.2**

0.1

42.4 Road crosses tracks to slag dump where the melted waste from the smelter operation is discarded. **38.1**

To the southwest are the metallurgical installations of the New Cornelia Division of the Phelps Dodge Corporation. The smelter and high stack are in the foreground and the flotation concentrator behind them on the slope of Concentrator Hill (Plate 6).

To the east are the tailings ponds where the discarded, finely ground waste is deposited. The copper minerals have been separated out by flotation in cells containing reagents that attach themselves selectively to the sulfide particles and make them float.

0.3

42.7 Road passes under pipe line conveying the tailings from the New Cornelia concentrator to the tailings ponds. **37.8**

0.4

43.1 The remains of Clarkstown (Rowood) in a narrow pass between the tailings ponds to the north and the waste rock dumps to the south. **37.4**

1.5

44.6 Darby Well Road, leading west from the highway, was an old, hazardous route to Yuma by way of Bates Well, in Growler Pass, and was also the older route to Sonoita, in Mexico, to the south. Darby Well, about 2 miles out on this road, was a source of water sold by vendors to the residents of Ajo in the early 1900's. **35.9**

0.1

44.7 Bridge across Darby Arroyo which drains a large central part of the Little Ajo Mountains. **35.**

0.3

45.0 Highway Mileage Marker 45. Around the southern edge of the waste dumps, Ajo Peak and North Ajo Peak can be seen as tall separate spires at the southern edge of the Little Ajo Mountains. The somewhat lower Pinnacle Peak and behind it the more massive Cardigan Peak, the highest and largest of the group, are more to the north. The first three are carved by erosion out of tilted volcanic rocks and the last mainly from Laramide intrusive (Figure 4, Section B-B′). **35.**

2.6

47.6 Bridge over Rio Cornez, the ephemeral stream draining the northern part of the Valley of the Ajo. Elevation 1,626 feet. A few miles south of here is the drainage divide between the north to northwest trending Rio Cornez and the westward draining Cuerda de Lena. (Spanish for "cord of wood"). The Valley of the Ajo is a structural valley bounded by fault block mountains and filled to an unknown depth by alluvium surfaced by dissected, coalescing bajadas which slope gently outward from a sharp break at the base of the steep mountain walls. **32.**

To the west of the highway is Black Mountain, an erosional remnant ridge of the Quaternary-Tertiary basaltic volcanics that once covered a more extensive area. The terraced, horizontal banding is due to the difference in erosional resistance between flows and tuffs and the brown-black color tinged with red is typical of the oxidized and weathered surfaces of such volcanic exposures.

To the east of the highway are the Pozo Redondo Mountains, composed of Tertiary basaltic and andesitic lavas and tuffs that have been faulted and tilted westward into a series of north-south, elongated blocks. Erosion has carved the blocks into a broken collection of steep walled mesas and plateaus of varying elevations.

3.9

51.5 Cattle guard. **29.**

1.4

52.9 Junction with the west end of State Highway 86 at Why. The shape of this intersection gave the small settlement its name but it also has been commonly known as Rocky Point Junction since the highway south through Sonoita, Mexico, leads to Puerto Penasco or Rocky Point, a popular beach and fishing area on the Gulf of California. **27.**

0.3

53.2 Cut-off road from Highway 86 curves in from the east. **27.**

Pima Co.

STRATIGRAPHIC AND VOLCANIC GEOLOGY TUCSON MOUNTAINS

FIELD TRIP V

FOREWARD

In the Tucson Mountains (Pl. 1) are exposed rocks of various ages from older Precambrian to Recent. Yet the records of certain epochs, or even entire periods, are missing. On the two day field trip, No. V, we will be concerned with formations originating during the time interval older Precambrian to Lower Miocene.

The history of investigations and of suggested interpretations of the complicated geology is to be found in this book. Many problems of Tucson Mountain geology are still unsolved.

The purpose of this field trip is to acquaint visitors with some typical exposures at widely-spaced, selected localities and to provoke discussions.

FIRST DAY, SUNDAY, APRIL 14, 1968

Leaders: P. E. Damon, D. L. Bryant, and E. B. Mayo
Driving Distance: ca. 50.3 miles
Logged Distance: ca. 48.3 miles
Starting Time: 8:00 A.M.

GENERAL STATEMENT

On the first day of Trip V the route is from the University via Speedway to the Tucson freeway, thence right (northwest) via the freeway along the axis of the Santa Cruz valley to Avra Valley road, then left (westward) to the northern tip of the range (STOP 1). The route then follows southwestward to the Arizona Portland Cement Company's paved road to their quarry (STOP 2) at the Twin Peaks (Picachos de Calera) on the western side of the range. From Stop 2 the route is first westward on Twin Peaks road, then southward on Sandario road to Picture Rocks road, which leads eastward to Cam-Boh picnic area (STOP 3). From this place the way is generally eastward via Picture Rocks road to STOP 4, then over Contzen pass via Wade road and Cortaro road to the Tucson freeway and back to Speedway.

The rocks seen on this first day will be the Precambrian Pinal Schist, Cretaceous (?) granite, and the Paleozoic marine section (at STOP 2); Tertiary volcanic and sedimentary formations will be examined at STOPS 1 and 4, and a small exposure of Cretaceous quartz diorite will be seen near STOP 3. Part of the route traverses Mesozoic volcanic or intrusive rocks. Cretaceous sedimentary, volcanic and intrusive rocks will be seen from a distance, as will be something of the structure of the range.

Segmental Mileage	Cumulative Mileage	
0.0	0.0	Intersection, Park Avenue and Speedway, westward (WATCH FOR TRAFFIC LIGHTS). Central part of Tucson Mountains lies directly ahead. The formation in view is the Cat Mountain Rhyolite, dated by the K-Ar method at about 68 ± 2 m.y. According to the K-Ar chronology for the Cenozoic of Evernden et. al. (1964), this date represents an event occuring in Pre-Cenozoic (Maestrichtian) time and not early Cenozoic as once believed. This formation is essentially a sequence of quartz latite ash flow tuffs. Some of the sources are thought to lie along and just west of the crest of the range, from which the flows appear to have spread northeastward.
1.6	1.6	Intersection of Speedway with Tucson freeway TURN RIGHT (northwest) MERGE WITH CARE with freeway traffic. The high, rugged mountains to the right are the

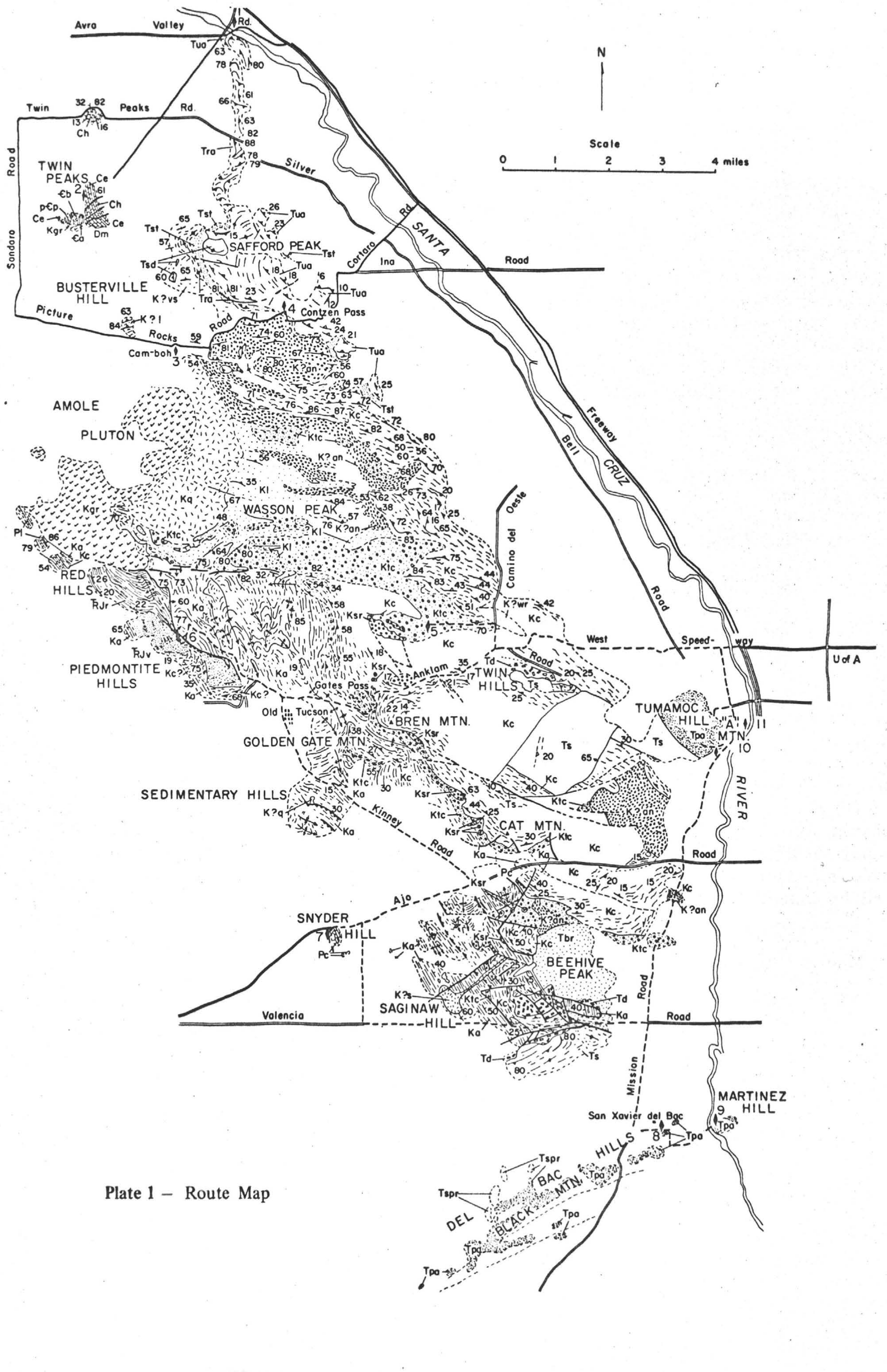
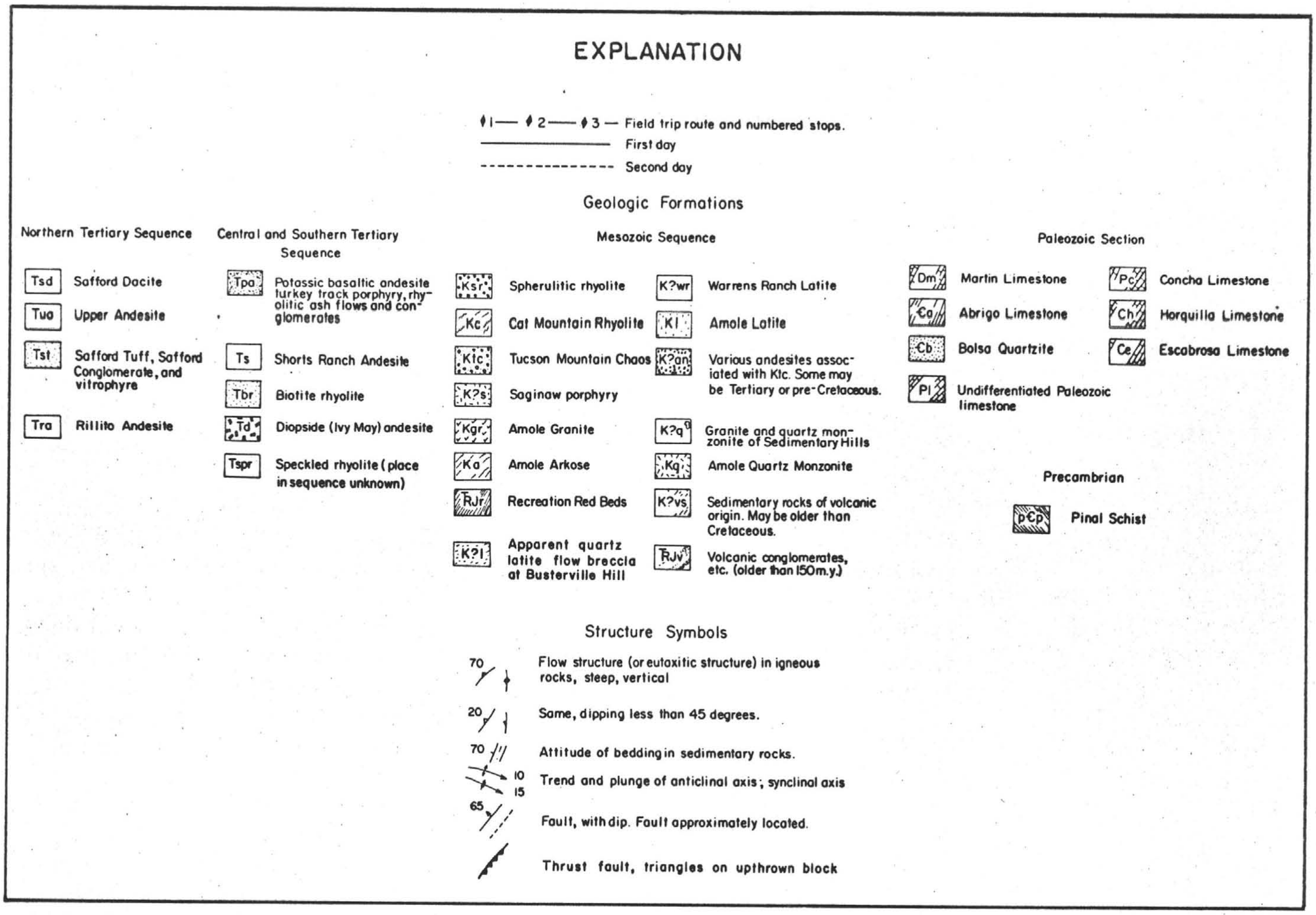


Plate 1 – Route Map



Santa Catalinas, a crystalline massif composed essentially of "old looking" gneisses of apparent Mid-Tertiary K-Ar cooling age (see paper by Damon, this book, for cross section and further details). This massif is intruded by coarse-granitic rocks which have cooled with the gneiss. The dome-like summit (Mt. Lemmon, 9,150 feet) is about 7,000 feet above the Santa Cruz River, which "flows" (when it runs) to the left of the freeway. Left (west) of the Santa Catalina Mountains and separated from them by a broad low gap, are the more subdued Tortillita Mountains, also a crystalline massif. The cooling age of these crystalline rocks is also mid-Tertiary.

Along the horizon to the left (southwest) extend the Tucson Mountains. Their lower slopes, below the Cat Mountain Rhyolite, consist of a chaotic mixture of Cretaceous Amole Arkose, intrusive andesite of unknown age, pre-Cretaceous Recreation Red Beds and volcanics, Paleozoic (mostly Permian) limestone and quartzite blocks, and even a very few blocks of older Precambrian Pinal Schist. This is the Tucson Mountain chaos of Kinnison (1959).

7.0 8.6 Wasson Peak, el. about 4,300 ft., highest point in the Tucson Mountains, at 9:00. The peak is composed of Cretaceous Amole Arkose, highly disturbed and intruded by irregular, generally east-west trending masses of Cretaceous (?) Amole Latite. In the general vicinity of Wasson Peak a broad, west-trending structural belt crosses and disrupts the usual northwest trend of structures in the range. In this transverse belt, as evidenced by the fact that Paleozoic limestone blocks can be found almost on the very summit of Wasson Peak, the Tucson Mountain chaos has been upheaved to a level much higher than that which it occupies farther south. In this part of the range the Cat Mountain Rhyolite is found only at low elevations in the eastern fringe of foothills.

5.3 13.9 Safford Peak, an east-west elongated dacite plug, at 9:00. The geology has changed greatly. Instead of Cretaceous or older rocks, this part of the mountains is composed of a Tertiary volcanic and sedimentary sequence. The Safford Dacite, which makes up the plug has yielded by K-Ar dating an apparent age of 24.5 ± 0.9 m.y. The slopes facing the party are composed of the Upper Andesite (apparent age, 27.9 ± 1.9 m.y.). To the right of Safford Peak a long, irregular dike of Rillito Andesite (apparent age 38.5 ± 1.3 m.y.) extends northward to the end of the range (Pl. 1).

In the distance, straight ahead, the tower-like peak is Picacho, an erosion remnant of a steeply-dipping volcanic sequence. To the right of Picacho are the Picacho Mountains, composed of crystalline gneisses.

2.2 16.1 SLOW, TURN RIGHT, off freeway to Avra Valley road. STOP. TURN LEFT onto Avra Valley road. STRAIGHT AHEAD and across bridge over the Santa Cruz river.

1.2 17.3 STOP NO. 1. Time: 15 minutes. Park on right shoulder. As already mentioned, the northernmost part of the Tucson Mountains is a huge north-trending dike of Rillito Andesite. Apparently molded around the northern tip of this dike is a hill composed of Upper Andesite. The roadcut at this place exposes a steep contact between Upper Andesite and older, mostly fragmental, rocks of volcanic origin.

0.1 17.4 Intersection with Arizona Portland Cement Company's road. TURN LEFT. The Twin Peaks (Picachos de Calera) with extensive quarries of the left-hand peak, are straight ahead. Permission to use this road, and access to the Paleozoic section (Pl. 1), has been granted through the courtesy of the Arizona Portland Cement Company.

1.9 19.3 Intersection with Twin Peaks road. STRAIGHT AHEAD. (Route into quarry and STOP 2 and return to Twin Peaks road has not been included in log.)

Intersection with Twin Peaks road. TURN LEFT (West).

1.2 20.5 Limestone hill on left in which according to Brown (1939, p. 712) Pennsylvanian strata are thrust onto Permian. As the road swings around the hill and heads west again, the tailings dump of ASARCO's open pit copper mine at Silver Bell comes into view almost straight ahead. To the right of the dump are the Silver Bell Mountains; to the left the Waterman Mountains.

1.6 22.1 Intersection with Sandario road. STOP. TURN LEFT (South). On the left (east) the Twin Peaks are in view, and beyond them the dacite crags of Safford Peak. Wasson Peak is in view at about 10:30. Straight ahead in the far distance are the Sierrita Mountains, composed of Precambrian granitic rocks as well as some much younger ones. At about 1:30 the sharp peak is Baboquivari, a porphyry plug. Farther to the right are the Coyote and Quinlan Mountains, with the white domes of the astronomical observatories visible on Kitt Peak, in the Quinlans. These mountains are composed of Teritary granitic rocks intrusive into probable Paleozoic strata. To the right of the Coyote and Quinlan Mountains, and connecting them with the Waterman Range, are the low, volcanic Roskruge Mountains. At 3:00 on the lower slopes of the Roskruge Mountains is what appears to be a basalt flow.

This is, in fact, the Recortado ash flow, dated radiometrically at 13 ± 1 m.y. by both the K-Ar and Rb-Sr methods.

4.0 26.1 Intersection with Picture Rocks road. TURN LEFT (East). This road passes through a thin stand of sahuaro, or giant cactus, palo verde (the bush with green branches), cholla (gray with spines), creosote bush, mesquite, and other desert shrubs.

2.3 28.4 Busterville hill on left, is composed of apparent quartz latite flow breccia, somewhat schistose, striking slightly north of east and dipping steeply northward. This hill is a projecting knob of the Mesozoic "basement" on the eroded surface of which the northern Tertiary sequence was deposited.

0.9 29.3 Boundary, Sahuaro National Monument. Just beyond this sign, TURN RIGHT.

0.1 29.4 **STOP NO.** 3. – LUNCH STOP. Time: 1 hour, 15 minutes. Cam-boh picnic area. Before leaving this place the party will observe, in a nearby wash a small exposure of the Amole Quartz Monzonite (K-Ar date, 72.9 m.y.). The hills and mountains to the south are exposures of the composite Amole pluton, which is composed of quartz monzonite, or quartz diorite, and granite. The northern contact of this pluton is concealed, but it seems to lie very near the picnic area. Exit from picnic area, TURN RIGHT (East).

0.8 30.2 STOP. Intersection with Kinney road. TURN LEFT. Ahead are the crags of Safford Peak (Safford Dacite neck) which intrudes the following sequence:

1. Steeply-dipping Cretaceous (?) sedimentary and volcanic rocks, truncated by a gently-dipping angular unconformity.

2. Resting on the unconformity, the Safford Conglomerate. Parts of this conglomerate, which is mostly of volcanic origin, appear to have been stream-transported; other parts resemble slope debris and show little evidence of water-handling. The thickness varies from 75 to 500 feet.

3. The Rillito Andesite, a brownish-gray, porphyritic rock, with dense matrix. This andesite intrudes the lower part of the Safford Conglomerate as dikes, and overrides it as stubby flows. Deposition of the Safford Conglomerate continued after emplacement of the Rillito Andesite. Conglomerate above the andesite contains clasts of the Rillito, whereas conglomerate below the andesite contains no Rillito clasts. The Rillito Andesite forms rocky ridges where it is intrusive; the lower tier of cliffs ahead are made up of flows of this andesite. Thickness unknown.

4. Overlying Safford Conglomerate and Rillito Andesite is the Safford Tuff, a pale yellowish-gray, porous, rather weakly-consolidated slope-former, situated between the lower and the upper tier of cliffs. The tuff varies in thickness from 20 to 100 feet, according to Imswiler (1959). There is a layer of black vitrophyre, averaging some 20 to 40 feet in thickness, resting on the Safford tuff and the vitrophyre is overlain by a layer of unconsolidated white ash, varying from a few inches to perhaps 10 feet thick.

5. The Upper Andesite rests on the white ash and makes up the upper tier of cliffs. This andesite is a cocoa-colored, porphyritic rock with a porous matrix. Locally, it exhibits some of the features of an ash flow, but at many places it somewhat resembles a lava flow.

0.8	31.0	Bend in road. Safford Peak at 9:30, Wasson Peak at 2:00. Cliffs of Upper Andesite ahead. Road traverses dark outcrops of Cretaceous (?) andesites.
1.0	32.0	**STOP 4.** Time: 2 hours, 30 minutes. The party will walk up a trail to see exposures of Safford Conglomerate, vitrophyre and Rillito Andesite, then return to stopping place and walk down a wash to see some structures in the Upper Andesite.
0.3	32.3	Contzen Pass. Begin descent. Note outcrops of vitrophyre in road cut on right.
0.6	32.9	Picture Rocks Retreat on right.
1.0	33.9	Ina Road. STOP. TURN RIGHT.
0.4	34.3	Cortaro Road. TURN LEFT.
1.3	35.6	Cross Santa Cruz River.
0.5	36.1	Freeway. STOP. TURN RIGHT onto paved road parallel with freeway.
1.8	37.9	Ina Road STOP. TURN LEFT, THEN RIGHT onto freeway. MERGE WITH CARE into traffic.
8.7	46.6	West Speedway, exit. TURN RIGHT off freeway.
0.1	46.7	TRAFFIC LIGHT. TURN LEFT onto Speedway. 1.6 miles to University.

