ARIZONA GEOLOGICAL SOCIETY

SOUTHERN ARIZONA GUIDEBOOK III

1968

EDITED BY

SPENCER R. TITLEY

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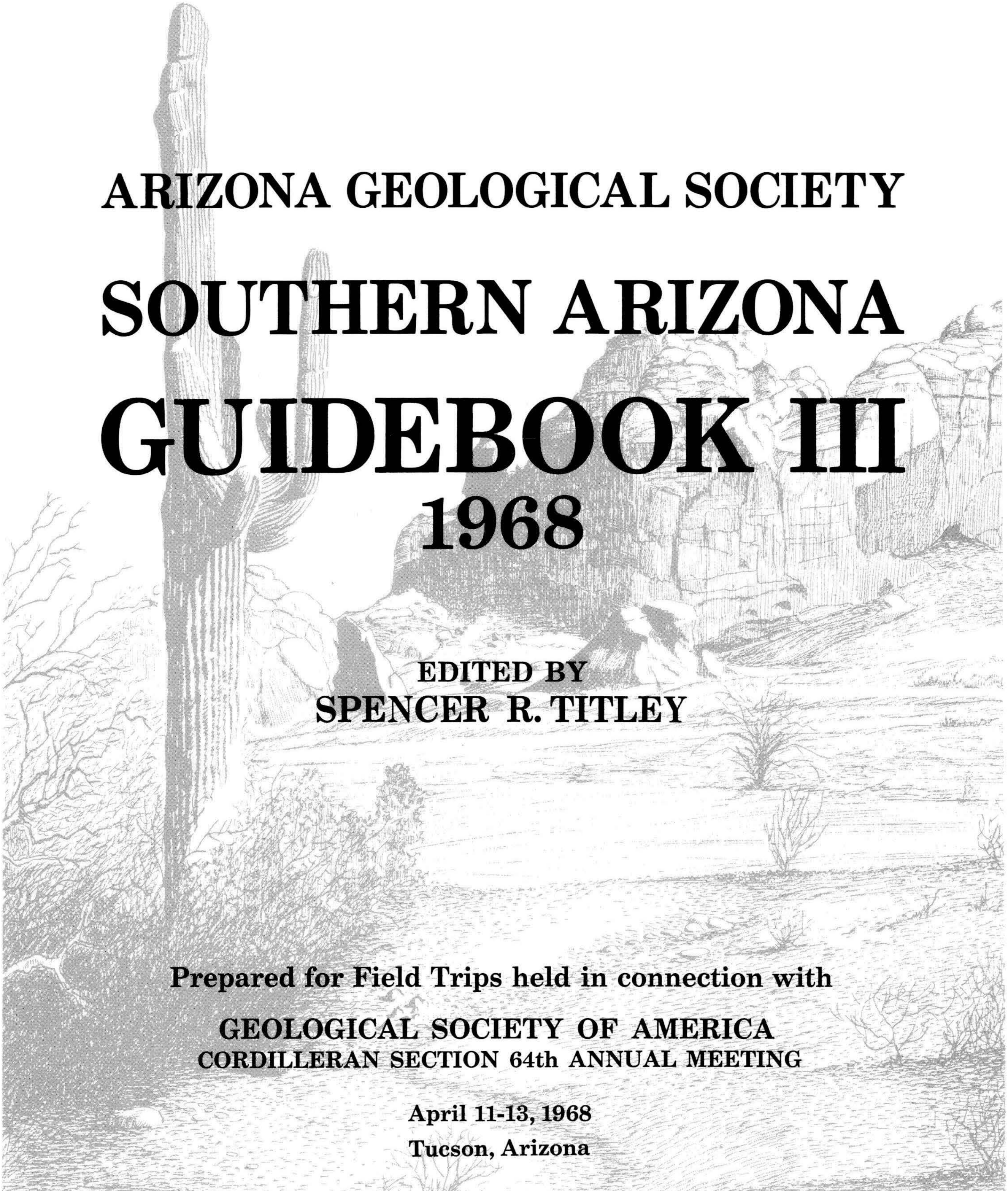

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1968

EDITED BY
SPENCER R. TITLEY

Prepared for Field Trips held in connection with

GEOLOGICAL SOCIETY OF AMERICA
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THIS GUIDEBOOK IS RESPECTFULLY DEDICATED TO THE

MEMORY OF

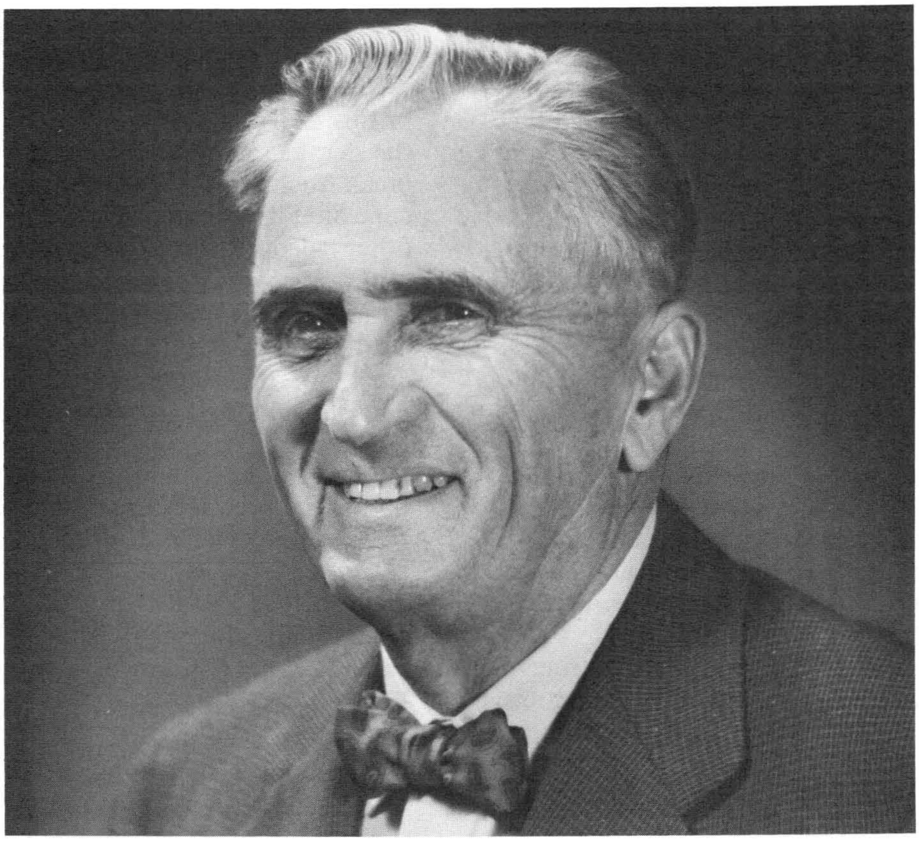
HARRISON ASHLEY SCHMITT

Scientist, Geologist, and Scholar

by

HIS MANY COLLEAGUES AND FRIENDS

IN THE SOUTHWEST



MEMORIAL OF HARRISON ASHLEY SCHMITT

> *"As I look back on four decades in mining geology I am impressed by the magnitude of the changes that have taken place. Many have said that change is often mistaken for progress and to some extent this has been true especially during the last decade. Much of the change, however, has resulted in real improvement."*
>
> *Harrison Schmitt – 1964*[1]

By

H. H. SCHMITT
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Houston, Texas

Harrison Ashley Schmitt was one of a generation of geologists who developed the art and science of mining geology into a leading factor in the unprecedented growth of mineral exploitation in the last thirty years. Loosely allied with such men as Augustus Locke, Hugh McKinstry and many others, he joined in branching from the footsteps of Waldemar Lindgren toward the application of detailed ore deposit studies to the exploration for new mines. Our generation, in the spell of great advances in exploration geophysics and geochemistry, has in part turned away from the path of applied ore deposition blazed by these men. However, the continued linking of Harrison Schmitt's name with recent porphyry copper developments in the Southwest–Christmas, Esperanza, Mineral Park and Battle Mountain–suggests that we have strayed too far. In the same manner that Harrison Schmitt and his generation combined the logic of chemistry and physics as they knew it with the descriptive philosophy of Lindgren, it is up to us to combine their concepts of applied ore deposition with the new techniques of geochemistry and geophysics.

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[1] Presented to the Arizona Geological Society, March 3, 1964. This memorial will be published in part by the Mineralogical Society of America in the March-April 1968 issue of the American Mineralogist.

"The Doctor" was born June 11, 1896, in Mankato, Minnesota, into the family of Harrison Lincoln and Esther Grannis Schmitt, a lawyer's family only one generation removed from the frontier. Although the necessity to be a carpenter, a smithy, or a hunter was rapidly disappearing, he nevertheless acquired these and related skills to his and his families' lasting pleasure and benefit. After graduating from Mankato High School he entered the University of Minnesota at Minneapolis apparently intent on studies foreshadowed by his boyhood "excursions" into chemistry. Upon the completion of his second year of university study he volunteered for duty with the Marine Corps where he and his fellows took part in another of our continuing attempts to preserve liberty on this planet. This period of national service during World War I appears to have fertilized a deep concern for the long term health of our society, a concern about which he continued to speak and write throughout his life.

It was also during his tour with the "Horse Marines" that his reading in geology and his affection for nature led him eventually to return to the University of Minnesota where he obtained a doctorate in geology in 1926. His thesis work in the Parral District of Chihauhua, Mexico, (1931) and other investigations in that country for the American Smelting and Refining Company began the first of two major phases in his studies of ore deposits. He continued this phase of detailed field studies with work on the vein, manto and pipe types of ore deposits in Mexico from 1922 to 1926, in southern Arizona, Virginia and the Central Mining District of New Mexico from 1927 to 1931 and subsequently as a consultant throughout Mexico and southwestern United States. This work gave him extensive if not unique knowledge of the structure, mineralogical associations and ore finding techniques related to pyrometasomatic and hypogene ore deposits and supergene alteration (1933a, 1933c, 1938, 1948). He generalized some of his early thoughts on the localization of ore deposits in the Southwest by writing (1933a):

> "...The universal association of the ore deposits of this province with sharp or localized features of structure supports a theory of occurrence in which the influence of such features is given first place. Preparation of the ground–that is, breaking and brecciation–is considered essential. Temperature doubtless has important influence in the separation and classification of the elements; the importance of chemical reactions with the wall rock is debatable; the influence of pressure, although minimized, must be considered where critical phenomena exist; the position of ore relative to the source hinges upon theories of the location of the source. But the need of an opening to start with cannot be escaped. Furthermore, judging from the conditions in this province this opening must connect with the depths of the earth's crust by a crosscutting break such as a high-angle fault, dike, breccia cone or chimney or a deep-cutting stock, neck or other igneous form.
>
> "A theory of occurrence that emphasizes ground preparation explains why ore deposits are limited to the first mile or two of the earth's crust, for the volume of the broken ground in many mineralized areas appears to diminish with the depth... Many have been impressed by the rapid downward diminution in the size of orebodies, of brecciated rock and the tendency for fissures, faults and dikes to focus in depth... In places where deep development has been done, many of the so-called stocks are seen to narrow to a focus also; that is, have the form of a funnel... In other words, some 'stocks' behave like ore; i.e., they tend to constrict downward in the first 1,000 ft. or so of the earth's crust.
>
> "The theory that most 'stocks' are truncated cupolas of batholiths has become so firmly established that it is heresy, perhaps, to suggest that the probabilities are good that many 'stocks' with which contact pyrometasomatic deposits are associated in this province and in adjoining areas have 'floors'. If such a condition is verified, the current theory for the origin of the contact pyrometasomatic and associated ore deposits will need revision for this province at least. There is already a large body of evidence showing that the deposition of many of the contact pyrometasomatic deposits in western United States was later than the consolidation of the adjacent exposed intrusives and if these intrusives are not the cupolas of batholiths the question of the source of the mineralizing fluids seems even more complicated than current theory suggests.
>
> "It seems likely that the primary factor in the localization and association of 'stocks', contact pyrometasomatism and ores, is a deep-cutting break of one sort or another in the earth's crust, (and) that the contact pyrometasomatic deposits are not derived from the 'stock' but that their association is the result of localization along mutual outlets to the earth's surface.
>
> "In conclusion, it is perhaps significant that mining geologists whose living depends on their success in applying geology, and especially those who have had good success in finding ore, continually emphasize the importance of studies of

> structure in solving the problems of ore occurrence, particularly the careful measurement of the rocks by large-scale methods of mapping. The successful application of mining geology in the past has been largely the result of such work. The writer believes, however, that specialized studies of outcrops and the less obvious surface expressions of ore, the alteration jackets or halos of orebodies, vertical zoning, oreshoot extension and the character of the roots and branches of orebodies will have a proportionately greater success in the search for ore in the future."

Dr. Schmitt's 1939 paper on the Pewabic Mine of the Central Mining District (1939b) is considered by many to be one of the foremost illustrations of the application of systematic field and laboratory investigations to a problem in ore deposition and mining. In the abstract of this paper he concluded:

> "The Pewabic mine is in the southeastern part of the zone of pyrometasomatism which surrounds the intrusive quartz monzonite at Hanover, New Mexico. Extensive development has proved that the south lobe of the intrusive is floored and that the sedimentary rocks, chiefly limestones, shales and intercalated quartz diorite sills, were thrust aside laterally by the magma. The overthrust, a minimum of 500 feet, was expressed by close folding accompanied by rock flowage of the bedded rocks in the upper plate of a flat thrust fault.
>
> "The less intense effects of the exomorphism resulted in marbleization of the limestone and hornstonization of the shales; the stronger effects were epidotization of the aluminous rocks and andraditization of the limestones. The lower plate was mildly metamorphosed. The sphalerite ore bodies, essentially uncontaminated by lead and copper, are localized by the intersection of the thrust fault with nearly vertical post-silicate northeast fault zones resulting in flatly pitching chimneys and ore blankets.
>
> "The facts indicate that the rocks were metamorphosed without volume change and that large amounts of silicon, iron, and zinc were brought in. Much of the silica can be accounted for by epidotization and chloritization of the aluminous rocks, and a question discussed is whether the silica, largely older than the sphalerite, may not have been derived from alterations by gaseous volcanic emanations."

During this period of detailed field studies he also wrote extensively on the use of systematic geological techniques in ore search and mining (1932b, 1932c, 1933b, 1936). He recognized and deplored the early stages of the current trend to deemphasize training in geologic mapping at the college level, writing in 1936:

> "Most recent discoveries of ore by geologic methods resulted from detailed studies of structural conditions and these had detailed large-scale mapping as their base. Few recent college graduates seem to have had training in mapping methods known to be effective... The student is expected to acquire the needed skill somehow after graduation; yet it may mean his bread and butter for several years. Indeed he may never learn to map well and therefore be ineffective in exploration."

His concern in this area continued throughout his career as reflected in this statement in 1960 (1960):

> "Many mining geologists avoid geological studies and mapping in the exhaustive detail necessary for success in many mining districts. Short-cuts are commendably sought, but are seldom successful in the hands of the inexperienced. This lack of accomplishment further spurs the drive to short-cut panaceas. But, ironically, the very short-cuts looked for are the dividends from many years of detailed outcrop and mine mapping. Beginners seldom can be convinced of this."

Soon after the end of the Second World War Dr. Schmitt's interests followed those of the mining industry into the exploration for disseminated, or "porphyry" copper deposits. This second phase of his study of ore deposits culminated in one of the most impressive string of successful mining property developments of which I am aware. Of particular note is his involvement in the discovery and development of ore bodies at the Christmas, Esperanza, Mineral Park and Peach mines in Arizona, and at Battle Mountain in Nevada. As part of his work with the Defense Minerals Production Agency of the Federal Government he was also involved in evaluation of the Bor Mines in Yugoslavia in 1951 and the Toquepala, Peru, copper deposit in 1952. Several other properties which he recommended in recent years show promise of becoming major producers in the near future. In 1960 he outlined the factors involved in the search for porphyry copper deposits, saying in part:

> "As for the more detailed outcrop inspection in a given district, many of the cappings of the copper-molybdenum disseminated deposits are characteristic enough to permit an efficient, quick, on-the-spot decision as to action. These are the cappings that have been said to be of low to moderate temperature hypogene origin and are characterized by silicification, argillization,

sericitization, biotitization and rarely chloritization...

"Other than the above more general type with which most of us are familiar, at least three others occur in Arizona:

> "(1) With the above general type of alteration still evident there is often enough jarosite to result in a high yellow outcrop as contrasted with the normal geothite brown. We generally correctly interpret this as representing high pyrite-non-commercial copper. But in recent months an enriched chalcocite zone of unknown size has been found under such an outcrop where some copper was visible in the form of turquoise. I confess that I have passed up similar outcrops in the past because most of them previously drilled had yielded high pyrite and low copper even when copper stains were common in the outcrop. In such outcrops we probably are overlooking some clue or clues as to the copper-pyrite ratio.
>
> "(2) There is the oxidized capping derived from a hypogene mineralization that has the appearance of sulphides in 'fresh' rock, that is, in rock that is not argillized, quartzified, sericitized or chloritized. There may or may not have been chalcocite enrichment. The hypogene secondary minerals, besides the sulphides, may include biotite and feldspar. This would seem to represent high temperature mineralization. Bagdad, Arizona, represents this type... There is abundant hypogene secondary biotite and feldspar associated with chalcopyrite, molybdenite, and pyrite. There is not much clay...

"The above described types of occurrence are likely to give cappings that depart from the norm. Nevertheless, it should be possible to judge them. There must be enough discrete 'limonite' to make possible a commercial amount of copper in depth and the 'limonite' should in part represent chalcocite, and/or chalcopyrite and/or bornite. As noted earlier a predominance of jarosite may not rule out possible commercial copper in depth, but normally it is less favorable. Furthermore, we like to see some copper staining in the outcrop and should not forget Locke's admonition to look for relict sulphides...

> "(3) Another type of disseminated copper deposit is presumed 'high temperature' mineralization in sedimentary and igneous rocks including a high proportion of limestone. Garnet and other silicates are characteristic. This type includes the Pima-Banner, Mission-Palo Verde and Peach ore bodies in the Sahuarita, Arizona, area. The Pima-Banner out-crop is really a wide lode and is largely covered by gravel. The exposed part contains silicates at the surface associated with unreplaced limestone. Copper stains are prominent and oxidized copper ore is found in pockets. The mineralization of the Peach ore body is similar. Veinlets and spots of brown 'Limonite' a millimeter or more in thickness are conspicuous.

"There are probably other types of outcrops that are significant in terms of ore. Experience indicates, however, that if the outcrop represents a section of the original protore, enriched or hypogene ore...it will be characterized by discrete veinlets and/or spots of 'limonite' and hematite. This is the essential ingredient. Paper thin veinlets or very small dots of original sulphides are not enough volume-wise to suggest an ore body. 'Limonitic' paint is not enough. In those few cases where all the iron is leached out, the walls are likely to be inert and the pyrite ratio high.

"We have been saying for some time that if we are to give a specific out-crop more than passing notice it must be well altered in the sense that the character of the original rock must be greatly modified. The normal cappings, as have been often described, present the aspect of an area of dirty white to gray coloration modified by 'limonite' and hematite of several colors and distributions. This type of capping is always brecciated and broken. We don't necessarily need to look for 'structure'; it is always there. The boundary or walls of the capping may be defined by the lack of any appreciable 'structure'.

"The question of copper staining of the outcrop is usually important although the outcrop over the ore body may have less visible copper than that over waste. That is, leaching may be thorough over the ore and some of the capping copper may migrate a long distance. Outcrop and plant sampling can be misleading. Sometimes secondary ore bodies are formed in the neighboring talus slopes, outwash and stream gravels. Molybdenum on the other hand, appears to be relatively stable and since it is nearly always present in the porphyry coppers of the Southwest it is a fair metallometric anomaly guide...

"A few...geological features of the...(More usual)...bulk-type ore bodies may be of interest:

> "(1) Copper enrichment resulting in chalcocite blanket ore bodies is not the exclusive type of gross copper disseminated ore body in Arizona. As is well known, primary chalcopyrite ore predominates at Ajo, but it also predominates or is important at the Pima-Banner, the Mission-Palo Verde and the Esperanza ore bodies at Twin Buttes; in the Bagdad, Ray and Safford copper ore districts and at Helvetia, Arizona.
>
> "(2) At the Esperanza mine and the Mineral Park copper mineralization areas where the chalcocite blanket form is well developed, the ore bodies are on topographic highs. These thin deposits are depressed and usually die out in the adjacent lower slopes and arroyos where either protore or primary ore is exposed in places. In detail the upper surfaces of the blankets though sub-level are fairly smooth-topped. They dip down and thin rapidly as the lower topographic elevations are approached...
>
> "(3) I cannot adequately evaluate the cup or inverted cone theory of Pennebaker. Since most of the bulk-copper deposits are in intensely brecciated ground, in contrast to most of the surrounding walls, they seem to have the aspect of permeable sponges. There seems to be supporting theory that in the ore body block of ground circulation of both hypogene and supergene fluids would be more active, penetrate deeper and spread out farther. The end result would be more elevated and lower grade protore sulphides outside of the 'cup' country. This should significantly aid in evaluating the best blocks of ground.
>
> "(4) Apparently, in some cases where sulphides are deposited in holocrystalline igneous rocks, without low temperature alteration such as argillization, upon oxidation the resulting copper minerals are concentrated in the outcrop. No chalcocite blanket is formed. This has been attributed to the easy availability of free alkali as a neutralizer from the partial breakdown of the originally fresh feldspar.
>
> "(5) In the Southwest there are many occurrences where primary sulphides outcrop over wide areas. This is the result of recent exposure through rapid erosion. The exposures are often protores, but are usually wholly barren pyrite. The suggestion is that possibly hypogene chalcopyrite exposures of commercial grade may have been overlooked because they have not been expected. They may be marked by superficial oxidation not over a few inches in thickness."

The broadening of Dr. Schmitt's experience with the ore deposits of the Southwest led him to think and write about his cumulative knowledge of these deposits. He was among the first to document the importance of the hot spring environment in epithermal mineral deposition (1950). Summarizing his thoughts as follows:

> "The postulated formation of the 'epithermal' ore bodies in the meteoric-water shell appears to simplify the explanation of several features of these deposits:
>
> > "(a) They show a nearly universal shallow bottoming. This bottom often may well be at the base of the vadose-water zone. In some districts a belt of primary ore bodies of a given vein parallels the present topography.
> >
> > "(b) The delicate layering of the vein minerals may be due to seasonal and longer climatic changes, i.e., changes largely in the quantity of water entering the meteoric-water shell.
> >
> > "(c) The difficulty of classifying many 'epithermal' minerals as hypogene or supergene is explained as the result of the intimate intermingling of the hypogene and supergene environments.
> >
> > "(d) 'Epithermal' ore bodies commonly do not outcrop, but the apex of the ore is at shallow depth. This is possibly explained by the rapid change in conditions near the original surface. Such a change is evident in the hot-springs areas.

He also continually reemphasized the importance of wall-rock alteration as a possible source of vein silica stating in 1954 that -

> "The known facts on the distribution of the silica in and associated with many ore deposits suggest that only a small proportion of this oxide is imported into the ore zone from distances measured in thousands of feet or more. Most of it appears to be derived from the desilication of alumino-silicate walls and transported for distances often measured in inches, and rarely more than hundreds of feet.
>
> "This belief suggests a unique approach to the theory of the character of the ore-forming fluids, and further, following Knopf, that the 'magma'

need not be called upon to supply much of the silica and perhaps none at all for many ore deposits.

"Speculation on the nature of the ore-making fluids leads to the further suggestion that they are similar to volcanic emanations. The original environment of the ore body could be a mass of structural open ground of one form or another that is the site of a pool or reservoir of condensate, connate, meteoric or sea water. This is activated by the 'volcanic emanations'. The alumino-silicate walls are attacked particularly by hot water and carbonic acid and the silicates broken down to form lower silica species and other minerals. The excess silica is moved to the more open ground. In the form of quartz, chalcedony, etc., it is progressively fractured and forms the channel and locus of deposition for most of the sulphides."

In more recent years the implications of subcontinental structure in the localization of and search for ore deposits (1959, 1966) attracted Dr. Schmitt's attention.

"The ore deposits of the West...and some of the larger igneous intrusives are associated with, and presumably genetically related to, the major fault zones, orogens, and tectogenes. Intersections are particularly sensitive, as noted by Billingsley and Locke long ago. Triple or more complex intersections are especially potent as localizers for ore districts and smaller mineralized units.

"The chief copper-producing area is in southern Arizona and just over the borders of neighboring states. It is clustered in or near the intersection of the Texas fault zone, a 'Precambrian' northeast lineation, and the Wasatch-Jerome orogen. Most of the copper deposits of the West occur along the Wasatch-Jerome orogen, and a large proportion of these appear to be a little east of a median line on or near a central 'channel'...

"An hypothesis is proposed that the metals are broadly zoned in the earth's crust and mantle and that they were originally derived from the meteoric material of the original earth. Presumably, copper, nickel, cobalt, and iron would be most abundant at the deepest levels; lead, zinc, silver, and gold at the next shallowest; and mercury, antimony, and arsenic near the surface. With such zoning, an especially deeply penetrating structure, such as a tectogene or geosuture, could release the deeper metals along with basic and ultrabasic rocks. Moderately deep orogens could remobilize copper and associated metals; whereas shallow remobilizations of the crust would be likely to deposit and concentrate the other base and the precious metals. Mercury and antimony may be especially susceptible to fumarolic and hot-spring shallow leaching and still shallower precipitation. The active agents of remobilization and collection and transfer of the elements are thought to be heat and gases from the degassing and (or) metamorphism of the earth.

"The persistence of copper metallization in the Southwest from Precambrian to possibly upper Tertiary is explained as the result of continued deep faulting of the crust, and it is suggested that in many places there has been a penetration of the lower crust or even to the mantle."

In the few years just prior to his death Dr. Schmitt had begun to compile his data and impressions on ore deposition and leached cappings related to disseminated copper and molybdenum deposits. Most of the papers have not yet been formally published although they were presented orally on numerous occasions (see, however, 1953a, 1959, 1960, 1961a, 1961b, 1962).

In spite of his positive successes in ore search and development, he wrote in a personal note in 1965 "I feel that an important contribution to the mining industry especially in the Southwest has been my rejection of hundreds of prospects that would otherwise have absorbed and wasted a good deal of exploration money". To this contribution we can add the on-the-job training of numerous young mining geologists and engineers who worked with him during nearly forty years of supervisory activity. His legacy to these men was the example of success resulting from the combination of professional knowledge and professional ethics.

As we look back on the development of Schmitt's studies of ore deposits there is a trend from the detailed to the general, but always with a clear rationale for these studies, namely, our need for the long term exploitation of the earth's mineral resources. As we look forward into the future that includes many new technological advances in field and laboratory methods, including exploration by remote sensing from space, we must not forget the need to understand as fully as possible what we are looking for. This is the lesson we should learn from Harrison Schmitt and his generation.

Dr. Schmitt was a Fellow of the Mineralogical Society of America and the Geological Society of America, and a member of the Society of Economic Geologists, the American Association for the Advancement of Science, the American Geophysical Union, the Geochemical Society of America and the American Institute of Mining and Metallurgical Engineers. He served on the councils of both the GSA and the SEG. He was a member of Sigma Xi, Sigma Gamma Epsilon and Gamma Alpha. His social fraternity at the University of Minnesota was Beta Theta Pi.

Harrison Schmitt was prominent throughout his professional career in the Arizona and New Mexico Geological Societies and local chapters of the AIME. He was an honorary life member of the New Mexico Geological Society and served as its president from 1951 to 1952. He was president of the Silver City AIME at the time of his death. In 1962 he was elected Man of American Mining for that year by Mining World.

His chief clients after becoming a consultant included Duval Sulphur and Potash Company; Lewisohn Copper Corporation; Banner Mining Company; American Smelting and Refining Company; Black Hawk Consolidated Mines Company; American Zinc Company; Kennecott Copper Corporation; Kerr–McGee Corporation; New Jersey Zinc Company; Peru Mining Company; U.S. Smelting, Refining and Mining Company; Quintana Petroleum Company. During the Depression years he organized the Shingle Canyon Mining Company and developed a small lead-zinc mine near Fierro, New Mexico. This mine was later sold to the U.S. Smelting, Refining and Mining Company.

Although El Paso, Texas, was the center of this early consulting activity he moved to Hanover, New Mexico, in 1933 where he had lived previously while working for New Jersey Zinc Company. The family then moved to nearby Silver City in 1937. Next to his beloved Minnesota lakes, Silver City remained "home" through the following years of travel.

Dr. Schmitt's interest in civic activities, education in particular, was reflected in his tenure from March 1961 to April 1964 as president of the Board of Regents of Western New Mexico University at Silver City. He was also in demand as a speaker not only in his profession but with civic groups who wished to hear about other of his varied interests, including archaeology, meteorology and economics. He was an honorary life member of Rotary International, an honor he valued as highly as any.

Harrison is survived by his wife, Ethel Hagan, a Tennessee-born teacher whom he married in 1929; by three children, Alexandra (Mrs. B. E. Decker, known as Sandra) of Woodland Hills, California, Harrison Hagan (Jack) of Houston, Texas, and Armena of Tucson, Arizona; two granddaughters, Janis and Linda Decker; and by three sisters, Mrs. Helen Staples of Wausau, Wisconsin, Mrs. Gretchen Strong, of Silver City, New Mexico, and Mrs. Wilhelmina Palmen of Wabasha, Minnesota. A daughter, Paula, died at age two in 1939.

"The Doctor" died of a first heart attack on October 26, 1966 at the age of 70. The week before his death he took his last trip with a client through Nevada and California examining several properties in some of the most beautiful mountain country in the world. He received "...as much pleasure from that trip as from any in recent years". This was the retirement he talked of for many years.

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FOREWORD

Guidebooks Number I and II, published by the Arizona Geological Society in 1952 and 1959 presented broad systematic information related to geology of this part of the Basin and Range Province. This Guidebook, the third, represents a departure from the previous broad outline format. The information presented is intended to update the previous volumes in those areas of study in which considerable advances have been made, and in which new data have been acquired. I believe that the general articles in the book reflect a fair sample of the proportion of efforts devoted to various geological studies in this region since publication of Guidebook II.

Perhaps the greatest amount of geological field and laboratory research work devoted to fundamental topics has been given over to intensified efforts at unraveling the problems of the Mesozoic and Cenozoic Eras and the nature of the Laramide Revolution. Such an evaluation is not intended to slight the work carried out in other subject areas as much fundamental geological field and laboratory study continues to be carried out across the broad spectrum of geological problems that exist in the region. While prior decades witnessed the development of present concepts of Paleozoic history, for example, preliminary solution of the complex problems of the Pennsylvanian and Permian, and evolution of working concepts of Precambrian history, the past decade of work has resulted in the gradual emergence of ideas of the history of the Mesozoic and Cenozoic Eras in this southern part of the Basin and Range Province.

Several factors have probably contributed to the heightened interest in this portion of the geologic column. Increased recognition of the importance of the Cenozoic as a consequence of its water potential and source of certain building materials has resulted in much study and a considerable body of new information. The search for copper and other metals in the Province has spurred interest in the events and the time that gave rise to these deposits. The acceleration of data gathering as the result of increasing numbers of geologists studying the problems, and the advent of new research tools has enabled workers to attack problems of volcanic stratigraphy hitherto considered too complex for solution by field methods alone. Such an example is the establishment of a chronologic framework for the Mesozoic–Cenozoic volcanic stratigraphy and thus the sedimentary stratigraphy at the Era boundaries. As another, new geophysical measurements have provided information useful to reinterpretation of the nature of structural evolution of the region.

I have attempted to select papers for the general part of the Guidebook that, although reflecting new interpretations also represent contributions or compilations of factual information relative to the problems which exist here. It is the hope of the Arizona Geological Society that the users of this book will find much stimulation from its content.

ACKNOWLEDGEMENTS

Many persons have contributed to the preparation and publication of this third Guidebook, not the least of whom have been the authors themselves. The cooperation of all who have contributed and their parent organizations is gratefully acknowledged. Dr. Evans B. Mayo, General Chairman of the 64th Annual Meeting of the Cordilleran Section of the Geological Society of America has materially assisted in organizing the Guidebook. Mr. Steven Congdon has overseen the matters of business management. Mr. J. David Lowell has organized the field trips. Drs. John W. Anthony and Esther A. Holm and Mrs. J. K. Percious have assisted in editing and proof reading.

I have received technical assistance from Mr. Douglas Peck of the University of Arizona Press. Mr. Robert Mills of Publication Services Inc. and his staff, particularly Miss Susan E. Klemt, have carried out spartan work against unbending deadlines to prepare the manuscript and their extremely competent assistance, and patience, is appreciated. Mr. Tad Nichols has contributed much of the aerial photography and Dr. John Sumner has contributed his aircraft and flight time. Mr. John Fitzgerald has kindly granted the permission for use of his art. Finally, I wish to thank the many members of the Society, particularly Professor Terah Smiley, its president, and my colleagues in the Department of Geology for their assistance and counsel in many matters related to preparation of the Guidebook.

S.R. Titley
Tucson, Arizona
March 1, 1968

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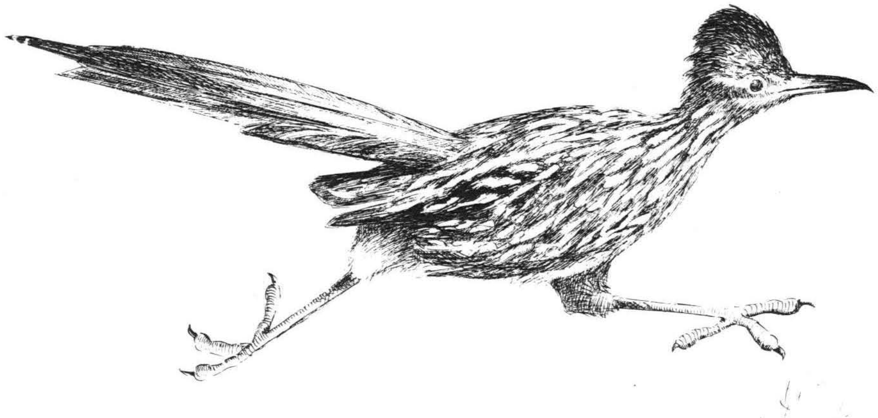
ROAD LOGS



VOLCANIC GEOLOGY, SOUTHWESTERN NEW MEXICO AND SOUTHEASTERN ARIZONA

FIELD TRIP I

THREE DAYS, MONDAY, APRIL 8 THROUGH WEDNESDAY, APRIL 10

LEADERS: Paul E. Damon, Edward S. Davidson, Wolfgang E. Elston, Frederick J. Kuellmer, Evans B. Mayo, Darwin Marjaniemi, Donald W. Peterson, Michael F. Sheridan and Elliot Gillerman

GENERAL STATEMENT

The purpose of this field trip is to examine some of the volcanic rocks of Southeastern Arizona and Southwestern New Mexico. Particular attention will be given to the petrography and stratigraphy of ash flows and discussion of ideas concerning their source areas.

FIRST DAY, MONDAY, APRIL 8

Leaders: M. F. Sheridan, D. W. Peterson, E. S. Davidson, W. E. Elston, and Elliot Gillerman
Driving Distance: 315 miles
Logged Distance: 315 miles
Starting Time: 6:30 A.M.
Assembly Point: Arizona State University Student Union

GENERAL STATEMENT

This trip begins at Mesa in the Salt River Valley and proceeds eastward to the region bordered to the N.W. by the Goldfields Mountains and to the S.E. by the Superstition Mountains within which Professor Sheridan has demonstrated evidence for two calderas of moderate size. (See accompanying paper by M. F. Sheridan). From there, the route follows U. S. Highway 60-70 along which there will be the opportunity to observe the petrography of a large ash flow sheet which attains a maximum thickness of 2000 feet in exposed sections, and extends over an area which may exceed 2000 square miles (See accompanying paper by D. W. Peterson). The trip will continue from Globe (Gila County Seat) along U. S. Highway 70 in a southeastwardly direction following the Gila River to the town of Safford which is the Seat of Graham County. From Safford the trip proceeds eastward to Arizona–New Mexico State Highway 78 which climbs the extension of the Mogollon Rim southeast of Clifton. The Mogollon Rim here is the topographic expression of a group of northwest trending faults that control plugs of flow-banded rhyolite, which locally form massive lava flows. Ash flows are absent. After crossing into New Mexico a final stop will view the western rim of the Mogollon Plateau, interpreted as the high level equivalent of a ring-dike complex 75 miles (125 Km) in diameter, surrounding a volcano-tectonic basin. Within the basin, local cauldrons are the source of ash-flow sheets more than 2000 feet thick. The last leg of the first days trip follows U.S. Highway 180 in a southeasterly direction to the field trip quarters at the Holiday Inn in Silver City. (See Fig. 1 and 2.)

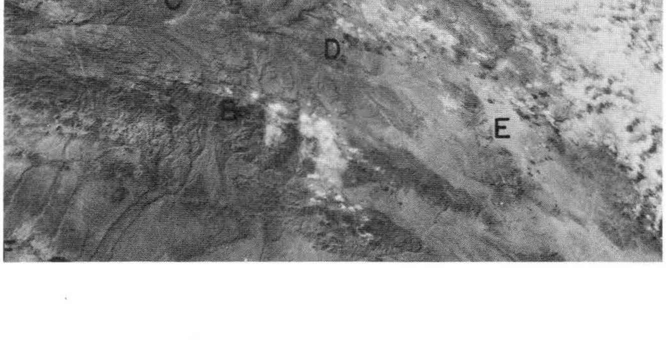


Figure 1 – Photograph taken at altitude of 87.6 miles from U.S. Navy Viking 12 rocket launched from White Sands Proving Ground on February 4, 1955. Much of southwestern New Mexico and southwestern Arizona is visible. The Pacific Ocean appears on skyline. Mogollon Plateau is the foreground (North is to the right). A = Mogollon Mountains, B = Black Range, C = Pinos Altos Mountains and Mimbres Valley, D = Gila Sag, E = San Augustin Plains, F = Rio Grande. –Photograph has been made available by courtesy of the U. S. Navy Research Laboratory.

Segmental Mileage	Cumulative Mileage	
0.0	0.0	Leave A.S.U. Student Union and proceed to campus outlet on highway 60-70-80-89.
0.4	0.4	Turn left and proceed eastward on highway 60-70-80-89 to Apache Junction.
16.0	16.4	East of the Bush Highway three main structural blocks can be seen in the volcanic complex to the northeast. The Goldfield Mountain front to the north is underlain by the basement granite. Above the granite is a band of non-welded rhyolite ash-flow tuff, which forms a conspicuous light-colored out-crop. The ash-flow tuff is in turn overlain by a black glassy dacite lava. The elevation of the Goldfield front is approximately 300 feet in the west to 2500 feet in the east. The volcanic sequence makes up only the upper 300-500 feet and thins to the west. To the east of the Goldfield Mountains is the Superstition Mountain block. This mass of ash-flow tuffs and lavas has an elevation of 5000 feet of which at least 2000 feet are part of the volcanic sequence. Whereas the Goldfield volcanics are dipping to the northeast, the ash-flow tuffs and lavas of the Superstition Mountains are horizontal. Between these two main mountain masses is an area with an elevation of 2000-2500 feet, which is underlain by steeply dipping lavas, ash-flow tuffs, and epiclastic volcanic breccias (lahars). The lahar units suggest volcanotectonic subsidence. The dips of the lahars and the outcrop distribution outline at least two caldera margins.
7.4	23.8	Apache Junction. BEAR LEFT on the Apache Trail, Arizona State Highway 88. The road traverses an alluvial fan for the next four miles. To the west a dark glassy rhyolite lava forms a conspicuous capping on the ash-flow tuff.

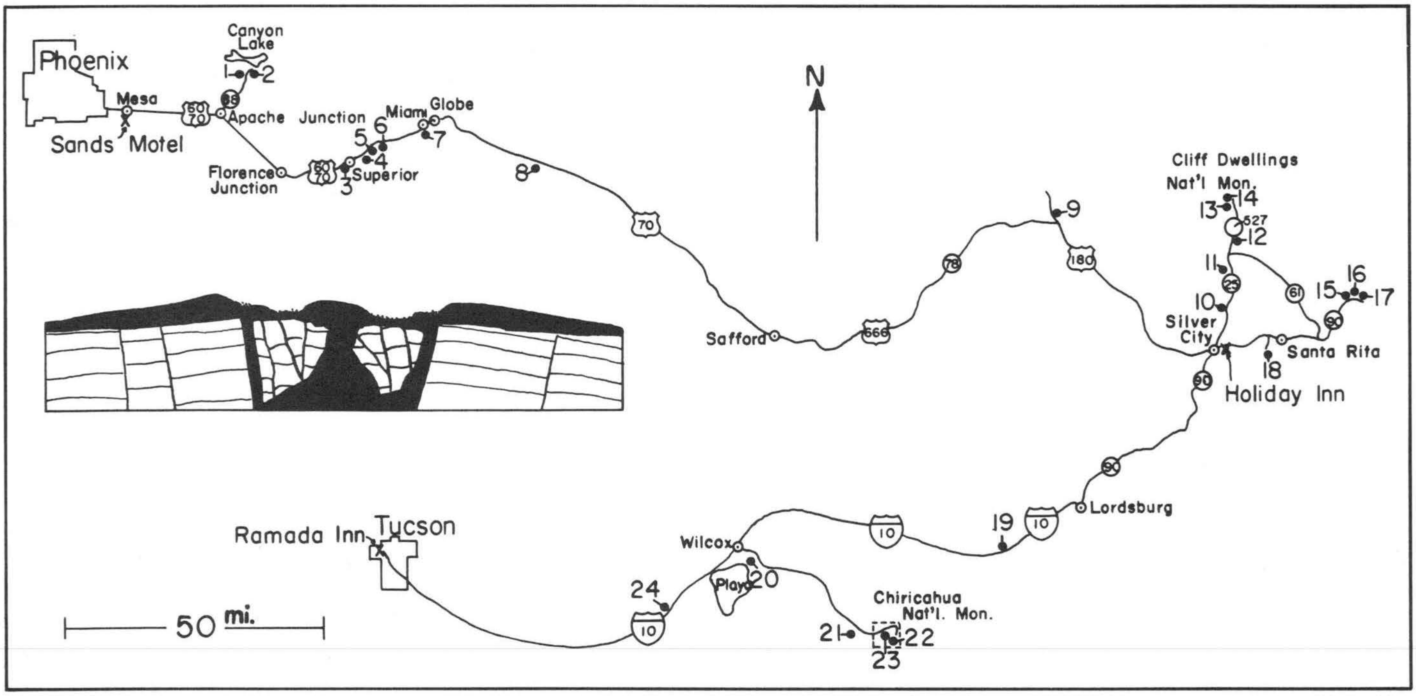


Figure 2 – Road log for field trip No. 1

4.0	27.8	One mile to the northeast outcrops of the lower epiclastic breccia interbedded with basalt dip to the N.E. For the next four miles the road crosses a pediment surface underlain by granite and arkose basement. A few basalt lavas and dikes can be seen in road cuts, but in general the basement surface is at road level.
		To the east, the near end of the Superstition block is composed of a massive andesite on which the horizontal-bedded ash-flow tuffs and lavas rest. North of the Superstition block the tuffs are strongly faulted and form a collapsed collar for the Black Mesa caldera to the north east. The tuffs are faulted down to an elevation of 3,500 feet.
		On both sides of the road are low hills of basalt and andesite. These are the oldest group of lavas in the Goldfield Mountains. The ash-flow tuffs rest on this basic complex along the Apache Trail, and the andesites overlie either granite basement or a thin older epiclastic breccia to the west.
4.0	31.8	The road climbs up through a basalt-andesite complex. This older complex is chiefly basic to intermediate in character being composed of basalt, andesites, and dacites. To the east ash-flow tuff can be seen to rest directly on the basic complex with the contact dipping to the northwest into the Willow Springs caldera.
0.3	32.1	Silicic ash beds may be seen in the road cut. Andesite breccia (lahar) forms the upper part of the basic complex along the road.
1.3	33.4	STOP 1 - Time: 1 hour - Park on the west side of the road. The party will climb to the top of the ridge to the west where a volcanic mudflow contact with the andesite complex is well exposed. From this vantage point a panoramic view to the west illustrates the stratigraphy and structure of a small caldera. The mudflows overlie ash-flows to the southwest and are in turn overlain by glassy rhyolite lavas to the west.
		Return to bus and proceed again to the northeast along State Highway 88.
0.4	33.8	Volcanic mudflows overlie ash flows in the canyon to the west.
0.1	33.9	A vertical glassy rhyolite dike cuts ash-flow tuffs on the east side of the road.
0.2	34.1	The complex flow banding of a large dacite dome is seen on the west.
0.1	34.2	The contact of the dome with ash-flow tuff is seen on the east.
0.8	35.0	The contact of the dome with volcanic mudflow is seen on the west side of the road. The lahar unit dips to the N.E. along the contact.
0.4	35.4	A lithoidal dike cuts volcanic mudflow at roadside.
0.3	35.7	A glassy dike cuts the mudflow at roadside. Glassy rhyolite lavas on top of the mudflows to the west resulted from extrusion through the dikes.
0.6	36.3	STOP 2 - Time: 20-30 minutes - A glassy dike which cuts the mudflow is exposed at road level. The dike is partly devitrified to jasper spherulites. Steep northeast dips of the mudflow at this stop are contrasted with the gentle southwest dips of mudflow unit across Canyon Lake.
		Return to Apache Junction.

