UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

# GUIDEBOOK FOR PAST FIELD TRIPS TO THE NEVADA TEST SITE

by

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Open-file Report

1969

69-38

This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards and nomenclature.

CONTENTS

## GENERAL INTRODUCTION

A wide variety of geological studies has been undertaken by the U.S. Geological Survey at the Nevada Test Site since 1957 in cooperation with the Nevada Operations Office of the U.S. Atomic Energy Commission. This book has been prepared as a guide to some of the major results of the Survey's studies in this area and has been divided into three topically oriented field trips.

In several respects the Nevada Test Site is located in an area that is especially interesting geologically. It lies along the projected trend of the Walker Lane and the Las Vegas Valley Shear Zone (Locke and others, 1940; Longwell, 1960), one of the major crustal features of the Basin-Range province. The shear zone itself, however, may not continue through the Test Site in a simple way (Burchfiel, 1965). The Test Site is in a belt of late Mesozoic thrust faults along the eastern side of the Cordilleran miogeosyncline. The eastern part of the Test Site area is characterized by the parallel Cenozoic topographic and structural elements generally associated with the Basin and Range province; the western part of the area was the locus of intense late Miocene and early Pliocene volcanism whose topographic and structural effects in part overprint the more typical Basin-Range geologic features. The Quaternary basin-filling deposits and some of the Tertiary volcanic rocks of Yucca Flat and nearby areas have been the principal media in which the underground nuclear testing program of the Atomic Energy Commission has been carried out.

## REFERENCES CITED


Burchfiel, B. C., 1965, Structural geology of the Specter Range quadrangle, Nevada, and its regional significance: Geol. Soc. America Bull., v. 76, p. 175-192.

Locke, A., Billingsley, P., and Mayo, E. B., 1940, Sierra Nevada tectonic pattern: Geol. Soc. America Bull., v. 51, p. 513-540.

Longwell, C. R., 1960, Possible explanation of diverse structural patterns in southern Nevada: Am. Jour. Sci., v. 258-A (Bradley Vol.), p. 192-203.

## PALEOZOIC STRATIGRAPHY AND POST-PALEOZOIC TECTONIC STRUCTURE OF NEVADA TEST SITE AND VICINITY

[Trip leaders: Forrest G. Poole and Harley Barnes]

The principal objectives of this trip are to examine parts of the thick miogeosynclinal section of Paleozoic rocks and some of the post-Paleozoic structural features in the Nevada Test Site and Las Vegas Valley region (fig. 1). Although the trip route offers distant views of most of the Paleozoic section and many post-Paleozoic structural features, only a few outcrops are accessible by bus for close-hand examination. Of the seven stops scheduled, three of them involve walking over parts of the Middle and Upper Cambrian, Middle and Upper Ordovician, Lower(?) and Middle Silurian, and Upper Mississippian rocks. Also, the Mine Mountain Thrust Fault can be studied at close hand.

The first walking stop is near the "silica quarry" at the southwest end of the Spotted Range. Here one can traverse the uppermost part of the Antelope Valley Limestone, the Eureka Quartzite, the Ely Springs Dolomite, and lower part of the "dolomite of the Spotted Range."

The second walking stop is at Mine Mountain to examine the type Mine Mountain thrust. Here one sees argillite of the Eleana Formation in the lower plate and highly fractured and altered carbonate rock of Devonian age in the upper plate.

The third walking stop is at the southern end of Teapot Ridge and Banded Mountain at the northwest side of the Halfpint Range to examine the upper part of the Bonanza King Formation and the Dunderberg Shale and Halfpint Members of the Nopah Formation.

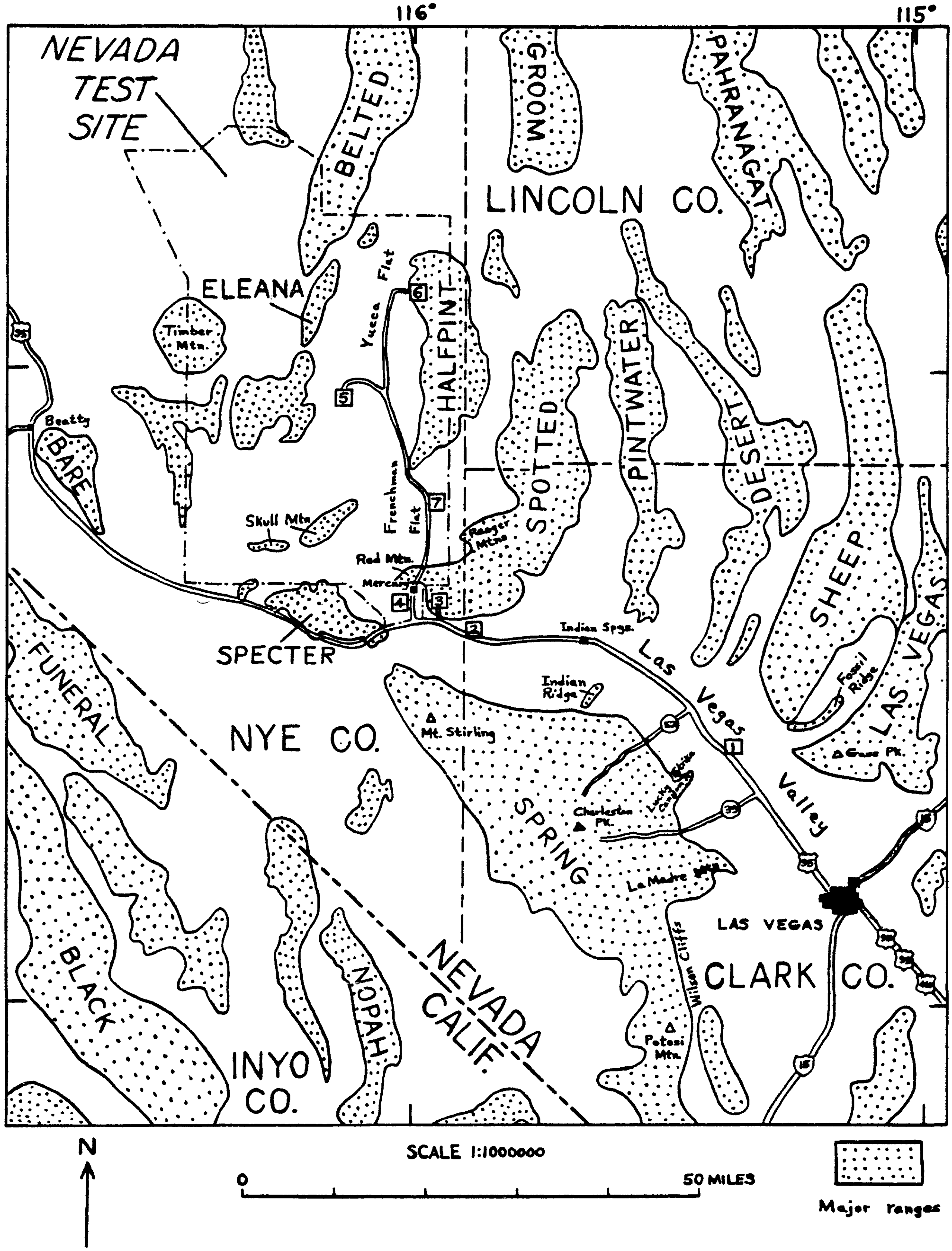


Figure 1.--Map showing route and stops for Paleozoic stratigraphy field trip.

## ROAD LOG AND TRIP GUIDE

[Clock references indicate direction of feature from bus]

| Distance | Cumulative mileage | |
|---|---|---|
| | ( 0.0) | [redacted] Road log begins at junction of The Strip and Flamingo Road. Travel west on Flamingo Road. |
| 0.6 | ( 0.6) | Junction with Interstate 15; turn right, go north on freeway. |
| 2.0 | ( 2.6) | Junction with Sahara Avenue; turn left, go west. |
| 2.1 | ( 4.7) | Junction with Decatur Blvd.; turn right, go north. |
| 4.5 | ( 9.2) | Junction with Tonopah Highway (U.S. 95); turn left, go northwest on expressway. |
| 2.6 | (11.8) | Craig Road to right leads to Nellis AFB....continue straight ahead. Potosi Mountain at 8:30 o'clock is capped by Monte Cristo Limestone of Mississippian age. Prominent ridge between 8 and 9 o'clock is capped by Kaibab Limestone of Permian age. Wilson Cliffs, composed of buff and red Navajo (Aztec) Sandstone of Triassic and Jurassic age between 8:30 and 9:30 o'clock, forms lower plate over-ridden by Keystone thrust. Narrow ridge at 9:30 o'clock is an erosional remnant of Keystone thrust; the ridge is capped by gray Goodsprings Dolomite of Cambrian and Ordovician age overlying red Navajo Sandstone. On La Madre Mountain between 9:30 and 11 o'clock are exposed carbonate rocks of Cambrian, Ordovician, Silurian(?), Devonian, Mississippian, Pennsylvanian, and Permian age. On Sheep Range at 1 o'clock the outcrops are rocks of Cambrian through Mississippian age. On Las Vegas Range between 1 and 3 o'clock most outcrops are the Bird Spring Formation of Pennsylvanian and Permian age. Muddy Mountains at 4 o'clock. Sunrise and Frenchman Mountains between 4:30 and 5:30 o'clock. |
| 2.0 | (13.8) | Ann Road to right....continue straight ahead. |
| 2.4 | (16.2) | Tule Spring Park Road to right....continue straight ahead. |
| 0.5 | (16.7) | Gravel borrow pit on right. |

| Distance | Cumulative mileage | |
|---|---|---|
| 1.3 | (18.0) | View of La Madre Mountain stratigraphy between 9 and 10 o'clock. Lower thin black band is dolomite of Devonian age (probably Ironside Dolomite Member of Sultan Limestone). It rests with apparent unconformity on a very thin gray dolomite of Devonian or possibly Silurian age which in turn rests unconformably on gray and brown silty and clayey carbonate of the Pogonip Group of Ordovician age. Above the Ironside Dolomite is limestone and dolomite of the Devonian Sultan Limestone. The main ridge is capped by Monte Cristo Limestone of Mississippian age. Small outlier just north of the end of the main ridge is composed of the Bird Spring Formation of Pennsylvanian and Permian age. |
| 1.3 | (19.3) | Charleston Park Road (Nev. 39) on left follows Kyle Canyon into heart of Spring Mountains....continue straight ahead. |
| 3.3 | (22.6) | Rest area on right....continue straight ahead. |
| 4.1 | (26.7) | STOP NO. 1. Park off highway on right side near sign "Emergency Parking Only" (fig. 2). Discussion of stratigraphic and structural evidence for Las Vegas Valley shear zone. Comparison of Ordovician, Silurian, Devonian, and Mississippian strata on opposite sides of Las Vegas Valley. The Sheep Range to the east consists of the typical thick miogeosynclinal section of eastern Nevada, whereas the ridge east of Lucky Strike Canyon to the west consists of a much thinner section containing several different facies. Thrust faults are correlated across the valley. Stratigraphic and structural evidence indicate about 30 miles of right-lateral movement along the Las Vegas Valley shear zone in post-Paleozoic time.<br>View of Sheep Range stratigraphy between 2:30 and 4 o'clock. The two prominent black bands at 3 o'clock are the lower member of the Ely Springs Dolomite repeated by faulting. Under the upper of the two black bands is the light-colored Eureka Quartzite. The Eureka is underlain by brownish-gray Pogonip Group carbonates which in turn are underlain by the Nopah Formation, the top of which has prominent black and white stripes. Above the black lower member of the Ely Springs is a unit of light-gray dolomite representing the upper member of the Ely Springs and lower part of the Silurian. The thin black band is a dark dolomite unit within the Silurian section. |

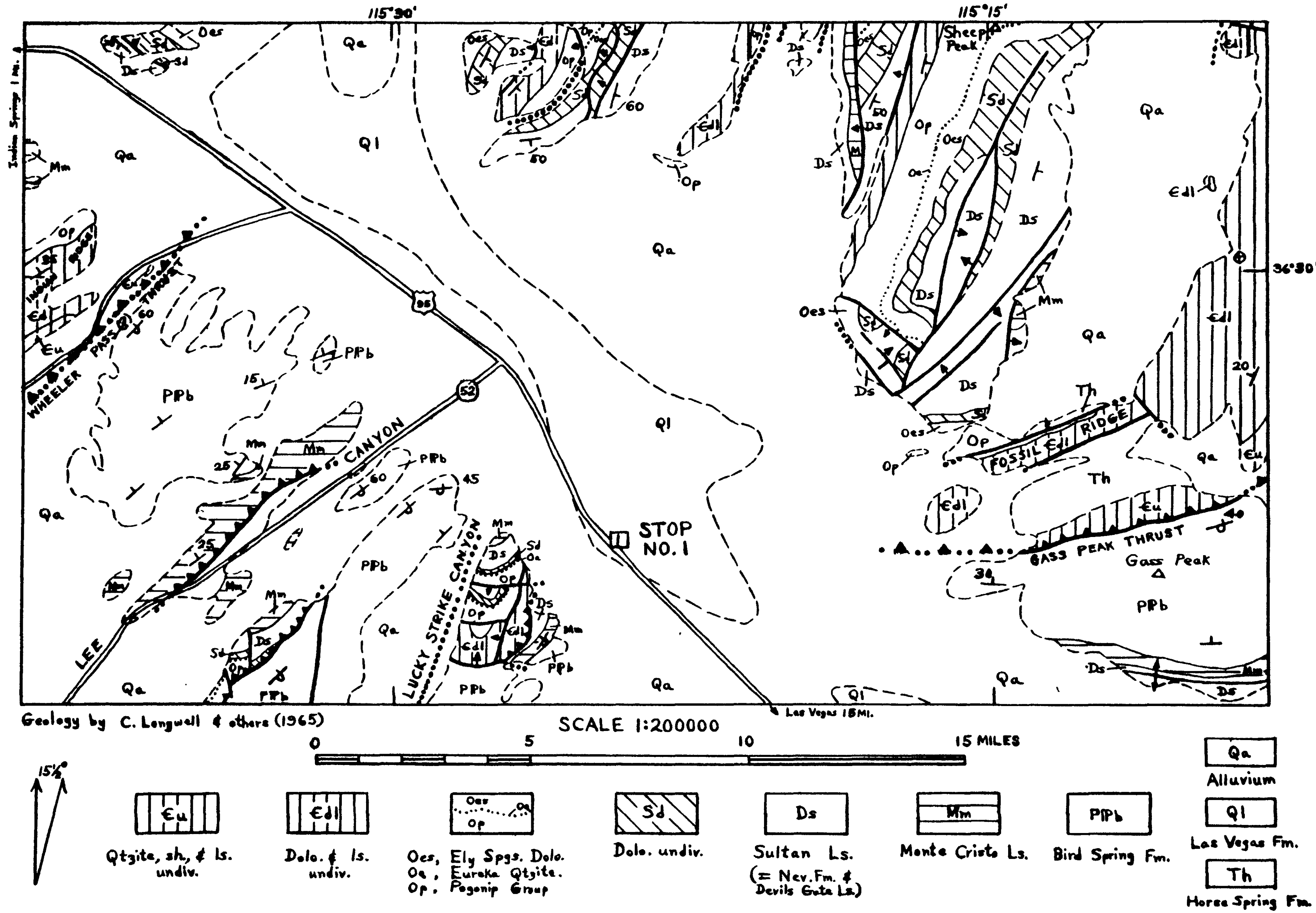


Figure 2.--Geology in vicinity of stop no. 1.