END OF FIRST DAY

SECOND DAY, MONDAY, APRIL 15, 1968

Leaders: E. B. Mayo, P. E. Damon, and D. L. Bryant
Driving Distance: 59.7 Miles
Logged Distance: 59.7 Miles
Starting Time: 8:00 A.M.

GENERAL STATEMENT

On the second day of Trip V, the route is from the university via Speedway and Anklam Road to Camino del Oeste, then right (North) to Trails' End Road and left to STOP 5 on Trails' End Wash. Return will be made to Anklam Road, then right over Gate's Pass and via Sahuaro Road to Kinney Road, then northwestward to Juan Santa Cruz picnic area at the northern end of the Piedmontite Hills, (STOP 6). The party will then travel southeastward over Kinney Road to Ajo Road, then westward to Snyder Hill, STOP 7. The route is then east, over the southern Tucson Mountains to Mission San Xavier del Bac; STOP 8, and Martinez Hill; STOP 9. Finally, the party will travel northward on Mission Road, to STOPS 10 and 11 on "A" Mountain.

The first objective of the second day of this field trip is to see something of the nature of the Tucson Mountain chaos and the Cat Mountain Rhyolite. Next a visit will be made to the locality of a 150 m.y. K-Ar date that removes some of the Mesozoic sequence from the Cretaceous, where it has reposed for nearly 30 years, and transfers it to the Jurassic, or perhaps the Triassic. A Permian exposure will then be visited, (Pl. 1) a brief review will be made to the Tertiary volcanic sequence in the southern Tucson Mountains and some exposures will be examined of the Lower Miocene potassic basaltic andesites. (Pl. 1).

Segmental Mileage	Cumulative Mileage	
0.0	0.0	Intersection, Park Avenue and Speedway. WATCH FOR TRAFFIC LIGHTS. STRAIGHT AHEAD (West) on Speedway.
1.6	1.6	Tucson Freeway. STRAIGHT AHEAD.
0.2	1.8	Cross Santa Cruz River.
0.3	2.1	Junction with Grande Avenue. STRAIGHT AHEAD. On left at 9:00 to 9:30 are the dark forms of Tumamoc Hill and "A" Mountain composed essentially of Lower Miocene potassic basaltic andesite (doreite) tilted gently southwestward.
0.8	2.9	Silver Bell Road. STOP. STRAIGHT AHEAD.
0.3	3.2	Curve. Cat Mountain, type locality of the Cat Mountain Rhyolite, at 10:15. Golden Gate Mountain and Bren Mountain at 11:00 to 11:30. These peaks, and most of the slopes facing the observer, are composed of Cat Mountain Rhyolite. The abrupt, rugged Twin Hills, in front of Golden Gate and Bren Mountains, are made up of Lower Eocene or Paleocene Shorts Ranch Andesite, with some diopside (Ivy May) andesite at their base (Kinnison, 1959).
2.4	5.6	Twin Hills at 9:00.
0.4	6.0	Junction with Anklam Road. STRAIGHT AHEAD.
0.5	6.5	Anklam Road curves left. KEEP STRAIGHT AHEAD.
0.1	6.6	Camino del Oeste. STOP. TURN RIGHT.

0.4	7.0	Trails' End Road. TURN LEFT. Just north of this turn, road cuts on Camino del Oeste expose the Cretaceous (?) Warren's Ranch Latite sill (Brown, 1939). This sill seems to be genetically related to an east-west swarm of quartz latite porphyry dikes named by Brown the Silver Lily dikes.
0.9	7.9	Limestone block on right, apparently embedded in Cretaceous (?) andesite. Other, probably Permian limestone blocks can be made out at the base of Cat Mountain Rhyolite cliffs at 12:00.
0.4	8.3	STOP 5. Time: 2 hours, park on north side of road. The party will see, in the near-by Trails' End Wash and on slopes to the northwest, some aspects of the Tucson Mountain chaos and of its relation to the Cat Mountain Rhyolite. Some Silver Lily dikes and an intrusion of spherulitic rhyolite will also be seen.
0.3	8.6	Turn around at Sahuaro School, return to Camino del Oeste.
1.4	10.0	Camino del Oeste. STOP. TURN RIGHT.
0.5	10.5	Anklam Road. STOP. TURN RIGHT.
1.8	12.3	The pale gray knobs to the right of the road are the spherulitic rhyolite of Brown (1939). According to Bikerman (1962) this rhyolite was the final, gas-poor remnant of the Cat Mountain magma, which rose sluggishly along the most favorable channels after the ash flow eruptions. High, jointed cliffs on both sides of road are welded ash flows. (Cat Mt. Rhyolite).
0.9	13.2	Gates Pass. SLOW. Road cuts in the pass expose a large block of Amole Arkose with almost vertical bedding, sandwiched between steeply-dipping masses of Cat Mountain Rhyolite. Beyond the pass, the cuts of the descending road expose some of the Tucson Mountain chaos. The structure of Bren Mountain, on the left, seems to be an inward-dipping funnel of Cat Mountain Rhyolite, breached on the north-east, and enclosed on the southwest by a partial collar of Tucson Mountain chaos, (P. A. Geiser, 1964). The chaos is in turn enclosed by a partial, inward-dipping collar of Amole Arkose.
		Amole Arkose dips almost everywhere, funnel-like, into Golden Gate Mountain on the right. This mountain, again, is enclosed on the southwest by a partial collar of Tucson Mountain chaos (Assadi, 1964). Details of the structure of the Cat Mountain Rhyolite on Golden Gate Mountain are still unknown.
0.4	13.6	Curve.
2.0	15.6	Old Tucson, famous movie location, on left.
0.1	15.7	Kinney Road. STOP. TURN RIGHT.
0.4	16.1	Junction with McCain Loop Road. KEEP STRAIGHT AHEAD. CAUTION, abrupt dips and sharp curves. On the left are the Piedmontite Hills, composed of andesitic conglomerates, sandstones and breccias, together with minor remnants of Recreation Red Beds, intruded by rhyolitic ignimbrite that is possibly equivalent to the Cat Mountain Rhyolite. On the right is the Eastern Rampart (Mayo, 1966) composed of Cat Mountain Rhyolite, and bordered discontinuously by a narrow zone of Tucson Mountain chaos. The hills in mid-distance, from 12:00 to 3:00, are composed of Amole Arkose, traversed by an east-west swarm of Silver Lily dikes. Amole Arkose is exposed on both sides of the road.

Figure 1 – Tucson Mountains viewed from the north. Safford Peak near the east end of the long east-trending ridge in upper third of photograph. Wasson Peak is flat topped ridge on skyline. –Photograph by Tad Nichols

The road passes over a low divide, and the buildings of the Arizona-Sonora Desert Museum come into view ahead. Beyond the museum are the maroon-colored Red Hills, composed of Recreation Red Beds. To the right of the Red Hills, the rugged, pale-colored mountain is made of Amole Granite (apparent age 71.4 ± 3.3 m.y).

1.9	18.0	TURN SHARPLY LEFT, WITH CARE, in front of caretaker's house onto road to Juan Santa Cruz picnic area.
0.3	18.3	Juan Santa Cruz. **STOP 6.** Time: one hour, 45 minutes, including time for lunch. The party will descend the wash to see exposures of the Museum porphyry, recently dated at approximately 150 m.y. The porphyry intrudes the Recreation Red Beds, which therefore must be older than 150 m.y., and cannot be Cretaceous, as has been thought since 1920. The possibility is now open that the Red Beds and associated volcanic conglomerates might be Triassic.
		After lunch, return to Kinney Road.
0.4	18.7	Kinney Road. STOP. TURN RIGHT.
1.8	20.5	Junction with McCain Loop Road. KEEP STRAIGHT AHEAD.
0.7	21.2	Junction with Sahuaro Road. KEEP RIGHT.

0.2	21.4	Old Tucson on left. Golden Gate Mountain at approximately 10:00; Sedimentary Hills at 12:00. The hills are of Amole Arkose, intruded by a small stock of quartz monzonite (the biscuit-shaped knob just to the right of 12:00).
1.9	23.3	Summit of pass between Golden Gate Mountain and the Sedimentary Hills. Cat Mountain comes into view at about 11:00 and to the right of it the isolated peaks of the southern part of the range. On the left is a line of cliffs of Cat Mountain Rhyolite.
1.6	24.9	Tucson Estates trailer village on left.
1.7	26.6	Ajo Road. STOP. TURN RIGHT. In the distance, to the right of the road, are the Roskruge Mountains. To the left are the Coyote and Quinlan Mountains, with the white observatory buildings visible on Kitt Peak. At about 11:00 is the high, tower-like peak of Baboquivari.
2.9	29.5	TURN LEFT onto dirt road on west side of Snyder Hill.
0.5	30.0	STOP 7. Time: 45 minutes. Snyder Hill is an exposure of Permian strata. Permian fossiles can be found in the weathered limestone. TURN AROUND.
0.5	30.5	Ajo Road. STOP. TURN RIGHT.
0.8	31.3	South Camino Verde. Dirt road. TURN RIGHT. (Note: In wet weather this road may be impassible, in which case it will be necessary to continue westward on Ajo Road to Ryan Field and to turn there onto Valencia Road (In this event, add 7.1 miles to the logged distance).
1.9	33.2	Valencia Road. STOP (no sign) TURN LEFT.
0.7	33.9	Black Mountain, composed of potassic basaltic andesite and turkey track porphyry at 2:00.

The Tertiary volcanic sequence in the southern Tucson Mountains is quite different from that in the northern part of the range. The southern sequence is as follows:

1. The diopside andesite of Brown (1939) called Ivy May andesite by Kinnison (1958), as yet not dated radiometrically, is considered, on field geological evidence, to be the oldest rock in the sequence.

2. The biotite rhyolite, apparently intrusive, has yielded a K-Ar age of 60.5 ± 1.8 m.y. Therefore, the rock appears to be Paleocene.

3. The Shorts Ranch Andesite furnished a K-Ar date of 56.8 ± 1.8 m.y.; so it appears to be Lower Eocene or Paleocene.

4. Turkey track porphyry from "A" Mountain was dated at 28.0 ± 2.6 m.y.; so the porphyry appears to be Oligocene in age.

5. Potassic basaltic andesite and rhyolitic tuff from "A" Mountain gave apparent ages of 27.0 ± 1.2 m.y. and 26.6 ± 0.9 m.y. respectively. These rocks also appear to be Oligocene in age.

In addition to the above, Leo Heindl (1959) mapped, on the northern slope of Black Mountain, exposures of a rock which he called the "speckled rhyolite."

0.9	34.8	Saginaw Hill, at 9:00 is a mineralized stock of Cretaceous (?) Saginaw porphyry (Kinnison, 1959). The stock intrudes steeply dipping Amole Arkose.
1.3	36.1	Summit, at 1:00 to 2:00 is Kinnison's (1959) Hill 14, made up of Shorts' Ranch Andesite, with diopside (Ivy May) andesite at the base. Outcrops along the road are Cat Mountain Rhyolite.
0.5	36.6	The rocky tower at 9:00 is Beehive Peak, a rhyolite plug, or swelling in a dike, situated in an area of intrusive biotite rhyolite. The rugged cliffs and crags in this general area are also made of biotite rhyolite.
2.1	38.7	Mission Road. TURN RIGHT.
1.9	40.6	TURN LEFT on road to San Xavier Mission.
0.7	41.3	San Xavier Mission, **STOP 8**. Time: 20 minutes. Visit mission and see turkey track porphyry. For section, map and discussion of the geology of the San Xavier District see accompanying paper by J. K. Percious.
		From here, TURN RIGHT on dirt road to Sahuarita Butte.
0.3	41.6	Intersection. TURN LEFT.
0.8	42.4	Road crosses bridge over Santa Cruz River.
0.1	42.5	**STOP 9**. Time: 20 minutes. Short climb to road cut in Sahuarita Butte on new highway. At this point we will see a section of potassic basaltic andesite. Mrs. Percious will discuss the geology of road cut and San Xavier District (road is under construction and so it may be necessary to make changes in the way at this point). Return to Mission Road.
1.9	44.4	Mission Road. STOP. TURN RIGHT.
1.9	46.3	Mission Road crosses Valencia Road. STRAIGHT AHEAD on Mission Road.
2.5	48.8	Road cut. According to Kinnison (1959) the rock at this place is Cretaceous (?) andesite overlain by remnant patches of Cat Mountain Rhyolite.
0.8	49.6	Ajo Road. STOP. STRAIGHT AHEAD. Quarry at 9:00 is in disturbed tuffaceous sediments surrounding what may be a pipe of Shorts' Ranch Andesite.
1.7	51.3	Road forks. TURN LEFT.
1.0	52.3	Exposures of potassic basaltic andesite and turkey track porphyry at base of "A" Mountain.
0.7	53.0	Congress Street, TRAFFIC LIGHT, TURN LEFT. Follow signs to top of "A" Mountain.
1.5	54.5	**STOP 10**. Time: 20 minutes, beside road on ascent to summit of "A" Mountain (Sentinel Peak). At this point, we will obtain a panoramic view of the southern Tucson Mountains and have the opportunity to see the mid-Tertiary volcanic sequence (potassic basaltic andesite, colluvial beds, airfall tuff and two ash flows). An idealized section of the southern Tucson Mountains is given in the accompanying paper by P. E. Damon.

0.4	54.9	**STOP 11.** At summit of "A" Mountain, Time: 10 minutes. Panoramic view of the city of Tucson in the Santa Cruz basin and surrounding ranges.
0.3	55.2	Outcrop on left repeats the stratigraphy observed at STOP 10.
1.1	56.3	STOP. TURN RIGHT.
0.3	56.6	GRANDE AVENUE. TRAFFIC LIGHT. TURN LEFT.
1.1	57.7	WEST SPEEDWAY. TRAFFIC LIGHT. TURN RIGHT. 2.0 miles to University.

END OF TRIP

HENRY EYRICH

THE EMPIRE MOUNTAINS, PIMA COUNTY, ARIZONA

F. W. Galbraith
University of Arizona

INTRODUCTION

The Empire Mountains occupy about 30 square miles in southeastern Pima County (fig. 48), and consist of two parallel ridges trending north-northeast. They are connected with the Santa Rita Mountains to the west by low rolling foothills and are separated from the Whetstone Mountains to the east by the broad floor of Cienaga Wash valley.

The Empire Mountains (fig. 23) are made up of marine limestone, shale, and quartzite of Cambrian, Devonian, Mississippian, Pennsylvanian, and Permian age, aggregating approximately 5,700 feet in thickness, and a series of Cretaceous (?) continental clastic deposits possibly 18,000 feet in thickness. The sedimentary rocks are intruded by stock-like bodies of quartz monzonite and granodiorite and by dikes ranging in composition from rhyolite to basalt.

The range has two structural parts - an underlying block of Cretaceous (?) rocks, and an overthrust block of Paleozoic and Cretaceous (?) rocks which is divided into four segments by northwesterly striking tear-faults. The thrust fault is exposed along the western edge of the mountains and dips to the east at a low angle. Within the overthrust block there are at least three separate imbricate thrust sheets. Domes, anticlines, and overturned folds have been formed in the Paleozoic rocks.

STRATIGRAPHIC UNITS

Bolsa (?) Quartzite

A small area of dense, glassy quartzite is exposed between the Pantano Hill stock and the Abrigo formation in the northern part of the range. Although the exposure is only a few feet in thickness, it is considered to be Bolsa quartzite because it is similar in appearance to typical Bolsa quartzite and lies conformably below the Abrigo formation.

Upper Cambrian Abrigo Formation

The Abrigo formation consists of soft, light gray to blue layers of limestone, alternating with thin beds of green shale, light gray sandstone, and brown to black chert. Beds are generally from one-half to three inches thick, lenticular, and their exposures have a characteristic mottled appearance. In some places the top of the formation is marked by a 5 to 6 foot bed of pure white quartzite. Maximum exposed thickness is 750 feet.

Upper Devonian Martin Limestone

The Martin limestone is composed of finely crystalline limestone, gray and moderately thick-bedded at the base, and thinner-bedded and less resistant to erosion toward the top. The top of the formation in the northern part of the range is marked by a horizon composed largely of Cladopora prolifica. In the southern part of the range a zone of soft, shaly beds has been interpreted as the top of the Devonian section. Metamorphism has transformed large masses of the lower limestones into

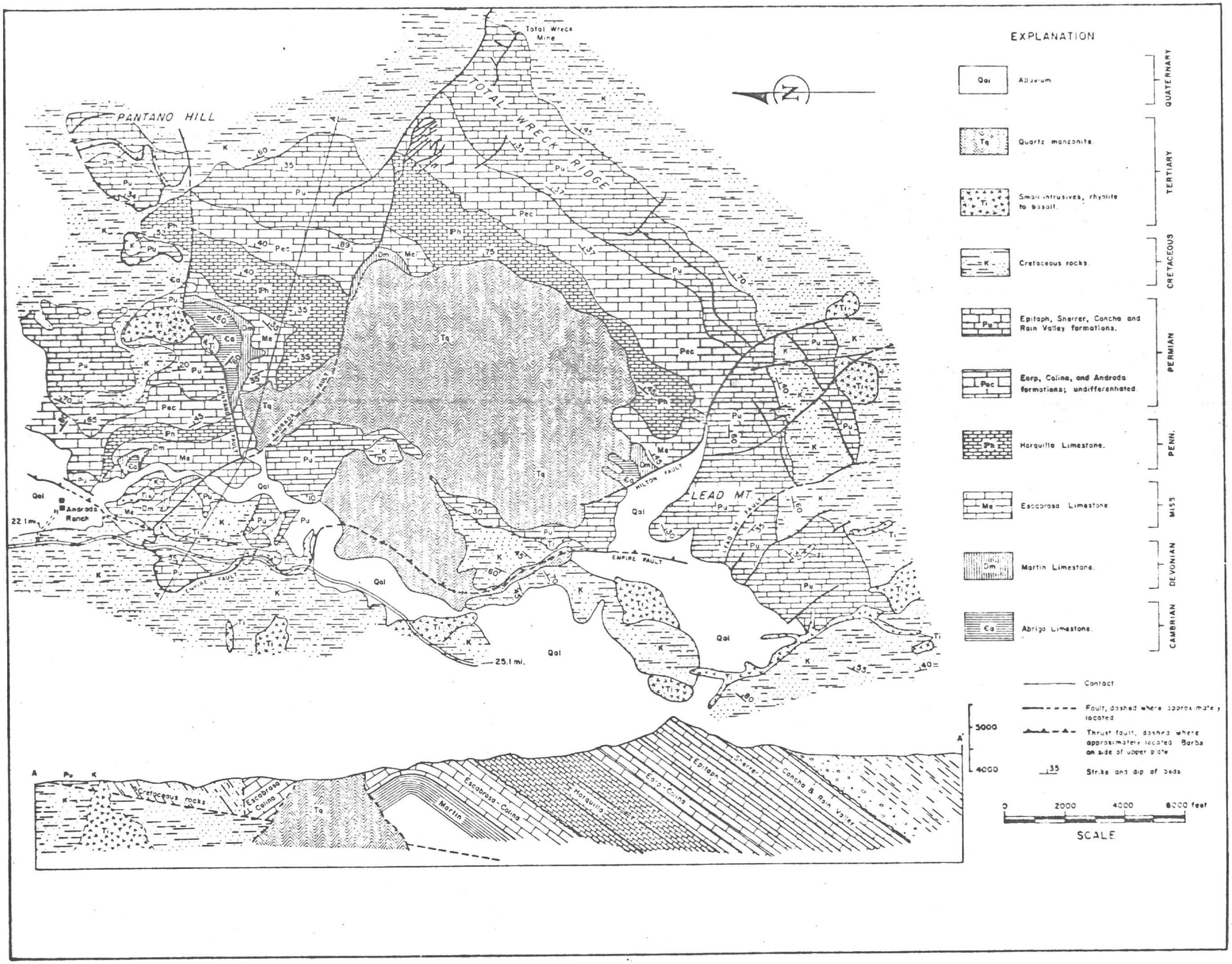


FIGURE 23. Generalized geologic map and cross section of the Empire Mountains, Cochise County, Arizona.

sparkling, sugary to coarsely crystalline marble. The thickness ranges from about 300 feet in the southern part to about 100 feet in the northern part of the range.

Lower Mississippian Escabrosa Limestone

The Escabrosa limestone is exposed almost continuously throughout the length of the range, but is unusual in that it is not a cliff-former in this area. The Escabrosa consists of light gray to blue, fine-grained limestone beds one to two feet thick. Metamorphism has changed much of the formation to white, coarsely-crystalline marble; which closely resembles the marbleized limestone in the Martin, and makes difficult the separation of Mississippian and Devonian limestones where the Cladopora prolifica horizon is not present. The Escabrosa ranges in thickness from 200 to 600 feet, thickening from south to north.

Pennsylvanian Horquilla Formation

A disconformity, marked in places by a thin bed of conglomerate separates the Horquilla from the underlying Escabrosa. The Horquilla generally consists of massive, blue-gray limestone alternating with soft calcareous shale. Individual beds are from 10 to 100 feet thick. Limestone beds are thicker than shale beds and stand out on weathered slopes, giving a coarsely banded appearance to the formation as a whole. In the northeastern part of the Empires, however, the lower part of the Horquilla formation consists of alternating limestone and quartzite beds, and shale predominates in the upper part. The limestone beds are one to three feet thick, fine grained, dark blue, and contain irregular chert inclusions. The quartzite beds are light gray or white on fresh surfaces and weather to buff.

Metamorphism has obliterated the bedding and blue-gray color of the limestone beds and changed the shale to hard, resistant, hornfels-like masses. The Horquilla is nearly 1, 200 feet thick in the central part of the range but thins northward to approximately 500 feet.

Pennsylvanian and Permian Andrada Formation

The Earp and Colina formations defined by Gilluly, Cooper, and Williams (1954), cannot be recognized in the Empire Mountains, and the term Andrada formation has been used by Wilson, E. D. (1951), Bryant (1955), and others for the undifferentiated equivalent beds. In the Empire Mountains the Andrada formation consists mainly of soft shale and marl, with some dense, dark blue-gray limestone from 10 to 200 feet thick, and, in the upper part, three beds of gypsum from 5 to 50 feet thick.