12.5	48.8	Apache Junction. Turn left on U. S. Highway 60-70-80-89 and proceed to the south east.
		For the next 20 miles, the highway parallels the trend of the Superstition Mountains, which lie to the north and northeast. This range, the locality of the fabled Lost Dutchman Gold Mine, is composed chiefly of volcanic rocks of Tertiary age: ash flows, air-fall and water-laid tuffs, lava flows and plugs, and mudflows that range from rhyolitic to basaltic in composition. The prominent layered cliffs making up the summit of the western part of the range are composed of ash flows of quartz latitic composition, probably belonging to the same ash-flow sheet that forms the "dacite" of Apache Leap east of Superior.
7.0	55.8	Road intersection to Kings Ranch.
1.6	57.4	Road intersection and scenic marker.
6.8	64.2	Road crosses Queen Creek.
1.4	65.6	Florence Junction. The hills just north of the highway are eastward-tilted blocks of remnants of the quartz latitic ash flows.
2.1	67.7	Magma-Arizona railroad crossing.
0.4	68.1	The rugged hills to the north are composed mainly of volcanic rocks of the Superstition Mountains complex. The volcanics overlie tilted and faulted Pinal Schist, granitic rocks, and sedimentary rocks of the Apache Group, all of Precambrian age.
1.9	70.0	Dromedary Peak at 2 o'clock. Faulted and sheared remnant of the ash flow resting on Pinal Schist.
1.3	71.3	Pinal Schist in roadcuts.
0.9	72.2	Gonzales Pass.
0.4	72.6	At 12 o'clock is Picketpost Mountain, a prominent landmark of the region.
2.5	75.1	Roadcuts in basaltic andesite of probable Tertiary age.
		For the next several miles, excellent views are had of Picketpost Mountain. At its base are rhyolitic lava flows which are overlain by a thick series of light-colored tuffs that make up most of the steep flanks. The mountain is capped by quartz latite lava flows that emerge from a vent on the eastern flank of the mountain. This lava has been K-Ar dated at 18.0±0.3 m.y. (Damon, et al., 1966).
1.3	76.4	Bridge across Queen Creek.
0.7	77.1	Entrance to Boyce Thompson Arboretum, a center for the study of desert biology and ecology, recently acquired by the University of Arizona.
2.1	79.2	Road to south leads to Superior Airport. Turn right and stop at flat area at top of rise.
		STOP 3 - Time: 15 minutes - Purpose is to point out and discuss general features of the Superior area. (See Figure 3)
		The basin in which we stand is occupied by alluvium and the Gila Conglomerate. At the east boundary of the basin is the Concentrator fault, trending north to

northwest, with its west side down. East of the fault lie eastward-dipping sedimentary rocks of late Precambrian and Paleozoic ages that have been intricately faulted by both north and east-trending fault systems. Many of the east-trending faults are mineralized, and one of them formed the Magma vein, the location of one of the major copper mines of Arizona. The pre-Tertiary rocks are overlain by the thick sequence of quartz latitic ash flows (dacite) that make up the towering cliffs of Apache Leap. The ash flow has been K-Ar dated at 19.6±0.6 m.y. (Creasey and Kistler, 1962; Damon and Bikerman, 1964).

To the southwest, toward the base of Picketpost Mountain, several light-colored pits mark areas where high-grade perlite has been mined from the rhyolitic lava flows.

Resume travel eastward on highway.

Figure 3 – Photograph looking toward the ENE. The town of Superior can be seen in the left foreground. Directly to the east of the town is a ridge of late Precambrian and Paleozoic sediments which dip eastward. U. S. Highway 60-70-80-89 emerges from the early morning shadows in the right foreground, crosses Queen Creek and disappears into a highway tunnel in the center of the photograph. The base of the Superior Dacite ash-flow sheet can be seen above the highway before it enters the tunnel. The water tank around which the old highway makes a hairpin turn (see log) can be seen in the bright sun at the edge of the morning shadow near the center of the picture. The Pinal Mountains make up the right background. –Photograph by Tad Nichols

0.5	79.7	Road forks. KEEP TO RIGHT on main highway. Left-hand fork goes through town of Superior.
0.1	79.8	Branch to right; follow sign to State Highway 177.
0.2	80.0	Turn left toward Superior.
0.1	80.1	Turn right onto old highway. Drive carefully; road is not maintained.
0.1	80.2	Cross Concentrator fault.
0.1	80.3	Bolsa Quartzite (formerly thought to be the Precambrian Troy Quartzite). The Bolsa, of Cambrian age, rests with sedimentary contact on diabase.
0.1	80.4	Martin Limestone (Devonian). The lowermost beds of the Martin are the host for important replacement copper mineralization in the Magma Mine.
0.1	80.5	Escabrosa Limestone (Mississippian). The prominent white cliffs of the area are part of the Escabrosa.
0.4	80.9	Manganese mineralization along faults in the Escabrosa Limestone.
0.1	81.0	Old road passes under the main highway's Queen Creek bridge.
0.1	81.1	Contact between the Escabrosa Limestone and Naco Limestone (locally Pennsylvanian).
0.2	81.3	Hairpin turn around water tank.
0.8	82.1	Contact between Naco Limestone and overlying ash flows.

STOP 4 - Time: 30 minutes - Purpose is to observe the basal part of the ash-flow sheet across the canyon to the south.

The rock of the ash flows has been called dacite on the basis of relative proportions of the phenocrysts, which consist mostly of plagioclase, moderate amounts of quartz and biotite, and small amounts of sanidine, hornblende, and opaque oxides. Chemically, however, the rock is a quartz latite.

Across the canyon, the Tertiary (?) Whitetail Conglomerate immediately above the Naco Limestone is overlain by nonwelded tuff. This tuff grades upward into densely welded black vitrophyre, which in turn is abruptly overlain by devitrified densely welded tuff with a brown aphanitic groundmass. As the crystallization of devitrification intensified upward, the color of the freshly broken rock gradually changes from brown to gray. Farther upward, as the degree of welding decreases, vapor-phase crystallization begins and progressively increases upward, and the color of the groundmass gradually changes from gray to nearly white. The road to the east passes through this sequence of zoning changes, which can be observed in roadcuts between this point and Oak Flat, about 2.3 miles to the east.

0.1	82.2	Claypool tunnel. Picnic Lunch (1 hour for lunch and examination of dacite).
0.3	82.5	Old road rejoins main highway.

At this point, the groundmass is grayish brown, a megascopic expression of rock in which the devitrification crystallization is considerably coarser than that of the

		brown groundmass nearer the base of the sheet. The flat, white streaks abundant in this rock represent highly flattened pumice fragments that are sites of vapor-phase crystallization–the lower-most expression of this type of crystallization in the ash-flow sheet.
0.5	83.0	Roadside rest.
		STOP 5 - Time: 15 minutes - The gray groundmass represents very thorough crystallization of devitrification. Much of the original welded tuff texture of the groundmass has been obliterated by this crystallization. The striking light-colored pumice fragments are much less flattened than at the last stop, but still show very considerable flattening. Vapor-phase crystallization is still confined to the pumice fragments.
0.1	83.1	As the road climbs eastward, the pumice fragments may be observed to become progressively less flattened upward, as can be observed in the successive roadcuts on the north side of the highway. With this change begins a progressive increase of permeation of the groundmass by vapor-phase crystallization, expressed by a gradual change of the groundmass to lighter shades of gray.
0.7	83.8	Bridge. Vapor-phase crystallization dominates the groundmass from this point upward, megascopically expressed by the very light gray color on freshly broken surfaces.
0.6	84.4	Entrance to Oak Flat Recreation Area. TURN RIGHT off the main highway.
		STOP 6 - Time 15 minutes - These outcrops represent the nonwelded upper part of the ash-flow sheet. Pumice fragments are essentially equidimensional, showing no flattening. Vapor-phase crystallization has permeated both the pumice fragments and the groundmass and has completely obliterated all the primary tuffaceous textures. The pumice fragments are very soft and crumble readily, leaving round holes on weathered exposures.
1.7	86.1	Bridge across creek of Devils Canyon.
0.4	86.5	Iron Canyon from the northeast joins Devils Canyon.
2.1	88.6	Large northwest-trending fault is exposed in roadcut on the south side of the highway, southwest side down.
0.4	89.0	Pinal Ranch. Eastern boundary of the ash-flow sheet in this area is a fault contact, but here it is buried beneath alluvium. For the next several miles, highway passes through the Tertiary Schultze Granite stock. The Schultze Granite has been dated at 57.8±1.3 m.y. (Creasey and Kistler, 1962; Damon, et al., 1964. Damon and Mauger, 1966).
1.0	90.0	Leave Pinal County, enter Gila County.
1.0	91.0	At 10 o'clock, site of Castle Dome open pit copper mine.
0.9	91.9	Bridge across Pinto Creek.
1.2	93.1	Road junction to Castle Dome copper mine. CONTINUE ON MAIN HIGHWAY.
0.2	93.3	At 2 o'clock, Pinal Mountains. The higher part of the range consists of the Pinal

		Schist and Madera Diorite, the lower rounded hills consist of Schultze Granite. The white outcrop at 1 o'clock is the Cretaceous or Tertiary Solitude Granite.
1.4	94.7	Pendant of Pinal Schist in the Schultze Granite.
0.9	95.6	As the highway descends along the canyon of Bloody Tanks Wash, it passes through spectacular outcrops of Schultze Granite showing strong jointing.
0.6	96.2	Intrusive contact between the Schultze Granite and Pinal Schist.
0.2	96.4	Bridge across Bloody Tanks Wash. Pinal Schist in roadcuts.
0.9	97.3	ENTER TOWN OF MIAMI, ARIZONA.
0.3	97.6	Bridge. Road crosses Miami fault, visible on north side of highway. Pinal Schist is on the west; Gila Conglomerate is on the east.
0.3	97.9	At 10-11 o'clock are the buildings and installations of Miami Copper Company on the skyline.
0.6	98.5	Road on left to Miami Copper Company. CONTINUE ON HIGHWAY. Note the large tailing dumps.
0.5	99.0	At 11 o'clock, International Smelter.
0.4	99.4	Traffic signal. Road on left to Inspiration Consolidated Copper Company.
1.6	101.0	Intersection with State Highway 88, the Apache Trail. Gila Conglomerate in roadcuts.
0.4	101.4	STOP 7 - Time: 15 minutes - View to the west over the Miami-Inspiration mining district. Parts of the operations of the Miami, Inspiration, and Copper Cities mines can be seen. Most of the peaks on the skyline to the northwest are capped by remnants of the ash-flow sheet.
0.2	101.6	At 12 o'clock, the rounded knobby rocks are part of the ash-flow sheet.
1.1	102.7	View of site of Old Dominion mine. The hills beyond the mine consist of Precambrian and Paleozoic sedimentary rocks and extensive diabase sills and dikes.
1.0	103.7	ENTER TOWN OF GLOBE, ARIZONA.
1.0	104.7	Gila County Court House on left.
1.6	106.3	Intersection of Highways U. S. 60 and 70. KEEP TO THE RIGHT ON U. S. 70. The route now leaves the Pinal Mountains, which were a highland and drainage-divide area through much of late Cenozoic time. The Phoenix basin to the west received sediment from the mountains through most of late Cenozoic time. The route now enters the Safford basin, where nearly continuous deposition continued into early Quaternary time. The deposition was terminated by differential uplift. Because of this uplift and subsequent erosion, about 800 feet of lower Quarternary sedimentary deposits was removed from the area. Remnants of the deposits are exposed on the slopes of mesas and benches, which are predominant in Safford and Duncan basins. The cycle of erosion is continuing in this area at the present time; the gravels exposed in roadcuts here and for several miles to the east are

		late Pleistocene in age and were deposited in the earlier versions of the present stream channels.
0.6	106.9	At 12 o'clock, Hayes Mountains, altitude 5,300 to 5,700 feet. The lone peak to the north is capped by a basalt flow that is early Quaternary in age. The rugged peaks and slopes to the south are composed of granite of Precambrian age, and the southwestward-dipping rocks on the south skyline are Precambrian and Paleozoic quartzite overlain by Paleozoic limestone.
0.4	107.3	Drainage divide. To the northwest, the streams drain into Pinal Creek, which is tributary to the Salt River. To the southeast the drainage is into the Gila River.
1.2	108.5	On right: State Highway 77 to Tucson.
5.7	114.2	Entering hills and ridges, erosional remnants of sediment probably are early Pleistocene in age. These sediments are termed informally the "upper unit of basin fill" and are the uppermost unit of Gilbert's (1875) Gila conglomerate. Note the characteristic red-brown to brown color, fine-grain size, local calcareous beds and tuff beds, and the even near-parallel bedding. The upper unit of basin fill is well sorted; the bedding, grain size, and good sorting contrast with the lenticular bedding, coarse material, and poorly sorted gravel of middle to late Pleistocene age. Here, the mesas slope northward to Aliso Creek and are gravel-capped terraces of streams tributary to the creek.
1.0	115.2	At 9 o'clock, the low hills to the north are part of the Apache Mountains and are underlain by Precambrian and Paleozoic quartzite. Near the southeast end are minor outcrops of grayish Paleozoic limestone.
3.5	118.7	Top of divide, approaching Safford basin. At 10 o'clock to 11 o'clock, the Natanes Plateau is on the skyline. The volcanic rocks on the skyline are andesite to basalt flows of middle Tertiary age. The low platform in the middle foreground is capped by basalt of early Pleistocene age. The altitude of the platform is about 4,000 feet, and it formerly was buried by the upper unit of basin fill (early Pleistocene in age). At 11 o'clock to 12 o'clock, the Gila Mountains–principally andesite flows and tuffs of middle Tertiary age. At 3 o'clock, the upper unit of basin fill crops out beneath the flow that caps the northernmost peak of Hayes Mountains. The top of the peak (4,200 feet altitude) corresponds to the approximate top of the upper unit of basin fill in this area.
4.5	123.2	STOP 8 - Time: 15 minutes - PARKING AREA: Note the volcanic vent of early Pleistocene age to the left. At 9 o'clock to 11 o'clock, basalt flows interbedded with the upper unit of basin fill (early Pleistocene in age). At 1 o'clock, Mount Turnbull in the Santa Teresa Mountains, altitude 7,945 feet.
2.7	125.9	Historical marker on the right side of the road. At 2 o'clock, San Carlos Lake behind Coolidge Dam - dam completed in 1928.
0.4	126.3	San Carlos River: Flows south to San Carlos Lake.
3.6	129.9	At 9 o'clock to 10 o'clock, Triplets Peaks, rhyolite breccia intrusives; the small hill at 1 o'clock is the same breccia. Note the tilting and minor structure in the

		basin fill, probably caused by the intrusives and the weight of the basalt flows. The route passes through exposures of the limestone and minor tuff bed facies of the upper unit of basin fill.
7.0	136.9	The limestone facies fingers out in the next few miles into the silt and sand facies of the upper unit of basin fill.
7.3	144.2	ROADSIDE REST AREA.
0.3	144.5	At 3 o'clock, lowland of the Gila River. At 1 o'clock, the flood plain has been cleared of phreatophytes and planted to grass. This is the upper end of the U. S. Geological Survey's Gila River project. The Survey is determining the amount of water consumed by the saltcedar (*Tamarix pentandra* Pallas) that formerly grew in the flood plain and the amount of water saved, if any, by removing the saltcedar and planting grass or other cattle forage.
3.3	147.8	Gila River bridge.
1.6	149.4	Entering Bylas, an Indian community.
5.9	155.3	Leaving the San Carlos Indian Reservation.
1.6	156.9	Geronimo: The gravel in the roadcut is a terrace of late Pleistocene age; parallel-bedded silt is the upper unit of basin fill (early Pleistocene in age).
4.9	161.8	ROADSIDE REST AREA at Blackrock Wash.
0.1	161.9	The Gila Mountains to the north are mainly andesite and other flows and tuffs of intermediate composition. All are of middle Tertiary age.
1.5	163.4	At 1 o'clock to 2 o'clock, Pinaleno Mountains; Mount Graham, altitude 10,713 feet, is the highest peak. The rock is Precambrian granite and granitic gneiss and hornblende to biotite schist.
1.0	164.4	At 2 o'clock, Red Knolls - the site where Blancan fossils were recovered from the upper unit of basin fill. The resistant beds are limestone and tuff.
3.5	167.9	Indian Hot Springs
6.5	174.4	Pima farming community; cotton, grain, and alfalfa are the principal crops.
8.6	183.0	At 3 o'clock, Frye Mesa, a dissected fan. The material on the slope is a fan-gravel facies of the upper unit of basin fill. The mesa is capped by a 5 to 10 foot-thick gravel deposit that cuts across the bedding of the basin fill.
1.5	184.5	Thatcher, home of the Eastern Arizona Junior College.
2.9	187.4	Entering Safford: Cottonfields west and east of town.
2.1	189.5	At 9 o'clock, pecan tree groves.
3.1	192.6	San Simon Creek: The gravel-capped terrace of San Simon Creek and the Gila River is well exposed.
3.0	195.6	Leaving the flood plain of the Gila River: The exposed gravel is upper Pleistocene terrace gravel.

3.3	198.9	Junction of U. S. Highway 666 and U. S. 70. Turn left and follow U. S. Highway 666. The basalt flows in this area are interbedded with the lower unit of basin fill, which probably is late Miocene to Pliocene in age. Wells drilled along this route penetrated about 400 feet of gravel. The upper 100 feet is a fan-gravel facies of the upper unit of basin fill (early Pleistocene in age) that rests with erosional unconformity on the lower unit of basin fill (Pliocene in age). The drill holes bottomed at about 3,000 feet above sea level (the altitude of the bed of the nearby Gila River) in andesite of middle Tertiary age. Here, the upper and lower units of basin fill were named the Gila conglomerate by Gilbert (1875). Gilbert also included scattered outcrops (upstream along the Gila River) of conglomerate that probably are correlative with volcanic rocks of middle Tertiary age.
1.7	200.9	Basalt low hill on left.
1.2	202.1	Road cut in basalt.
3.7	205.8	Bridge. Basalt (QTb) faulted against Cretaceous andesite (Ka) with intrusions (Ti) at 3 o'clock.
1.5	206.3	Cross road. Cretaceous andesite at 3 o'clock, overlain by Tertiary rhyolite (Tr) at 2 o'clock.
0.9	207.2	Curves. Road rises to higher Quaternary terrace.
0.8	208.0	Curve, road cuts in terrace gravels. Hills capped by Tertiary rhyolite on left and right.
0.3	208.3	Depositional contact of calichified Quaternary terrace gravels on coarsely porphyritic gray rhyolite flows and associated pumice bed. Flow banding of rhyolite lavas has variable dips.
0.1	208.4	Altered rhyolite in road cuts.
0.2	208.6	Terrace gravels and road cuts.
0.5	209.1	Calichified terrace gravels on left. Rhyolite in hills all around.
0.6	209.7	Road cut in terrace gravel. Bedded pumiceous rhyolite tuff at 11 o'clock.
0.4	210.1	Road cut on right in highly vesicular Tertiary andesite (Ta).* The andesite underlies the rhyolite exposed over the previous 2.3 miles.
0.3	210.4	Culvert.
0.2	210.6	Curves ahead. Road cut on left exposes fault zone: conglomerate of andesite boulders in a sandy tuffaceous matrix is faulted against Tertiary andesite. The andesite is intruded by rhyolite with intensely contorted but generally steep, gray and pink flow bands.
0.2	210.8	Culvert. Contact of flow-banded rhyolite intruded into andesite flows, flow breccias, and agglomerates. At the intrusive contact, the rhyolite is autobrecciated over a 5-foot zone.
0.4	211.2	At 9 o'clock, Tertiary andesite (Ta) is overlain by bedded rhyolite pumiceous tuff, capped by a rhyolite flow.

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*Abbreviations of geologic map units are according to the Geologic map of Graham and Greenlee counties, Arizona (Wilson and Moore, 1958) in Arizona and according to the Reconnaissance Geologic Map of Mogollon thirty-minute quadrangle (Weber and Willard, 1959) and Reconnaissance Geologic Map of Virden thirty-minute Quadrangle (Elston, 1960) in New Mexico.

0.7	211.9	Fault brings rhyolite flow against Tertiary andesite. Road cuts for next 0.9 miles are in rhyolite flow rock with contorted flow bands. See sketch for view from 7 to 8:30 o'clock. (Figure 4)

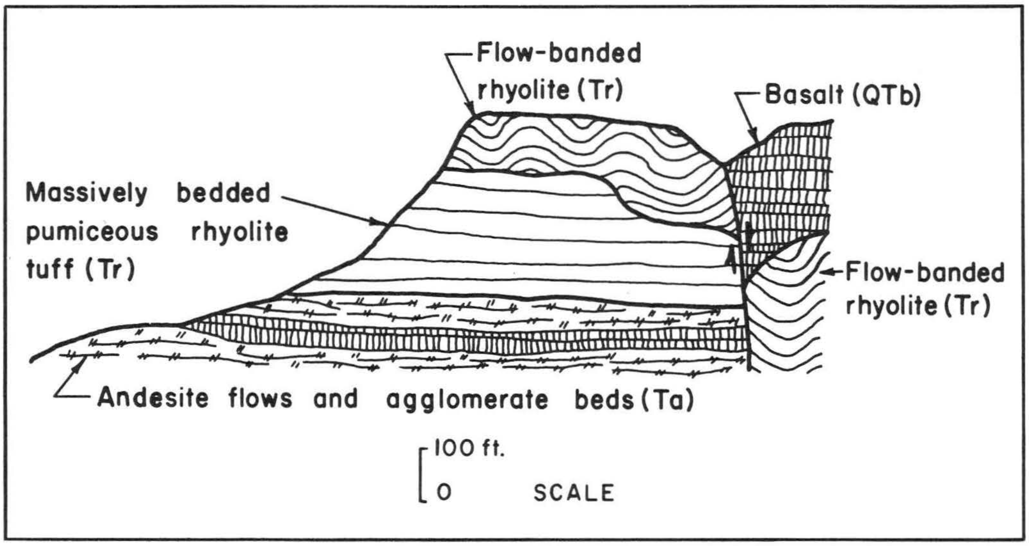

Figure 4 – Sketch of view north from mile 211.9. From a field sketch by W. E. Elston.

0.9	212.8	Curve right. Fault brings andesite (Ta) ahead up against rhyolite with subhorizontal flow bands. The andesite is brecciated over a 70-foot fault zone. Road cuts for the next 1.8 miles are in reddish vesicular andesite.
2.0	214.8	Culvert, curve right, windmill at 2:30 o'clock. Cross northwest-trending fault zone which brings late basalt (QTb) down against Tertiary andesite (Ta). Tertiary rhyolite (Tr) is faulted out. Tertiary andesite is brownish-red with pyroxene phenocrysts, deuterically altered to a greenish color. Weathered basalt resembles the andesite but fresh hand specimens are black, finely crystalline, and contain sparse olivine phenocrysts.
0.7	215.5	Rest area on left. Basalt (QTb) on hills around.
1.3	216.8	For the next 4.2 miles, basalt (QTb) can be seen in contact with Quaternary terrace gravels belonging to terraces of several levels. Watch for sharp curves as the road descends toward the valley of the San Francisco river.
2.9	219.7	Cattle guard.
0.2	219.9	Sign: Warning–down grade 2 miles.
1.2	221.1	Approximate contact of terrace gravels and underlying late Tertiary Gila Conglomerate. Terrace gravels and Gila both contain boulders derived from earlier basalt.
1.1	222.2	Bridge across San Francisco River.
0.2	222.4	Bar on left - <u>KEEP GOING</u>
0.1	222.5	Road cuts exposed fine-grained facies of Gila Conglomerate beneath Quaternary axial gravels with prominent channeling and rounded boulders.
0.5	223.0	Road forks, follow right fork.

0.1	223.1	Stop sign STOP. Cross Arizona Highway 75 and continue straight ahead on Arizona Highway 78, past drive-in theater and bar. For the next 7.4 miles the road crosses Gila Conglomerate and terrace gravels.
1.1	224.2	Road forks, keep to left fork. Right fork leads to Clifton airport.
1.0	225.2	Road forks, continue on paved right fork. Morenci dumps at 9 o'clock.
1.0	226.2	Steeple Rock visible at 2 o'clock. According to Elston (1960) the rocks of Steeple Rock Peak are part of a complex section of rhyolite ash flows, air-fall tuffs, water-laid sandy tuffs, and flows, interlayered with fine-grained andesite and porphyritic latite. These rocks are preserved in the graben portion of a complicated northwest-trending fault zone. A K-Ar age of 34.7±1.0 m.y. for a sample collected near the base of the section (Damon, et al., 1967), and the fact that the section is overlain by a rock resembling the "Turkeytrack Porphyry" of southeastern Arizona indicate that the rhyolites and associated rocks are Oligocene, correlative to the Datil Group of central New Mexico. Along the road followed by this field trip, northwest of Steeple Rock, the entire Datil-equivalent complex is represented solely by a basal pink sandstone overlain by thick section of flow rhyolite and rhyolite breccia. There are no ash flows or other pyroclastic rocks. At deeper erosion levels, numerous rhyolite intrusive plugs are aligned along individual faults that make up the northwest-trending fault zone. They intrude intensely altered andesite (at least partly Cretaceous in age, on the basis of paleobotanical evidence), host to ore deposits of the Steeple Rock mining district. The entire zone of faulting, alteration, intrusion, and mineralization trends toward the important Morenci mining district, where Phelps-Dodge Corporation is mining a Laramide porphyry copper deposit in a large open pit. The geology of the area between Morenci and Steeple Rock is poorly known. As far as can be determined, the fault zone represents the south-eastward structural extension of the Mogollon Rim. The escarpment visible to the east, about 5 miles ahead is a fault-line scarp, eroded back several miles from the fault zone. It forms the surface expression of the Mogollon Rim. Ash flows and other pyroclastic rocks appear to become more abundant as the escarpment dies out toward the southeast.
1.7	227.9	Pavement ends.
2.0	229.9	Fault zone and escarpment of Mogollon Rim ahead. Chocolate brown layered rocks, best seen between 1 and 4 o'clock in foreground, are Tertiary and/or Cretaceous andesites. Flow-banded rhyolite intruded into and overlying the andesite forms low crag from 10:30 to 11 o'clock and part of high crag from 1 to 1:30 o'clock. Bedded rhyolite pyroclastics above andesite (absent along the road) are visible in mountain and beyond gap at 2 o'clock. The mountains visible in the distance from 8 to 1 o'clock are the escarpment which probably represents the continuation of the Mogollon Rim.
0.5	230.4	Altered andesite in gullies on both sides of road.
0.2	230.6	Outcrop of rhyolite with flat-lying flow bands near the road and steeply-dipping bands at 9 o'clock, probably part of intrusive body. Smokestack of Morenci smelter visible at 7:30 o'clock.
0.2	230.8	For the next 0.3 miles the road crosses a sinuous intrusive contact of rhyolite into andesite. The rhyolite has steep flow bands and is autobrecciated at the contact.

0.3	231.1	Start descent. Outcrops of Tertiary or Cretaceous andesite. Note prominent terrace at 12 o'clock.
0.4	231.5	Culvert. Andesite forms cliffs along drainage.
0.3	231.8	Culvert, hairpin turns. Outcrops of altered andesite flows and bedded tuffs.
0.4	232.2	Sharp turn to the right. Road runs on top of terrace noted 1.1 miles back. Crags formed by eroded rhyolite domes intruded into andesite at 5:30, 6:30, 9:30 and 11 o'clock.
0.8	233.0	Cattle Guard.
0.4	233.4	Sign Mule Creek 17 miles, Silver City 74 miles.
0.7	234.1	Cattleguard, enter Apache National Forest. Line of rhyolite intrusions and wedges of rhyolite tuff mark major northwest-trending fault zone from 2:30 to 8 o'clock. The road crosses the disturbed zone over the next 1.1 miles.
1.1	235.2	Begin steep ascent up the escarpment of the Mogollon Rim. For the next 1.3 miles, the curving road crosses altered andesites, flows, breccias, and tuffs dipping northwest. (Figure 5)
1.3	236.5	Road crosses an intrusive rhyolite body with contorted, but generally flat-lying flow bands, possibly a sill. Note near-vertical northwest-trending joints. After a sharp turn to the left, mountains of Oligocene rhyolitic pyroclastics, including numerous ash flows are visible in the distance at 2 o'clock. In the country traversed by our road these pyroclastics are conspicuous by their absence.
0.5	237.0	Road parallels northwest-trending fault contact of Tertiary or Cretaceous andesite and basalt. Although the basalt is shown as QTb on the Graham and Greenlee Counties map, it is overlain on the New Mexico side of the state line by rhyolite (Upper Rhyolite, Tvr) with a K-Ar date of 18.6 m.y. (Weber and Bassett, 1963) The same rhyolite is shown on the new U.S.G.S. Geologic map of New Mexico (Dane and Bachman, 1965), as QTr. A basalt or "basaltic andesite" similar to, and probably once continuous with, the one seen here, in the Gila valley was dated at 20.6±1.5 m.y. (Damon, et al. 1967). The Geologic map of New Mexico shows it as QTba. The same rocks are correctly shown as Tertiary by Weber and Willard (1965), and Elston (1960). They are clearly older than the main stage of Basin and Range faulting and their Miocene isotopic ages should not have surprised the map compilers.
		The fault zone contains a sliver of consolidated conglomerate, rhyolite with contorted flow bands, and rhyolite vitrophyre in various stages of alteration and devitrification.
0.2	237.2	After sharp turn left, a massive rhyolite flow, approximately 1,000 feet thick, can be seen across the canyon from 1 to 4 o'clock. The basal part of the flow is brecciated. From 11 to 12 o'clock basalt containing pseudomorphs of goethite after olivine ("iddingsite") forms cliffs.
0.2	237.4	Tunnel in thick rhyolite flow breccia, dip 50-55° NW. Across the canyon the breccia can be seen to lie on pink sandstone and to grade upward into massive flow rhyolite. (Figure 6).

Figure 5 – Photograph shows Arizona Highway 78 ascending to escarpment forming the eastward extension of the Mogollon Rim. At this point the Mogollon Rim is comprised of Tertiary rhyolitic volcanic rocks and Tertiary and/or Cretaceous andesites. The mountain ranges bounding the Gila Wilderness area are visible in the distant background. – Photograph by Tad Nichols

0.2	237.6	Gravel pit on left exposes bedded rhyolite talus, dip 32° downslope, capped by coarse basalt talus. Bedrock exposed in the quarry shows a rhyolite breccia, similar to the rock in the tunnel 0.2 miles back, in fault contact with rhyolite with contorted flow bands and local autobrecciation. Except as noted, the road remains in flow-banded rhyolite for the next 3.0 miles. The fault in the gravel pit strikes N. 30° W.
0.5	238.1	Small dike of vitrophyre with gas cavities on left.
0.1	238.2	We're on top at last! Forest soil, no outcrop. What a relief!
1.3	239.5	Bridge, road cut and massive flow rhyolite
0.4	239.9	Bridge
0.6	240.5	Road cut shows depositional contact of black vesicular andesitic phase of QTb on rhyolite flow (Tr). The top of the rhyolite is channeled, with about 2 feet of relief. Between

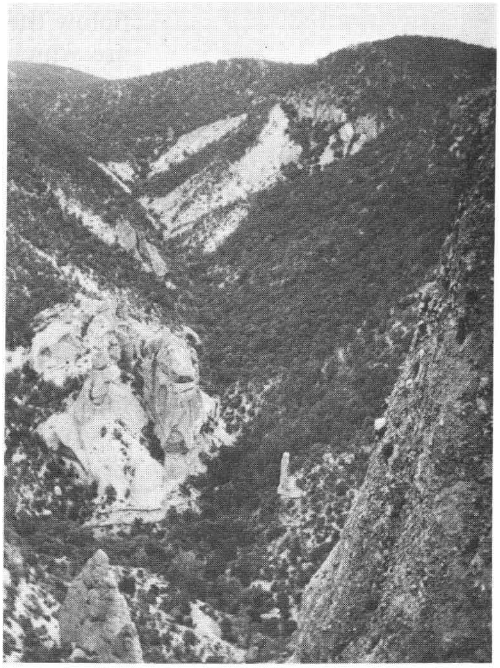

Figure 6 – View south from mile 237.4. Layered material at bottom of canyon is pink sandstone. Overlying cliff-former is rhyolite flow breccia, similar to material in right foreground. Massive flow-banded rhyolite forms the bulk of the range.
–Photograph by W.E. Elston

rhyolite and andesite there is a thin regolith of rhyolite fragments in sandy matrix. The basal andesite is a slightly oxidized flow breccia, overlain by massive flow rock with plagioclase phenocrysts. Locally the andesite shows prominent flow folds. The road follows the rhyolite-andesite contact for the next 1.7 miles.

0.4	240.9	Beyond a sharp left curve, andesite with sandy interbeds is in fault contact with brecciated rhyolite. The fault strikes N. 60° E. and intersects the road again 0.35 miles beyond this point.
0.9	241.8	Ruins of ranch on right.
0.9	242.7	Culvert. Rhyolite flow rock is exposed for the next 0.6 miles.
0.6	243.3	Culvert. Road follows depositional contact of Gila (?) Conglomerate on rhyolite.
0.3	243.6	Culvert. Fault contact between flow banded rhyolite and Gila (?) Conglomerate.
0.2	243.8	Culvert. Gila (?) dips 10° NE.
0.2	244.0	Arizona-New Mexico state line. Welcome to Land of Enchantment! Doesn't the air feel a bit fresher? And the road rougher? The Gila(?) includes laminated pumiceous beds, channel deposits, and even-bedded sandstone, all intertongued with fanglomerate deposits.
0.4	244.4	Leave Apache National Forest, enter Gila National Forest, downgrade for the next 3 miles. Small-scale normal fault in Gila (?) on left.
0.4	244.8	Culvert. Depositional contact of Upper Rhyolite (Tur–18.6 m.y.) on Gila (?). Below the contact Gila (?) is well-bedded and contains diatomite. The older rhyolite which we saw underneath Gila (?) 1.5 miles back, was gray and contained few phenocrysts. The Upper Rhyolite is vitrophyric, partly divitrified, black to brown, and contains abundant phenocrysts of quartz, biotite, and sanidine. This rhyolite locally has a perlitic phase in which the perlitic nodules have cores of obsidian, the "Apache tears" well-known to rock hounds.
0.2	245.0	Fault contact of Upper Rhyolite (Tur) and poorly-bedded fanglomeratic facies of Gila (?) in road cut on left. The Upper Rhyolite apparently intertongues with the Gila (?); the fanglomerate exposed here is younger than the Upper Rhyolite. The pumiceous basal zone of the post-Tur Gila (?) is exposed in the valley on the right. Sorry about the terminology. It definitely has not been approved by the Committee on Stratigraphic Nomenclature! The proportion of fanglomerate increases upward in the Gila, indicating the onset of the main phase of Basin and Range faulting.
0.2	245.2	Many road cuts in pumiceous phase of the Gila (?) for the next 1.2 miles.
0.7	245.9	Fault contact of pumiceous and fanglomeratic facies of Gila (?).
0.2	246.1	Pumiceous Gila (?) becomes massive and develops columnar joints. Since this is a field trip dealing with ash flows and we haven't seen an ash flow for one heck of a long time, we'll interpret it as an ash flow. Any arguments? The rock contains numerous lithic fragments and small phenocrysts of quartz, biotite, and sanidine. In hand specimens it resembles the Deadwood Gulch Rhyolite of the Mogollon region 25 miles to the northeast (Ferguson, 1927), which forms a thin but persistent sheet in the Mogollon Plateau east of here and overlies all older volcanic rocks with a pronounced angular unconformity.

1.5	247.6	Leave Gila National Forest. No more outcrops of Gila (?) for a while. Alluvium and terrace gravels ahead. Mogollon Mountains on the skyline.
2.4	250.0	Mule Creek Post Office. Tertiary basalt in hills at 9 to 10 o'clock.
1.1	251.1	Cattle guard.
0.9	252.0	Upper Rhyolite and Tertiary basalt in hills on left.
1.5	253.5	Tertiary basalt on left.
0.8	254.3	Crossroads. Mule Mountains at 3 o'clock are a complex of Upper Rhyolite. Upper Rhyolite is exposed in several road cuts for the next 0.5 mile. Note near-vertical flow bands and perlitic zones.
0.5	254.8	Leave outcrop belt of Upper Rhyolite (Tur), enter outcrop belt of an older latite, mapped by Weber and Willard, (1959) as part of the Datil Formation.
0.2	255.0	Post-Datil basalt in road cuts.
0.7	255.7	Quaternary terrace gravels in road cuts.
0.5	256.2	Good view of Mogollon Mountains from 9 to 1 o'clock. The Mogollon Mountains have been interpreted by Elston (1965) as the southwestern rim of a near-surface ring-dike complex, 75 miles in diameter. The dikes are fault-controlled, arcuate belts of flow-banded rhyolite of several ages, generally becoming younger toward the center of the structure. The interior of the ring-dike complex is a large volcanic-tectonic basin, which topographically forms the drainage basin of the upper three forks of the Gila River. Within the major structure local cauldrons appear to have been vents for at least two major ash-flow compound cooling units. Each ash-flow cooling unit thickens to more than 2,000 feet within its cauldron and is either absent or considerably thinner outside of it. The rocks visible in the Mogollon Range from this point include ash flows, intrusive and extrusive flow banded rhyolites and quartz latites, as well as intercalated andesite flows and tuffs. The entire complex is capped by dark-colored latites andesites and basalts. A number of vents and calderas of basaltic rocks have been recognized.
0.6	256.8	Road to H-Y ranch on right. Rhyolite and latite, included by Weber and Willard (1959) in the Datil Formation, can be seen on both sides of the highway for the next 2.1 miles.
2.0	258.8	Culvert and cattleguard.
0.2	259.0	West-dipping hogback of Tertiary rhyolite ash flow at 3 o'clock.
0.7	259.7	Intersection of New Mexico Highway 78 and U. S. 180. STOP and then turn left on U. S. 180.
1.1	260.8	Hills at 9 o'clock have been mapped as Datil rhyolite, undifferentiated. The highway follows a major asymmetrical graben which forms the outer limit of the Mogollon Plateau. The graben is here bordered by major faults on the east side and relatively minor faults on the west side. It is filled by Gila Conglomerate (late Tertiary) and Quaternary terrace gravels. Several rivers have entrenched themselves in various stretches of the graben; at present we are in the drainage basin of the San Francisco River.

0.9	261.7	Culvert
1.5	263.2	Sign–Leopold Vista ahead
0.3	263.5	STOP 9 - Time: 15 minutes - Pull off into parking area at Leopold Vista. Discussion of structure and volcanic stratigraphy of Mogollon Mountains and surrounding area. (Figure 7).

SUMMARY OF THE GEOLOGY OF THE MOGOLLON RANGE SOUTHWESTERN NEW MEXICO

By

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The Mogollon Range attains an elevation of over 10,000 feet and is composed of Tertiary ash-flows and flow-banded rhyolites associated with subordinate andesites, basalts and volcanic sediments. Structurally, the Range forms part of the western raised rim of the Mogollon volcano-tectonic depression (Elston, 1965) and is bordered on the west side by an asymmetrical graben, now filled with Gila conglomerate. The volcanic sequence west of the graben is substantially abbreviated compared with the great thickness of material, especially flow-banded rhyolites and ash flows, constituting the rim.

Volcanic units in the Mogollon Range have been tentatively classified into four major associations that correspond closely to the sequences proposed by Elston and Coney (1967). Each volcanic association includes thick ash flows and protrusive flow-banded rhyolites.

(1) The basal part of the section, described at Mogollon by Ferguson (1927). The oldest known unit is the Whitewater Creek Rhyolite, a massive ash flow exposed in the bottoms of only two canyons. The overlying Cooney Quartz Latite is about 2,000 feet thick and consists of a series of ash flows characterized by well-developed phenocrysts of sanidine, sodic plagioclase and biotite. It is separated by andesite flows from the massive porphyritic Sacaton Quartz Latite*, at least 3,000 feet thick, forming a topographic dome centered around Sacaton Mountain. Parts of this unit probably correspond to the Pacific Quartz Latite at Mogollon. Together with the Fanney Rhyolite, described below, these rocks form the bulk of the western rim of the Mogollon Plateau.

(2) The Apache Spring Quartz Latite* consists of two-feldspar quartz-latite ash-flow tuffs at least 2,500 feet thick, that crop out east of Sacaton Mountain but apparently did not significantly overflow the elevated rim of the Mogollon Plateau. Its age is 27.3±0.8 m.y. (Damon et al., 1967). A feature interpreted as a faulted cauldron wall has been recognized in the field and it is believed that these ash-flows were largely restricted to a cauldron structure 12–15 miles in diameter, superimposed on the main Mogollon Plateau volcano-tectonic structure. Associated with these ash-flows are over 2,000 feet of two- feldspar flow-banded rhyolite, forming an elongated dome on the rim of the Mogollon Plateau structure. At least

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*New stratigraphic terms, first introduced and defined by Elston, are marked with an asterisk.

two ages of extrusion are represented by the flow-banded rhyolite–(a) a pre-Apache Spring rhyolite that forms the bulk of Holt Mountain and is probably continuous with the Fanney Rhyolite at Mogollon (Ferguson, 1927). The Range between Holt and Nabours Mountains is capped with Apache Spring Quartz Latite ash-flow tuff filling an ancient erosion channel cut into the older flow-banded rhyolite (b) a post-Apache Spring rhyolite that lies farther east and forms relatively thin, subhorizontal flows overlying the quartz-latite ash-flow tuffs. Intrusive rhyolite dikes and trends of sub-vertical flow-banding within the main body of pre-Apache Springs (Fanney) rhyolite are aligned parallel to the regional structure of the Mogollon Plateau. Pre-Fanney andesite flows are found only west of the highest parts of the rim, and possibly were prevented by a topographic barrier from overflowing into the central depression in this area.

