INFORMATION TO USERS

This material was produced from a microfilm copy of the original document. While the most advanced technological means to photograph and reproduce this document have been used, the quality is heavily dependent upon the quality of the original submitted.

The following explanation of techniques is provided to help you understand markings or patterns which may appear on this reproduction.

1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting thru an image and duplicating adjacent pages to insure you complete continuity.
2. When an image on the film is obliterated with a large round black mark, it is an indication that the photographer suspected that the copy may have moved during exposure and thus cause a blurred image. You will find a good image of the page in the adjacent frame.
3. When a map, drawing or chart, etc., was part of the material being photographed the photographer followed a definite method in "sectioning" the material. It is customary to begin photoing at the upper left hand corner of a large sheet and to continue photoing from left to right in equal sections with a small overlap. If necessary, sectioning is continued again – beginning below the first row and continuing on until complete.
4. The majority of users indicate that the textual content is of greatest value, however, a somewhat higher quality reproduction could be made from "photographs" if essential to the understanding of the dissertation. Silver prints of "photographs" may be ordered at additional charge by writing the Order Department, giving the catalog number, title, author and specific pages you wish reproduced.
5. PLEASE NOTE: Some pages may have indistinct print. Filmed as received.

University Microfilms International
300 North Zeeb Road
Ann Arbor, Michigan 48106 USA
St. John's Road, Tyler's Green
High Wycombe, Bucks, England HP10 8HR

7814781

MILLER, ELIZABETH LOUISE
GEOLOGY OF THE VICTORVILLE REGION,
CALIFORNIA.

RICE UNIVERSITY, PH.D., 1978

RICE UNIVERSITY

GEOLOGY OF THE VICTORVILLE REGION, CALIFORNIA

by

Elizabeth Louise Miller

A THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

Thesis Director's signature:

B C Burchfiel

Houston, Texas

July 1977

ACKNOWLEDGEMENTS

Many individuals made significant contributions to the successful completion of this report. Dr. B. C. Burchfiel suggested and supervised this project. His help in the field and discussions concerning the regional geology of the southern Cordillera were invaluable. Drs. H. C. Clark and G. Armeniades served on the thesis committee. I would like to thank many people who visited me in the field with whom I discussed my ideas and who provided new insight to and/or clarification of the geologic relationships in this area: Dr. Gregory Davis (USC), Calvin Miller and Dr. D. Zenger (Pomona College), Dr. Richard Arculus and Dr. Hans Ave Lallemant (Rice University), Dr. L. Silver (Cal Tech), Michael Carr, Scott Cameron, and Chuck Weisenberg. Bruce Schechkter provided able assistance in the field during 1975. Dr. Beni Troxel discussed with me the geology of the Shadow Mountains and kindly lent me maps and air photographs of the area he had mapped.

I wish to especially thank both the Southwestern Cement and Riverside Cement Companies for their help during this project and for their permission to work in the area. Mr. Doug McIver and others of the Southwestern Cement Company were particularly helpful and interested in this project. Riverside Cement Company kindly allowed me to look at all their geologic cross-sections and data from their quarry areas. Pfeizzer Chemical Company gave me a tour through the Pierce Quarry area.

Financial support for the field and laboratory work was provided by National Science Foundation grant GA 43311 awarded to Dr. Burchfiel, and by Continental Oil Company of Houston. Rice University furnished most of the needed field equipment and laboratory facilities. Financial support covering tuition and living expenses were provided by Rice University Fellowhsips (1973-1975), Continental Oil Fellowship, Rieber Award and by National Science Foundation grant GA43311 awarded to Dr. Burchfiel for portions of the 1975-1977 academic years.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PLATES
(In Back Pocket)

INTRODUCTION

I. Regional Setting and Scope of Investigation

The geology of the central and western Mojave Desert is complex and poorly understood. Because of this complexity, problems posed by the geology of this area are perhaps best understood in the more regional context of the stratigraphy and structure of the more extensively studied southeastern part of the Mesozoic Cordilleran fold and thrust belt:

The eastern part of the Mesozoic Cordilleran fold and thrust belt extends from Canada to southeastern California. In southern Nevada and southeastern California, this thrust complex begins to exhibit a structural style unlike the fold and thrust belt further to the north. This structural style is characterized by the involvement of Precambrian crystalline rocks in the lower part of thrust plates, deformation of platform-facies rocks beneath the easternmost thrust fault, superposition of early, middle, and late Mesozoic deformational events, and also by the presence of extensive Mesozoic volcanism and plutonism within the easternmost portions of the fold and thrust belt (Burchfiel and Davis, in prep.) The change in structural style from decollement-type thrusting to the north to this style of deformation in the southernmost part of the belt has been explained in terms of the cross-cutting of earlier paleogeographic trends of the

Precambrian and Paleozoic miogeosynclinal deposits by a northwest-trending Andean-type Mesozoic magmatic arc (Burchfiel and Davis, 1975). This magmatic arc was formed along a modified, truncated margin of the North American continent (Hamilton, 1969; Burchfiel and Davis, 1975).

The structural behavior peculiar to the southernmost part of the Cordilleran fold and thrust belt can be followed into the New York Mountains (Burchfiel and Davis, in press) and Devil's playground area (Dunne, 1972, 1977) of southeastern California. To the south and west of these exposures lies a large, poorly understood terrain, the interpretation of which is complicated by the large percentage of Mesozoic intrusive rocks of the magmatic arc.

Some of the westernmost exposures of sedimentary rocks belonging to the miogeosynclinal sequence of the southern Cordilleran are present in the Victorville and San Bernardino area (fig. 1) of the southwestern Mojave. Because the central and western Mojave Desert is geologically complex and poorly understood, the study of these westernmost exposures of metasedimentary rocks is crucial to an understanding of the development of this portion of the southern Cordillera. This study has attempted to answer some very fundamental questions concerning this portion of the Cordilleran belt:

1) West-northwest to east-southeast cross sections across the Precambrian and Paleozoic miogeosynclinal

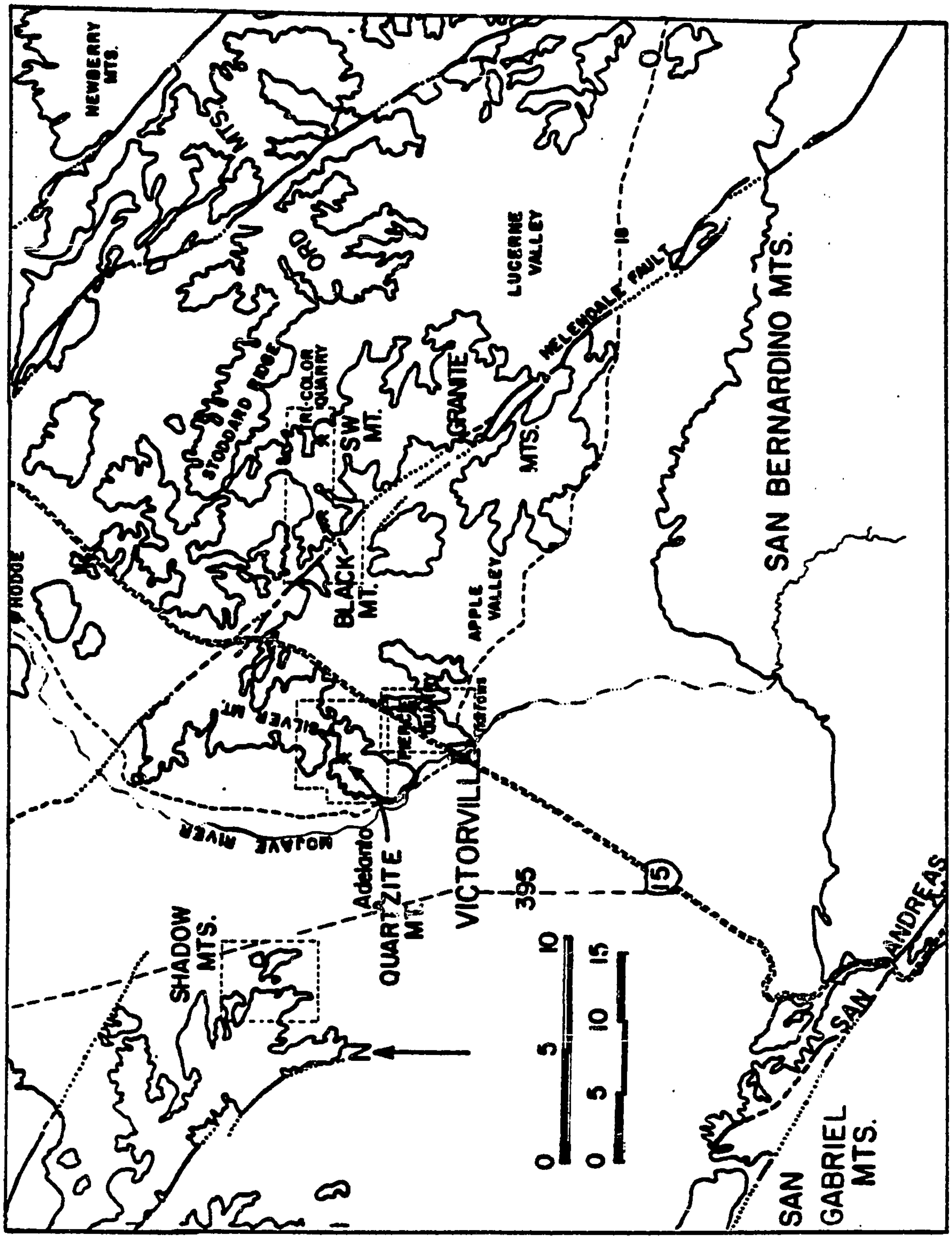


FIGURE 1. Index map of the Victorville region showing approximate boundaries of smaller areas mapped (dashed lines) and localities referred to in text. Base map from Rogers (1967).