Many beds of the Andrada formation exhibit a complete change in lithologic character within a few hundred feet along strike. The formation as a whole is soft, and erosion has carved the main north-south wash from these unresistant beds.

Locally, metamorphism along intrusive contacts has converted part of the Andrada formation to a fissile, light gray, sericite schist which resembles the Precambrian Pinal schist. Where the formation lies at greater distances from intrusive bodies, the limestone has been marbleized, and the shale has been indurated or silicified to hornfels-like masses which closely resemble the metamorphosed Horquilla.

The Andrada formation ranges in thickness from 300 to 1,500 feet. It is thickest in the central part of the range and thins to the north.

Permian Epitaph, Scherrer, Concha, and "Rainvalley" Formations

The undifferentiated Epitaph, Scherrer, Concha, and "Rainvalley" formations, from 1,250 to 2,250 feet in thickness, are the most prominent rocks in the Empire Mountains. They form the crests of the highest ridges and their western slopes are usually sheer cliffs that are visible for miles. Although these formations, defined by Gilluly, Cooper, and Williams (1954), can be readily recognized, they have been mapped as a unit.

The Epitaph consists of a series of thick, massive, fetid limestone beds 90 to 300 feet thick and forms the prominent westward facing cliffs along the higher parts of the range. The Scherrer formation is made up of two gray, vitreous, orthoquartzite members separated by a massive, blue, dolomitic limestone which usually contains irregular masses of silicious material. The lower quartzite member ranges in thickness from 90 to nearly 800 feet; the middle dolomitic limestone member is from 30 to 150 feet thick; and the upper quartzite member is from 30 to 250 feet thick. The thicknesses are greater in the southern part of the range, but the great change over relatively short distances is believed to be due to unrecognized low angle thrust faulting. The Concha and "Rainvalley" formations make up an unbroken series of limestone beds above the Scherrer, and form the eastern slopes of the highest ridges. The Concha maintains a thickness of about 500 to 600 feet and consists of dark gray to blue limestone beds which are thick, massive, and fetid, and contain abundant chert nodules in many places. The "Rainvalley" consists of light gray dolomitic limestone which is thinner bedded than the Concha, and a few thin beds of brown to buff quartzite.

Cretaceous (?) Beds

Cretaceous (?) rocks are divided into two major units, those on the east and those on the west sides of the thrust fault. The lack of fossils and marker beds prevents correlation across the thrust. The strata on the west side of the fault are further subdivided into a northern and southern series, separated by a high-angle fault. These strata are considered to be of probable Cretaceous age, because of their lithologic similarity to rocks in the Santa Rita Mountains (Schrader, 1915; Stoyanow, 1949).

On the east side of the Empire Mountains a series of conglomerate, shale, sandstone, and limestone beds lies unconformably upon a deeply eroded surface cut on Paleozoic rocks. The differences in dip between the Cretaceous (?) and Paleozoic strata are slight, but the differences in trend are clearly visible on aerial photographs. The lower part of the series consists predominantly of sandy maroon shale containing one or more beds of conglomerate composed of pebbles, cobbles, and boulders of Paleozoic limestone. In places conglomerate rests directly upon the eroded surface of the "Rainvalley" or older formations, and elsewhere the lowest bed of conglomerate lies upon 400 feet of maroon Cretaceous (?) shale. The maroon shale series grades upward into coarse gray arkosic sandstone and predominantly gray shale with occasional thin beds of limestone which are either extremely shaly or black and fetid. These Cretaceous (?) beds dip southeast from 20 to 30 degrees and are about 8,700 feet thick. The alluvium of Cienega Wash valley covers them to the east.

On the western side of the range, below the thrust plane of the Empire fault, the Cretaceous (?) beds consist of a northern and southern series separated by a high angle fault. The northern series is made up of coarse gray to brown arkosic sandstone, greenish-gray shale, and occasional lenticular limestone beds which are extremely thin-bedded and either light gray or jet black and fetid. Lithologically these beds are similar to those which lie above the maroon shales on the eastern flank of the mountains and may be either their equivalent, or represent the beds now concealed beneath the alluvium of Cienega Wash valley.

The southern series of Cretaceous (?) beds west of the thrust is made up of thick boulder conglomerate alternating with felsic lava flows and tuffs. Their relationship to the other Cretaceous (?) strata is not known, but they are presumably younger than the arkosic sandstone and shale, because they contain numerous fragments of arkosic rocks which appear to be identical with those exposed to the north. This series may be in part as young as Tertiary in age.

The structural and stratigraphic relationships of the Cretaceous rocks between the Empire and Santa Rita Mountains are complex, and it has not yet been possible to establish a continuous sequence between these two ranges. Near the crest of the Santa Ritas, the maroon shale and limestone conglomerate series lies unconformably on the Paleozoic rocks and dips eastward, and an arkosic sandstone and shale series is present. The total thickness of Cretaceous rocks between the Santa Rita Mountains and the western margin of the Paleozoic section in the Empire thrust block may be about 18,000 feet, but the possibility of duplication by folding or faulting cannot be disregarded.

INTRUSIVE ROCKS

The central part of the Empire Mountains is occupied by the Sycamore quartz-monzonite which extends for about two miles along the trend of the range as a roughly elliptical body less than one mile wide. On the western side of the mountains it is in contact with the Cretaceous (?) beds of the basement block; along the remainder of its border it rests against the Paleozoic rocks of the overthrust block. The quartz-monzonite is light gray and medium to coarse grained.

Small bodies of granodiorite, rhyolite porphyry, rhyolite, and diorite porphyry are exposed near the Sycamore stock, and small dikes of aplite, syenite, trachyte, rhyolite, diorite, andesite, and basalt occur throughout the Empire Mountains.

STRUCTURE

The Empire Mountains are divided into two structural parts, a basement block of Cretaceous (?) rocks, in part folded into a series of broad anticlines and synclines with east-west axes, and in part dipping steeply to the east; and an overthrust block of Paleozoic and Cretaceous (?) strata which dip eastward at about 45 degrees. East-west and north-south faults have added to the structural complexity of the range.

Basement Block

The basement block is exposed in and forms the foothills between the Empire and Santa Rita ranges. It is divided by a high-angle, northwest-southeast fault into two distinct parts. The northern part consists of Cretaceous (?) arkosic sandstones and shales, and the southern part consists of Cretaceous (?) boulder-conglomerate and volcanic flows and clastic rocks. The rocks of the northern series have been folded into broad anticlines and synclines with east-west axes striking nearly at right angles to strata above the thrust. The amplitude of the folds is greater than 2,000 feet and the dip of the beds on the flanks range from 40 to 60 degrees. The conglomerate and volcanic strata of the southern series dip from 65 to 80 degrees to the east. Along a large part of its length the fault which separates the two series is occupied by a dike of rhyolite porphyry.

Overthrust Block

The dominant structural feature of the Empire Mountains is a low-angle fault which crops out along the western edge of the mountains and appears to dip gently toward the southeast. Although the outcrop of the fault is covered largely by the alluvium, it is exposed southwest of the Andrada Ranch where Permian limestone rests on the folded Cretaceous (?) rocks of the northern series. To the south, where the fault is not exposed, Cretaceous (?) rocks are almost everywhere exposed on the west bank of Davidson Canyon, and, except in the vicinity of the Sycamore stock, Paleozoic rocks make up the east bank.

In the northernmost part of the range, imbricate thrust structure is strikingly developed. At the southwestern base of Pantano Hill, limestone beds rest on Cretaceous (?) maroon shale and limestone conglomerate. Near the crest of Pantano Hill, a basal Cretaceous (?) limestone conglomerate, 30 to 50 feet thick, rests on the eroded surface of the Scherrer formation. Above the conglomerate is a sliver of Martin limestone, replete with Atrypa reticularis, and Escabrosa limestone.

The main overthrust block of the Empire Mountains is broken by east-west faults which divide it into four segments. The large horizontal component of displacement on some of these faults (about 8,000 feet on the Andrada fault and 6,000 feet on the Pantano fault) and the fact that they cannot be traced into the Cretaceous rocks of the basement block to the west, strongly suggests tear-faults which formed during the period of overthrusting. Structure within the individual segments also suggests that the displacement along these faults is the result of horizontal rather than vertical movement. In the northern segment, the Paleozoic formations are domed, and imbricate structure is present; in the north central segment, the Paleozoic rocks have been folded into a symmetrical anticline whose roughly north-south axis plunges steeply to the south; in the south central segment, there is an asymmetrical anticline with steeper dips to the west than to the east; and the southern segment apparently has been rotated on the thrust plane so that the formations exposed just south of the Hilton fault strike east instead of north.

The direction of the thrust appears to have been from the southeast. The Cretaceous (?) rocks below the imbricate thrust plates wedge out in this direction. The asymmetrical anticline and syncline which involves the Abrigo and Martin formations adjacent to the Hilton fault dips 45 degrees southeast. South of the Andrada Ranch a fold in the same formations is sharply overturned to the north, and the Martin limestone has been moved northward along a low-angle fault over the crushed shaly beds of the Abrigo formation.

Normal Faults

North-south normal faults in the Empire Mountains are inferred from displacements of formational contacts, but their outcrops are concealed by alluvium in most places. The amount of vertical displacement on these faults appears to have been moderate, amounting to only a few hundred feet at a maximum.

Interpretation of Structure

Large-scale overthrusting in southeastern Arizona has been described in the Santa Rita and Empire Mountains by Schrader (1915) and Wilson, R. A. (1934), in the Tucson Mountains by Brown (1939), and in central Cochise County by Gilluly (1956). Thrust faults of considerable magnitude are also known to be present in the Rincon, Sierrita, and Huachuca Mountains. In the Empire Mountains, the intensity of thrusting and accompanying folding and shearing contrast with the comparatively small-scale normal faulting exhibited along their flanks. Although the Empire Mountains outwardly exhibit the typical form of Basin-and-Range tilted-blocks, the displacements along the normal faults appear to be too small to account for the structural relationships of the Empire Mountains to the adjoining Santa Rita and Whetstone ranges. The author concludes that the structural development of the Empire Mountains was controlled by regional compression.

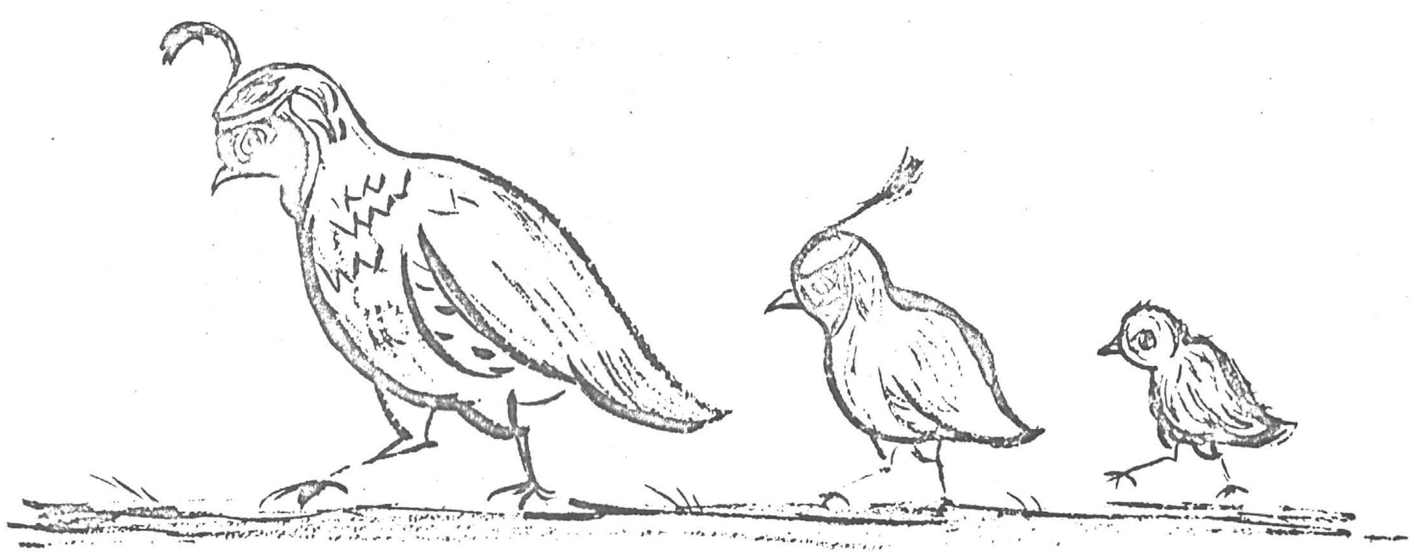


FIGURE 24. Cochise Head and Rhyolite Canyon, Chiricahua Mountains, Arizona, from southwest. Columns were eroded from welded tuffs of Rhyolite Canyon formation; Cochise Head is composed of Faraway Ranch formation; dark hills in middle distance are Precambrian, Paleozoic, Mesozoic, and probable Tertiary rocks in thrust complex. Conical peak on right is Sugarloaf Mountain, remnant of a thick rhyodacite flow. Photo by Tad Nichols.

Pima Co

SANTA CATALINA MOUNTAINS

TRIP III, ROAD LOG

Thursday, April 2, 1959

Leader: R. L. DuBois

Driving distance: 117.5 miles

Logged distance: 117.5 miles

Starting time: 7:00 a.m.

General Statement

This field trip is planned to encircle and cross part of the largest crystalline massif in southern Arizona. The trip starts at the University of Arizona campus and proceeds via Oracle Road along the west side of the Santa Catalina Mountains to Oracle Junction (fig. 46), then goes by way of the Burney Mines Road to Oracle, and turns southeastward to Peppersauce Canyon. From there the route leads generally south and up a rough dirt road to Summerhaven and the road to the radar station on Mount Lemmon. (Unauthorized persons are not permitted on radar station grounds). The return to Tucson is via the Mount Lemmon Highway, down the southeastern ridge of the Santa Catalina Mountains, past the Palisades Ranger Station, General Hitchcock Lookout, and Molino Basin.

The party will see the following features: (1) The broad, westward-plunging folds in the gneisses of Pusch Ridge, north of Tucson; (2) the cross section of a huge, asymmetrical fold north of Pusch Ridge; (3) the unconformity separating the older Precambrian Pinal schist from the younger Precambrian Apache group; (4) the faint flow traces and crossed foliations of the Oracle granite; (5) the Paleozoic and Cretaceous (?) rocks of Peppersauce Canyon and country to the south; (6) the Leatherwood quartz diorite and metamorphosed Apache group on Mount Lemmon; (7) pegmatitic replacements of the quartz diorite near Mount Lemmon; and (8) the sheared granitic gneiss and the various banded gneisses on the southern slope of the Santa Catalinas.

0.0	0.0	Start behind the Geology Building, University of Arizona. West to Park Avenue. Stop sign. TURN RIGHT (north) to Fort Lowell Road. Traffic lights on Speedway Blvd. and Grant Road. At 1:00, Santa Catalina Mountains, composed of banded gneisses in broad folds plunging toward left and forming dip slopes toward observer.
2.3	2.3	Fort Lowell Road. Stop sign. TURN LEFT (west) to Oracle Road. Traffic lights at N. First Avenue and N. Stone Avenue. Tucson Mountains at 12:00, composed of Cretaceous Amole sediments and volcanic rocks, overlain at left (south) and in foreground by Tertiary Cat Mountain rhyolite and other volcanic rocks.
1.3	3.6	Oracle Road. Stop sign. TURN RIGHT (north). Traffic light at Prince Road. Tortolita Mountains at 11:30, composed mostly of crystalline rocks, structure unknown. Santa Catalina Mountains at 1:00.
2.0	5.6	Bridge across Rillito Creek. Late Cenozoic sediments are exposed in north bank and in road cuts beyond.
1.5	7.1	STOP NO. 1 (10 minutes). PICTURE POINT (fig. 18A). Park as directed. A brief talk will be given on features in view up Pima Canyon. High peaks and left wall of canyon are massive phase of granitic gneiss overlain and underlain by banded gneiss.
1.6	8.7	Ina Road intersection. Altitude 2,500 feet. Enter area shown on figure 46.
3.1	11.8	The thin edge of a massive granitic layer on Pusch Ridge at 4:00 begins on slope to right and can be followed into high cliffs to northeast, underlain by dark, thinly banded gneisses. Development of this structure can be watched on way to next stop. Continue past exposures of late Cenozoic sediments.
3.0	14.8	Bridge across Canada del Oro. Road cut in late Cenozoic sediments on hill above.

1.2	16.0	STOP NO. 2 (10 minutes). PICTURE POINT (fig. 18B). Pull into Rancho Romero entrance on right and PARK. A brief talk on features in view will be given. On western face of the Santa Catalina Mountains the massive granitic layer arches gently over banded gneisses which, almost directly east of the view point, reverse in dip and greatly steepen, forming an asymmetrical fold. The steep spur to the east is the northerly limb of the fold. High point on forested ridge is Mount Lemmon.
3.8	19.8	Rail N Ranch Road on right. CONTINUE STRAIGHT AHEAD. Good view of western front of Santa Catalina Mountains. Charoleau Gap (eroded on a fault) at 2:00; Samaniego Ridge (highest part) at 3:00; Mount Lemmon, 3:30; northern edge, asymmetrical fold, 4:30; peaks in massive phase, granitic gneiss at 5:00. On some low hills at 3:00, remnant patches of metamorphosed sediments, possibly the Apache group, have been found. In the Tortolita Mountains at 9:00, the structure appears to dip south.
1.5	21.3	Village, altitude 3,100 feet. Route continues past bluffs of late Cenozoic sediments on right. At 12:00, Black Mountain, composed of older Precambrian granite and Pinal schist, with some younger Precambrian Apache group sediments and some Cretaceous-Tertiary volcanic rocks.
4.0	25.3	Oracle Junction, altitude 3,280 feet. TAKE ROAD TO RIGHT. Route ascends northeastward over late Cenozoic sediments. At 2:00, Apache Peak; at 2:30, Rice Peak in Santa Catalina Mountains.
5.7	31.0	Burney Mines Road, altitude 3,800 feet. TURN RIGHT onto dirt road. View of Santa Catalina Mountains to south. At 12:00, Mount Lemmon and Samaniego Ridge; at 11:00, Rice Peak; Apache Peak at 10:00. Oracle Hill at 9:30 and Alta Hill at 9:00. The Mogul fault passes through the saddle at the north base of Apache Peak. The area north of the fault is underlain by Oracle granite, intruded by dikes of diabase and andesite.
0.6	31.6	Outcrop of Oracle granite on hilltop at left.
0.9	32.5	Road forks. TAKE ROAD TO RIGHT. Altitude 3,900 feet.
0.2	32.7	STOP NO. 3 (10 minutes). A brief talk on features in view will be given. The view eastward up the valley is along the trace of the Mogul fault. Oracle granite is on left (north) side of the fault; Apache group and some Paleozoic sediments (Cambrian Troy quartzite) are on the right (south). Older Precambrian Pinal schist occupies the fault zone in this vicinity. Road forks. TAKE LEFT BRANCH, and descend.
0.7	33.4	Exposure of Pinal schist in wash. Dump of Copper Hill prospect on hill above.
0.5	33.9	STOP NO. 4 (10 minutes). After passing an outcrop of late Cenozoic conglomerate on right, arrive at exposure on left showing Scanlan conglomerate, at base of Apache group, resting on an irregular erosion surface on upturned Pinal schist. Toward right end of the outcrop, the Pioneer shale of the Apache group rests with faulted contact on the Scanlan. Somewhat farther down the wash and on the righthand side are more Pioneer exposures. Note the condition of these rocks for comparison with the same Apache group rocks that will be seen farther within the mountains to the southeast.
0.2	34.1	TURN AROUND.
1.4	35.5	First road fork, TURN RIGHT.
0.2	35.7	Second road fork, TURN RIGHT. Route winds through hills of Orache granite traversed by dikes and quartz veins.
2.9	38.6	STOP NO. 5 (10 minutes). Gate. Here (200 feet to left of road) are exposed dark inclusions, schlieren, and parallelism of minerals, features used in making the structural map of the Oracle granite (fig. 19). There are also some inclusions of vein quartz.
0.4	39.0	Road intersection. CONTINUE STRAIGHT AHEAD, between exposures of Oracle

granite.

0.9	39.9	Intersection. Follow main road STRAIGHT AHEAD.
0.5	40.4	Highway. Stop sign. TURN RIGHT.
0.5	40.9	Oracle, altitude 4,514 feet.
0.3	41.2	Leaving Oracle, road forks. TAKE RIGHTHAND BRANCH.
0.4	41.6	Begin dirt road. Galiuro Mountains, mostly eastward-tilted Cretaceous-Tertiary volcanic rocks, at 12:00.
2.5	44.1	San Manuel smelter stack in view at 12:00. Route passes to left of smooth American Flag Hill, composed largely of diabase intruded into Oracle granite. Dikes of diabase are exposed in road cuts.
0.4	44.5	Road forks. TAKE RIGHTHAND BRANCH. Left branch goes to the new town of San Manuel. Apache Peak at 1:00.
1.0	45.5	American Flag ranch. Good exposures of Oracle granite in wash.
0.8	46.3	Road intersection, Triangle Y ranch sign. Altitude 4,420 feet.

Optional Stop (not to be included on field trip).

Turn right on Triangle Y ranch road.

0.3	0.3	Road forks, TAKE RIGHTHAND BRANCH. Road crosses diabase outcrop just before this fork.
0.2	0.5	Road forks, TAKE LEFTHAND BRANCH.
0.3	0.8	Road forks, TAKE LEFTHAND BRANCH.
0.7	1.5	STOP. Granite outcrop just below road has faint foliation in two directions (fig. 19). TURN AROUND.
1.5	3.0	Intersection with Mount Lemmon road. TURN RIGHT.