(3) A one-feldspar rhyolite ash-flow tuff, Moonstone Tuff of Wargo (1959), now re-named Bloodgood Canyon Rhyolite*, age 23.2-26.5 m.y. (Damon et al., 1967), crops out in the forks of the Gila River and their tributaries about 20 miles to the east, but was not found in the Mogollon Range. Masses of one-feldspar flow-banded Jerky Mountains Rhyolite*, younger than the two-feldspar rhyolites in the Mogollon Range, crop out in a broad arc that includes the Jerky Mountains about 20 miles east of the Mogollons and probably represents a segment of another cauldron wall. Within the cauldron the Bloodgood Canyon Rhyolite is about 2,000 feet thick, but several ash flows tens of feet thick overflowed the cauldron and spread tens of miles south, northwest, and north.

(4) Ash flows and stratified, waterlaid Deadwood Gulch Rhyolite Tuff (Ferguson, 1927) overlies all older formations with strong unconformity, and attains a maximum thickness in the Mogollon Range of over 1,000 feet, thinning both westward and eastward. The source of this material is unknown.

Capping the sequence in the Mogollon Range are basalts, latites and basaltic andesites of the Bearwallow Mountain Formation*, locally over 1,000 feet thick, which lie unconformably on older formations. A basaltic vent is located 1 mile west of the town of Glenwood, and two basaltic calderas each about 3 miles in diameter, have been recognized near Willow Mountain and Mogollon Baldy respectively. Several other basaltic centers, mostly calderas, are known on the Mogollon Plateau.

East of the Mogollon Range, Gila Conglomerate and pediment gravels slope gently towards the center of the Mogollon Plateau volcano-tectonic structure. They represent partial infilling of its central basin following subsidence along faults of post-Bearwallow Mountain age. A complex history of faulting, hydro thermal alteration and mineralization occurred along the western foot of the range; post-Bearwallow Mountain faulting formed the outer graben.

0.3 263.5 STOP 9 (cont.)

Panoramic view, facing the Aldo Leopold Memorial (the monument is a piece of Kneeling Nun quartz latite ash-flow tuff from the Santa Rita area.)

9 o'clock, San Francisco Canyon

11 o'clock, Nabours Mountain

11:30 o'clock, Junction of Sheridan Canyon with Big Dry Creek in foreground. Note huge gravel fan. Holt Mountain in background.

12:00 o'clock, Sheridan Mountain

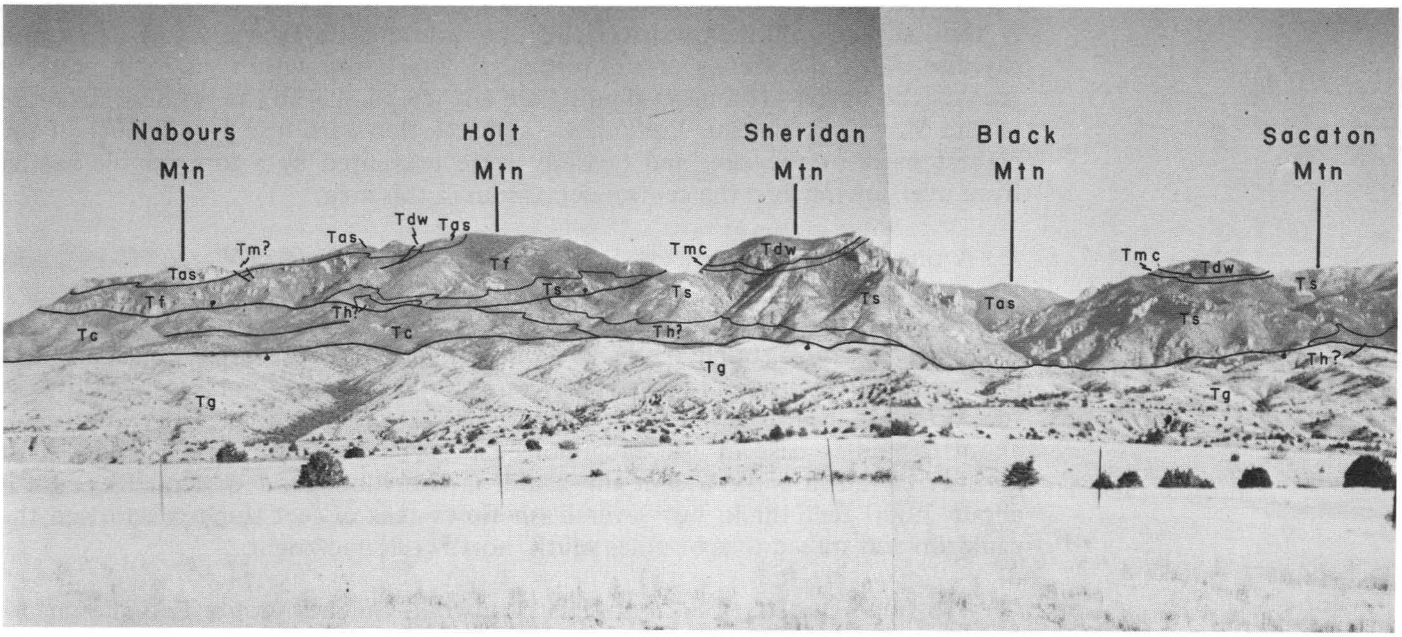

Figure 7 – Panoramic view of part of Mogollon Mountains from Leopold Vista (Stop 9). Tc–Cooney Quartz Latite, Th ? Houston (?) Andesite, Ts–Sacaton Quartz Latite, Tf–Fanney Rhyolite, Tmc–Mineral Creek Andesite, Tas–Apache Spring Quartz Latite, Tdw–Deadwood Gulch Rhyolite, Tm (?) Mogollon (?) Andesite, Tg–Gila Conglomerate. See article by Elston, this guidebook, figure 2, columns IV and V for correlation and figure 3 for geologic structure.
–Geology by R.C. Rhodes, Photograph by W.E. Elston

12:15 o'clock, Canyon of Big Dry Creek, Black Mountain in background.

12:30 o'clock, West Baldy and Sacaton Mountain

1:00 o'clock, Haystack Mountain

2:30 o'clock, Seventyfour Mountain

The Aldo Leopold Memorial commemorates the founder of the federal Wilderness Program. The Gila Wilderness, of which the Mogollon Mountains form a part, is the oldest Wilderness Area in the United States, founded in 1924. The late Aldo Leopold was the father of Luna P. Leopold, and Estelle Leopold, both distinguished geologists of the U. S. Geological Survey.

Return to U. S. Highway 180, head south.

3.9	267.4	Junction with New Mexico 78 on right. Continue straight ahead on U. S. 180.
1.8	269.2	Cross bridge after descending to lower terrace level.
0.5	269.7	Culvert. Diatomaceous lake beds, part of the Gila "Conglomerate", at 9 o'clock.
1.3	271.0	Cross bridge. Many road cuts in Gila lake beds for the next mile.

1.2	272.2	Cross bridge.
1.0	273.3	For the next 1.3 miles, hills to the right of highway are made up of diatomaceous Gila lake beds overlain by basalt. Bulldozer cuts show that there has been some prospecting for commercial diatomite.
1.2	274.5	Gila lake beds on right include green clay and white diatomite.
2.5	277.0	Buckhorn bar at 3 o'clock. We're now heading down Duck Creek Valley. Mogollon Baldy at 8:30 and Seventyfour Mountain at 9 o'clock. Mogollon Baldy elevation 10,778 feet, is the second highest peak of the Mogollon Range.
1.4	278.4	Green clay lake beds and Gila at 3 o'clock.
0.7	279.1	Good view of the mouth of Gila Canyon at 11 o'clock. The Gila River cuts through the rim of the Mogollon Plateau in a magnificent canyon, up to 3,000 feet deep. The mouth of the canyon is the proposed site of the $27,000,000 Hooker Dam. In the proposed dam site there is evidence for post-Wisconsin faulting, in the form of repetition of Wisconsin-age terraces.
		Near the mouth of the Gila Canyon, the Mogollon Mountains split into two structural prongs: the Diablo-Copperas prong, which continues eastward and forms the southern rim of the Mogollon Plateau and the Pinos Altos prong, which trends southeast. The volcanic stratigraphy of the area is as follows, beginning with the oldest: (1) A complex of intensely hydrothermally altered and mineralized andesites and rhyolites (including minor ash flows), intruded by bodies of monzonite and diabase. The age of this complex is unknown, but it may be correlative with Laramide andesite breccias and intrusives of various types at Pinos Altos. (2) Relatively unaltered andesite and latite flows and pyroclastic rocks. (3) Quartz latite ash flow tuffs interbedded with minor water-laid andesite tuffs. The quartz latite ash flows are in part continuous with the Tadpole Ridge Quartz Latite which we will see tomorrow at Cherry Creek in the Pinos Altos Mountains. A sample collected near the base gave a K-Ar date of 31.2±0.9 m.y. (Damon, et al. 1967) within the range of the type-Datil of the Bear Mountain in Socorro County. (4) Bedded pumiceous tuff overlain, on the north side of the Gila River only, by a thick banded rhyolite flow. This rock is similar in lithology to the Fanney Rhyolite of the Mogollon mining district (Ferguson, 1927), and the Mimbres Peak Rhyolite of the Mimbres Valley (Elston, 1957). The Mimbres Peak has been bracketed between 29.8±0.8 m.y. (Damon et al., 1967), and 34 m.y. (McDowell, 1966). The Fanney is older than the 27.3±0.8 m.y. Apache Spring Quartz Latite of the Mogollon Mountains, which is absent here. Flow-banded rhyolite also forms intrusive bodies along faults. (5) The Bloodgood Canyon Rhyolite ash flow tuff, which forms the prominent white ledges near the tops of the mountains on both sides of the Gila Canyon. The Bloodgood Canyon Rhyolite is a massive rhyolite ash flow compound cooling unit, over 2,000 feet thick in its cauldron in the interior basin of the Mogollon Plateau. It is a couple of hundred feet thick in the exposures visible from this point, which are on the rim of the Mogollon Plateau. If the weather is clear, several distinct cliff-forming units can be seen from this point; each cliff represents the most welded zone of an individual ash flow. A single ash flow, 50 to 100 feet thick lithologically resembling the Bloodgood Canyon crops out in the hills to our right. Its stratigraphic position within the Bloodgood Canyon sequence is unknown, but a K-Ar age of 26.5±1.2 m.y. was reported by Damon and Bikerman (1964) from a sample collected in the Schoolhouse Mountain quadrangle by Wargo. A sample collected from the top of the section near Reserve, 60 miles to the north gave an age of 23.2±0.7 m.y. (Damon,

		et al, 1967). Lithologically, the Bloodgood Canyon Rhyolite consists of a matrix of exceedingly fine shards, barely resolvable under the microscope, prominent phenocrysts of rounded quartz and sanidine cryptoperthite ("moonstone") up to 2mm in diameter, sparse biotite (usually brassy in color), but no plagioclase. Rocks of this type and of the same stratigraphic position have been traced from the Pinos Altos Mountains to the San Francisco Mountains and the margins of the San Augustin Plains (Elston and Coney, in press) a distance of over 90 miles. The name *Moonstone Tuff* was coined for the Formation by Wargo (1959). Since moonstone occurs in many rocks of widely different ages and origins, the name has now been replaced by the term Bloodgood Canyon Rhyolite. An ash flow unit as widespread and as widely differing in ages as this one may well have erupted from several centers. (6) Olivine basalt.
1.4	280.5	Basalt section in hills at 3 o'clock repeated by faults
2.5	283.0	Mouth of Gila Canyon at 9 o'clock. Bloodgood Canyon Rhyolite ash flow tuff forms upper cliff, Tadpole Ridge Quartz Latite ash flows, continuous with the Cherry Creek section, which will be visited tomorrow, form the lower cliffs.
1.0	284.0	Enter village of Cliff.
0.5	284.5	Downtown Cliff. Junction with New Mexico 211 to Gila on left. Stay on U. S. 180.
1.3	285.8	Bridge across Gila River. Outcrops of massive flow-banded rhyolite beyond bridge on left.
1.2	287.0	Riverside post office.
0.8	287.8	Bridge.
0.5	288.3	Outcrops of flow-banded rhyolite on both sides of highway.
2.5	290.8	Road cut in flow-banded rhyolite.
1.7	292.5	Cross bridge and curve.
0.9	293.4	Volcanics of Silver City range at 9 o'clock consist of a thick section of rhyolite ash flows, flows, and flow breccias (Datil ?) overlain, in turn, by basaltic andesite, local lenses of conglomerate, 100 feet of Bloodgood Canyon Rhyolite, a second zone of basaltic andesite, and a thick section of Gila Conglomerate with minor rhyolite tuff beds in the lower part and basalt flows in the upper part. The entire range is a fault-block mountain, tilted 25 to 30° NE. The road is flanked by Gila Conglomerate.
1.3	294.7	Cross bridge
0.6	295.3	Cross bridge. Leave outcrop belt of Gila Conglomerate. Outcrops of altered flow-banded rhyolite for the next 0.8 miles.
0.7	296.0	Mangas Springs bar and gas station on right.
1.6	297.6	Red, hydrothermally altered rhyolite at 3 o'clock, cross Mangas Valley. Alteration is associated with manganese mineralization (Wargo, 1959).

0.3	297.9	Cross bridge.
1.0	298.9	Outcrops of Gila Conglomerate and a fine display of Quaternary terraces on both sides of the Mangas Valley.
1.5	300.4	Note classic case of gullying caused by overgrazing at 3 o'clock. Gully development is confined to north side of fence line.
2.2	302.6	Hills on right from 7 o'clock are in the Schoolhouse Mountain quadrangle. Wargo (1959) has mapped about 9,000 feet of predominantly rhyolite overlying a basal andesite, divided into six formations (Saddle Rock Canyon Formation, Kerr Canyon Formation, Delta Formation, Mangas Creek Formation, McCauley Formation, Cherokee Creek Formation) and further subdivided the 24 members. This immense section, which may correspond to the Datil Group (or Formation) of central New Mexico, is overlain by tuff, breccia, about 100 feet of Bloodgood Canyon Rhyolite and Gila Conglomerate interlyered with basalt. The volcanics are in fault contact (Wild Horse Fault) with the Precambrian igneous and metamorphic complex that makes up the main mass of the Big Burro Mountains (Hewitt, 1959).
3.0	305.6	Good view of volcanics of Silver City Range at 9 o'clock. Many exposures of nearly flat-lying Gila Conglomerate for the next 3.5 miles.
1.3	306.9	Cross bridge.
2.0	308.9	Continental Divide. Numerous exposures of tilted (older?) Gila-type conglomerate for next 1.0 miles.
1.0	310.0	Bridge
0.2	310.2	Road cut in flat-lying Gila Conglomerate
0.8	311.0	Road cuts in Devonian Percha Shale and Mississippian Lake Valley Limestone, faulted, intruded by Laramide porphyries, hydrothermally altered, intensely deformed, and generally a mess, for the next 1.6 miles.
1.0	312.0	Cross bridge.
0.4	312.4	Town of Silver City, seat of Grant County, ahead. Note dumps of manganiferous iron ore in Boston Hill on right. The Silurian Fusselman Dolomite is the ore bearing horizon.
0.6	313.0	Junction of U. S. 180 and New Mexico 90 (Hudson Street); End of road log. Turn left on Hudson Street and continue on highways 180 and 90 to Holiday Inn.
2.0	315.0	HOLIDAY INN, RELAX UNTIL MORNING.

SECOND DAY, TUESDAY, APRIL 9

Leaders: Wolfgang E. Elston and Frederick J. Kuellmer
(We are indebted to the New Mexico Geological Society and to field trip leaders W.W. Baltosser, R.M. Hernon, W.R. Jones, F.J. Kuellmer, W.E. Elston, R.W. Weber and F.D. Trauger for permission to use portions of the road log for their Sixteenth Field Conference).
Driving Distance: 145 miles
Logged Distance: 144 miles
Starting Time: 8:00 A.M.
Assembly Point: Holiday Inn Motel

GENERAL STATEMENT

The second day's trip is northward from Silver City to Gila Cliff Dwellings National Monument, returning by way of the Sapillo and Mimbres Valleys, the west flank of the Black Range, and the Santa Rita-Central mining district. For the first 9 miles, from Silver City through Pinos Altos, the caravan traverses a terrace of Upper Cretaceous Colorado Shale and Cretaceous-Tertiary andesite breccia, cut by porphyritic stocks, innumerable dikes, and veins. The next 17 miles are across the complexly faulted Pinos Altos Range, composed of Tertiary volcanic rocks and Gila Conglomerate, and down to Sapillo Creek. For the following 7 miles the route ascends Copperas Peak, probably a Tertiary andesitic volcano, from which one may obtain a sweeping view of the vast Gila Wilderness. From there, for the next 12 miles the caravan descends into the Upper Gila Basin, probably a large volcano-tectonic sink, to wind up at Gila Cliff Dwellings National Monument. After backtracking to Sapillo Creek the route for 28 miles is through the Sapillo and Mimbres Valleys, past Roberts Lake and across the Continental Divide, with extensive views of late Tertiary Gila Conglomerate and Quaternary terraces on the way. A side trip will go to the west flank of the Black Range, where the vent area of the Kneeling Nun Quartz Latite ash-flow tuff will be examined. The last leg of the trip, from San Lorenzo back to Silver City, is through the heart of the most productive metal-mining district in New Mexico, in which mineralization is controlled by Laramide porphyry bodies intruded into Paleozoic and Cretaceous sedimentary rocks. A stop at the base of the Kneeling Nun ash-flow tuff, which changes from a poorly welded rhyolite, to intensely welded quartz latite in the basal 100 feet, will conclude the day.

Segmental Mileage	Cumulative Mileage	
0.0	0.0	STARTING POINT on right side of New Mexico Highway 25 at junction with U.S. Highway 180, opposite Shamrock station on the left, heading north towards Pinos Altos.
0.2	0.2	Cross gully. Dike in Colorado Shale on the right.
0.4	0.6	TURN LEFT on New Mexico Highway 25 at Ranch Club. Ridge at 10 o'clock is a resistant dike in Colorado Shale. Dikes in dike complex trend northeast and constitute more than 50 percent of the exposed rock. Outcrops of Colorado Shale are characterized by their yellow to buff weathered color.
1.2	1.8	Crest of topographic rise. Ahead, "W" Mountain marks southern edge of Pinos Altos Range; consists of Colorado Shale and Cretaceous-Tertiary andesite breccia intruded by dikes and Tertiary monzonite intrusive stocks.
0.9	2.7	Light-colored dike of andesite porphyry on the right. Silver City Range, at 9 o'clock on horizon, contains a well-exposed northeast-dipping section of Paleozoic and Cretaceous sedimentary rocks, resting on the Precambrian.

0.4	3.1	Porphyritic dike in road cut.
0.1	3.2	Inferred contact between Colorado Shale and overlying Cretaceous-Tertiary andesite breccias.
0.1	3.3	Side road on right to Hickel place. Contact between Cretaceous-Tertiary andesite breccia and intrusive Tertiary monzonite.
0.2	3.5	Cross gully. Exposures of monzonite on the right. Road parallels general trend of dikes in this area.
0.6	4.1	Cross arroyo. Road cut on left at curve exposes monzonite cut by dike.
0.2	4.3	Poorly exposed Cretaceous-Tertiary andesite breccia cut by Cretaceous-Tertiary augite-biotite monzonite and dikes.
0.2	4.5	Gully along contact of monzonite and Tertiary Pinos Altos stock, composed of hornblende quartz monzonite porphyry.
0.1	4.6	Road cut on the right in weathered, highly fractured hornblende quartz monzonite porphyry. Silver Hill at 10 o'clock is mainly andesite breccia cut by dikes. Mine dumps near base of Silver Hill. Road from here to Pinos Altos is on Pinos Altos stock.
0.2	4.8	At 3 o'clock, Cooks Peak on skyline, seen through a gap in the Cobre Mountains, was a famous landmark for early travelers in this region. It consists of a granodiorite porphyry stock. Cobre Mountains consist of Tertiary volcanics including several ash-flow cooling units of which the Kneeling Nun Quartz Latite, Box Canyon Rhyolite and Caballo Blanco Rhyolite are the most prominent. Smelter stack at Hurley visible at 5 o'clock from just beyond this mileage point.
0.2	5.0	Old mill site on the left.
0.3	5.3	Road curves to left. Side road junction on right. Numerous mine dumps on slopes ahead. Dark-colored dumps to the left are in diorite on the Pacific claims, whereas light-colored dumps to the right are from the Pinos Altos quartz monzonite stock. The Pacific Mine was credited in 1905 with total production of over $1,000,000 (Lindgren, et al., 1910, p. 298). The values were mostly in copper and gold, with some silver.
0.5	5.8	Road cuts in Pinos Altos stock.
0.6	6.4	Southwest corner of old Gopher (Golden Giant) claims. Gopher shaft, on the right, is 520 feet deep. Extensive tunnels extend from the 400 foot level and from four other levels. (Paige, 1910, p. 120). Values were mostly in gold and silver. Water level in the shaft was at 46 feet in 1954. Official Scenic Historic Marker states: "The Pinos Altos Mountains rise to an elevation of over 9000 feet. The Continental Divide crosses the highway at this point. Elevation 7067 feet. In this area are extensive gold, silver, and copper deposits mined as early as 1803. Pinos Altos was southwestern New Mexico's first gold camp and once the seat of Grant County." Metal production of the Pinos Altos district prior to 1950 has been estimated at $9.7 million. Gold and zinc were the most important metals mined (Anderson, 1957).

0.2	6.6	Road curves to left at large two-story house. Road trends due north in front of house. Main crest of Pinos Altos Range ahead. Headwaters of Bear Creek in valley at 10 o'clock. At 9 o'clock are workings of Aztec-Asiatic claims. The Aztec-Asiatic veins are extensions of the Pacific claim and are similar in character. Mina Grande, Mogul, and Kept Woman Mines produced gold, silver, copper, lead, and zinc.
0.1	6.7	Fork in road. BEAR LEFT on Alternate New Mexico Highway 25. Caravan passes through old town of Pinos Altos. PLEASE DRIVE SLOWLY.
0.1	6.8	Bridge. Cross arroyo in headwaters of Bear Creek.
0.1	6.9	TURN RIGHT. Follow pavement past Pinos Altos Mercantile and Buckhorn Saloon on right; oldest schoolhouse in Grant County on left. The Tatsch family is responsible for restoration of many of the historic buildings in Pinos Altos. Once almost a ghost town, Pinos Altos has recently been revived by an influx of people, including a number of artists, who appreciate its scenery, climate, and historic atmosphere.
0.5	7.4	Cross Bear Creek on Pinos Altos stock. First gold discovery was made in placer gravels in creek bed. According to reports, some placers are still being worked occasionally and small amounts of gold are being recovered. Old placer claims are still valid and not open to the public, except locally for a fee.
0.1	7.5	Old mine adit on right.
0.1	7.6	Road junction on the right. KEEP STRAIGHT AHEAD.
0.5	8.1	Cross side gulch. House on left is one of the early adobe structures in this area.
0.2	8.3	Cattle guard. Gila National Forest Boundary. CAUTION! NARROW, WINDING ROAD AHEAD. Outcrops of Pinos Altos hornblende quartz monzonite porphyry stock.
0.3	8.6	Cretaceous-Tertiary andesite breccias and mafic dikes cut by apophyses of Pinos Altos stock.
0.2	8.8	"Early Grant County" style miner's cabin on slope to the right. Pinnacles of Tertiary Tadpole Ridge Quartz Latite ash flows ahead.
0.2	9.0	Base of Tadpole Ridge ash flow sequence here is a vitrophyre resting unconformably on the late Cretaceous-early Tertiary igneous sequence. Ash flow tuffs are more than 1000 feet thick. According to Elston (this guidebook) they are essentially the same age as the Kneeling Nun–Caballo Blanco section of the Black Range–Santa Rita area to be visited this afternoon, but belong to a different volcanic province. The two provinces are separated by a physical barrier, the north-trending Santa Rita–Hanover–Fierro axis. Note zone of king-size spherulites at top of vitrophyre. These rhyolite ash flows can be distinguished from the younger Bloodgood Canyon sequence exposed near the Cliff Dwellings by an abundance of biotite and the absence of moonstone (sanidine cryptoperthite) and rounded quartz. For details of volcanic section on this log of the trip, see accompanying paper by Elston (Fig. 2, Column II).
0.1	9.1	Fault. Vitrophyre downthrown against Cretaceous-Tertiary andesite breccias and mafic dikes.

0.1	9.2	Placer mining tailings in creek bed on the left.
0.1	9.3	Bridge across Mill Creek. Outcrops of stony quartz latite ash flows with vitrophyric base.
0.1	9.4	Gold placers on the left. Terrace gravels in road cut on the right.
0.4	9.8	Bridge crossing Little Cherry Creek.
0.6	10.4	STOP 10 - Time: 20 minutes - Curve, trail to Ben Lilly Memorial marker at left. Plaque located on north side of outcrop about 50 yards west of highway reads as follows:

> 1856 – Ben V. Lilly – 1936
>
> Born in Alabama and reared in Mississippi, Ben V. Lilly, in early life, was a farmer and trader in Louisiana, but turned to hunting of panther and bears with a passion that led him out of the swamps and canebrakes, across Texas, to tramp the wildest mountains of Mexico, and finally to become a legendary figure and dean of wilderness hunters in the southwest. He was a philosopher, keen observer, naturalist, a cherisher of good hounds, a relier on his rifle, and a handicraftsman in horn and steel. He loved little children and vast solitudes. He was a pious man of singular honesty and fidelity and a strict observer of the Sabbath. New Mexico mountains were his final hunting range and the charm of the Gila Wilderness held him to the end.
>
> Erected in 1947 by friends.

The Tadpole Ridge Quartz Latite (see accompanying photograph) has not yet been studied in detail. It consists of numerous ash flows; four cliff-forming columnarly-jointed welded zones separated by relatively unwelded benches can be seen from this point. Biotite from a sample collected at Ben Lilly Memorial gave a K-Ar age of 31.2±0.9 m.y. (Damon et al., 1967). Because of faulting no complete section has been measured, but total maximum thickness must be 1,000 to 2,000 feet. The source(s) of the unit is (are) unknown, but it has not been found east of the Santa Rita–Hanover–Fierro axis. (Figure 8)

The lower members contain phenocryst of oligoclase-andesine, sanidine, biotite, little or no quartz except in a narrow resistant ledge. Occult quartz becomes more abundant toward the top of the formation which grades into rhyolitic rock. Differentiation within individual members has not yet been studied. Planar structures consisting of crystal-lined vapor-phase cavities with alteration halos are more obvious than collapsed pumice fragments. Only the lowest member has a vitrophyric base.

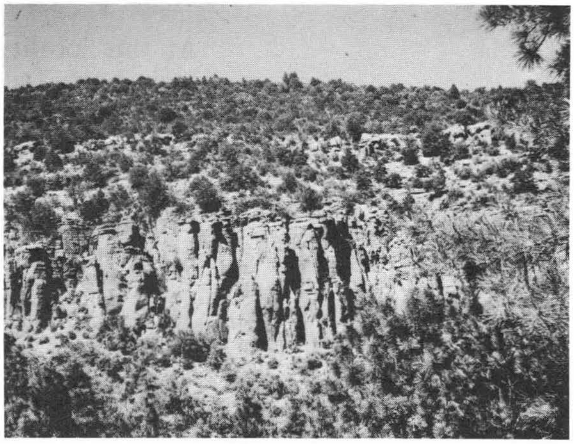

Figure 8 – Typical ash-flow tuff member of Tadpole Ridge Quartz Latite, west side of Cherry Creek. –Photograph by W.E. Elston

		A few tuffaceous sandstone members are present at the top of the formation, which interfingers with the basal porphyritic andesite member of the Alum Mountain Formation.
		Along the highway the Tadpole Ridge Quartz Latite lies unconformably on pre-Tertiary rocks, but toward the west, along Bear Creek, several hundred feet of bedded rhyolite air-fall tuff and sandy water-laid tuff and older purple-brown andesite progressively wedge in beneath the Tadpole Ridge Quartz Latite.
0.4	10.8	Descending into Cherry Creek Canyon. Note gradation in tall columns of welded ash flow tuff from sheeted zone above to massive pinnacles below.
0.1	10.9	Fresh road cut in tuff on right shows lighter color more Felsic composition(?), and less indurated character than more highly welded portions seen previously.
0.8	11.7	Cross Cherry Creek.
0.1	11.8	Entrance to Cherry Creek campground on right. Annual precipitation in this area averages about 21.3 inches a year, (47 years of record at Pinos Altos).
1.4	13.2	Entrance to McMillan campground on right.
0.6	13.8	Abundant xenoliths of a wide variety of volcanic rock types shown in road cut in rhyolite tuff.
0.7	14.5	Red andesite interlayered with quartz latite tuff in creek floor on the right. Entering the Membres fault zone, which trends WNW between here and the Gila Canyon, SE from here to the Cook's Range, and has been traced south in the subsurface from the Cook's Range to the Mexican border; a distance of over 100 miles. Displacement in the Tertiary volcanics alone is up to 9,000 feet, the cumulative displacement since the beginning of Laramide deformation is far greater.
		The northeast block of the Mimbres fault has moved down relative to the southwest block. In the Silver City–Santa Rita mining area the fault marks the northeastern limit of the mineralized pre-Tertiary rocks.
		At this locality, the base of the Alum Mountain Formation has been faulted against the Tadpole Ridge Formation. Elongated domes of flow-banded rhyolite are locally intruded in the fault zone.
0.2	14.7	Cattle guard. Redstone Cabin of U.S. Forest Service on the left.
0.2	14.9	ROAD FORK. Keep left on road to Gila Cliff Dwellings.
0.2	15.1	Fault. Thin-bedded tuffaceous sandstones of Tadpole Ridge Quartz Latite on the south are in fault contact with flows and breccias of the porphyritic andesite member of the Alum Mountain Formation, downthrown on the north.
0.3	15.4	At curve, Meadow Creek road junction. Northwest-trending fault crosses highway. Flowbanded intrusive rhyolite plug domes lie to east of road. Route ahead passes through altered andesites.

0.2	15.6	Intrusive rhyolite on the right.
0.1	15.7	Sharp bend in road. Outcrops of red porphyritic andesite of Alum Mountain formation.
0.7	16.4	In road cut on left, andesites of Alum Mountain formation in depositional contact on rhyolite ash flow. Ash flow is the downfaulted top to the Tadpole Ridge Quartz Latite.
0.3	16.7	At curve, fault in side gulch crosses road alignment. Fine-grained dark latite member of the Alum Mountain formation exposed on hill slope to the right.
0.3	17.0	Head of Trout Creek.
0.3	17.3	On right, sandstone member of Alum Mountain formation with porphyritic Andesite member below and dark Latite above. This sandstone may be a tongue of a thick sandstone section exposed below mafic andesite east of Signal Peak. The sandstone there forms a thick wedge on the edge of the structural and buried topographic high that separates the Mogollon Mountains and Black Range–Mimbres Valley ash flow provinces.
0.1	17.4	Bridge. Dark latites on slopes to the right, beyond which route crosses another outcrop belt of red andesite.
0.6	18.0	Snow Creek Cabin road on left. Fault zone. Small banded rhyolite intrusive body in gully on left.
0.2	18.2	Bridge across Trout Creek. Olivine basalt faulted against porphyritic andesite of Alum Mountain formation in a fault zone nearly ¼ mile wide. Bloodgood Canyon Rhyolite below the basalt rests on basaltic agglomerate with sandy matrix. Dark Latite member of Alum Mountain formation nearly faulted out of this section. Buff sandstones and pumiceous sandstones are interbedded with the basal part of the basalt.
0.3	18.5	Late Tertiary basalt in road cuts on right.
0.4	18.9	Pine Flat. Fault. Top of Bloodgood Canyon Rhyolite crops out beyond piles of crushed stone to the right. Late Tertiary basalt on both sides of the road beyond curve.
1.2	20.1	Fault(?). Bloodgood Canyon formation on right is the thin end of a great wedge that is about 2,000 feet thick northwest of the Gila Cliff Dwellings. There, the moonstone-bearing tuff is intensely welded and forms spectacular 700-foot cliffs in the canyons of the West and Middle Forks of the Gila River. This ash flow sequence is younger than the one we passed in Cherry Creek (23.2 to 26.5 m.y., see discussion in yesterday's log at 91.3 miles). It is distinctly younger than the known range of the type–Datil or the rocks of the Black Range–Mimbres–Santa Rita area. Overlying basalt crops out ahead capping the crest of a narrow spur ridge.
1.8	21.9	Approximate contact of Gila Conglomerate with underlying basalt.
0.4	22.3	STOP 11 - Time: 15 minutes - Trout Creek Canyon on the left; Trout Creek is one of the principal tributaries of Sapillo Creek. A fault of westerly to west-northwesterly trend has downthrown Gila Conglomerate on the south side against

andesite and calcic latite flows and breccias of the Alum Mountain formation on the north side of the canyon. Post–Bloodgood Canyon basalts and basaltic andesites directly overlie the andesite–latite sequence on Horse Mountain and Wild Horse Mesa at the mouth of Trout Creek. The intervening thick section of moonstone–bearing Bloodgood Canyon Rhyolite ash flow and Jerky Mountain Rhyolite of the eastern part of the Mogollon Mountains and the Diablo Range (in the distant view to the west and northwest) is missing here due to eastward thinning and pre-basalt erosion. The basaltic sequence is in turn truncated by the unconformity at the base of the Gila Conglomerate, consequently the Gila in the immediate vicinity rests directly upon the Alum Mountain andesite–latite sequence. The section extending from the Alum Mountain andesites and latites through the Jerky Mountain Rhyolite was assigned to the Datil Formation (Weber and Willard, 1959; Willard et al., 1961). More recent work by Elston and associates indicates that they are younger than the known age range of the Datil Formation. This seems to account in part for the preservation of primary volcano tectonic structures on the Mogollon Plateau, but not elsewhere.

0.4	22.7	CAUTION! USE LOW GEAR. Road ahead descends into Sapillo Creek Canyon with steep grades and sharp curves.
0.5	23.2	Cattle guard.
0.5	23.7	Andesites of Alum Mountain formation exposed in road cuts.
0.2	23.9	Granny Mountain dead ahead (post–Bloodgood Canyon basalt). CAUTION! SHARP CURVE TO RIGHT, FOLLOWED BY SHARP CURVE TO LEFT.
0.7	24.6	CAUTION! DANGEROUS CURVE TO RIGHT.
0.3	24.9	Depositional contact of Gila Conglomerate on red porphyritic andesite of Alum Mountain formation. Gila dips about 10 degrees northeast.
0.9	25.8	Cross floor of side canyon. Basalt Gila Conglomerate in road cut on right.
0.2	26.0	Bridge over Sapillo Creek. Fault that crosses canyon just beyond the bridge dropped Gila against red andesite. A complicated fault zone extends from this point for about 2 miles along the route ahead. The Gila Primitive Area borders the road on both sides. The southeastern corner of the Gila Wilderness Area is about 1½ miles to the northwest.
0.1	26.1	Road junction. TURN LEFT on New Mexico 527, leaving New Mexico Highway 25. Gila Conglomerate rests in depositional contact on andesite in slopes to left.
0.4	26.5	Major fault ahead. Reversed dips in Gila are due to drag.
0.1	26.6	Entering main part of fault zone, and continuing for about the next 1.2 miles. This zone forms part of the ring or polygon of fractures surrounding the Mogollon Plateau, which we are about to enter. The ring fractures control only a few small rhyolite dikes along the highway (compared with enormous masses east and west) instead, a major andesite and latite eruptive center (near Alum Mountain) is located on the fracture zone and is surrounded by intense hydrothermal alteration.
0.2	26.8	Elongated rhyolite intrusive in road cut on left is locally mineralized, containing specularite and pyrite. Flow banding dips about 45 to 50 degrees northeast.

0.2	27.0	Leaving intrusive rhyolite. Altered zones ahead.
0.5	27.5	Prominently altered volcanics of the andesite–latite sequence of the Alum Mountain formation. Hydrothermal alteration, very possibly solfataric in character, has profoundly altered the rocks in the vicinity of Copperas Canyon and Alum Mountain (seen later at Stop No. 12). Bleaching and variegated staining by iron oxides resulting from almost total destruction of the original minerals by hypogene and supergene processes has obscured the original structures and textures of the rocks. The nature of the alteration is poorly known, but includes extensive argillization, with halloysite (endellite) as one of the conspicuous products, pyritization, and local silicification. Alunite is prominent in the Alum Mountain zone, where it is associated with abundant alunogen and halotrichite.
0.3	27.8	Crossing Copperas Canyon. Crags of silicified volcanics on the right.
0.3	28.1	Entering northwest–trending fault zone.
0.2	28.3	Tongue of silicified rhyolite (?) on right. Road cut ahead in highly altered volcanics.
0.3	28.6	Abandoned clay pit, formerly worked by Reese Mining and Manufacturing Co. Inc. on the right. Argillized volcanics utilized in the manufacture of brick and tile in a plant at Silver City, in 1964-65.
0.6	29.2	Northwest–trending fault zone with associated intense alteration.
0.8	30.0	Northwest–trending fault zone cutting porphyritic andesite.
0.4	30.4	Fault.
0.4	30.8	Cattle guard. Fault zone. Copperas Peak at 10 o'clock (elevation over 7800 feet). Buck Hannen Mountain at 12:30 o'clock.
0.3	31.1	Tuff, sandstone, and conglomerate intercalated with andesite. Buck Hannen Mountain contains intercalated vitrophyres and fine–grained andesite flows. All of these rocks are tentatively included in the Alum Mountain formation.
0.5	31.6	Bedded tuffs dipping 17° NE. Entering small structural basin, probably a caldera about one mile in diameter.
0.4	32.0	Tuffs here dip 23° SSW as result of dip reversal across structural basin.
0.4	32.4	Center of basin.
0.6	33.0	Spectacular road cut on left exposes highly contorted flow banding in partially devitrified vitrophyre at contact with volcanic conglomerate on the western inner rim of the caldera.
0.3	33.3	STOP 12 - Time: 20 minutes - PARK ON LEFT. This point (altitude 7450 feet) provides a scenic view of the Gila Wilderness Area, the first such area designated by the U.S. Forest Service (1924), containing nearly 500,000 acres that are protected from commercial exploitation. The headwaters of the three forks of the Gila River lie within a structural and topographic basin rimmed on the west by the Mogollon Mountains, on the north by a series of isolated peaks and broad divides, on the east by the Black Range, and on the south by the Pinos Altos Range. Elevations range from a little over 4600 feet where the Gila River

debouches from the mountains on the west, to 10,892 feet on the summit of Whitewater Baldy in the Mogollon Mountains.

Exposed rocks consist of a thick sequence of Tertiary volcanics and associated intrusives, and clastic sediments derived therefrom. Below is the Alum Mountain formation of andesite flows and flow breccias, succeeded upward by dark-colored latite flows and breccias that crop out in both walls of the Gila Canyon from just below the junction of the East and West Forks southwestward and southward across the divide into the lower reaches of Sapillo Creek. The overlying Bloodgood Canyon Rhyolite ash flow tuff, visible on cliffs across the Gila, thickens rapidly from a wedge edge in the south wall of the Gila Canyon west of its junction with Sapillo Creek and southwest of this point, northward into the Diablo Range. In the Diablo Range, a thick "protrusive" mass of flow–banded rhyolite appears probably below Bloodgood Canyon Rhyolite, a segment of the ring–dike complex postulated by Elston. The exact stratigraphic relations of this unit are uncertain and it has not yet been named. Lithologically it resembles the post–Bloodgood Canyon–Jerky Mountain Rhyolite.

Locally, the Bloodgood Canyon Rhyolite is lapped on conformably by basaltic andesite flows, flow breccias, and minor pyroclastic equivalents that blanket the upper slopes of the north wall of the Gila Canyon in and about Brushy Mountain. They probably correlate with the Bearwallow Mountain Formation which caps the high peaks and eastern slopes of the Mogollon Mountains, and makes up the broad cone of Black Mountain some 17 miles to the north. Basinward, additional flows and ash flows wedge in between Bloodgood Canyon Rhyolite and Bearwallow Canyon(?) basaltic andesite.

Overlapping all of the volcanic assemblage, and locally interfingering with the late basalts, is an extensive blanket of mudstone, sandstone, and conglomerate composed of volcanic detritus, with local lenses of interbedded rhyolite tuff. This sequence constitutes the Gila Conglomerate, to which frequent reference will be made at subsequent points along today's route. The widespread distribution of the Gila Conglomerate within the structural basin of the headwaters of the Gila River reflects a characteristic relationship of the Gila River with structural, as well as topographic, basins elsewhere in southwestern New Mexico and southeastern Arizona.

The Gila Conglomerate and older rocks have been cut by high-angle faults of prevailingly northwesterly trend, paralleling the trend of the frontal faults along the western border of the Mogollon Mountains at this latitude.

0.4	33.7	Small fault in road cut on right. Just beyond the fault is a trail, on the right, to the Gila River.
0.2	33.9	Cattle guard.
0.2	34.1	Volcanic breccias and minor tuffs of Alum Mountain formation on the right.
0.2	34.3	View to west shown in panorama photo. (Figure 9).
0.5	34.8	Platy andesites in road cut. Good view across drainage basin of the upper Gila River toward Black Mountain and Beaver Points (Bearwallow Mountain(?) basalts, and andesites), a volcanic center near the center of the basin that preserves some of its original morphology. Note analogy with large lunar crater–raised walls, depressed inner floor, central peak.