sequence of the southern Great Basin region show thickening to the northwest both by addition of units along unconformities and by the thickening of individual units (Burchfiel and others, 1974; Stewart, 1970) (fig. 18). Stewart and Poole (1975) first identified rocks of the Precambrian-Cambrian clastic portion of this sequence in the San Bernardino and Victorville areas. Distinctive differences exist between sequences with cratonal, marginal and miogeosynclinal affinities (fig. 18). To which facies do the sediments in the Victorville area belong?

2) Isopach lines and facies boundaries for stratigraphic units trend North-northeast in Nevada and appear to bend more westerly in California with the exception of isopach lines for platform rocks which continue to trend north-south (Burchfiel and Davis, in prep.) (fig. 19). Is this change in trend real or do paleogeographic trends swing southward again as shown on many paleogeographic maps (i.e. Stewart and Poole; 1974, Poole, 1974)?

3) The third question regarding this region is when were the rocks in the Victorville area first deformed? The Late Devonian-Early Mississippian Antler orogenic event, attributed to the closure of a back arc basin along the western edge of the continent (Burchfiel and Davis, 1975), culminated in emplacement of the Roberts Mountain thrust in western Nevada. The thrust belt shed

an apron of Mississippian clastics eastward from the thrust complex; carbonate sedimentation continued uninterrupted further to the east in the miogeosynclinal terrain (Poole, 1974). Poole (1974) has extended the Mississippian clastic wedge southward to the San Andras fault. Is there any evidence for clastic rocks of this age in the Victorville area? Similarly, were rocks of the Victorville area involved in Permo-Triassic deformation associated with the Sonoma event which caused eastward thrusting of the Havallah sequence in western Nevada? Rocks similar to the Havallah sequence in western Nevada are exposed much further to the south in the El Paso Mountains along the Garlock fault (Garlock Series, Dibble, 1967).

4) The Permo-Triassic truncation of the western edge of the continent, first suggested by Hamilton (1969), must have occurred somewhere west of the area studied in this report. Is there any evidence from the Victorville region for the proximity or the timing of this truncation event?

5) Following the proposed truncation event, a northwest-trending Andean-type volcanic and plutonic arc was established along the modified edge of the continent (Hamilton, 1969). Thrusting in the eastern belt of the southern Cordillera is believed to have begun in the Middle to Late Triassic and the trends and geometry of

the thrusts controlled by a pattern of ductility contrasts within the crust which was related to the development of the Mesozoic magmatic arc (Burchfiel and Davis, 1975). The Victorville area lies within the trend of the Andean-type arc. What data are present in this area that bear on the age of inception of the volcanic-plutonic arc, and how does the timing and style of thermal and deformational events within the batholitic trend relate to the better understood sequence of events to the east?

6) Mesozoic volcanic rocks as well as sedimentary rocks are exposed in the Victorville region. In the southern part of Nevada, Mesozoic sedimentation is represented by marine sandstone and limestone of the Lower Triassic Moenkopi Formation. Middle Triassic to Cretaceous rocks are clastic non-marine sedimentary rocks. These sedimentary rocks interfinger with volcanic and volcaniclastin strata of a "western volcanic suite" in the area of the Soda Mountains (Grose, 1959). It is commonly assumed that during Mesozoic times an entirely volcanic terrain existed to the west of the Soda Mountains (Gross, 1959; Stanley and others, 1971). Do the Mesozoic sediments in the Victorville region provide any indication as to what the paleogeography was like within the magmatic arc itself?

Many of these questions are closely related to one another, and although these were the major questions asked during the course of this investigation, not all of them could be answered given the geological complexity of the area, the limited exposure of metasedimentary rocks, and the lack of data from adjacent terrains. However, data bearing on aspects of all of these questions is presented in this report. If not conclusive, the data at least offer a better basis for the understanding of the tectonics of this portion of the southern Cordillera as well as a better framework for future studies in this complex area.

II. Geographic Setting and Access

The Mojave Desert is bounded on the west and southwest by the San Andreas fault and on the north by the Garlock fault (fig. 17). The rapidly growing town of Victorville in the southwestern Mojave Desert lies 85 miles (142 km) northeast of Los Angeles on U. S. Interstate 15. The areas mapped during this study from west to east include the eastern Shadow Mountains, the Quartzite Mountain area, the Pierce quarry area, and the Sidewinder-Black Mountain area. Their locations are shown on the index map (fig. 1).

The land surface in this region consists of isolated hills, mountains or groups of mountains which are separated by extensive areas of alluvium. The base level of the Mojave River drainage as it flows through Victorville is approximately 2400 feet (720 m). The highest elevations within the areas mapped are 5125 feet (1538 m) at Sidewinder Mountain and 4532 feet (1360 m) at Quartzite Mountain.

Because of proximity to Cajon Pass and the higher elevation, the climate in the Victorville region is cooler than in most other parts of the Mojave Desert. Afternoon winds from the Cajon Pass-San Bernardino direction generally prevent temperatures higher than 105° F during the summer months.

Access to the individual areas mapped during this study is good. All roads are shown on the topographic base of the individual areas mapped. Most access roads described below are shown on the California Division of Mines and Geology San Bernardino geologic map sheet.

Access to the Quartzite Mountain area is either through the Riverside Cement Company plant at Oro Grande on Highway 66 (north of Victorville) or by a private dirt road which runs from the Stoddard Wells Road exit off Interstate 15 through the Quartzite Mountain area westward to the major quarries. Permission to enter this area must be obtained from the Riverside Cement Company, or from the Southwestern Cement Company in Victorville for the quarry area on the south side of Quartzite Mountain. A steep, partially paved road has been constructed to the top of Quartzite Mountain for servicing the microwave relay towers at the peak. There is a locked gate at the bottom of this road. The Pierce quarry area is owned and operated by Pfeizzer Chemical Company in Victorville.

Access to the Sidewinder Mountain area is by the unpaved but very good Stoddard Well Road off Bell Mountain

Road. To reach the roof pendant rocks of Sidewinder Mountain and the Tri-Color quarry area, one takes either the Lucerne Valley cutoff or the gas pipeline road off Stoddard Well Road. A large part of the Black Mountain area is being actively quarried by the Southwestern Cement Company. The road to the Black Mountain quarries off Bell Mountain Road is paved, but permission is needed before entering the quarry area. Blasting operations are carried out daily in many of the quarries at Black Mountain.

Several dirt roads off Highway 395, north of Adelanto (Desert Flower Road, Refuse Disposal Site road) lead to the eastern Shadow Mountains.