1.6	47.9	Copper-lead mill on right. On trace of Mogul fault. Crushed Oracle granite along road. Road winds up hill, makes a hairpin curve above 3C ranch, crosses fault, and continues southwestward over exposures of Escabrosa limestone, and through cuts in Escabrosa and in late Cenozoic conglomerate.
1.8	49.7	Peppersauce Canyon, altitude 4,630 feet. LUNCH STOP (30 minutes). The canyon has been eroded here into various sedimentary rocks. Near here are the type localities of the Cambrian Santa Catalina, Southern Belle, and Peppersauce Canyon formations (Stoyanow, 1936, p. 476). The route southward crosses Cretaceous (?) graywackes with steep northeast dips and, locally, gentle southwest dips. At a few places, the Escabrosa limestone can be seen above the road to the southwest, apparently resting on the Cretaceous (?) rocks.
2.1	51.8	Just around hairpin curve, boulders of coarse-grained granite (Oracle granite?) appear in the Cretaceous (?) sediments.
0.2	52.0	Bridge across stream in Cretaceous rocks below Escabrosa limestone in Nugget Canyon. The Cretaceous is strongly sheared, and the shear planes dip gently westward. Road ascends, crosses saddle, and descends through Cretaceous (?) sediments and, near foot of slope, crosses a narrow band of faintly foliated and lineated rock that may be Wallace's (1954) metadiorite.
1.6	53.6	Cross Catalina Wash. Exposures of late Cenozoic conglomerate.
0.5	54.1	Hairpin curve, altitude 4,590 feet.
0.2	54.3	PICTURE POINT (fig. 18C). Panorama of northeast flank of Santa Catalina

		Mountains. Dip slopes on Paleozoic rocks from 11:00 to 2:00. Rice Peak at 11:30. Blocks of younger Precambrian Barnes conglomerate lie scattered on surface. Observe shapes of pebbles for comparison with Barnes pebbles higher in the mountains.
1.1	55.4	Catt'. guard, altitude 4,740 feet.
1.1	56.5	Hairpin curve above Stratton Canyon. Road descends past exposures of vesicular latite of Cretaceous (?) or Tertiary (?) age.
0.5	57.0	Cross stream in Stratton Canyon.
0.2	57.2	Road forks. TAKE RIGHTHAND BRANCH.
0.3	57.5	Cross bridge. Schistose rocks exposed in cuts closely resemble Pinal schist, but are believed to be sheared younger Precambrian Pioneer formation.
0.6	58.1	Barnes conglomerate on hilltop at right. Road ascends past exposures of sheared Pioneer formation, intruded by large sills of rather coarse-grained, foliated quartz latite (Peirce, 1958).
1.8	59.9	Bridge.
0.3	60.2	Gold Mill on left. Above this place, road crosses exposures of older Precambrian Oracle granite, followed above by sheared sediments, mapped by Peirce (1958) as Cambrian. Road ascends in hairpin loops.
1.9	62.1	Cross stream below Lower Control mine.
0.5	62.6	On dark, locally flow-banded, sheared Leatherwood quartz diorite.
0.6	63.2	Lower Control mine.
0.3	63.5	Portal in Leatherwood quartz diorite, altitude 5,670 feet.
0.3	63.8	Curve, fresh Leatherwood exposure, view ahead and above of undifferentiated Paleozoic marble, capped by Escabrosa (?) limestone on Rice Peak.
0.8	64.6	Copper showings in bank are part of dump from mine workings at Stratton Camp.
0.4	65.0	STOP NO. 6 (5 minutes). On curve where road crosses small stream. Outcrops of Leatherwood quartz diorite.
1.8	66.8	STOP NO. 7 (5 minutes). Leatherwood outcrops with especially well-developed secondary foliation and lineation.
1.2	68.0	Water for cars only.
1.8	69.8	Cattleguard.
0.2	70.0	Paved road. Pegmatites in Leatherwood quartz diorite. Altitude 7,820 feet. TURN RIGHT.
0.2	70.2	Road forks, TAKE RIGHTHAND BRANCH. Road leads upward past cuts in metamorphosed Apache group and Leatherwood quartz diorite.
1.5	71.7	Saddle with exposures of Apache group on left, guard station on right. Altitude 8,250 feet. Route ascends past excellent exposures of silicated Apache group.
1.7	73.4	TURN AROUND. Below radar station at summit of Mount Lemmon. Altitude 8,950 feet (about 200 feet below summit).
3.0	76.4	Road intersection. STOP, then TURN RIGHT.
0.2	76.6	Mount Lemmon Lodge. STOP (10 minutes) for refreshments. CONTINUE STRAIGHT AHEAD.

0.7	77.3	STOP NO. 8 (10 minutes). Pegmatites replacing Leatherwood quartz diorite. TURN LEFT on road that winds up hillside.
1.3	78.6	Paved road. STOP, watch traffic, TURN RIGHT.
1.0	79.6	Apache group sediments in road cut.
0.7	80.3	STOP NO. 9 (10 minutes). Bear Wallow. Folds in Apache group, overturned southward.
0.7	81.0	Road cuts in granitic gneiss.
1.1	82.1	View of Dos Cabezas Mountains ahead in far distance.
0.5	82.6	Road cuts in granitic gneiss. Cross contact between gneiss and Apache group.
0.2	82.8	Palisades Ranger Station, altitude 7,945 feet. Enter area shown in figure 20.
0.6	83.4	Contact, Apache group — Pinal schist and gneisses.
0.1	83.5	Contact, Apache group — Pinal schist and gneisses. Route descends through cuts and over very extensive exposures in the granitic gneiss. In some exposures a secondary foliation is developed.
5.1	88.6	STOP NO. 10 (10 minutes). Hitchcock Lookout. Panorama of Tucson and surrounding mountains. Lookout is on augen gneiss with foliation striking nearly east-west and dipping gently northward. Lineation strikes northeast. View includes Dos Cabezas Mountains in far distance, S 80° E, with Winchester Mountains in foreground; to the right, on far horizon, the Chiricahua Mountains; Spud Rock, S 35° E; Rincon Peak S 30° E; Mt. Wrightson in Santa Rita Mountains, S 15° W; Sierrita Mountains, S 45° W; Baboquivari Peak, S 55° W; Coyote-Quinlan Mountains, S 65° W, with Tucson Mountains in foreground; Cathedral Rock N 75° W. Route descends into canyon of Bear Creek.
Warning:		Begin descent beyond this stop. Road is paved from here on, but the grades are steep and the curves are sharp. Please control speed and allow ample space between cars.
4.9	93.5	Begin sharp curve out of Bear Creek canyon. A few dark layers appear in the augen gneiss.
0.4	93.9	Sharp curve, cross small side canyon. Route continues past Federal Prison Camp to Molino Basin. Amount of dark material interlayered in the gneiss gradually increases so that the augen gneiss grades into the banded augen gneiss. Ridge across valley to right is the Catalina Forerange.
3.1	97.0	Hairpin curve in Molino Basin. Picnic grounds on right. Route leads down along the right (west) wall of Molino Canyon, past spectacular outcrops of the banded augen gneisses, then curves right and gradually descends southern slope (practically a dip slope) of the Catalina Forerange.
5.8	102.8	Road emerges from mountains. Altitude 3,160 feet. Leave areas shown in figures 20 and 46.
4.8	107.6	Road junction. CONTINUE STRAIGHT AHEAD.
1.6	109.2	Road junction. CONTINUE STRAIGHT AHEAD.
1.9	111.1	Road forks. TAKE LEFT FORK.
0.5	111.6	TURN RIGHT onto Speedway.
5.6	117.2	Stop light at N. Mountain Ave. TURN LEFT.
0.2	117.4	Stop sign. TURN RIGHT.
0.1	117.5	End of trip.

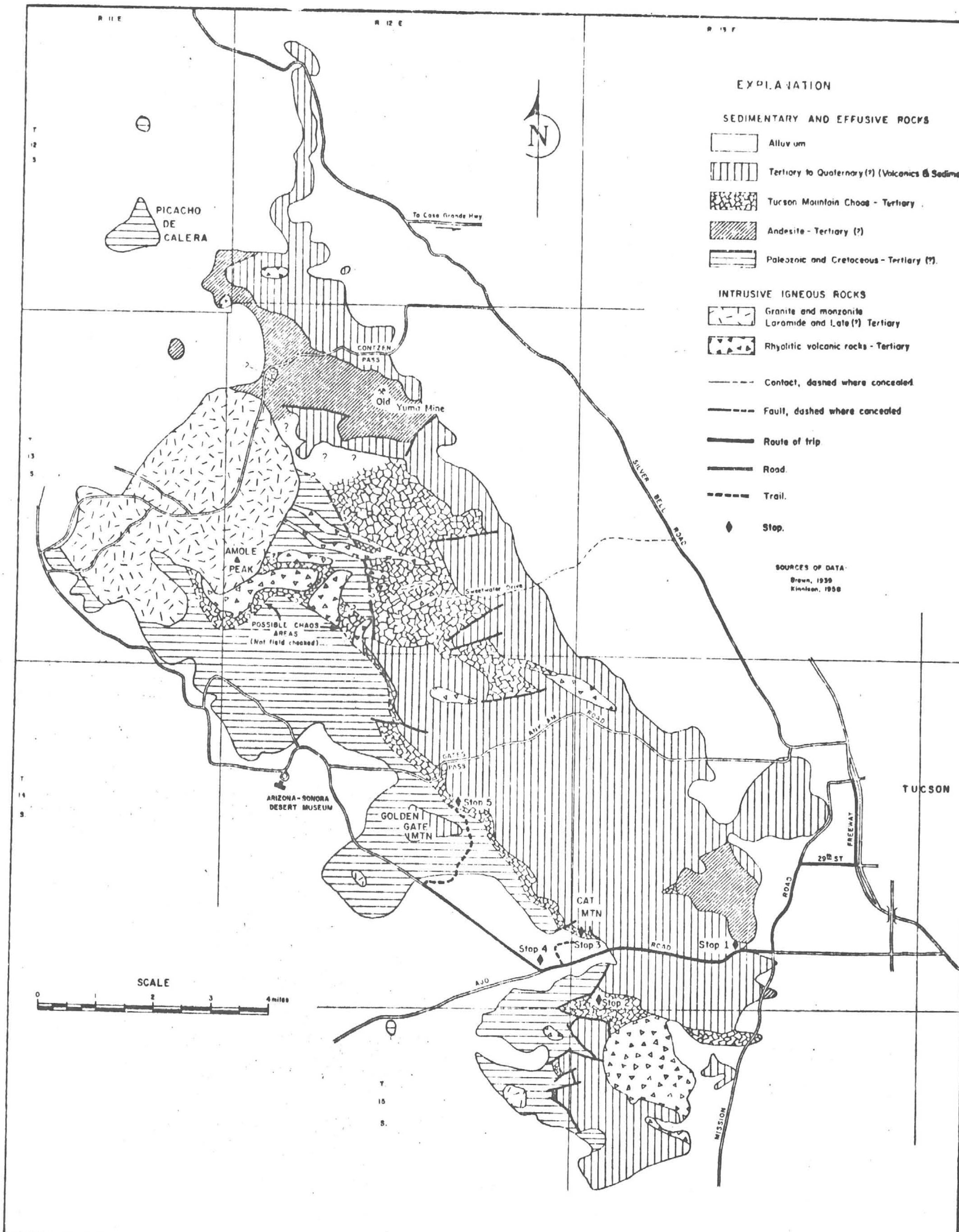


FIGURE 47. Geologic sketch map of Tucson Mountains, Pima County, Arizona, showing route of Field Trip IV.

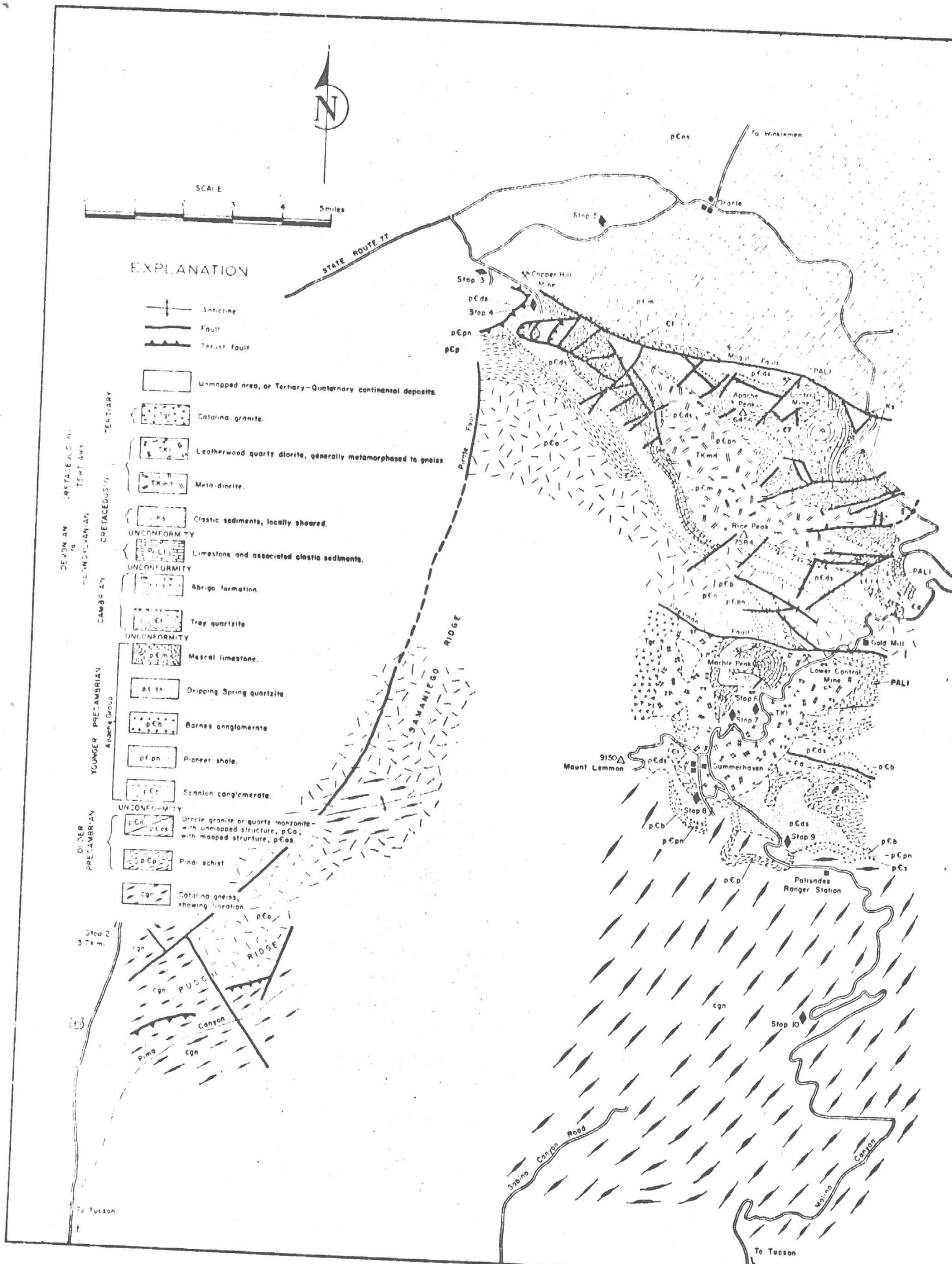


FIGURE 46. Structure map of the central part of the Santa Catalina Mountains, showing most of the route of Field Trip III.

Pima Co.

GENERAL GEOLOGY OF SOUTHEASTERN ARIZONA

TRIP V, ROAD LOG

First Day -- Sunday, April 5, 1959

Leaders: E. B. Mayo and W. D. Pye

Driving Distance: 141.7 miles — Logged Distance: 132.9 miles

Starting Time: 8:00 A. M.

General Statement

This trip (fig. 48) begins at Tucson in the Santa Cruz valley and proceeds southeastward to Mountain View, between the Tanque Verde and Rincon Mountains on the north and the Santa Rita Mountains on the south. The route then turns southward, between the Empire Mountains on the east and the Santa Rita Mountains on the west, to Sonoita. From Sonoita the way leads eastward between the Mustang and Whetstone Mountains, crosses the San Pedro River, and continues to Tombstone. From Tombstone the trip proceeds southward into the Mule Mountains to Bisbee and then to Douglas.

The party will see: (1)The broadly folded, foliated gneisses of the Santa Catalina, Tanque Verde and Rincon Mountains; (2) the Paleozoic sediments of the Empire Mountains, thrust over Cretaceous rocks; (3) the Paleozoic sediments of the Mustang Mountains, and the Paleozoic section on the eastern face of the Whetstone Mountains; (4) the Paleozoic and Cretaceous sediments, Mesozoic and Tertiary intrusions, and Cretaceous volcanic rocks of the Tombstone Hills; (5) the Precambrian basement, overlain by Paleozoic and Cretaceous sediments, and intruded by Mesozoic granite in the Mule Mountains; (6) the open pit portion of the Phelps Dodge operation at Bisbee; (7) the Cretaceous section east of the Lavender pit; and (8) the southern part of Sulphur Springs Valley.

0.0	0.0	Junction, Palo Verde and Benson highway. Follow U. S. Highway 80 southeastward across Santa Cruz Valley. At 3:30 in distance is the dump of Pima open pit mine; Helmet Peak and Sierrita Mountains in background; (Trip I). From 9:00 to 10:00, the Santa Catalina (Trip III), Tanque Verde and Rincon Mountains, composed mainly of banded gneisses deformed into broad, westward-plunging folds; at 12:00, Whetstone Mountains; at 2:00, Santa Rita Mountains; at 5:00, Tucson Mountains (Trip IV). Highway leads up a nearly imperceptible grade; the desert floor here is clothed by dark green creosote bushes; with cholla cactus becoming more abundant eastward.
8.3	8.3	Palo verde (covered with yellow flowers in years of abundant rainfall) and slender, spiney ocotillo are abundant.
1.3	9.6	At 9:00: Bare slopes of the western spur of Tanque Verde Mountains are formed on a broad, westward-plunging anticline of gneiss.
5.0	14.6	Vail intersection. At 10:00: Foothills in Colossal Cave area are overthrust blocks of Paleozoic sediments. Patches of crystalline rocks are locally exposed between mountains to north and south. Much of the pass area is underlain by Miocene (?) Pantano beds and alluvium. Some crystalline plates have been thrust over the Miocene (?) sediments (Brennan, 1957).
2.9	17.5	Mountain View. TURN RIGHT on State Highway 83 to Sonoita. Empire Mountains are on left and Mt. Fagan, at north end of Santa Rita Mountains is on right. Yucca, ocotillo and mesquite cover ground.
3.0	20.5	Prospect dump at 2:00. Just after passing entrance to TM Ranch, road cuts through Cretaceous (?) sediments.
1.6	22.1	Andrada Ranch. Enter area shown on figure 23. Empire Mountains to left. Hill nearest road is Permian limestone thrust over Cretaceous (?) shale. Steep cliff on skyline is Eagle Bluff, composed of Permian limestone. Hills to right of road are Cretaceous (?) volcanic rocks. Exposures in wash south of Andrada Ranch are mostly Paleozoic limestones (Galbraith, 21).

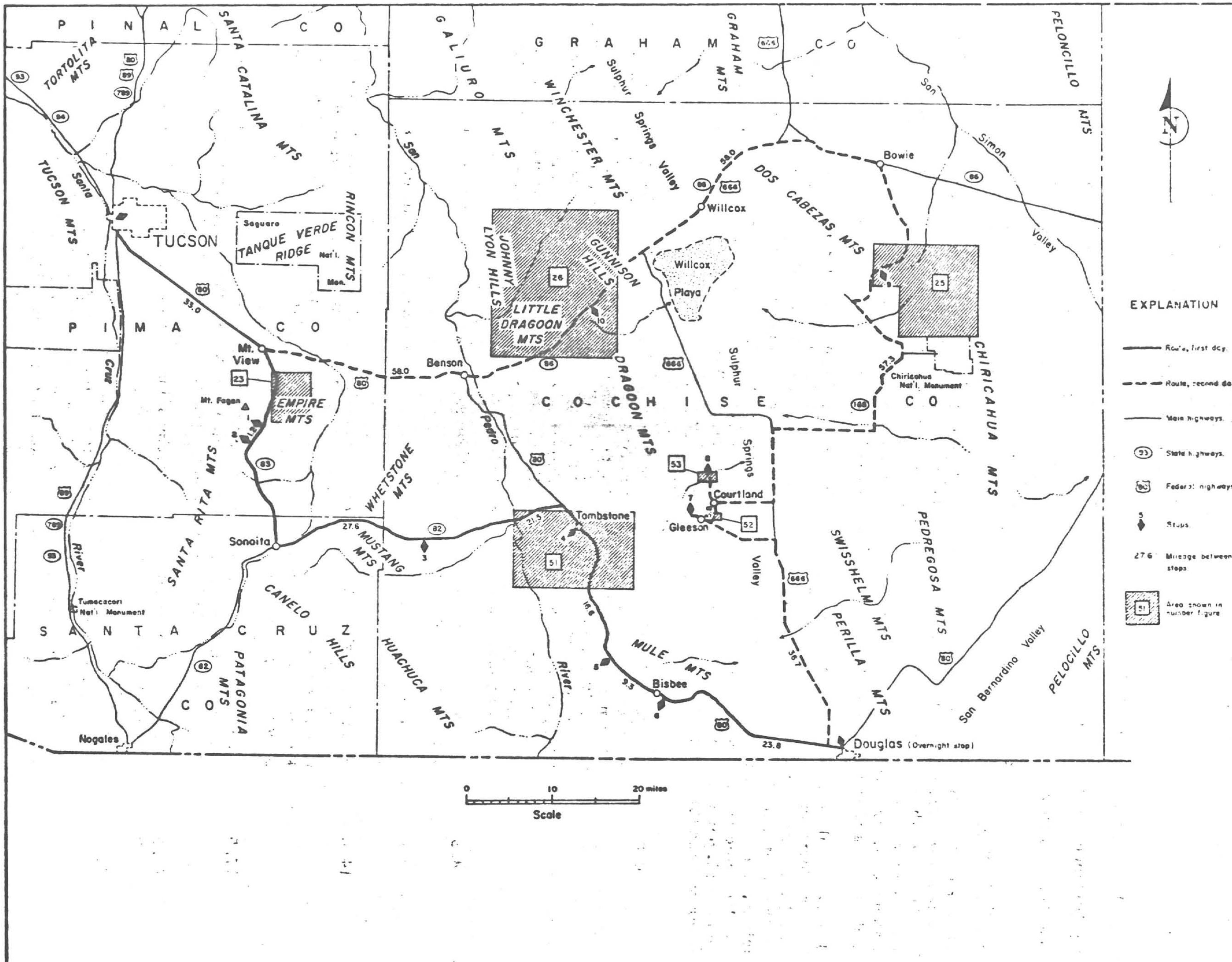


FIGURE 48. Index map of southeastern Arizona showing route of Field Trip V and locations of areas shown on smaller-scaled maps.