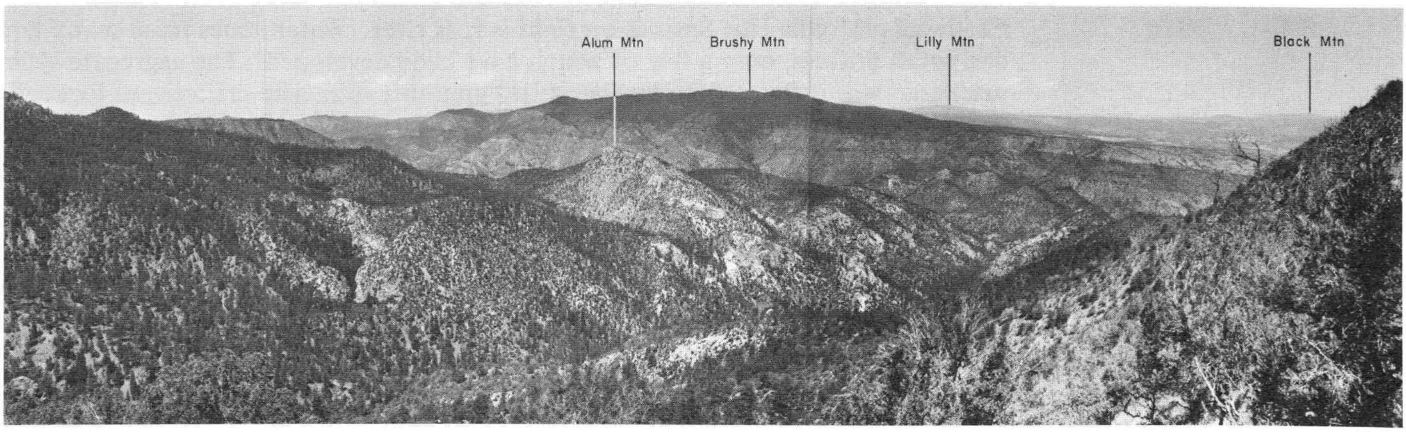

Figure 9 – Panoramic view across Gila Canyon of southern rim of Mogollon Plateau. Rocks in foreground and lower slopes of Brushy Mountain are part of the Alum Mountain Formation, hydrothermally altered. Cliff just below wooded top of Brushy Mountain consists of Bloodgood Canyon Rhyolite ash-flow tuff. Top of Brushy Mountain is Bearwallow Mountain (?) Basalt. Lilly Mountain in background consists of post-Bloodgood Canyon, pre-Bearwallow Mountain Jerky Mountains Rhyolite. All rocks dip northward into the Gila Sag, interpreted as a volcano-tectonic depression. Black Mountain (right background) is a volcano near the center of the Gila Sag. – Photographs by F.D. Trauger, U.S. Geological Survey

0.9	35.7	Cliffs of Bearwallow Mountain(?) Formation and Bloodgood Canyon Rhyolite at 12 o'clock on north side of the East Fork of the Gila River.
0.4	36.1	Unconformable contact of Gila Conglomerate on andesite of Alum Mountain formation.
0.8	36.9	Scenic view point of the Gila River on the left. Gila Conglomerate in road cuts ahead.
0.5	37.4	Cliffs of Gila Conglomerate on right; note jointing. A series of northwest–trending faults cuts the canyons of the forks of the Gila River.
0.3	37.7	Excellent exposures of the Gila Conglomerate in road cuts on left.
0.6	38.3	XSX Ranch at 3 o'clock. Basalt underlies Gila Conglomerate in canyon at 9 o'clock.
0.1	38.4	Well-rounded terrace gravels resting on Gila Conglomerate.
0.5	38.9	Basalt overlain by terrace gravels on left.
0.1	39.0	Road junction on right to Lyon's Lodge. Lyon's Lodge lies at the foot of a spectacular cliff of Bloodgood Canyon Rhyolite ash flow tuff, the only place where a really good exposure of this immense compound cooling unit is accessible by road within the Gila Basin. Unfortunately, the road is impassable by bus, although at times of low water it can easily be forded in a sedan – columnar joints, widened by weathering, hide numerous pre-historic cliff dwellings.
0.1	39.1	Bridge over Gila River at junction of East and West Forks.
0.4	39.5	Gila Conglomerate resting on basalt in road cut on left.
0.4	39.9	Cattle guard. Pinnacles of Gila Conglomerate across river on right. Major fault beyond pinnacles brings Bloodgood Canyon Rhyolite and overlying Bearwallow Mountain(?) basalt in contact with Gila.

0.1	40.0	Cattle guard. Gila Hot Springs on right across river. Water issues from many large and small orifices, only a few of which have been developed. The aggregate visible discharge was estimated to be about 100 gpm in 1962. The orifices are located in a large fault zone. Water issues at temperatures that are constant at about 147°F. Other hot springs are located in this general area, and increments of hot water are added to the river locally, by seepage, in amounts sufficient to raise the temperature of the river water by several degrees. A characteristic of the hot springs waters in this area is a relatively low content of total dissolved solids, 414 ppm for Gila Hot Springs, a high pH, up to 8.2 and relatively large amounts of fluorides and silica; some of the thermal discharge may be juvenile water.
0.3	40.3	Doc Campbell's Vacation Center (store). Bloodgood Canyon Rhyolite beyond the store. Downfaulted blocks of Gila Conglomerate overlying Bearwallow Mountain(?) basalt. Faults cross route diagonally to the left. For many years Doc acted as Superintendent of Gila Cliff Dwellings National Monument–at $1.00 a year. There was no paved road to the Monument until 1966.
0.2	40.5	Road cut. Terrace gravels overlying rhyolite tuff.
0.1	40.6	Cattle guard. County Line. Leaving Grant County, entering Catron County.
0.2	40.8	Basalt overlying Bloodgood Canyon Rhyolite. Because of hot-spring activity in this area the rocks are altered and sanidine lacks the "moonstone" irridescence.
0.2	41.0	Little Creek. Gila faulted against basalt across canyon on the right.
0.4	41.4	Cross distributary of West Fork of Gila River.
0.3	41.7	Bluffs of Gila Conglomerate on right. Faulted Gila on basalt visible through tributary canyon notch.
0.9	42.6	Cross dry wash.
0.5	43.1	Heart Bar Ranch. Now a game farm of the State Department of Game and Fish.
0.2	43.3	Fork left to Gila Cliff Dwellings. Go straight ahead, past Visitor Center.
0.1	43.4	Bridge across Gila River.
0.2	43.6	Visitors Center on right. Continue on service road closed to the general public.
0.3	43.9	Entrance to Forest Service trailer park on right.
0.1	44.0	STOP 13 - Time: 20 minutes - Looking up the Middle Fork of the Gila River at this point, one sees a basal section of dark andesite flows. About 6 miles upstream, the Bloodgood Canyon Rhyolite ash flow tuff crops out underneath this unit. Regional reconnaissance mapping by Peter J. Coney and Wolfgang E. Elston originally suggested that the andesite approximately correlates with the Last Chance Andesite of the Mogollon mining district (Ferguson, 1927) but recent work has indicated it may be younger. The notch above the layered, chocolate–colored andesite is made by thin conglomerate and a little pumiceous rhyolite tuff. Only a few feet thick at this point, this unit thickens systematically to the north and northwest.

A short distance upstream, the rhyolite tuff develops columnar joints and takes on the appearance of a poorly welded pumiceous ash flow. Good exposures of the rock can be seen along New Mexico 61 north of Beaverhead, 15 miles to the north. The unit thickens to about 400 feet on the west side of Black Mountain. It has tentatively been correlated with the Deadwood Gulch Rhyolite (Ferguson, 1927), although toward Mogollon massive, columnarly jointed zones disappear and bedded pumiceous tuff takes their place. It appears to reach its maximum thickness of around 1,000 feet in the highest part of the Mogollon Range, which we saw yesterday from Leopold Vista. The Deadwood Gulch Rhyolite has not yet been dated but it lies on older rocks with a pronounced angular conformity. The persistence of thin sediments at the base of the Deadwood Gulch Rhyolite, and the angular conformity, indicate that the Mogollon Plateau was bevelled to an area of low relief prior to its deposition. Much of the present relief developed subsequent to eruption of the Deadwood Gulch Rhyolite and even subsequent to the deposition of the Gila Conglomerate. The Gila Conglomerate not only fills part of the inner basin of the Mogollon Plateau, it also forms a structural basin with marginal dips commonly around 10° and locally as high as 30°. The differential movement between the floor and the mountainous rim of the Mogollon Plateau occurred in many stages over a long, but as yet unknown, period of time. Some stages of subsidence can clearly be correlated with eruption of major ash flow cooling units such as the Bloodgood Canyon Rhyolite and the earlier Apache Spring Quartz Latite ash flow tuff. Others, such as the post-Gila stage cannot be associated with any known ash flow. Active hot-spring activity and a Bouguer anomaly of about -30 milligals (Woolard and Joesting, 1964) show that the area is still active and has not yet reached isostatic equilibrium.

The thin conglomerate and tuff representing the southern terminus of the Deadwood Gulch Rhyolite at this stop is overlain by a hypersthene latite flow tentatively correlated with the Wall Lake Latite south of Beaverhead. Farther north, this flow is in turn overlain by olivine–bearing basalt from Black Mountain tentatively correlated with the Bearwallow Mountain formation.

0.3 44.3 STOP 14 - Time: 15 minutes - End of road. Garbage dump.

This point affords a good view of the Diablo Mountains to the west, which are made up of a huge mass of flow-banded rhyolite, so far found only in fault contact with the Bloodgood Canyon Rhyolite, interpreted as one of the inner arcuate intrusions surrounding the volcano–tectonic basin within the Mogollon Plateau. If the weather is clear, the 800-foot vertical cliffs made by Bloodgood Canyon Rhyolite ash flow along the West Fork of the Gila and Little Creek, one of its tributaries, can be seen. (Figure 10)

In the canyon of the Middle Fork, about 10 miles northwest from here (as the crow flies, not as the river winds) the Bloodgood Canyon Rhyolite dips underneath a great mass of flow-banded Jerky Mountains Rhyolite, the same age or younger than the rhyolite of the Diablo are. Incomplete field work by Peter J. Coney farther north indicates that the Jerky Mountains Rhyolite can be followed into Elk Mountain, a ridge that trends northwesterly from Black Mountain (the central volcanic peak of the Mogollon Plateau) toward the rim of Mogollon Plateau. Block faulting, including graben formation, with a northwesterly trend is prominent around Elk Mountain. As yet, no evidence has been found for resurgent doming within the Mogollon Plateau, but the Elk Mountain region suggests a possible analogy with a domes and grabens well known from the interiors of smaller cauldrons, such as Jemez (Valles), New Mexico; Timber Mountain, Nevada; and Creede, Colorado.

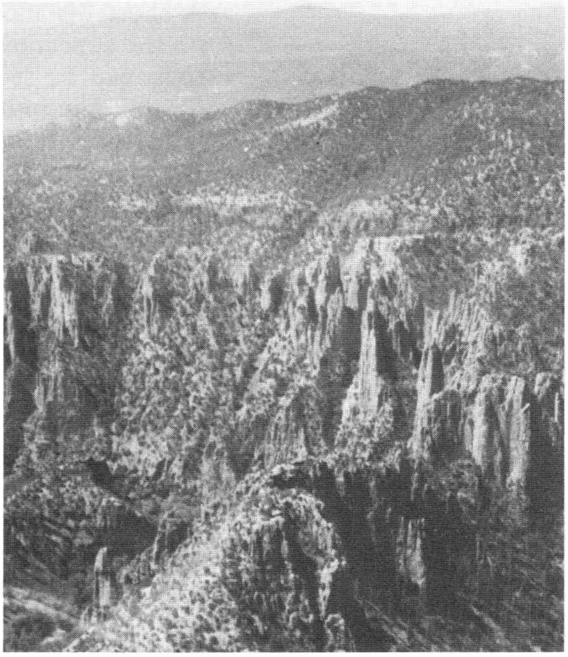

Figure 10 – Cliffs of Bloodgood Canyon Rhyolite ash flow tuff on Middle Fork of Gila River, south of Black Mountain. –Photograph by W.E. Elston, from aircraft piloted by J.F. McCauley, U.S. Geological Survey

		Because of lack of time, we will not be able to visit the Gila Cliff Dwellings. The earliest known occupation of the site was around A.D. 450. Subsequently, it became one of the centers of the Mogollon culture. It was abandoned for unknown reason around A.D. 1300.
		Turn around and return to junction of New Mexico highways 25 and 527.
18.2	62.5	Junction of New Mexico highways 527 and 25 at Sapillo Creek. TURN LEFT ON highway 25.
0.3	62.8	Lower Gila Conglomerate in road cuts on left.
0.2	63.0	Cross north-northwest-trending fault, down thrown on west side.
0.3	63.3	Dip. Cross Salt Creek. Lower Gila here dips up to 25° NE.
0.5	63.8	Bridge.
0.1	63.9	Cross Fault.
0.1	64.0	Bridge. Old meerschaum(sepiolite)mines about 1 mile up tributary canyon to the left. Sepiolite occurs in veins cutting Gila Conglomerate and is therefore late Tertiary in age. The gangue is quartz and small crystals of iceland spar calcite. The occurrence is very different from the usual association of sepiolite with serpentinite.
0.1	64.1	Cattle guard.
0.5	64.6	Site of abandoned milling town of Meerschaum across Sapillo Creek to the right. A series of northwest–trending faults repeats the upper part of the Gila Conglomerate.
0.2	64.8	Bridge. Upper Gila Conglomerate dips 10° ENE.
0.4	65.2	At 10 o'clock, basalt within lower Gila faulted against upper Gila.
0.2	65.4	Fault (as above) crosses route. Gila basalt in lower Gila faulted against upper Gila.
0.1	65.5	Bridge.
0.2	65.7	Cross wash.

0.1	65.8	Reddish sandstone in lower Gila.
0.1	65.9	Red clastic dike along fracture in Gila Conglomerate on left.
0.1	66.0	Lake Roberts ahead on the right. Sapillo Creek is impounded by a dam set on an intra–Gila basalt or basaltic andesite, the resistant outcrop of which has resulted in local constriction of the canyon walls.
0.8	66.8	Cross gulch. Upper Gila dips 20° NE.
0.4	67.2	Cross tributary wash. Entrance to campgrounds of Lake Roberts on right.
0.2	67.4	Terrace gravels, sands, and silts in road cut on the left.
0.2	67.6	Cross Sapillo Creek.
0.6	68.2	At 10 o'clock, excellent cliff exposures of Gila Conglomerate showing well developed bedding and conspicuous jointing. Canyon here follows the approximate strike of the Gila. Fault in canyon at western end of cliff.
0.4	68.6	Cross tributary wash.
1.4	70.0	Mouth of Rocky Canyon to left.
0.4	70.4	Cross Sapillo Creek channel.
0.2	70.6	Massive, less indurated facies of the upper part of Gila Conglomerate in the slopes of Skates Canyon to right.
0.2	70.8	Side road to Skates Canyon on right.
0.5	71.3	Massive Gila in cliffs at 2 o'clock.
0.5	71.8	Lower end of Gattons Park at the mouth of Terry Canyon.
0.1	71.9	Cross channel of Sapillo Creek.
0.8	72.7	Lower end of Gattons Park at 3 o'clock. A basalt flow near the top of the Gila Conglomerate on the skyline has been dated at 6.3±0.4 m.y. (Damon, personal communication) and must be close to the minimum age of the Gila Conglomerate in this area. It is nearly flat-lying and probably younger than the main stages of Basin-and-Range faulting. A basaltic andesite cut by Basin-and-Range faults and interbedded with basal Gila or pre-Gila sediments in the Gila Valley about 60 miles southwest from here gave a whole–rock age of 20.6±1.5 m.y. These ages bracket both the Gila Conglomerate and Basin-and-Range faulting.
0.4	73.1	Entering upper Gatton Park. GOS Ranch to left. Valley is carved in Gila Conglomerate.
0.1	73.2	Cattle guard.
1.9	75.1	Continental Divide. Sign gives elevation of 6500 feet, but it actually must be about 6640 feet, as indicated by a bench mark below this point. Eroded Gila to the left. Entering Mimbres River drainage. Is this really the Continental Divide? The Mimbres River drains into a closed basin of the Basin and Range Province near Deming.

0.2	75.3	Junction of New Mexico Highway 61 on left, which is a part of the Outer Loop Drive via Beaverhead (Highway 61 is an excellent access route to the inner volcano-tectonic depression of the Mogollon Plateau) Bench mark, 6599 feet. Route passes down headward drainage of West Fork of Mimbres River through a valley cut in the ubiquitous Gila Conglomerate. Warning: Don't attempt the Outer Loop Drive without lots of gas. There are no gas stations between Mimbres and Glenwood, a 6 to 8 hour drive!
1.3	76.6	Terrace gravels overlying Gila Conglomerate on spur to right.
0.4	77.0	Entrance to Camp Thunderbird on right. This is the Pilgrim Fellowship camp of the Congregational Churches.
1.1	78.1	Excellent exposures of Gila Conglomerate in cliffs to left. Note etched relief of bedding.
0.2	78.3	Road junction on left. Confluence of North, East, and West Forks of Mimbres River.
0.5	78.8	Mouth of Cottonwood Canyon on right. Dead timber on hill slopes resulted from drought of the early 1950's. Dendroclimatic studies by Schulman (1956, p. 67) indicate that the current drought, which began in New Mexico about 1943, is the most severe since that of the late 1200's.
0.4	79.2	Gaging station to left.
0.3	79.5	Mimbres Ranger Station on right. The 6.3 m.y. old basalt flow interbedded with gently northward–dipping Gila Conglomerate is visible on skyline at 10 o'clock.
0.2	79.7	Cattle guard. Leaving Gila National Forest.
1.6	81.3	SLOW! Wash-out ahead at mouth of Allie Canyon.
0.2	81.5	Cattle guard.
0.3	81.8	Terrace gravels in road cut on right overlie highly conglomeritic facies of the Gila Persistent terrace levels which become more prominent further down the Mimbres Valley.
0.4	82.2	Bridge.
0.3	82.5	Terrace gravels on Gila Conglomerate in road cut on right.
0.2	82.7	Bridge.
0.4	83.1	Entrance to Bear Canyon Lake on right. Bear Creek is perennial in part of its upper reaches; the lake is maintained by underflow.
0.2	83.3	Rhyolite ash flow tuff on the right is correlative with Caballo Blanco Rhyolite of Dwyer quadrangle, K-Ar age of 29.8±0.8 m.y. (Damon, et al., 1967). For correlation, see Figure 2, Column I in article by Elston, this guidebook. Although the Caballo Blanco Rhyolite is the youngest ash flow of the thick rhyolite section in the Black Range–Mimbres Valley–Santa Rita area, it is older than three major ash flow units that took part in development of the Mogollon

		Plateau; the Apache Springs Quartz Latite, Bloodgood Canyon Rhyolite and Deadwood Gulch Rhyolite. The Mogollon Plateau ash flow province is therefore largely younger than the volcanics to the south and the type–Datil to the north.
0.2	83.5	Bridge. Bear Canyon dam to right. Caballo Blanco Rhyolite ash flow tuff at bridge abutment. The Caballo Blanco is characterized by abundant phenocrysts of doubly terminated smoky quartz, sanidine, biotite, and sparse plagioclase. Its maximum known lateral extent is 45 miles (from the North Fork of the Mimbres to the Knight Peak graben) thickening systemetically northwestward toward a probable source in the Black Range. The maximum thickness of typical Caballo Blanco is about 350 feet. Toward the Black Range, other ash flows appear above and below, giving a total thickness of about 600 feet.
0.8	84.3	Terrace gravels abutting rhyolite tuff in road cuts on right.
0.2	84.5	Caballo Blanco on right. Fault contact of tuff with Bear Springs(?) Basalt just ahead.
0.2	84.7	Basalt on Caballo Blanco tuff on right.
0.1	84.8	Ranch house on right. Volcanics here swing westward away from the Mimbres Valley.
0.6	85.4	Mouth of Shingle Canyon on right.
0.1	85.5	Entering town of Mimbres.
0.2	85.7	Bridge.
0.3	86.0	Mimbres Post Office and store. Route from here to San Lorenzo is largely over Quaternary terrace gravels.
0.4	86.4	At 2 o'clock, trace of Mimbres fault along which Precambrian rocks and overlying Paleozoic section are faulted against Gila Conglomerate. Northwestern continuation of this fault seen earlier today at head of Cherry Creek.
0.8	87.2	Bridge. Cooks Peak at 1 o'clock. Probable continuation of Mimbres fault crosses Crooks Range to the left of Cooks Peak.
0.3	87.5	Bluffs of Gila Conglomerate at 9 o'clock. Hillsboro Peak (elevation 10,011 feet) on skyline.
1.4	88.9	Lower Paleozoic strata in cliffs to right.
1.1	90.0	Village of San Lorenzo to the left.
0.4	90.4	Junction of road to San Lorenzo on left.
0.2	90.6	EXTREME CAUTION! Junction with New Mexico Highway 90 on the left. TURN LEFT on New Mexico 90.
0.6	91.2	From 7 to 12 o'clock scarp formed of upthrown block on southwest side of Mimbres Valley fault. At 11 o'clock, lower brownish slopes are of Precambrian spotted greenstone; dark brown outcrops are of Bliss formation, note 2 ledges

marking resistant sandstone beds; ledges of gray limestone above Bliss are the early Ordovician El Paso Formation; high dark–brown cliff capping escarpment is late Ordovician Montoya limestone. At 10 o'clock on south (left) side of canyon note several down–faulted blocks capped by the Montoya cliff.

0.5 91.7 Bridge.

0.1 91.8 Fork in highway. Follow State Highway 90 on Left Fork

0.3 92.1 Bridge across Mimbres River. Tertiary consolidated gravels and unconsolidated terrace gravels ahead for the next four miles. The Tertiary gravels are identical with those we've been seeing for the past two days. However, since we have crossed the Continental Divide, some people apply the term Santa Fe Conglomerate instead of the term Gila Conglomerate. However, the Mimbres River flows neither into the Atlantic nor the Pacific, but ends in an interior basin near Deming, New Mexico. Also, the gravels are continuous, extending across the Continental Divide, from the Mimbres into the Sapillo Valley, as well as from the Mimbres Valley eastward across the southern Black Range into the Rio Grande Valley (Home of the Santa Fe Group alluvial sediments). The distinction here appears purely arbitrary. Let's leave this problem to the stratigraphers and get on with the job of worrying about ash flow.

4.0 96.1 Fault, on the left side of the highway, a sliver of Caballo Blanco Rhyolite ash-flow tuff is exposed unconformably underneath Gila (?) (Santa Fe?) Conglomerate and faulted against a basaltic andesite, probably equivalent to the Bear Springs Basalt and bracketed between the 26.6±0.8 m.y. date for the overlying Swartz Rhyolite and the 29.8±0.8 m.y. date for the underlying Caballo Blanco, (Damon, et al., 1967). It is clearly older than the post–Bloodgood Canyon basalts and basaltic andesites of the Gila Cliff Dwellings area. (Figure 11)

To the right across the valley, a depositional contact between Bear Springs Basalt and Caballo Blanco Rhyolite can be seen. About 20 feet of sandstone intervene between the two units.

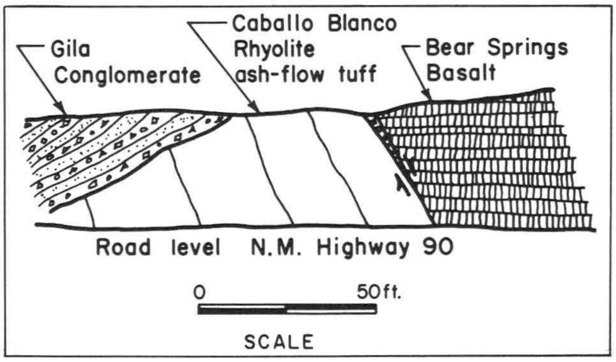

Figure 11 – Field relations at mile 96.1, (second day) from a sketch by W.E. Elston

0.3 96.4 For the next 1.9 miles, a descending section of Bear Springs Basaltic Andesite, reddish sandstone, Caballo Blanco Rhyolite Tuff and Kneeling Nun Quartz Latite ash flow tuff is exposed in low cuts on the left side of the highway. Contact relationships and thicknesses are difficult to judge because of faulting. The Kneeling Nun Quartz Latite tuff is the main objective of this part of the field trip. The road traverses what appears to be the vent area of this extensive ash flow cooling unit. Kuellmer (1954) estimated its minimum thickness at 1300 feet; its maximum thickness in the vent area is much greater but cannot be accurately measured because no base is exposed and the section may be repeated by faulting. The ash flow tuff shows rectangular jointing in some places and high–angle, closely–spaced (10 in. or less) sub–parallel jointing elsewhere along this stretch of the road. Three main phases can be recognized along the highway and a stop will be made at each:

1. Massive ash flow tuff with planar structures dipping 20 to 40 degrees southwesterly, rectangular jointing, abundant xenoliths generally less than 30 mm in size, and sparse vapor-phase cavities.

2. Xenolith or chaotic megabreccia zone, containing accidental rock fragments ranging in size up to 80 feet in length. The xenoliths may be surrounded by reaction rims of stony rhyolite. Black vitrophyre masses intimately interpenetrate both the tuff and the fragments of the xenolith zone on a large and small scale. The vitrophyres may be cut by ramifying fractures along which normal tuff material has formed. The long axes of xenoliths tend to be vertical (Elston). The rocks comprising the xenoliths are in order of decreasing abundance: (a) Andesite of the type immediately underlying the Kneeling Nun Quartz Latite. Andesite makes up approximately 90% of the xenoliths. (b) Red shale and sandstone of the Permian Abo Formation. (c) Limestone from the Pennsylvanian Magdalena Group (d) Limestone and shale from the Mississippian Lake Valley and Devonian Percha Formations. (e) Granitoid rocks. According to Kuellmer (1954), the xenolith zones extend more than 3 miles long in a north–south direction and up to half a mile wide. Within the normal ash flow tuff regional dip of planar structures is 20 to 40° SW; whereas in the xenolith zone, dips as steep as 82° have been recorded. In many places the volume of xenoliths exceeds the volume of Kneeling Nun Quartz Latite matrix.

3. A phase of massive ash flow tuff densely welded and characterized by subparallel vertical joints only inches apart and more widely spaced southwest-dipping joints.

Later this afternoon, after leaving the Black Range, we will see, in the Bayard area 20 miles to the southwest, the Kneeling Nun Quartz Latite as it appears away from the vent area. There it is a typical columnar–jointed quartz latite ash flow compound cooling unit with a pumiceous rhyolitic base.

1.9 98.3 Xenolith zone.

0.3 98.6 "Normal" Kneeling Nun, lacking large xenoliths.

0.4 99.0 Enter Gila National Forest.

0.7 99.7 STOP 15 - Time: 20 minutes - Kneeling Nun Lookout. Examine massive phase of Kneeling Nun Quartz Latite tuff. No large xenoliths are present. The rock is a grayish–pink welded tuff containing abundant fragmented phenocrysts of sanidine, quartz, and biotite, all of which are 2 mm and less in size. Sparse, small (2 in. and less) xenoliths of andesitic material and several granitoid xenoliths (14 in. and less long) may be seen. The lighter–colored lenses forming a planar structure are abundant, as well as less obvious cognate (?) fragments, blocky and ellipsoidal in shape, with coarser phenocrysts (to 5 mm).

When this unit was mapped in 1950, published descriptions of welded tuffs emphasized properties demonstrating their air-borne nature. Many of the properties of the Kneeling Nun tuff in this vicinity such as the lack of obvious pumice fragments, the abundance of crystal fragments (up to 69%), the near lack of bedding or sorting, linear gas cavities, the uniform regional dip of planar structures coupled with great irregularities within the xenolith zone, irregular vitrophyre masses, and closely–spaced sub–parallel vertical joints seemed to deviate from those emphasized for ash falls. Today it is recognized on the basis of work by Ross and R.L.

Smith, Boyd and others, that proximity to an eruptive center and great thicknesses of particulate ash flows can produce the intensity of welding and crystallization found in this area. Furthermore, subsequent work by Kuellmer, Elston, Giles and others demonstrates the continuity of this rock with distant Kneeling Nun welded tuff areas.

The layered, columnarly–jointed part of the Kneeling Nun Quartz Latite can be seen in the distance. The formation was named after a single weathered-out column that overlooks the Chino Mine at Santa Rita.

The moonstone–sanidine pegmatite of Grant County, New Mexico, described briefly by Kelley and Branson (1947) and Kuellmer (1954, p. 79-81) is found about three miles north–northwesterly from this stop. The pegmatites are not zoned, contain sanidine crystals as much as 24 inches long, large dipyramidal quartz and biotite. The fracture–filling pegmatitic lenses are within a miarolitic porous rhyolite porphyry injected into the Kneeling Nun Tuff. Mineral similarities; intimate spatial distribution of the pegmatite, porphyry, and tuff; lack of zoning; porous nature of the porphyry matrix; and geographic proximity to the xenolith zones suggest a vapor–rich late–stage fumarolic and intrusive origin, consanguineous with the Kneeling Nun tuff.

0.7 100.4 Numerous exposures of xenolithic rock for the next mile. In places the exposures in road cuts approach absolute chaos.

1.0 101.4 Cattle guard. STOP 16 - Time: 20 minutes - Examine xenoliths of various lithologic types and reaction rims. A partial description of the STOP is found under item 2 of the 96.4 mileage entry. Except for the road cuts, the mapped boundaries between xenolith zones and massive Kneeling Nun tuff are somewhat arbitrary. The tuff here is petrographically like that of the previous stop except for fresh brown biotite which shows less or no crinkling and no hematitic rims. Many of the contacts between tuff, xenoliths, or vitrophyre are marked by a slightly browner or orange–brown rim of a stony tuff which contains lenticular planar structures. The planar structures on a stony rim about a xenolith may be parallel to the xenolith contact. Phenocrysts in the rims are identical to those in the tuff proper. The rim matrix is cryptocrystalline with radial or spherulitic finely intergrown fibers radiating outward from crystal fragments and very fine dendrite–shaped intergrown masses. (Figure 12a, Figure 12b)

The xenoliths of andesitic volcanic rocks differ only slightly from the original rock. The matrix is more opaque (ferric oxides), contains small secondary spheroidal masses of intergrown quartz, sericite, and zeolites, thin veins of quartz and fresh biotite, and small sericite grains.

The rims are enriched in Si and K, and lower in Na relative to the vitrophyres. This shift in composition makes the stony rims more rhyolitic than the vitrophyre. This crystallization is believed to have been facilitated by both volatiles contained in the xenoliths and volcanic gases.

0.1 101.5 Massive Kneeling Nun without large xenoliths for next 0.3 miles. Shortly after the road starts down hill a large sugarloaf–like spire of rhyolite porphyry may be seen at about 2 o'clock, looking down into the valley. The porphyry is a small plug intrusive into the Kneeling Nun tuff and consists of white sanidine phenocrysts (to 2 + cm in length) and quartz dipyramids set in a white xenomorphic–granular, friable matrix. The intrusive resembles the porphyry of the Rabb Canyon pegmatite area except that the sanidine has a white silken luster instead of a blue moonstone chatoyance.

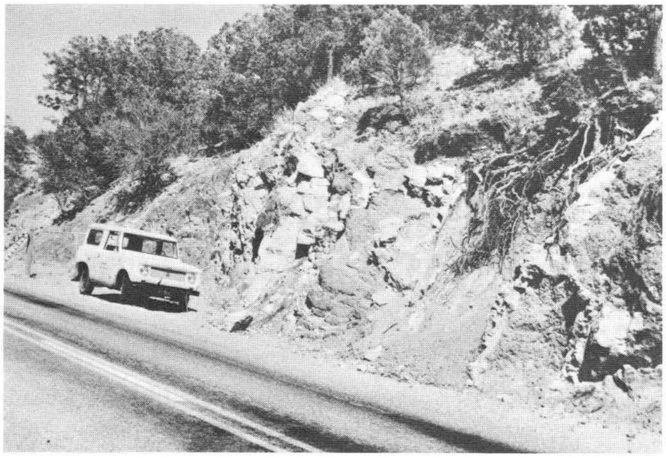

Figure 12a – Xenolith zone in Kneeling Nun Quartz Latite. The ramifying light-colored bands are Kneeling Nun; the grey areas are xenoliths, consisting of andesite in the foreground. The large xenolith directly behind the fence at the back of the vehicle is Paleozoic sedimentary rock, largely converted to hornfels. Its bedding is vertical.

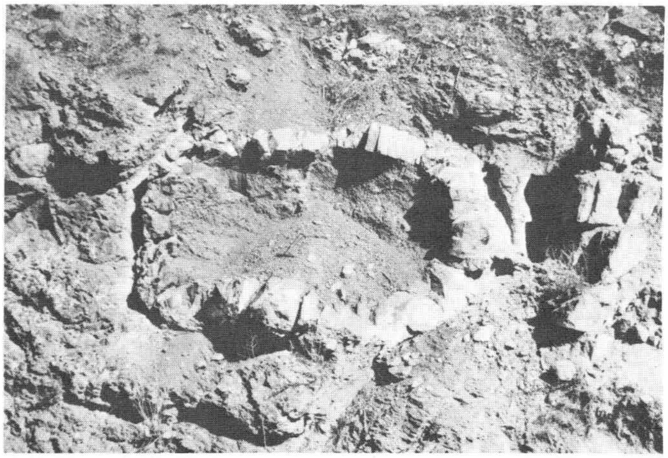

Figure 12b – Closeup of single andesite xenolith in Kneeling Nun Quartz Latite, showing reaction rim, and vitrophyre below xenolith. Note hammer for scale. –Photographs by W.E. Elston

0.3	101.8	Narrow xenolith zone, massive Kneeling Nun beyond.
0.8	102.6	Bridge across Gallinas Creek. Enter "Devil's Backbone Geological Area" (no kidding, that's what the Forest Service sign says). The Devil's Backbone is a deep gorge with precipitous cliffs made up of the phase of Kneeling Nun Quartz Latite tuff characterized by closely–spaced sub–parallel vertical joints. The matrix of the rock locally takes on a glassy appearance.
0.6	103.2	Bridge across Gallinas Creek. STOP 17 - Time: 20 minutes - Examine closely–fractured phase of massive Kneeling Nun Quartz Latite tuff. The rock is a crystal–rich tuff with abundant phenocrysts of sanidine, quartz, and biotite (1–2 mm. size) and abundant fragments of andesitic(?) volcanic rocks (10 cm and less). Toward the west end of the gorge, there are sparse blocks of andesite (and andesite–lined cavities) up to about 15 feet in diameter. The closely–spaced joints trend north–south, and range from vertical to 70 degrees dip. At the east end of the gorge, a second set of fractures marked by rubble zones, hematite–stained joints, and/or a gash–vein type of bending of the vertical joints strikes about N20W, and dips 48° W. At the west end of the gorge (mileage: 102.6) rubble zones and less prominent joints trend about N50W and dip 28° NE. (Figure 13)

Exactly 5.5 and 5.6 miles east of the bridge at this stop (0.4 and 0.6 miles westward from Emory Pass) are dikes of a green vitrophyre intruded into the andesitic volcanic rocks. The green vitrophyres are slightly to considerably devitrified along the contact and contain 10% phenocrysts of sanidine, quartz, and granophyric intergrowths. The only other occurrence of granophyric phenocrysts, in a glassy matrix, of which Kuellmer is aware, is the African rift valleys. No time for this trip to go there. If you have a chance visit these outcrops sometime. The glass is clearly intrusive.

		Turn around and return to San Lorenzo.
12.6	115.8	Fork of New Mexico Highways 61 and 90. Take Highway 90, left fork.
0.3	116.1	Mimbres fault; Mimbres valley fill on east side is in fault contact with Precambrian on west side.
0.3	116.4	Top of Precambrian greenstone, base of Bliss Sandstone. The exposed section was measured and made available by Messrs. Robert M. Hernon and William R. Jones.

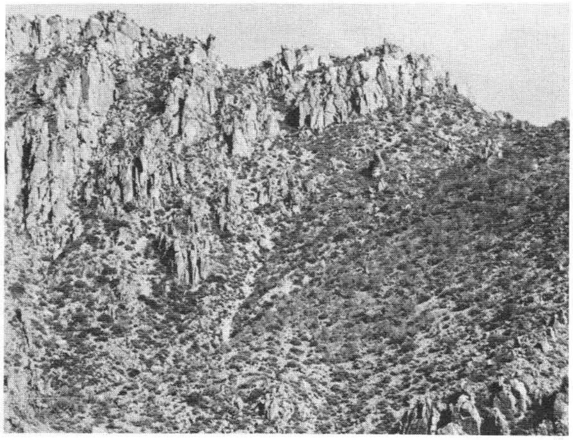

Figure 13 – Closely-jointed xenolith-poor Kneeling Nun in Devil's Backbone area. –Photograph by W.E. Elston

Ordovician:	
Montoya Group	103 + feet
Aleman Formation – cherty and dolomitic limestone	70 ± feet
Upham Dolomite – cliff	21 feet
Cable Canyon Sandstone	12 feet
El Paso Group	559 feet
Bat Cave Formation – limestone with dolomite and sandstone near top: cherty beds, siliceous laminae, scattered fossils	400 feet
Sierrite Limestone	159 feet
Cambrian:	
Bliss Sandstone – shaly and sandy dolomite, shale, conglomerate, sandstone, abundant glauconite	146 feet
Precambrian – spotted greenstone	

0.1	116.5	Reddish–brown, cross–bedded sandstone of Bliss in road cut on right.
0.15	116.65	Top of Bliss Sandstone, base of El Paso limestone, 50 to 100 feet above highway. High ledge on north (right) side of road is chert horizon in lower part of Montoya.
0.15	116.8	Large fault crosses road. Paleozoic section downdropped on south (left) side of road. Fault passes down canyon to the east. At 9 o'clock Montoya "limestone."
0.3	117.1	At 11 o'clock thick sill of quartz monzonite porphyry lies above Montoya; base of sill crosses road at 93.7 miles.
0.2	117.3	Silurian Fusselman Dolomite on right.
0.1	117.4	Sill.
0.5	117.9	Bridge. Late Devonian Percha Shale on left showing flat dip to west.
0.1	118.0	Rhyolite intrusive (soda rhyolite of Lasky) mixed with Percha Shale on left.

0.8	119.1	Bridge.
0.3	119.4	Breccia border between Percha Shale and rhyolite plug.
0.1	119.5	Top of Percha Shale, base of Mississippian Lake Valley Limestone to left.
0.3	119.8	Bridge. Percha Shale in road cuts. At 2 o'clock distant ledge is lower cliff–forming member of the Lake Valley which overlies the Percha Shale. Ten degrees westerly dip. Valley underlain by Percha Shale.
0.5	120.3	Top of Percha Shale, base of Lake Valley Limestone to right of road.
0.2	120.5	Bridge. Beyond bridge (west) is crinoidal member of the Lake Valley Limestone, locally called Hanover Limestone, the chief host rock for zinc ores of Central Mining District. Large white chert nodules and crinoidal composition are distinguishing features; at the south end of the Hanover–Fierro Stock contact, metasomatically replaced by almost pure andradite garnet. Base of Pennsylvanian Oswaldo Limestone, basal parting shale (±15 feet) on south (left) side of road; note chert nodules in limestone are black.
0.3	120.8	Base of thick later quartz diorite sill; locally, because of its persistent stratigraphic position called the "Marker Sill."
0.3	121.1	Top of Marker Sill. Contact dips gently southwest. Side road to left. At 9 to 11 o'clock, prominent cliff is Kneeling Nun Quartz Latite welded ash flow tuff.
0.5	121.6	Cross contact of Oswaldo Limestone into Syrena Limestone, Syrena has 40-foot shale bed at base (both Pennsylvanian).
0.9	122.5	Dip Sign: Syrena–Oswaldo contact crosses road diagonally. For about one mile road is on Oswaldo Limestone with gentle southwest dip. Bench Mark U-126 on right side of road, center of dip. Elevation 6,602.483 feet.
0.4	122.9	Cattle guard. Ridge on left is capped by Beartooth Quartzite (Upper? Cretaceous, approximately Dakota–equivalent). Dips gently south.
0.2	123.1	At 10 o'clock, Chino Pit (copper), Kennecott Copper Corporation. Trail on right side of highway follows latite dike. Dike cutting Oswaldo Limestone. (Figure 14)
0.2	123.6	Road to right leads to Georgetown. This was an active silver mining district around the turn of the century. Several (inactive) mines, a few deer, and a couple of claim jumpers are all that one may find there today.
0.1	123.7	Road cut in southeast–dipping, severely altered Syrena Limestone.
0.4	124.1	At 10 o'clock, head frame of Oswaldo No. 2, zinc operation of Kennecott Copper Corporation. Mine workings mainly in Oswaldo and Hanover limestones, 300 to 400 feet below collar.
0.2	124.3	Large north–trending granodiorite dikes cross road, altered Syrena Limestone at surface.
0.1	124.4	Magnetite lenses mined from shallow open pit on right side of road in altered Syrena.

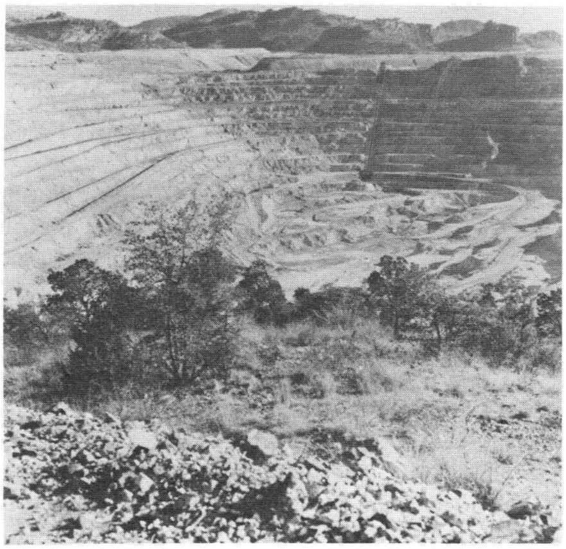

Figure 14 – Chino copper mine of Kennecott Copper Corporation – largest mine in New Mexico. Note skip—haulage system on far wall. Hills in background are of Tertiary volcanic rocks (mainly Kneeling Nun Quartz Latite ash-flow tuff) which unconformably overlie the mineralized Laramide porphyry body. Much of the oxidation and secondary enrichment is pre—volcanic, and preserved from erosion by the volcanic rocks that once blanketed the ore body. —Photograph by W.E. Elston

0.1	124.5	Santa Rita Store (abandoned) and Post Office. Road intersection. Kearney mine of American Zinc headframe at 1 to 2 o'clock.
0.4	124.9	At 11 o'clock, head frame of Princess Shaft of U.S. Mining, Smelting and Refining Company.
0.1	125.0	Side road on right to Kearney—Pewabic Zinc Mines of Empire (New Jersey) Zinc Company. (Road crosses Kearney breccia pipe 0.1 mile from main highway).
0.05	125.05	Altered Syrena and Oswaldo Limestones intruded by granodiorite dikes. One of the better zinc producing structures of the district.
0.05	125.1	Contact of Wimsattville basin fill and Oswaldo Limestone. Tertiary Wimsattville Formation underlies the bowl-shaped area ahead. Bull Hill at 2 o'clock is a later Tertiary low—quartz plug which intruded the Wimsattsville Formation. Igneous rock is almost completely altered to clay; a few veinleta of alunite and sparse pyrite have been noted in the mass.
0.2	125.3	Beautiful bedding in tailings form New Jersey Zinc Company mill. The present is not always the key to the past.
0.1	125.4	At 2 o'clock, Bull Hill.
0.2	125.6	Railroad crossing; Hanover Wash. New Jersey Zinc Company Mines at 3 o'clock. Railroad cut on left is Wimsattville Formation dipping 20-30° S. Latite dikes also exposed in cut. The Wimsattville basin fill has remarkably steep dip (up to vertical to overturned) at the edge of the basin; dips flatten toward the center. Rocks are massive fanglomerate at base, finer—grained and bedded toward top. Roughly circular basin has been ascribed to anything for meteorite impact to rapid subsidence accompanying formation of Hanover contact—metasomatic zinc deposit. Junction of New Mexico highway 90 and New Mexico 356. Turn left on New Mexico 356.
0.4	126.0	Edge of Wimsattville Basin.
0.1	126.1	Escarpment of Beartooth Quartzite on left cross drainage.