III. Previous Geologic Work

Hershey (1902) first described the geology of the Victorville area. Hershey applied the name Oro Grande series to the limestone-quartzite sequence exposed at Quartzite Mountain. Although he did not map this area or find any fossils, he suggested that the Oro Grande sequence was correlative with the Lower Cambrian of Inyo County (Hershey, 1902, as discussed in Miller, 1944). Miller (1944) described the geology of parts of the Barstow quadrangle. He reported the occurrence of crinoidal fragments at Sparkhule Mountain in the Oro Grande metasedimentary rocks and concluded that all the older metasedimentary rocks in this area were Carboniferous in age. Bowen (1954) published a detailed report and map of the 30 -minute Barstow quadrangle and established a tentative stratigraphy for the area. Based on fossil occurrences at Sparkhule Mountain, he, like Miller, considered the Oro Grande metasedimentary rocks to be Carboniferous in age. In this work Bowen differentiated the older Oro Grande metasedimentary rocks from the post-Power Permian Fairview Valley Formation exposed in the Black Mountain area, and included a list of fossils identified from the clasts within the Fairview Valley Formation conglomerates. Bowen (1954) also presented fairly detailed petrographic descriptions of the Triassic-Jurassic (?) Sidewinder volcanic sequence and the Jurassic-Cretaceous (?) plutonic rocks in the study area. The Quartzite Mountain area mapped by the author was mapped in the same detail by Bowen and Ver Plank (1965). Structural complications in this area, however, led them to establish an erroneous stratigraphy and hence led to an erroneous structural interpretation of this area. Dibblee (1960a, b, c) mapped the 15-minute Apple Valley, Shadow Mountains and Victorville quadrangles in reconnaissance. His extensive mapping in the western Mojave Desert was synthesized in an impressive and widely used guide to a large area of poorly understood geology (Dibblee, 1967). Dibblee (1967) used Bowen's (1954) tentative age assignments for rocks in the map area. His structural interpretations in the Quartzite Mountain area differed from that of Bowen (1954) and Bowen and

Ver Plank (1965), and compare more closely with those in this work. Stone (1964) mapped the Black Mountain area in detail as part of a master's degree thesis at University of California at Riverside. I was only aware of this reference after I had finished work in this area. Stone's conclusions, however, differ significantly from those presented in this report. Troxel and Gunderson (1970) mapped the Shadow Mountains except for their easternmost edge, which was mapped as part of this study. They considered the metasedimentary rocks in the Shadow Mountains to be Upper Paleozoic (?). Poole (1974) suggested that these rocks were southernmost exposures of Mississippian Antler foredeep deposits.

The older part of the metasedimentary rocks of the "Oro Grande" sequence at Quartzite Mountain were finally correctly identified by Stewart and Poole (1975) who correlated this section and a similar section in the San Bernardino Mountains to the Precambrian-Cambrian clastic portion of the Cordilleran miogeosynclinal sequence in the Nopah range and Providence Mountains. Their correlation of the rocks in the San Bernardino Mountains was, with some modification, substantiated by Tyler (1975).

Potassium-Argon radiometric dates for some of the Mesozoic batholithic rocks in the area were determined by Armstrong and Suppe (1973). 40Ar/39Ar age release spectra on plutonic rocks of the study area will be obtained during June, 1977 in cooperation with

Dr. J. Sutter at Ohio State. Presently two samples, key to bracketing the age of the Fairview Valley Formation, are being processed by Dr. L. Silver at Cal Tech for U/Pb dates on zircon separates.

IV. Present Study

Geologic mapping was done directly on topographic maps made by enlarging portions of the U. S. Geological Survey 7¼-minute Victorville, Helendale, Turtle Valley, Apple Valley North, Stoddard Well, and Fairview Valley quadrangles to a scale of approximately 1:12,000 for the Quartzite Mountain, Sidewinder Mountain, and Black Mountain areas. Mapping was done directly on the 7¼-minute topographic maps for the Shadow Mountain and Pierce Quarry areas. Air photographs were used primarily for mapping alluvium - bedrock contacts and recent faults in the area. Most of the mapping was done in the early summer of 1975 and the spring of 1976; a total of about four months was spent in the field. One month was spent in the Spring Mountains, Nevada, where the author had the opportunity to become familiar with the unmetamorphosed Paleozoic carbonate sequence.

Stratigraphic thicknesses reported for the Mesozoic Fairview Valley Formation were measured in the field with a Jacobs staff. All other reported thicknesses were determined from maps and cross-sections. Approximately 250 thin-sections were examined to expand on the metamorphic, igneous and sedimentary petrology of the rocks studied. Four hornblende and biotite mineral separates were obtained from igneous rocks in the area for 40Ar/39Ar age dates, the results of which will be available too late to be included in this report.

The four areas mapped for this study, the eastern Shadow Mountains, the Quartzite Mountain area, Pierce Quarry area, and the Sidewinder Mountain-Black Mountain area, form a series of exposures which extend approximately 40km in an east-west direction. These exposures are separated by broad expanses of alluvium. The age of the rocks, style of deformation, and thermal history of these isolated areas varies considerably. For this reason, it was necessary to describe the geology of each area separately; these descriptions are followed by a summary of the geologic history of the whole area. Because it was necessary to describe the geology of each area separately, there is, unfortunately, some repetition of geologic data and numerous references within the description of one area to sequences and relationships in other areas.

GEOLOGY OF THE QUARTZITE MOUNTAIN AREA

I. Stratigraphy

LATE PRECAMBRIAN TO CAMBRIAN STRATA

General Statement

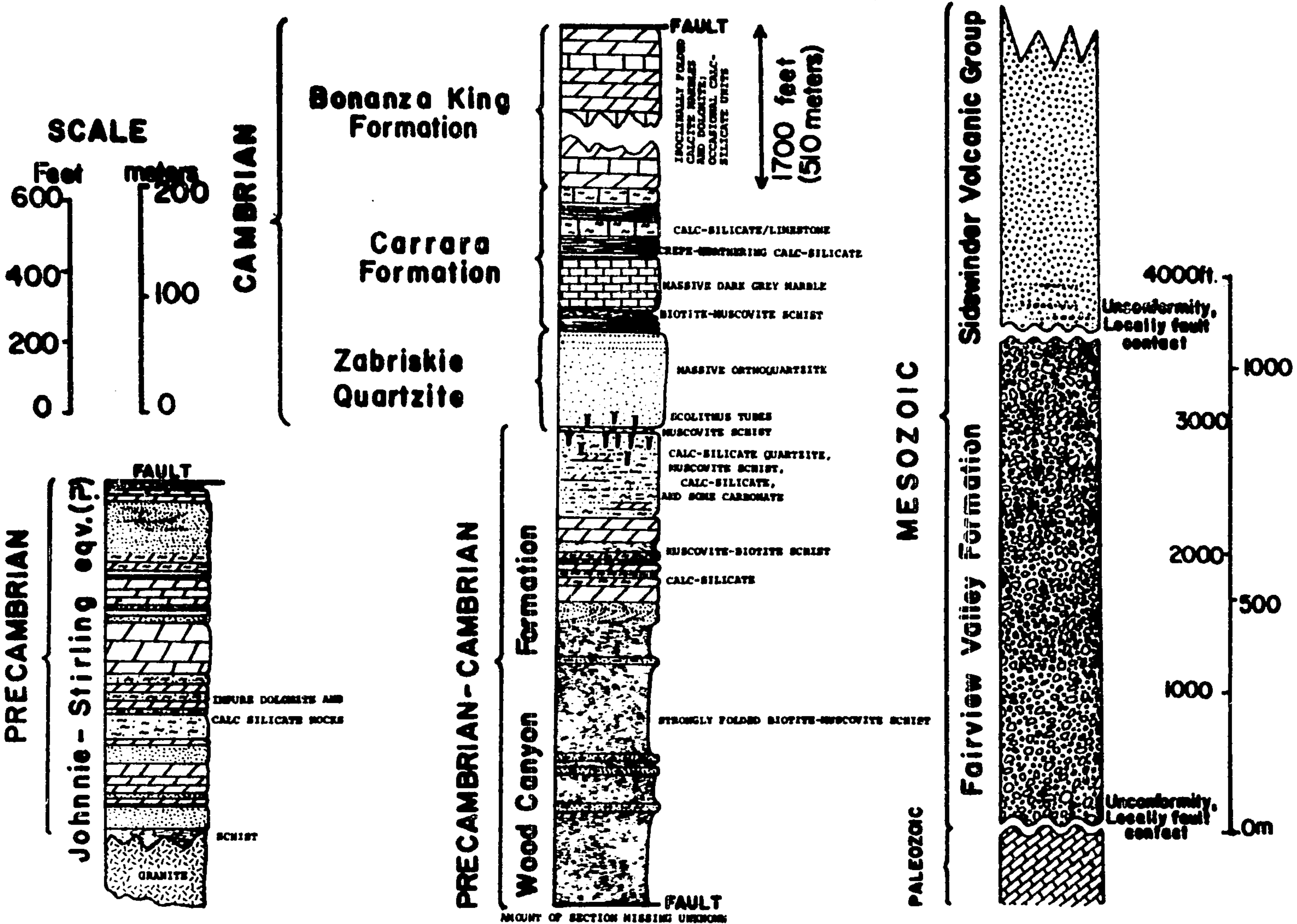
Several partial sections of Late Precambrian and Cambrian strata crop out in the Quartzite Mountain area. The metasedimentary rocks have been highly deformed and tectonic transposition of bedding has occurred in all but the most brittle rock types. The rocks have been metamorphosed to biotite grade, and have undergone repeated episodes of contact metamorphism. The metasedimentary rocks at Quartzite Mountain were correlated with the miogeosynclinal sequences of the southern Great Basin by Stewart and Poole (1975). Their correlation is valid and is followed in this work with slight modification. Because metamorphism and tectonism have obliterated practically all fossil evidence and modified original stratigraphic thicknesses in this area, correlation of these strata with less deformed sequences elsewhere is, by necessity, based primarily on gross lithologic characteristics and sequence of rock types rather than on detailed stratigraphic or paleontologic data. A composite lithostratigraphic column of the Late Precambrian to Cambrian rocks is shown in figure 2.