According to Schrader (1915), the Empire Mountains consist essentially of a granitic core, located some three miles south of the Andrada Ranch, surrounded by a mantle consisting chiefly of Cretaceous (?) sediments. Along the eastern and southeastern sides of this core, the Paleozoic floor on which the Cretaceous rests has been thrust northwestward over the granite; in the northern and western parts of the mountains, Paleozoic klippen rest on granite and Cretaceous rocks (Galbraith, 21).

3.0	25.1	Cretaceous (?) volcanic rocks along route for about 4.0 miles. Leave area shown on figure 23.
4.6	29.7	Road to Rosemont on right. At 2:30: Dumps of Rosemont mining district are near crest of ridge.
0.2	29.9	Cretaceous (?) conglomerate along road for next one-half mile.
0.6	30.5	Cuesta ahead, composed of Tertiary sediments of the Sonoita bolson, is being dissected by the north-flowing Cienega Wash. Cretaceous (?) beds crop out along north slope of escarpment.
1.9	32.4	STOP 1. (20 minutes) Whetstone Mountains are due east; Little Dragoon Mountains N. 65° E.; Empire Mountains N. 35° E.; Rincon peak, N. 30° E.; Tanque Verde Mountains, N. 10° E.; Mt. Fagan, N. 40° W.; dumps of Rosemont district, N. 80° W.; Mt. Wrightson (9,432 feet) in the Santa Rita Mountains, S. 65° W.; Cuesta ahead.

The geology of the Santa Rita Mountains has become known largely through the pioneering work of Schrader (1915), a recent study by the U. S. Geological Survey (Creasey and Quick, 1955), and theses by students of the Department of Geology, University of Arizona (Dunham, 1937; Popoff, 1940; Johnson, 1951; Anthony, 1951; Sulik, 1957; Browne, 1958; and Lutton, 1958). From the viewpoint at this stop one sees the eastern slope and skyline of the Santa Rita Mountains from the northern end to Mt. Wrightson (fig. 49A). Most of this slope consists of Cretaceous sediments which dip eastward. Underlying these, along the crest of the range, is the Paleozoic sequence, ranging from the Cambrian Bolsa quartzite upward to the Permian Scherrer formation. The Paleozoic rocks, according to Schrader (1915), have been thrust westward over a granitic basement which is west of the crest. In Sawmill Canyon, about 5 miles in front of Mt. Wrightson, is a west-northwest-trending left lateral strikeslip fault (Lutton, 1958). Mt. Wrightson itself is rhyolite, flanked on the east by andesite and on the west by quartz diorite, granite, and a thin septum of dark greenish schist, thought by Schrader (1915) to be of possible Cambrian age.

The Rosemont mining camp, a southeasterly extension of the Helvetia copper-gold-silver district, is located on the west side of the crest. According to Schrader (1915), the copper mineralization at Rosemont was mostly in silicified Paleozoic limestone near intrusive contacts.

0.4	32.8	Road climbs through southeast-dipping Tertiary beds, covered with grass, juniper, mesquite and scrub oak.
1.4	34.2	STOP 2. (20 minutes). View southeastward over grassy uplands, mountains and Sonoita Valley: On the left, the Whetstone Mountains; at 11:00, Mustang Mountains; 12:00, Huachuca Mountains; from 12:00 to 2:00, Canelo Hills; at 3:00, Mt. Wrightson.
1.6	35.8	Greaterville-Box Canyon road to right.
1.1	36.9	Coronado National Forest boundary.
0.8	37.7	At 2:30: Abandoned oil derrick; hole was drilled to depth of 3,394 feet and bottomed in "shale" (Johnson, 14).
2.2	39.9	Cenozoic red beds in bluff to right.
0.5	40.4	Enter Santa Cruz County. Rolling surface is covered by grass, bear grass, yucca, scrub oak and mesquite.

3.7	44.1	Sonoita. STOP. TURN LEFT (east) on Highway 82. In the Canelo Hills to the south, a sequence of Cretaceous (?) and Tertiary (?) conglomerates, redbeds and volcanic rocks, totalling perhaps 3,500 feet, has been overridden, possibly from northeast to southwest, by about 2,200 feet of Permian deposits. Route leads toward pass between Whetstone Mountains on left and Mustang Mountains on right.
5.2	49.3	Bridge. Road winds over Tertiary valley fill. Yucca becomes abundant near base of Mustang Mountains on right.

The western half of the Mustang Mountains, southwest of Rain Valley (fig. 49B), is composed of Permian sediments which were first described as the Snyder Hill formation and divided into 5 members (Bryant, 1951). Later, Bryant (1955) correlated the 4 lower members with the Scherrer and Concha formations and described the top member as the "Rainvalley formation." These rocks are locally overlain by Cretaceous (?) clastics and Tertiary rhyolite. The massive cliffs south of the highway are Permian Concha limestone.

Grantham Mountain, the summit near the southern end of the ridge, is rhyolite, and Quail Peak, the highest point near the northwestern end, is capped by Cretaceous clastics and rhyolite. On Grantham Mountain, the Permian rocks may have overridden the Cretaceous (?), possibly from northeast to southwest, on a gently-inclined thrust. Cretaceous (?) rocks are exposed at several places along the northeastern base of the ridge. Postthrust (?) normal faults have divided the area into many small fault blocks.

The Mustang Mountains northeast of Rain Valley and the southern part of the Whetstone Mountains have not been mapped in detail. The northern half of the Whetstones has been mapped by Tyrrell (1957).

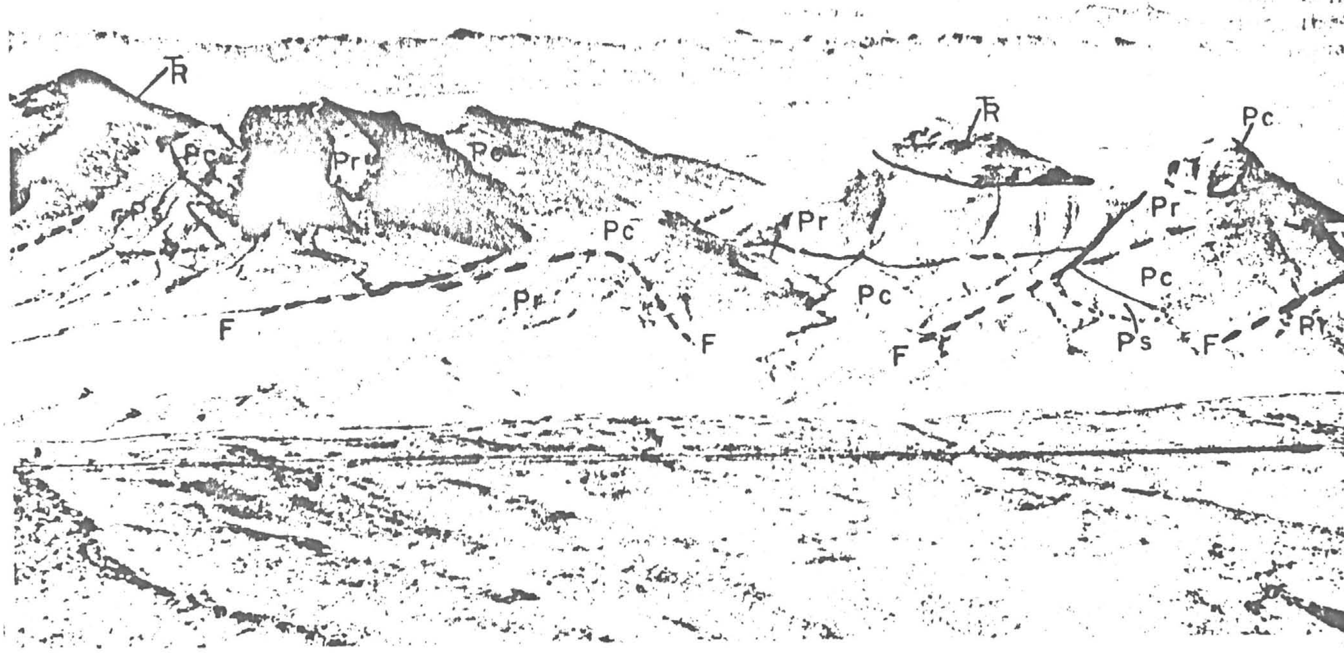
2.5	51.8	At 2:00: High dome is "The Biscuit", with cliffs of Concha limestone; at 10:00, granitic core of Whetstone Mountains, flanked by Paleozoic formations from 11:00 to 12:00.
2.6	54.4	At 2:30: Sharp folding in Permian limestones, near northwestern end of Mustangs.
2.4	56.8	Rain Valley ranch on right.
0.4	57.2	Road passes around south end of Whetstones with their sharply folded Paleozoic sediments. Enter Cochise County.
4.6	61.8	STOP 3. (15 minutes). There will be a brief discussion of the Paleozoic section exposed in the east face of the Whetstone Mountains to the left of the road (fig. 50A). The San Pedro Valley lies ahead, and beyond, the Dragoon Mountains are at 11:00, and the Mule Mountains are at 1:00. The Huachuca Mountains are at 3:00.

On the northeastern slope of the northern Huachuca Mountains, older Precambrian granite crops out with a few small patches of gently northeast-dipping Cambrian Bolsa Quartzite resting on the granite near the foot (Alexis, 1949). High within the mountains, the Bolsa quartzite and overlying Paleozoic rocks are overlain by a thick Cretaceous section. This entire section dips rather steeply southwestward. The Cretaceous rocks are broadly folded and the beds are locally overturned.

The structure is a huge anticline with a Precambrian core and limbs of Paleozoic and Cretaceous sediments overturned and overthrust to the southwest (Alexis, 1949). The crest has been eroded and the present highest part of the Huachucas is the steep southwest flank of the fold. The thrust surface rises at a moderate angle toward the southwest from beneath the granite core, then flattens, and locally reverses in dip. Weber (1950) shows essentially the same structural picture in the east-central Huachucas, except that the southwestward thrusting is developed on both sides of the core and imbrication is well developed.

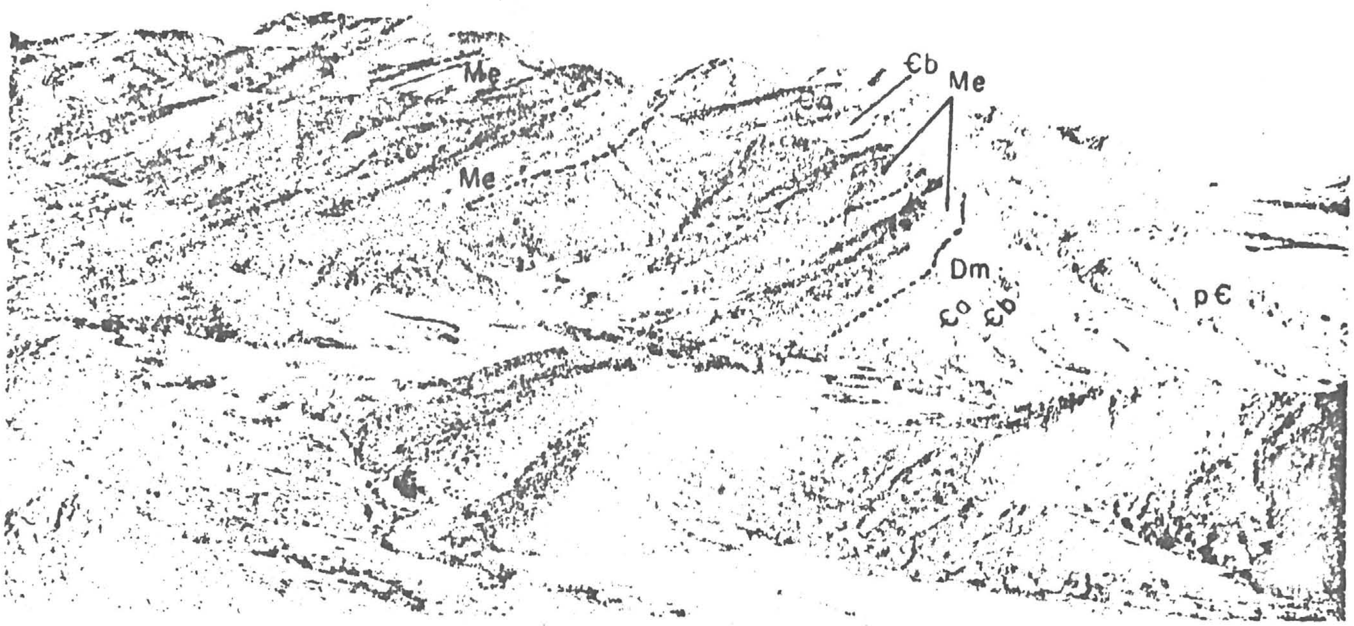
0.8	62.6	Sands Ranch entrance on left. Eight miles north on Sands Ranch Road (for jeeps only) is an excellent Paleozoic section from Precambrian through Permian (fig. 50A).

A. Mount Wrightson, Santa Rita Mountains, from northeast. The Sawmill Canyon fault zone occupies the transverse trench in foreground.

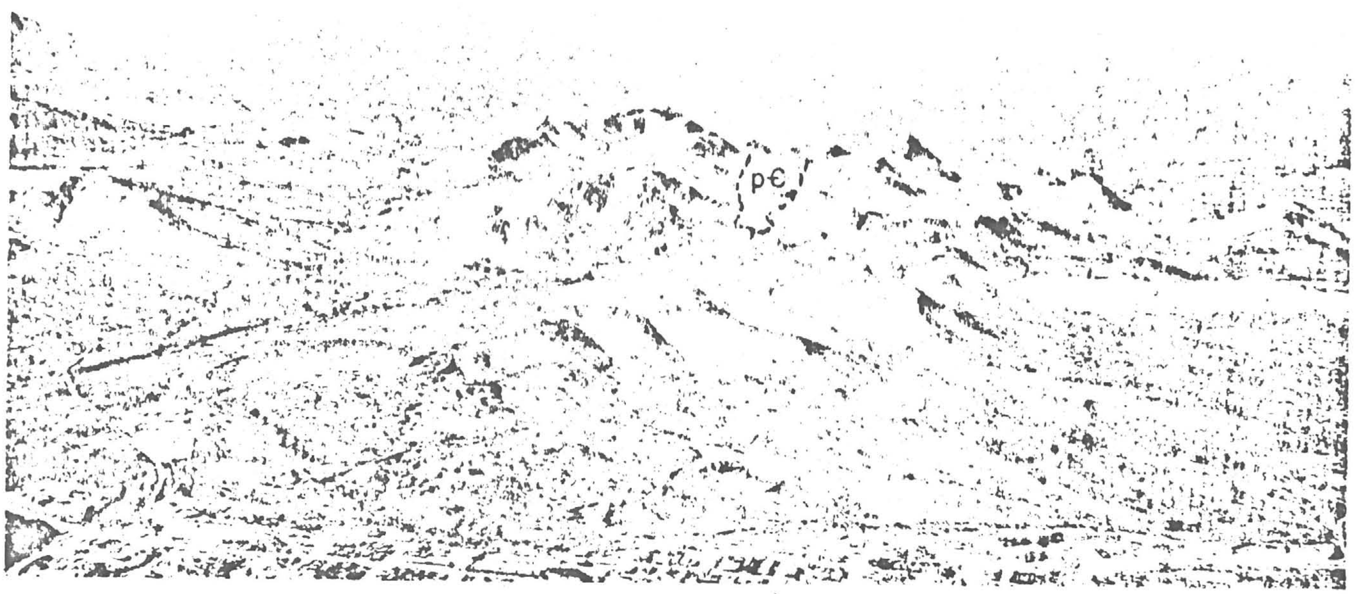


B. Mustang Mountains from north. Left to right: Grantham Mountain; Cave Cliff; Quail Peak; The Bisbuit. Tertiary rhyolitic volcanic rocks underlain by Cretaceous (?) clastic rocks (Tr); Permian "Rainvalley" formation (Pr), Concha limestone (Pc), Scherrer formation (Ps). Canelo Hills in background.

FIGURE 49. Aerial views of Mount Wrightson in the Santa Rita Mountains and the Mustang Mountains, Cochise, Pima, and Santa Cruz Counties, Arizona. Photos by Tad Nichols.



A. Faulted Paleozoic section on east face of Whetstone Mountains, seen from the south. Smooth slopes at right are on Precambrian rocks. Cambrian Bolsa quartzite (€b), Abrigo formation (€a); Devonian Martin formation (Dm); Mississippian Escabrosa limestone (Me), overlain by Pennsylvanian-Permian succession. Hills in foreground are Pennsylvanian strata.



B. Tombstone Hills from north (fig. 51). Precambrian (p€)core of north-south anticline. On east flank, Paleozoic formations, west to east, are Cambrian Bolsa quartzite and Abrigo limestone, Devonian Martin limestone, Mississippian Escabrosa limestone, Pennsylvanian Horquilla limestone. The Horquilla limestone underlies Grand (Emerald) Gulch in the left hand part of the picture. Huachuca Mountains in distance on right; Mule Mountains on left, in front of the haze.

FIGURE 50. Aerial views of Whetstone Mountains and Tombstone Hills, Cochise County, Arizona. Photos by Tad Nichols.

0.7	63.3	Fort Huachuca turn off on right. Continue STRAIGHT AHEAD. Tombstone Hills lie ahead. The Tombstone Hills are a minor geologic province of great interest and complexity. The type localities of four Paleozoic formations, the Pennsylvanian Horquilla limestone, the Pennsylvanian-Permian Earp formation, and the Permian Colina limestone and Epitaph dolomite are in these hills (Gilluly, 1956). Some two to five miles south-southwest of Tombstone, a north-trending anticline (fig. 50B), flanked on the east by the Paleozoic sequence and overlain unconformably on the west by the Cretaceous Bisbee formation, brings up a core of older Precambrian Pinal schist and albite granite. In the southern part of the hills and in Government Butte to the southeast, the Paleozoic rocks are in east-west folds that have been overturned to the south, and, locally, have ridden, relatively, southward on north-dipping flat thrusts. Following this deformation, the area apparently was eroded, and a volcanic sequence (Tertiary Bronco volcanics), commencing with andesite and progressing to quartz latite tuff, was erupted. Gilluly (1956) suggested that subsequent to this, northwest-trending folds and thrusts and some east-northeast tear faults were formed. These events seem to have been followed by emplacement of the Uncle Sam (quartz latite) porphyry (Gilluly, 1945), the Schieffelin granodiorite, intrusive rhyolite (?) and andesite porphyry. The Uncle Sam porphyry may have been emplaced, in part, along a flat thrust. Most of the productive silver-lead mines of Tombstone were located in a north-of-west-trending syncline in the Cretaceous Bisbee formation. The ore was associated with northeast fissures, where these crossed the famous "rolls" -- intense minor contortions within the syncline. The stratigraphy of the Tombstone district was discussed by Ransome (1916) and the geology in relation to the ore deposits has been described by Butler, Wilson and Rasor (1938) and by Butler and Wilson (1938).
1.2	64.5	Graham village; road continues eastward over Tombstone pediment (Bryan, 1926; Gilluly, 1956). Bryan (1926) described 3 pediments in the San Pedro Valley. The Tombstone surface is the oldest and highest; the Whetstone surface is younger than the Tombstone surface and is the most widely developed in the valley. The youngest and lowest surface is called the Aravaipa and is developed locally along the San Pedro River, a few feet above the flood plain of the inner valley.
3.2	67.7	At 11:00: Cochise Stronghold, retreat of the famous Apache chief, is in the Dragoon Mountains.
0.6	68.3	At 2:30: Fairbank Hills, composed of Tertiary Uncle Sam porphyry intruded into Cretaceous or Tertiary Bronco volcanics; at 4:00: Ft. Huachuca at the base of Huachuca Mountains; at 9:30 to 10:00: Little Dragoon Mountains.
2.3	70.6	Road descends from Tombstone pediment to younger Whetstone pediment.
2.8	73.4	Bridge across the San Pedro River. The San Pedro River rises in Sonora, Mexico, and flows northward to join the Gila River at Winkelman, Arizona. Higher cliffs along edges of inner valley are composed of beds of late Pliocene (?) or early Pleistocene age. The flood plain of the inner valley of the San Pedro River and the Aravaipa surface form the two successive surfaces above the channel of the river. Mesquite and cottonwood trees grow profusely on the floodplain of the inner valley. Overpass crosses Southern Pacific tracks; Fairbank station on left. Enter area shown on figure 51.
3.0	76.4	At 7:00 to 9:00: Dissected alluvial deposits of the San Pedro Valley; at 2:00 to 3:00: Tombstone Hills.
1.3	77.7	At 3:00: Uncle Sam Hill, composed of Tertiary Uncle Sam porphyry.
0.7	78.4	At 2:00: Tombstone.
0.6	79.0	Stronghold granite at Cochise Stronghold in Dragoon Mountains to the north.
0.7	79.7	Intersection with U. S. 80. STOP. TURN RIGHT.