| Dis-tance | Cumulative mileage | |
|---|---|---|
| | | The Devonian rocks above are similar to the Nevada Formation and the Devils Gate Limestone of the Test Site. On the opposite side of the valley is a view of the Lucky Strike Canyon section between 9 and 11 o'clock. At 10 o'clock a white streak representing the distal end of the Eureka Quartzite may be seen just below a prominent black unit which is probably equivalent to the Ironside Dolomite Member of the Sultan Limestone (Nevada Formation) of Devonian age. A thin light-gray dolomite separates the Eureka and Ironside. This dolomite contains the Ordovician Ely Springs Dolomite and possibly a thin Silurian section. The Devils Gate Limestone forms the remainder of the ridge above the black Ironside (Nevada Formation). The Mississippian Monte Cristo Limestone forms the north-dipping slope of the main ridge and cannot be seen from here. The well bedded outcrops at 11 o'clock, north of Lucky Strike Canyon are the Bird Spring Formation. Below the Eureka at Lucky Strike Canyon section is gray and brown silty and clayey carbonate of the Pogonip Group. The black dolomite just above the valley fill at 9:30 o'clock is the upper part of the Nopah Formation. Fossil Ridge at 4 o'clock is composed of Cambrian and Ordovician rocks. Gass Peak thrust at 4:30 o'clock separates upper plate of Cambrian rocks on left from lower plate of Pennsylvanian-Permian rocks of the Las Vegas Range on the right. |
| 1.9 | (28.6) | Lucky Strike Canyon Road to left. Road to right leads to Corn Creek Field Station of U.S. Fish and Wildlife Service which manages the Desert Game Range. Continue straight ahead. (Longwell and others, 1965) |
| 0.7 | (29.3) | Badland topography at 3 o'clock developed on Las Vegas Formation. These yellowish-gray lake beds have yielded fossil mollusks and mammals that indicate a Pleistocene date. |
| 3.7 | (33.0) | Lee Canyon Road (Nev. 52) on left....continue straight ahead. At 9 o'clock on skyline is Mummy Mountain. Corn Creek Range at 3 o'clock is composed of Cambrian and Ordovician strata. Desert Range at 2 o'clock is composed of Cambrian to Devonian strata. |

| Dis- tance | Cumulative mileage | |
|---|---|---|
| 3.6 | (36.6) | Playa of Three Lakes Valley at 2 o'clock. Pintwater Range at 1 o'clock is composed of Cambrian to Devonian strata. Indian Ridge at 10:30 o'clock is composed of Cambrian and Ordovician rocks. Ridge between 8 and 10 o'clock is composed of Bird Spring Formation. The Wheeler Pass thrust probably separates these two ridges. |
| 1.9 | (38.5) | Camp Bonanza (BSA) and Cold Creek Road on left.... continue straight ahead. |
| 4.3 | (42.8) | Southwest end of Pintwater Range between 1 and 3 o'clock is composed of Ordovician and Silurian-Devonian rocks. Ridge at 10 o'clock consists of gray cliffs of Monte Cristo Limestone and alternating brown silty and sandy limestone slopes and gray limestone of the Bird Spring Formation. Prominent high point on skyline ridge at 9:30 o'clock is Wheeler Peak. |
| 2.1 | (44.9) | Light-gray outcrop of 3 o'clock is mostly Devonian carbonate. |
| 1.2 | (46.1) | Village of Indian Springs. Indian Springs Valley is at 3 o'clock. White and brown outcrops in distance at 1 o'clock are Eureka Quartzite. Dark dolomite on ridge at 12:30 o'clock is Upper Cambrian Nopah Formation. Gray and brown outcrops forming prominent ridge south of village (9 to 11 o'clock) are Bird Spring Formation. |
| 3.3 | (49.4) | Village of Cactus Springs. Prominent black and white banded dolomite on ridge between 1 and 3 o'clock is upper part of Nopah Formation. |
| 2.3 | (51.7) | Prominent ridge on skyline between 9 and 12 o'clock is northwest end of Spring Mountains; Wheeler Peak at 9:30 o'clock, Mount Stirling at 10:30. |
| 1.8 | (53.5) | Road to right leads to test well 4....continue straight ahead. Las Vegas Formation lake beds forming yellowish-gray badland topography along highway. |
| 3.2 | (56.7) | Brown and gray outcrops immediately north of highway are Pogonip. |
| 1.2 | (57.9) | Same. |
| 0.5 | (58.4) | Gravel borrow pit at 3 o'clock. |

| Distance | Cumulative mileage | |
|---|---|---|
| 0.8 | (59.2) | STOP NO. 2. Park off highway on right side near sign designating Nye-Clark County line (fig. 3). View of Spotted Range stratigraphy between 12:30 and 4 o'clock. Rocks seen are typical thick miogeosynclinal strata similar to the Sheep Range section. They include Ordovician Pogonip limestone, Eureka Quartzite, Ely Springs Dolomite; Silurian dolomite; Devonian dolomite, Nevada Formation dolomite and quartzite, Devils Gate Limestone (includes some dolomite and quartzite); uppermost Devonian and Lower to Upper Mississippian rocks cannot be seen from here. Strata seen generally dip 30° to 40° northwestward forming the southeast limb of the Spotted Range syncline. White quartzite member of the Eureka just above valley fill at 1:30 o'clock is overlain by black dolomite of the lower member of the Ely Springs. Skyline ridge between 12:30 and 2:30 o'clock is South Ridge capped by Devils Gate Limestone; Spot Peak at 2 o'clock. Nevada-Devils Gate contact on skyline at 1:30 o'clock. Prominent black band with brownish slope-former below is the lower part of the Nevada Formation and can best be seen in middle part of range between 2 and 2:30 o'clock. |
| 3.7 | (62.9) | Turn right onto gravel road leading to "silica quarry." Low ridges in foreground between 10:30 and 2:30 o'clock are Ordovician Antelope Valley Limestone. Ridge on skyline between 11 and 1 o'clock includes Eureka Quartzite through Devils Gate Limestone. |
| 1.7 | (64.6) | STOP NO. 3. Turn around and park short of the "silica quarry" (fig. 4). This is the first of the walking stops. The quarry is in the white quartzite member of the Eureka Quartzite. The brittle quartzite has been granulated along faults and requires no additional crushing for commercial use, only grading. It is quarried intermittently and reported to be marketed in Las Vegas for domestic use. This stop includes a close-hand examination of the uppermost Antelope Valley Limestone, Eureka Quartzite, Ely Springs Dolomite, and "dolomite of the Spotted Range" (fig. 5). |
| 1.7 | (66.3) | Tonopah Highway, turn right and go west. |

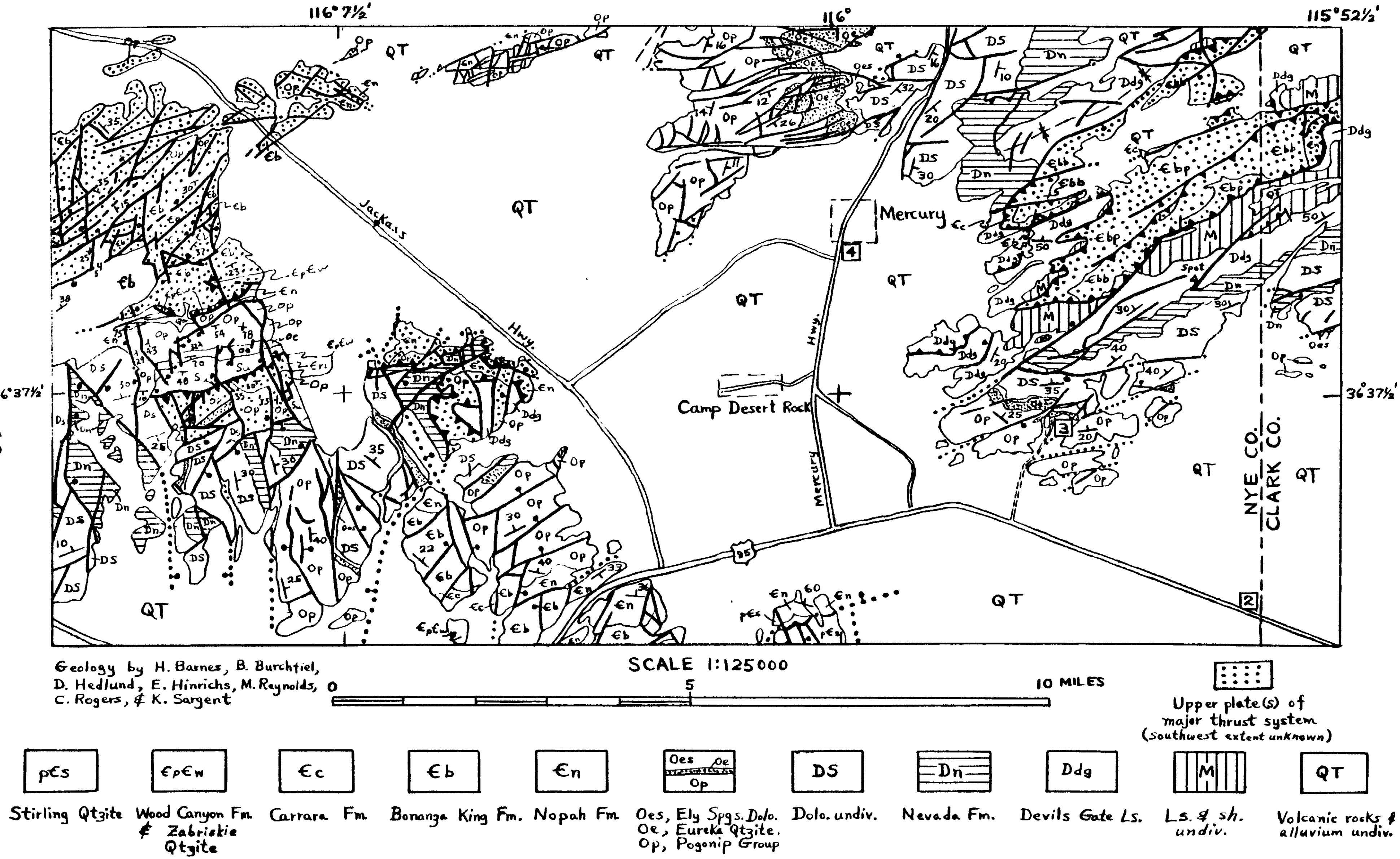


Figure 3.--Generalized geology in vicinity of stops 2, 3, and 4.

Table 1.--Explanation of map symbols for Figures 4, 6, and 7

| | |
|---|---|
| Qa | ALLUVIUM |
| Tv | VOLCANIC ROCKS |
| | ELEANA FORMATION |
| Mej | Unit J |
| Mei | Unit I |
| Meh | Unit H |
| Mc | CHAINMAN SHALE |
| Mt | LIMESTONE OF TIMPI WASH |
| Mm | MERCURY LIMESTONE |
| MDnc | NARROW CANYON LIMESTONE |
| Ddg | DEVILS GATE LIMESTONE |
| | NEVADA FORMATION |
| Dnu | Upper part |
| Dnl | Lower part |
| Ddn | DEVILS GATE LS. and NEVADA FM. undivided |
| | DOLOMITE OF SPOTTED RANGE |
| Duf | Unit F |
| DSue,d | Units D and E undivided |
| Suc | Unit C |
| Sub,a | Units A and B undivided |
| DSu | DOLOMITE OF SPOTTED RANGE undivided |
| Oes | ELY SPRINGS DOLOMITE |
| Oe | EUREKA QUARTZITE |
| | ANTELOPE VALLEY LIMESTONE |
| Oaa | Aysees Member |
| Oar | Ranger Mountains Member |
| Oa | ANTELOPE VALLEY LIMESTONE undivided |
| | NOPAH FORMATION |
| Ꞓns | Smoky Member |
| Ꞓnh | Halfpint Member |
| Ꞓnd | Dunderberg Shale Member |
| | BONANZA KING FORMATION |
| | Banded Mountain Member |
| Ꞓbbd | Unit D |
| Ꞓbbc | Unit C |
| Ꞓbbb,a | Units A and B undivided |
| Ꞓbp | Papoose Lake Member |
| | CARRARA FORMATION |
| $Ꞓc_7$ | Unit 7 |
| Ꞓcj | Jangle Limestone Member |
| Ccl | Lower part |

EXPLANATION OF MAP UNITS IN TABLE 1.

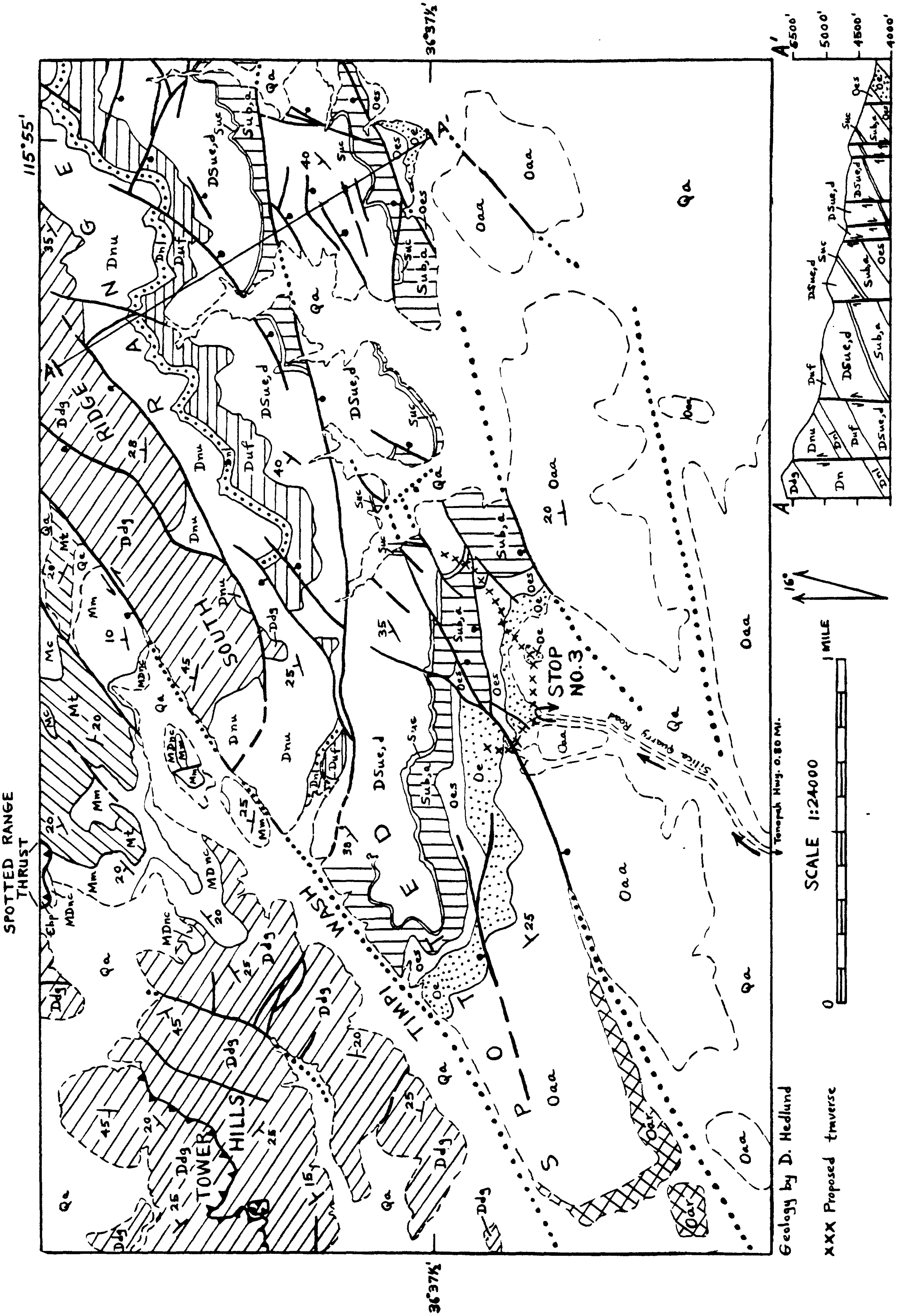


Figure 4.--Geology in vicinity of stop no. 3.

| Age | | Fm. | Mbr. | Thickness, feet | Lithology 1 inch = 500 feet | Color of outcrop | Brief description | Fossils† |
|---|---|---|---|---|---|---|---|---|
| DEVONIAN | Middle | Nevada (1160) | upper | 300+ | | Lt. & med. gray | Lt. to dk. gray banded dolo., aphanitic to coarse grained, some vugs in coarse parts; faint to distinct laminae & thin beds; forms cliff. | |
| | | | | 35 | | Dk. gray / White | Sandy dolo. to dolo. ss.-qtzite, quartz grains subrounded to well rounded fine to medium size, dolo. medium grained; laminated to thin bedded, some cross-laminae; forms cliff. | |
| | ? Lower | | lower | 220 | | Lt. olive gray | Clayey, silty, & sandy dolo., aphanitic to fine grained; common chert lenses & blebs in upper part; sandy parts composed of v. fine quartz grains; laminated to thin beds; forms slope. | Twig-like algae? |
| | | ? Dolo. of Spotted Range (1440) | ? f | 355 | | Very lt. gray | Med. to lt. gray dolo., some darker beds locally; aphanitic to fine grained; some v. fine to medium quartz grains in top 60 ft.; laminated to thin bedded, laminae commonly etch out in aphanitic parts; forms ledgy slope & cliffs. | |
| ? SILURIAN | ? Middle | | e | 450 | | Banded lt. & med. gray | Lt., med, & dk. gray dolo, fine to medium grained, some coarse-grained vuggy beds, common color & texture mottling; laminated to v. thin beds; forms ledgy slope & cliffs. | Coral-head ghosts<br>Palmatozoan columnals |
| | | | d | 110 | | Lt. gray | Gray dolo., fine to medium grained; color & texture mottling | Brachiopod, coral, & stromatoporoid ghosts |
| | | | c | 150 | | Black | Dk. to med gray dolo., fine-grained; common chert layers, lenses, & blebs; laminated to thin bedded; forms ledgy slope. | *Halysites*, *Favosites*, *Alveolites* |
| | | | b, a | 375 | | Lt. & yell. gray | Med gray mottling; fine to coarse grained, vuggy, common texture mottling; generally poorly bedded & massive, some distinct laminae to thin beds; forms cliff. | Pentameroid brachiopods<br>Coral-head ghosts<br>Palmatozoan columnals |
| ? ORDOVICIAN | ? U / ? L / ? Middle | ? Ely Springs Dolo. (450) | ? upper | 150 | | Lt. gray | Med. to lt. olive gray dolo.; aphanitic to fine grained, quartz sand zone near top; basal 25 ft. silty & clayey; lam.-thin bedded; ledgy | *Glyptorthis* sp., *Austinella* ? sp., *Sowerbyella* ? sp., rhynchonellid, acrotretid. |
| | | | lower | 300 | | Black | Dk. to med. gray dolo., fine grained; quartz sand in basal 50 ft; some chert lenses & blebs, commonly replaced by white dolo.; laminated to thin bedded; forms cliff | Streptelasmatid horn corals<br>Pelmatozoan debris |
| | | ? Eureka Qtzite (325) | ? white qtzite | 105 | | White | Vitreous qtzite to fine & medium grained ss., laminated to thick bedded, some cross-laminae; forms slope | |
| | | | varicolored qtzite | 135 | | Brown | Varicolored, mottled qtzite, v. fine-fine grained, silty; lam.-thin bedded | Worm borings ? |
| | | | x-lam. qtzite | 14 | | Brown | Fine-coarse grained ss-qtzite; cross-laminated; forms ledge. | |
| | | | carbonate | 18 | | Yellow | Medium-coarse grained silty & clayey dolo & minor ls.; forms slope | *Phragmodus undatus*, *Ozarkodina* sp., *Belodina* |
| | | | basal qtzite | 53 | | Brown | Fine-grained ss.-qtzite, some dolomitic parts; quartz laminae; cliffy | Worm borings ? |
| | | Antelope Valley (1200±) | upper | 241* | | Med. gray & yellow mottling | Gray ls. & yellowish silty ls., aphanitic - coarse-grained; minor chert lenses & blebs; forms ledgy slope & cliffs. | *Goniotelina*?, *Isotelus*?, *Calliops* aff. *C. troosti*, *Ceraurinella* ? sp., ostracodes, conodonts |
| | | | middle | 100+ | | Med. gray | Med. dk gray ls., aphanitic - medium grained; forms cliffs. | *Palliseria*, *Maclurites*, *Receptaculites* |

* Thickness from R. Ross, Jr. (1964); † Fossils identified by W. Oliver, Jr., R. Ross, Jr., & L. Wilson.