Johnnie-Stirling equivalent (?)

Lithology: A sequence of dolomite, orthoquartzite, and

FIGURE 2

STRATIGRAPHY, QUARTZITE MOUNTAIN AREA



THICKNESSES ARE APPROXIMATE TECTONIC THICKNESSES, MEASURED FROM MAP calc-silicate rocks is in fault contact with rocks equivalent to the Precambrian-Cambrian Wood Canyon Formation on the south flank of Quartzite Mountain (Plate I). These rocks were not discussed or correlated by Stewart and Poole (1975) and therefore merit a more detailed treatment than the rest of the sequence exposed at Quartzite Mountain. Where best exposed (hill 4138), layering within the sequence dips moderately to the northwest, and approximately 1000 feet (300m) (tectonic thickness) of section is exposed. The sequence is intruded by late Mesozoic granitic rocks to the south and consists from its exposed base upwards of: 1) quartz-biotite schist along the intrusive contact, 2) massive orthoquartzite and dolomite, 3) thinner-layered dolomite and calc-silicate rocks, 4) massive dolomite with some quartzite and calc-silicate rocks, which are overlain by a very massive orthoquartzite with occasional medium-scale trough cross-stratification, and 5) dolomite and muscovite schist. The top of the section is in fault contact with the Wood Canyon Formation.

The quartzite units within this sequence arc compositionally very mature, containing 95-99% quartz. In thin section they are medium to coarse-grained quartzite; grain growth and sutured boundaries between grains have obliterated all original grain boundaries. Inpurities within these quartzites have reacted with the quartz and are now calc-silicate minerals such as tremolite, diopside, and forsterite. Because the original bedding in the weaker carbonate units of this sequence have been tectonically transposed by isoclinal folding, it is possible that portions of this sequence have been repeated and/or extensively tectonically thinned or thickened. A lithologic description of these rocks is shown in figure 2.

South of the major exposure of the proposed Johnnie-Stirling equivalent(?) rocks, is a northwest-southeast trending roof pendant in granitic rocks which contains orthoquartzite and dolomite which were probably continuous with the section described above prior to granitic intrusion (Plate I).

Age and Correlation: The sequence described above has been tentatively assigned a Precambrian age for the following reasons:

1) The remainder of the sequence exposed at Quartzite Mountain ranges in age from the Precambrian-Cambrian Wood Canyon Formation upward to Paleozoic carbonate rocks correlative with the Cambrian Bonanze King Formation. None of these formations are similar to the proposed Johnnie-Stirling equivalent(?) rocks.

2) Data from elsewhere in the study area and from the San Bernardino Mountains (Tyler, 1975; Stewart and Poole, 1975; Hollenbaugh, 1970) indicate that the Paleozoic succession in this area contains only carbonate rocks. Orthoquartzites are confined to the Precambrian-Lower

Cambrian portion of the stratigraphic succession.

3) The intensity of deformation and metamorphism affecting these rocks, as well as their highly mature sedimentology, eliminates the possibility of a Mesozoic age for these rocks.

Correlation of the sequence described above to rocks of known Precambrian age elsewhere is more problematic. In the southern Great Basin, the Precambrian-Cambrian Wood Canyon Formation is underlain by the Precambrian Stirling Quartzite which is in turn underlain by the Johnnie Formation. Older Precambrian strata of the Pahrump Group of probable "Beltian" age and the Noonday Dolomite are apparently confined to a large west-northwest trending depositional trough or basin in the Death Valley region (Wright and others, 1975). Because of the probable Precambrian age of the metasedimentary rocks in question, and because the Wood Canyon Formation is elsewhere underlain by the Stirling Quartzite and the Johnnie Formation, the sequence described from Quartzite Mountain has been tentatively correlated to Johnnie-Stirling equivalent(?) units. It is stressed that this correlation is at best only tentative.

One of the problems involved in correlation of these rocks at Quartzite Mountain is that, in the study area, there are no exposures of strata in depositional contact with Precambrian crystalline basement, thus the stratigraphy of the basal part of the Late Precambrian succession is unknown.

The Stirling Quartzite in the southern Great Basin contains appreciable dolomite and limestone only in its "D" unit (Stewart, 1970). Sedimentary sequences exposed in the nearby San Bernardino Mountains contain strata correlative with the Stirling Quartzite. Here, the Stirling rests depositionally upon Precambrian gneissic basement (Tyler, 1975). Most of the Stirling in the San Bernardino Mountains however, consists of quartzite, but a unit in the upper part of the Stirling, correlative with Stewart's (1970) "D" unit is approximately 200 feet (60m) thick and consists of laminated, fine-grained calcite marble interbedded with minor thin-bedded quartzite (Tyler, 1975). The Stirling Quartzite sequence in the San Bernardino Mountains exhibits little similarity to the sequence at Quartzite Mountain (Burchfiel, pers. comm.), but because of the general paucity of outcrop and lack of stratigraphic data on Precambrian sediments in the Western Mojave, facies changes within the Stirling Quartzite sequence may have occurred in this area, and the probable Precambrian sequence at Quartzite Mountain may contain Stirling equivalent units.

As discussed below, lithologic differences between the Wood Canyon Formation in the study area and in the San Bernardino Mountains may reflect more basinward deposition of the Quartzite Mountain sequence with respect to the sequence in the San Bernardino Mountains. If this is the case, it is possible that the older Johnnie Formation was present at one time in the Victorville region (addition of older units along the basal unconformity on Precambrian crystalline rocks from the craton toward the miogeosyncline is typical of east-southeast to west-northwest sections in southern Nevada and the eastern Mojave (Stewart, 1970; Dunne, 1972)). The Johnnie Formation in the southern Great Basin is characterized by a heterogeneous and in part laterally variable sequence of shale,siltstone, quartzite, conglomerate, limestone and dolomite that ranges from 100 to over 5000 feet (30-1500 m) in thickness (Stewart, 1970). The Johnnie-Stirling equivalent(?) sequence at Quartzite Mountain contains predominantly massive orthoquartzite and dolomite units. Although some calc-silicate rocks occur within the sequence, it contains only rare units of the metamorphic equivalents of shale and siltstone which characterize the Johnnie Formation in the southern Great Basin. Because the Johnnie Formation is quite variable (laterally) compared to higher units in the Upper Precambrian and Lower Cambrian sequence of the southern Great Basin, which are regionally far more uniform (Stewart, 1970), it is possible that the sequence at Quartzite Mountain is equivalent to part of the Johnnie Formation.

In the light of these complications, assignment of the rocks at Quartzite Mountain as Johnnie-Stirling (?) equivalent , is at best tentative only.

Wood Canyon Formation

Thickness and lithology: The Wood Canyon Formation is best exposed on the upright limb of the Quartzite Mountain anticline. Here, the lower part of the exposed section, in fault contact with Johnnie-Stirling equivalent(?) (Plate 2), consists of approximately 840 feet (tectonic thickness) (252m) of multiple deformed biotite-muscovite-quartz schist with occasional feldspar, and thin silty quartzite beds. These schists are overlain by about 240 feet (72m) (tectonic thickness) of interlayered dolomite, schist and calc-silicate rocks, with dolomite constituting around 70% or more of this unit. The dolomitic unit occurs approximately 230 feet (69m) (tectonic thickness) from the top of the formation. Although it is not always continuous along strike, the dolomitic unit nevertheless is present persistantly at one place or another in the upper Wood Canyon Formation. The dolomitic unit is overlain by a thick section of thin to medium bedded greenish calc-silicate-bearing quartzite, siltstone and calc-silicate rocks. At the top of the upper unit, greenish calc-silicate-bearing quartzite contain traces of Scolithus tubes. The more quartzitic units within the Wood Canyon Formation occasionally exhibit relict medium-scale trough cross-stratification.

The Wood Canyon Formation is transitional to the Zabriskie Quartzite through a thin sequence of non-calcareous muscovite-rich quartzite and schist.

A lithologic description of the Wood Canyon Formation is shown in figure 2.

Age and Correlation: The Wood Canyon Formation in the Quartzite Mountain area was correlated to strata within the southern Great Basin by Stewart and Poole (1975). In the Great Basin area, the Wood Canyon Formation can be divided into three members; a lower siltstone member with some thin layers of fine to very fine grained quartzite, A middle more resistant quartzite member which contains conglomerate, conglomeratic quartzite, and minor siltstone; and an upper siltstone and quartzite member, the upper half of which contains dolomite and limestone beds (Stewart, 1970). The base of the Cambrian occurs within the middle of the formation, the lowest occurrence of Ollenellid trilobites is in the upper member of the Wood Canyon Formation (Stewart, 1970). In deformed and metamorphosed equivalents of the Wood Canyon Formation, the presence of Scolithus tubes in the uppermost Wood Canyon and lower Zabriskie Quartzite, and the presence of the distinctive Zabriskie Quartzite above the formation, constitute the most important criteria for recognition and correlation of the Wood Canyon Formation.