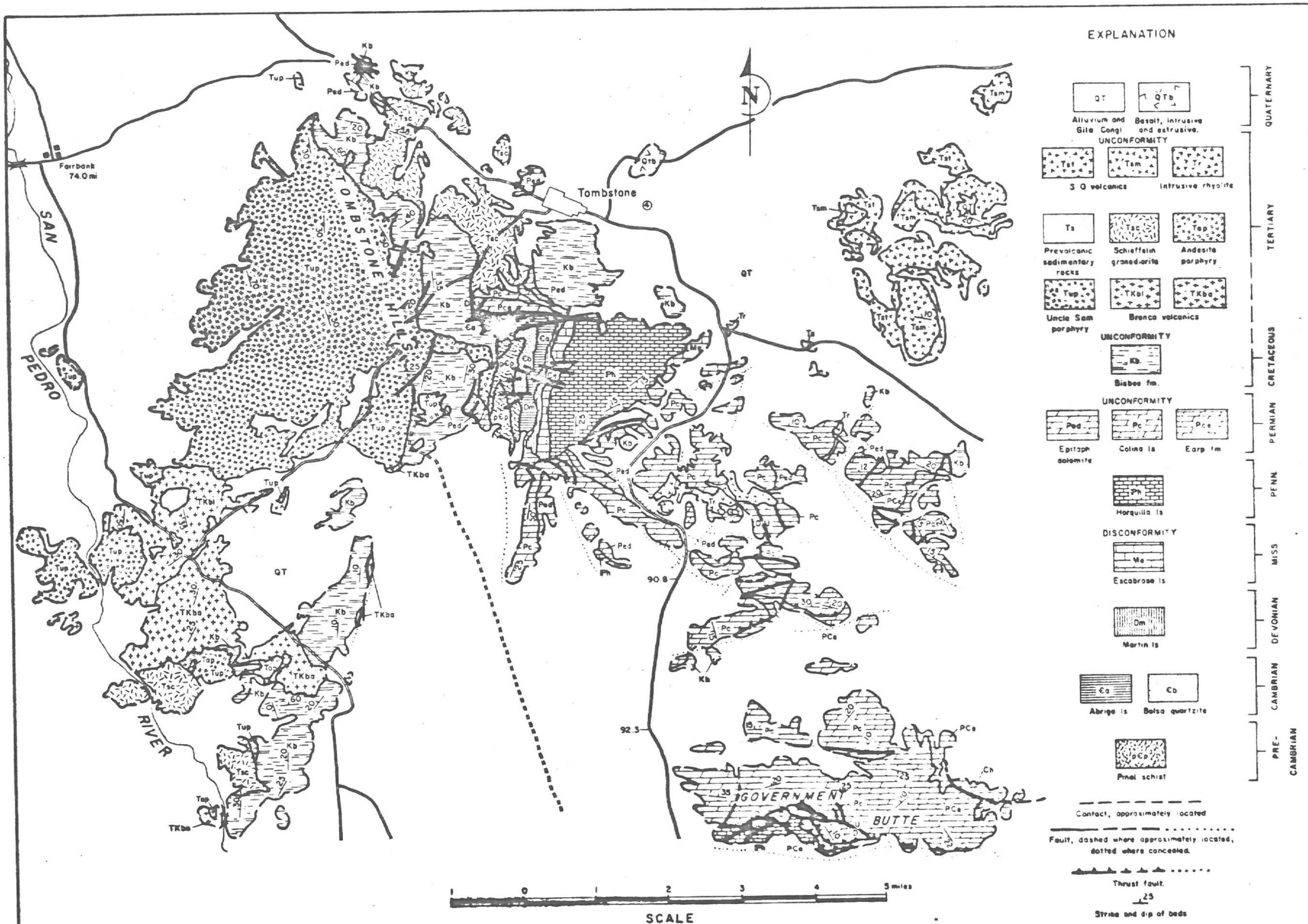


FIG. 51
GEOLOGIC MAP OF TOMBSTONE HILLS AND GOVERNMENT BUTTE
COCHISE COUNTY, ARIZONA

After J Gilluly, R S Cannon, Jr., W B Myers, S C Creasey, F S Simons, J H Wiese, and E Bowles, 1934-47

1.6	81.3	Bridge. Road cut in Pliocene-Pleistocene conglomerate.
0.9	82.2	Entering Tombstone, famous old silver mining camp. Today Tombstone prides itself on being "the town too tough to die". Boothill Graveyard at left. Altitude, 4,539 feet.
0.8	83.0	STOP 4. (One hour). Lunch and visit to Million Dollar Stope and other points of interest. According to Meinzer and Kelton, (1913, p. 14) the rich silver deposits of Tombstone were discovered in February, 1878, by A. E. Schieffelin. Schieffelin had been warned that he would find a tombstone instead of a fortune in Cochise's domain, and in remembrance of this warning he named the district Tombstone. "Thousands of locations were staked out and many valuable discoveries made and a city sprang into existence as if by magic." It enjoyed great fame and prosperity in the early eighties, but was later eclipsed by the Bisbee district. Among the surviving features of this picturesque old mining camp are the Boothill Graveyard at the northern edge of the town, and the Million Dollar Stope, one block west of the center of town.
0.7	83.7	Gleeson-Pearce road turns off at left. Continue on Highway 80, through road cuts in Pliocene-Pleistocene conglomerate.
0.7	84.4	At 2:00: Hill is mostly Pennsylvanian Horquilla limestone and Tertiary intrusive rhyolite.
0.2	84.6	Permian Colina limestone exposed in ridge on right. For next two miles road cuts are in the Colina and Mississippian Escabrosa limestones.
1.4	86.0	At 3:00: Contact between Escabrosa limestone below and Horquilla limestone above.
1.1	87.1	At 12:00: Government Butte; Paleozoic limestones in hills to right and left; Colina limestone to right.
0.8	87.9	Road descends rapidly through cuts in Colina limestone and intrusive rhyolite.
0.3	88.2	Tertiary intrusive rhyolite in red hill at left and in low red hills to right. Colina limestone in hills above and behind rhyolite; Huachuca Mountains at 2:00; Cananea Mountains in Mexico at 12:00. On some days, smoke from the Cananea smelter can be seen in front of the Cananea Mountains.
0.7	88.9	At 3:00: Colina limestone dipping steeply northward. At 9:00: Contact between Permian Epitaph dolomite and the underlying Colina. At 8:30 nearly horizontal beds of the Epitaph form the rounded hill.
0.5	89.4	At 10:00: Earp Hill, type locality of Pennsylvanian-Permian Earp formation. Anticline exposed in grey Colina limestone is thought by Gilluly to be related to a flat thrust that crops out on south slope of Earp Hill.
0.5	89.9	Looking back at Earp Hill, pinkish beds of Earp formation appear to be overridden by Colina limestone.
1.6	91.5	Government Draw. At 11:00: Government Butte is Colina limestone. Cretaceous Bisbee group and volcanic rocks are exposed in San Pedro Valley at right.
1.5	93.0	At 9:00: Complicated structure on south side of ridge in Colina, Horquilla and Epitaph formations. In Government Butte and in Earp Hill, some formations are thought to have moved relatively southward, overriding other rocks. Leave area shown on figure 51.
1.2	94.2	At 7:00 to 8:00: Complex structure on south side of Government Butte. Mule Mountains at 9:00 to 2:00. Ransome's (1904) classic paper on the Bisbee mining district gave the Mule Mountains a prominent position in southeastern Arizona geology. Here the Paleozoic

section was described and the Cambrian Bolsa quartzite and Abrigo limestone, the Devonian Martin limestone, the Mississippian Escabrosa limestone, and the Pennsylvanian-Permian Naco limestone (since raised to group status) were named (see articles 6 through 10). In the Cretaceous system, the Lower Cretaceous Bisbee group, consisting of the Glance conglomerate, Morita formation, Mural limestone and Cintura formation, was defined (Fergusson, 11).

The oldest rock found in the Mule Mountains is the older Precambrian Pinal schist, which was intruded by the Juniper Flat granite. The age of the Juniper Flat granite has long been under discussion. It is known to intrude the Paleozoic sequence, and Ransome assigned the granite to the Triassic or Jurassic. The upper contact is not so readily defined and it was only recently that the Juniper Flat granite was shown clearly to be overlain depositionally by the Bisbee group. It could be Nevadan in age.

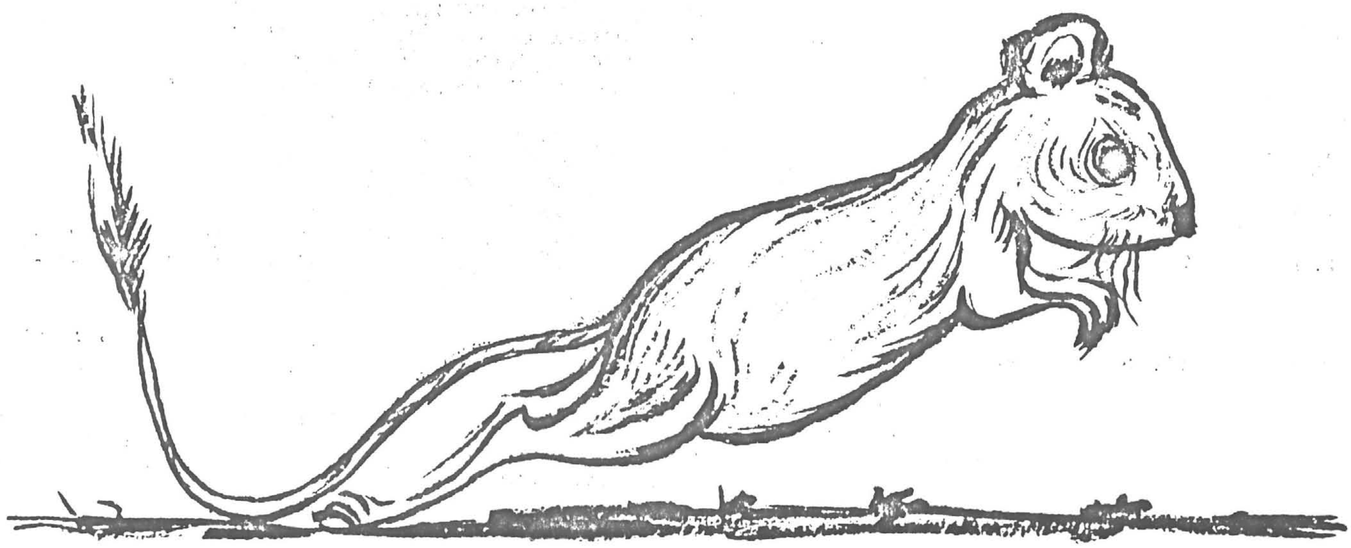
Although interpretations of structure are handicapped by a lack of information on the southwestern part of the Mule Mountains, the structure of this area resembles that of the Tombstone Hills. Nearly east-west structural trends occur in the Bisbee and Tombstone districts, whereas to north and south the trends are more nearly meridional. The resulting over-all pattern resembles a large "S"-curve with a nearly east-west central bar. A thrust fault southeast of Bisbee appears to have adjusted north-south trends to east-west structures in that area.

0.5	94.7	Gently dipping Cretaceous Morita formation in ridge at left. At 11:00; apparent contact of Morita on Pinal schist. Gilluly (1956) shows a thin layer of Glance conglomerate at the contact. A fault separates the Morita and Paleozoic rocks along the south side of Government Butte.
1.5	96.2	Escabrosa limestone is in hill to left of road; Horquilla in hill to right.
0.3	96.5	Bridge, just past curve. Route ascends southward into the Mule Mountains. On skyline ahead, the west-dipping Paleozoic sediments seem to change strike from south toward east.
0.4	96.9	Cambrian Bolsa Quartzite and Abrigo limestone are cut by Triassic or Jurassic Juniper Flat granite along ridge to left of road ahead. Escabrosa limestone at right.
0.5	97.4	Juniper Flat granite and Devonian Martin limestone on right of road.
0.9	98.3	Enter highway cut in Martin limestone. Just before entering cut, Bolsa quartzite on left. On right side of cut, intrusive rhyolite. On emerging from cut, note stock of intrusive rhyolite in late Paleozoic sediments straight ahead.
0.2	98.5	Cliff of Escabrosa limestone on right.
0.1	98.6	Exposures of Cambrian Bolsa quartzite and Abrigo limestone on left.
0.2	99.7	STOP 5. (15 minutes) Juniper Flat granite straight ahead and on left, where it intrudes Paleozoic rocks and Early Precambrian Pinal schist. At 8:30 to 9:00, Bolsa quartzite overlain by Abrigo limestone; at 9:30, knob of granite; at 10:30, Pinal schist on hill. At 10:00, on skyline, Morita formation dipping gently northeast. Fault passes up valley. Upthrown side is on the north. To the south, Escabrosa limestone on skyline overlies Martin limestone; Abrigo limestone is present under Martin beyond ridge. Escabrosa to west; exposures of Horquilla limestone in distance, through gap.
0.2	99.9	Road ascends Tombstone Canyon through cuts in granite and in faulted slivers of Cambrian Bolsa and Abrigo rocks.
0.7	100.6	Cliffs ahead are Juniper Flat granite.
0.8	101.4	Juniper Flat granite to left and Pinal schist at right. Road and stream apparently follow contact up canyon. Ransome's map shows an intrusive contact, but the contact may be the westward continuation of the Dividend fault (B. S. Butler, oral communication).

1.5	102.9	Road cuts in Pinal schist. Granite in cliffs and slopes to left of road.
1.9	104.8	TURN LEFT on old road over pass.
0.3	105.1	Tunnel entrance below at right.
0.2	105.3	Mule Pass (altitude 6,038 feet). Road loops down Mule Gulch. Dumps at new Lavender pit can be seen below in canyon. Granite and Pinal schist in road cuts.
0.3	105.6	Hairpin turn. At 11:00, top of Mural Hill on skyline, capped by Mural limestone; below is the southeast end of the Juniper Flat granite. Hill east of granite is Pinal schist. Road enters Bisbee, altitude 5,300 feet, and winds downward, through sharp curve in Martin limestone at Castle Rock in middle of town.
2.4	108.0	Copper Queen Hotel. Pinal schist crops out at its back door; bright colored granite porphyry at 10:00; Naco group at 3:00.
1.0	109.0	STOP 6. (30 minutes) Lavender pit of Phelps Dodge Corporation. Talks will be given on the open pit operation and on the geology of the Bisbee mining district, which has a production in excess of 2 billion dollars.
0.8	109.8	Traffic circle, TURN RIGHT, off circle at sign reading El Paso and Douglas. The Glance conglomerate is exposed in road cut to right just beyond circle. To the left is a cliff of Mural limestone near the crest of a ridge with Morita underneath.
0.2	110.0	Shattuck Denn Mine at 9:00.
0.4	110.4	Stripping dump on right. Morita formation in hills to the left and right dips eastward.
1.1	111.5	Paved road turns off to right. CONTINUE STRAIGHT AHEAD.
0.9	112.4	To left is a gray cliff of Mural limestone. Stoyanow (1949) separated the less resistant lower beds from Ransome's Mural and called it the Lowell formation. Here, the Lowell formation forms a smooth slope just below the Mural limestone (restricted) cliff and is underlain by the Morita beds. The Cintura formation lies above the Mural cliff. At 1:00 is a fault with Morita (?) at right, Mural on left.
0.4	112.8	Road cut in vertical beds; highway crosses the Mural limestone, and continues in the Cintura formation.
1.0	113.8	Leave lower Mule Gulch.
0.2	114.0	Sulphur Springs Valley ahead.
0.1	114.1	Elfrida short cut on left; CONTINUE ON HIGHWAY. Highway bears right along base of mountains composed of Cretaceous sediments. Sulphur Springs Valley on left; Perilla Mountains at 10:00, with Guadalupe Mountains beyond in New Mexico; Swisshelm Mountains at 8:30, Pedregosa Mountains at 9:00 to 9:30.
2.4	116.5	Phelps Dodge smelter at 10:30.
1.3	117.8	High mountain at 1:30 is in Mexico.
0.9	118.7	Culvert over Glance Creek. At 3:00, limestone of the Naco group in the Mule Mountains are thrust westward (?) over Cretaceous sediments. In hills at 12:00, the Cretaceous Mural limestone dips gently southwest.
1.1	119.8	Pass exposure of Mural limestone on left; curve left; pass Mural exposure on right.
0.9	120.7	At 9:00, Swisshelm Mountains; at 9:30, Chiricahua Mountains (high and dark) in distance; at 10:00, Pedregosa Mountains; at 10:30, Perilla Mountains, all on the far side of Sulphur Springs Valley. Mural limestone quarried on right for smelter flux.

9.8	130.5	Phelps Dodge smelter on right; cross bridge over Whitewater Draw. Whitewater Draw flows into Mexico and joins the Rio Yaqui which flows into the Gulf of Lower California.
0.6	131.1	Road to Elfrida enters on left. CONTINUE STRAIGHT AHEAD.
1.0	132.1	Enter Douglas, altitude 3,990 feet, founded 1902 and named after Dr. James Douglas, one of the principal developers of large scale mining operations in Arizona.
0.4	132.5	Underpass and curve right.
0.4	132.9	Gadsden Hotel.

- END OF FIRST DAY -



GENERAL GEOLOGY OF SOUTHEASTERN ARIZONA

TRIP V, ROAD LOG

(Continued)

Second Day -- April 6, 1959

Leaders: E. B. Mayo and W. D. Pye

Driving Distance: 225.7 miles

Logged Distance: 216.9 miles

Starting Time: 7:00 A. M.

General Statement:

The route leads northward, along the axis of Sulphur Springs Valley to Elfrida. From Elfrida the course is westward to the southern Dragoon Mountains and the old mining camps of Gleeson and Courtland. It will then continue northward along Sulphur Springs Valley, finally turning eastward to ascend the outwash apron of the Chiricahua Mountains. The route will then head northward and northeastward over Apache Pass, and on to Bowie and State Highway 86. From Bowie the route is southwestward to Willcox, then along the northern margin of Willcox Playa. It ascends southwestward past the northern edge of the Red Bird Hills, passes between the Gunnison Hills and Steele Hills, crosses the Little Dragoon Mountains via Texas Canyon, and descends to Benson on the San Pedro River. Beyond Benson the highway ascends westward between the Whetstone Mountains on the south and the Rincons on the north to Mountain View, and on to Tucson.

The party will see: (1) the thrust blocks, intrusions and abandoned mining camps of the southern Dragoon Mountains; (2) some of the volcanic rocks of the northern Chiricahua Mountains; (3) the Precambrian granite and the Cretaceous and Paleozoic sections in Apache Pass; (4) Willcox Playa, lowest part of Sulphur Springs Valley; (5) the Paleozoic section of the Gunnison Hills, and the younger Precambrian Apache and Paleozoic sequences of the Little Dragoon Mountains; (6) the porphyritic granite of Texas Canyon; and (7) the steeply-dipping Miocene (?) Pantano beds west of Benson.

0.0	132.9	Leave Gadsden Hotel.
0.3	133.2	Underpass, and curve left.
0.6	133.8	Leave Douglas.
1.0	134.8	U. S. Highway 666. TURN RIGHT. At 3:00, Perilla Mountains; at 1:00, Pedregosa Mountains, with Chiricahua Mountains beyond; at 12:15, Swisshelm Mountains; at 10:30, Dragoon Mountains; at 9:00 to 10:00, Mule Mountains. Route leads northward along Sulphur Springs Valley.

The correlation of lower Paleozoic strata in this area is in question at the present time. Sabins (1957a) described the Cambrian Bolsa and Abrigo strata in Arizona as the lithogenetic equivalents of the Cambrian Bliss and Ordovician El Paso strata in New Mexico, whereas Epis and Gilbert (1957) contend that they are not. The problem is reviewed by Dickenson (6); see road log at mileage 236.7 . In the Chiricahua Mountains, Sabins (1957a) proposed the Devonian Portal formation which he suggested was a facies change between the Martin limestone of southern Arizona and the Devonian Percha shale of New Mexico. Epis, Gilbert and Langenheim (1957) suggested that, in the Pedregosa and Swisshelm Mountains, the equivalent of the Portal formation is only the lower part of the Martin limestone. They proposed to separate the lower part of the Martin as the Swisshelm formation and suggested that the Devonian Percha, Portal, Swisshelm and Morenci formations are all somewhat older than the Martin limestone (Pye, 7).

6.9	141.7	Bisbee-Douglas airport on right. Continue northward along axis of valley between Swisshelm Mountains on right and Mule Mountains on left.

Sulphur Springs Valley extends northward about 90 miles from the International Boundary. It has an average width of about 20 miles, and an area of about 1,800 square miles. The southern two-fifths of this area, the Douglas basin, is trib-

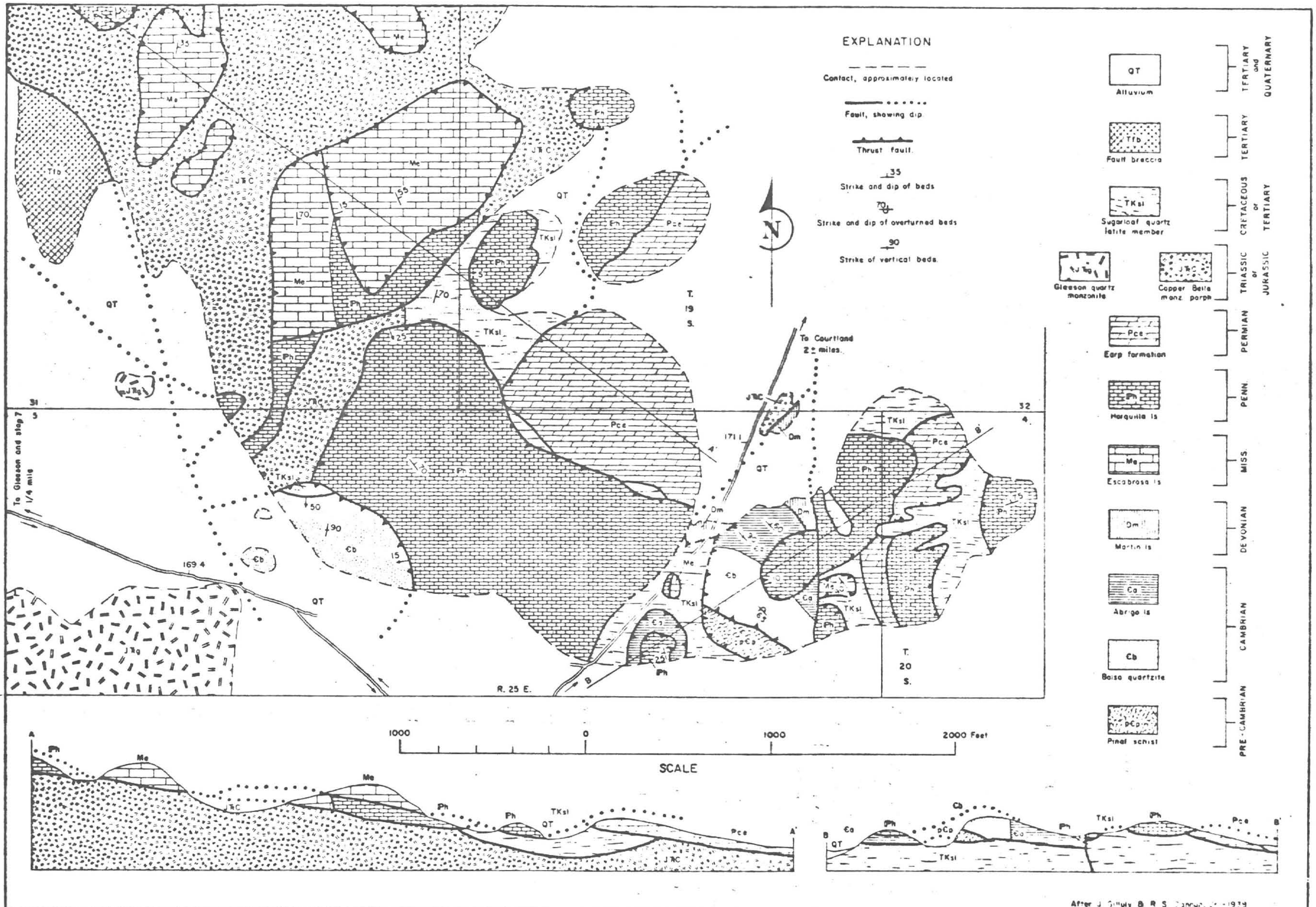


FIGURE 52. Geologic sketch map and cross sections of area east of Gleeson, Cochise County, Arizona, illustrating representative relationships in the thrust breccia of the Courtland-Gleeson area, (after Gilluly, 1956).

utary to Whitewater Draw, which drains into the Yaqui River in Mexico; the northern three-fifths forms a depression of interior drainage, the Willcox basin, with a large barren alkali flat, the Willcox Playa (mileage 274.6), in the lowest part. The valley is named for Sulphur Springs at the southern end of the alkali flat, about six miles north of Pearce. The valley alluvium ranges in thickness from less than 100 feet to more than 2,000 feet (Meinzer and Kelton, 1913; McKee, 1951). Lake beds are known to occur within the valley fill (Meinzer and Kelton, 1913; Coates, 1955).