Stratigraphy by F. Poole

Figure 5.--Stratigraphic section in vicinity of stop no. 3.

| Distance | Cumulative mileage | |
|---|---|---|
| 0.5 | (66.8) | Massive gray cliffs at 3 o'clock are the Palliseria-bearing limestone in the middle part of the Antelope Valley Limestone (lower part of the Aysees Member of the Antelope Valley Limestone in the Ranger Mountains). Underneath are brown slopes of the Orthidiella-bearing silty limestone (Ranger Mountains Member of the Antelope Valley Limestone in the Ranger Mountains). Ridge on skyline between 11 and 1 o'clock is Specter Range. Skull Mountain at 2 o'clock, is composed of volcanic rocks and capped by black basalt flows. |
| 1.5 | (68.3) | Mercury interchange, bear right and follow Mercury Highway northward. |
| 1.0 | (69.3) | Outcrops in foreground at 3 o'clock are Antelope Valley Limestone; hill with relay tower at 2 o'clock is Devils Gate Limestone. Red Mountain between 11 and 1 o'clock has similar stratigraphy to "silica quarry." Skull Mountain is at 10 o'clock. Specter Range between 7 and 10 o'clock. |
| 1.4 | (70.7) | Camp Desert Rock Road to left....continue straight ahead. |
| 1.3 | (72.0) | Badging and Security Offices on right. Stop at Badging Office to obtain badge permitting entry into NTS. Security officer at main entrance will check your badge. |
| 0.2 | (72.2) | Mercury Bypass Road to left....continue straight ahead. |
| 0.3 | (72.5) | STOP NO. 4. Park in large parking area to right of highway (fig. 3). View of Spotted Range and Specter Range geology. Red Mountain between 9 and 12:30 o'clock is composed of gray and brown Ordovician Antelope Valley Limestone on left through Eureka Quartzite, Ely Springs Dolomite, and Silurian dolomite on right. Strata on Red Mountain generally dip eastward forming the northwest limb of the Spotted Range syncline. Mercury Ridge between 1 and 2 o'clock is composed mainly of Devonian Nevada Formation and Devils Gate Limestone. North Ridge between 2 and 3 o'clock is composed of Middle and Upper Cambrian carbonates thrust over Devonian and Mississippian rocks (Spotted Range thrust) in the axial portion of the Spotted Range |

| Distance | Cumulative mileage | |
|---|---|---|
| | | syncline. South Ridge between 2:30 and 4 o'clock consists of Ordovician through Mississippian rocks forming the southeast limb of the Spotted Range syncline. Tower Hills at 4 o'clock are Devils Gate Limestone. Specter Range between 7 and 9 o'clock contains Cambrian through Devonian rocks. Eagle Peak at 8:30 o'clock is composed of vertical strata of Antelope Valley Limestone; on left is stratigraphically higher white and brown Eureka Quartzite, black and gray Ely Springs Dolomite, and gray and black dolomite of Silurian age. Just north of Eagle a major thrust fault (Specter Range thrust) brings Upper Cambrian and Ordovician rocks over the Eagle Peak section, which is similar to the situation in the southwestern part of the Spotted Range. The Spotted Range thrust and the Specter Range thrust are believed to be parts of a single major thrust system (C.P. thrust) in the Test Site area. |
| 0.6 | (73.1) | Mercury, Nev. USGS Office trailers and core storage buildings on left. |
| 0.6 | (73.7) | Mercury Bypass junction on left....continue straight ahead. |
| 1.1 | (74.8) | Security Gate to forward areas. Badge will be checked. |
| 0.2 | (75.0) | Checkpoint Pass (el. 4,165±). Brecciated and faulted Silurian dolomite in canyon walls for next mile. |
| 1.0 | (76.0) | Emerge from canyon and continue descent into Frenchman Flat. View of Frenchman playa ahead (12 to 12:30 o'clock). Ranger Mountains between 2 and 3 o'clock are composed of Antelope Valley Limestone, Eureka Quartzite, Ely Springs Dolomite, "dolomite of Spotted Range", and Nevada Formation. Aysees Peak at 1 o'clock in the Spotted Range consists of Ordovician rocks. Massachusetts Mountain of southern end of Halfpint Range between 11 and 1 o'clock is composed of volcanic rocks. Low hills west of Frenchman Flat composed of volcanic rocks. |
| 0.3 | (76.3) | Green building on left is pumping station 4; one of several pumps that lift water 700 feet vertically from three wells in Frenchman Flat over Checkpoint Pass to Mercury for domestic use. White outcrops between 9 and 10 o'clock are Eureka Quartzite. |

| Distance | Cumulative mileage | |
|---|---|---|
| 1.0 | (77.3) | Green building on left is pumping station 3. |
| 0.8 | (78.1) | Mercury Highway curves to left. Junction on right with Road 5-01. Bear right (straight ahead) following Road 5-01 north. |
| 0.8 | (78.9) | Green building on left is pumping station 2. |
| 0.9 | (79.8) | Gravel road to right leads to water well 5A.... continue straight ahead. |
| 0.6 | (80.4) | Gravel pit at 3 o'clock. A major source of gravel for Test Site construction projects. |
| 1.1 | (81.5) | Old Indian Springs stage road crosses highway from northwest to southeast. |
| 1.2 | (82.7) | Road to left leads to water well 5B. Bear left following this road. |
| 0.3 | (83.0) | Stop sign. Water well 5B and storage tanks on left. Take paved road 5-05 trending northwest. |
| 2.9 | (85.9) | Stop sign. Junction with Mercury Highway. Turn right and go north. |
| 1.5 | (87.4) | Cane Spring Road to left....continue straight ahead. |
| 3.2 | (90.6) | Gravel road to right leads to a microbarograph site.... continue straight ahead. |
| 1.1 | (91.7) | Gravel road to left....continue straight ahead. At 10 o'clock is a window of Mississippian (brown) and Pennsylvanian (light gray) rocks below the Cambrian (gray) rocks of the C.P. thrust. Brownish-weathering outcrops at 11:30 o'clock are Cambrian Carrara Formation. C.P. Hogback between 12 and 3 o'clock is composed of volcanic rocks. |
| 2.1 | (93.8) | Yucca Pass (el. 4,065$\pm$). Control Point buildings on left. Continue straight ahead. Begin descent into Yucca Flat. |
| 1.2 | (95.0) | Junction with Orange Road on left. Turn left on Orange Road and go northwest. |

| Distance | Cumulative mileage | |
|---|---|---|
| 0.4 | (95.4) | U.S. Weather Bureau tower at 9 o'clock. This 500-foot-high tower is instrumented to obtain wind data. |
| 1.4 | (96.8) | Junction with Mine Mountain Road on left. Turn left on Mine Mountain gravel road and go west. |
| 3.1 | (99.9) | Ridge between 7 and 10 o'clock includes Pogonip and Eureka of upper plate of C.P. thrust. |
| 0.7 | (100.6) | Ridges of Devonian carbonate between 11 and 2 o'clock. These rocks are in the upper plate of the Mine Mountain thrust and in the lower plate of the C.P. thrust. |
| 0.3 | (100.9) | Crossing Mine Mountain thrust. |
| 0.4 | (101.3) | Junction on left at mercury concentrator....continue straight ahead. |
| 0.7 | (102.0) | STOP NO. 5. Mine Mountain Pass. Turn around and park on road leading east from pass (fig. 6). Walk eastward along old road to Mine Mountain (el. 5,410) and northeast along ridge top to overlook point for lunch. Traverse will cross Eleana Formation argillite (Mississippian) of lower plate, Mine Mountain Thrust Fault, and Devonian carbonate of upper plate. Overlook point offers an excellent panorama of Mine Mountain thrust and of Yucca Flat. |
| 7.0 | (109.0) | Retrace route to Mercury Highway. Turn left and go north on Mercury Highway descending into Yucca Flat. |
| 0.3 | (109.3) | Road to right leads to Yucca Flat airstrip on playa.... continue straight ahead. |
| 2.8 | (112.1) | Equipment storage yard at water well 3 on left.... continue straight ahead. Well supplies drinking water for C.P. installation. |
| 1.1 | (113.2) | Angle Road to right....continue straight ahead. |
| 1.8 | (115.0) | Area 3 storage yard on right at water well A.... continue straight ahead. Well supplies water for drilling operations. |
| 0.7 | (115.7) | Drill rig repair yard on right and Tippipah Spring Road to left....continue straight ahead. |

| Dis-tance | Cumulative mileage | |
|---|---|---|
| 1.1 | (116.8) | BJY intersection. Continue straight ahead on Mercury Highway. |
| 2.9 | (119.7) | Circle Road to left....continue straight ahead. |
| 1.3 | (121.0) | Papoose Lake Road to right through storage yard. Turn right and follow Papoose Lake Road. |
| 0.6 | (121.6) | Road intersection, bear left. |
| 0.1 | (121.7) | Same. |
| 0.2 | (121.9) | Same. |
| 0.5 | (122.4) | Road intersection, bear right. |
| 0.4 | (122.8) | Same. |
| 0.4 | (123.2) | Same. |
| 0.2 | (123.4) | Road intersection, turn left leaving Papoose Lake Road. |
| 0.3 | (123.7) | STOP NO. 6. Teapot Ridge-Banded Mountain. Turn around and park where road curves to right (fig. 7). This is the last walking stop. Traverse will cross the upper part of the Bonanza King Formation and the Dunderberg Shale and Halfpint Members of the Nopah Formation.(fig. 8). |
| 2.7 | (126.4) | Retrace route to Mercury Highway. Turn left on Mercury Highway and go south through Yucca Flat, over Yucca Pass, into Frenchman Flat. |
| 21.1 | (147.5) | Turn left onto road 5-05 (60° turn) leaving Mercury Highway. |
| 2.9 | (150.4) | Stop sign. Well 5B. Continue straight ahead. |
| 0.3 | (150.7) | STOP NO. 7. West edge of Frenchman playa. Park on right shoulder of road. View of Ranger Mountains stratigraphy and other features in the Spotted Range south and east of here. The Ranger Mountains section is one of the best exhibits in the Test Site area of rocks ranging from the base of the Antelope Valley |

EXPLANATION OF MAP UNITS IN TABLE 1.

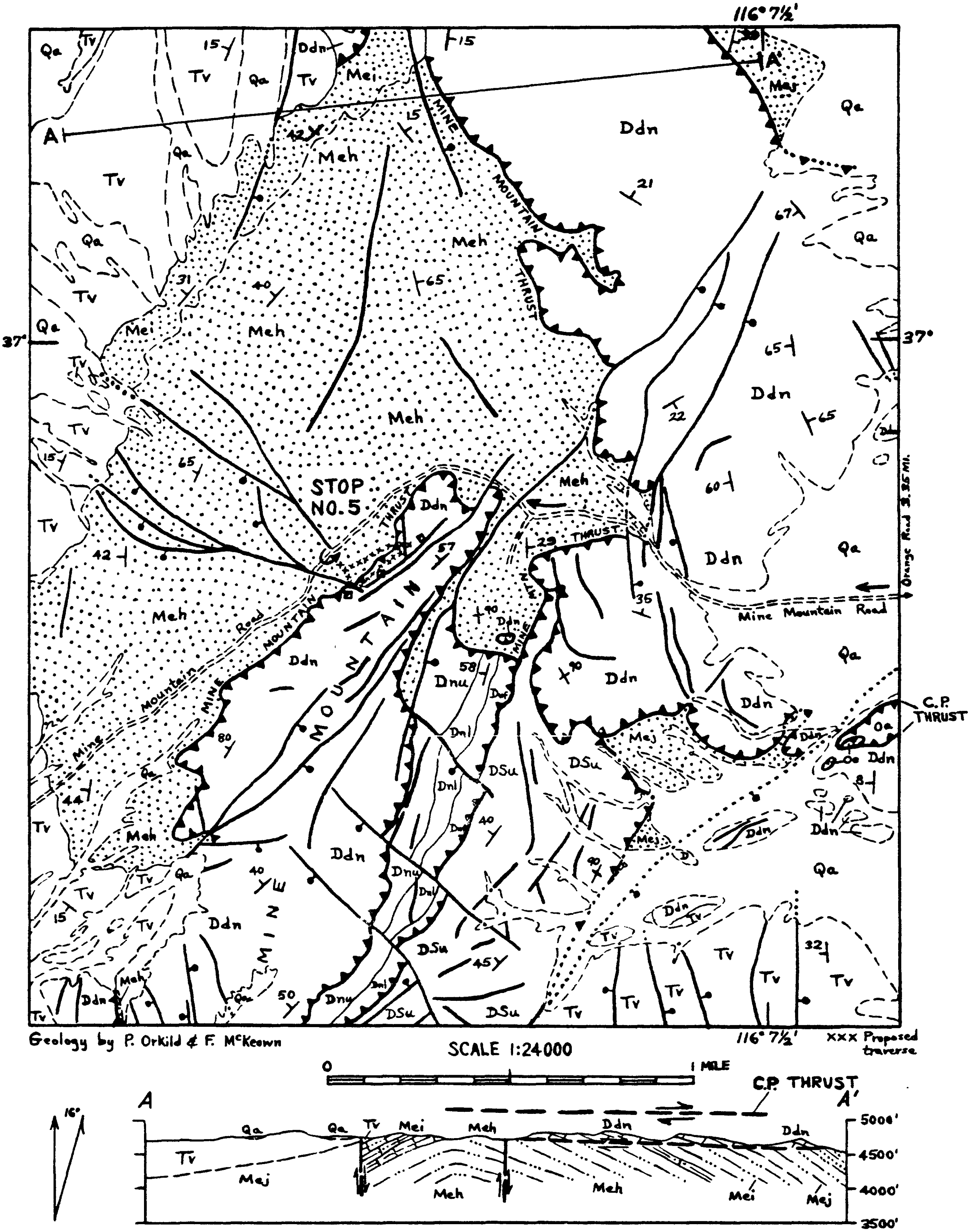


Figure 6.--Geology in vicinity of stop no. 5.

# EXPLANATION OF MAP UNITS IN TABLE 1.

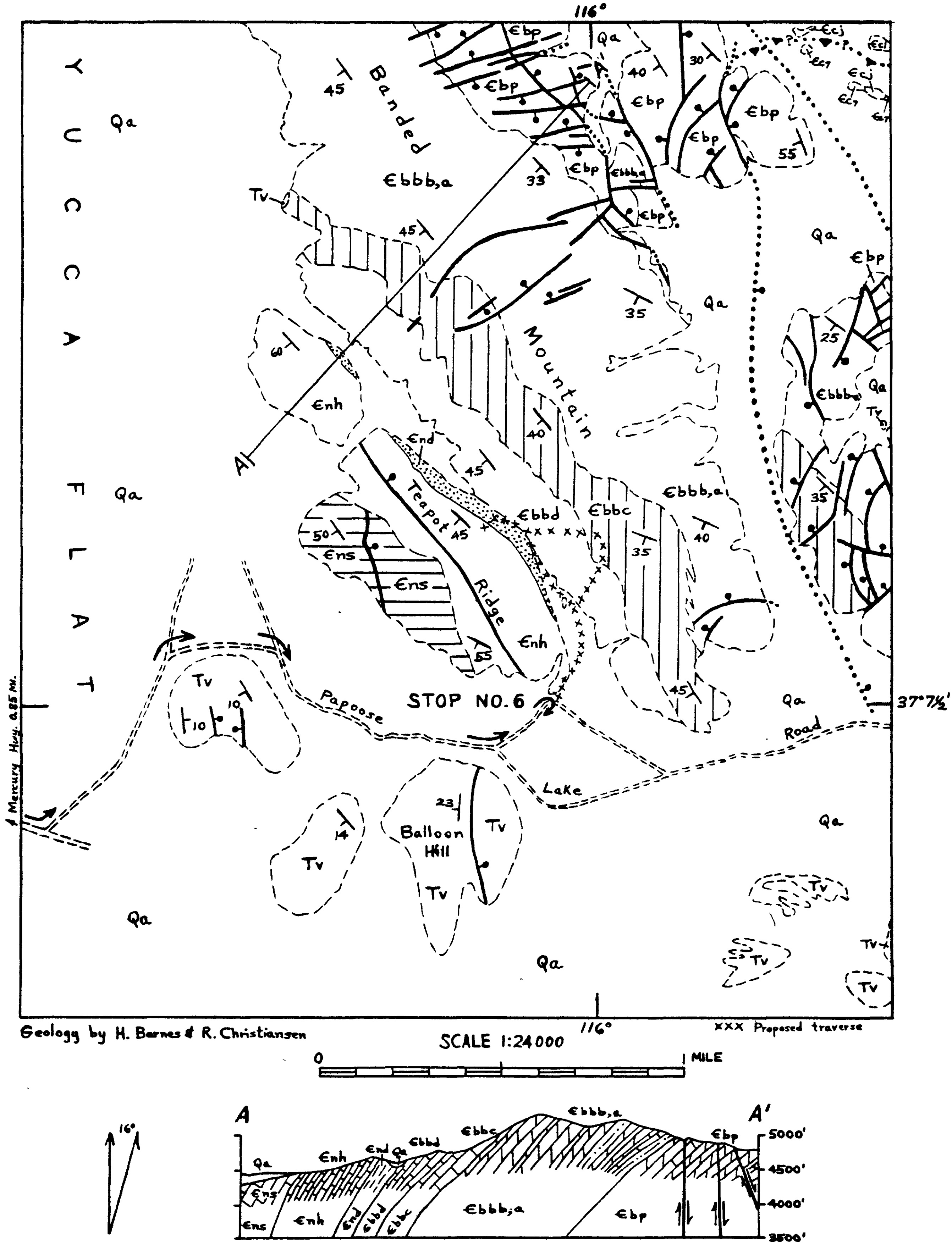


Figure 7.--Geology in vicinity of stop no. 6.