0.7	126.8	Curves in road. Exposures of Colorado Shale intruded by dike swarm.
0.4	127.2	Kneeling Nun Quartz Latite forms cliff from 8:30 to 12.
0.5	127.7	Road cuts in Colorado Shale with dikes and sills.
0.7	128.4	City limits of Vanadium. Turn left, cross railroad tracks.
0.2	128.6	Cobre loading point. Kneeling Nun Quartz Latite above Cretaceous sediments at 3 o'clock.
0.2	128.8	Road forks. Turn right, cross railroad tracks and bridge across Bayard Canyon.
0.1	128.9	Crossroad. Keep going straight ahead. The valley ahead of us follows the trace of the mineralized Groundhog Fault. The Groundhog Mine, owned by Asarco, is one of the leading producers of lead and zinc in New Mexico.
0.1	129.0	Road forks. Take right fork on dirt road. Left fork leads to No. 1 Shaft of Groundhog Mine.
0.2	129.2	STOP 18 - Time: 30 minutes - Park at former main office Asarco Groundhog Mine. On foot, follow lower road through gate, for about 1/8 mile, cross Bayard Canyon and follow left fork of road (the better of the two forks, it leads to Groundhog No. 5 shaft up Lucky Bill Canyon to second gate for another 1/8 mile. The base of the Kneeling Nun Quartz Latite is well exposed to the right. The basal Kneeling Nun is a slopeforming, poorly consolidated rhyolite overlain by welded cliff–forming rock. About 100 feet above the base, the rock is a quartz latite. The change in composition is gradational and independent of the degree of welding. Above the basal 100 feet, the next 500 feet are a nearly homogeneous quartz latite. At the top of the section rock becomes slightly more rhyolitic.

ASH-FLOW TUFFS OF THE COBRE MOUNTAINS

By

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Lucky Bill Canyon extends southeast for about 2 miles into the Cobre Mountains. The pinkish-white-to-red cliffs and slopes that surround all sides are of the Kneeling Nun Quartz Latite, a partially-to-densely welded crystal-rich ash-flow tuff. The valley floor is here on a small window through the Kneeling Nun into the underlying tuffaceous sandstones of the Sugarlump Tuff. Looking up the canyon, at 10 o'clock is the headframe of American Smelting's Groundhog No. 5 shaft; about 2 miles directly over the hill from the shaft is the south rim of Kennecott's Chino pit. The peaks in the background toward the head of the canyon, from 10:30 to 2 o'clock, are capped by scattered patches of Bear Springs Basalt. Underlying rocks are in descending order: cliffs of Caballo Blanco Rhyolite ash-flow tuff, Rustler Canyon Basalt, Box Canyon Rhyolite; slopes of thin local clastics and vitrophyre possibly equivalent to the Mimbres Peak Formation, the thick upper partially welded zone of the Kneeling Nun Quartz Latite ash-flow tuff (see

Figure 15). At 4 o'clock is an excellent exposure of the Kneeling Nun/Sugarlump contact (Figure 16).

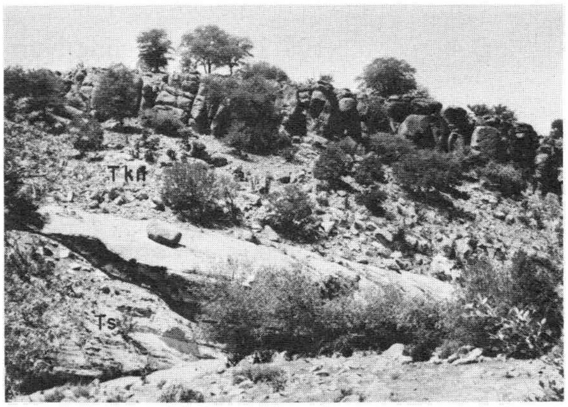

Figure 15 – Base of Kneeling Nun Quartz Latite ash-flow tuff, near mouth of Lucky Bill Canyon. Ts–Sugarlump Tuff, Tkn–Kneeling Nun Quartz Latite. Note darkening of color and increase in degree of welding upward in the Kneeling Nun Quartz Latite. –Photograph by W.E. Elston

The Cobre Mountains consist of three broadly defined, predominantly volcanic sequences: a lower and very thick andesite and latite (Rubio Peak Formation), a middle pyroclastic sequence with related flows and clastics, and the upper andesites and basalts. The Caballo Blanco and Sugarlump are the upper and lower members, respectively, of the middle pyroclastic sequence. Regional homoclinal dips in the Cobre Mountains are gently to the southwest; in the northern part of the range the average is around 10°. The strata in this area are also broken by a series of small north–northeast trending normal faults. Relative displacements vary, but the cumulative effect has been one of a progressive downthrow to the west. The Groundhog No. 5 shaft is on a small horst bounded by several of these faults cutting across the canyon. The pattern of downthrow sharply terminates at the mouth of Lucky Bill Canyon; San Jose Mountain (opposite Bayard Canyon) is on a large uplifted block that forms the footwall of the northeast trending Groundhog Fault, a major structural feature of the area. Because of faulting, the middle pyroclastic sequence is best preserved in the northwestern part of the range, and is admirably exposed in Lucky Bill Canyon.

The dominant exposures in the canyon are of the compound cooling unit of the Kneeling Nun, which in this area is around 420' thick. Five distinct and genetically related flow units have been recognized in the sheet; the upper four comprise the top 150'. The basal flow unit (270' thick) is a simply zoned cooling unit. It has a partially welded top and base (the grayish-pink slope formers) and a thick middle zone of dense welding (the bold red cliffs). Partings have been recognized in this flow unit, but they are scattered and discontinuous. The variations in welding are gradational and this part of the sheet has been interpreted as the result of a continuous eruptive episode.

Phenocrysts in the unit range from 25 to 60%, and consists of quartz, sanidine, sodic plagioclase, biotite, opaque oxides, and trace amounts of sphene, zircon, hornblende, and clinopyroxene. The groundmass has been completely crystallized (devitrified), and there is a well-developed vapor-phase zone. The unit shows strong vertical compositional zoning that ranges from a basal quartz latite crystal-vitric tuff to an overlying latite crystal tuff. Variations may be abrupt but they are systematic, and consist of an upward increase in the number and size of phenocrysts, and in the proportion of ferromagnesian and plagioclase phenocrysts, with an accompanying decrease in the amount of quartz and the alkali feldspar/plagioclase ratio. Examples of such variation in the Lucky Bill Canyon section are the upward decrease in quartz from 36 to 5% (of phenocrysts) and of the alkali feldspar/plagioclase ratio from 2.0 to 0.25. Detailed studies have been carried out on major

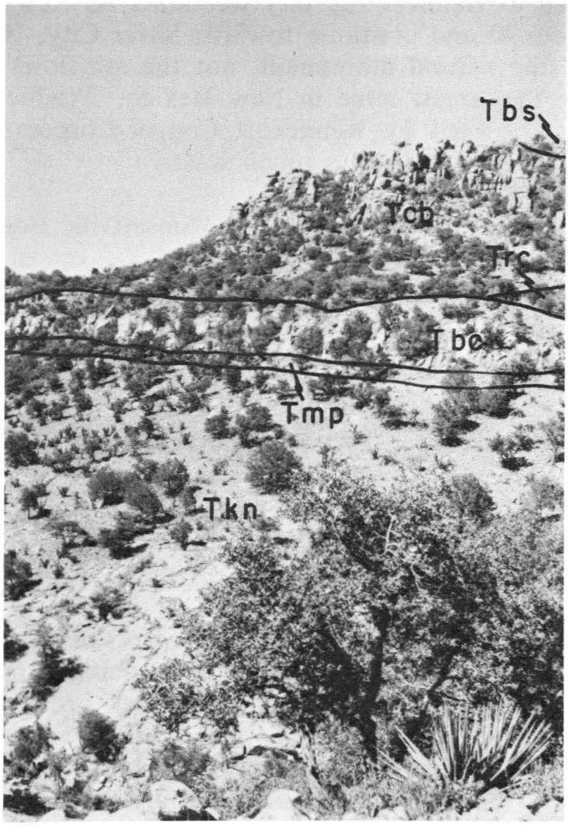

Figure 16 – Upper part of Tertiary rhyolite section in Cobre Mountains, head of Lucky Bill Canyon. Tkn–Poorly welded top of Kneeling Nun Quartz Latite ash-flow tuff; Tmp–Mimbres Peak Formation (vitrophyre and sandstone); Tbc–Box Canyon Rhyolite ash-flow tuff; Trc–Rustler Canyon Basalt; Tcb–Caballo Blanco Rhyolite ash-flow tuff; Tbs–Bear Springs Basalt. –Photograph by W.E. Elston

and trace elements in biotites and their matrix. The chemical data substantiates and complements the modal indications of a systematic vertical compositional zonation. Examples for biotite are the upward increase in Cu, Sr, Ba, and Ca, and a decrease in Rb and Mn.

All of the data is consistent with the explanation of an upward gradation and differentiation of progressively silicic and less crystal-rich melt within the pre-eruptive Kneeling Nun magma chamber. The rhyolitic material in the upper part of the chamber was erupted first, followed by more latitic material from increasingly lower levels. Eruption and deposition were more or less successive and continuous, at least for the lower two-thirds of the sheet (basal flow unit) – effectively resulting in an inverted replica of the compositionally zoned magma.

In the writer's interpretation, the initial compositional zoning in the Kneeling Nun magma resulted from protracted crystal settling concurrent with upward volatile (and alkali?) migration or transfer. The migration rate of water and other volatiles (whether in solution or as a separate phase) was not very high, and crystallization was well advanced prior to any upper level saturation. Further crystallization in this upper level – corresponding to the basal parts of the sheet – thus took place in a melt that had been previously zoned by crystal fractionation. Late-stage crystallization was simultaneous throughout the chamber, but at differing rates due to the vertical upward decrease of crystallization temperatures. The basal one-third of the sheet (for a distance of 60' to 80' above the Kneeling Nun – Sugarlump contact) represents crystal and water-rich residual silicate-melt equilibrium. The upper two-thirds (or so) of the unit represent lower-level magma that was in part crystal cumulate, and had in part crystallized more completely.

The Caballo Blanco Rhyolite which is compositionally zoned similarly to the Kneeling Nun (Basal rhyolite to capping quartz latite), has also been studied in detail. The general petrogenesis is identical to that of the Kneeling Nun.

0.2 129.2 STOP 18 (cont.)
Return to bus.

3.6	133.8	Return to Hanover the way we came, via New Mexico 356. Turn left on New Mexico 90 and continue towards Silver City. On the way, note the Kneeling Nun (the natural monument, not the ash flow) and the dumps from the Chino Mine, the largest mine in New Mexico. Production from this porphyry copper deposit, owned by Kennecott Copper Corporation, is 22,000 tons per day of ore and about twice as much waste.
0.4	133.2	Cattle guard. Western edge of Wimsattville Formation.
0.2	133.4	Road cut parallels Tertiary dikes; Oswaldo Limestone in walls of cut.
0.2	133.6	Road crosses quartzose dike.
0.05	133.65	Road crosses later Tertiary quartzose dike, 30 feet wide.
0.25	133.9	At 3 o'clock Humbolt Mountain is capped by Beartooth Quartzite, which is underlain by Abo Sandstone (Permian) and Syrena Limestone (Pennsylvanian). Outcrops on both sides of road are of the Oswaldo Formation.
0.8	134.7	Edge of Copper Flat stock in contact with the Oswaldo Formation which is here tightly folded into series of anticlines and synclines concentric with the stock margin. Clay pit in altered stock on left side of road. Idle Copper Flat mines from 1 to 2 o'clock. Road crosses eastern margin of Copper Flat stock, the main part of which underlies the shallow basin on the right side of the road. Oswaldo Formation is domed, dipping away from the intrusive at about 35° on the left side of the road.
0.3	135.0	Southern contact of stock with the Oswaldo Formation.
0.1	135.1	Cross top of Oswaldo Formation into the Syrena Limestone.
0.1	135.2	Historic marker says: "Kneeling Nun, 3 miles (to east). Most famous of many historic landmarks in the Black Range country is the Kneeling Nun, so named for its resemblance to a nun kneeling in prayer before a great altar. Many legends have grown up around the giant monolith, which rests near the summit of the Santa Rita range." Both the nun and the altar are quartz latite welded tuffs. All "legends" concerning the Kneeling Nun are of recent origin; G. K. Gilbert (1875) referred to the landmark as the Kneeling Jesus!
0.2	135.4	Road on dip slope of Syrena. 11 o'clock in middle distance is Lone Mountain. 12 o'clock is the Big and Little Burro Mountains. The Silver City Range is at 2 o'clock on the horizon and the Pinos Altos Range at 3:30 and 5 o'clock.
0.4	135.8	Syrena Formation in road cut.
0.2	136.0	Left side of road, Syrena underlies Beartooth Quartzite; Abo missing. The unconformity at the base of the Beartooth Quartzite accounts for the progressive cutting out of Paleozoic formations toward the west. In the Big Burro Mountains the Beartooth Quartzite lies on Precambrian.
0.1	136.1	Top of Beartooth Quartzite.
0.3	136.4	Sandstone and shale of the Colorado Formation in right road cut dips 10° SW.

0.1	136.5	Road curves to right. Extension of St. Helena, Eighty-eight, and Peerless No. 2 vein follows highway on right side to the northeast for about 0.5 mile. Vein dips 70° E; it is in later quartz diorite sill.
0.1	137.2	At 2 o'clock is Peerless Mine (inactive), most westerly mine of the Central Mining District. Mine is in a wide belt of narrow fissures which strike north–northeast through the sill and which contain quartz, pyrite, gold, and some lead and zinc sulfides.
0.1	137.3	Road cut in later quartz diorite sill.
0.2	137.8	Side road. Fort Bayard on right; Central to left. All outcrops are the later quartz diorite sill.
0.2	137.5	Turn right on U.S. Highway 180 to Silver City, New Mexico.
0.35	138.15	Later quartz diorite sill or laccolith. Contact dips gently west. The sill is 2000 to 3000 feet thick and underlies a large area on both sides of the road for about a mile east and west from this point. The town of Central and the Fort Bayard Hospital are on this sill.
0.25	138.4	Contact of the Colorado Formation and later quartz diorite sill.
0.05	138.45	At 3 o'clock, 200 feet from highway, light colored rocky hill is outcrop of rhyolite porphyry plug. Large sanidine crystals occur in this plug. North trending fault crosses road in valley, with downdropped block on west side.
0.25	138.7	At 9 o'clock from road edge to top of hill is white tuffaceous sand and rhyolite crystal tuff.
0.3	139.0	Road cut in shale and sandstone of the Colorado Formation dipping gently eastward.
0.35	139.35	Lone Mountain at 9 o'clock.
0.4	139.75	Good exposure in road cut of sandstone and black fissile shale of the Colorado Formation intruded by dikes and sill of basic dike complex.
0.25	140.0	Dikes in Colorado Formation on right. Arenas Valley ahead.
0.6	140.6	Drive-in theater on right.
0.5	141.1	Colorado Formation with dikes.
0.3	141.4	Dike complex on left (south) side of road.
0.55	141.95	Side road to right.
0.1	142.05	The contact between the Colorado Formation and the overlying andesite breccia is on the north (right) side of the highway. The andesite breccia underlies the terrain from the near highway to the foot of the Pinos Altos Range, and consists of subhorizontal andesite, rhyolite tuff and basaltic andesite. South (left) of the highway the Colorado Formation extends for 1 to 2 miles, where it is overlapped by the Gila Conglomerate (Pliocene). Isolated patches of the andesite breccia occur south of the highway. Dike complex with small inclusions of

		Colorado Formation next 0.6 miles. This is common in the Fort Bayard quadrangle.
0.55	142.6	Highway crosses Maud Canyon.
0.6	143.2	Dikes in Colorado Formation for the next 0.8 miles.
0.8	144.0	At 2 o'clock, Bear Mountain; at 3 o'clock, Gomez Peak, cone-shaped is a quartz monzonite plug; at 4 o'clock Pinos Altos Mountain; zinc-lead limestone replacement deposits are on west side of the highest peak.
		STOP AT HOLIDAY INN.

THIRD DAY, WEDNESDAY, APRIL 10

Leaders: Paul E. Damon, Wolfgang E. Elston, Darwin Marjaniemi and Evans B. Mayo. (We are indebted to the New Mexico Geological Society and to field trip leaders J. W. Hawley, F. E. Kottlowski, F. D. Trauger and T. A. Netelbeek for permission to use portions of the road log for their Sixteenth Field Conference).

Driving Distance: 196 miles
Logged Distance: 283.9 miles
Starting Time: 8:00 A.M.
Assembly Point: Holiday Inn Motel

GENERAL STATEMENT

The third day's route leads southward from Silver City. Crossing the Little Burro, Big Burro, and South Burro (Gold) Mountains, the route will be near the Boston Hill, Tyrone, White Signal, and Gold Hill mining districts. Near Silver City, lower Paleozoic strata crop out, but most of the road cuts the rest of the way to Lordsburg are in Gila Conglomerate, Precambrian units, and Tertiary volcanic rocks.

South of Lordsburg the Pyramid Mountains, made up of Cretaceous and Tertiary igneous rocks, are the site of the Lordsburg mining district, where copper-silver-gold ores are being mined today. Skirting the north edge of the Pyramids, the route leads southwestward across South Alkali Flat in the intermontane Animas Valley—a relic of Pleistocene Lake Animas.

Near the New Mexico-Arizona border the road crosses the Peloncillo Mountains at Steins Pass, then trends west-northwest south of the volcanic Vanar Hills and north of the complex Dos Cabezas Range (See accompanying paper by Rolfe Erickson). At Willcox the trip proceeds in a southeast direction past Wisconsin age Lake Cochise (Willcox Playa). The route crosses old beach ridges and then follows the southwest flank of the Dos Cabezas to the Chiricahua National Monument where there will be several stops to see the extensive ash flow sheet, the Rhyolite Canyon formation (See paper by Darwin Marjaniemi).

On the return trip a stop will be made to see the Laramide Texas Canyon Granite pluton which has intruded Cretaceous sediments in the Little Dragoon Mountains. The road (U.S. Highway 101) then continues in a eastward direction across the valley of the San Pedro River through road cuts in the Pliocene-early Pleistocene Benson Beds. After passing through the city of Benson, the route proceeds in a northwesterly direction through outcrops of Cretaceous sediments and the Pantano beds of Oligocene-Miocene age. Dating of interbedded lavas and ash flows has demonstrated that this thick accumulation of sediments varying from fine grained lacustrine beds to very coarse fanglomeratic deposits accumulated primarily during Oligocene and Miocene time. Overlying Plio-Pleistocene sediments are essentially flat-lying in contrast to the tilted earlier Cenozoic deposits.

Segmental Mileage	**Cumulative Mileage**	
0.0	0.0	Intersection of Broadway and Copper in front of Grant County Courthouse. Cuts in the hillside behind the courthouse are in the Silver City quartz monzonite porphyry stock. Murals on walls of courthouse foyer were painted by Peter Hurd as a WPA project.
0.2	0.2	West contact of Silver City stock crosses road. Outcrops at right are on dip slope of Fusselman Dolomite, which is 75 feet thick and highly altered.
0.1	0.3	Outcrops of Percha Shale in road cuts. Silver City stock forms inconspicuous outcrops to the left. On the right, a narrow dike of diorite porphyry parallels road near fence. Boston Hill iron-manganese deposits at right have shipped about 1.5 million tons of ore averaging 10 to 35% Mn and 26 to 46% Fe to Pueblo Colorado; current production is 20,000 to 40,000 tons per year.

0.55	0.85	At 3 o'clock north end of cemetery; side road to manganese dump. Silver City stock crops out on ridge at 9 o'clock.
0.20	1.05	Side road on left to Scott Park, airport, and Whitewater.
0.25	1.30	At 12 o'clock, Big Burro Mountains in distance. Road cuts in Gila Conglomerate composed mainly of fragments of Silver City stock. This fairly well consolidated rock is in the Lower Gila.
0.05	1.35	At 3 o'clock, additional outcrops of Lower Gila in gully on left.
0.1	1.45	Approximate trace of Treasure Mountain fault zone, a major northwest structure that borders part of the Silver City Range. This zone may continue along the west front of the Lone Mountain uplift, approximately through Apache Tejo and Faywood Hot Springs, and along the southwest side of the Cooks Range.
0.1	1.55	Side road to right. Good view of the manganese workings on the south slope of Boston Hill at 3 o'clock. For next 3 miles, outcrops of consolidated Lower Gila Conglomerate in road cuts, locally overlain by Late Pleistocene to Recent gravels.
0.75	2.3	Side road on right; Lower Gila Conglomerate crops out in stream bed 3/4 mile up road; strikes northwest, dips 3° E. Little Burro Mountains in foreground at 12 o'clock; Big Burro Mountains in distance at 1 o'clock.
0.1	2.4	At 9 o'clock Lone Mountain is a dip slope of Paleozoic limestone rising above the Bayard surface. Cooks Peak beyond on skyline. At 10 o'clock, if not hazy, the distant Florida Mountains.
1.65	4.05	Cross wash. Road cuts ahead show Gila locally overlain by terrance gravels.
0.25	4.3	At 9 o'clock channel fill in terrance gravels.
0.3	4.6	Cross Pipeline Draw, which either marks the trace of another major northwest structure or is the principal structure of the fault zone of which the Treasure Mountain fault is a part; zone extends southeast and roughly parallels San Vicente Arroyo. About a mile to the northwest, along side road, Lower Gila crops out in stream channel; strike is N. 10° W., dip 25° E.
0.4	5.0	In road cuts on right, small faults in Upper Gila control iron and manganese staining. Manganese was mined in the Little Burro Mountains and stockpiled after World War II. This may be a fault zone involving total displacement of appreciable significance. A suggestion of the fault zone can be traced for many miles in a southerly direction on aerial photographs. Southwest from this point, along the highway, outcrops are mostly of arkosic unconsolidated Upper Gila Conglomerate. At the Silver City water wells on the Woodward Ranch 2 miles to the west, and 1/2 mile southwest of Pipeline Draw, the Upper Gila is 900 feet thick.
0.5	5.5	At 3 o'clock terrace gravels over Upper Gila Conglomerate in road cut.
0.3	5.8	Curve in road. At 3 o'clock 0.35 mile to right off road, indurated Upper(?) Gila beds strike N. 15° E., and dip 25° W.
1.6	7.4	Note coarsening of Upper Gila Conglomerate; constituents derived from Big Burrow Mountains before uplift of Little Burro Mountains.

0.6	8.0	Very coarse Upper Gila Conglomerate, consisting mainly of igneous rocks from Big Burro Mountains.
0.5	8.5	Small white mine dump at 2:30 o'clock, west of windmill, is in rhyolitic tuff, probably on trace of northwest border fault of Little Burro Mountains. Ground-water cascade along east side of Little Burros in this vicinity.
0.25	8.75	The same(?) fault crosses the road at a small angle. White and pink rhyolitic tuffs crop out in gully at right. In road cut to left, Gila gravels.
0.15	8.9	Tertiary rhyolitic tuffs in road cuts continue to top of ridge. Strikes and dips are highly variable, indicative of structural complexity.
0.3	9.2	At 2 o'clock reddish outcrops on ridge are Gila Conglomerate.
0.05	9.25	Crest of Little Burro Mountains. Severely altered Cretaceous or Tertiary porphyry in road cuts.
0.1	9.35	At 9 o'clock mine dumps in bleached porphyry.
0.3	9.65	Outcrops of Gila Conglomerate on right.
0.35	10.0	Entering Mangas fault zone. Triangular facets on spur ridges and large slickensided surfaces along southwest side of the Little Burro Mountains indicate recent movement along the fault. The fault separates altered igneous rocks from Gila Conglomerate in the valley. The Gila Conglomerate is 628 feet thick in the city wells at Tyrone.
0.3	10.3	Road cut in Upper Gila Conglomerate.
0.1	10.4	A bore hole 0.1 mile off road to left (east) found Gila Conglomerate to depth of 1200 feet.
0.25	10.65	Side road on right; 1-1/2 miles to Tyrone; to Whitewater on left. Note iron oxides deposited in wash from leaching water of Tyrone operation. Exploratory bore holes in the hills to the west of Mangas Draw, in vicinity of Tyrone, found Gila Conglomerate 200 to 800 feet thick. The Tyrone porphyry deposit, inactive since about 1920, is being redeveloped by Phelps Dodge Copper Corporation at a cost of 100 million dollars.
0.4	11.05	Gravel of Gila Conglomerate in road cuts for next several miles. East contact of Tyrone quartz monzonite stock with Precambrian granite follows road on right.
0.25	11.3	Big Burro Mountains from 1 to 4 o'clock.
0.55	11.85	From 8 to 9 o'clock–everyone look back except driver–old Phelps Dodge Corporation mill and tailing dump.
1.25	13.1	Road is on flat pediment surface formed on Precambrian rocks, extending for several miles. Outcrops of fine- to medium-grained, pink biotite granite. From 11 to 12 o'clock is Saddle Mountain, a Tertiary(?) rhyolite plug. From 12 to 1 o'clock is Tullock Peak, another rhyolite plug.
0.55	13.65	In road cut at right, white felsite and dark diabase dikes in Precambrian granite. Dikes are abundant in the Precambrian of the Big Burro Mountains. More acidic

		varieties trend east to northeast, locally as swarms. Northwest trends prevail among the more basic dikes.
0.15	13.8	Cross Cherry Creek.
0.15	13.95	Road cut in Precambrian granite cut by diabase dike. For next 2.2 miles road crosses slightly dissected surface of the Big Burro Mountain pediment, cut mostly on rocks of Precambrian age which are chiefly granite, in places deeply weathered. A ground-water cascade drops the water table toward the east (left) about 600 feet in a distance of 1.25 miles. A major structure along the east front of the Burro Mountains is inferred for this area.
1.0	14.95	Rhyolite and andesite dikes in road cut. Big Burro Mountains at 2 o'clock. Jacks Mountain, altitude 7986 feet, has a TV relay station, was formerly the site of a solar observatory, abandoned after nearby smelters began operations.
0.7	15.65	Side road at right.
0.5	16.15	At 9 o'clock, Tullock Peak is a rhyolite plug. At foot of ledge, contact with Precambrian granite, which is cut by dikes, visible in road cut. At 12 o'clock Three Sisters Peaks, a series of rhyolite plugs.
0.15	16.3	Cross Walnut Creek fault; trends southeast along west base of Tullock Peak.
0.25	16.55	Side road at left to 7XV ranch.
0.3	16.85	White Signal schoolhouse (abandoned) at right. Cross Walnut Creek.
0.1	16.95	Altered Precambrian granite in road cut at entrance to the White Signal Mining District.
		The White Signal Mining District was widely prospected for gold, silver, and copper in the early days, but total production was probably well below $50,000. Fluorspar, turquoise, bismuth, lead, and zinc also have been reported. Uranium minerals autunite and torbernite, discovered in 1920 and mined until the late 1920's for the radium content to make "radioactive water". From the latter part of World War II until the mid 1950's the district was involved in the "uranium boom". Extensive prospecting resulted in the shipment of four carloads of ore.
0.05	17.0	At 9 o'clock near house is the Combination Mine (gold).
0.4	17.4	Bridge. Junction with Separ road on left.
0.75	18.15	In road cut, Precambrian granite cut by dikes.
0.4	18.55	Road cut, right side; 5-foot shear zone in granite contains considerable torbernite. Diabase dike strikes across road.
0.25	18.8	Side road to Merry Widow shaft (wooden headframe) on right. An east-west quartz-pyrite vein was prospected in the early days for gold (found only in the upper levels) and copper. Torbernite and autunite were recognized on the dumps in 1920.
0.2	19.0	At 12 o'clock, an east-trending silicified zone stands out; mine dumps at its base.

		This is part of a major structural trend, characterized by faults, veins, and rhyolite dikes, that extends across the south side of the Big Burro Mountains.
0.4	19.4	The mountains at 10 o'clock have been erroneously called the Little Burro Mountains in some older literature; they are called "Gold Hills" by local people, but purists insist that "Gold Hill" is a particular mountain in the range. They are sometimes described as "the southwest part of the Burro Mountains". Trauger refers to them as the "South Burro Mountains". The U.S.G.S. map of New Mexico takes the coward's way out and leaves them unnamed.
0.1	19.5	Cattle guard. Jack Mountain is at 2 o'clock, elevation 7986 feet.
0.4	19.9	Cattle guard. Entering Gila National Forest. Side road at right to Sprouse and Copeland mines. These are on a northeast-trending shear zone, partly the contact between Precambrian granite and the Tyrone monzonite stock. Chalcopyrite is the main ore mineral.
0.45	20.35	Road cut in deeply weathered Precambrian granite cut by quartz veinlets. At 3 o'clock, ridge formed by rhyolite dike, part of east-trending dike swarm.
0.3	20.65	Just behind and to west of Jacks Mountain is Burro Peak, altitude 8035, highest point in range.
0.4	21.05	Side road on right. At 3 o'clock, white rhyolite dike at base of hill. This is the northern limit of a pediment cut on granite at the south and east sides of the Big Burro Mountains. Hill at 1:30 o'clock shows prospect working for fluorite on the Moneymaker claim. Pediment extends about 12 miles to the south.
0.25	21.3	Rise marks Continental Divide, incorrectly located about 4.4 miles further west on earlier maps and road signs. Diabase dike in road cut. At 2 o'clock the Wild Irishman mine workings along rhyolite dike. This mine is also known as the Neglected and as the Rainbow. A wide silicified zone is topographically prominent for about a mile westward from the shafts. Copper and gold are the valuable metals, the gangue is quartz and barite. Gold Hills at 12 o'clock.
0.45	21.75	Whitetail Canyon bridge.
0.1	21.85	At 2:30 o'clock prominent east-trending dike. Quartz felsite dikes in road cut.
0.1	21.95	Approximate trace of Taylor fault, separating Precambrian granite from Gila Conglomerate to south. The Taylor fault forms the northeast side of the Knight Peak graben which separates the Gold Hills from the Big Burro Mountains. Road cuts in Gila Conglomerate and valley fill for the next 3 miles. At the southern end of the Knight Peak graben the Tertiary volcanic section resembles the Rubio Peak-Mimbres Peak-Caballo Blanco-Bear Springs succession in the Mimbres Valley (see Elston, this guidebook, Fig. 2, Column I). Erroneous accounts of Quaternary post-Gila volcanics (Ballman, 1960), based on mapping errors, are perpetuated on the U.S.G.S. Geologic Map of New Mexico.
1.5	23.45	Gold Gulch road on right. McComas Massacre sign reads: "One of the last Indian Massacres occurred here March 1883, when Judge and Mrs. H. C. McComas of Silver City were slain by a raiding band of Charcahaus (sic) Apaches, led by the celebrated chief, Chato. Fate of McComas' six year old son, taken into captivity by the Indians, is still

unknown." The McComas', traveling by buckboard, were on their way to Lordsburg.

1.25	24.7	Walking X Ranch road crossing.
0.1	24.8	Culvert; crossing possible north-trending fault zone; a lineament can be identified on air photos and traced across areas underlain by granitic and sedimentary rocks.
0.05	24.85	Knight Canyon Road.
0.9	25.75	Incorrectly located Continental Divide sign.
0.1	25.85	Approximate contact of Gila Conglomerate and Tertiary rhyolitic volcanics.
0.25	26.1	Road cut exposes rhyolitic flows, light-gray and pink tuffs, folded and faulted, dipping 40-50° to the northeast into the Knight Peak graben. At the end of the road cut, on the right hand side, exposure of the Malone fault. This is the border fault on the west side of the graben, putting massive Precambrian granite in contact with highly sheared white rhyolitic tuffs.
0.5	26.6	Road cuts in deeply weathered Precambrian granite.
0.4	27.0	Cattle guard. Side road to microwave tower on right. At 10 o'clock Hornbrook Mountain, altitude 7048 feet, highest point in the Gold Hills. The Gold Hills are formed of Precambrian granite and metamorphic rocks such as amphibolite and gneiss, a migmatite complex and a diabasic dike swarm of unknown age.
0.35	27.35	Road cut in Precambrian granite intruded by quartz veins, aplites, and pegmatites.
0.3	27.65	Road cut in deeply weathered granite and diabase dikes.
0.25	27.9	At 3 o'clock, 1 mile to the north, is Knight Peak, a palisade of rhyolitic flows dipping steeply to northeast. The Tertiary volcanics are faulted against Precambrian rocks.
1.0	28.9	High level slope deposits, resting on granite, in road cuts.
0.5	29.4	Mill Canyon and Knight Canyon roads to right.
0.1	29.5	Road cut on left shows quartz veins in decomposed granite.
0.2	29.7	Entering Hidalgo County.
0.3	30.0	Rock ridge, surrounded by alluvium and cut by road, is rhyolitic dike.
0.2	30.2	At 9 o'clock, about a mile from road, workings in pegmatite were prospects for rare earths, discovered in early 1950's by detection of radioactivity.
0.3	30.5	Rhyolite dike with flow banding forms ridge to right and crosses road.
0.2	30.7	Road cut in Precambrian black schist, gneiss, and amphibolite intruded by granite and pegmatite dikes. Note nodular weathering in diorite dike.

0.15	30.85	Cattle guard. At 9 o'clock more prospect workings in white pegmatite on hill crest. Leaving Gila National Forest.
0.05	30.9	Dioritic intrusive cut by road.
0.1	31.0	Side road on left goes to prospects.
0.1	31.1	Road cut at left in Precambrian granite, gneiss, and pegmatities. Same rocks with diabase dikes crop out along highway for next 1/2 mile. At 4 o'clock rhyolitic volcanics form "Knight Peak" cuesta.
0.5	31.6	At 1 o'clock in distance, Mount Graham on the horizon behind the northern Peloncillo Mountains. The closer hills from 1 to 2 o'clock are Summit Hills, Canador Peak, and Black Mountain. Steeple-rock at 2 o'clock is in a horst of rhyolite pyroclastics, faulted up in the Mogollon Rim fault zone which we crossed yesterday farther north.
0.2	31.8	Approximate contact between Precambrian rocks and pediment gravels. At 3 o'clock outcrops of light-colored rhyolitic tuffs beneath pediment/alluvial-fan gravels along Wood Canyon. Road curves to left. Apache Mountain at 10 o'clock, altitude, 6951 feet, is of Precambrian garnetiferous gneiss and amphibolite schist cut by fine-grained granite, and by dikes of diabase and pegmatite.
		Free milling gold and silver were formerly mined from oxidized quartz-pyrite veins at Gold Hill. The district was discovered in 1884 and was active until the oxidized ores containing free gold ran out about 1900. In those days, the small town of Gold Hill occupied the site of the present McWhorter Ranch in Gold Hill Canyon. Production after 1900 was sporadic.
0.45	32.25	From 12 to 2 o'clock, Peloncillo Mountains on skyline extending southward as a low range, while the Chiricahua Mountains in Arizona form skyline from 10 to 12 o'clock. City of Lordsburg at 10 o'clock across valley, with Pyramid Mountains immediately behind. Alkali Flats playas in Animas Valley at 11 and 12 o'clock.
0.15	32.4	Side road on left to Gold Hill Mining District.
1.35	33.75	Dip. Road is descending on thick alluvial fan washed from the Burro Mountains. Schwennesen (1918, p. 25) noted: "A rather remarkable feature in connection with the Burro Mountains is the immense accumulation of rock waste that is piled against its southwestern flank and that stretches in a broad, sweeping slope from a zone far up the side of the range nearly to the Southern Pacific Railway. This accumulation seems to be greatly out of proportion to the mass and elevation of the range." Pre-Pleistocene bedrock (volcanics) crops out beneath a thin veneer of gravel along Wood Canyon near the highway and a similar relationship occurs to the northwest along Thompson Canyon. A part of Schwennesen's "immense accumulation" therefore is a pediment cut on bedrock and capped by a thin cover of gravels.
1.75	35.5	At 1:30 o'clock low hills in valley are formed by Precambrian granite and gneiss. Peloncillo Mountains on skyline.
0.35	35.85	Cross shallow wash. At 10 o'clock beyond Pyramid Mountains is Animas Range; its main mass is a huge accumulation of quartz latite ash-flow tuff.

0.2	36.05	At 9:30 o'clock the Little and Big Hatchet Mountains on skyline are largely made up of a thick section of, respectively, Lower Cretaceous and Paleozoic sediments. The road for the next three miles runs directly down the pediment-fan slope; the gradient decreases from 130 feet per mile in the first mile, to 100 feet the second mile, and to 70 feet the third mile.
2.0	38.05	At 7:30 o'clock, Gold Hill, marked by prospects and dumps, at south end of Apache Mountain.
1.05	39.1	Dip. Hit it slow. Black Drilling Co. No. 1, 4-1/2 miles to right, reported "show of oil" although T. D. 730 feet was probably in volcanics or valley fill.
0.3	39.4	At right, side road to Thompson Canyon.
1.9	41.3	Bridge. Six oil tests have been drilled in a cluster centered 10 miles to the west at 1:30 o'clock. Total depths ranged from 100 to 1800 feet; oil and gas shows were reported. Four holes appear to have bottomed in bolson deposits or tuffaceous volcanics. The Phillips-Owens-Bouton No. 1, T. D. 1800 feet, probably penetrated at least 1369 feet of bolson deposits and volcanics, and may have bottomed in Cretaceous. The Long and Beck No. 1 State, T. D. 1495 feet, was probably in Tertiary sediments all the way. Both tests reported shows.
0.2	41.5	Victorio Mountains in distance at 9 o'clock. Coyote Hills, Little and Big Hatchet Mountains (on horizon) at 10 o'clock. Pyramid Mountains from 10 to 1 o'clock. Shakespeare (ghost town) at 12 o'clock in foothills of Pyramid Mountains. The Pyramid Mountains appear to be a north-south elongated fault block, tilted gently to the south. The oldest rocks, basalt flows, believed to be Cretaceous in age, crop out at the north end of the range and are overlain to the south by a thick series of Tertiary Rhyolitic volcanics. The basalts are intruded by a stock of porphyritic granodiorite of presumed Late Cretaceous-Early Tertiary age.
		CAREFUL, STOP AHEAD.
1.6	43.1	Road Fork, veer left. Slow, approaching junction. Left turn ahead.
0.2	43.3	STOP. Junction with U.S. Highway 70 to Duncan, Morenci, Safford, Globe, Miami (Arizona). TURN LEFT.
0.65	43.95	Historic Marker, reading: "Historic Lordsburg lies on the old Butterfield stage route. In 1872, confidence men salted a nearby mountainside with African and Brazilian diamonds. The resultant sale of stock became known as the Diamond Swindle. The ghost town of Shakespeare, once a mining center, is three miles south." The first buildings were erected in Shakespeare about 1856. During the silver boom of 1870-73, the town had a population of about 3000 with no school, no church, and no law.
0.5	44.45	Lordsburg city limits. Road crossing Lordsburg Draw, which drains the Lordsburg Valley northwestward into the Lower (northern) Animas Valley. In 1961 a skeleton of a mammoth was uncovered about 8 feet below the ground surface in borrow pit located just east of U.S. Highway 70 at the south edge of Lordsburg Draw. To the east the valley grades into the extensive plain of Luna County called The Antelope Plains. Upstream (stream?) are three small playas.
0.3	44.75	Sign on side road: Lordsburg, "On route of the old Butterfield Trail 1858-1881. Town established 1881 during the building of the Southern Pacific Railroad from California to Texas. Principal industries are farming. Elevation 4245."

		At 8 to 9 o'clock Gold Hills. Note extensive alluvial fans/pediment from 6 to 9 o'clock. SLOW. JUNCTION AHEAD.
0.75	45.5	Underpass beneath Southern Pacific Railroad. SLOW. BEAR RIGHT. Turn right after one underpass, taking U.S. 80 West.
0.1	45.6	Join U.S. Highway 80 West.
0.4	46.0	Cross railroad tracks.
0.8	46.8	West City Limits of Lordsburg. Hill at 10 o'clock is remnant of rhyolite volcanic vent.
0.6	47.4	Hills at 11:30 o'clock are of interlayered glassy andesite and rhyolite tuffs. Basalt flows on Lee Peak at 10 o'clock; the 85 Mine (copper), leased from Phelps Dodge Corporation, is at the base of 85 Hill at 9:30 o'clock. The workings along the Emerald vein strike northeast on the hillside.
1.6	49.0	"Granite" quarry in rhyolite at 12 o'clock on north side of Steins Pass through the Peloncillo Mountains.
2.1	51.1	Crest of rise. Low hills to right and left are of basalt-andesite intruded and overlain by rhyolite. At 12 o'clock in distance, Peloncillo Mountains with Chiricahua Mountains to the west.
1.05	52.15	Road cuts in rhyolite and basalt-andesite volcanic rocks. Steep hills at 9:30, 10:30, and 2:30 o'clock are rhyolite necks and dikes intruded into andesite flows and breccias.
0.6	52.75	Gary overpass. Cost several hundred thousand dollars to link two parts of a ranchers dissected property.
0.75	53.5	Sign: Road Forks 9, Tucson 150 miles. Hill at 2:30 o'clock of tuffs and basalt-andesite marks west edge of Pyramid Mountain block. Area to west is probably downfaulted. Buffalo Oil Company No. 1 drilled 3-1/2 miles to right, T.D. 700 feet, bottomed in valley fill, drilled and abandoned.
0.6	54.1	Highest beach bar of Pleistocene Lake Animas; altitude about 4190 feet. Outcrops of lacustrine gravel and silt are about 0.1 mile wide along this east shoreline. The playas of South Alkali Flat (12 o'clock) and North Alkali Flat (2 o'clock) are mere remnants of a lake that was 29 miles long and 4 to 8 miles wide. Air photos show spectacular mudcracks, one-quarter of a mile across. The flats were submerged to a depth of 35 to 40 feet, and an arm of the lake extended up the Lordsburg Draw to the small playas east and southeast of Lordsburg (Schwennesen, 1918). Later, a river system developed and meandering channels, complete with oxbows, are easily spotted on air photos.
		The lake bed is bordered on the north and northeast by a sand dune area of about 30 square miles. The nearest dunes are at 4 o'clock, about 3 miles to the north across Tobosa Flats, where Lordsburg Draw merges with North Alkali Flats. The dunes reach a height of 60 feet and were blown from the lake bed by southwesterly winds. At present, most of the dunes are stationary, being held by mesquite and creosote bush.