Because of the lack of a thick sequence of quartzite beneath the dolomitic unit of the Wood Canyon in the map area, it is possible that only the upper member of the Wood Canyon Formation is represented in the Quartzite Mountain area. Tyler (1975) reported 415 feet (124m) of Wood Canyon in the San Bernardino Mountains which contained no calcareous units. According to Stewart (1970), the carbonate unit of the upper Wood Canyon Formation is not present in the thinner and more cratonic sequences of the Wood Canyon such as those exposed in the Providence and Marble Mountains, California. The northwestward thickening of the dolomitic units in the upper Wood Canyon (Stewart, 1970; Diehl, 1974) is interpreted by Diehl (1974) as a basinward increase in carbonate content. The presence of a fairly thick dolomitic unit in the upper Wood Canyon of the Quartzite Mountain area may reflect more basinward deposition of these strata with respect to the rocks in the San Bernardino Mountains.

Zabriskie Quartzite

Thickness and lithology: The Zabriskie Quartzite (fig. 2, Plate I) is by far the most easily identified rock unit in the map area. The Zabriskie is a vitreous white to pinkish-red massive orthoquartzite. Its composition is greater than 99% quartz, and it is quarried for silica refractory in this area. Bedding within the Zabriskie is very indistinct, occasionally marked by wispy grey laminations. On Quartzite Mountain, the Zabriskie Quartzite is about 300 feet (90meters) thick. Because of its massiveness and brittleness, this thickness may be close to an original thickness before deformation. Although evidence for tectonic shearing and slicing was

was noted in places along the upper and lower contacts of the Zabriskie, on Quartzite Mountain the transition from the Wood Canyon Formation occurs within a thin sequence of non-calcareous micaceous quartzite and schist, and the upper Zabriskie is transitional to the overlying Carrara Formation as thinner bedded quartzite grades upward into crepe-weathering thinly layered calc-silicate rocks and limestone belonging to the basal Carrara Formation.

Vestiges of more resistant, whitish, Scolithus tubes are present in the basal Zabriskie on Quartzite Mountain; these are generally not at right angles to bedding indicating that although it behaved relatively brittley with respect to the other lithologies during deformation, the Zabriskie Quartzite has probably undergone significant internal deformation.

Age and correlation: The Zabriskie Quartzite, which is assigned an Early Cambrian age on the basis of its stratigraphic position, forms a westward thickening wedge that is up to 1,000 feet (300m) thick in the southern Great Basin area (Stewart, 1970). Its stratigraphic position is unique in that it overlies a succession of predominantly clastic rocks of Late Precambrian age and underlies the Carrara Formation which contains significant limestone. The Zabriskie's orthoquartz composition, its unique stratigraphic position, and the presence of Scolithus tubes at its base makes it an easily identifiable marker unit even in severly deformed and metamorphosed terrains.

Carrara Formation

Thickness and lithology: Strata assigned to the Carrara Formation crop out widely in the map area. The Carrara is best exposed on the overturned limb of the anticline on Quartzite Mountain (map), where it is approximately 440 feet (132m) (tectonic thickness) thick. It consists from its base upwards of 1) a transitional sequence of thinly layered, crepe-weathering calc-silicate rocks and grey limestone; 2) a thin layer of dark biotite-muscovite schist; 3) a very thick unit (200 feet, 60m) of pure, dark-grey weathering, grey limestone marble; 4) a thick sequence of calc-silicated calcareous siltstone, thinly layered crepe-weathering calc-silicate rocks and grey limestone, and minor biotite-muscovite schist (fig. 2). Strata labeled as Carrara (?) on the map, along the road through Oro Grande Canyon, consist of grey and interlayered grey and white limestone marbles, some calc-silicate rocks, and darker schistose rocks. Because these rocks in Oro Grande Canyon are not in stratigraphic sequence with the easily identifiable Zabriskie Quartzite, and because they appear slightly different from the Carrara sequence elsewhere, they are only tentatively assigned to the Carrara Formation.

Age and correlation: The Carrara Formation in the southern Great Basin area, assigned an Early and Middle Cambrian age on the basis of trilobites, consists largely of siltstone and carbonate rocks, and is transitional between the generally quartzitic sequences below the relatively clean carbonate sequences above. In the map area, the position of the Carrara Formation above the Zabriskie Quartzite and below the purer carbonate sequences which overlie it has been the diagnostic criteria in its recognition and correlation.

Some notable differences exist between the Carrara Formation in the map area and descriptions of the regional characteristics of the Carrara in the southern Great Basin area. In the Great Basin, the Carrara's lower half consists of siltstone, shale, and limestone. Its upper half consists of limestone, silty limestone and limy siltstone with the carbonate content increasing toward the top of the formation where it is transitional into younger predominantly carbonate lithologies (Stewart, 1970). It appears that in the Victorville area, the lower half of the Carrara Formation is predominantly carbonate, while in the southern Great Basin it is the upper portion of the Carrara that contains the greater percentage of carbonate. Over much of the area of the southern Great Basin, the Carrara Formation contains a 20-60 foot (6-18m) unit of quartzite near the base of the formation which is lithologically similar to the Zabriskie Quartzite. This quartzite unit is not present within the Carrara in the study area. The absence of the quartzite unit at the base of the Carrara may be related to the change from clastic to carbonate sedimentation within this portion of the miogeosyncline during lower Carrara times.

Bonanza King Formation

Thickness and lithology: Above strata correlative with the Carrara Formation, on the overturned limb of the Quartzite Mountain anticline, is a thick 1700 feet (510m) (tectonic thickness) sequence of white dolomite and dolomitic limestone marble with occasional more resistant, thin, calc-silicate units. Because of isoclinal folding and metamorphism, all traces of original bedding and lithological characteristics have been obliterated in these rocks. Compositional layering within this sequence strikes northwest and dips steeply to the southwest or northeast. The sequence is in fault contact on its east side with northeast-trending, northwest-dipping Zabriskie Quartzite and Wood Canyon Formation.

Age and correlation: Because of intense folding and metamorphism, no lithologic succession could be established within this carbonate sequence. Because of its stratigraphic position above the Lower and Middle Cambrian Carrara Formation, these carbonates probably represent a portion of the Bonanze King Formation of Middle to Late Cambrian age which overlies the Carrara and crops out over much of southern Nevada and the eastern Mojave Desert. At Sidewinder Mountain, identifiable members of the Bonanza King Formation have been mapped which substantiates this age assignment and correlation of the more deformed carbonate rocks exposed above the Carrara at Quartzite Mountain to the Bonanza King Formation.

Undifferentiated Meta-carbonate Rocks

At three localities in the Quartzite Mountain map area, meta-carbonate rocks of undetermined age crop out. In the easternmost portion of the map area, patchy outcrops of severely contact metamorphosed calcite and dolomite marble are present, perhaps in stratigraphic succession above the Carrara Formation (Plate I).

At Sparkhule Mountain (Plate I), a large outcrop of coarse-grained grey to white calcite marble is being quarried by the Riverside Cement Company. Miller (1944) reported the occurrence of poorly preserved Mississippian (?) fossils from the Sparkhule area. Bowen (1954) returned to Miller's fossil locality but found no further material, however, he reported brachiopod and crinoid debris of Carboniferous age from elsewhere on Sparkhule Mountain. Although the limestones on the northwest side of Sparkhule Mountain are not as badly recrystallized as the rocks in the main quarry area, no further fossils were obtained from these rocks during this study.

In the area of the Shay quarries and Dent Mine (Plate I), calc-silicate rocks, schist, and marble lie to the north of meta-hypabyssal (?) rocks along a north-dipping contact. This sequence dips to the north, becomes more calcareous upward and consists of pure marble at the Shay quarry (Riverside Cement Co. data). Calc-silicate and schistose units are exposed on the south side of the steep southwest-dipping fault which separates these rocks from the Zabriskie Quartzite exposed along the northeast rim of the quarries. It is not known whether the rocks in the Shay quarry - Dent Mine area are part of the proposed Johnnie-Stirling equivalent(?) sequence as the southeastward continuation of the fault which separates these rocks from the Zabriskie Quartzite along the northeast rim of the quarry is not known (Plate I). Thus these rocks are designated undifferentiated meta-carbonate rocks.

For this same reason, it is not known whether the northwest-southeast-trending outcrop of calc-silicate, dolomite, and impure limestone south of Klondike Mine (Plate I) is part of the Shay quarry - Dent Mine undifferentiated meta-carbonate sequence of part of the Johnnie-Stirling equivalent (?) sequence to the east and northeast. This outcrop has also been designated as undifferentiated meta-carbonate rocks.