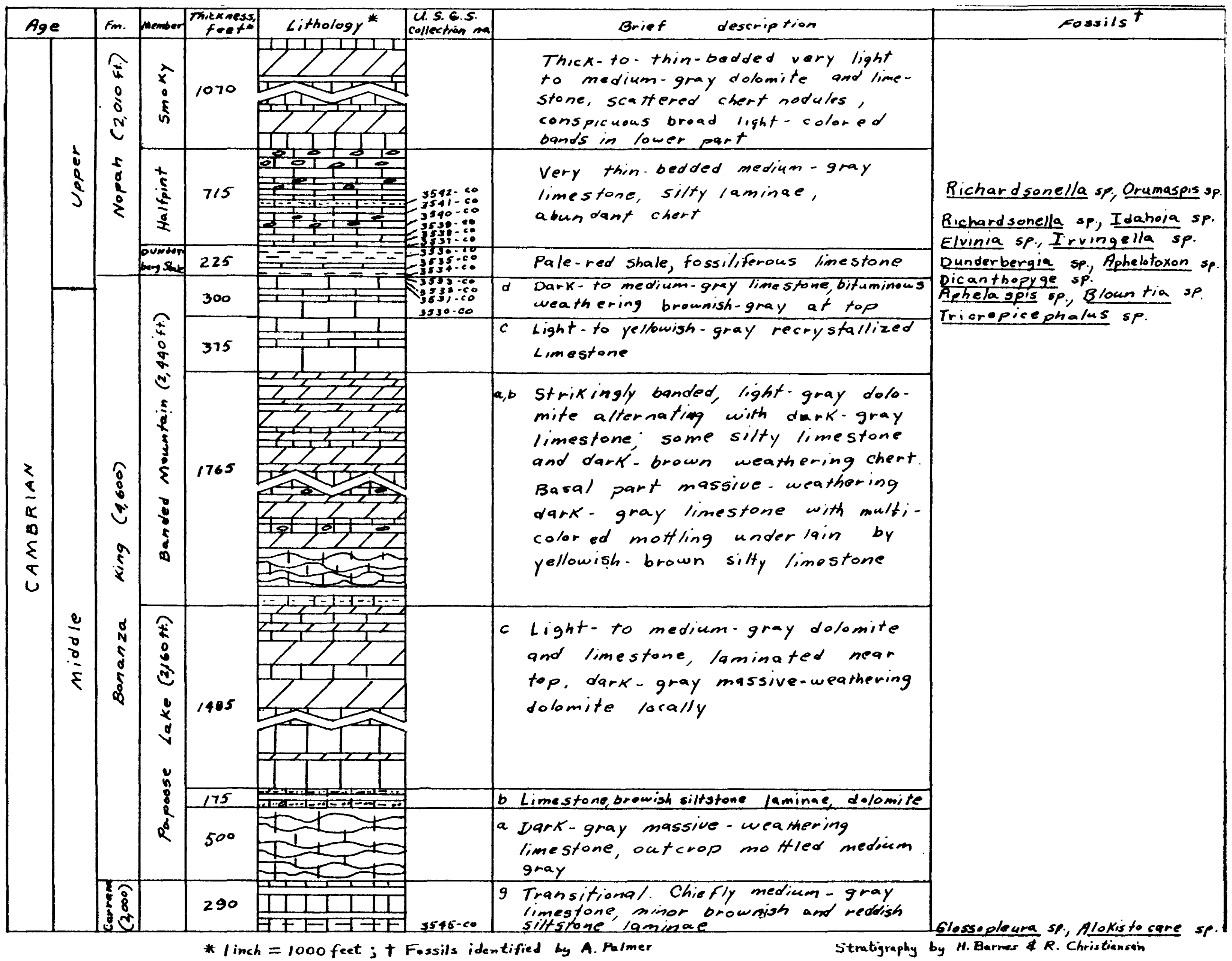


Figure 8.--Stratigraphic section in vicinity of stop no. 6.

| Dis-tance | Cumulative mileage | |
|---|---|---|
| | | Limestone, through the Eureka Quartzite, Ely Springs Dolomite, "dolomite of the Spotted Range," and the lower part of the Nevada Formation. Strata in the Ranger Mountains generally dip 15°-30° southeastward forming the northwest limb of the Spotted Range syncline. Middle and Upper Cambrian carbonate rocks of the Spotted Range thrust may be seen over Mercury Ridge south of here. |
| | | Turn right onto paved road 5-01 and retrace route back. |

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## TIMBER MOUNTAIN CALDERA AND RELATED VOLCANIC ROCKS

/Trip Leaders: Robert L. Christiansen, Paul P. Orkild, Frank M. Byers, Jr., and Wilfred J. Carr/

The southwestern Nevada volcanic field is a complex assemblage of rocks covering an area of several thousand square miles, mainly in southern Nye County. Most of these rocks are silicic ash-flow tuffs. The central area of the field is a faulted and dissected volcanic plateau of about 2,500 square miles extending northwestward from Yucca Flat. A number of volcanic centers have been located in the southwestern Nevada field, and those associated with the large-volume ash-flow units generally are collapse calderas. Known calderas in the immediate vicinity of the Nevada Test Site include the Silent Canyon caldera (Noble and others, 1966; Orkild and others, 1966), the Timber Mountain caldera (Byers and others, 1964; Christiansen and others, 1965), and the Black Mountain caldera (Christiansen and Noble, 1965). Several other known and probable calderas have been described in the surrounding region by various investigators.

The Tertiary volcanic section of the southwestern Nevada field includes many units. One needs to be familiar with only a few of these units for the purposes of this trip, but table 2 lists all the major units of the Test Site area for general reference. Major units related to the same volcanic centers and having close lithologic and petrographic similarities are named as formations; individual ash-flow cooling units (ignimbrites in the sense of Mackin, 1960) are designated as members.

Timber Mountain caldera is the largest and is topographically the best expressed of the calderas now known in the southwestern Nevada volcanic field. A large volume of volcanic rocks, virtually all of them rhyolites and quartz latites, is associated directly with this volcanic structure which is about 20 miles in maximum diameter. Most of this volume, about 500 cubic miles, is accounted for by the Timber Mountain Tuff, an ash-flow unit that extends over an area more than 90 miles across. The remainder of the volcanic suite related to the Timber Mountain volcanic structure consists mainly of rhyolitic lava flows and ash-fall tuffs. All of these rocks are about 11 million years old, within the limits of experimental precision of the K-Ar dating method (R. W. Kistler, 1964, written comm.). The rocks of the Timber Mountain center are, thus, about coincident with the Miocene-Pliocene boundary (Evernden and others, 1964).

Timber Mountain caldera is defined by a wall and rim that are preserved around nearly 270° of its circumference, a ring-fracture zone, and a central structural dome (Carr, 1964) formed by magmatic resurgence after collapse. A moat-like topographic low marks the ring-fracture zone and the limit of the depressed portion of the caldera. In these structural and topographic features the Timber Mountain structure resembles the Valles caldera of New Mexico (Smith and others, 1961). The Timber Mountain collapse caldera can be shown to have formed during or immediately after eruption of most of the Rainier Mesa Member of the Timber Mountain Tuff. The Rainier Mesa is

Table 2.--Major units of the southwestern Nevada volcanic field, in the Nevada Test Site area

| Unit | General lithology | Center | Reference |
|---|---|---|---|
| THIRSTY CANYON TUFF | Peralkaline ash-flow tuffs | Black Mountain caldera | Noble and others, 1964 |
| Labyrinth Canyon Member | | | |
| Gold Flat Member | | | |
| Trail Ridge Member | | | |
| Spearhead Member | | | |
| TIMBER MOUNTAIN TUFF | Rhyolitic to quartz-latitic ash-flow tuffs | Timber Mountain caldera | Orkild, 1966 |
| Ammonia Tanks Member | | | |
| Tuff of Cat Canyon | | | |
| Rainier Mesa Member | | | |
| PAINTBRUSH TUFF | Rhyolitic to quartz-latitic ash-flow tuffs | Probable caldera west of Timber Mountain | Orkild, 1966 |
| Tiva Canyon Member | | | |
| Yucca Mountain Member | | | |
| Pah Canyon Member | | | |
| Topopah Spring Member | | | |
| Stockade Wash Member | | | |
| WAHMONIE FORMATION | Dacitic to rhyodacitic lavas, breccias, tuffs, and sandstones | Wahmonie Flat-Mt. Salyer | Poole and others, 1966 |
| SALYER FORMATION | | | |
| BELTED RANGE TUFF | Peralkaline ash-flow tuffs | Silent Canyon caldera | Sargent and others, 1966 |
| Grouse Canyon Member | | | |
| Tub Spring Member | | | |
| TUFF OF CRATER FLAT | Quartz-latitic ash-flow tuffs | Unknown | Christiansen and Lipman, 1965; Poole and others, 1965 |
| OLDER ASH-FLOW TUFFS | Rhyolitic to dacitic | Various centers | |

present in much of the caldera wall but is also a component of the debris flows and breccias that line the base of the wall. The Ammonia Tanks Member is virtually coextensive with the Rainier Mesa Member, and the two are conformable over most of their areal extent. However, the Ammonia Tanks is unconformable on the Rainier Mesa in several places near the caldera wall, is undeformed in the outer part of the moat, and overlies the debris flows and breccias with their included Rainier Mesa blocks. Tuffs that are very similar to the Ammonia Tanks Member (the tuff of Cat Canyon) form the central dome of the caldera.

The caldera is centrally located in the area over which the Timber Mountain Tuff is distributed; zonal features of the ash-flow cooling units indicate that they were hottest closest to the caldera; the rhyolitic lavas of the caldera dome, moat, and rim are chemically, petrographically, and chronologically related to the Timber Mountain Tuff; and formation of the caldera was nearly synchronous with the Timber Mountain ash-flow eruptions within a period of no more than a few hundred thousand years. These factors together indicate that the caldera occupies the source area of the tuffs and that the collapse was related to the rapid and voluminous magma withdrawals represented by the Timber Mountain Tuff. There may have been a period of collapse associated with the later portions of the Timber Mountain Tuff as well as with the Rainier Mesa Member, but this cannot be conclusively demonstrated because sediments and lavas of the caldera moat bury certain critical relations.

Figures 9 and 10 show the generalized geologic structure and one possible reconstruction of the events that produced the Timber Mountain caldera.

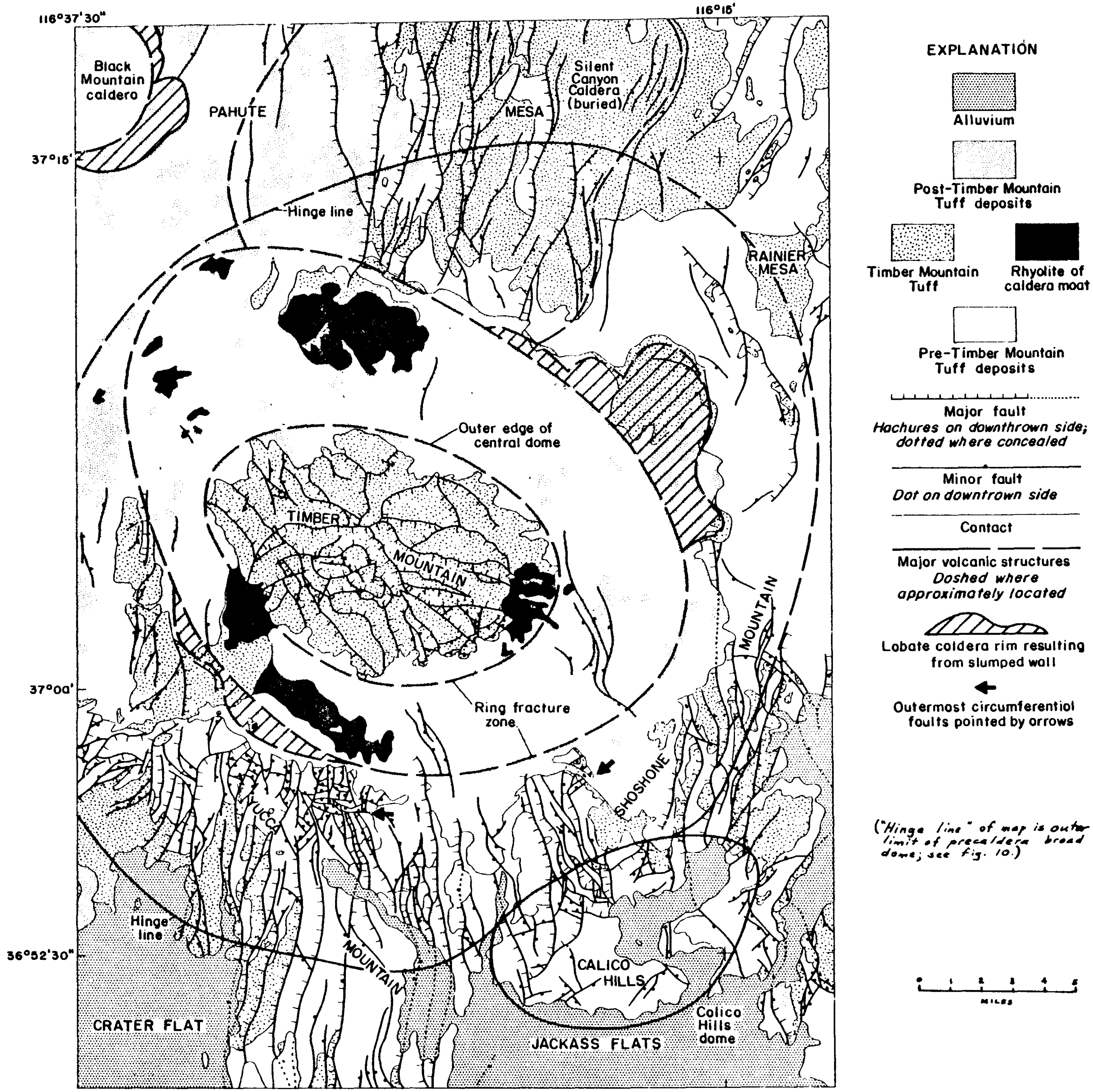



Figure 9. Structure map of Timber Mountain caldera and vicinity.