Irrigation farming, mostly concentrated near and south of Elfrida, is the most important industry in the southern basin of Sulphur Springs Valley, except for copper smelting. The agricultural areas are determined by depth to water and character of the soil. The Willcox basin is also extensively farmed except for the alkali flat. Ranching is practiced mostly in the higher lands bordering the valley.

7.6	149.3	Dos Cabezas Mountains at 1:00; Pinaleno, or Graham, Mountains at 12:30 in far distance; Sulphur Hills in foreground.
1.1	150.4	Curve right. Flat-topped Bowie Mountain at northern end of Chiricahua Mountains at 1:00 (fig. 54A); Square Top Hills at 12:30.
3.0	153.4	McNeal, altitude 4,154 feet. Road enters from left; KEEP STRAIGHT AHEAD. Pinaleno (Graham) Mountains at 12:00, with Pearce Hills and Sulphur Hills in foreground. From here northward, agriculture increases.
3.7	157.1	Cochise Head (fig. 24), named for its resemblance to the head of the famous Apache chief, is in view on the Chiricahua skyline at 2:00; Swisshelms at 3:00. Granitic intrusions into Paleozoic sediments are visible on western slope of the northern end of the Swisshelms.

Loring (1947) mapped the Mountain Queen area on the eastern side of the Swisshelms near their northern end. The structure is a large anticline with a granitic core dated by Loring as Cretaceous. The granite is partly sheathed by the Bolsa quartzite which is overlain by the younger Paleozoic succession. The Paleozoic formations on the eastern limb of this fold have been thrust westward toward the granite core, according to Loring, and, locally, Upper Paleozoic strata rest with thrust contact on the Cambrian. To the east, Tertiary volcanic rocks overlie the thrust structure.

2.2	159.3	Road from Bisbee enters at left. KEEP STRAIGHT AHEAD into Elfrida.
1.3	160.6	Gleeson road. TURN LEFT.
1.0	161.6	Pavement ends. KEEP STRAIGHT AHEAD. Red, biscuit-like knob at 12:30 is Sugarloaf Hill (not Sugarloaf Mountain shown in fig. 24), composed of Sugarloaf quartz latite. The geology and structure of the Dragoon Mountains has been mapped in detail (Gilluly, 1956). Older Precambrian Pinal schist is exposed along the southwestern base and in the southern part of these mountains; the Paleozoic section, sliced by many flat thrusts and cut by later steep reverse faults, lies in disorder along the eastern slope (fig. 52). Northwest of Courtland, along the eastern base of the mountains, the Bisbee formation lies under the thrust plates in a northeastwardly-overturned, southeastward-plunging syncline. Most of the southern end of the Dragoon Mountains is composed of Gleeson quartz monzonite, a possible correlative of the Juniper Flat granite of the Mule Mountains. Associated rocks in the Dragoons that may be of approximately the same age are the Copper Belle monzonite porphyry, the Cochise quartz monzonite and the Turquoise granite.

Subsequent to emplacement of these granitic rocks, but before the thrusting, a volcanic formation, the Sugarloaf quartz latite, accumulated. The thrust sheets seem to have advanced from southwest to northeast. The belt of thrust slices bends abruptly eastward along the northern border of the Gleeson quartz monzonite, then bends southward again to Courtland and Gleeson. The east-west portion of the thrust belt may be a tear, controlled by the shape of the Gleeson quartz monzonite, or by the southward plunge of the syncline of the Bisbee formation. The thrusting movements have resulted in extremely complicated structures. The thrusts originated in post-Bisbee time. The earliest adjustments were on flat overthrusts; later ones were on steep upthrusts.

Subsequent to the thrusting, in the Cochise Stronghold area, the Stronghold granite was emplaced, apparently causing only a broad, gentle doming of pre-existing structures. Southeast of the main mass, dike-like or sill-like bodies of the Stronghold granite were injected along the strike of the Bisbee formation.

The mining camps of Courtland and Gleeson are located in the most complicated portion of the belt of thrust slices, east of the Gleeson quartz monzonite. The geology and ore deposits of the Courtland-Gleeson area were briefly discussed by Ransome (1913) and later by Wilson (1927).

2.1	163.7	Road bends to northwest; Sugarloaf Hill at 11:30.
3.2	166.9	Road bends to north-northwest.
0.4	167.3	Thrust blocks ahead.
0.5	167.8	At 2:00, reddish-colored Brown's Peak composed of Cambrian Bolsa quartzite. Road passes over Horquilla limestone in thrust block.
0.8	168.6	Courtland turn off to right. KEEP STRAIGHT AHEAD. Enter area shown on figure 52 in 0.3 mile.
0.6	169.2	Gleeson Hill on right, with contorted Escabrosa and Horquilla limestones thrust over Copper Belle monzonite porphyry. Dumps of Silver Bill mine.
0.5	169.7	Shannon Mining Company road on right. KEEP STRAIGHT AHEAD.
0.2	169.9	TURN RIGHT into Gleeson.
0.2	179.1	STOP 7. (30 minutes). Workings on Gleeson Hill to east explore thrust faults dipping east. Escabrosa limestone is overlain by Horquilla on ridge top. Copper Belle monzonite porphyry forms slopes below limestone. Small block of Bolsa quartzite makes knob at southwest base. Copper Belle monzonite porphyry, Cretaceous-Tertiary Sugarloaf quartz latite, Cambrian Abrigo limestone and Mississippian Escabrosa limestone are exposed in patches. Brown's Peak, with Bolsa quartzite underlain by Turquoise granite, is on skyline to northeast. The pink mountain to the northwest is alaskite associated with Gleeson quartz monzonite. TURN AROUND.
0.2	170.3	TURN LEFT on main road.
1.2	171.5	TURN LEFT on Courtland road. Sugarloaf quartz latite to right before turn. Low hills to left are Gleeson quartz monzonite.
0.5	172.0	Bolsa on Brown's Peak at 10:00. Exposures at 11:00 to 1:00 are Escabrosa limestone, Horquilla limestone and Sugarloaf quartz latite. Leave area shown on figure 52.
0.5	172.5	Hill at right of road is composed of thrust slices. Tertiary (?) Sugarloaf quartz latite rests on Horquilla limestone. In hill at left of road, Mississippian Escabrosa limestone rests on Pennsylvanian Horquilla.
0.6	173.1	At 9:00, on northeast side of Gleeson Hill, note Escabrosa and Horquilla limestones on Copper Belle monzonite porphyry. The dumps are located approximately along trace of thrust. Low ridge of Sugarloaf quartz latite extends east from Brown's Peak at 10:30.
0.1	173.2	At 9:00, in gap between Gleeson Hill and Brown's Peak, note Sugarloaf quartz latite on Escabrosa limestone. Pinkish summit beyond, on skyline, is alaskite.
0.6	173.8	Ridge of pink Sugarloaf quartz latite at 9:00. Road enters from left. KEEP STRAIGHT AHEAD.
0.1	173.9	Hill ahead at 11:30 is Escabrosa limestone on Copper Belle monzonite porphyry.

		Old buildings of Courtland at 10:00; red, mineralized zone to left. Bolsa along ridge on skyline overlies Abrigo limestone and Sugarloaf quartz latite, all in thrust slices. At 10:00 is rounded pink hill of Sugarloaf quartz latite. Hill at 1:30 is of Escabrosa and Martin limestones on Copper Belle monzonite porphyry.
0.6	174.5	Road intersects from right. STRAIGHT AHEAD to Courtland.
0.4	174.9	Courtland. Enter area shown on figure 53.
0.4	175.3	Road crosses thrust slice of Escabrosa limestone and descends to North Courtland.
0.2	175.5	North Courtland. Bolsa knobs are on right of road.
0.6	176.1	Top of rise. Hill to north is Sugarloaf quartz latite.
1.1	177.2	STOP 8. (20 minutes). Road intersects from left. Bold, jagged outcrops of the post-thrust, Tertiary (?) Stronghold granite at 10:30 in the Dragoon Mountains. At 10:00, minor, northwest-trending masses of Stronghold granite are intruded along the strike of the Bisbee formation. The strong, east-west fault zone along the northern border of the Gleeson quartz monzonite is to the west. Alaskite forms the high peak, which was also seen from Gleeson. North of the fault zone are northwest-trending ridges, capped by Bolsa quartzite, with Paleozoic sediments, Bisbee formation, Cretaceous volcanic rocks and Copper Belle quartz monzonite in successive thrust slices down slope. Hills to east and northeast are Sugarloaf quartz latite. TURN AROUND, retrace route through Courtland.
2.7	179.9	TURN LEFT (east).
0.7	180.6	From left to right on far side of Sulphur Springs Valley are the Dos Cabezas, Chiricahua and Swisshelm Mountains. The sharp peak at the northern end of the Chiricahua Mountains is Helen's Dome; to the right, the nearby flat-topped summit is Bowie Mountain. Cochise Head is at 11:00 and the high part of the Chiricahua Range is at 11:30-12:00. The volcanic hills in the valley are mostly Tertiary Pearce volcanics. Road again descends the long bajada to the valley floor. For 20 years following the Gadsden Purchase in 1853, the Chiricahua Apaches virtually controlled Sulphur Springs Valley and the surrounding territory. After 1872, when danger from the Indians had somewhat lessened, many cattle ranches were established in the valley and near the surrounding mountains. Gilbert and Loew (1873) studied the northeastern part of the valley. Loew remarked concerning the shallow depth to water and announced that "crops will be raised this year for the first time". In 1880, the main line of the Southern Pacific Railroad was built across the northern part of the valley, and the village of Willcox grew to be the supply station for a large surrounding area (Meinzer and Kelton, 1913).
6.2	186.8	STOP SIGN. TURN LEFT ON Highway 666.
1.9	188.7	Hills to right, extending north from the Swisshelm Mountains are Cambrian, Devonian and Mississippian sediments and Tertiary volcanics (Darton and others, 1924).
5.6	194.3	Square Top Hills on right are Bisbee formation and Escabrosa limestone (Gilluly, 1956). Pearce Hills ahead and on left are Tertiary Pearce volcanics. The rich silver-gold ore bodies of the Pearce district occurred on north-of-west-striking veins in the volcanic rocks (Endlich, 1897) and were mined out long ago.
1.2	195.5	TURN RIGHT on State Highway 181.
1.2	196.7	Ash Creek Ridge, with Bisbee group and Paleozoic limestone, to south. Chiricahua Mountains ahead.
0.8	197.5	Curve right, then left, toward Chiricahua Mountains. The Chiricahua Mountains, once the heart of Chiricahua Apache territory, are one of the most impressive

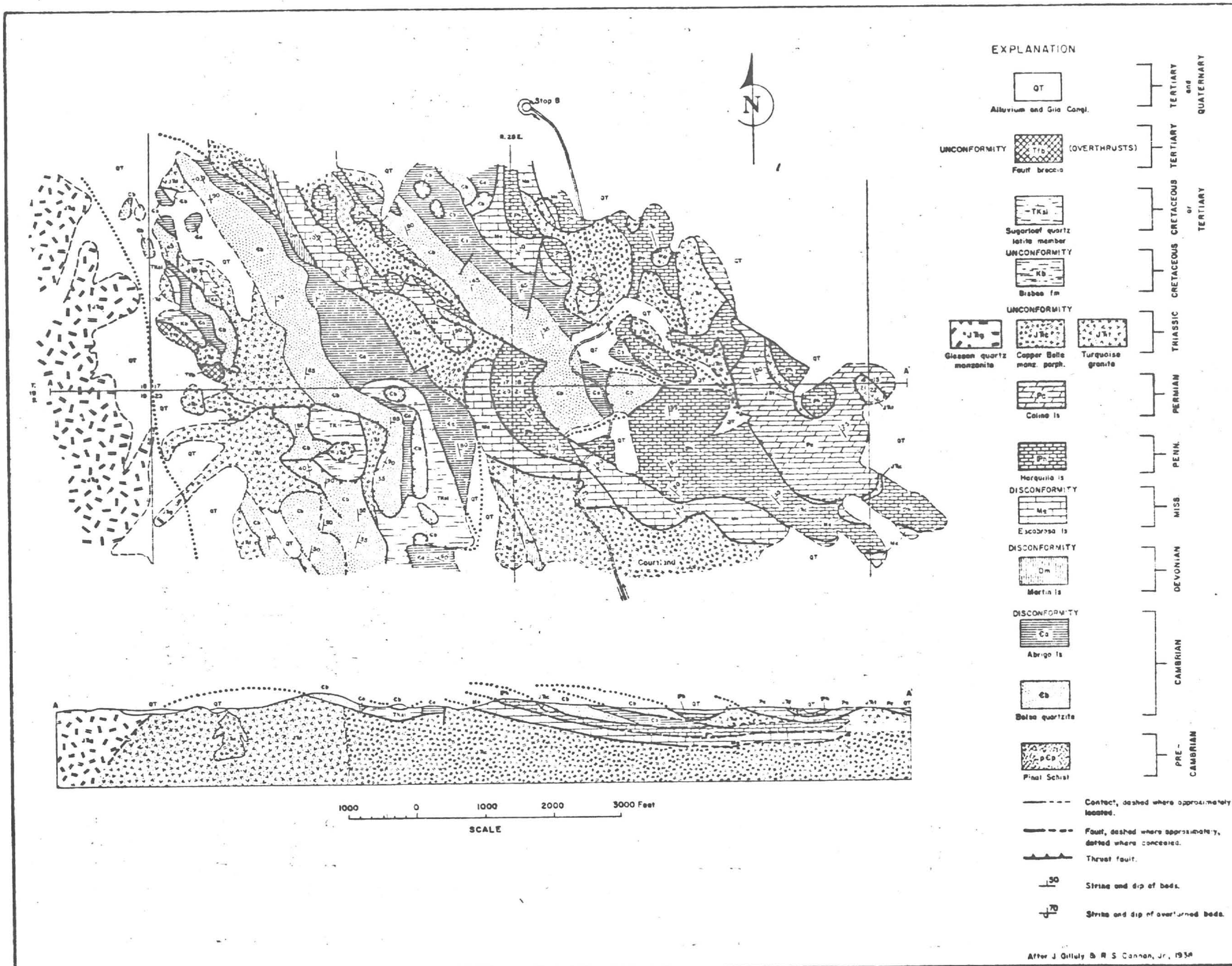


FIGURE 53. Geologic sketch map and cross section of thrust breccia near Courtland, Cochise County, Arizona (after Gilluly, 1956).

ranges in southeastern Arizona. They are about 40 miles long and 20 miles wide; the two summit peaks, Fly's Peak and Chiricahua Peak are nearly 9,800 feet above sea level. The higher portion of the Chiricahuas is dark with a conifer forest.

The high, central portion of the Chiricahuas is composed mostly of Tertiary volcanic rocks, although Paleozoic and Cretaceous rocks crop out locally. The geology at the northern end has been described by Enlows (1955) and Sabins (1957b). The Chiricahua Range is essentially a north-trending mass, but near its northern end, it turns westward and continues, beyond Apache Pass, as the Dos Cabezas Mountains.

The geology of the northern Chiricahuas and of the Dos Cabezas Mountains differs from that of the southern end. In the Dos Cabezas Mountains, the older Precambrian rocks are Pinal schist, intruded by foliated Sheep Canyon granite and nonfoliated Rattlesnake Point granite. The younger Precambrian Apache group is not present (Lance, 4).

The Paleozoic section includes the Cambrian Bolsa quartzite; the Cambrian and Ordovician El Paso formation (Dickenson, 6); the Upper Devonian Portal formation (Pye, 7); Lower Mississippian Escabrosa limestone; Upper Mississippian Paradise formation (Thomas, 8); Pennsylvanian Horquilla limestone; Pennsylvanian and Permian Earp formation (Havenor, 9); and the Permian Colina limestone, Scherrer formation and Concha limestone (Bryant, 10). These are unconformably overlain by the Cretaceous Glance conglomerate and "Middle and Upper Bisbee strata" (Sabins, 1957a; Fergusson, 11). Southward, the latter in turn are overlain by Tertiary volcanic rocks (Mayo, 22).

The change in trend from a northerly direction in the main mass of the Chiricahuas to a westerly direction in the northern Chiricahuas and Dos Cabezas seems to have been adjusted in post-Comanche time by curved overthrusts, concave to the southwest. There were two periods of thrusting here, as in the Dragoon Mountains, and some of the earlier thrusts were folded as the later ones came forward. The allochthonous blocks moved northward, or northeastward, from the concave toward the convex sides of the arcs. Several tear faults were formed; one, the fault in Emigrant Canyon, has a strike slip of perhaps 2 miles (Sabins, 1957b; fig. 25).

8.5	206.0	Cochise Head at 10:30 (fig. 24). This rugged, 8,000-foot mountain was eroded from the Tertiary volcanic Faraway Ranch formation.
2.0	208.0	TURN LEFT, follow Highway 181. Dirt road to Turkey Creek Recreation Area continues eastward.
0.8	208.8	Cross tree-lined channels of Turkey Creek.
0.8	209.6	Dos Cabezas Peaks at 11:00; Helen's Dome and flat-topped Bowie Mountain at 1:00. Tertiary volcanic rocks to right of road and in Pat Hills to left ahead. Volcanic rocks in Sulphur Hills far down slope to left may be Cretaceous in age.
2.9	212.5	Hills are Tertiary volcanic rocks, probably of the Faraway Ranch formation.
2.2	214.7	Curve right. Conical peak at 1:00 is Sugarloaf Mountain, composed of welded rhyolite tuff, capped by a thick flow of rhyodacite, youngest member of the Rhyolite Canyon formation.
3.5	218.2	Cross usually dry bed of Pine Creek. Bowie Mountain ahead (fig. 54A).
0.4	218.6	Paved road to Chiricahua National Monument turns right. KEEP STRAIGHT AHEAD on dirt road.
0.8	219.4	Cross dry bed of Pinery Creek. Chiricahua National Monument to right. Finely pinnacled topography has been etched on welded tuff of the Rhyolite Canyon formation.
0.9	220.3	Bowie Mountain at 3:00 with Helen's Dome immediately to left. Both mountains are steeply south-plunging synclines of older Precambrian quartzite in Pinal schist (Sabins, 1957b). To right is the area where the steeply southwest-dipping

		Paleozoic and Cretaceous rocks are thrust northeastward against the Marble Quarry syncline block which contains the folded Fort Bowie thrust (fig. 25).
2.5	222.8	Dos Cabezas Mountains at 12:00 to 1:00. The two summit peaks are Cretaceous or Tertiary volcanic rocks.
4.6	227.4	Apache Pass road. TURN RIGHT to Bowie.
1.3	228.7	Curve left.
1.2	229.9	At 3:00, on lower southwestern slope of Bowie Mountain, Bolsa quartzite, overlain by younger Paleozoic and Cretaceous strata, rests with steeply south-dipping depositional contact on tightly folded Pinal schist and quartzite. The synclines of older Precambrian quartzite acquired their steep plunge after the Paleozoic and Comanche sediments had been deposited on them (Sabins, 1957b).
1.2	231.1	Low hills ahead and to the right are Precambrian Rattlesnake Point granite. Paleozoic and Comanche (Bisbee) rocks on skyline at 12:00. Enter area shown on figure 25.
0.9	232.0	Curve right; Apache Pass ahead.
1.7	233.7	Top of Apache Pass, altitude 5,115 feet, is in Precambrian Rattlesnake Point granite. Peloncillo Mountains ahead on skyline. The Overland Mail, from St. Louis to San Francisco and return, which first moved over the Butterfield Trail in 1858, was routed through Apache Pass. The service was interrupted by Indian trouble for the first time in its history one night in 1861 (Judd, 1958). Following a battle between the Indians and Union troops near the pass in 1862, Fort Bowie was established by Colonel George W. Bowie. In spite of every military effort however, Cochise, whose stronghold was in the rugged, easily defended portion of the Dragoon Mountains, prevented white settlement in the region for ten more years. In 1872, General O. O. Howard concluded a treaty of peace with Cochise, which was honored until the great war chief's death in 1874. Following the death of Cochise, there were other Indian uprisings, but never again were the Apaches so effective a bar to white settlement as they had been under Cochise.
0.4	234.1	Site of wagon train massacre, 1861.
0.2	234.3	Butterfield stage trail at right, below road.
0.8	235.1	STOP 9. (One hour, lunch will be served.) Old Fort Bowie ruins are about 2 miles southeast. Helen's Dome is tower-like peak nearly due south. High, flat-topped mountain to left is Bowie Mountain. Contact between Horquilla limestone and upthrust Rattlesnake Point granite is just west of ruins.
0.4	235.5	Granite is highly disturbed and darkened, and intruded by dikes.
0.2	235.7	Steep, upthrust contact of Bisbee group, with a limestone conglomerate member, to east and crushed granite to west. Road leads down through sheared and contorted Bisbee group,
0.6	236.3	Thin layer of Glance conglomerate by rock cairn on turn, underlain successively by marbleized Escabrosa limestone, thin-bedded Portal formation, and the El Paso limestone. The absence of younger Paleozoic rocks may be due to thrusting.
0.2	236.5	El Paso limestone on Bolsa quartzite to right, in ridge across canyon.
0.2	236.7	Bolsa quartzite, overlain by El Paso limestone and dipping southward, is exposed both east and west of the road. In wash to the right (east), the upper, silty portion of the Bolsa is well exposed (Dickenson, 6).
0.1	236.8	Pinal schist below Bolsa on right. Emerge from canyon.
0.4	237.2	On left, high on mountain, the contact is in view between the foliated, older Pre-

cambrian Sheep Canyon granite on the northeast and the Pinal schist on the southwest. Leave area shown on figure 25.