0.3	54.4	East edge of South Alkali Flat. This is the lowest part of the Animas Valley, which extends from a divide 58 miles to the south near the Mexican boundary to a low divide near Summit, New Mexico (14 miles north). The valley is bordered by the Peloncillo Mountains to the west and the Animas and Pyramid Mountains on the east. Schwennesen (1918) divided the valley fill into four kinds of deposits: (1) Stream deposits, including materials spread on alluvial fans by sheet wash, (2) lake deposits, (3) wind deposits, (4) basalt lavas, interbedded with and on top of the unconsolidated valley fill. The valley fill is correlated with the Gila Conglomerate of Pliocene to Pleistocene age. A section about 330 feet thick is exposed north of Summit along drainage to the Gila River.
1.95	56.35	Sign: Animas Exit 1 mile. Cross culvert amid South Alkali Flat playa. At 9:30 o'clock Animas Range on horizon; at 10 o'clock Table Top Mountain in distance; Peloncillo Mountains from 10 to 3 o'clock; Steins Pass at 1 o'clock; Chiricahua Mountains on horizon from 11 to 12:30 o'clock. Animas Range is composed chiefly of thick series of volcanic rocks except near the north end where upper Paleozoic beds are thrust over Lower Cretaceous strata.
1.2	57.55	Interstate 10 goes under overpass of New Mexico Highway 338, which leads left (south) to the village of Animas. About 12,000 acres of farmland, mainly cotton, are irrigated from deep wells near Animas. The Animas Valley is separated from the Gila River valley by broad low saddle near Summit, New Mexico (4 o'clock distant), whose elevation is only 165 feet above the lowest point in the Animas Valley. The Gila River and its principal tributaries have been cutting into thick Pliocene-Pleistocene deposits along their courses, but dissection has not extended very far from the main drainage lines. Schwennesen (1918, p. 33) believed that if the conditions promoting down cutting continue the gullies which head on the north side of the divide between the Animas and Gila basins will cut headward, drain the Animas basin into the Gila River, and cause extensive dissection of the Animas basin into the Gila River, and cause extensive dissection of the Animas and Lordsburg Valleys.
0.7	58.25	Sign: Road Forks 4, Tucson 145 miles.
2.35	60.6	Sign: Rodeo-Douglas Exit 2 miles. Spectacular cliffs carved from rhyolitic volcanics at 3 o'clock. At 10:30 o'clock on the eastern slopes of the Peloncillo Mountains are small mines and prospects. The range (Gillerman, 1958) consists of pre-Tertiary sedimentary rocks from a point 3 miles south of Steins to Granite Gap (10 miles south of Steins) where U.S. Highway 80 crosses enroute to Douglas, Arizona.
2.0	62.6	Road cuts in lacustrine beach sand and gravel on west edge of Lake Animas. The lake is probably of late Wisconsin age, correlative with Lake Estancia and Lake San Agustin in central and west-central New Mexico. To the north in the Virden-Duncan valley of the Gila River, Morrison (1964) mapped gravel deposits which he believes were related to a large lake or lakes of mid-Pleistocene age. He found stream gravels of probable late Pleistocene age covering two strath terraces along the Gila and unconsolidated alluvial gravel, sand, and silt that underlie a still lower, younger terrace of Recent age. There are many other ancient lake beds in this part of the Basin and Range province: Lake Cochise in Sulphur Springs Valley was northwest of the Chiricahuas, Lake Cloverdale in the San Luis Valley (south of Animas Valley),

		Playas Lake in Playas Valley (30 miles south of Lordsburg), a lake in the Mexican part of Hachita Valley, and many lake beds in Mexico in northwestern Chihuahua.
0.4	63.0	Road forks; junction of Interstate 10 and U.S. 80. Continue ahead on U.S. 80.
0.1	63.1	STOP - Time: 15 minutes - See note by Gillerman.
1.75	64.85	Turnoff to ghost town of Steins on right.
0.75	65.6	Cretaceous or Tertiary andesite on left, Quarry Peak Rhyolite forms cliffs on right.
0.6	66.2	Road cut in hydrothermally altered Cretaceous or Tertiary andesite.
0.4	66.6	Rhyolite intrusive into andesite on left.
0.8	67.4	Outcrops of Cretaceous–Tertiary andesite end.
1.2	68.6	State Line – leaving New Mexico, entering Arizona. Watch out for Gila Monsters! Quaternary alluvium.

GEOLOGY TO BE SEEN FROM A STOP AT ROAD FORKS

By

Elliot Gillerman
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Directly ahead (west) the road and railroad cross the Peloncillo Mountains through historic Steins Pass. Volcanic rocks are the surficial rocks in this area, but further south Cretaceous and Paleozoic sediments, and Precambrian granite are exposed in parallel northwest-trending fault blocks. These can be seen forming the range from a point about 3 miles south of Road Forks and extending southward for about 13 miles. South of the sedimentary rocks and the granite, the Tertiary Weatherby Canyon Ignimbrite (described elsewhere in this report) extends southward for many miles.

In the area west of Road Forks the volcanic rocks have been divided into an earlier (probably Cretaceous) sequence and a younger Tertiary sequence. The older sequence makes up the low hills and higher peaks west and southwest of Road Forks and consisting of over 5,000 feet of northward dipping dark gray, red, and purple andesite flow rock and breccia characterized by abundant epidote. The rocks are fine-grained with small phenocrysts of epidotized feldspar and pyroxene. Some dacite and basalt are included in the sequence. The gray to purple color of the rock imparts a characteristic color to the terrain occupied by the andesite. These rocks crop out west of Road Forks along the highway.

The younger Tertiary sequence crops out north of the railroad west and northwest of Road Forks. Three separate units can be seen. The Quarry Peak Rhyolite forms prominent Quarry Peak (see Figure 17) just north of Steins, and the Steins Mountain Quartz Latite forms Steins Mountain Peak (the higher conical peak just north of Quarry Peak) and the hills to the north (Figure 18). A thin basalt lies between the two.

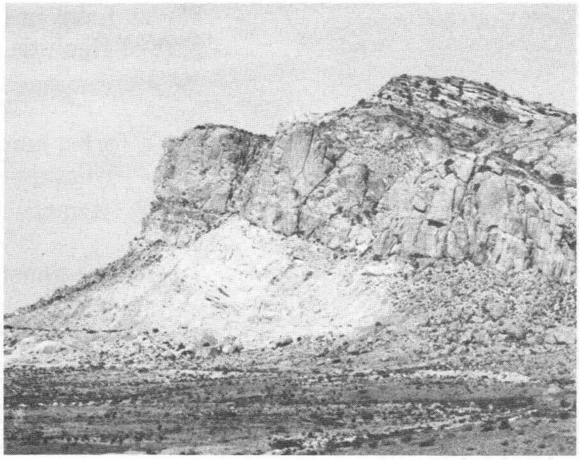

Figure 17 – Quarry Peak Rhyolite complex on Quarry Peak. Low hills in foreground are underlying andesitic volcanic rocks. –Photograph by Elliot Gillerman

The Quarry Peak Rhyolite consists of over 1,000 feet of rhyolite flows, lithic tuffs, and breccias, which dip 15°-30° N. The rock is mostly gray to white, fine-grained, with a few small inconspicuous quartz and feldspar megacrystals. Some of the tuffs and breccias are well bedded and well sorted, and reflect deposition in shallow lakes. The tuff and breccia are postulated as representing violent volcanic eruptions which fragmented solidified vent-filling lava. Fine volcanic ash mixed with the breccia fragments fell on land and in shallow lakes. Accretionary lapilli, or chalizoidites, formed during the explosive activity, are present locally. The interbedding of the lithic tuffs and the lavas indicate more than one eruptic cycle of explosion, lava flow, solidification of the plug, and explosion again.

The basalt (more properly, an andesite) occupies the lower slopes of Steins Mountain. The rock is dark gray to black, fine-grained, holocrystalline, nonporphyritic, and consists almost wholly of andesine laths (An_{46}) with about 2 percent magnetite. It is uniform in texture and composition.

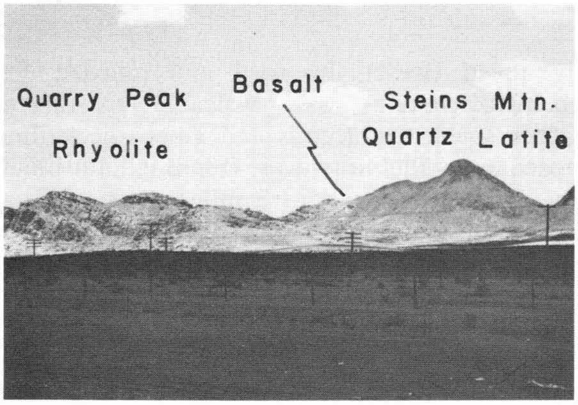

Figure 18 – Northward–dipping Quarry Peak rhyolite complex on Quarry Peak (left) overlain by Steins Mountain Quartz Latite on Steins Mountain (highest peak in picture) and the 50-foot thick basalt unit which separates these two acidic rock types. Steins Pass, through which the historic Butterfield Trail, and the present–day railroad and highway cross the Peloncillo Range, is on the south side (left) of Quarry Peak. The view is westward from a point on Interstate 10 about 1¼ miles west of Road Forks. –Photograph by Elliot Gillerman

The porphyritic Steins Mountain Quartz Latite constitutes most of Steins Mountain and contrasts sharply in color and topographic expression with the Quarry Peak Rhyolite. The rock is hypocrystalline porphyritic-aphanitic pinkish-gray rock with numerous embayed euhedral quartz and feldspar phenocrysts. Lithic and small vitric fragments are common. Many of these are flattened and elongated, and are oriented in layers producing a eutaxitic structure. Some of the vitric fragments are devitrified and recrystallized into quartz and feldspar, but others are still glassy. The matrix is a structureless mass of clay including chlorite, containing ghosts of glass shards, and was probably originally tuffaceous in nature. The rock is considered to be a devitrified crystal tuff.

		The Steins Mountain Quartz Latite and the underlying basalt dip northward at low angles and were laid down across the previously tilted and beveled Quarry Peak rhyolite, from which they are separated by an angular unconformity. The age relationships of the Steins Mountain Quartz Latite and the Weatherby Canyon Ignimbrite further south are indeterminate, but both are Tertiary, consist largely of pyroclastic fragments and are products of explosive volcanism. They may be different phases of one period of violent volcanic activity.
		West of Steins a quartz latite dike crosses the highway, trending northwest, and may be seen intruding the Quarry Peak Rhyolite just west of the summit.
		Immediately north of Steins, a small circular rhyolite plug which exhibits inward dipping planar structures around all sides occupies a small hill. The plug may have been a vent, and the source of some of the rhyolitic rocks constituting the Quarry Peak Rhyolite complex.
0.8	69.4	Latite flows make up peaks in Vanar Hills at 2 o'clock. Cochise Head, in northern Chiricahua Mountains, is in view at 10 o'clock. This remarkable feature has been carved by erosion out of the Faraway Ranch Formation (Enlows, 1955).
		The lower slopes of the Chiricahua Mountains, below Cochise Head are composed mostly of Precambrian Rattlesnake Point granite (Sabins, 1957). Overlying this granite, and perhaps down-faulted into it is a Paleozoic section consisting, in ascending order, of the Cambrian Bolsa Quartzite, the Cambrian and Ordovician El Paso Formation, the Devonian Portal Formation, the Mississippian Escabrosa Limestone and Paradise Formation, the Pennsylvanian Harquilla Limestone, the Pennsylvanian-Permian (?) Earp Formation, and the Permian Colina Limestone, Scherrer Formation and Concha Limestone. Stratigraphically overlying, and at places structurally underlying these rocks is the Cretaceous Bisbee group, with the Glance Conglomerate at the base. The above-mentioned rocks have been invaded by silicic intrusions of Tertiary age. They are overlain by Tertiary volcanic rocks.
		The southern, main part of the Chiricahua Mountains, in the far distance, trends almost due north, but toward the northern end the trend changes to west-northwest and almost due west.
2.65	72.0	Curve. Vanar Hills end on right. Apache Pass, between the Chiricahua and Dos Cabezas ranges at 10:30. The rugged mass to the left of the pass is Bowie Mountain which is composed of Precambrian quartzite.
		Beginning near Apache Pass, the Rattlesnake Point granite becomes separated from the Paleozoic-Mesozoic section by a belt of Older Precambrian Pinal Schist. To the right (west) of the pass, the place of the Rattlesnake Point granite is taken by the Precambrian Sheep Canyon granite.
3.9	75.9	The Whitlock Hills, of volcanic rocks, are at 1:30. The Graham Mountains, a block of crystalline gneiss, rising to 10,700 feet, are at 1 o'clock. The area around the Dos Cabezas Peaks, at 11:30 is composed of giant, intrusive breccia. (See accompanying paper by Rolfe Erickson).
1.6	77.5	Checking station in San Simon Valley.

1.2	78.7	Cross east fork of San Simon Creek, then west fork.
1.4	80.1	Entering San Simon, elevation 3608.
1.6	81.7	Curve. Just to the left of the Graham Mountains are the much lower Greasewood Mountains, and in the far distance, just beyond the northwest end of the Dos Cabezas Mountains is the southern end of the Winchester Mountains.
2.6	84.3	The light-colored, blocky outcrops at 10:30 are part of a large granodiorite stock (see paper by R. Erickson).
4.4	88.7	The Gila Mountains are in view at 2 o'clock, beyond the Whitlock hills.
7.4	96.1	Entering Bowie, elevation 3762.
0.8	96.9	Lone Star Cafe on right.
1.8	98.7	Fisher Hills, of Tertiary rhyolite at 1:30, with Greasewood Mountains behind them. Winchester Mountains at 11:45.
3.2	101.9	Rest area. Fisher Hills at 3 o'clock.
0.2	102.1	Overpass, cross Gold Gulch.
2.9	105.0	First exit to Safford.
2.7	107.7	Road cut in Gila(?) Conglomerate.
0.9	108.6	Safford exit.
1.1	109.7	Road cuts in Gila(?) Conglomerate.
2.9	112.6	Railroad Pass, elevation 4,932. Circle I Hills of Precambrian granite and schist at 1:30; Winchester Mountains at 12:30; Little Dragoon Mountains at 12 o'clock; Dragoon Mountains at 11 o'clock. Highway passes around northwestern end of Dos Cabezas Mountains.
4.6	117.2	Spike E Hills of Precambrian schist at 3 o'clock; Dos Cabezas at 9 o'clock. Chiricahua Mountains at 9:30 o'clock; Swisshelm Mountains, with Sulphur Hills in front at 10 o'clock. The Big Dragoon Mountains are at 11 o'clock to 12 o'clock, the Little Dragoons at 1 o'clock, and the Winchesters at 1 o'clock to 3 o'clock.
2.8	120.0	Entering Willcox, elevation 4,168, in the Willcox basin of Sulphur Springs Valley.
1.3	121.3	TRAFFIC LIGHT. TURN LEFT, onto road to Chiricahua National Monument. Cross railroad tracks, and drive across floor of Willcox Playa, a remnant of Pleistocene Lake Cochise.

Ancient Lake Cochise (Meinzer and Kelton, 1913) 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 suggest that this lake existed during one of the earlier glacial stages, possibly the Kansan. (Arizona Geological Society Guidebook 2, p. 248).

Austin Long (1966) used the carbon-14 dating method to establish a Wisconsin chronology for Lake Cochise. According to him, the lake existed continuously from before 30,000 years B.P. to 13,000 B.P. During that time, the lake was at least 30 miles long. Between 13,000 to 11,500 B.P. the lake level was drastically reduced and arroyos were cut into earlier lake deposits. Pluvial conditions again prevailed during the last phase of Wisconsin Lake Cochise which lasted about 1000 years from 11,500 to 10,500 B.P. Playa conditions have prevailed since 10,000 B.P. with consequent deflation and dune formation.

Dos Cabezas Mountains at 11 o'clock.

2.4	123.7	Beach ridges of the Pleistocene lake.
2.1	125.8	STOP 20 - Time: 20 minutes - (to note line-up of regional structures; a strand of the Texas Lineament).
1.5	127.3	Kansas Settlement turn off. BEAR LEFT. Paleozoic rocks ahead and to the right at 1 o'clock.
3.0	130.3	Curve. Road heads for defile ahead.
3.0	133.3	Bold outcrops of Precambrian quartzite at 11 o'clock. Hogback on right exposes the Paleozoic section, non-conformable on Precambrian granite.
		In this Paleozoic section Gilbert (1875) found the Ordovician fossil Euomphalus trochiscus.
2.7	136.0	Entering Dos Cabezas practically a ghost town, the population is 9. However, note new store as sign of impact of war on poverty.
1.3	137.3	Helen's Dome in the Chiricahua Mountains at 12 o'clock. Rapakivi granite (quartz monzonite) crops out on both sides of the road.
2.2	139.5	Bowie Mountain at 9:30.
0.4	139.9	The contact between the Rapakivi granite and the Bolsa quartzite crosses the road. Swisshelm Mountains at 12 o'clock; Sulphur Hills at 12 to 1 o'clock.
1.4	141.3	The Pearce volcanics, in the Pearce Hills are at 2:30; the Pat Hills (shallow intrusions and volcanics) are at 1:30, the Chiricahua Mountains at 11 o'clock, and Apache Pass at 9 o'clock.
2.8	144.1	Curve. Bowie Mountain is plainly in view at 9 o'clock composed of a well-exposed, steeply south-plunging syncline of Precambrian quartzite. Prior to tilting, the syncline was truncated by an erosion surface on which was deposited the Cambrian Bolsa Quartzite. The Bolsa now forms a low,narrow ridge, visible near the base of the mountain. The Apache Pass road turns off to the left. KEEP STRAIGHT AHEAD on pavement.
6.3	150.4	Curve. Sugarloaf Peak, at 2 o'clock is a remnant of a quartz latite flow some 220 feet thick which caps the Rhyolite Canyon Formation, a sequence of ash flow tuffs which has been eroded into the pinnacled topography seen in the distance.

The succession of volcanic rocks in this part of the Chiricahua Mountains is as follows (Enlows, 1955; Sabins, 1957; Fernandez and Enlows, 1966; See previous paper by Marjaniemi) (1) At the bottom of the sequence is the Nipper Formation, mafic volcanic conglomerates, flows and associated sedimentary rocks . . ." (Sabins, 1957, p. 1323). (2) Next in sequence is the Faraway Ranch Formation. "The unit consists of a complex of volcanic flows and agglomerates and some stream-deposited tuff and lacustrine deposits." (Idem. p. 1325). (3) The uppermost unit is the Rhyolite Canyon Formation, subdivided by Enlows (1955, p. 1221) into 9 members, including the 220 foot rhyodacite flow at the top, and totalling 1927 feet in thickness. This unit, composed essentially of ash flows, rests with minor unconformity on the Faraway Ranch Formation.

3.4	153.8	Road junction. STOP 21 - Time: 10 minutes - View to rear of northern Chiricahua Mountains, Apache Pass. Dos Cabezas Mountains, Pinal Mountains, Winchesters, Catalina Mountains and Rincon Mountains. Ahead are the Swisshelm Mountains and high part of the Chiricahua Mountains. TURN LEFT. Erickson Ridge, at 12 o'clock is Faraway Ranch Formation, K-Ar dated by D. Marjaniemi at 27.7 ± 0.7 m.y.
4.1	157.9	Entrance to Faraway Ranch on left. Crags ahead are capped by unit 6 of the Rhyolite Canyon Formation, with white ash at the base, underlain by Faraway Ranch Formation.
1.1	159.0	Park Headquarters, on right.
0.7	159.7	Camp ground on left.
0.7	160.4	Turn out on left. Natural Bridge trail.
0.9	161.3	Exposure on right of ash layer, overlain by vitrophyre, at the base of unit no. 6.
0.2	161.5	On right is a better exposure of relations at the base of unit no. 6. There is a turn out just below.
0.2	161.7	Turn out.
1.1	162.8	Bonita Park red beds on right. Faraway Ranch Formation exposed on left.
0.3	163.1	Nipper Formation, faulted up(?) on right. Faraway Ranch exposures on left.
0.2	163.3	Exposures of Rhyolite Canyon Formation on right.
1.8	165.1	Massai Point. STOP 22 - Time: 1 hour - After stop, begin return trip, exposures of Faraway Ranch Formation at 12 to 3 o'clock in Cochise Head. Rhyolite Canyon Formation in road cuts on left. Dated by K-Ar at 24.9 ± 0.6 m.y. (D. Marjaniemi.)
0.8	165.9	Nipper Formation exposed on left.
0.3	166.2	Red bed exposures.
0.8	167.0	Cattle guard.
0.4	167.4	China Boy.

1.2	168.6	STOP 23 - Time: 30 minutes - Turn out on right at Natural Bridge trail.
0.5	169.1	Organ Pipe formation. Ash parting visible to the left and high above ahead and to the right.
0.4	169.5	Camp ground entrance on right.
0.5	170.0	Headquarters on left.
3.3	173.3	Road junction at outlet of Rhyolite Canyon. Dragoon Mountains ahead, with jagged outcrops of Tertiary Stronghold Granite at 11:30.
3.0	176.3	Junction with road to Elfrida TURN RIGHT. Bowie Mountain ahead. Helen's Dome at 11 o'clock.
1.1	177.4	Curve left.
1.9	179.3	Curve right, Dos Cabezas peaks at 12:30.
5.8	185.1	Apache Pass road turns off on right.
1.0	186.1	Curve right. Dos Cabezas peaks at 12 o'clock.
2.7	188.8	Entering foothills of Dos Cabezas Mountains.
0.7	189.5	Bolsa-Rapakivi Contact.
3.0	192.5	Bridge.
0.4	192.9	Dos Cabezas village.
4.5	197.4	Pass last hill on left. Winchester Mountains at 12 o'clock.
10.2	207.6	Entering Willcox.
0.5	208.1	Intersection with State Highway 66. TRAFFIC LIGHT. TURN LEFT.
0.6	208.7	Leaving Willcox, Highway traverses flat grassland on lacustrine sediments of Lake Cochise, along the northern border of Willcox Playa. 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	211.6	Santa Catalina Mountains in distance at 1:30; Little Dragoon Mountains ahead; Dragoons at 10 to 11 o'clock. Passing around southern end of Winchesters.
2.5	214.1	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	216.1	Bisbee-Douglas turn off on left; underpass. Start climb out of Willcox basin, up mesquite-covered slopes.
3.3	219.4	Pass between Red Bird Hills on left and Steele Hills on right. Road cut at north end of Red Bird Hills exposes the Glance Conglomerate of the Bisbee group. The Little Dragoon Mountains and outlying ridges expose sections of Paleozoic formations (Gilluly, et al., 1954).

1.4	220.8	Road cut in alluvial conglomerate.
1.7	222.5	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 to the south (left).
1.3	223.8	Older Precambrian Pinal Schist, overlain unconformably by the younger Precambrian Apache group and by the Paleozoic sequence to the Mississippian Escabrosa Limestone is exposed in the Little Dragoon Mountains at 3 o'clock. Start climb toward Texas Canyon through road cuts in alluvial conglomerate.
1.5	225.3	Johnson Camp turn off on right. Underpass. Contact of Texas Canyon granite with older Precambrian Pinal Schist at 1:30. Texas Canyon granite has been K-Ar dated at 50.3 ± 2.5 m.y. (Livingston, et al., 1967).
0.6	225.9	Curve left. Entering Texas Canyon. Road cuts are in Tertiary Texas Canyon Granite. The well developed joints in this granite and an elusive parallelism of feldspar phenocrysts strike northeast.
1.6	227.5	STOP 24 - Time: 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 the Dragoon Mountains is 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	227.9	Pinnacles of Tertiary Stronghold Granite at Cochise Stronghold in Dragoon Mountains at 9:30. Highway descends through cuts in Texas Canyon Granite.
1.3	229.2	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	231.6	Emerge from Texas Canyon. Whetstone(?) pediment cut on granite at left, descends toward San Pedro Valley.
0.6	232.2	Huachuca Mountains at 10:30; Whetstones at 11:30 with Mustangs at southern end and Santa Ritas in view beyond. On the eastern face of the Whetstones is probably the finest exposure of the Paleozoic section in southern Arizona. Younger Precambrian Apache Group and Paleozoic sedimentary rocks are exposed in the Little Dragoons at 3:30.
1.4	233.6	Johnny Lyon Hills, with core of older Precambrian granite and schist, bordered by rocks ranging in age from Precambrian to Cretaceous, at 3 o'clock; Rincon Mountains at 2 o'clock. Gneisses in the Rincons dip moderately northeastward, and are cut by a set of strong, steep fractures. Tombstone Hills at 9 o'clock.
3.6	237.2	San Pedro Valley beds of probable Pliocene or Pleistocene age appear in gullies to left of road.
0.2	237.4	Begin descent through San Pedro Valley beds from Whetstone(?) pediment to Aravaipa surface. Pliocene and early Pleistocene fossils have been found in these beds at a lower level near the valley axis.

2.1	239.5	Entering curve right. San Pedro Valley beds in view across valley.
2.4	241.9	Bridge across San Pedro River.
0.7	242.6	Underpass. Benson, elevation 3,580.
1.7	244.3	Leaving Benson. Red sediments to south and southwest of highway contain the Benson fauna of Blancan (late Pliocene to early Pleistocene) age.
1.9	246.2	Whetstone overpass. Whetstone Mountains at 10 o'clock; Rincon Mountains at 2 o'clock. Curve right, enter cuts in red sediments.
5.1	251.3	Underpass. Santa Rita Mountains on skyline at 10 o'clock.
1.6	252.9	Road cut in alluvial conglomerate.
1.0	253.9	Road cut in Cretaceous sedimentary rocks, dipping steeply southward. Small hills at 9 o'clock are Cretaceous(?) sedimentary rocks.
2.2	256.1	Amole overpass. Road cuts beyond are in Miocene(?) Pantano beds that dip moderately westward.
3.1	259.2	Pantano underpass and bridge over Cienega Creek, followed by road cuts in Pantano beds, unconformably overlain by alluvial conglomerate.
1.3	260.5	Bridge over wash. Road cuts in steeply-dipping Pantano beds beyond.
1.6	262.1	Wash, with very steeply dipping Pantano beds, unconformably overlain by gently dipping alluvial conglomerate in west bank.
0.3	262.4	Ash flow underlying fine grained argillaceous Pantano beds has been K-Ar dated at 36.7 ± 1.1 m.y. (Damon and Bikerman, 1964).
0.2	262.6	Cretaceous sedimentary rocks to left of road and more in cuts beyond. Dark flow or dike on left.
0.7	263.3	Wash. Pantano beds in road cuts beyond.
0.9	264.2	Davidson Canyon; cuts in alluvial conglomerate beyond.
1.1	265.3	Santa Catalina Mountains in view at 2 o'clock; Mt. Fagan at north end of Santa Ritas at 9:30.
1.1	266.4	Underpass. Sonoita road turns off at left. Sierrita Mountains at 10 o'clock, with mine dumps in front.
2.9	269.3	Underpass. Saguaro National Monument and Vail road turns off at right.
1.9	271.2	Curve left, then right. Tucson Mountains at 12 o'clock; Black Mountain at 11 o'clock; Sierrita Mountains 10 o'clock. (Trip IV); Coyote-Quinlan Mountains in far distance at 10:30.
10.8	282.0	Tucson Mountains ahead (Trip V).

1.9 283.9 TRAFFIC LIGHT. TURN RIGHT onto Palo Verde road. Via Palo Verde and Speedway it is 8.8 miles to the University of Arizona campus.

- END OF TRIP -

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MESOZOIC STRATIGRAPHY AND LARAMIDE TECTONICS OF PART OF THE SANTA RITA AND EMPIRE MOUNTAINS SOUTHEAST OF TUCSON, ARIZONA

FIELD TRIP II

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INTRODUCTION

The Santa Rita and Empire Mountains are the nearest ranges southeast of Tucson; their northermost ends lie only 20 miles away. Much of the geology in this area is typical of a larger region lying roughly between Tucson, Nogales, Benson, and Bisbee, in which the U. S. Geological Survey has almost completed a series of detailed maps and related stratigraphic and structural studies during the last 8 years. J. R. Cooper, S.C. Creasey, P.T. Hayes, R.B. Raup, Jr., F. S. Simons, and the present authors have been, or are still, engaged in this work.

This field trip is planned to illustrate two of the more important geologic features, whose recognitions are results of this work: (1) a relatively complete Mesozoic stratigraphy, and (2) a complex 3-phased deformation during the Laramide orogeny. Although not all areas investigated include a fully developed Mesozoic sequence or evidence of the entire Laramide history, most areas contain some parts of the sequence or some aspects of this history. In a few areas that will not be visited on this field trip because of the greater distance from Tucson, certain rocks or structural relations are even more clearly illustrated than they are in the northern Santa Rita and Empire Mountains.

Geology

In brief, the geologic record of the region begins with Precambrian Pinal Schist into which coarsely porphyritic granitic rocks were intruded. During Paleozoic time about 5,000 feet of marine sediments were deposited discontinuously. The largest disconformities in this sequence occur between Cambrian and Devonian strata, between Devonian and Mississippian strata, and between Mississippian and Pennsylvanian strata. By the middle of the Permian the seas had left the area.

During the Triassic and possibly also parts of the Permian and Jurassic a thick pile of rhyolitic and dacitic volcanics were deposited in a subaerial environment. The volcanics contain intercalated conglomerate and eolian sandstone, and are associated with red beds. More rhyolitic tuff overlies the red beds. The age of these rocks is obtained from radiometric determinations and is supported by geologic relations to other dated rocks. During Late (?) Triassic time a monzonite pluton was emplaced and during Middle Jurassic time several major granite plutons were also emplaced. The earliest hints of post-Paleozoic faulting go back to this interval.

During latest Jurassic or earliest Cretaceous time the region was strongly uplifted. Rhyolitic to dacitic volcanic rocks were deposited in several ranges and, on them, sedimentary rocks many thousands of feet thick were deposited in much of the region during the late Early Cretaceous; most widespread and best dated of these deposits is the Bisbee Formation (Bisbee Group to the southeast).

During early Late Cretaceous we find the earliest signs of the first phase of the Laramide orogeny in the form of a major unconformity in the sedimentary record, and of northeast-southwest-directed compression and, locally at least, thrust faults in the tectonic record. During the late Late Cretaceous many more thousands of feet of sedimentary rocks were deposited, apparently in local basins. These rocks are also folded by northeast-southwest compression, providing the latest signs of the first phase of the orogeny. Toward the end of the Late Cretaceous dacitic breccia and rhyodacitic welded tuff were spread, apparently from several centers, as forerunners of the major magmatic activity that followed. All the present ranges received some plutonic intrusions of granitic rocks during the next phase (or phases) of the Laramide and in some ranges there are numerous stocks and many rock types represented. In most ranges, too, thrusting, normal faulting and tear faulting occurred during the end of the Cretaceous and the beginning of the Tertiary.

In the northern Santa Rita Mountains the geologic record also permits a distinction between a second and a third phase of the Laramide orogeny, both involving northwest-directed tear and thrust faulting. Quartz monzonite plutons were injected between these phases and quartz latite porphyry were intruded after the third phase, so that these phases are datable by radiometric means.

During the field trip we will stop at outcrops representative of the major groups of Mesozoic volcanics and sedimentary rocks: The Triassic volcanics, the red beds associated with them, the Bisbee Formation, the Upper Cretaceous sedimentary rocks, and the uppermost Cretaceous volcanics. We will also stop to see evidence of northeast-directed deformation and the evidence to separate the second from the third phase involving northwest-directed tear and thrust faults. The map pattern of folds in the Lower Cretaceous rocks truncated by unconformably overlying uppermost Cretaceous rocks and the change in the stress picture between phase 1 and 2 must suffice to demonstrate their temporal separation, for outcrops demonstrating the early Late Cretaceous unconformity are not accessible by bus.

ROAD LOG

Leave Tucson, driving east on Interstate Highway 10. Road log begins at junction of Highway 10 with State Highway 83. Figure 1 shows route of field trip and general geology.

Segmental mileage	Cumulative mileage	
0.0	0.0	Junction. TURN RIGHT (S) on State Highway 83, toward Sonoita. Empire Mountains on the left (E) are made up of Paleozoic and Mesozoic sedimentary rocks in a complexly faulted anticline. The core of the anticline is composed of a quartz monzonite stock of Laramide(?) age, which cuts across the Empire thrust fault along the western flank of the mountains. Mt. Fagan, at the north end of the Santa Rita Mountains, on the right (W) consists of Upper Cretaceous dacitic and rhyodacitic volcanic rocks that rest with angular discordance upon folded sedimentary rocks of the Bisbee Formation. In the valley between the Santa Rita and Empire Mountains the Upper Cretaceous volcanic rocks lap across the Empire thrust fault.
1.6	1.6	Roadcuts on right (W) in quartz monzonite of probable early Tertiary age, overlapped to the south by gravel of Tertiary or Quaternary age.
0.5	2.1	Bluffs to left (E) across wash are sedimentary rocks of the Bisbee Formation. In Davidson Canyon, about a mile to the east, these sediments rest unconformably upon diorite gneiss of Precambrian(?) age.
1.4	3.5	Roadcuts in south-dipping rocks of the Bisbee Formation. Hill at 1:00 is part of a west-northwest-trending syncline in quartzites of the Bisbee Formation. Low hill at 11:30 is Permian Concha Limestone and Rainvalley Formation in upper plate of the Empire thrust fault.
0.9	4.4	Enter area shown on figure 1.
1.6	5.1	Empire thrust fault is here concealed. Permian limestone in upper plate strikes north and dips 20° E. Bisbee sedimentary rocks in lower plate strike west and dip steeply north.
0.6	5.7	SLOW for sharp turn to left off highway.
0.1	5.8	Turn left (E) onto old highway and proceed 0.5 mile to STOP 1.
		Hills on right (E) side of road are capped by Glance(?) equivalent that is cut by a dike of quartz latite porphyry.

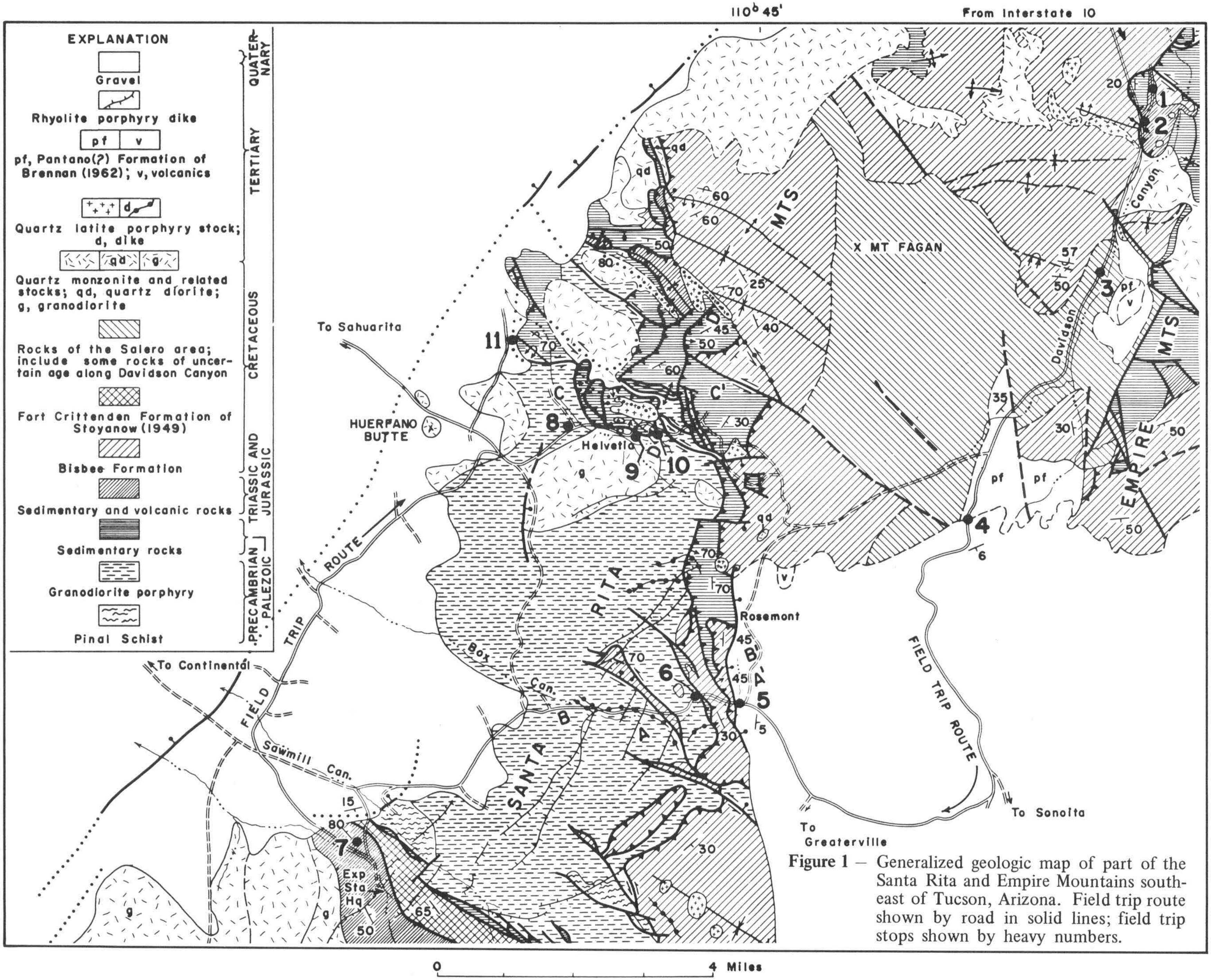

Figure 1 – Generalized geologic map of part of the Santa Rita and Empire Mountains southeast of Tucson, Arizona. Field trip route shown by road in solid lines; field trip stops shown by heavy numbers.

		STOP 1. Sedimentary rocks of probable Triassic age are exposed in roadcuts and in the slopes leading down to the arroyo to the west. They rest on the Rainvalley Formation (Permian) that forms the dip slope of the hill west of the arroyo, and they are overlain by limestone pebble conglomerate that is probably correlative to the Glance Conglomerate. Uplift, faulting, and erosion preceded deposition of the Glance(?) in the area so that only about 250 feet of the Triassic(?) sedimentary rocks remain. About a mile east-northeast, a thicker section is exposed that includes some latitic tuff in the upper part.
		If the bus cannot turn around at this stop, it may proceed 0.4 mile to borrow pit on left, turn around, and return to pick up party at STOP 1. Return to Highway 83 and STOP 2. (Road log mileage does not include detour for STOP 1.)
		STOP 2. Roadcuts in shaly rocks of the Bisbee Formation and conglomeratic mudstone of Triassic(?) age. The Empire thrust fault zone between them dips 5-10° E. Rhyolitic dikes with conspicuous flow banding seem to cut the fault zone.
0.2	6.0	Pediment gravel to left (E) across Davidson Canyon rests on eroded surface of quartz monzonite. Foothills of Empire Mountains are synclinal roof pendants of Paleozoic and Mesozoic sedimentary rocks. Hill at 12:00, west of road, is Scherrer Formation (Permian) in the west limb of the syncline. Mesozoic sediments form ridge east of road.
1.1	7.1	Quartz monzonite beneath gravel in roadcut appears to underlie the Scherrer Formation at 1:00.
		For the next 3 miles, the bedrock near the road is of sedimentary and volcanic breccias of intermediate composition of Late Cretaceous age. Some rhyolitic dikes of Tertiary age cut them.
1.4	9.0	STOP 3 (Optional). Park on left (E) at entrance to ranch road. Cuts expose volcanic conglomerate of Late Cretaceous age. Clasts in the conglomerate include sandstone and siltstone derived from the Bisbee Formation.
1.5	10.5	Pantano(?) Formation of mid-Tertiary age of Brennan, (1962) on west side of road, faulted against the Upper Cretaceous volcanic rocks.
0.3	7.4	Prospect pit at 2:30 is in carbonates of the middle member of the Scherrer Formation. The contact with quartz monzonite is a few feet below the prospect. Roadcuts ahead are in a complex of quartz monzonite, quartz latite porphyry, and rhyolite. They contain some inclusions of hornfelsed sedimentary rocks of uncertain age.
0.2	7.6	Dike of quartz latite strikes northwest, and dips 70° SW. The westerly trending ridges at 2:00 are of quartzite beds in the Bisbee Formation, which form an isoclinal syncline overturned to the south. The axial plane of the syncline dips about 55° N.
		Exposures from here to STOP 4 are of the Pantano(?) Formation.
1.0	11.5	Road to Rosemont on right. Dumps of the Rosemont mining district at 2:30 near crest of ridge.
0.2	11.7	Mid-Tertiary conglomerate along road to STOP 4.