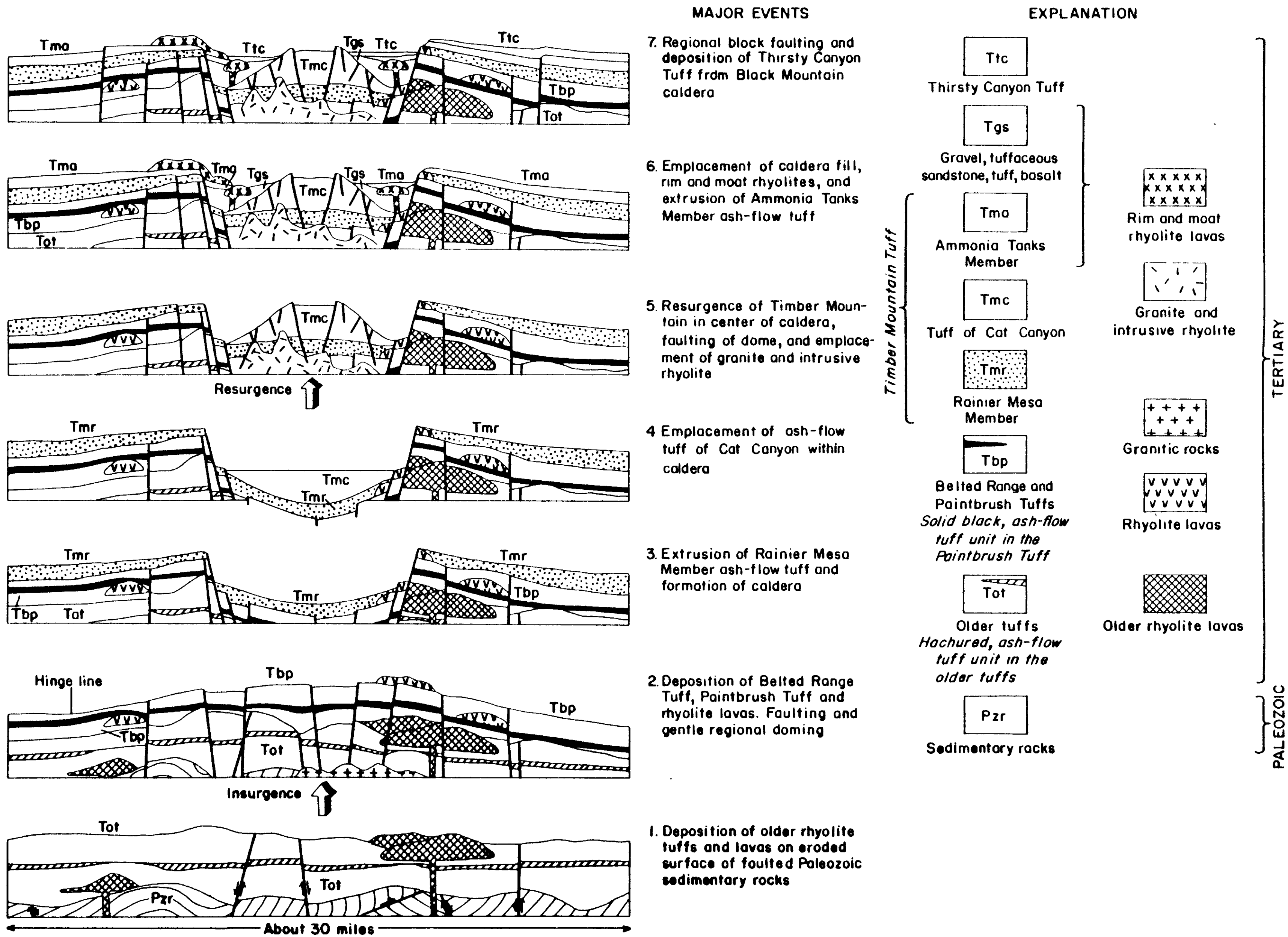


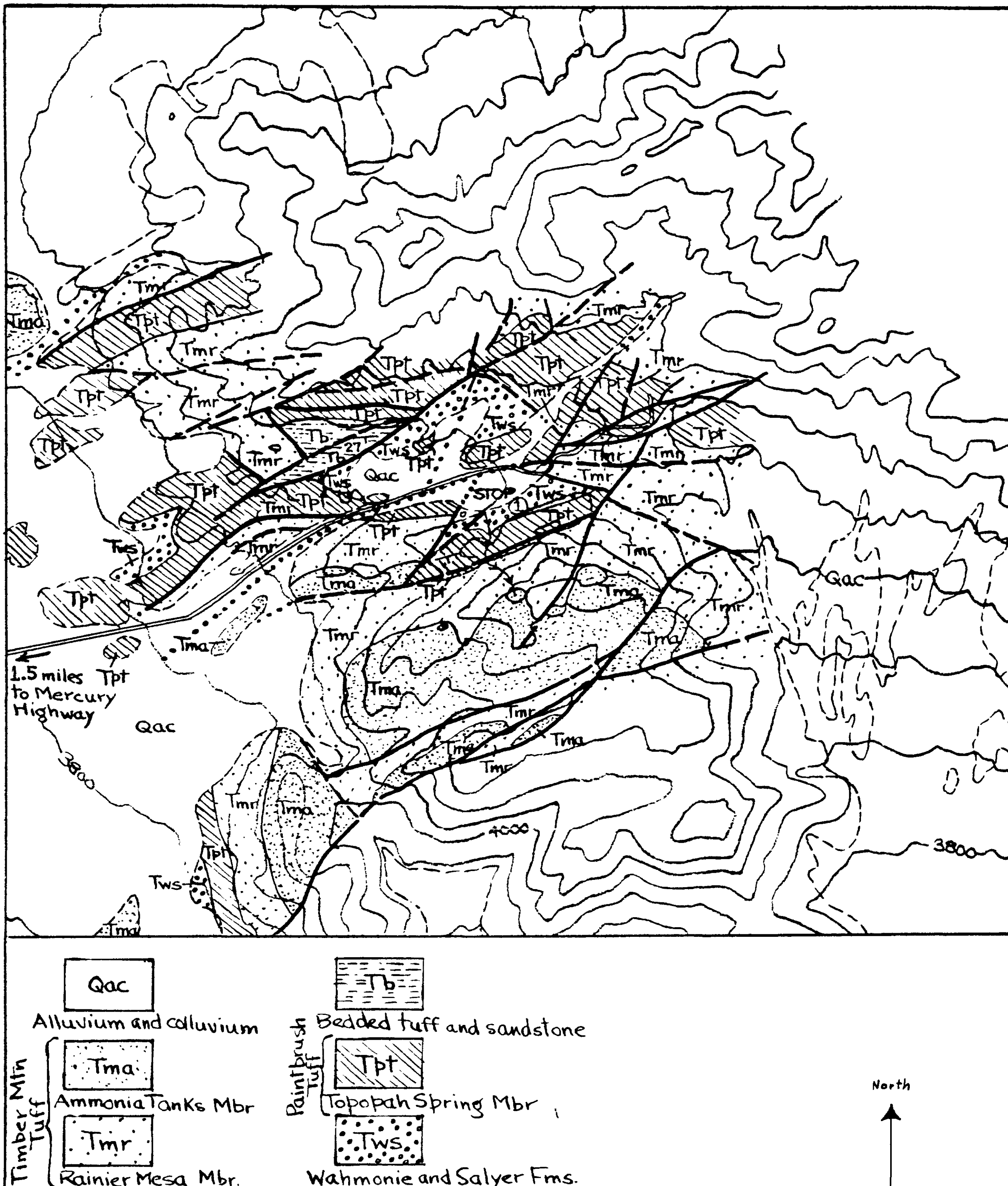

Figure 10.--Diagrams of geologic history of Timber Mountain caldera, Nevada

## ROAD LOG AND TRIP GUIDE

The route of this trip from the point of departure, the Flamingo Hotel in Las Vegas, to Mercury, Nevada, is the same as that for the Paleozoic stratigraphy field trip except for the four stops which the latter will make en route. This portion of our trip can be followed in the guide for the Paleozoic stratigraphy trip.

[All mileages in the following log are approximate.]

| Distance | Cumulative mileage | |
|---|---|---|
| 0 | (0) | Turn off from U.S. Highway 95 to Mercury, Nev.; entrance to Nevada Test Site and camp facilities. |
| 5 | (5) | Check Point Pass; security guard station. Pass through Silurian dolomites. |
| 2 | (7) | Enter Frenchman Flat, southern edge of the Tertiary volcanic basin. Sedimentary rocks at base of Tertiary section on left side of road. |
| 4.5 | (11.5) | View northward of Salyer-Wahmonie complex of dacite-rhyodacite lavas, breccias, tuffs, and minor sediments onlapped locally by Timber Mountain Tuff. |
| 6.5 | (18) | Eastern extent of Salyer-Wahmonie lavas on right side of road, overlain by thick section of Paintbrush and Timber Mountain Tuffs. |
| 3.5 | (21.5) | Gate to Microbarograph Road; turn off highway to right. (Gate is generally locked, and key must be obtained from Security Officer.) |
| 2.5 | (24) | <u>STOP NO. 1 Section of Timber Mountain Tuff (fig. 11)</u>. Here we will climb over a stratigraphic section of the Timber Mountain Tuff and some underlying units at a place about 20 miles southeast of Timber Mountain caldera, not far from the limit of the Timber Mountain Tuff in this direction. This will be the hardest walk of the day and will involve a climb of about 350 feet.<br><br>At the base of the section, near the busses, we will cross a few outcrops of sandstone and tuff at the distal end of the Salyer-Wahmonie complex. We will then cross through the Topopah Spring Member of the Paintbrush Tuff in which we will see some of its typical welding and crystallization zones as well as a conspicuous compositional change shown by an upward increase in phenocryst content and proportion of biotite. |




SKETCH MAP OF GEOLOGY AT STOP 1, MICROBAROGRAPH ROAD

Scale: 1:24000

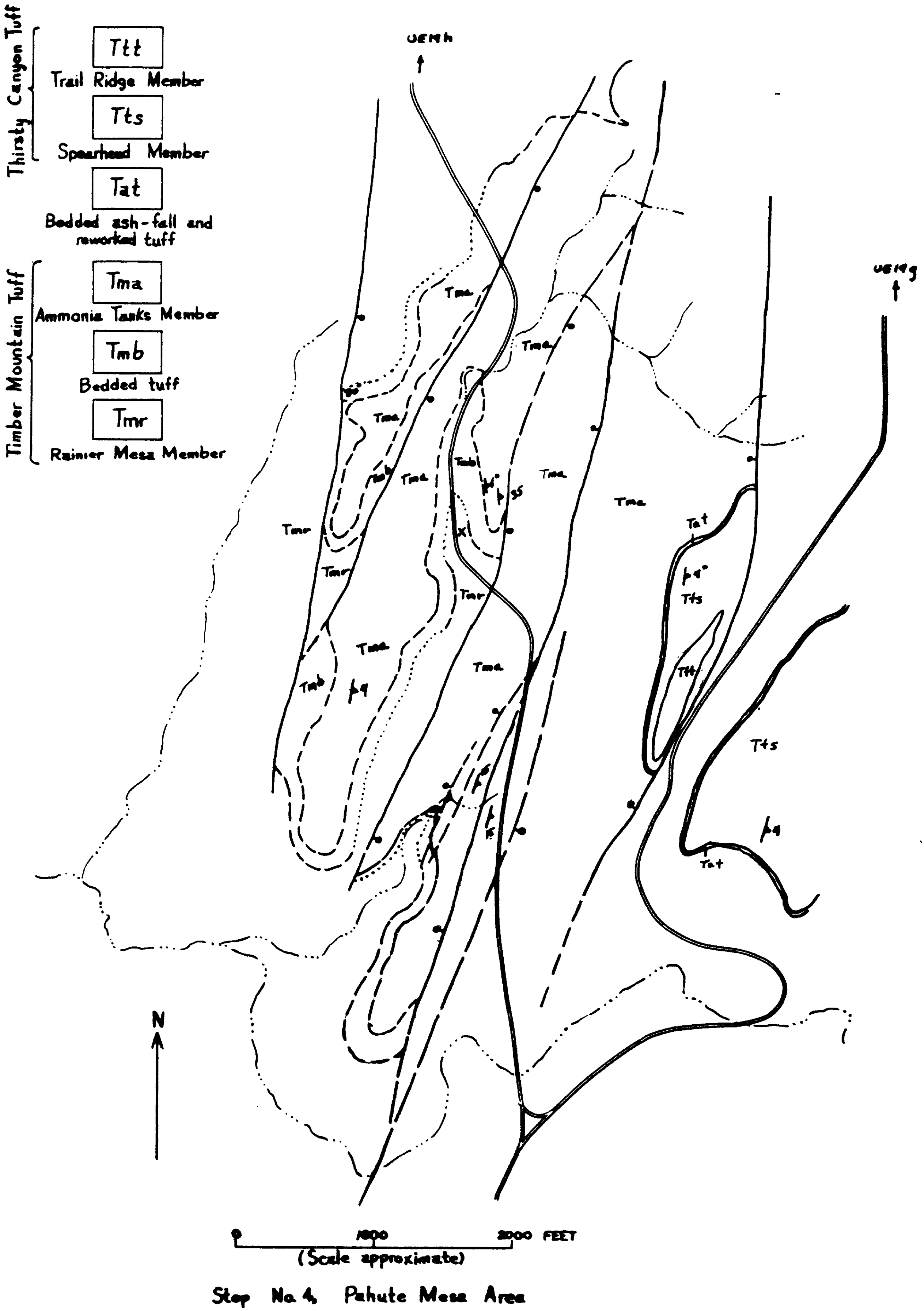
Contour interval 100 ft.

0 ½ 1 MILE

Figure 11

| Distance | Cumulative mileage | |
|---|---|---|
| | | The base of the Rainier Mesa Member of the Timber Mountain Tuff is faulted against the upper Topopah Spring. We begin in the nonwelded glassy base of the Rainier Mesa, pass up through progressively more welded tuffs, encounter the contact of the devitrified zone, and climb through densely welded devitrified tuff. Above this we will see a vapor-phase zone and the nonwelded glassy top of the member. Thin ash-fall beds between the Rainier Mesa and Ammonia Tanks Members are covered where we will cross the contact. The Ammonia Tanks is thin and only partially welded at this place. It strongly resembles the Rainier Mesa, but with luck you may find a few crystals of sphene, a diagnostic accessory mineral present in the Ammonia Tanks but not in the Rainier Mesa. |
| | | A number of criteria exist for distinguishing the Rainier Mesa and Ammonia Tanks although many of them have only local significance and most of them probably will not be obvious to those newly acquainted with the area. It should be noted, however, that where field criteria fail, there are distinctive modal petrographic characteristics for each member. In addition the Rainier Mesa has a natural remanent magnetization reversed to the earth's present field whereas the Ammonia Tanks has a normal NRM. |
| 0 | (24) | Return to busses. |
| 2.5 | (26.5) | Return to highway. |
| 3.5 | (30) | Enter Yucca Flat, near eastern edge of Tertiary volcanic basin. Control Point buildings on left. |
| 1 | (31) | Turn left onto Orange Road. |
| 8.5 | (39.5) | Turn left onto Tippipah Spring Road. |
| 2.5 | (42) | Pass through Syncline Ridge. Paleozoic basement here is Pennsylvanian-Permian Tippipah Limestone, equivalent to most of the Bird Spring Formation of areas to the south. These are the youngest pre-Tertiary sediments of the Test Site region. Mississippian clastics derived from the Antler orogenic belt are just northwest. Stay to right where road forks just ahead. |
| 4 | (46) | Base of Tertiary section, upper Miocene welded tuff. |

| Dis-tance | Cumulative mileage | |
|---|---|---|
| 3 | (49) | Edge of Timber Mountain caldera. We will drive along wall rocks eroded back from the original edge. Timber Mountain, the resurgent central dome, is on the skyline to the west. |
| 4 | (53) | STOP NO. 2 View of Timber Mountain caldera. We will walk up on the low hogback west of the road to view Timber Mountain caldera. The wall, rim, and moat are visible on the north, east, and southwest sides of the caldera; the central dome is about 7 miles west-southwest. The Timber Mountain Tuff on the caldera rim will be pointed out. The Ammonia Tanks Member is also present inside the caldera, forming the hogbacks which onlap the base of the wall, including the one we will stand on. |
| 0 | (53) | Return to busses. |
| 7 | (60) | Drive to stop 3 for lunch. |
| 0 | (60) | STOP NO. 3 Rainier Mesa Member of Timber Mountain Tuff. We will examine the Rainier Mesa Member in a roadcut on Pahute Mesa, very near the source of the tuff at Timber Mountain caldera. The member here unconformably overlies ash-fall tuff and pumice. We will walk along the road examining lithologies representing welding and crystallization zones as high as the densely welded devitrified zone. The busses will drive ahead to the end of our walk. |
| 1 | (61) | Return to busses. |
| 9.5 | (70.5) | The canyon west of the road, about one quarter mile past the construction yard, is in densely welded Rainier Mesa; the roadcut just past the yard is in ash-fall tuff and pumice beds between the Rainier Mesa and Ammonia Tanks; bluffs just to the right of the road are Ammonia Tanks. Turn off just beyond to the right onto the UE19h road. |
| 2 | (72.5) | STOP NO. 4 Bedded tuff between members of Timber Mountain Tuff (fig. 12). We will pick up the stratigraphic section here about where we left it at stop 3. On both sides of the road at road level is the vapor-phase zone of the Rainier Mesa Member in its quartz-latitic phase; the Rainier Mesa we have seen previously is the stratigraphically lower, less |




Stop No. 4, Pahute Mesa Area

Figure 12

| Dis-tance | Cumulative mileage | |
|---|---|---|
| | | phenocryst-rich and less biotitic, rhyolite phase. Above this is the glassy nonwelded top of the Rainier Mesa and discontinuously exposed ash-fall tuff and pumice beds between the members. At the crest of the ridge east of the road we will see the rhyolitic basal Ammonia Tanks Member. |
| 0 | (72.5) | Return to busses. |
| 2 | (74.5) | Return to Pahute Mesa highway and turn right. For the next one quarter mile toward the west, the road cuts down through densely welded Rainier Mesa to a fault scarp at which the Ammonia Tanks is downdropped toward the west. |
| 1 | (75.5) | Roadcut in pumice below Ammonia Tanks Member. |
| 2.5 | (78) | STOP NO. 5 View of Black Mountain (fig. 13). We will stop briefly at the roadside to look westward across Pahute Mesa toward Black Mountain. The plateau surface in front of us is about the least dissected portion of the Pliocene volcanic plateau of the southwestern Nevada volcanic field. It is formed by the only slightly faulted depositional surface of the Thirsty Canyon Tuff, which had its source in the area of a caldera centered at Black Mountain. The mountain itself is a constructional volcano which nearly fills the caldera, the eastern rim of which should be faintly visible if the day is clear. |

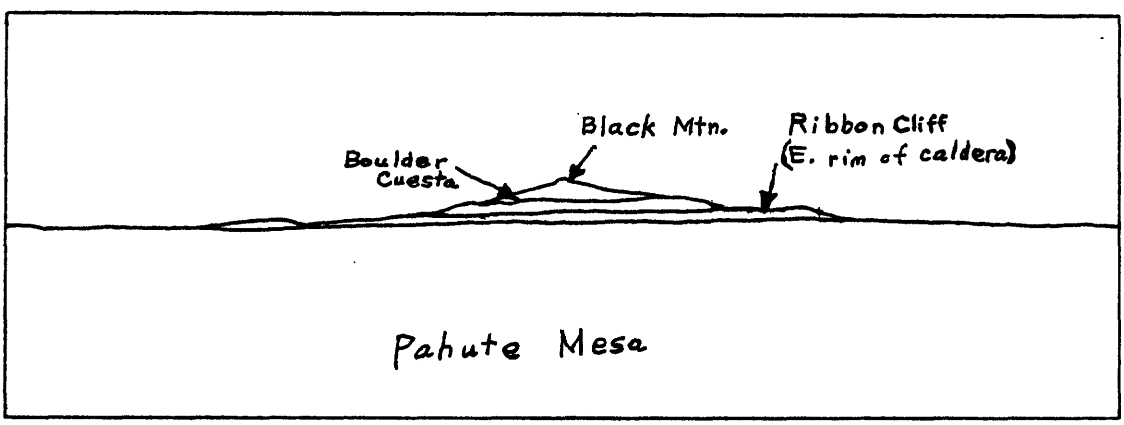
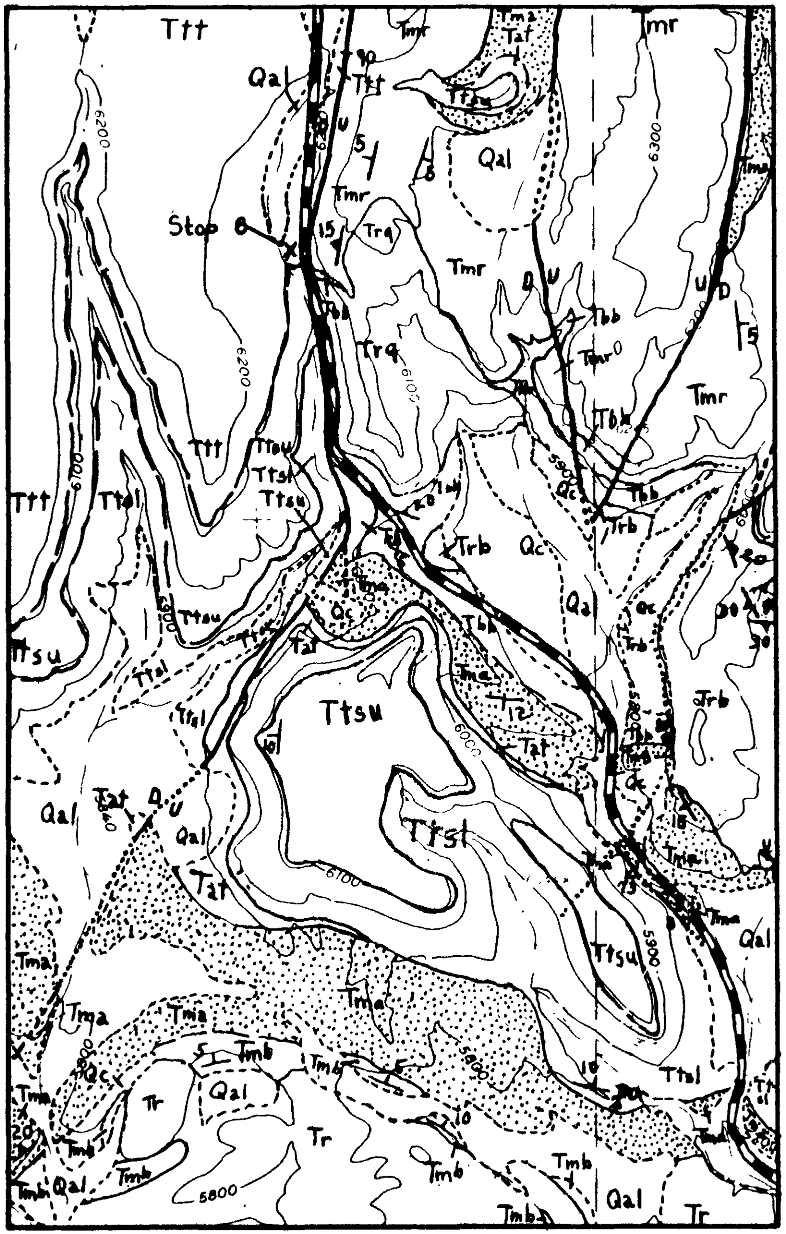