2.5	239.7	San Simon valley ahead. Peloncillo Mountains, along Arizona-New Mexico State Line, form northeast side of the valley. Pinaleno (Graham) Mountains form a high ridge at 10:00, with low Fisher Hills in front. Mt Graham rises to an altitude of 10,716 feet. Whitlock Hills at 12:00. Smelter smoke at Morenci can sometimes be seen at about 1:30.

The San Simon Valley, beginning about 18 miles north of the International Boundary, extends north-northwestward 85 miles to the Gila River near Safford. Maximum width of the valley is about 35 miles. According to Schwennesen (1917), the valley fill in this vicinity consists of three units: (1) about 150 feet of stream deposits, (2) 350 feet of blue clay lake beds, and (3) a basal series of stream deposits, including conglomerate, exceeding 850 feet in thickness. Knechtel (1936), on fossil evidence, assigned a Pliocene age to deposits near Safford. The stratigraphic relationships between sub-surface units near San Simon and Safford are not known.

Although some ground water near San Simon is under artesian pressure, wells must be pumped to supply sufficient water for agricultural purposes. Water is pumped for irrigation purposes near Bowie, also. The geologic control of ground water in this valley is discussed briefly by DeCook (1952). Deep wells and test holes are discussed by Konlowski (1953) and Johnson (14).

According to Sabins (1957b), the Portal Drilling Co. well No. 1, located about 16 miles south of San Simon, penetrated about 2,000 feet of alluvium above rhyolite and bottomed at 5,800 feet in rock like that of the Rhyolite Canyon formation. The Arizona Oil & Gas Corp. State No. 1 well, drilled to a depth of 7,568 feet, three miles from bedrock outcrop north of Dunn Springs Mountain, encountered only valley fill and deposits of rhyolite gravel. These data indicate large-scale normal faulting marginal to the northern Chiricahuas (Sabins, 1957b).

3.0	242.7	At 9:00, bold outcrops of light-colored Tertiary silicic intrusion in contact with Sheep Canyon granite on ridge. Dos Cabezas Peaks on skyline at 9:30.
3.0	245.7	Back on pavement.
3.2	248.9	STOP SIGN. Bowie, altitude 3,762, and intersection with State Highway 86. TURN LEFT.
2.0	250.9	Bridge over Buckeye Wash. Highway 86 leads westward over rolling plain, covered by mesquite and occasional yucca.
2.7	253.6	Culvert. On right, Fisher Hills, of Tertiary volcanic rocks, trend west-northwest, parallel to front of Dos Cabezas Mountains on left. Foothills of the Dos Cabezas range, near highway, are older Precambrian Pinal schist.
2.5	256.1	Going into right turn. Bridge over Gold Gulch; underpass just beyond. Graham Mountains ahead are older Precambrian granite and gneiss.
1.7	257.8	Road to Safford, Globe and Morenci turns off at right. Greasewood Mountains, at southern end of Grahams, at 1:30, are mostly Tertiary volcanic rocks with exposures of Precambrian granite. Winchester Mountains at 12:00.
1.1	258.9	Road cuts in alluvial conglomerate for next several miles. Rolling surface, leading through Railroad Pass, is covered with grass and yucca.
2.7	261.6	West branch of Safford road joins highway from right.
3.5	265.1	Railroad Pass, altitude 4,932. Circle I Hills of Tertiary volcanic rocks on Precambrian granite and schist at 1:30; Winchester Mountains at 1:00; Little Dragoon Mountains at 12:00; Dragoon Mountains at 11:00. Road passes around northwestern end of Dos Cabezas Mountains.
3.4	268.5	Spike E. Hills, of Precambrian granite, at 2:30, seem to be a continuation of the westward trend of the Dos Cabezas Mountains. Good view of Winchester

Mountains beyond. Little Dragoons at 1:00; Dragoons at 12:00. Willcox Basin ahead. The geology of this basin and its surroundings has been reviewed by Jones and Cushman (1947).

1.4 269.9 Northeast edge of ancient Lake Cochise (Meinzer and Kelton, 1913). Chiricahua Mountains at 9:30; Pat Hills, Sulphur Hills and Swisshelm Mountains at 10:00.

2.8 272.7 Entering Willcox, altitude 4,168, in the Willcox basin of Sulphur Springs Valley. Ranching and irrigation farming, using pumped water, are practiced near Willcox. The status of the underground water supply has been reviewed by Coates (1952). Sites of nearby oil test holes and of one deep water well are shown on figure 10 (Johnson, 14).

1.9 274.6 Leaving Willcox, highway traverses flat grassland, growing on lacustrine sediments of Lake Cochise, along the northern border of Willcox Playa.

Ancient Lake Cochise (Meinzer and Kelton, 1913) possibly existed during the Wisconsin stage of the Pleistocene epoch. The lake may have been 20 miles long and 11 miles wide. Near Willcox, its shore line is marked in part, today, by a gravelly beach ridge buried by post-Wisconsin wind-blown sand. Data from wells indicate that, beneath thicknesses ranging up to 280 feet of alluvial sediments, there exists a thick layer of dark blue to black clay, probably deposited in a large, quiet body of water. Thus there seems to have been another, older and larger lake in this basin long before the time of ancient Lake Cochise. Meinzer and Kelton suggested that this lake existed during one of the earlier glacial stages, possibly the Kansan.

The Winchester Mountains, at 2:30, are mostly Tertiary-Cretaceous volcanic rocks, but rocks ranging in age from Precambrian to Cretaceous crop out in the southern spurs.

2.9 277.5 Santa Catalina Mountains in view in distance at 1:30; Little Dragoon Mountains ahead; Dragoons at 10:00 to 11:00. Passing around southern end of Winchesters.

2.5 280.0 Willcox Playa at 9:30. Croton Springs, near which the beach ridge is especially well developed, are on the northwest edge of the playa. Highway crosses beach ridge.

2.0 282.0 Bisbee-Douglas turn off on left; underpass. Start climb out of Willcox basin, up mesquite covered slopes.

3.3 285.3 Pass between Red Bird Hills on left and Steele Hills on right. Road cut at north end of Red Bird Hills in Bisbee formation. The Little Dragoon Mountains and outlying ridges contain well-exposed sections of Paleozoic sediments (Gilluly, Cooper and Williams, 1954). The geology of this area is shown on figure 26 (Cooper, 23).

1.4 286.7 Road cut in alluvial conglomerate.

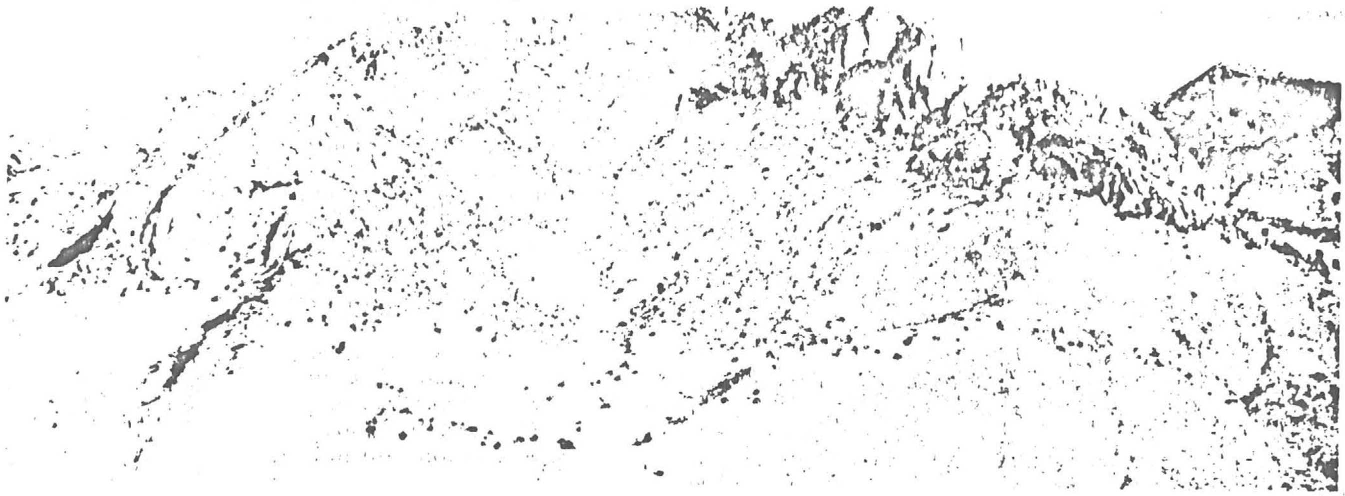
1.7 288.4 Cross low gap in Scherrer Ridge, a northern extension of the Gunnison Hills. On Scherrer Ridge, south of the highway, are the type localities of the Permian Scherrer formation and Concha limestone, and, in the Gunnison Hills three miles farther south is the type section of the Upper Mississippian Black Prince limestone (Gilluly, Cooper and Williams, 1954). Steeply dipping Paleozoic rocks can be seen in the Gunnison Hills to south (left).

1.3 289.7 Older Precambrian Pinal schist overlain by younger Precambrian Apache group and by Paleozoic sequence in Little Dragoon Mountains at 3:00 (fig. 54B). Start climb toward Texas Canyon, through road cuts in alluvial conglomerate.

1.5 291.2 Johnson Camp turn off on right. Underpass. Contact of Texas Canyon granite with older Precambrian Pinal schist at 1:30.

0.6 291.8 Curve left. Entering Texas Canyon. Road cuts are in Texas Canyon granite.

The Little Dragoon Mountains and the Johnny Lyon Hills, to the northwest, have been mapped by Cooper, Silver and others (Cooper and Silver, 1954; Cooper, 23).



A. Bowie Mountain from southwest. Syncline of older Precambrian quartzite plunges toward observer. Sharp, narrow ridge in foreground is Cambrian Bolsa quartzite, overlain toward observer by the succession of Paleozoic strata.

B. South face of Little Dragoon Mountains from east-southeast (fig. 26). Ground in lower left is Precambrian Pinal schist, overlain on right by younger Pre-cambrian Apache group, and this in turn is overlain by Paleozoic strata up through the Mississippian Escabrosa limestone, which caps Johnson Peak (right center) and the high peak to its left. Rincon Mountains on distant skyline.

FIGURE 54. Aerial views of Bowie Mountain and Little Dragoon Mountains, Cochise County, Arizona. Photos by Tad Nichols.

The Texas Canyon granite has been shown to be of Tertiary age. The well developed joints in this granite and an elusive parallelism of feldspar phenocrysts strike northeast.

1.6	293.4	STOP 10. (20 minutes). Texas Canyon rest area. Exposures of jointed porphyritic Texas Canyon granite. View westward into San Pedro Valley with Whetstone Mountains beyond. Ridge to left of highway is of Mesozoic volcanic rocks. Mt. Glen, in Dragoon Mountains across highway to south. Dos Cabezas Peaks to east beyond and to left of the Gunnison Hills. High Chiricahuas to southeast beyond Sulphur Springs Valley.
0.4	293.8	Pinnacles of Tertiary Stronghold granite at Cochise Stronghold in Dragoon Mountains at 9:30. Highway descends through cuts in Texas Canyon granite.
1.3	295.1	Turn off to Dragoon is on left. Dark patches of Mesozoic volcanic and sedimentary rocks in granite on ridge to right. Ridge of Mesozoic rocks on left.
2.4	297.5	Emerge from Texas Canyon. Whetstone (?) pediment cut on granite at left, descends toward San Pedro Valley.
0.6	298.1	Huachuca Mountains at 10:30; Whetstones at 11:30, with Mustangs at southern end and Santa Ritas in view beyond. Younger Precambrian Apache group and Paleozoic sediments exposed in Little Dragoons at 3:30.
1.4	299.5	Johnny Lyon Hills, with core of older Precambrian granite and schist, bordered by rocks ranging in age from Precambrian to Cretaceous, at 3:00; Rincon Mountains at 2:00. Gneisses in Rincons dip moderately northeastward, and are cut by a set of strong, steep fractures. Tombstone Hills at 9:00.
3.6	303.1	San Pedro Valley beds of probable Pliocene to Pleistocene age aprear in gullies to left of road.
0.2	303.3	Begin descent through San Pedro Valley beds from Whetstone pediment to Aravaipa surface. Late Pliocene or early Pleistocene fossils have been found in these beds at a lower level near the valley axis, (Gidley, 1922; Gilmore, 1922; Wetmore, 1924; Gidley, 1926; Bryan, 1926; Stirton, 1931; Gazin, 1942). The geology of the San Pedro Valley in relation to ground water has been briefly discussed by Heindl (1952a and b).
2.1	305.4	Entering curve right. San Pedro Valley beds in view across valley.
2.4	307.8	Bridge across San Pedro River.
0.7	308.5	Underpass. Benson, altitude 3, 580. Benson is the principal community in the San Pedro Valley north of Bisbee. The main industry in the San Pedro Valley is cattle ranching, with some irrigation farming, mining and tourist trade.
1.7	310.2	Leaving Benson. Red sediments to south and southwest of highway contain the Benson fauna of Blancan (late Pliocene to early Pleistocene) age.
1.9	312.1	Whetstone overpass. Whetstone Mountains at 10:00; Rincon Mountains at 2:00. Curve right, enter cuts in red sediments.
5.1	317.2	Underpass. Santa Rita Mountains on skyline at 10:00.
1.6	318.8	Road cut in alluvial conglomerate.
1.0	319.8	Road cut in Cretaceous sediments, dipping steeply southward. Rincon Mountains at 3:00; small hills at 9:00 are Cretaceous (?) sediments. Empire Mountains at 10:30, with Santa Ritas beyond.
2.2	322.0	Amole overpass. Road cuts beyond are in moderately west-dipping Miocene (?) Pantano beds (Brennan, 1957; Wood, 13).
3.1	325.1	Pantano underpass and bridge over Cienega Creek, followed by road cuts in Pantano beds, unconformably overlain by alluvial conglomerate.

1.3	326.4	Bridge over wash. Road cuts in steeply-dipping Pantano beds beyond.
1.6	328.0	Wash, with very steeply dipping Pantano beds, unconformably overlain by gently dipping alluvial conglomerate in west bank.
0.5	328.5	Cretaceous sediments to left of road and more in cuts beyond.
0.7	329.2	Wash. Pantano beds in road cuts beyond.
0.9	330.1	Davidson Canyon; cuts in alluvial conglomerate beyond.
1.1	331.2	Santa Catalina Mountains in view at 2:00 (Trip III); Mt. Fagan at north end of Santa Ritas at 9:30.
1.1	332.3	Sonoita turn off at left. Mountain View. Colossal Cave area at 3:00; Sierrita Mountains at 10:00, with Pima open pit dump in front (Trip I).
2.9	335.2	Saguaro National Monument and Vail road turns off at right.
1.9	337.1	Curve left, then right. Tucson Mountains at 12:00; Black Mountain at 11:00; Sierrita Mountains at 10:00 (Trip I); Coyote-Quinlan Mountains in far distance at 10:30; Santa Catalinas at 2:00.
10.8	347.9	Tucson Mountains ahead (Trip IV). The three pyramidal peaks are Tertiary Cat Mountain rhyolite. Black Mountain at southern end is composed of Tertiary volcanic and alluvial rocks (Heindl, 25). Pinnacles between are in the Beehive-Saginaw Hill area (Kinnison, 24). In low pass between Santa Catalina and Rincon Mountains, at 4:00, are klippen (?) of limestone and Pantano red beds resting on the gneisses.
1.9	349.8	TRAFFIC LIGHT. Intersection of Benson Highway and Palo Verde road. Via Palo Verde and Speedway, it is 8.8 miles to University of Arizona Campus.

- END OF TRIP -

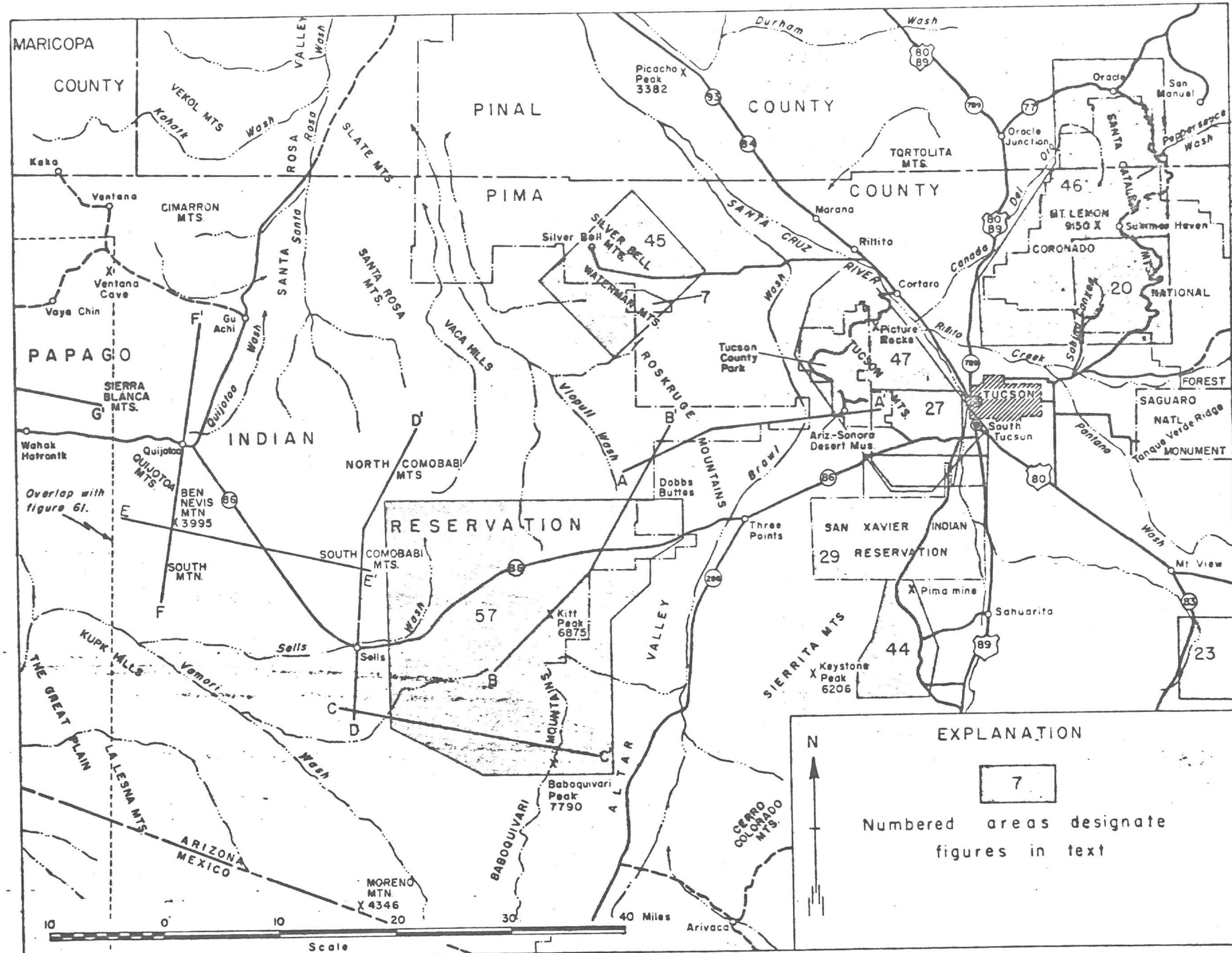


FIGURE 55. Index map of a part of central southern Arizona showing route of east half of Field Trip VI, locations and figure numbers of maps for Field Trips I, II, III, and IV and related articles, and generalized locations of diagrammatic cross sections shown in figures 56, 59, and 60.

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GEOLOGY AND STRUCTURAL ENVIRONMENT OF THE SIERRITA MOUNTAINS, PIMA COUNTY, ARIZONA

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GEOLOGY AND STRUCTURAL ENVIRONMENT

OF THE

SIERRITA MOUNTAINS, PIMA COUNTY, ARIZONA

I INTRODUCTION

Geologic mapping was undertaken in the Sierrita Mountains as part of a Doctoral program at the University of Arizona, Tucson.

During the study, approximately 35 square miles was mapped in detail, with particular attention given to specific areas of great or significant structural complexity and their relation to mineralization in the vicinity.

A combination of field studies and photogeologic interpretation was used in order to define regional and local structural controls for disseminated copper-molybdenum mineralization in and adjacent to the study area.

Gratitude is expressed to the faculty of the University of Arizona, Department of Geology for their assistance in this work and to Bear Creek Mining Company for making numerous reports and drill cores available for study.

II SUMMARY AND CON CLUSIONS

Rocks ranging from Lower(?) Cretacous through Quaternary in age are exposed in the eastern Sierrita Mountains. A thick sequence of andesitic and rhyolitic pyroclastics and flows, the Oxframe Formation of Lower(?) Cretaceous age, is unconformably overlain by dominantly rhyolitic pyroclastics of Upper(?) Cretaceous age. The entire volcanic sequence is intruded by a complex group of intrusives, ranging from diorite to alaskite and including quartz monzonite, granodiorite, and granite, as well as dikes of basaltic,andesitic and latitic composition. The intrusives are early Tertiary in age, related to the Laramide orogeny. Though compositionally and geographically separate, the intrusives appear to represent products of the differentiation of a single magmatic source and were emplaced over a very short span of time (approximately 5 million years).

Structural elements defined include (1) a post-volcanic, pre-intrusive east-west compressional force which produced northwesterly-trending, high-angle wrench faults characterized by left lateral movement, (2) a similar east-west compressional episode, post-intrusive in age, which produced northeasterly-trending wrench faults, (3) domal uplift associated with emplacement of the intrusives which tilted the volcanic sequence and produced essentially north-trending faults in the pediment east of the range.

Mineralization, ranging from extensive porphyry copper-type concentrations of copper and molybdenum to small high-grade veins containing lead, copper, silver and gold, is present in the district. Small uraniferous concentrations occur at one locality. Radiometric age dating indicates a close correlation between ore deposition and intrusion of the equigranular granodiorite, suggesting a genetic relationship between the two. Structural control of the Esperanza Wash copper-molybdenum deposit is