0.6	12.3	STOP 4. Unconformable contact of Pliocene and Pleistocene gravel on conglomerate of the mid-Tertiary Pantano(?) Formation. Panorama of the south end of the Empire Mountains to the east across Davidson Canyon. Sediments of the lower part of the Bisbee Formation dip as much as 60° southeast and south in the allochthonous block of the Empire Thrust fault. Between the vantage point and Davidson Canyon sedimentary rocks of the upper part of the Bisbee Formation dip as much as 50° E. in the autochthonous block. Upper Cretaceous volcanic breccia laps across the Empire thrust fault and rests unconformably on the upturned and eroded Bisbee Formation of both blocks, indicating that the Late Cretaceous volcanism occurred after the displacement of the Empire thrust fault. Escarpment to south is eroded in Pliocene and Pleistocene gravels that are well-exposed along the road for the next 2 miles. The beds dip as much as 10° SE.
4.7	16.8	Turn right (SW) onto Greaterville and Box Canyon road.
.4	17.2	Turn right (W) at junction, keeping on main road.
1.6	18.8	Slow for Thurber Ranch.
1.3	20.1	Turn right (NW) at Greaterville junction, keeping on Box Canyon road.
1.4	21.5	Outcrops to left (SW) are of Pliocene and Pleistocene gravel, slightly tilted eastward past their initial dip.
.4	21.9	STOP 5. Bisbee Formation. Glance(?) equivalent in a limestone pebble facies, crops out south of the wash. Maroon siltstone and arkosic sandstone of the Morita(?) equivalent (Willow Canyon Formation of the Bisbee Group of Tyrrell 1964) dip eastward in roadcuts to the west. Instead of underlying the Morita (?) as is normal, the Glance(?) equivalent is thrust over that formation, where it dips westward. Small slivers of Devonian Martin Formation (not shown on generalized geologic map) are caught along the thrust fault. One such sliver is exposed low on the slope north of the road. Half a mile to the north, Mississippian Escabrosa Limestone lies along the thrust fault. The normal fault between the probable Glance and the Pliocene and Pleistocene gravel to the east is exposed in a small prospect north of the road. See sections A-A′ and B-B′ of figure 2.
.7	22.6	STOP 6. Bisbee Formation and Precambrian granodiorite. Series of roadcuts from east to west shows, respectively: (a) Morita(?) equivalent (Willow Canyon Formation of Tyrrell 1964) red siltstone and light-gray arkosic grit and sandstone, grading downward into (b) arkose, arkosic conglomerate, and arkosic sedimentary breccia facies of the Glance(?) equivalent and (c) granodiorite source rock of the arkose. Faulting near the base of the Glance is minor and the slice of Cambrian Bolsa Quartzite between the granodiorite and the arkosic conglomerate exposed south of the canyon is probably nearly in place as an erosional remnant beneath the pre-Bisbee unconformity. A half mile north of the road there is a large body of Bolsa Quartzite and the overlying Cambrian Abrigo Formation in a similar position between granodiorite and Glance(?). The rapid change in facies of the Glance(?) between STOPS 1 and 2 may be partly due to tectonic telescoping, but it may also be due to rapid initial changes that reflect local deposition around hills of pre-Bisbee age of various provenance. The age of the granodiorite has been interpreted from field evidence either as Jurassic or as Precambrian. Geologic relations used to infer a Jurassic (specifically

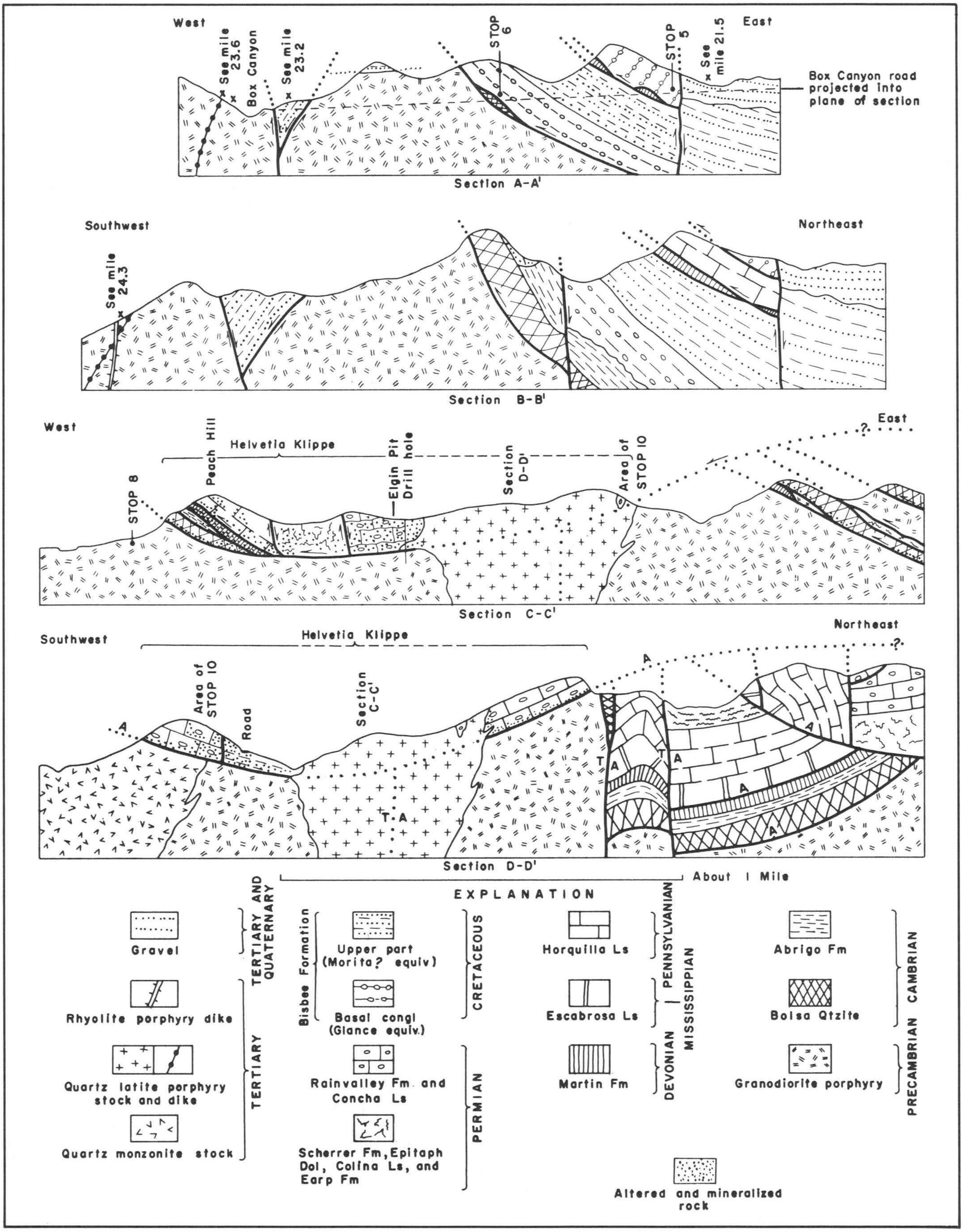

Figure 2 – Diagrammatic structure sections in area shown on figure 1. A-A′ and B-B′ along Box Canyon, C-C′ and D-D′ at Helvetia show approximate endpoints of sections (fig. 1)

a post-Paleozoic–pre-Early Cretaceous) age occur 2 1/2 miles north of Box Canyon, where there is a peculiar mixture of granodiorite and Bolsa Quartzite, a mixture suggestive of flowage of the granodiorite into the quartzite, but presently interpreted as a flowage of remobilized quartzite into the granodiorite. In most places, moreover, the basal part of the Bolsa, a 25-foot thick conglomerate, is present and is parallel to the basal contact. The shearing that does occur along that contact is probably minor south of the complexly deformed area around Helvetia and need only reflect local adjustment as the rocks were tilted and minor thrusting where the overlying Bisbee is folded. About 1 1/4 miles north of STOP 6 some of this shearing may even have predated the deposition of the Bisbee Formation.

Radiometric dates of the granodiorite include:

Pb-alpha	(zircon)	1450 ± 160 m.y.
Sr-Rb	(whole rock)	800 ± 80 m.y.
K-Ar	(biotite)	55.5 ± 1.7 m.y.

These dates are interpreted to mean that the rock was initially crystallized during the Precambrian but that reheating of some rock during the Laramide recrystallized the biotite. Recrystallization of biotite is verified under the microscope.

.6	23.2	Red beds of the Bisbee Formation appear along the road in a graben in the granodiorite. A component of tear faulting is suspected along the bounding faults but can not be unequivocally determined.
.4	23.6	Precambrian granodiorite 200 feet southeast of dry(?) waterfall was sampled for Pb-alpha and Sr-Rb radiometric dates. A thick northeast-trending rhyolite porphyry dike lies north of the road a few hundred yards west of the fall, and a thin quartz latite porphyry dike an additional few hundred yards west of the rhyolite dike.
.7	24.3	Two dikes of rhyolite porphyry (Pb-alpha, 40 ± 10 m.y.; K-Ar, 26.1 ± 0.8 m.y.) are part of a swarm of dikes that fill post-Laramide tension fractures. In the southern part of the Santa Rita Mountains a mineralized quartz vein swarm fills this fracture system. The rhyolite porphyry dikes cut a quartz latite porphyry dike exposed near the switchback 0.1 mile farther west and is again exposed downhill (W) of the switchback. These dikes form part of an older group, some of which are shoots of the late Laramide quartz latite porphyry plutons.
1.0	25.3	Precambrian granodiorite a few hundred yards below the switchback provides datable biotite (K-Ar, 55.5 ± 1.7 m.y., probably a recrystallization age).
.2	25.5	Turn left (SW) toward Madera Canyon and Continental.
2.4	27.9	Spur to left (SE) is underlain by Pinal Schist intruded by the Precambrian granodiorite. Small white cut on far side of wash about 1/4 mile south of the road exposes a gouge consisting of schist to the east and of the oldest local gravel (Pliocene and Pleistocene) to the west. Nearby, this gravel dips as much as 15° into the range. Similar young range-front faults appear along northeast-trending segments of the Santa Rita and Patagonia Mountains.
.8	28.7	Sharp turn to left (SE) just past the wash of Sawmill Canyon.
.7	29.4	STOP 7. Low roadcuts expose reddish-gray sandstone, conglomerate, and siltstone of the Upper Cretaceous sedimentary rocks. These lie along the Sawmill Canyon

fault zone, which trends southeastward across the range and contains numerous slices of Paleozoic rocks. The nearest small slice of Paleozoic rock lies on the low hill half a mile to the southeast; farther southeast the Paleozoic slices become more numerous and larger, and the stratigraphic sequence of individual fault slices is more complete. The fault zone has had a long and complex history, possibly beginning during Triassic time, and certainly involving movement during early Late Cretaceous and early Tertiary, but ending before the close of the Oligocene. Much movement need only have been vertical but some early thrust faulting occurred, and lateral displacement may also be significant, but has not been conclusively demonstrated.

Walk west to low hill. Bus continues, empty, to the sharp junction, turning right (W). It may be necessary for the bus to turn at the entrance to the corral another .4 mile up the road and then to return to the junction, now turning left (W) toward Continental.

.5	29.9	Road log mileage measurements continue to the sharp junction, and beyond the junction to pickup area but do not include the distance to corral and back.
.5	30.4	STOP 7 (continued). Bus waits at foot of hill for walkers. Outcrops on hill are of rhyodacite welded tuff and a few intercalated thin beds of quartzitic sandstone of the middle member of the formation of Mt. Wrightson (Triassic). Highest ridge to south is an extension of this unit; ridge to south-southeast is capped by andesitic and rhyolite volcanics, thick eolian sandstone, and some pillow lavas, all of the upper member of that formation; spur to west-southwest is underlain by a leucocratic quartz monzonite of Laramide age; and the saddle west of the spur is underlain by a Laramide granodiorite.
.4	30.8	Junction. Keep on main road to right (NW).
1.3	32.1	Junction. CAUTION. Turn right (NE) through cattle guard and then immediately to the left (N) onto Helvetia road.
.6	32.7	Junction. Keep straight ahead (NE) on main road.
.5	33.2	Crossroad. Keep straight ahead (NE).
1.1	34.3	Junction. Keep straight (NE) ahead on main road.
0.4	34.7	Junction. Turn right (NE) on main road crossing Box Canyon wash.
1.7	36.4	Junctions. Keep straight ahead (NE) on main road.
.6	37.0	Precambrian granodiorite east of road contains abundant pods and dikes of aplite. Huerfano Butte and pediment to northwest are underlain by Laramide quartz monzonite. At the butte there also is altered aplite.
1.5	38.5	Junction. Keep straight ahead (E) on Sahuarita-Helvetia road.
.1	38.6	Junction. Turn left (NE) on main road, to Helvetia.
.3	38.9	Cemetery on left (NW) side of road.
.9	39.8	STOP 8. Park at junction. Review geology of west side of Helvetia district. Peach Hill to northeast is underlain, in rising succession, by Precambrian granodiorite, a brown rib of tectonically thinned Cambrian Bolsa Quartzite, slivers of

metamorphosed Cambrian Abrigo Formation and Devonian Martin Formation, and a cap of Pennsylvanian Horquilla Limestone. A major thrust fault underlies the quartzite and minor ones overlie it and overlie the Martin. East of Peach Hill the rocks above this major thrust fault also include Permian and Cretaceous rocks. Together they are here called rocks of the Helvetia klippe.

The Helvetia klippe is 1 1/2 miles long and 3/4 mile wide; its well-exposed basal thrust fault dips inward to form a saucer-shaped surface. Abundant drill holes, as reported by A. M. Heyman and by F. A. Michel in their unpublished MS theses (Univ. of Arizona), provide more detail on the position and configureation of this thrust fault, and show that, where penetrated by drilling, the klippe lies on granitic rock. Present work indicates that the klippe rests on the edges of two stocks of Laramide quartz monzonite (K-Ar 52.2 ± 1.6 m.y.) and probably on a septum of Precambrian granodiorite separating the stocks. The center and eastern end of the klippe is cut by (or contains?) a small quartz latite porphyry stock of late Laramide (56.3 ± 1.7 m.y.) age. Evaluating these ages presents an additional problem, which need not involve a discrepancy with the geologic relations.

Resume trip, keeping to main road (E).

0.5 40.3 Junction. Keep to main road, straight ahead (E) and past the ghost town of Helvetia. Production has been largely of Cu, Pb, and Ag, valued at about $4 million between 1908 and 1950.

.2 40.5 Junction. Keep to main road, straight ahead (E).

.2 40.7 STOP 9. Roadcut exposes thrust fault at the base of the Helvetia klippe, here consisting of the Permian Scherrer Formation. The klippe overlies Laramide quartz monzonite (K-Ar 52.2 ± 1.6 m.y.) that underlies the entire basin to the south. Therefore the fault is part of phase 3 of Laramide deformation. Hill to east is capped by the Permian Concha Limestone, a slice of which the road crosses just to the north. Farther along the road to the northeast the Concha is separated from altered rocks of the Bisbee by a northwest-trending vertical fault zone, along which there has been considerable mineralization.

0.4 41.1 STOP 10. Walk up road on hill to the southwest for a review of the geology of the east side of Helvetia district. Range crest to the southeast is underlain by the Precambrian granodiorite, capped by steeply eastward-dipping Bolsa Quartzite. The hill on the range crest to the east, between the roads, is underlain by a small stock of quartz latite porphyry that is suggested by Michel and Heyman to be the root area of the quartz latite porphyry body involved in the Helvetia klippe. The ridge north of this hill is capped by Permian Concha Limestone and Rainvalley Formation. The low hills half a mile to the northeast of STOP 10 contain imbricate thrust slices of lower Paleozoic rocks and of Precambrian granodiorite. These thrust plates truncate several northwest-trending tear faults, a pattern repeated at other places in the district (see fig. 1). Note on the map that other tear faults merge with thrust faults, to show their contemporaneity. Several of the quartz monzonite stocks cut thrust faults and locally are injected along tear faults, thereby concealing portions of the tear. These stocks, then, serve to separate phase 2 from phase 3 of the Laramide orogeny; the one phase of deformation predates the stocks, the other phase of deformation postdates the stocks directly, or postdates the structures that controlled the emplacement of the stocks.

A problem arises here concerning the geologic relations between the quartz latite porphyry stock associated with the Helvetia klippe and the thrust fault beneath the Helvetia klippe. Does the stock cut the thrust fault, or has it been transported in, perhaps from the stock along the range crest to the east? Neither the evidence obtained from a drill hole through the edge of the small outlier of the stock directly north of Helvetia townsite, as cited by Michel and Heyman, nor the relations around the east edge of the stock provide conclusive evidence of the relations. Although the solution of this problem is immaterial to the 3-phase Laramide thesis, it may be important to the explanation of the timing and of the controls of mineral emplacement.

Walking tour of area of tear faults,east edge of Helvetia kilippe, and stock follows.

Resume trip, returning past Helvetia townsite and STOP 8.

2.5	43.6	Junction. Keep right (W) on main road toward Sahuarita.
.1	43.7	Junction. Keep right (NW) on main road toward Sahuarita.
.8	44.5	Crossroad. Turn right (NE).
1.4	45.9	STOP 11. (optional). Park at junction immediately past the cattle guard. Bus turns while group walks north along road about 100 yards to see the overturned fold of Mississippian Escabrosa Limestone and Pennsylvanian Horquilla Limestone. Dark-gray conglomeratic phyllite lies at or near the base of the Horquilla where it is as severely metamorphosed as it is here; elsewhere there are two thin clastic beds 50 to 120 feet above the base. Note that the fold axis strikes parallel to the tear faults of phases 2 and 3, to suggest the fold was formed before the northwest-trending tear faults and their associated thrust faults. The early deformation (deformations?) is geologically dated in 3 situations: (1) In several places in the Santa Rita and Empire Mountains undeformed uppermost Cretaceous volcanics lie unconformably on folded Lower Cretaceous rocks; (2) An unconformity in the northern Huachuca Mountains, 30 miles southeast of Helvetia, places Upper Cretaceous rocks across a tear fault which bounds thrust faults in Lower Cretaceous rocks; (3) Some rocks of Late Cretaceous age in the southern Santa Rita and Huachuca Mountains are folded in a system parallel to the folds in nearby Lower Cretaceous rocks. Phase 1, then, occurred during early Late Cretaceous or slightly later Late Cretaceous time, and it may not be fully synchronous throughout the region. Return to Sahuarita-Helvetia road.
1.4	47.3	Crossroad. Turn right (NW) on main road.
10.5	57.8	Follow main road to the fields along the Santa Cruz River Valley. Turn left (W).
.7	58.5	Sahuarita. End of field trip. Turn right (N) on Highway 89 for Tucson.

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ENGINEERING GEOLOGY
TUCSON AND BENSON AREAS

FIELD TRIP III

Sunday April 14, 1968

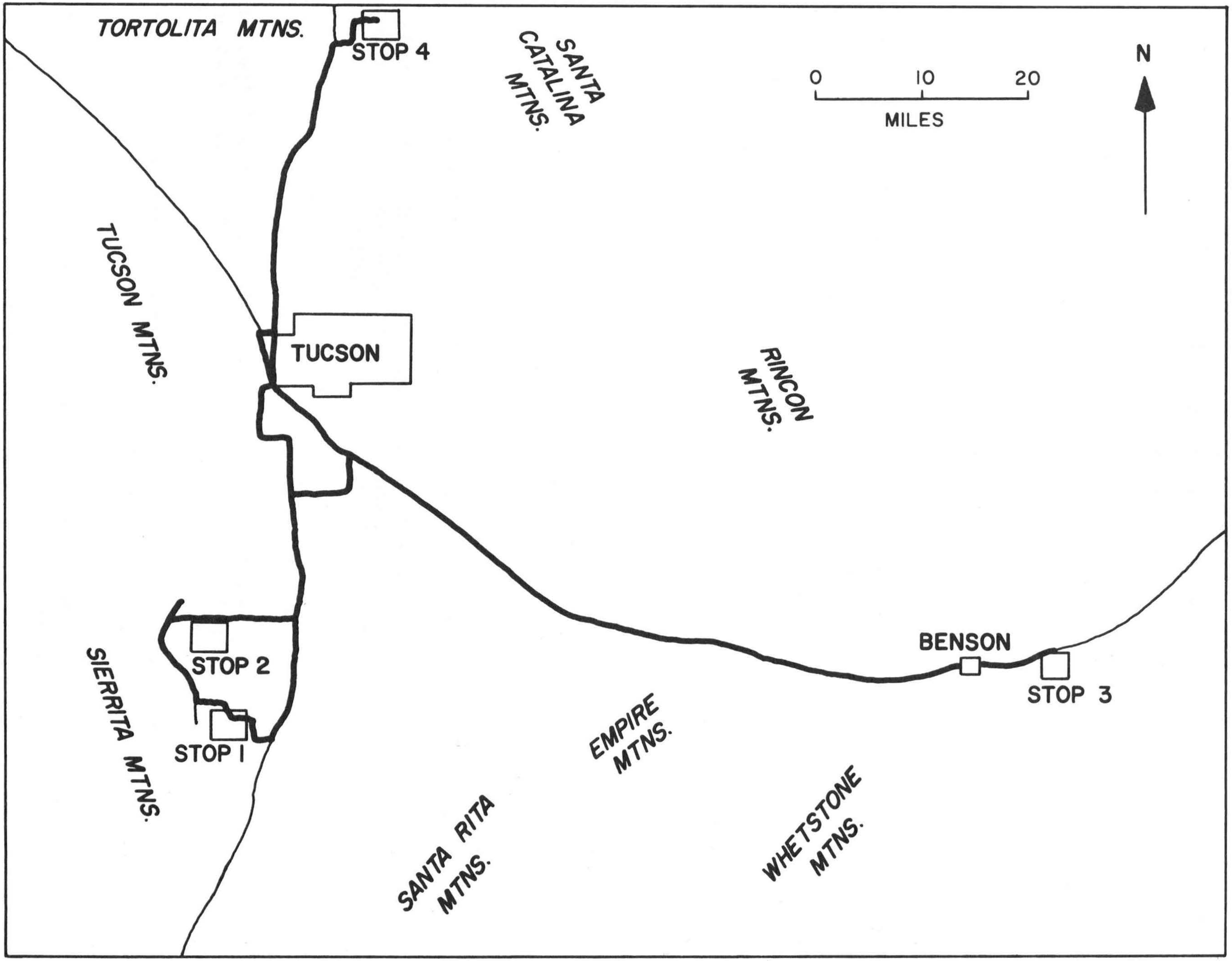
Leader: W.C. Lacy
Contributors: Frank Anderson, R.D. Call, David Hammel, G.A. Kiersch, W.C. Peters
Driving Distance: 220 Miles (Approximately)
Starting Time: 7:30 A.M.
Finish Time: 4:30 P.M. (Approximately)

GENERAL STATEMENT

The trip begins in Tucson and proceeds to the large-scale overburden stripping operation of the Anaconda Company, Twin Buttes development, south of town. Following a brief stop at the Mission Mine of the American Smelting and Refining Company for a discussion of bedrock excavation and related subjects in the engineering geology of open pit mines, the route will continue to Benson for the inspection of an uncommonly well-developed example of soil piping and collapse. The trip will end at Golder Dam, north of Tucson, with a survey of geologic and engineering conditions involved in earth-fill dams and damsites.

The assembly point will be at the Mines-Geology building, University of Arizona. The road log begins at the intersection of Speedway Boulevard and Stone Avenue. The trip will pass through Tucson during the traverse so that participants wishing to leave early for travel connections may do so.

Segmental Mileage	Cumulative Mileage	
0.0	0.0	Intersection of U. S. Highway 80 and 89 (Stone Avenue) with Speedway Boulevard. Follow Speedway toward the West.
0.8	0.8	Turn LEFT onto the Freeway approach road.
0.7	1.5	Enter Freeway, U. S. Interstate 10, WATCH FOR MERGING TRAFFIC.
0.4	1.9	The south end of the Tucson Mountains to the west of the highway, comprises deformed Cretaceous arkose and shale with Tertiary intrusives and volcanics. Sentinel Peak ("A" Mountain) is composed of flat-lying Tertiary basalt flows (Brown 1939).
1.6	3.5	TURN RIGHT onto Interstate 19.
1.6	5.1	At 2:00, Black Mountain, a mesa composed of Tertiary rhyolite at the base, San Xavier conglomerate beds in the middle, an upper andesitic zone, and capped by basaltic flows.
2.8	7.9	PROCEED EAST on Valencia Road East Cloverleaf, toward Nogales. The San Xavier Mission is visible to the south.
0.4	8.3	Rincon Mountains at 11:00, composed of foliated Precambrian gneisses in a series of westward-plunging folds. The higher Santa Catalina Mountains lie to the north of the Rincons.
1.3	9.6	TURN RIGHT on Nogales Highway, immediately past Sunnyside School.


TORTOLITA MTNS.
STOP 4
SANTA CATALINA MTNS.
0
10
20
MILES
N
TUCSON MTNS.
TUCSON
RINCON MTNS.
STOP 2
BENSON
STOP 3
STOP I
EMPIRE MTNS.
SIERRITA MTNS.
SANTA RITA MTNS.
WHETSTONE MTNS.

ROAD LOG MAP

0.1	9.7	Santa Rita Mountains between 10:00 and 12:00. Sierrita Mountains to the right of the highway; this range, and the Pima Mining district in its eastern foothills, has been the site of silver, lead, zinc, and copper mining since Spanish Colonial times and is now the most active mining development area in Arizona.
2.3	12.0	Twin Buttes, near Anaconda's new open pit mine at 1:00. Mission Mine and Pima Mine dumps at 2:00.
5.2	17.2	At 3:00, near highway, massive erosion caused primarily by overland flooding from Santa Cruz River during December 1965.
4.1	21.3	Sahuarita. School buildings at 3:00 have been subject to severe foundation problems resulting from what appears to be collapsing soil.
1.9	23.2	Large dumps at 2:00 are dikes for tailings from the Twin Buttes concentrator.
0.9	24.1	Santa Cruz River.
2.1	26.2	TURN RIGHT on Duval Mine Road.
0.6	26.8	TURN RIGHT on La Canada Road.
0.9	27.7	TURN LEFT on Twin Buttes Mine Road, gravel road.
2.6	30.3	STOP No. 1. Gate to Twin Buttes Mine. Cars will be escorted through the mining area by Anaconda Company guides. NOTE: The mileage involved during this part of the tour is not included in the road log.
0.0	30.3	Return to mine gate, retrace route for 0.4 miles.
0.4	30.7	TURN LEFT.
1.5	32.2	TURN LEFT.
1.4	33.6	TURN RIGHT on Mission Road, paved road.
1.6	35.2	Helmet Peak, at 1:00, consists of Paleozoic limestone folded into a sharp south-southeastward plunging anticline. It is a fault-bounded block flanked by Cretaceous (?) rocks. Klippen resembling Helmet Peak have been investigated by drilling to the south and east of Helmet Peak (Copper 1960).
2.4	37.6	San Xavier Mine, one of the most important producers of lead and zinc in Arizona from 1943 to 1952. The mine was in operation from 1880 until 1959. Replacement ore bodies have been developed to a depth of 900 feet. Oxidation extends irregularly to a depth of 400 feet.
0.7	38.3	Banner Mining Company Mineral Hill Mine and concentrator at 2:00. The mine was a copper producer during the 1950's. The concentrator with a capacity of 1000 tons per day, formerly served the Mineral Hill and Palo Verde Mines; it is now being used in metallurgical research.
1.3	39.6	TURN RIGHT on Pima Mine Road.
1.0	40.6	Palo Verde Mine. The 1000-foot shaft intersects high grade copper ore in tactite.

0.4	41.0	TURN RIGHT to Mission Pit observation point.
0.2	41.2	STOP No. 2. An explanation of geological features and engineering geology problems will be given. The geology of the Mission Mine is covered by Kinnison 1966.
0.2	41.4	TURN RIGHT on Pima Mine Road and continue eastward.
0.6	42.0	At 3:00, Mission concentrator, capacity 15,000 tons per day.
5.1	47.1	Santa Cruz River. Present natural entrenchment began in 1893–outset of major trenching of entire Santa Cruz system. Ensuing water table changes and human activities have altered the vegetation pattern (Hastings and Turner 1965).
0.8	47.9	TURN LEFT, following Nogales Highway to the north.
6.1	54.0	TURN RIGHT, onto Hughes Access Road.
6.5	60.5	TURN RIGHT (North) onto Palo Verde Boulevard.
0.6	61.1	TURN RIGHT onto Benson Highway (U. S. 80). Watch for major traffic.
9.3	70.4	At 9:00, Tanque Verde Ridge, a spur of the Rincon Mountains displaying a broad westward plunging anticline in gneiss.
4.9	75.3	At 10:00, the foothills in the vicinity of Colossal Cave are formed in overthrust blocks of Paleozoic sediments. Between the Rincon Mountains, to the north of the road, and the Santa Rita Mountains to the south there are patches of crystalline rocks representing the remnants of thrust plates. Pantano beds of Miocene (?) age underlie the thrusts in many places and also constitute many of the exposures in road cuts within the next six miles.
2.9	78.2	At 1:00 are the Whetstone Mountains comprising sharply folded and faulted Paleozoic and Mesozoic sediments (Tyrrell 1957). At 2:00 are the Empire Mountains with a granitic core, with a mantle of Cretaceous sediments, and with Paleozoic klippen remnants (Galbraith 1959). At 3:00 are the Santa Rita Mountains.
2.1	80.3	Road cut in coarse conglomeratic Pantano beds of Miocene (?) age. The Pantano formation in this area consists of about 13,500 feet of conglomerate, sandstone, mudstone, and argillaceous limestone with local flows of andesite porphyry.
1.0	81.3	Cretaceous sediments in road cut.
3.4	84.7	Cienega Creek. Pantano beds in road cuts on both sides of creek and from this point to Amole overpass.
3.3	88.0	Amole overpass.
2.5	90.5	Road cuts in steeply dipping Cretaceous sandstone, siltstones, and shales.
7.1	97.6	San Pedro Valley ahead (Smith, D. G. 1963). Benson is a center for ranching, irrigation farming, and mining. Quaternary deposits in the San Pedro Valley include fluvial, alluvial and lacustrine-like material ranging from Illinoian fan alluvium on the long slope from the Whetstone Mountains to Kansan valley fill deposits along the river. At 1:00 are the Dragoon Mountains (Gilluly 1956). At 12:00 are the Little Dragoon Mountains (Cooper and Silver 1964).

Figure 1 – View from the west looking eastward toward Santa Cruz Valley. Pima Mine nearest and on the right and ASARCO's Mission Mine on the left. Note displacement of benches within slump pattern in the Pima pit. –Photograph by Tad Nichols

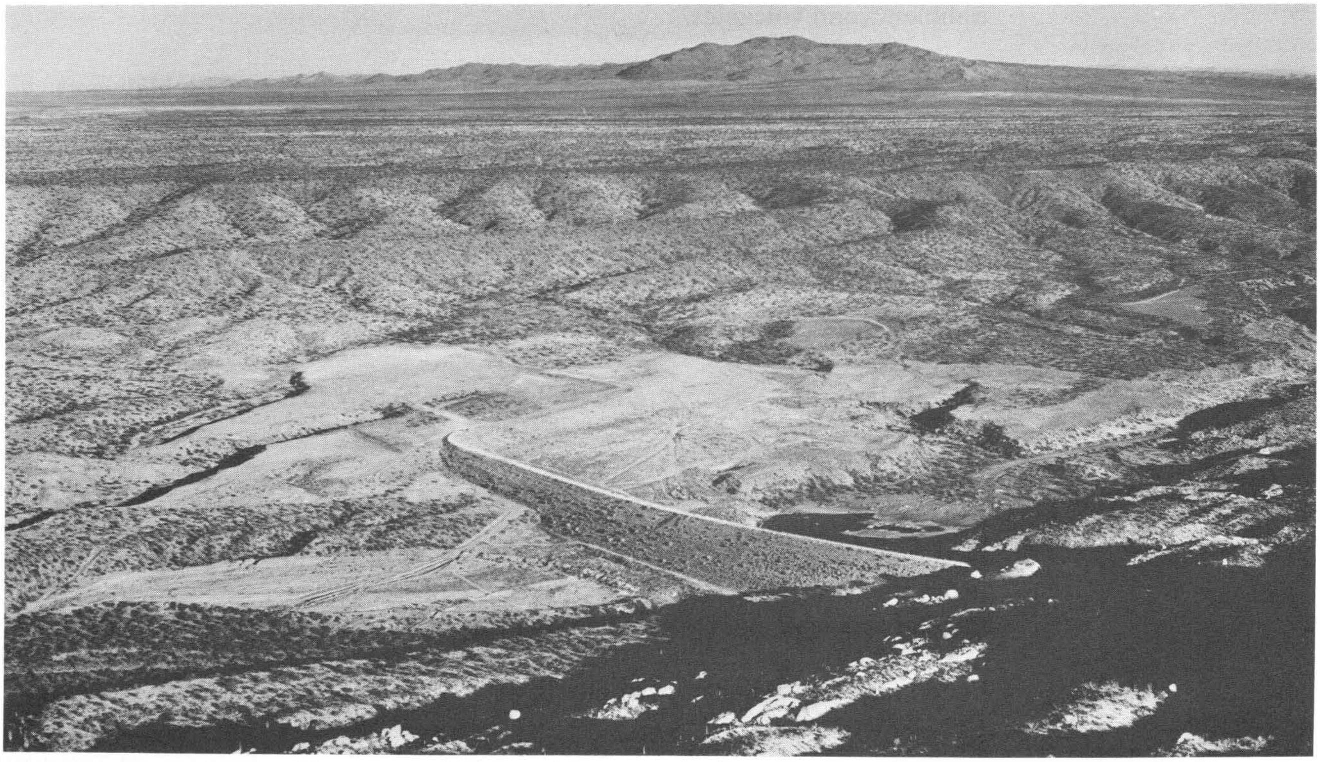


Figure 2 – Golder Dam. View across Bajada looking westerly from Catalina Mountains toward Tortollita Mountains. –Photograph by Tad Nichols

1.7	99.3	Red siltstones to the south and southwest of the highway are part of late Pliocene to early Pleistocene valley fill.
1.6	100.9	TAKE LEFT FORK, Route 86, toward Wilcox.
0.3	101.2	San Pedro River.
3.0	104.2	STOP No. 3. Cars will be guided to parking area. A short walk is necessary to view soil piping and collapse. References on piping phenomena in this general area include Jones 1967, Benites 1967, and Anderson 1968.
0.0	104.2	Back to cars for return to Tucson and Golder Dam.
0.3	158.9	Santa Catalina Mountains at 1:00 to 2:00 (DuBois 1959 and Pierce 1958). The core of the range is a granitic-gneissic complex with Precambrian and post-Cretaceous components. Precambrian, Paleozoic, and Cretaceous (?) sediments are exposed along the eastern flank. The western and southwestern flanks, toward the viewer, are principally gneisses and metasediments. Major deformation and metamorphism have been assigned to Precambrian and Tertiary stages. In addition, late Cenozoic beds on the margins of the range have been faulted and folded. To the west, at 9:00, is the northern part of the Tucson Mountains. Safford Peak, near the north end of the range, is a dacitic volcanic neck. Wasson Peak, the highest point in the range, consists of arkosic sediments of Cretaceous age plus granitic and monzonitic intrusives. Many of the small outlying hills along the eastern front of the range are klippen of Paleozoic limestone resting on Cretaceous sediments and volcanics.
43.1	147.3	CONTINUE on highway (Junction of Palo Verde Boulevard with highway).
3.0	150.3	CONTINUE on Freeway, Interstate 10, over ramp.
3.0	153.3	Sentinel Peak ("A" Mountain) and Tumamoc Hill at 9:00 in the Tucson Mountains. To the north of Tumamoc Hill are tilted rhyolitic and andesitic volcanics.
4.0	157.3	"Miracle Mile" exit, LEAVE FREEWAY.
1.3	158.6	Intersection, just past Evergreen Cemetery. TURN LEFT on Highway 80 and 89 toward Florence. WATCH MERGING TRAFFIC.
2.0	160.9	Rillito Bridge. Rillito Creek, similar to most drainages near Tucson is subject to periodic flooding. In December 1965, this creek washed out bridges at North Campbell Avenue and First Avenue to the east of this point. Rillito Creek and its major tributary, Pantano Wash, are the sources of most of the material for the mineral aggregate industry in Tucson (Williams 1967).
0.3	161.2	Road cuts in dissected alluvial fan gravels.
1.8	163.0	Frost-free citrus farming belt along the foothills of the Santa Catalina Mountains. Irrigation is from wells ranging in depth from 300 to 700 feet. The static water level is about 200 feet.

1.2	164.2	At 11:00 are the Tortolita Mountains, composed of Precambrian granite, schist, and gneiss with smaller areas of Paleozoic limestone and with Cretaceous to Teritary volcanics.
2.7	166.9	Intersection of two major normal faults in the Santa Catalina Range. One, trending West-Northwest, bounds the Tucson Valley. Another major fault, trending northeast, forms the western front of the mountains.
2.9	169.8	Pusch Ridge, the spur of the Santa Catalina Mountains at this point, displays an asymmetrical anticline in gneiss.
2.9	172.7	Canada del Oro Bridge. Golder Dam is in the upper reaches of Canada del Oro Creek. At 2:00 is Mount Lemmon, part of a local Winter sports area.
4.9	177.6	TURN RIGHT on Hardin Road.
2.1	179.7	TURN LEFT on paved road.
0.3	180.0	TURN RIGHT on dirt road at "Lago del Oro" sign.
1.4	181.4	TURN LEFT at "Golder Dam" direction sign.
1.1	182.5	CONTINUE past Cattle Guard.
3.0	185.5	View of Golder Dam.
0.7	186.2	STOP No. 4, for an explanation of the geologic setting, engineering problems, and control measures at the dam.
0.0	186.2	Return to cars for trip to Tucson.
26.8	213.0	Stone Avenue and Speedway Boulevard intersection, end of logged mileage.

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STRUCTURE AND ORE DEPOSITS OF THE PIMA MINING DISTRICT *

FIELD TRIP IV

Leaders: Dean Lynch and S. R. Titley
Driving Distance: 93.0 miles
Logged Distance: 46.5 miles

GENERAL STATEMENT

The Pima Mining District has been the subject of intense interest and organized study on the part of mining companies for the past fifteen years and as a consequence, it has yielded four new major copper ore bodies—The Pima mine, the Mission development, Esperanza mine and Anaconda. These properties all depart somewhat from the usual character of "porphyry copper" deposits and open the possibilities for additional discoveries.

The structural environment of these ore bodies is exceedingly complex and there is no general agreement as to either the character of the structural elements or the chronology of events. All features appear to reflect continued left-lateral movement along a west-northwest direction.

The field trip route leads south from Tucson to the eastern slope of the Sierrita Mountains where isolated hills rise above the bajada to reveal a kaleidoscopic version of the underlying geology.

The starting point of the road log is the Third Street entrance to the University of Arizona at Park Avenue. The caravan will disband after the Esperanza mine stop and individual parties may return to Tucson immediately, or, if they prefer, remain to visit additional points of interest along the route.

Segmental Mileage	Cumulative Mileage	
0.0	0.0	Intersection of Park Avenue with Third Street at entrance to the University of Arizona. Follow Park Avenue southward.
7.0	7.0	Intersection of Park Avenue and Valencia Road. Turn right on Valencia.
1.8	8.8	Freeway overpass. At 1:00, the southern Tucson Mountains composed essentially of strongly deformed Cretaceous arkose and shale and Tertiary intrusive and volcanic rocks.
1.8	10.6	Intersection of Valencia and Mission Roads. Turn south on Mission Road. Enter San Xavier Indian Reservation.
1.8	12.4	STRAIGHT AHEAD, follow Twin Buttes Road. Mission Road turns off to the left to Mission San Xavier del Bac. At 2:00, Black Mountain, a lava capped mesa which rises 1,000 feet above its base to an altitude of 3,703 feet. In ascending order it is composed to speckled rhyolite, "San Xavier conglomerate beds," andesite flows, all of middle (?) Tertiary age.
		Most of the San Xavier Indian Reservation is covered by alluvial deposits which range in age from Tertiary through Quaternary. The older alluvium is encountered widely in well borings. South of Black Mountain, the older alluvium averages about 200 feet thick and appears to have been deposited on a moderately rolling surface with shallow northeast-trending valleys separated by ridges. Southeast and northwest of the reservation, well logs indicate that the alluvium is at least 700 feet thick.

* This Road Log is modified after Lacy and Titley (1959), AGS Guidebook II

1.2	13.6	At 12:00, the Sierrita Mountains and their northeast-sloping pediment with occasional peaks rising above its surface. Cretaceous arkose and Tertiary volcanic rocks are found west of the road just north of the southern reservation boundary. Heindl (1959) proposes a N 60° W fault between these rocks and the Precambrian granites to the south.
7.6	21.2	Intersection of Twin Buttes Road and Pima Mine Road. Turn left and continue east.
1.0	22.2	At 3:00, Palo Verde headframe originally owned by Banner Mining Company and now under lease to Anaconda.
.4	22.6	At 3:00, Mission Mine public viewing point. At 1:00, ASARCO Mill and waste dumps.
.3	22.9	ASARCO haul road overpass. At 9:00 waste dumps.
.7	23.6	Entrance to Mission Unit, ASARCO. Watch for concentrate trains.
.3	23.9	STOP 1. Mission Unit. (Dennis Hall & others) Leave Mission Mine and return to Pima Mine Road and turn left. Continue to intersection of Pima Mine Road & Twin Buttes Road.
2.7	26.6	Twin Buttes Road, turn south and continue.
.6	27.2	At 9:00, the north end of Mineral Hill composed of Cambrian Bolsa Quartzite resting uncomformably upon Precambrian granite. Klippen of Paleozoic limestone rests on Precambrian granite at 3:00.
.6	27.8	At 9:00, Banner Mining Company's Mineral Hill mine. The Mineral Hill mine has been worked intermittently since 1882. Its present activity dates from 1951 and it has capacity to produce the treat 400 tons per day of high-grade copper ores.
		Ore bodies occur at or near contacts of Tertiary(?) granite intrusives with Paleozoic limestone and quartzite. The deposits are pyrometasomatic type with contact zoning of the tactite and ore minerals. The principal ore bodies are aligned along an east-west reverse fault which dips 35°-50° to the south. This fault has been offset by north-trending vertical tears. Three hundred feet below the surface, granite forms the footwall of the reverse fault. Ore bodies are localized where fault intersections occur adjacent to intrusives. A hydrated garnetite, locally called "clay-garnet," is the most favored host rock. Ore shoots are irregular in size and distribution and they generally dip at a flatter angle than the localizing reverse fault.
		Principal copper mineralization is as chalcopyrite, with minor bornite and chalcocite associated with local magnetite, pyrrhotite, molybdenite and scheelite.
		The mine was closed down by a strike in May of 1963 and never reopened. Subsequently, the Anaconda Company leased most of Banner's holdings in Pima County. Anaconda is presently using the facilities as a pilot mill for their Twin Buttes operation.
.9	28.7	At 9:00, San Xavier mine, among the earliest of Arizona's lead/zinc producers, was worked by Jesuits and Spaniards prior to 1875.

Ores are essentially of lead and zinc with values in copper and silver. They are typical pyrometasomatic deposits, although they cannot be related directly to any intrusive. Ore bodies occur in a wedge of Paleozoic limestone bounded by east-west reverse faults dipping at about 55° to the south. Where these reverse faults are intersected by vertical north- to east-trending tear faults, steeply dipping ore shoots are formed. Intersections of the reverse faults with flat thrusts have formed flat-lying ore shoots. Ore mineralization has replaced these brecciated zones within the limestones, particularly where earlier metamorphism had converted the limestone to a hedenbergite tactite. The principal ore minerals are galena, sphalerite and chalcopyrite; these replace the silicate minerals in the tactite. Ore bodies have been developed to a depth of 900 feet below the surface. Oxidation extends erratically to a depth of 400 feet.

Outcroppings adjacent to the road indicate the complexity of structure and show the typical lead-zinc gossan in the altered tactite.

At 5:00, on West San Xavier Hill, Paleozoic limestone has been thrust over Precambrian granite. A klippe of limestone caps the northward-trending ridge and a syenite intrusion has come in along the thrust with accompanying metamorphism and copper mineralization. This is the northwest edge of the large San Xavier thrust which can be traced for three miles to the south where it is cut off by a left-lateral fault. To the north it disappears under alluvial cover at the edge of the San Xavier Indian Reservation.

.2	28.9	Banner Mining Company Research Laboratory. The company is currently engaged in metallurgical research to profitably process copper oxides in limestone gangue. Mr. Alan Bowman, President, Banner Mining Company reports that initial results are very encouraging.
.1	29.0	A part of the Lower (?) Cretaceous section consisting of arkose and shale is exposed in the wash. To the east, up the wash, plug-like bodies of intrusive andesite and breccia are exposed cutting the sedimentary rocks.
.2	29.2	TURN RIGHT on Dogtown Mines Road. You pass by dumps of many old lead-silver mines of the Olivette group of claims. Between 1886 and 1893 about $740,000 value in silver was removed from these claims from narrow fissure veins striking from north to east and dipping at about 40° to the east and north. Ores contained chalcopyrite, bornite, freibergite, sphalerite and galena along with pyrite and crustiform quartz. Ore shipments are reported to have carried 20 percent lead and 100 to 300 ounces of silver.
1.9	31.1	Road intersection, keep straight ahead.
1.3	32.4	STOP 2. This is the site of the Paymaster mine, which lies along the western edge of the San Xavier thrust sheet. Brecciated intrusive andesite and Cretaceous (?) arkosic quartzite are thrust over Precambrian (?) granite along this fault zone. The breccias and thrust zone have been strongly silicified. Klippen of brecciated andesite and quartzite form low hills to the west of the thrust sheet. From a vantage point on the top of the small hill immediately northwest of the Paymaster mine, the San Xavier thrust can be traced by color differences and different topographic expression of the Precambrian (?) granite and the Cretaceous clastics and intrusives on either side of the fault. The Paymaster mine is estimated to have produced about $220,000 in silver and lead from 1887 to 1908. The ore occurs in narrow fissures striking north-northeast

		and dipping steeply to the west. It is reported that at 250 feet in depth below the surface the veins dip to the east and follow down the andesite breccia-granite contact. Two veins were developed: the Lead vein which contained principally galena; and the Iron vein which carried pyrite with a little chalcopyrite and tetrahedrite. The veins were gougey and had suffered from vigorous post-mineralization faulting in the general plane of the veins.
		Return by same road.
1.3	33.7	Dogtown Road intersection, keep to the right. You are passing by an andesite intrusive cut by many small veins.
.5	34.2	Intersection, keep left.
.3	34.5	STOP 3. Breccia Hill. The origin of the silica-cemented quartzite breccia is unknown. It may be (1) of sedimentary origin; (2) as intrusive breccia-pipe structure; (3) a breccia related to the San Xavier thrust; (4) a klippe of a second overlying thrust sheet; or (5) a frontal phase adjacent to an intrusive plug.
1.3	35.8	At 9:00, on a little hill about 50 yards north of the road there is a thin limestone bed in the Cretaceous (?) clastics carrying abundant fossil algae and oysters.
.1	35.9	Twin Buttes Road. Pima dumps at 12:00. At 11:00, Helmet Peak rises beyond East San Xavier Hill. Helmet Peak is composed of Paleozoic limestone folded into a sharp anticlinal fold that plunges steeply to the south-southeast. It is bounded by faults and, at least in part, has been thrust to the south and east over Cretaceous (?) rocks. This is shown by klippen of limestone whose nature has been demonstrated by drilling south and east of Helmet Peak. The axis of the Helmet Peak fold has been swung out of alignment with the other folds of the area during a period of westward thrusting.
		Turn right on Twin Buttes Road.
.2	36.1	STOP 4. Follow down wash to the east for 50 yards. The "Helmet fanglomerate," of possible middle Tertiary age, is separated from Tertiary tuff to the north by a fault—or is it a sedimentary contact? The fanglomerate and tuff appear to be essentially postmineral.
		Immediately past this stop is a road labeled "Sahuarita Road". This is an error by the Pima County Highway Dept. This is the original Helmet Peak Road. However, it does come out at Sahuarita.
.1	36.2	At 1:00, CWT Headframe.
.4	36.6	Amygdaloidal andesite porphyry flow or shallow sill in "Helmet" fanglomerate.
.5	37.1	About 600 yards west of the road is an andesite dike cutting the "Helmet" fanglomerate.
1.5	38.6	Road to Continental Exploration, Inc. CWT Unit, Nevada Shaft. Follow Twin Buttes Road.
.8	39.4	Straight Ahead. Sahuarita Road turns left.