Figure 13.--Sketch of profile of Black Mountain looking west across Pahute Mesa from Stop 5.

| Distance | Cumulative mileage | |
|---|---|---|
| 0 | (78) | Return to busses. |
| 1 | (79) | STOP NO. 6 Relations between caldera wall and moat, and Basin-Range faulting (fig. 14). This stop is at the intersection of the north wall of Timber Mountain caldera with a north-trending Basin-Range fault. It and others of this area bend southwestward near the caldera to approach it perpendicularly, but displacement on these faults ends abruptly or decreases markedly at the wall. The Thirsty Canyon Tuff is downdropped on the west side of the fault and forms part of the volcanic plateau described at Stop 5. The Thirsty Canyon thickens notably from the upthrown to the downthrown block showing that the fault predated the Thirsty Canyon and was later rejuvenated.<br><br>The upthrown block east of the fault exposes two precaldera rhyolitic lava flows extruded from the area of the present moat. These flows are onlapped by bedded tuff and breccia with lithic inclusions of the flows and by the Rainier Mesa Member, which here has a vitrophyric zone near its base.<br><br>The Rainier Mesa occurs here only in the wall, outside the caldera, whereas the Ammonia Tanks Member occurs both at the rim and inside the caldera where it rests on a rhyolite flow in the moat. |
| 0 | (79) | Return to busses. As we leave this stop the busses will pass down through an upper light-gray glassy zone, a middle devitrified zone, and a dark-gray basal vitrophyre of the upper, quartz-bearing precaldera rhyolite flow. |
| 2 | (81) | At the bend in the road we pass through the caldera wall where the Ammonia Tanks inside the caldera onlaps the precaldera rhyolite flows and interlayered ash-fall tuffs of the wall. The Ammonia Tanks here is overlain by the Thirsty Canyon Tuff which also partially fills the caldera. Basin-Range faults have little or no displacement in the Thirsty Canyon, but just below here a small fault parallel to the caldera margin has been rejuvenated slightly and the Thirsty Canyon downfaulted against the Ammonia Tanks. |




Stop 6.-- Geologic map showing relations between the north wall and moat of Timber Mountain caldera and basin range faults

Figure 14.

EXPLANATION

| Qal | Qc |
|---|---|

Alluvium (Qal) and colluvium (Qc)

Thirsty Canyon Tuff

- Ttt — Trail Ridge Member
- Ttsu / Ttsl — Spearhead Member: Ttsu, upper tuff; Ttsl, lower tuff

Tat — Airfall tuff

Timber Mountain Tuff

- Tma — Ammonia Tanks Member
- Tmb — Bedded tuff
- (caldera collapse)
- Tmr — Rainier Mesa Member

Tr — Rhyolite of caldera moat

Rhyolite flows of Scrugham Peak Quadrangle

- Trq — Quartz-bearing rhyolite (No. 4)
- Trb — Biotite rhyolite (No. 3)

Tbb — Bedded tuff and breccia

NORTH

0 ½ 1 MILES

| Distance | Cumulative mileage | |
|---|---|---|
| 1 | (82) | As we leave the area of figure 14, we pass through the moat rhyolite which underlies the Ammonia Tanks in the caldera. This lava flow was erupted through the ring-fracture zone which forms the caldera moat. |
| 2.5 | (84.5) | STOP NO. 7 View of north end of Timber Mountain caldera. This stop will be near the roadside to view the north wall, moat, and central dome of the caldera. The Timber Mountain Tuff on the rim and the Ammonia Tanks Member onlapping the base of the wall will be pointed out. Basaltic lavas erupted through ring faults buried in the moat lie just to the south. Time and bus transportation preclude our being able to visit Timber Mountain, but some of the principal structural features of the dome will be noted (figs. 15 and 16). |
| 0 | (84.5) | Return to busses. |
| 5 | (89.5) | Turn left onto Airport Road. |
| 2 | (91.5) | Turn left onto road to Test Well 8. |
| 3 | (94.5) | STOP NO. 8 Relations at caldera wall, Test Well 8 (figs. 17 and 18). At this stop we will see the eroded wall of Timber Mountain caldera and the relative positions of some of the units closely related to caldera structure. This area is within an embayment of several miles in the caldera wall. The postcaldera Ammonia Tanks Member forms the large hogback to the south; this unit flowed in against the north wall and dips southward toward the caldera because of the effect of differential compaction during welding between the feather edge on the wall and the thick section in the moat. The Ammonia Tanks is also present about 1,000 feet higher on the rim of Pahute Mesa, a short distance to the north. Beneath the Ammonia Tanks is a local sequence of bedded tuffs overlying, in the bottom of the valley, the distal edge of a late quartz-latitic ash flow of the Rainier Mesa Member. This is the only exposure of the Rainier Mesa within the caldera, and it apparently is a late ash flow that was emplaced during or just after the last stage of collapse. At the base of this local Rainier Mesa ash flow in several places is debris deposited on the caldera |

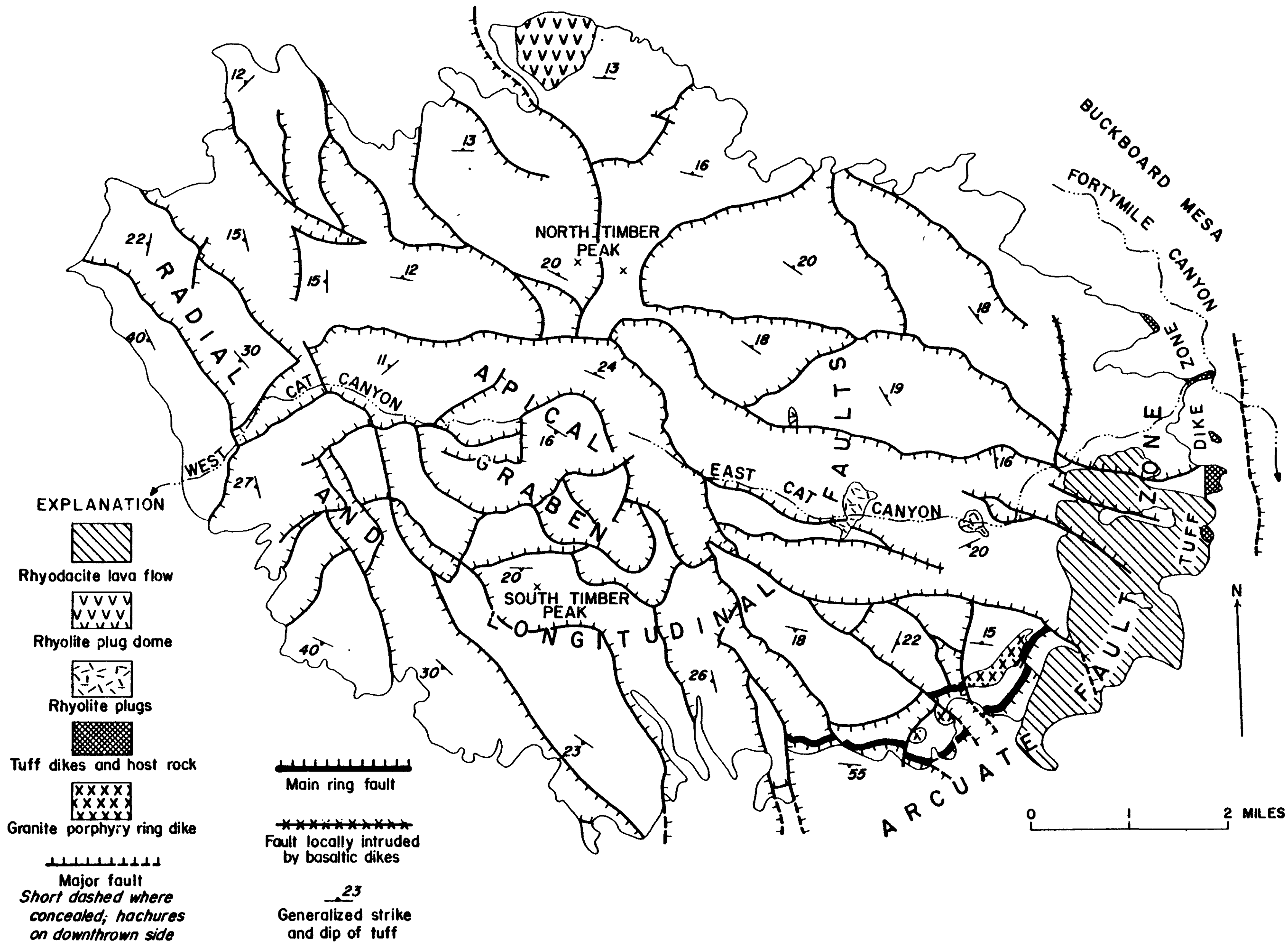



Figure 15.--Sketch of major structural elements of the Timber Mountain resurgent dome

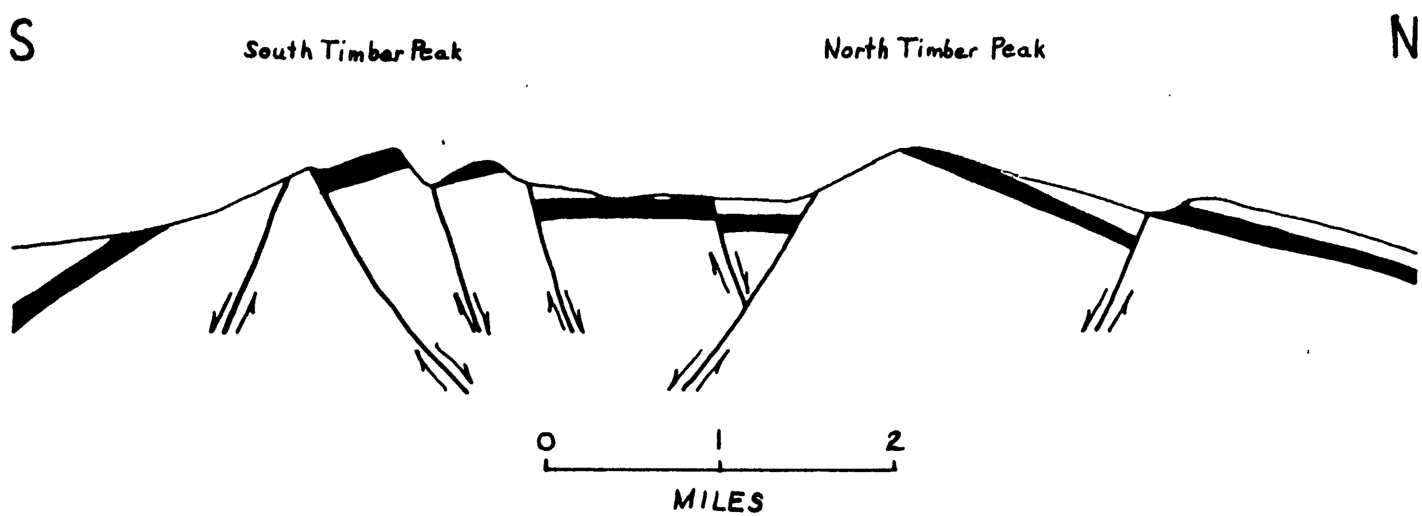



Figure 16.— Diagramatic section through Timber Mountain, central dome of the caldera. Structure indicated by arbitrary reference unit.

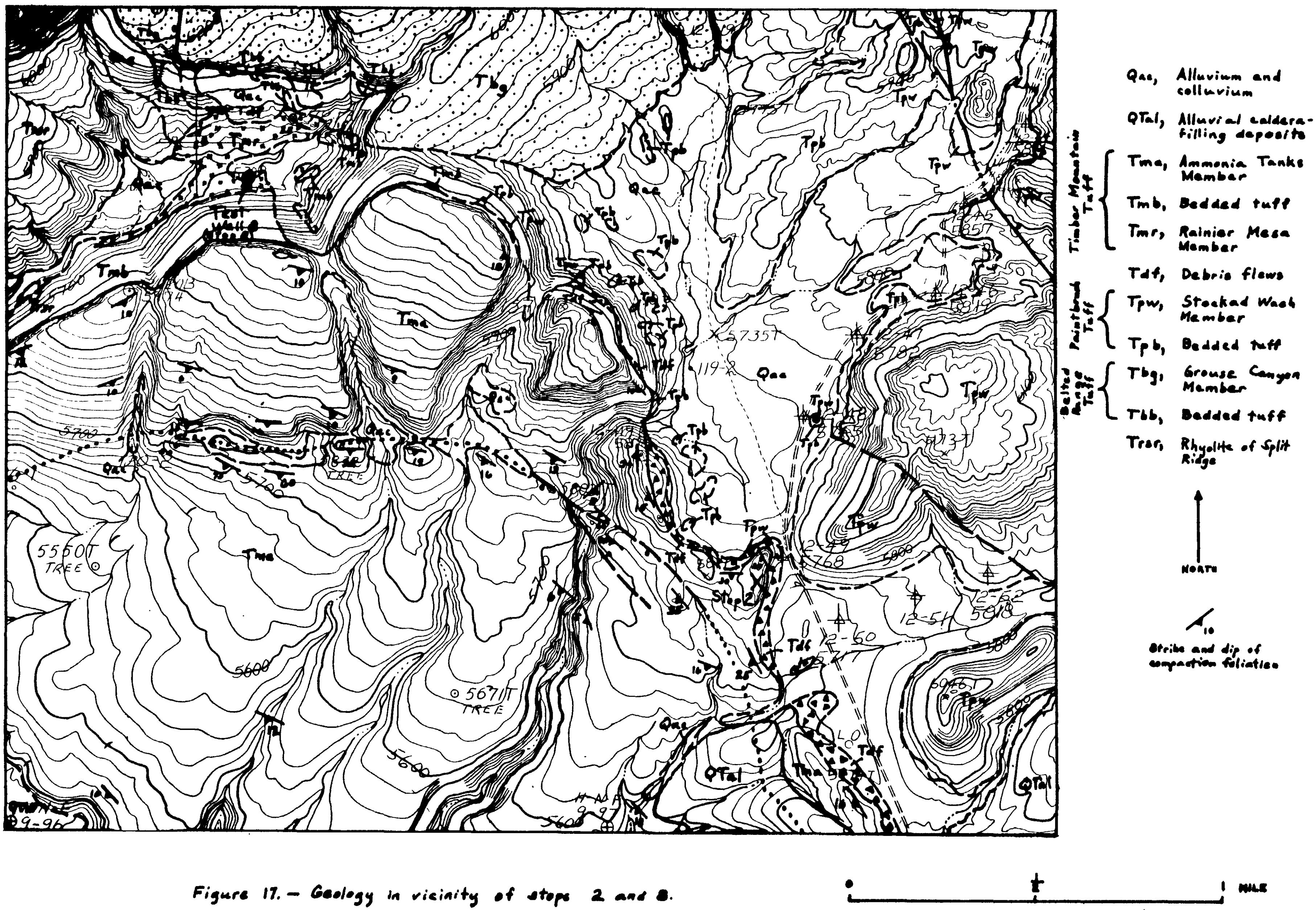



Figure 17. — Geology in vicinity of stops 2 and 8.