MESOZOIC METASEDIMENTARY ROCKS OF THE FAIRVIEW VALLEY FORMATION

General Statement

Mesozoic metasedimentary rocks crop out in the northwestern corner of the map area and at the northeastern tip of Sparkhule Mountain (Plate I). The lithology of these rocks in these two places is quite different, but because of correlation with units mapped in the Black Mountain area (this study), these metasedimentary rocks have been assigned to the Mesozoic Fairveiw Valley Formation.

Massive Conglomerate (fv_1)

Thickness and lithology: In the north easternmost portion of the map area, a thick sequence (approximately 3530 feet, 1059m) of greenish conglomerate and interbedded finer clastic sedimentary rocks is exposed (Plate I). The conglomerate is interpreted to rest unconformably on the underlying meta-carbonate rocks of the Carrara Formation and undifferentiated meta-carbonate rocks, although along most of the contact with these older rocks, a faulted contact may be demonstrated (Plate I). Low topography and poor exposure in this area obscure the true relationship of these rocks to the underlying meta-carbonate rocks but it is believed that along portions of the contact, the original unconformable relation may occur (Plate I). An unconformable relationship is suggested by: 1) cobbles of underlying units in the conglomerate and 2) more highly deformed and metamorphosed rocks below the contact.

The sequence of conglomerate and interbedded finer clastic sedimentary rocks strikes east-west to west-northwest and dips very steeply to the north. No top and bottom indicators were seen in these sediments, but because of the presumed unconformable relationship to the underlying meta-carbonate rocks, it is believed that the sequence is upright. Clasts within the conglomerate are derived predominantly from metasedimentary (meta-quartzites, marble, chert, and occasional thinly layered calc-silicate rocks similar to those within the Carrara Formation), plutonic (monzonitic to granitic) and volcanic rocks. Clase size is highly variable: in some places clasts of over 30cm in diameter are present, although generally clasts are 15cm or less in diameter and vary from very well rounded to angular. Sorting is very poor. Occasional layering is present in the matrix which consists of finer-grained carbonate, quartzose, feldspathic (primarily orthoclase), chert and volcanic debris. The matrix and most of the non-quartzose clasts are severely contact metamorphosed, and consist primarily of bright green epidots, minor garnet, and other fine-grained calc-silicate minerals.

The amount of finer-grained interbedded sedimentary rocks increases upward through the sequence of conglomerate. In the vicinity of the hill with "tunnels", these rocks are highly altered and become chalky and kaolinized. Conglomeratic layers with resistant quartzite clasts and some very fine-grained thinly laminated cherty units are occasionally present; most of the rocks on this hill are so severely mineralized and hydrothermally altered that all original sedimentary features have been obliterated.

Silty Limestone, Calcareous Siltstone and Carbonate Conglomerate (fv_2, fv_3)

Thickness and lithology: At the northern tip of Sparkhule Mountain, silty limestone, calcareous siltstone and carbonate conglomerate and limestone are preserved in a N30E trending graben, down-faulted with respect to undifferentiated metacarbonate rocks (cu) to the northwest and southeast; this group of rocks being in turn up-faulted with respect to younger rocks of the Sidewinder Volcanic Group to the east (Plate I). The rocks in the graben, although somewhat deformed, preserve most of their original sedimentary structures; their degree of metamorphism or recrystallization is minor compared to that which affected the older metacarbonate rocks on the upthrown side of the graben and that which affected the older Late PE to Cambrian metasedimentary rocks in the Quartzite Mountain area. The rocks in the southwestern part of the graben are medium grey fine-grained silty limestone with small (1cm) black chert nodules and chert lenses of 1-10cm in length, flaggy orange-weathering silty limestone and calcareous siltstone and fairly pure grey limestone. The conglomerate unit (fv_3) overlies(?) orange-weathering calcareous siltstone in the northeastern half of the graben. The conglomerate contains some clasts of coarse-grained marble, but the predominant clast type is limestone and silty limestone, similar in appearance to the lithologies within the sequence itself. Clasts containing crinoidal hash were found within this unit.

Age and Correlation: The rocks discussed above can be correlated with the Mesozoic Fairview Valley which is well-exposed in the Black Mountain area. For an extensive discussion of this formation and its age assignment, the reader is referred to the discussion in the section below. Briefly, the Fairview Valley Formation at Black Mountain unconformably overlies plutonic rocks correlative with plutons dated at 230±3m.y., indicating that the formation is Mesozoic in age.

The lithology of the massive conglomerate exposed in the eastern portion of the Quartzite Mountain map area is similar to conglomerates at the base of the Fairview Valley Formation in the Black Mountain area. One of the most striking similarities between the rocks of these two areas is the ubiquitous presence of clasts derived from monzonitic plutonic rocks, like those unconformably beneath the Fairview Valley Formation at Black Mountain. The monzonite is distinctive in that it contains a high percentage of perthitic orthoclase (40-60 modal percent) and no modal quartz. The orthoclase and plagioclase of the monzonite are lathe-like and exhibit a dintinctive primary igneous foliation. The unconformable relationship of the conglomerate to the metasedimentary rocks at Quartzite Mountain is based primarily on the fact that the conglomerates contain abundant clasts of the metasedimentary rocks. This also indicates that the conglomerates were deposited after a major deformational and thermal event affected this area, a conclusion identical to that reached in the Black Mountain area.

The sedimentary rocks exposed on the northern tip of Sparkhule Mountain are lithologically very similar to rocks in the upper portion of the Fairview Valley Formation in the Black Mountain area. The carbonate conglomerate within the sequence at Sparkhule contains fossiliferous limestone clasts. Carbonate clasts containing fossils up to Lower Permian in age (Bowen, 1954) are abundant in, and characteristic of, the upper part of the Fairview Valley Formation in the Black Mountain area.

SIDEWINDER GROUP

General Statement

Mesozoic volcanic rocks crop out extensively both in the area studied and in adjacent terrains (Rogers, 1967). These were first named by Miller (1944) as the "Sidewinder Valley Metavolcanics" and later renamed by Bowen (1954) as the Sidewinder Volcanic Series, of which Sidewinder Mountain is the type locality. The designation "Sidewinder Group" is preferred here as "series" is a time-stratigraphic term that should not be used in rock-stratigraphic sense (ACSN, Code of Stratigraphic Nomenclature, 1961, Article 9f). Furthermore, the data presented below indicates that 1) Sidewinder volcanic rocks do not appear to be the same age everywhere, and 2) it is possible that rocks of the Sidewinder Group may, in the future have to be divided into two or more formations. The sequence in the area studied contains primarily stratified pyroclastic rocks but metasedimentary units and hypabyssal intrusives are also common.

Sidewinder Group in the Quartzite Mountain Area

Description: Volcanic rocks of the Sidewinder Group are extensively exposed in the Silver Mountain area fig. 1). Only the southernmost tip of this mountain is included in the map area. Units within the volcanic sequence dip very gently to the north, and are sub-horizontal in places. In the easternmost portion of the map (Plate I), the volcanic rocks unconformably overlie tactite of the undifferentiated metacarbonate unit as well as portions of the near-vertically dipping Fairview Valley massive conglomerate. Portions of the contact between the volcanic rocks and the underlying rocks may be faulted, but the original relation to the underlying rocks was unconformable (Plate I). The lowest exposed volcanic unit in this area is a dark green, structureless, non-bedded dacite-quartz latite flow rock. Where it overlies the metacarbonate rocks, this unit contains fine-grained volcanogenic sediments with fine to very fine-grained sand-size angular to rounded quartz grains supported by a very fine-grained matrix which now consists of primarily coarse epidote, antinolitic hornblende, muscovite and tremolite. Right above the basal unconformity are lenses of pebble conglomerate containing clasts of limestone, meta-quartzite, chert and volcanic rocks fragments within a finer-grained matrix. The dacite-quartz latite flow unit is overlain (hill 4251) by a sequence of welded tuffs which in turn is overlain by a thick sequence of light colored, felsic, glassy flow units which exhibit a variety of devitrification textures. None of the units within this sequence are very laterally extensive; some units within the sequence may actually be hypabyssal intrusive rocks rather than extrusive flow units.

In thin section, all of these volcanic rocks and volcanogenic sedimentary rocks exhibit a high degree of alteration which is generally typical of rocks of the Sidewinder Group throughout the area. No original mafic minerals remain in these rocks although relict outlines are sometimes present in thin section suggesting the presence of biotite and hornblende altered to epidote/clinozoicite, actinolite/hornblende, chlorite and magnetite. Plagioclase phenocrysts in the volcanic rocks vary from slightly to completely sericitized. The welded tuffs sometimes exhibit relict outlines of the welded glass shards in thin section although all original glassy material has devitrified.

Age and Correlation: Although rocks of the Sidewinder Group are extensively exposed in the study area and in adjacent terrains, there has been virtually no work done on defining the absolute age and/or stratigraphic correlation between their major areas of outcrop.