Figure 1 – Twin Buttes (Anaconda) development in January 1968, viewed from the east. Sierrita Mountains in the background with Esperanza Mine showing near top-center of photograph. Twin Buttes pit just visible beyond dumps in the foreground. Twin Buttes are just within right edge of photograph near the top.

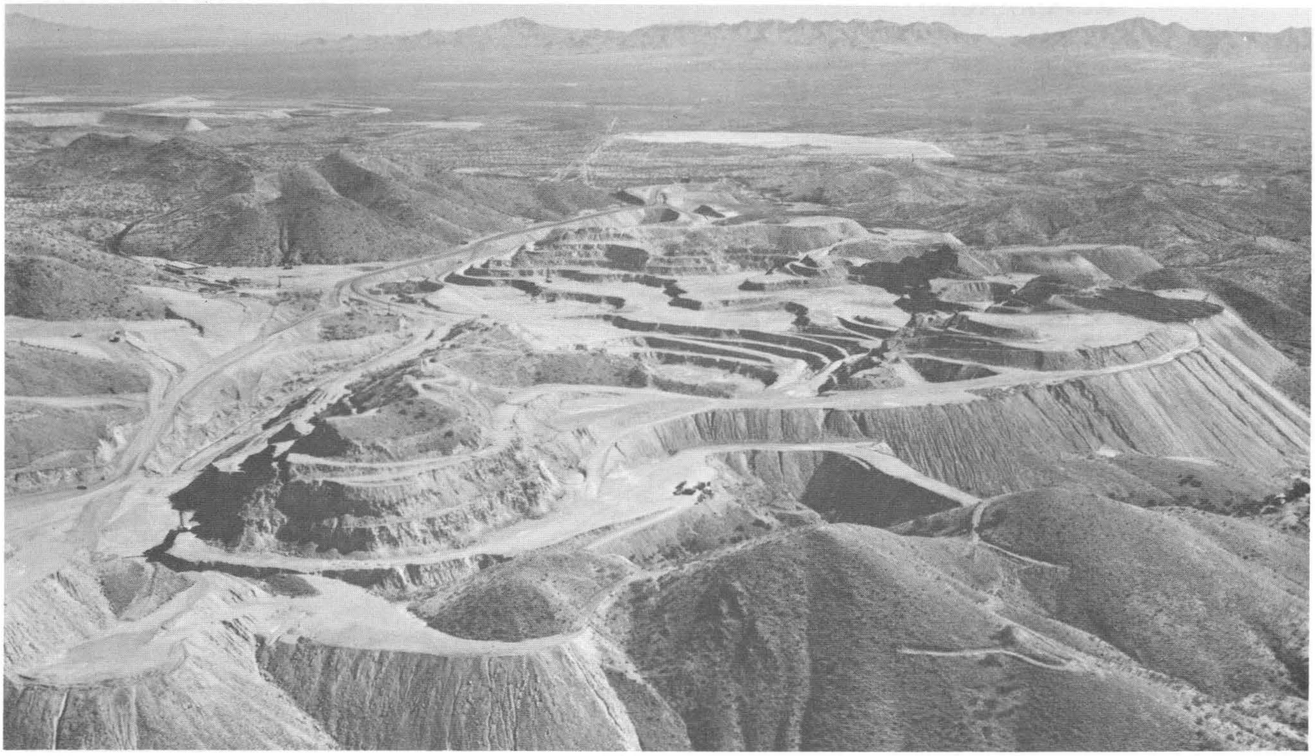


Figure 2 – Esperanza Mine viewed from the west in January 1968 looking across the Santa Cruz Valley toward the north end of the Santa Rita Mountains on the skyline. Tailings pond in the middle distance and Twin Buttes development near the top-left portion of the picture. Sierrita development to take place in ground of bottom-right portion of photograph. –Photographs by Tad Nichols

.3	39.7	Keep Right. Access road to Anaconda millsite to the left. Follow new alignment of Twin Buttes Road.
.7	40.4	At 9:00, Anaconda overburden dumps. 460 feet of overburden to strip before they reach bedrock. At 12:00, McGeeville at the base of the Sierrita Mts. At 8:00, Copper Queen Mine. During the nineties various gophering operations were carried on in the oxide copper showings in this area south of Twin Buttes. In 1905 the Twin Buttes Mining Company was formed and a railroad was built from Tucson. Remains of an old engine can still be seen just north of the Copper Glance mine. Operations were carried out until 1913 with the greatest attention concentrated on the Morgan group, a mile southwest of the Queen mine. Since that time, these properties have been profitably exploited by a series of leasors and companies. A total of over eight million dollars in copper has been removed from ore bodies in tactite. Road cut is through Paleozoic limestone.
1.5	41.9	Straight Ahead. McGee Road turns right. Microwave transmission tower on the left.
1.8	43.7	Duval Mine Road. Stop. Turn right.
2.8	46.5	Duval Mine Gate. (Lynch) You may return to Tucson along the same route by which you came, or follow the Duval Mine Road 7.2 miles to its intersection with U. S. Highway 89, turn left and follow it to Tucson.

REFERENCE

Heindl, L.A., 1959; Geology of the San Xavier Indian Reservation, Arizona; Ariz. Geol. Soc. Guidebook II, 1959, p. 152-159.

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

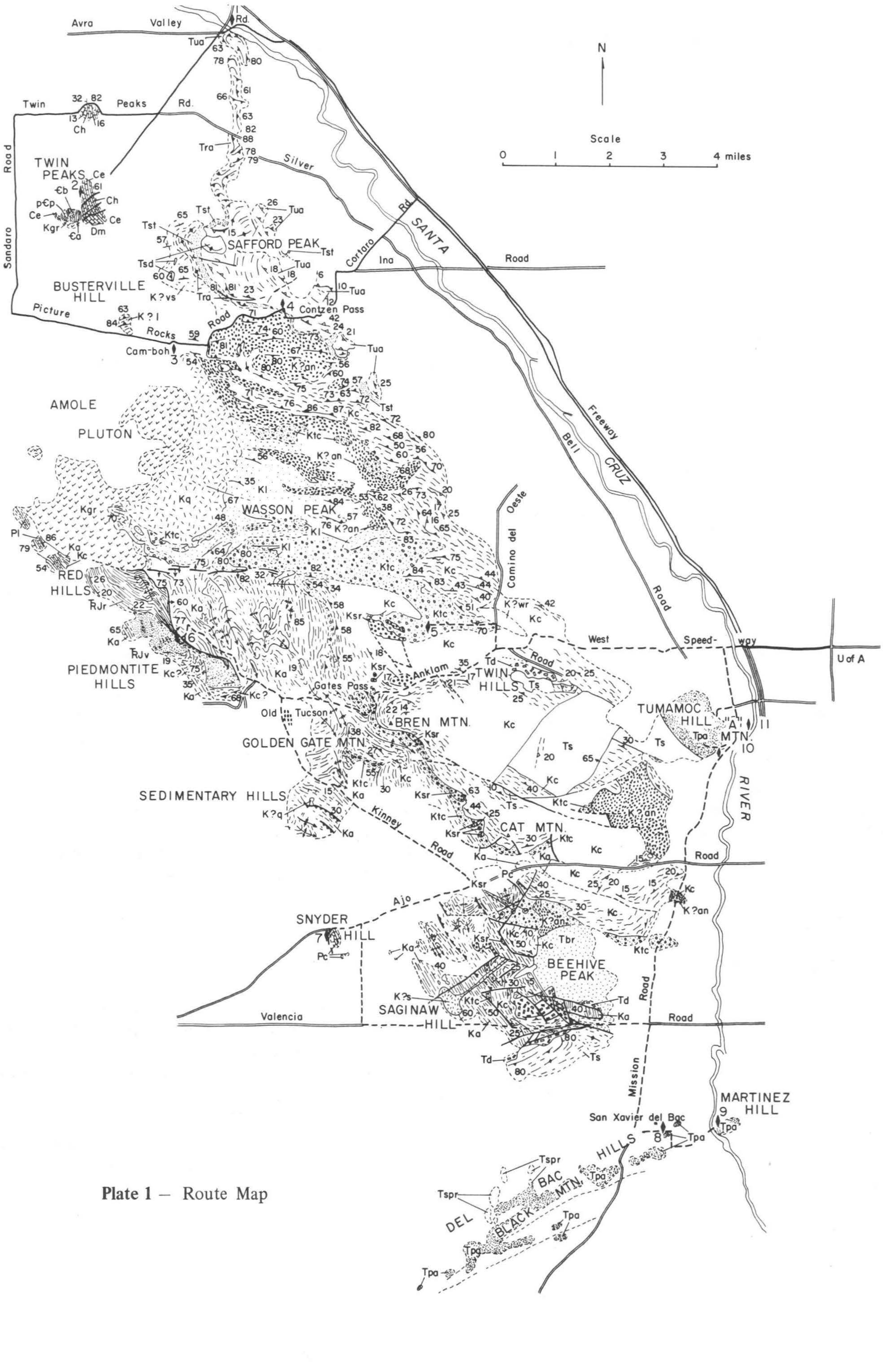


Plate 1 – Route Map

EXPLANATION

♦1 — ♦2 — ♦3 — Field trip route and numbered stops.
——————— First day
- - - - - - - - Second day

Geologic Formations

Northern Tertiary Sequence

Tsd	Safford Dacite
Tua	Upper Andesite
Tst	Safford Tuff, Safford Conglomerate, and vitrophyre
Tra	Rillito Andesite

Central and Southern Tertiary Sequence

Tpa	Potassic basaltic andesite turkey track porphyry, rhyolitic ash flows and conglomerates
Ts	Shorts Ranch Andesite
Tbr	Biotite rhyolite
Td	Diopside (Ivy May) andesite
Tspr	Speckled rhyolite (place in sequence unknown)

Mesozoic Sequence

Ksr	Spherulitic rhyolite	K?wr	Warrens Ranch Latite
Kc	Cat Mountain Rhyolite	Kl	Amole Latite
Ktc	Tucson Mountain Chaos	K?an	Various andesites associated with Ktc. Some may be Tertiary or pre-Cretaceous.
K?s	Saginaw porphyry		
Kgr	Amole Granite	K?q	Granite and quartz monzonite of Sedimentary Hills
Ka	Amole Arkose	Kq	Amole Quartz Monzonite
TRJr	Recreation Red Beds	K?vs	Sedimentary rocks of volcanic origin. May be older than Cretaceous.
K?l	Apparent quartz latite flow breccia at Busterville Hill	TRJv	Volcanic conglomerates, etc. (older than 150m.y.)

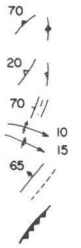
Paleozoic Section

Dm	Martin Limestone	Pc	Concha Limestone
€a	Abrigo Limestone	Ch	Horquilla Limestone
€b	Bolsa Quartzite	Ce	Escabrosa Limestone
Pl	Undifferentiated Paleozoic limestone		

Precambrian

p€p	Pinal Schist

Structure Symbols



Flow structure (or eutaxitic structure) in igneous rocks, steep, vertical
Same, dipping less than 45 degrees.
Attitude of bedding in sedimentary rocks.
Trend and plunge of anticlinal axis; synclinal axis
Fault, with dip. Fault approximately located.
Thrust fault, triangles on upthrown block

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 northeast, 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.

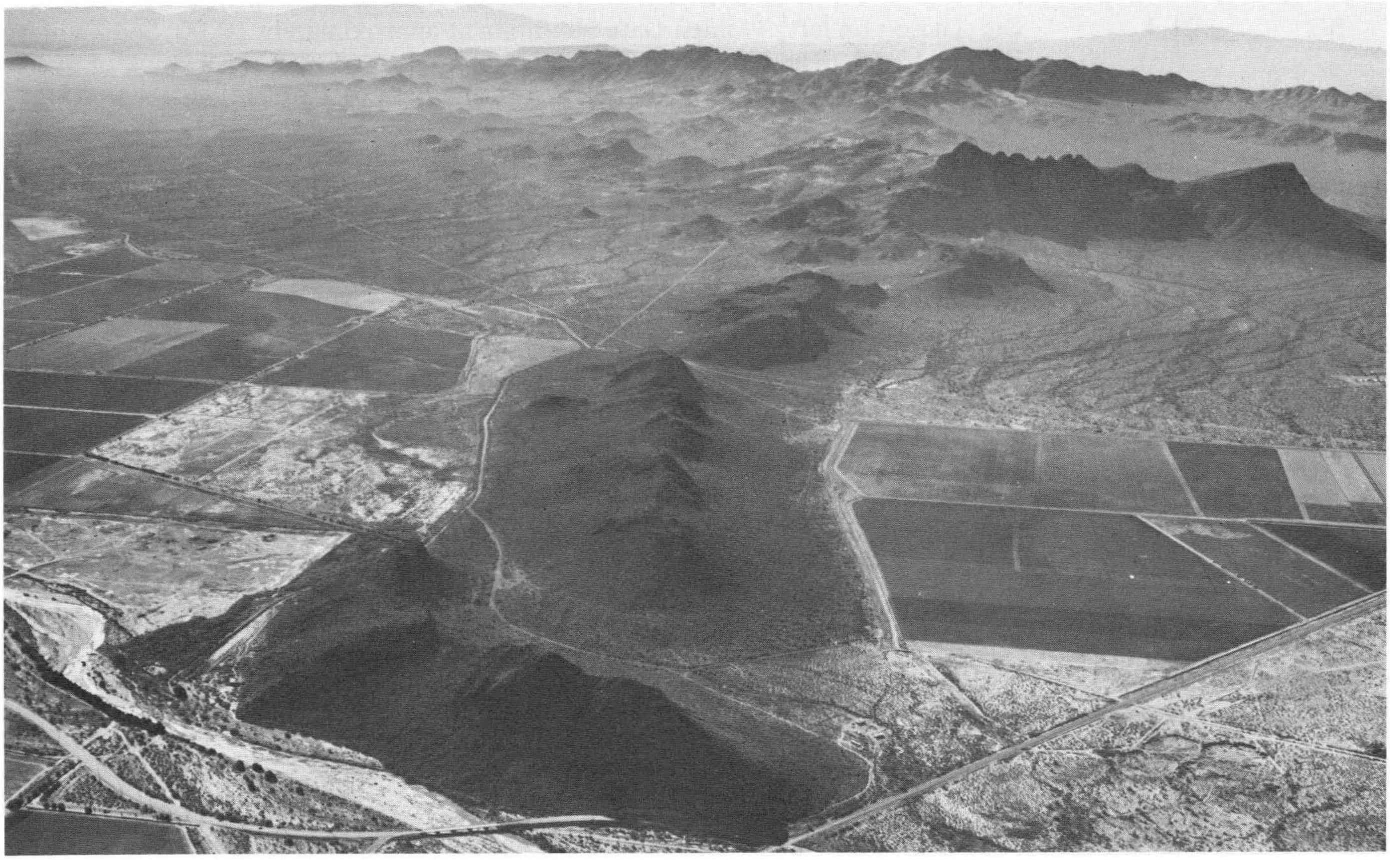


Figure 1 – Tucson Mountains viewed from the north. Safford Peak near the east end of the long east-trending ridge in upper third of photograph. Wasson Peak is flat topped ridge on skyline. –Photograph by Tad Nichols

		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

QUATERNARY GEOLOGY OF THE SAN PEDRO RIVER VALLEY

FIELD TRIP VI

64th Meeting of the Cordilleran Section GSA
University of Arizona, Tucson, 1968

Co-leaders: Vance Haynes, P. J. Mehringer, Jr., Everett Lindsay, George Lammers, and Larry D. Agenbroad
Driving Distance: 170 miles
Starting Time: 8:00 A.M.
Assembly Point: Ramada Inn

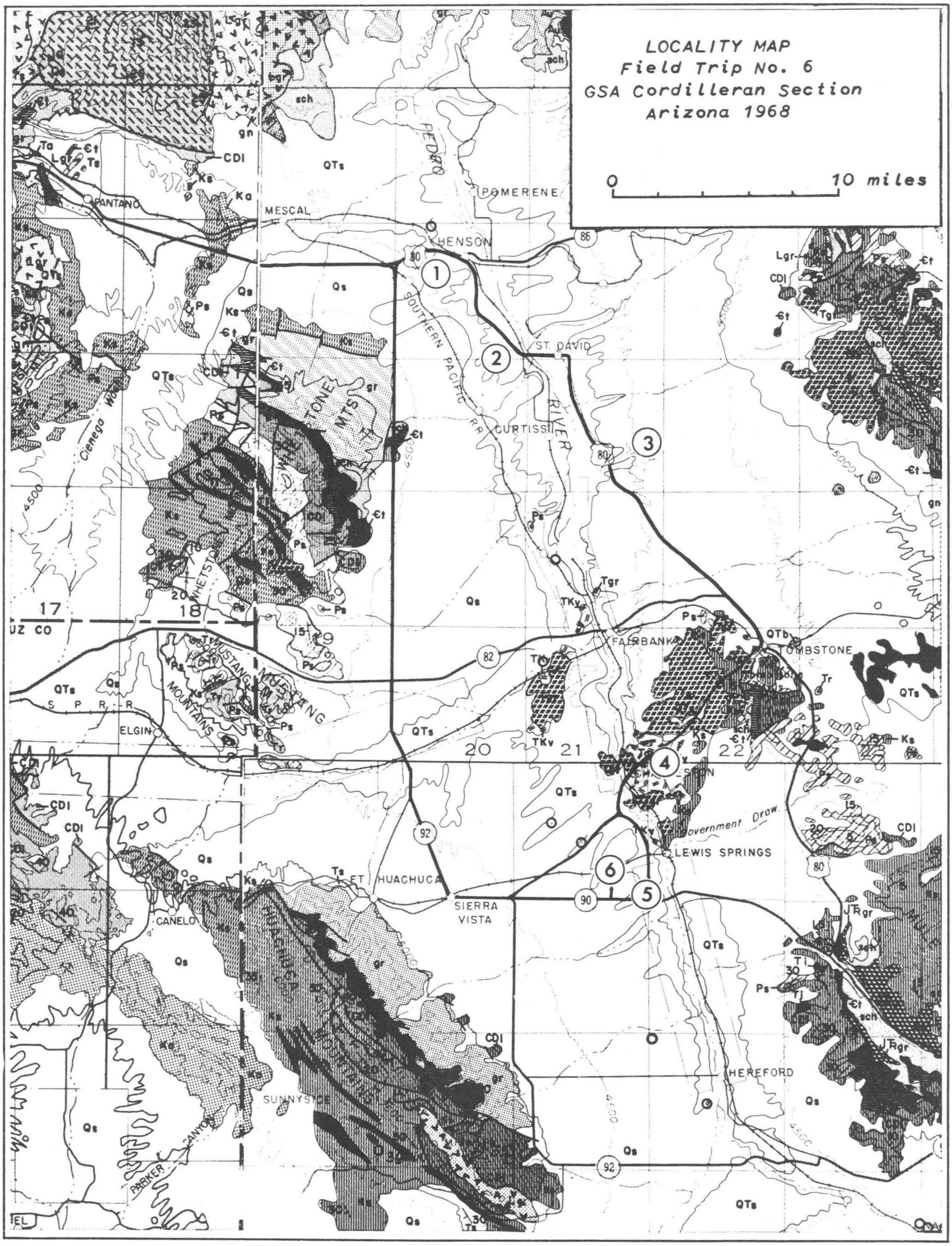
GENERAL STATEMENT

Pleistocene and Recent alluvium and lacustrine sediments will be examined at several important vertebrate fossil localities and mammoth hunting sites in the San Pedro Valley between Benson and Hereford, Arizona.

The stratigraphic position of paleosols, fossils, and unconformities at the Mendivil Ranch, Post Ranch, Curtis Ranch, Wolfe Ranch and Murray Springs localities will be discussed in relation to Pleistocene boundary problems. Geomorphology of the area will be examined, making use of Gemini IX satellite photographs.

The geology of each stop is described in the following log, supplemented by the bibliography in the *Guidebook*.

Segmental Mileage	**Cumulative Mileage**	
0.0	0.0	RAMADA INN, Tucson.
20.0	20.0	Roadcuts along both sides of U. S. Highway 80 between Davidson Canyon and Cienega Creek expose the Pantano beds of early Tertiary age. The beds of indurated sand and gravel are tilted and represent the latest major episode of faulting prior to the deposition of fine-grained beds (Plio-Pleistocene) within the intermountain basins. Volcanic ash beds within the Pantano formation have been dated by the potassium-argon method at about 33 x 10^6 years. (Damon & Bikerman, 1964) and equivalent beds near Mineta ridge contain vertebrate fossils of Miocene age. (Lance, J. F., 1960).
30.0	50.0	STOP 1 (remain on board) Mendivil Ranch, St. David formation. Stop off the pavement near the bottom of the grade, across from the A&W root beer stand (on the left). The St. David Formation was named by Robert Gray (1967) for flat-lying fluviatile and lacustrine beds in the San Pedro Valley in the vicinity of Benson and St. David (south of Benson). This group of late Pliocene-Pleistocene continental deposits was formerly called Benson beds, and contains the Benson (Blancan) and Curtis Ranch (late Blancan or Irvingtonian) faunas. Faunas of the St. David Formation are presently being studied by George Lammers (University of Arizona). He will provide a tentative faunal list of the sites in the St. David Formation. Continue on Highway 80 (Interstate 10) through Benson. The mountains to the east, ahead of you, are the Dragoon Mountains; the rugged terrain is called Cochise's Stronghold and was one of the last refuges of the Apache Indians. Turn south (right) after passing Benson business district, following state route 86 toward Tombstone.


LOCALITY MAP
Field Trip No. 6
GSA Cordilleran Section
Arizona 1968
0
10 miles
PANTANO
MESCAL
POMERENE
HENSON
86
80
1
2
3
4
5
6
ST. DAVID
SOUTHERN PACIFIC R.R.
CURTISS
SAN PEDRO RIVER
WHETSTONE MTS
Cienega Wash
17
18
20
21
22
82
FAIRBANK
TOMBSTONE
MUSTANG MTS
MUSTANG MOUNTAINS
S P R R
ELGIN
92
90
FT HUACHUCA
SIERRA VISTA
LEWIS SPRINGS
Government Draw
CHARLESTON
CANELO
HUACHUCA MOUNTAINS
SUNNYSIDE
PARKER CANYON
HEREFORD
QTs
Qs
Ks
Ps
Ꞓt
CDl
Tgr
TKv
QTb
Tr
Lgr
gr
sch
gn
JTRgr
Ti
4500
5000
4600

1.7	51.7	Small bluffs to the right of the road are capped by a Quaternary granite wash that overlies the St. David Formation. Bone scrap identified as *Bison* by J. Lance occurs on some of these bluffs.
0.2	51.9	Cochise Gardens cemetary Gidley wash, site of the first report of the Benson fauna (Gidley 1926), is at the base of the terrace behind the cemetary. Probable location of the Gidley quarries are below and to the left of the brown water tank on the terrace.
1.1	53.0	STOP 2 (dismount) Post Ranch turnoff. Turn right on the dirt road leading to the farm house and walk back to several of the sites in the large amphitheater at the base of the terrace. These sites are stratigraphically about 50 feet higher than those at Mendivil Ranch, and the assemblages are included in the Benson fauna. Drive south on state route 86, toward Tombstone.
3.0	56.0	San Pedro River
1.0	57.0	St. David.
1.5	58.5	Artesian wells in the vicinity of St. David provide a good supply of water for agriculture in this part of the San Pedro Valley. Apache Powder Plant (manufacturing explosives and fertilizer) is across the river to the right (west).
3.5	62.0	Light-colored strata cropping out on the left (east) are similar in lithology and stratigraphically positioned to beds containing the Curtis Ranch fauna.
1.2	63.2	STOP 3 - (Remain on board) - Highway rest area. Curtis Ranch site (CIT locality) is directly east of here, at the base of the light-colored strata approximately one-half mile to the east.
1.5	64.7	Road to Curtis Ranch site (continue toward Tombstone, as there is no place to park). Dirt road to the left leads to a Curtis Ranch locality (Gidley site), approximately 2.5 miles from Highway. NOTE: Much of the route between STOPS 3 and 4 is over Bryans Tombstone surface.
6.3	71.0	Junction State Route 86 and State Route 82. Continue on State Route 86, into Tombstone.
3.8	74.8	Tombstone, turn right to Charleston.
7.4	82.2	Lindsey Ranch turn-off.
0.6	82.8	STOP 4 (remain on board) Lindsey Ranch – Lacustrine units of the Boquillas and Lehner formations crop out along the sides of gullies and rest against the Bronco volcanics. Fossil mammoth, horse and bison have been found apparently eroded from the Boquillas formation. The widespread distribution of the Boquillas lacustrine beds throughout the valley suggests the presence of a large lake in the San Pedro Valley during Wisconsin time. NOTE: From STOP 4 to our lunch stop at the ghost town of Charleston on the San Pedro River we cross eroded volcanics within the area of Bryan's Whetstone

		surface. A bench forming the base of the Charleston Hills corresponds to this surface. On the west side of the river the surface is marked by a pronounced whitening, due to carbonate rubble and coatings on gravel.
2.4	85.2	LUNCH STOP San Pedro River Between the lunch stop and STOP 5 we will cross the Whetstone surface, ascend the Tombstone surface making a wide loop, and descend to the Whetstone surface again at the Wolfe Ranch locality. A well developed red soil is characteristic of the Tombstone surface.
7.0	92.2	Buena School
6.0	98.2	STOP 5 From STOP 5 at the Wolfe Ranch locality we will ascend the scarp between the Tombstone and Whetstone surfaces and proceed to STOP 6 at Murray Springs.
1.8	100.0	Murray Springs turn-off.
1.9	101.9	STOP 6 (dismount). Murray Springs Arroyo – An unusually complete stratigraphic sequence representing most of Wisconsin and Recent time is exposed by Murray Springs Arroyo. The sequence contains a buried Clovis site where mammoths were hunted and butchered about 11,000 years ago. While at the site the archaeology, palynology, and paleontology of these deposits will be described. NOTE: We will return to Tucson via Sierra Vista and the pediment on the east side of the Whetstone Mountains. The character of the Plio-Pleistocene sediments underlying the Tombstone surface and a pronounced red soil of probable Sangamon age is evident in several road cuts and natural exposures along the way.

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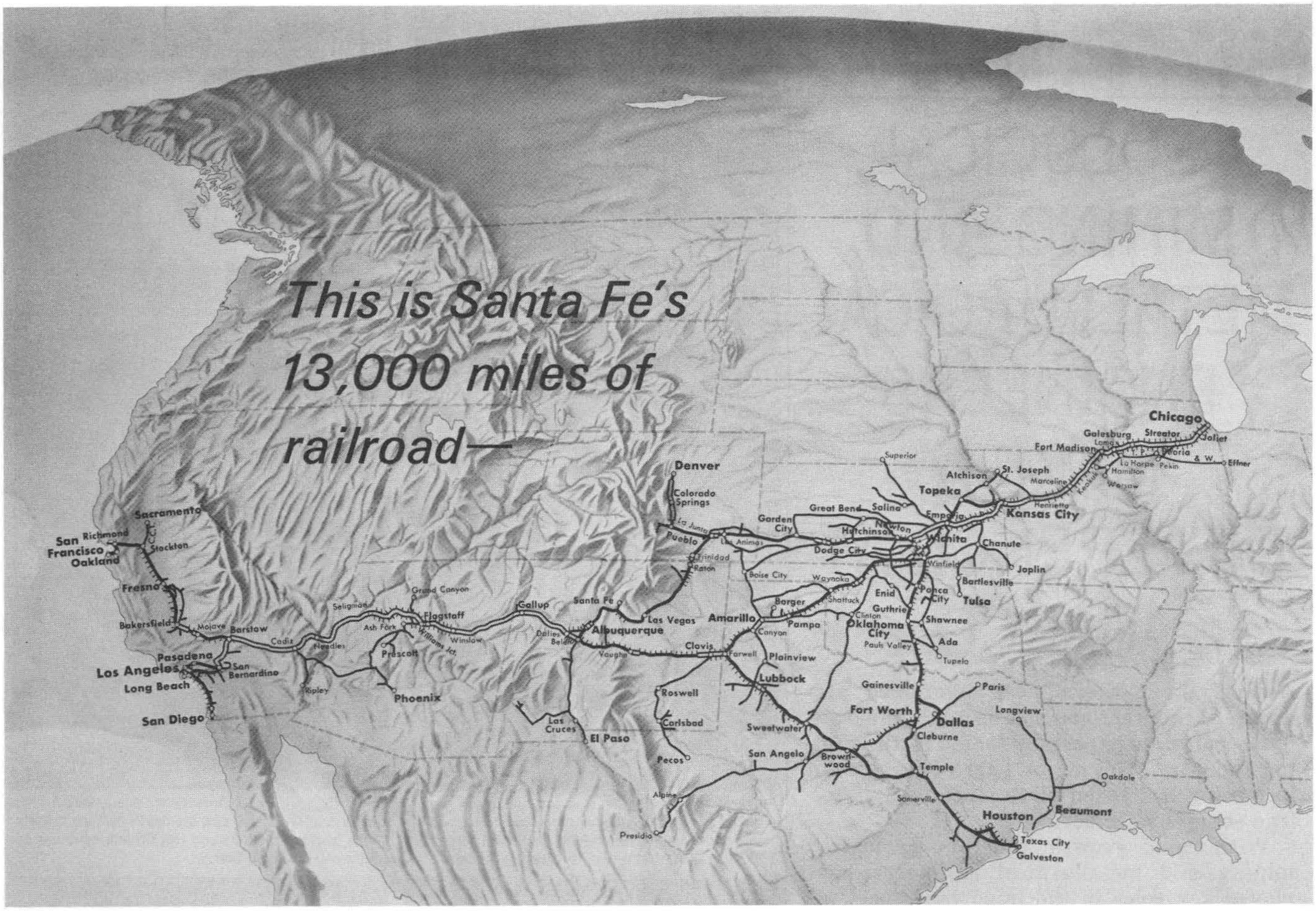
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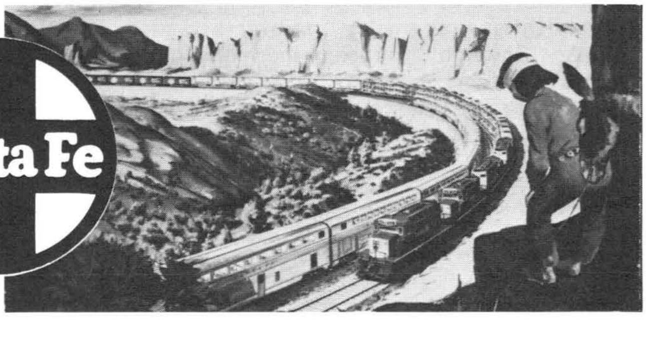

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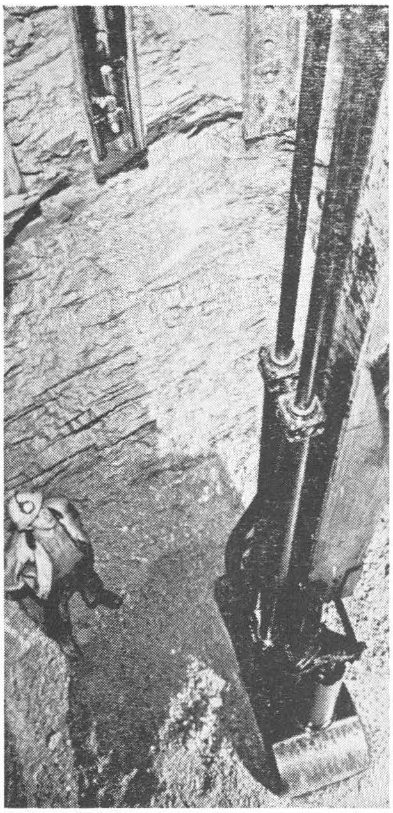

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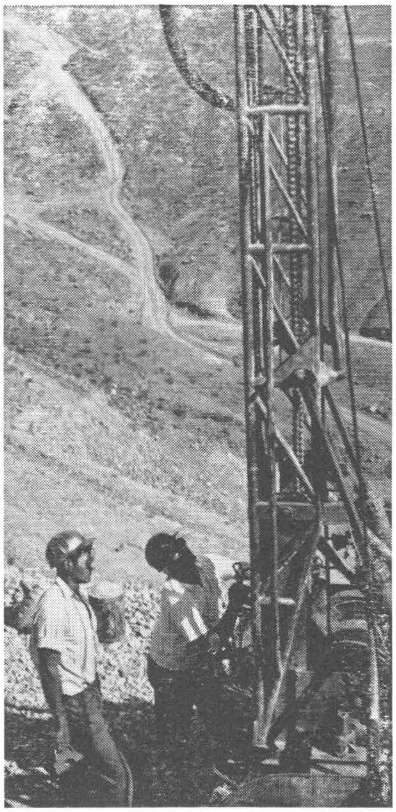

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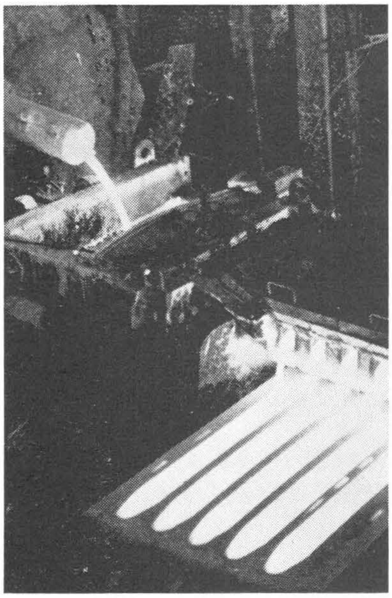
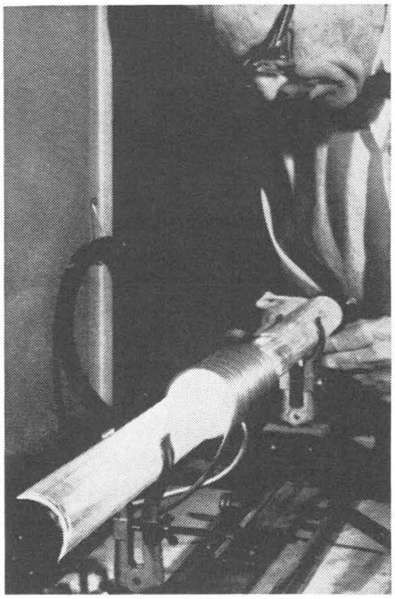


Smelting and refining operations are continually studied in Asarco's laboratories and plants. This picture shows copper being cast into wire bars at the company's Perth Amboy, New Jersey, plant.



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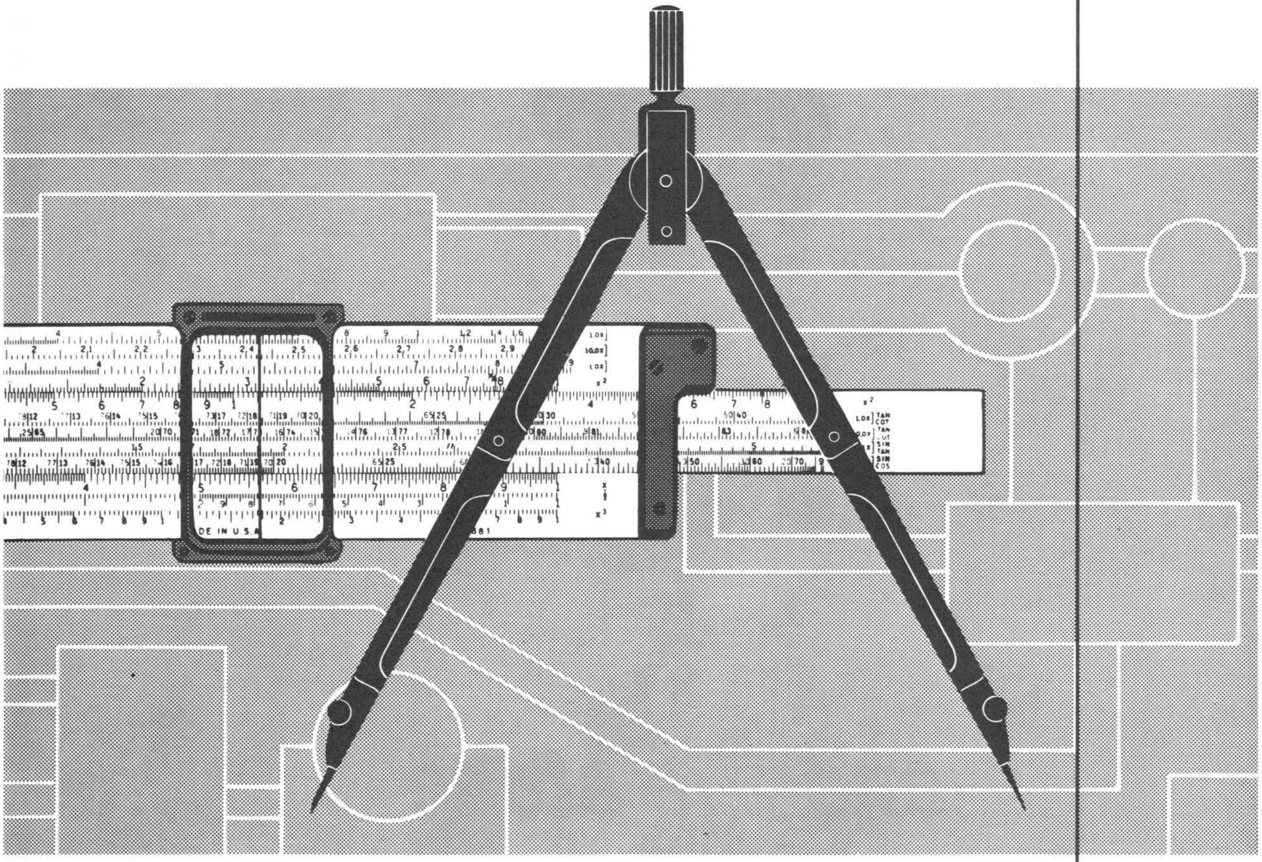

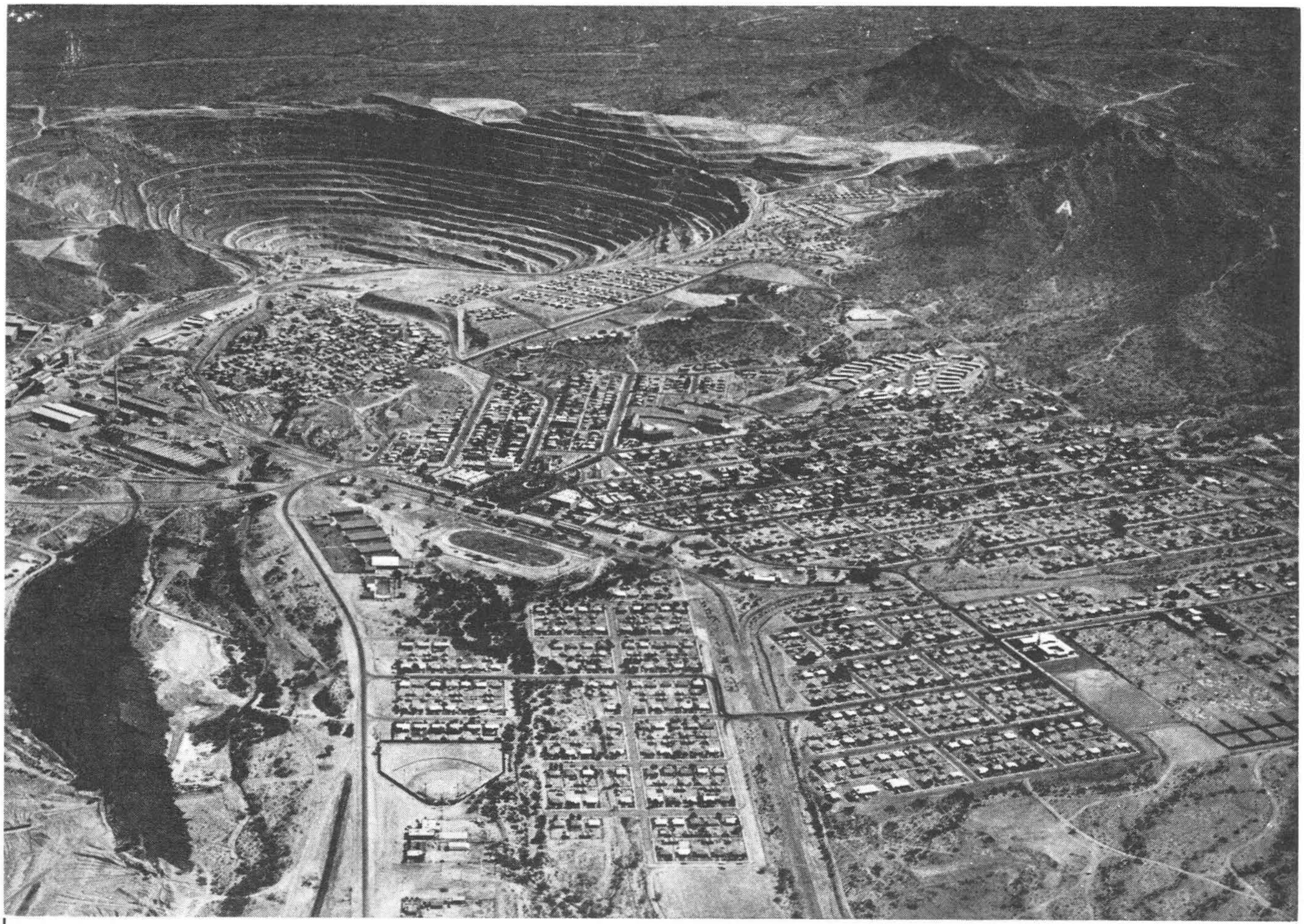

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