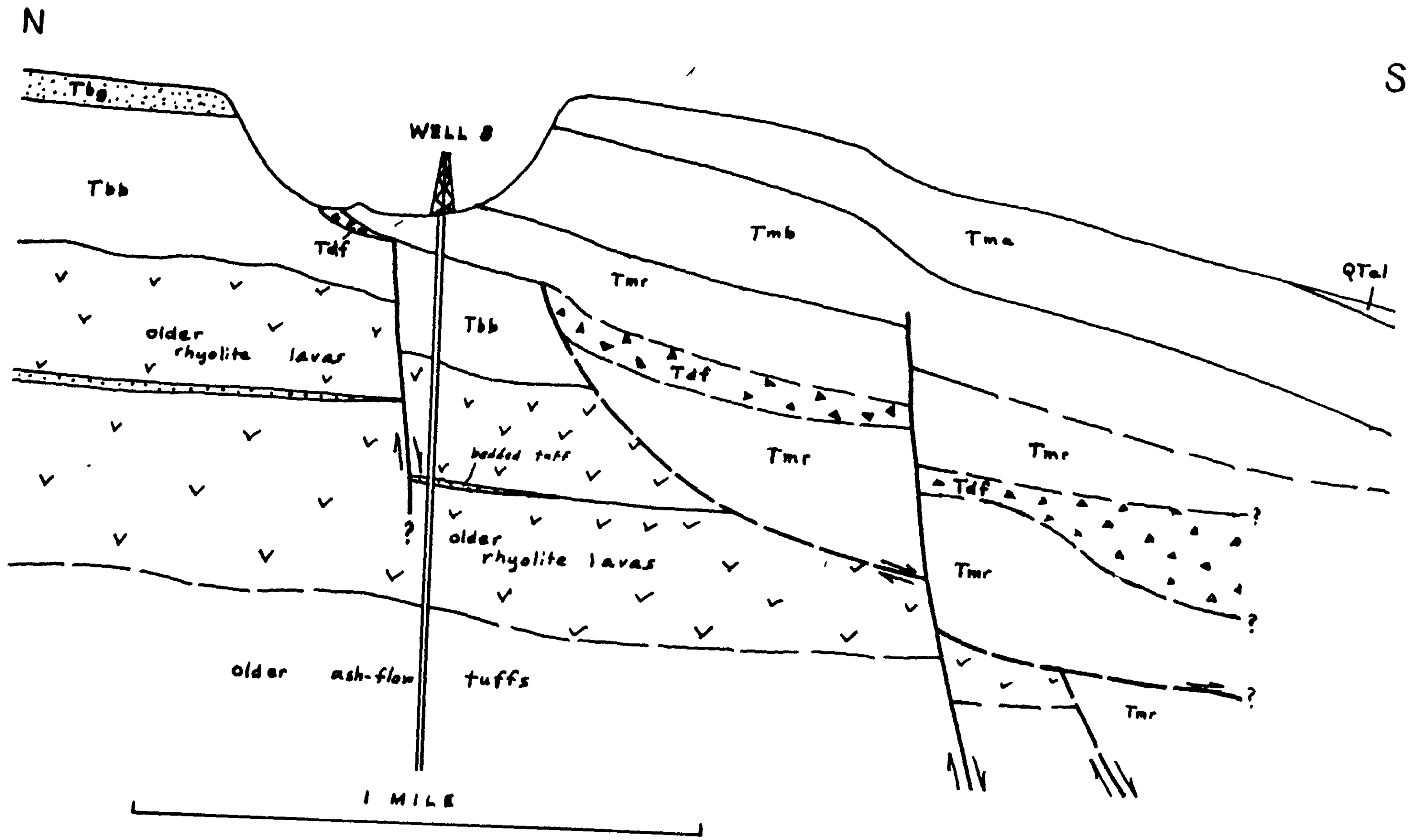



Figure 18.— Diagrammatic sketch of relations at Test Well 8. Vertical scale exaggerated arbitrarily; stratigraphic units as in fig. 17.

| Distance | Cumulative mileage | |
|---|---|---|
| | | wall as a result of collapse. This debris includes fragments of the tuffs and lavas forming the caldera wall, including fragments of the main phase of the Rainier Mesa represented on top of Pahute Mesa. |
| | | Test Well 8, in the bottom of the valley, is located at the edge of this embayment of the caldera; it is collared in Rainier Mesa, but within a few feet the well penetrated into older tuffs and lavas of the caldera wall. The ring faults along which collapse occurred must begin just beyond Test Well 8, buried under the Rainier Mesa and Ammonia Tanks exposures. A detailed gravity survey of this area has confirmed this interpretation. |
| 0 | (94.5) | Return to busses. |
| 3 | (97.5) | Return to Airport Road, turn left. Just beyond we rejoin pavement. If the hour is late, as it probably will be, we will stay on this paved road and return directly to Mercury. If there is time for an additional stop, we will turn right at this place toward the airport and follow the log as continued below for the optional Stop 9. |
| 3.5 | (101) | Join Buckboard Mesa Road, turn left. |
| 2 | (103) | Pass Thirsty Canyon Tuff in the caldera moat. |
| 5 | (108) | STOP NO. 9 (OPTIONAL). Post-Rainier Mesa, pre-Ammonia Tanks debris flows at caldera wall (fig. 19). We will leave the busses on the road, walk about one quarter mile toward the north to a small reservoir, and follow a small gulch down from the reservoir for about one half mile. In this gulch we will see good exposures of the debris flows, lying on bedded tuff of the caldera wall and containing fragments up to about 10 feet in diameter of all the precaldera units in this area including the Rainier Mesa Member. At the top of the section, some sorting and bedding are seen in the mudflows which below are completely nonsorted. Just north of this traverse the debris flows are overlain by a hogback of the Ammonia Tanks dipping westward into the caldera, as shown on the accompanying map. |

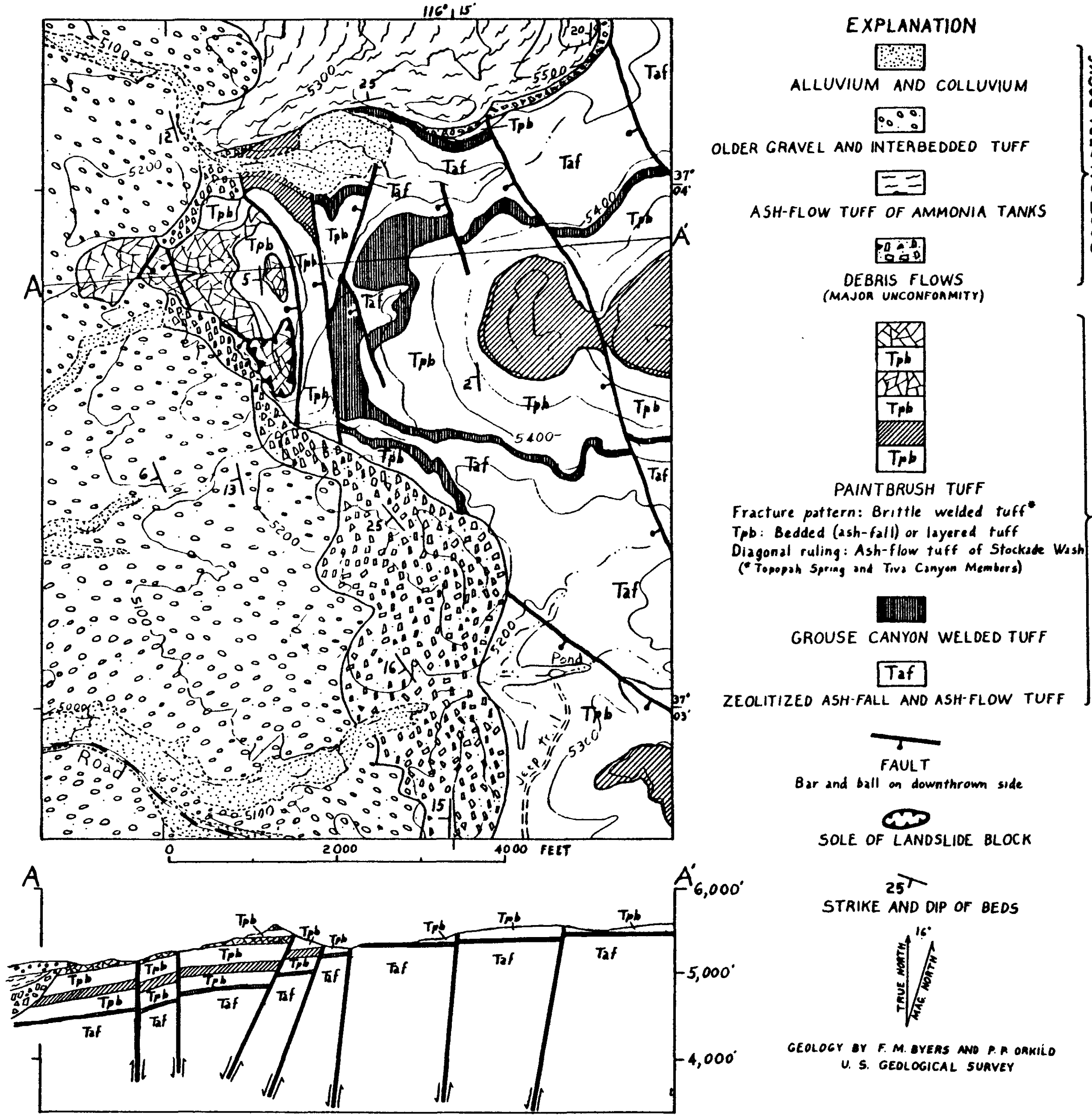



Fig. 19.—GEOLOGIC RELATIONS AT EASTERN MARGIN OF TIMBER MOUNTAIN CALDERA, NEVADA TEST SITE

| Dis-tance | Cumulative mileage | |
|---|---|---|
| 0 | (108) | Return to busses. |
| 4 | (112) | Return to pavement, turn left onto Tippipah Spring Road. |
| 4 | (116) | Turn right on Orange Road. |
| 35 | (151) | Mercury. |

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# ENGINEERING GEOLOGY AND SURFACE EFFECTS OF NUCLEAR EXPLOSIONS

/Trip Leaders: F. A. McKeown, F. N. Houser, E. M. Shoemaker, and W. L. Emerick/

Most of the features to be observed on this field trip will be examples of effects of explosions, and most of the description given at the stops will emphasize the principal geologic features pertinent to the results or use of explosions. In addition, as much as possible of the regional and local geology will be described.

Readers of this part of the guidebook are referred to the selected bibliography for details of the effects at some of the sites. Participants are referred to the road log for the Paleozoic stratigraphy field trip in the front of this book for points of interest between Las Vegas and Mercury and between Mercury and Frenchman Flat near stop 1 where this guide begins.

## Trip Guide

### Frenchman Flat

Several air-burst tests were conducted in the area prior to the moratorium on nuclear testing in 1958. The valley is underlain by playa deposits and alluvium, probably about 5,000 feet deep in the center of the basin. Tertiary volcanic deposits are thick on the north side of the valley, which marked the edge of the Tertiary volcanic basin, and are virtually absent on the south side.

### STOP NO. 1 Pre-Buggy II sites

Trenches formed by high-explosive charges in alluvium will be examined. This trenching project was conducted by the U.S. Army Engineers Nuclear Cratering Group in 1963. A resumé of the areal geology and some current activities in the Frenchman Flat area will be given.

### En route to stop 2

The principal area of interest most easily seen from a moving bus along this route is the area near Yucca Pass. The hills west of the pass are Cambrian dolomite and limestone; east of the pass is the C.P. Hogback made up of welded ash-flow tuffs and vitric nonwelded tuffs. The complex of buildings west of the road at the top of the pass is the Control Point for all tests in Yucca and Frenchman Flats.

Several miles north of Yucca Pass a detour will be made through Area 3. This area is used by the Los Alamos Scientific Laboratories for underground testing of nuclear explosions. Many sinks may be seen along the road, the largest of which resulted from the BILBY event.

STOP NO. 2. BILBY sink.

This sink resulted from collapse of the ground surface over the site of an explosion with a yield of about 200 kilotons at a depth of 2,413 feet in tuff, detonated on September 13, 1963. The sink is about 1,800 feet in diameter and 80 feet deep. Discussion of the origin and detailed features of sinks will be delayed until stop 4, after several of them have been visited.

STOP NO. 3. AARDVARK sink (fig. 20).

The morphology of this sink is typical. A device of low-intermediate yield (20-199 kilotons) detonated at a depth of 1,434 feet created the cavity into which tuff and alluvium collapsed to form the sink. The accompanying figure is a map and description of this sink.

STOP NO. 4. CUP sink (fig. 21).

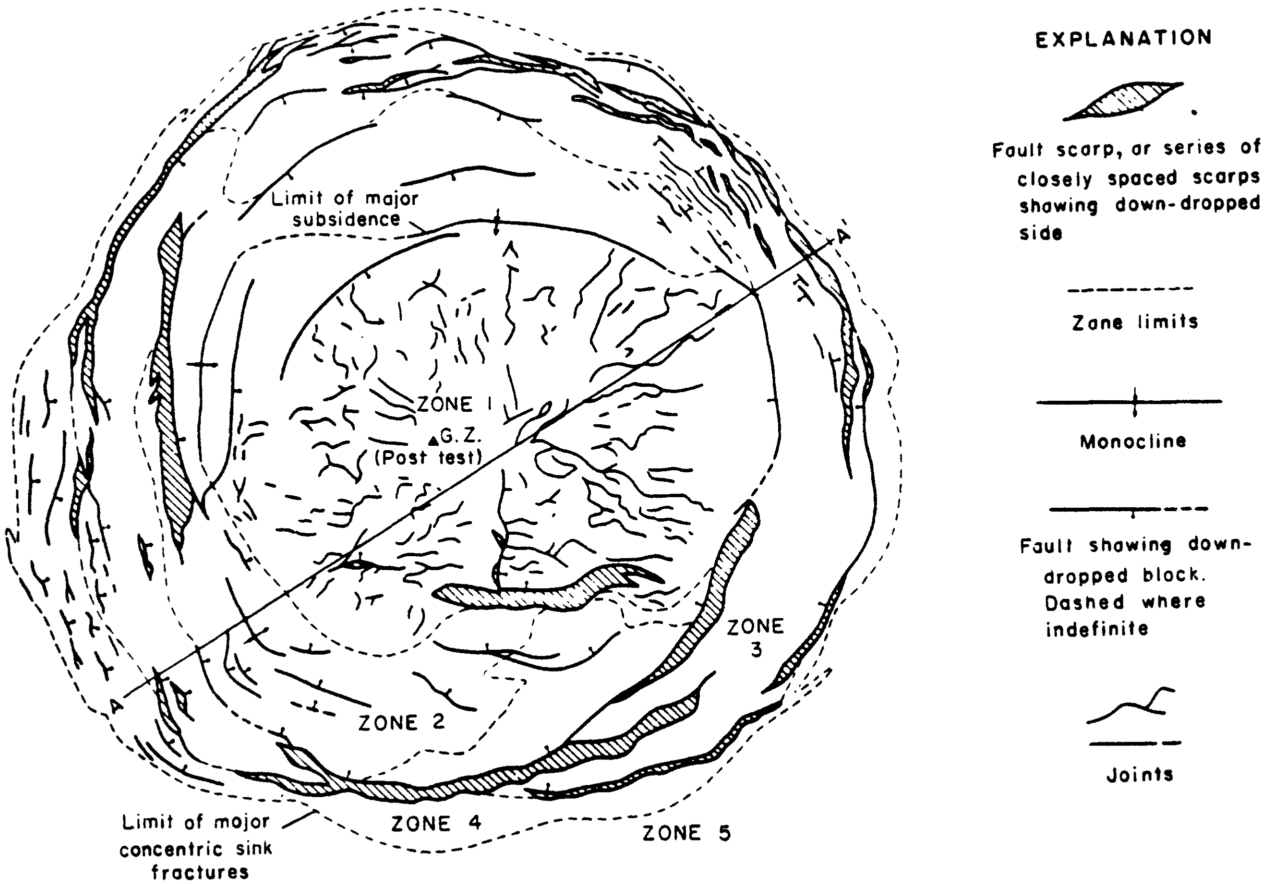
This sink resulted from detonation of a low-intermediate-yield device. The sink is about 950 feet in diameter and 185 feet deep. The attached map shows the pattern of cracks produced by the explosion. Discussion of these cracks and the character of this unique sink as well as features of the sinks in general will be given in the field.

STOP NO. 5. Trench across Yucca Fault scarp.

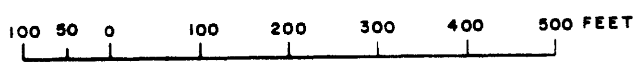
The trench was cut so that the nature of the cracking and movement along the Yucca Fault during some of the explosions could be seen. Description of this and other cracking of the ground surface over explosion areas will be given.

STOP NO. 6. Jangle U and Teapot ESS craters. (fig. 22).

The Jangle U and Teapot ESS craters, both produced by shallow subsurface nuclear explosions with yields of $1.2 \pm 0.5$ kilotons (TNT equivalent), structurally resemble craters produced by meteorite impact. Both craters are formed in Pleistocene and Recent alluvium. The alluvium consists of irregularly bedded and crossbedded sand and gravel. A well defined sequence of pedocal paleosols occurs in the Pleistocene alluvium and can be correlated over a significant part of the valley in which the beds formed. The craters have a center-to-center separation of about 600 feet and are formed in essentially the same beds.




MAP OF AARDVARK SINK




EXAMPLE OF SINK STRUCTURE, YUCCA FLAT

Definitions of structural zones:

Zone 1.--Comprises central part of sink where major subsidence occurred. Characterized by radial fractures and pressure ridges, and, in deeper sinks, by landslides. G.Z., ground zero.