Bowen (1954) described the regional characteristics of the Sidewinder Volcanics as, "The exposures consist of overlapping, interfingering, irregularly shaped masses of dacite, quartz latite, latite-andesite and rhyolite. True andesite is uncommon and basalt rare." The extreme lithologic heterogeneity and lack of lateral continuity of units within the volcanic sequence, coupled with their generally advanced state of alteration are some of the more obvious reasons hindering correlation of the volcanics from place to place. Alteration has, in general, also precluded the acquisition of reliable geochemical and/or radiometric age data from these rocks.

Volcanic rocks belonging to the thick Sidewinder sequence exposed on Silver Mountain have been shown to unconformably overlie probable Plaeozoic(?) undifferentiated carbonate rocks as well as near vertically dipping conglomerates correlative with the post-230+8 m.y. old Fairview Valley Formation at Black Mountain. Because rocks of the Sidewinder Group at Quartzite Mountain overlie near vertical dipping Fairview Valley Formation conglomerate, it is clear that they post-date a deformation which occurred after deposition of the Fairview Valley Formation.

At Black Mountain, volcanic rocks unconformably overlie Fairview Valley sedimentary rocks along an erosional unconformity but perhaps do not post-date a major folding event as they are involved in the same cleavage-producing deformation which caused NW-SE folding of the Fairview Valley rocks about steep axial planes. These relationships indicate that the sub-horizontal volcanic rocks at Quartzite Mountain may be a younger part of the Sidewinder Group than the volcanic rocks which overlie the Fairview Valley Formation at Black Mountain. This also suggests that the Sidewinder volcanic rocks may ultimately have to be divided into two or more units. A very thick succession of volcanic rocks of the Sidewinder Group occurs in fault contact with the more highly sheared volcanic rocks above the Fairview Valley Formation at Black Mountain: because they are not as highly tectonized as the volcanic rocks above the Fairview, this portion of the Sidewinder volcanic rocks may be somewhat younger than the tectonized volcanic rocks.

Many hypabyssal dikes cross-cut the deformed Fairview-Sidewinder sequence at Black Mountain; these dikes may be related to continuing volcanism and the extrusion of the later, less deformed volcanic rocks in this area. These complex time-relationships, and the variation in the degree of deformation exhibited by rocks of the Sidewinder Group within the area studied suggests that these sequences may represent successive spisodes of volcanism or continuous volcanism within a time and space framework at times associated with deformation. Substantiating this interpretation of continuous or episodic volcanism through time is the presence of abundant volcanic debris within the Fairview Valley Formation: this indicates that volcanism occurred prior to, and perhaps during, the deposition of the pre-Sidewinder Fairview Valley Formation.

Detailed mapping, geochmical, and geochronological work on rocks of the Sidewinder Group will be necessary before this complicated sequence of extrusive and hypabyssal rocks and their relation to the plutonic rocks of this area is fully understood.

Rocks of the Sidewinder Group at Quartzite Mountain have been intruded by granitic and quartz monzonite bodies to the east of Mack's peak (Plate I). No age data are available for this cross-cutting event, but if these granitic and quartz monzonite intrusions are related to larger quartz monzonite plutons in the Quartzite Mountain area dated near Victorville by Armstrong and Suppe (1933) at 72 ± 1.4m.y., they provide an upper limit for the age of rocks of the Sidewinder Group in this area.

CENOZOIC ALLUVIUM

Both older (Qoal) and recent alluvium (Qal) have been mapped in the Quartzite Mountain area. The older dissected alluvium is widely distributed along the course of the Mojave River and is Pleistocene in age (Bowen, 1954). Erosional remnants of older alluvium are related to Recent down cutting of the Mojave River drainage system.

INTRUSIVE ROCKS

General Statement

The metasedimentary and metavolcanic rocks in the Victorville area are present as roof pendants within batholithic rocks of Cretaceous age. Many aplitic, granitic and quartz monzonite dikes associated with this latest intrusive event cross-cut all structural trends within the rocks of the roof pendants. Within the Quartzite Mountain roof pendant itself, several older intrusive events are recorded. The recent dating of several plutons in the nearby Granite Mountains (fig. 1) by Calvin Miller (pers. comm.) has shown that the earliest plutons known in this area are 230±8 m.y. old. Plutonism and volcanism within the Victorville area probably occurred episodically or continuously from 230m.y. ago until about 60m.y. ago which is the predominant youngest potassium-argon age obtained for batholithic rocks in the area (Armstrong and Suppe, 1973). Because of this long history of plutonism, the oldest rocks in the area have undergone a highly complex thermal history.

Older Intrusive Rocks in the Quartzite Mountain Area

Amphibolite dikes: Dark green, hornblende-rich dike rocks are very common in the older Late Precembrian to Cambrian metasedimentary rocks of Quartzite Mountain. These dikes are not shown on the geologic map because of their small size. Most of the dikes exhibit a hornblende-biotite lineation trending N40W, parallel to the trend of the fold axes formed during the second deformation in this area. In thin-section these amphibolite dikes contain 30-50% hornblende, 0-30% biotite, and some altered zoned plagioclase phenocrysts in a much finer matrix consisting predominantly of plagioclase with minor percentages of potassium feldspar (less that 3-5%) and quartz (5-10%). Presence of relict, zoned, plagioclase phenocrysts within a finer-grained matrix indicates that these were once hypabyssal dike rocks. The high percentage of hornblende and plagioclase indicate that these dike rocks had the composition of diorite or gabbro before metamorphism.

As the second deformation in the Quartzite Mountain area elsewhere caused only local regrowth of the biotite formed during the first deformation, it is probable that the amphibolite dikes, initially diorite or gabbro, were recrystallized during the first deformation which involved upper greenshist grade metamorphism, rather than during the second deformation. If this is true, the lineation developed during the metamorphism of these dikes could be evidence for the colinearity of the first and second deformations.

Meta-hypabyssal igneous rocks(?): In the southeastern portion of the map area, from east and south of the exposures of the Precambrian Johnnie-Stirling eq.(?), to the highway through Oro Grande, a unit labeled h crops out. These rocks are intruded on the east by batholithic quartz monzonite. The rocks are light grey to brownish grey, very fine grained, and are foliated to slightly gneissic. Bowen and VerPlank (1965) indicated that these were probably granitized aluminous sediments and/or sheared granitic rocks. Dibblee (1967) mapped these as Precambrian granitic gneisses.

In thin-section, these rocks contain approximately 3-5% biotite (rarely some hornblende) which is always optically aligned and defines the foliation within the rocks. Strung out clots of coarser-grained semi-sericitized plagioclase grains, minor quarts, K-feldspar and biotite occur within a very fine-grained matrix of quartz, plagioclase, K-feldspar and biotite. Some thin-sections of these rocks contain some large sericitized relict plagioclase grains. The presence of coarser-grained clumps of plagioclase and occasional large, intact relict plagioclase porphyroblasts in a much finer-grained matrix indicates that these rocks may be sheared and metamorphosed equivalents of felsic hypabyssal intrusive rocks, rather than sheared Precambrian basement rocks as proposed by Dibblee (1967) or granitized metasedimentary rocks as proposed by Bowen and Ver Plank (1965).

In the Pierce quarry area (mapped in reconnaissance during this study), rocks petrographically identical (although not as sheared) to the meta-hypabyssal igneous rocks(?) of the Quartzite Mountain area occur in obvious intrusive relationship to older metacarbonate rocks. As here these rocks are not as sheared, their igneous textures are obvious in thin-section.

Undifferentiated Granitic Rocks

The Quartzite Mountain metasedimentary rocks are preserved as a small roof pendant within a large granitic pluton which outcrops extensively in this area. Mapping was not done within these plutonic rocks and for this reason they are labeled only as undifferentiated Upper Mesozoic granitic rocks. Most of this plutonic terrain, however, consists of medium-grained, homogeneous, quartz monzonite. Although not continuous in outcrop, it is probably part of the same quartz monzonite pluton exposed in the Victorville Upper Narrows area (fig. 1) where it has been dated by Armstrong and Suppe (1973) as 72±1.4 m.y. old. These Upper Cretaceous plutonic rocks are the youngest instrusives in the map area. Aplite, granite and quartz monzonite dikes related to the emplacement of this pluton cross-cut all structures in the metasedimentary rocks of the map area. Some of the larger cross-cutting dikes are shown on the map. A passive emplacement mechanism is indicated for these plutonic rocks as structural trends can be followed from one segment of the roof pendant to another across the larger dikes, for example on the southeastern tip of Quartzite Mountain (Plate I).

A few small aplite and granite dikes were observed in the Quartzite Mountain metasedimentary rocks that were boudinaged along axes parallel to the E-W trending axes of the latest deformation affecting the rocks of this area. These granitic dikes must pre-date this latest deformation as well as pre-date the emplacment of the major quartz monzonite plutonic rocks of the area.