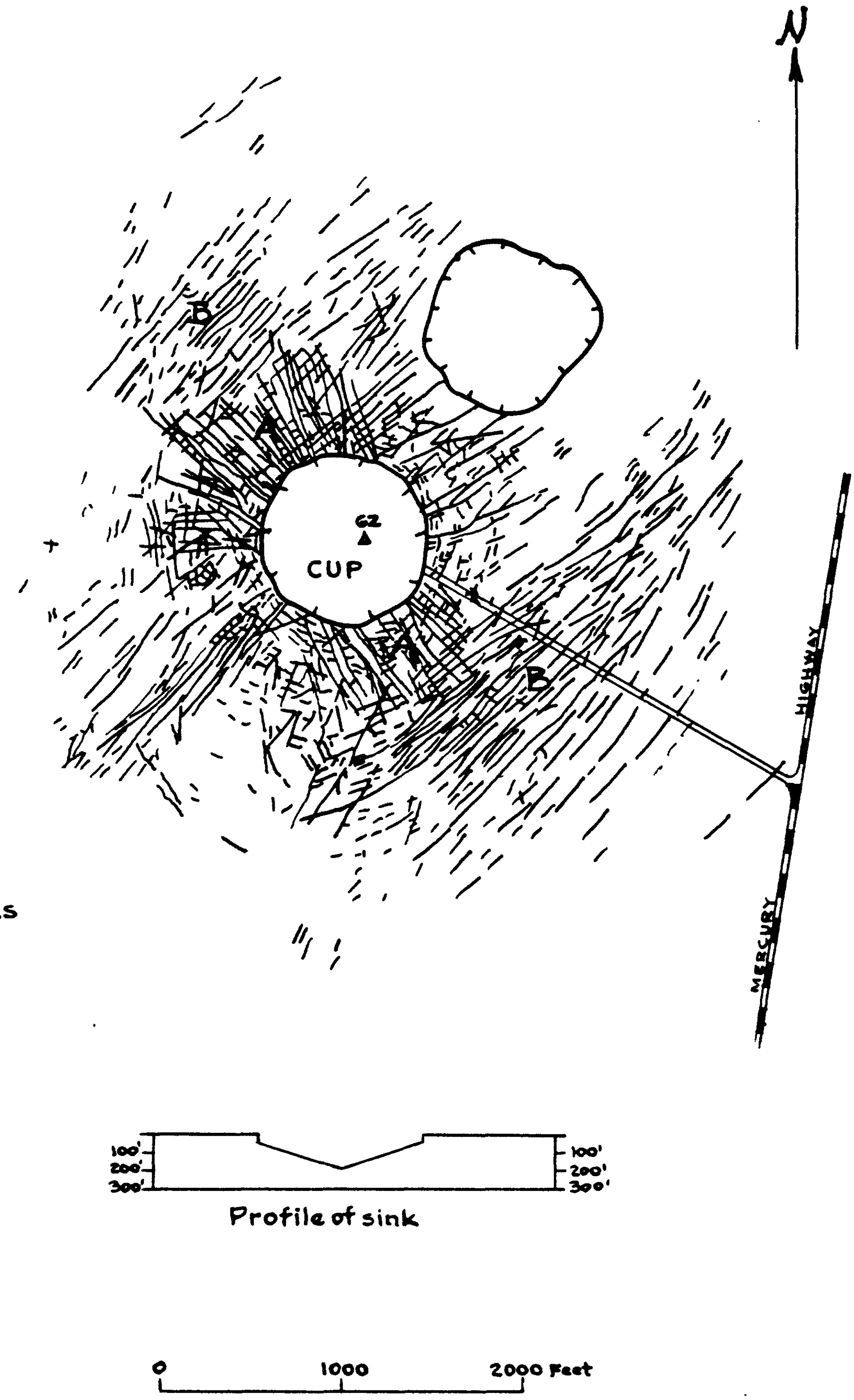
Zone 2.--Inward dipping fault blocks outlined by intersecting concentric, outward-dipping faults and fractures.

Zone 3.--Subsided, slightly rotated or unrotated blocks outlined by steeply dipping, intersecting concentric fractures; grabens are common. Inner edge of zone is generally lower than outer edge.

Zone 4.--Numerous concentric fractures; no obvious subsidence, but precise pre- and postshot contouring shows frequent broad depressions overlapping into Zone 5.

Zone 5.--Original terrain without obvious deformation related to subsidence. Commonly fractured by explosion-induced movement.

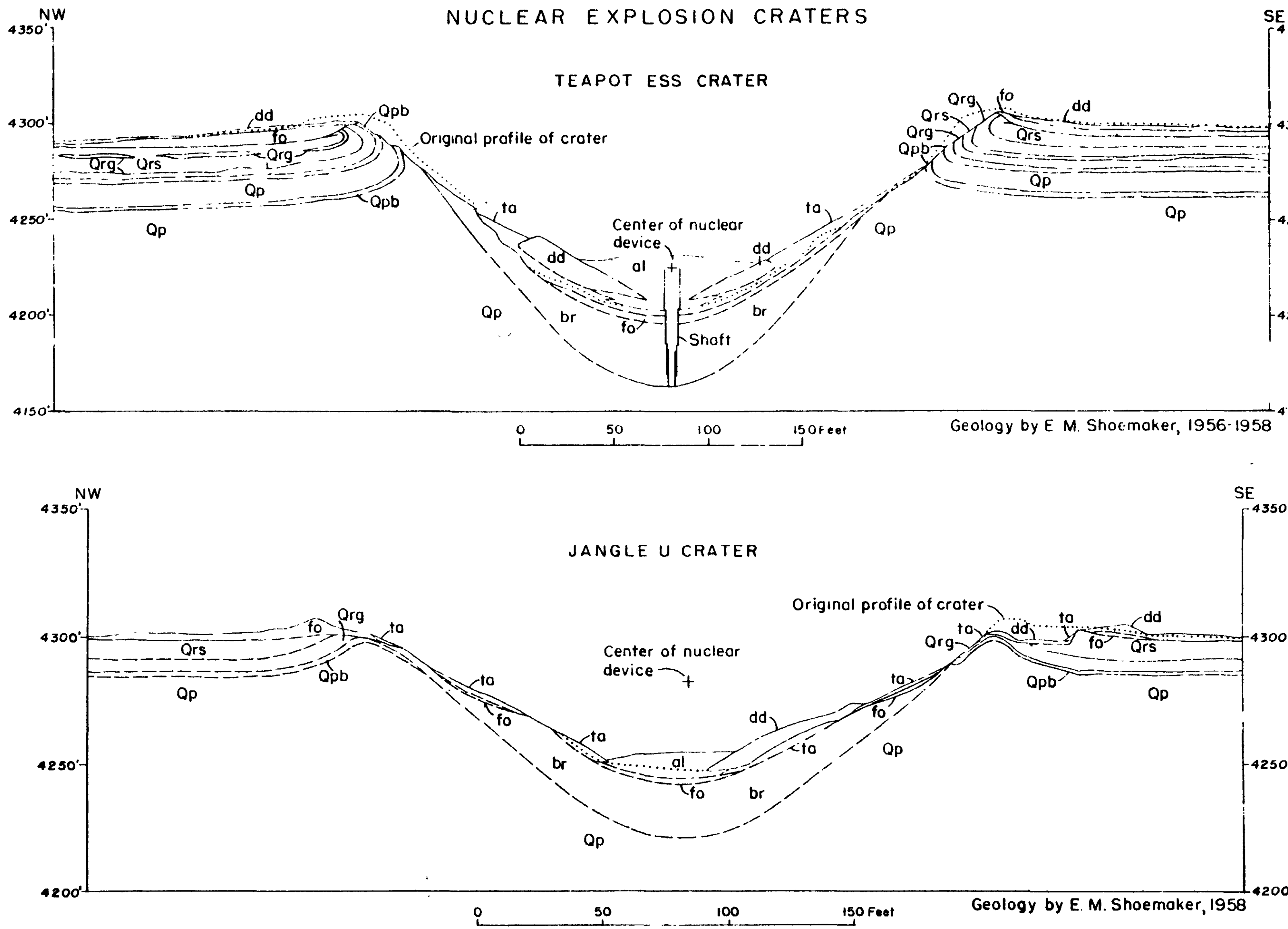
Figure 20




A- concentric and radial cracks
B- tangential cracks

Figure 21

SKETCH SHOWING SURFACE EFFECTS AND PROFILE OF SINK AT CUP SITE, NEVADA TEST SITE




dd, dump material moved by bulldozer or power shovel
ta, scree formed in crater
al, alluvium deposited in crater
fo, fallout and throwout
br, breccia

Qrs, Recent sand
Qrg, Recent gravel
Qpb, Pleistocene paleosol, B horizon
Qp, Pleistocene alluvium

Figure 22

In the Jangle U crater, in which the depth of burst was approximately 18 feet, alluvial beds are deformed in an asymmetric ring anticline beneath the crest of the crater rim. The beds are sheared off in the crater wall, along which there is slight drag. Slabs of alluvium up to 10 feet across are stacked on top of the anticline and on less strongly deformed beds on the outer flank of the crater rim. In the Teapot ESS crater, in which the depth of burst was 67 feet, the beds are deformed in an overturned syncline that overlies the crater wall. The upper rim of the wall is overturned and locally passes outward into debris that roughly preserves, inverted, the original alluvial stratigraphy. The axial surface of the syncline is a cone that is concentric with and a few feet below the crater wall.

The floors and lower walls of the two craters formed by these explosions are underlain by a compact breccia consisting of slightly to strongly compressed and sheared blocks of alluvium set in a matrix of smaller blocks and alluvial detritus. The original bedding of the alluvium is partially preserved in the breccia, but in some places individual blocks derived from one stratigraphic horizon have been introduced into parts of the breccia composed mainly of blocks from another horizon. Glass, formed by fusion of alluvium resulting from shock, is dispersed through the matrix of the breccia in the form of droplike, spindle-shaped, and irregular lapilli. Bedding in the breccia is overturned and is locally in fault contact with less distuubed beds along the walls.

STOP NO. 7. Sedan crater.

The Sedan crater is about 1,216 feet in diameter and 323 feet deep. It is similar in many structural respects to the Teapot ESS crater. Evidence of minor slumping around the rim will be pointed out if still preserved by the time of the trip. The slumping probably resulted from strong ground motion (about 1 g acceleration) from an intermediate-yield explosion about 4,900 feet away. Character and distribution of the ejecta will be observed.

STOP NO. 8. View of USGS Tunnel.

This is the location of the first contained large underground explosions in the United States. These tests were conducted with high explosives in 1956 by the U.S. Geological Survey for the Atomic Energy Commission as part of the feasibility studies for the underground testing of nuclear devices.

STOP NO. 9. Tunnel area on Rainier Mesa (fig. 23 and 24).

This was the area of the first contained underground nuclear explosions. A brief description of the locations and effects of several nuclear explosions detonated in the Rainier Mesa area will be given. Some of these are shown on the two accompanying maps.

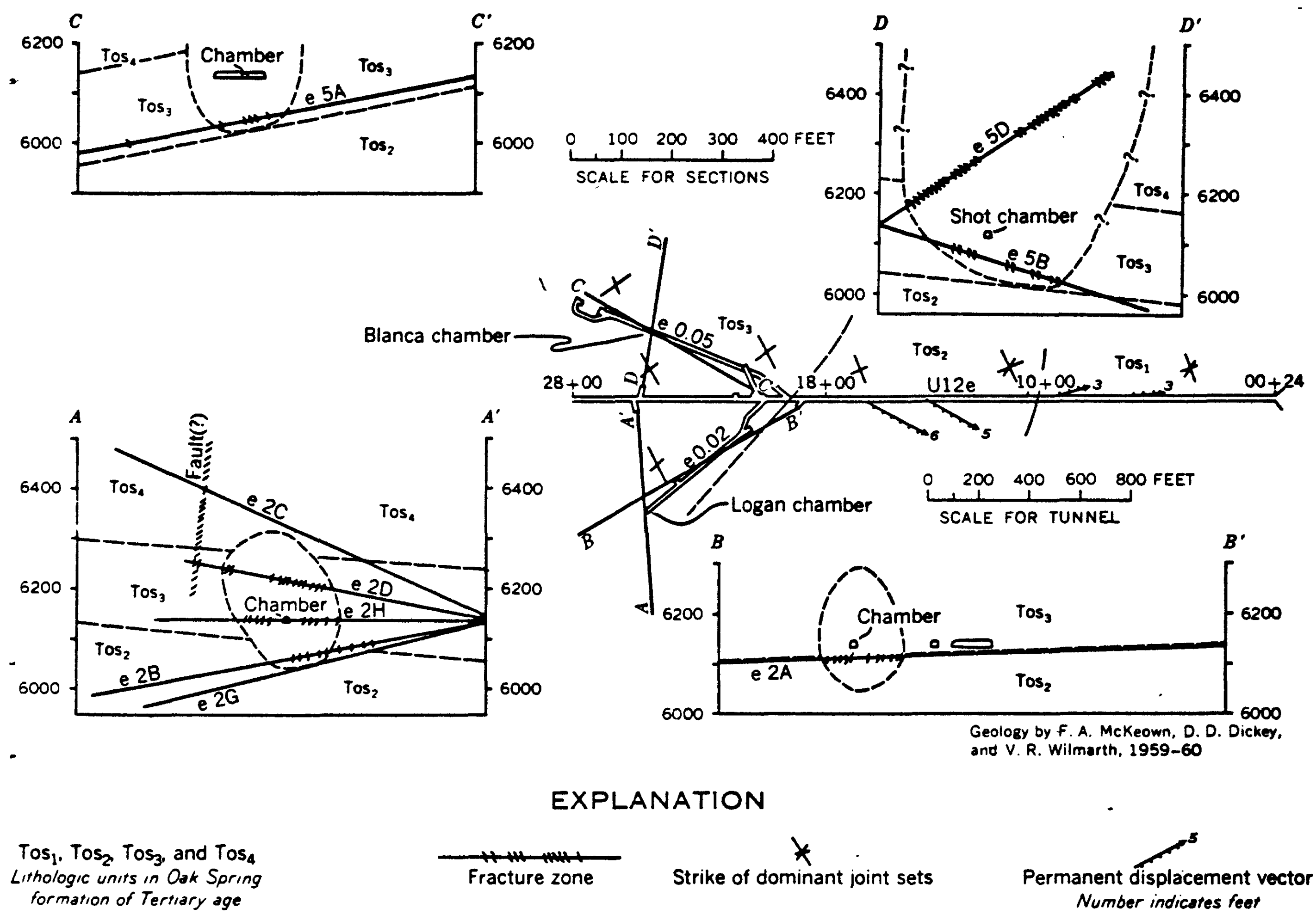



Figure 23. –Geologic map and sections of part of U12e tunnel complex, showing exploratory drill holes and some effects of the Logan and Blanca explosions. (After Wilmarth and McKeown, 1960.)

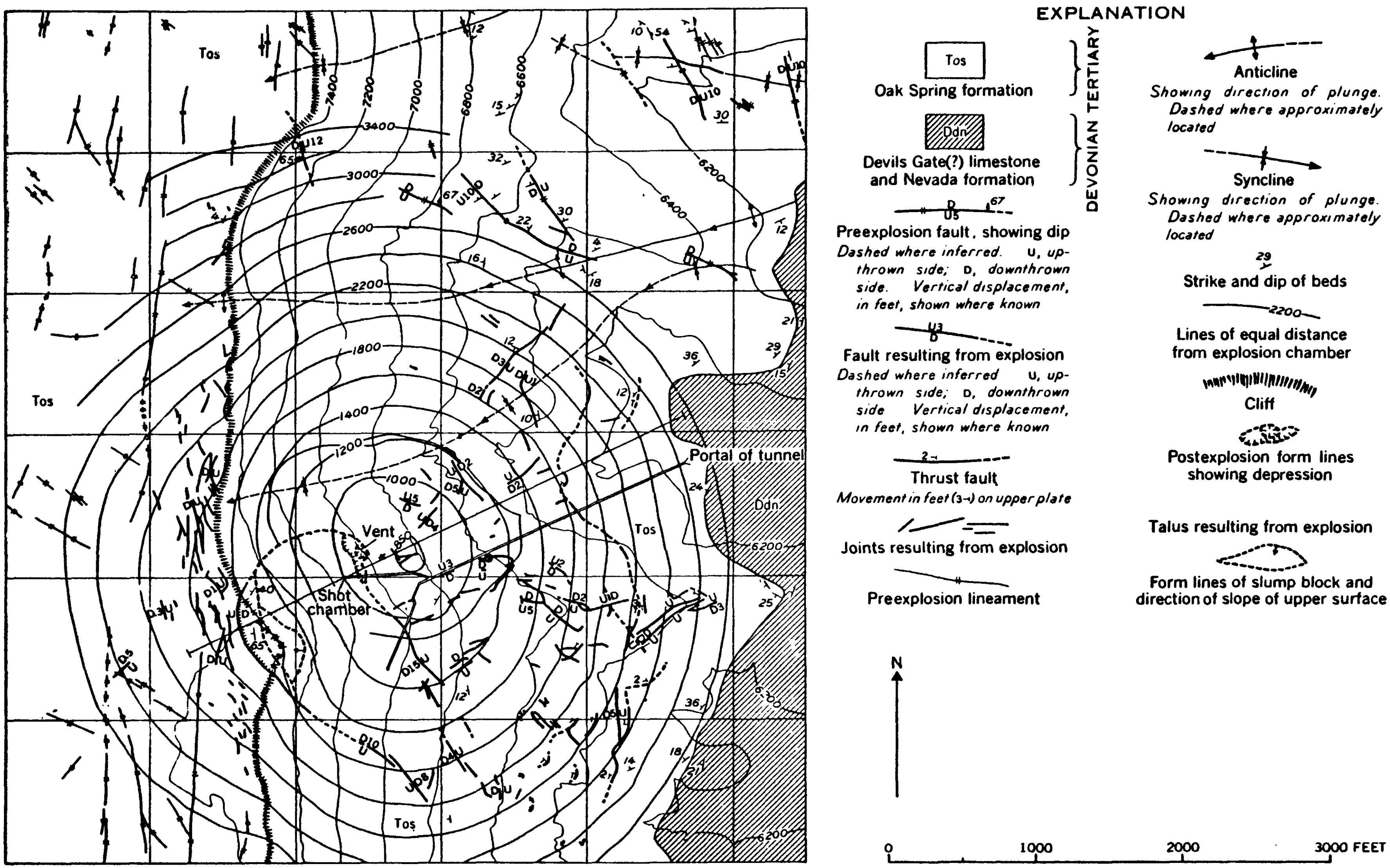



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Figure 24.—Geologic map of the U12e tunnel area showing joints and faults caused by the Blanca explosion, Nevada Test Site, Nye County, Nev., (after Wilmarth and McKeown, 1960).

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