II. Deformation and Metamorphism

INTRODUCTION

The metasedimentary rocks in the Quartzite Mountain area have undergone a complex thermal and deformational history. At least three episodes of folding have affected these rocks. The folding events are all pre-Upper Cretaceous in age. The earlier two episodes of deformation were accompanied by dynamothermal metamorphism. The term "dynamothermal metamorphism" as defined by Winkler (1974) is used loosely here because it is not known whether this metamorphism is truly extensive and of a regional nature. Because the Victorville area lies within the trend of the Southern Cordillera Mesozoic magmatic belt and therefore has been subjected to repeated episodes of plutonic intrusion, it is possible that metamorphic events in this zone may be closely related in time and space to the intrusive centers themselves. Pre-Upper Cretaceous faulting has also affected these rocks. Although the magnitude and significance of the faulting in the older Precambrian-Cambrian rocks in the area is not known, none of the faults juxtapose rocks of different metamorphic grade and deformational intensity. Two significant angular unconformities have been mapped in the Quartzite Mountain area. All of the metasedimentary rocks of the map area have been affected by repeated (and often local) contact metamorphic events. All structures in the area have been intruded by batholithic plutons of probably Late Cretaceous age.

SEQUENCE OF EVENTS

The first event to affect the older Precambrian-Cambrian rocks in this area was an intense folding event that produced isoclinal folds and transposition of bedding in all the more ductile rocks of the area, particularly within the carbonate rocks. This folding event was accompanied by upper greenschist grade metamorphism as shown by foliation defined by the preferred orientation of both biotite and muscovite developed in the more pelitic rocks. There is little evidence available on the trends of fold axes and axial planes formed during this first deformation because these features have been strongly refolded by later events. Color banding on S_1 surfaces (probably the intersection of S0x1) on the upright limb of the Quartzite Mountain anticline trend N40W, suggesting that the earliest deformation may have produced folds of that trend which are colinear with the second phase folds. As discussed above, most of the amphibolite dikes, the oldest intrusive rocks in the area, often exhibit a hornblende lineation which trends N40W, colinear with fold axes formed during the second deformation. It is not clear whether these dikes were metamorphosed during the first or second deformational event. Because the metamorphism associated with the second deformation in the Quartzite Mountain area caused only local regrowth of the biotite foliation developed during the more intense metamorphism which accompanied the first deformation, it is possible that the amphibolite dikes, initially diorites or gabbros, were recrystallized during the first deformation rather than during the second. If this is true, the lineation developed during the metamorphism of these dikes would be additional evidence for the colinearity of the first and second deformations.

The fault on the northeast flank of Quartzite Mountain juxaposes the northwest trending Cambrian Bonanza King Formation with northeast trending Zabriskie Quartzite and Wood Canyon Formation,cuts across structural trends developed during the first deformation. F_2 fold axes and S_{1x2} lineations in the Wood Canyon Formation on the east side of the fault trend N40W and plunge 30-40 degrees to the northwest. As these have the same orientation as the F_2 folds on the west side of this fault, the faulting must have occurred prior to or at the time of the second deformational event.

The second folding event produced the Quartzite Mountain anticline (Plate I). The anticline is defined by the folding of bedding within the Zabriskie and upper Wood Canyon quartzites about a N50-60W, 30NW fold axis and southwest dipping axial plane. The fold is also defined by the folding of the S_1 surface developed during the first deformation in the Wood Canyon dolomitic member about this axis. S_{1x2} lineations in both the carbonate rocks and Wood Canyon schist in the Quartzite Mountain area are well developed and trend N40-50W, plunging about 30 degrees to the northwest. The second deformational phase is characterized by the development of two distinct but related sets of colinear megascopic folds. Rocks of the Wood Canyon in the core area of the Quartzite Mountain anticline display occasional folds with N40-50W trending axes which have fanning fracture cleavage; some of the axial planes of these folds dip to the northeast. The cleavage surfaces of these folds are intersected by the better developed southwest dipping axial plane cleavage of slightly later but more pervasive F_2 folds. These two sets of folds are probably closely related in time and belong to successive stages of the second deformational event, the rocks exhibiting slightly more brittle behavior during the first stage that during the second.

Schist in the Wood Canyon Formation in the Quartzite Mountain area exhibits evidence for a later third deformation along east-west-fold axes and steep axial planes. Local cleavage produced during this deformation causes crinkling of previously developed foliation surfaces along east-west axes. Small folds associated with this deformation are exposed in Comet Quarry (Plate I). This deformation may have been late and affected all metasedimentary rocks in the area: occasional aplitic dikes possibly associated with the latest granitic intrusions in the area are boudinaged along east-west axes related to this deformational episode. These three deformational episodes all predate intrusion of the quartz monzonite batholithic rocks.

A series of faults cut the older rocks of the Quartzite Mountain area. The significance of and the magnitude of displacement along these faults is not clear, however none of the faults juxtapose rocks of different metamorphic grade and deformational intensity. The Late Cretaceous granitic rocks of the area intrude these faults, so the faults must be pre-Upper Cretaceous in age. The steep northeast dipping fault which juxtaposes Precambrian-Cambrian Wood Canyon Formation against Precambrian Johnnie-Stirling equivalent(?) on the southwest flank of Quartzite Mountain postdates the second deformational event as it cuts across trends developed during this deformation. This fault is cut by the fault which juxtaposes gently dipping Zabriskie and Wood Canyon against Johnnie-Stirling equivalent(?) along the west side of the hill underlain by the Johnnie-Stirling equivalent(?). This later fault dips moderately to the west along the wall of the Canyon, at first juxtaposing Zabriskie against Zabriskie, cuts down-section in the Wood Canyon Formation exposing the dolomitic member along the west wall of the Canyon, then cuts slightly up-section to the south cutting out the dolomitic member of the upper Wood Canyon. To the southwest it again cuts down-section and continues to the west where it may be truncated near the Klondike mine by the steep southwest dipping fault which juxtaposes

Zabriskie against undifferentiated carbonate rocks in the Shay Quarry area. These first two faults may not have major displacements if the gently dipping Wood Canyon and Zabriskie sequence (hill 3800) is part of the upright limb of the Quartzite Mountain anticline.

The relative age of the east-west trending, steeply south dipping fault which juxtaposes Cambrian Carrara(?) against the Wood Canyon Formation along the south side of Oro Grande Canyon is not known as it cannot be demonstrated whether this fault cuts or is cut by the faults described above. Foliation in rocks on both sides of this fault are essentially parallel. A small outcrop of overturned Zabriskie and Carrara is present just south of Mack's peak (Plate I). The reason for this overturned sequence is not understood; possibly faulting in this zone is more complex than the available field evidence suggests, particularly if faulting post-dates previously formed complex structures.

Massive conglomerate of the Fairview Valley Formation rests unconformably on the older metasedimentary rocks in the northeast corner of the map area. Although the Fairview Valley Formation has been affected by contact metamorphism, as evidenced by the sericitic alteration of plagioclase in the clasts of the conglomerate and the ubiquitous presence of coarse-grained epidote/clinozoisite in both clasts and matrix, the Fairview Valley rocks in the Quartzite Mountain area do not exhibit any evidence of dynamothermal metamorphism and lack penetrative foliation or cleavage. This strongly suggests that the erosion of the Precambrian-Cambrian metasedimentary rocks and the deposition of the Fairview Valley Formation conglomerate post-dates the second deformational phase which affected the older rocks in this area. Map-scale evidence to substantiate this interpretation is, however, lacking, and one could argue that the lack of penetrative foliation or cleavage in the conglomerate might be due to its much more massive lithology and more brittle behavoir at the conditions of metamorphism prevailing during deformation.

With the exception of the fault discussed above which juxtaposes Bonanza King and Zabriskie - Wood Canyon Formation, and which predates F_2, it is not known whether the other faults described above pre-date or post-date this unconformity.

Prior to the deposition of the almost flat-lying Sidewinder volcanic rocks of this area, pre-Sidewinder age rocks were involved in a period of high-angle faulting as evidenced by faults which down-drop Fairview Valley Formation rocks with respect to underlying older metasedimentary rocks. These faults do not offset the Sidewinder volcanic rocks and hence pre-date the deposition of the volcanic rocks. It is not known whether this faulting episode was associated with and/or post-dated a significant folding episode affecting Fairview Valley and older rocks; the extent of outcrop is insufficient to answer this question. Near vertical dips within the Fairview Valley conglomerate beneath the volcanics of the Sidewinder group may be related solely to a faulting episode, to folding, or to both. Silty limestone and limestone cobble conglomerate of the Fairview Valley Formation which are exposed on the northern side of Sparkhule Mountain are obviously deformed as shown by flattening of clasts within the conglomerate parallel to bedding. Lack of exposure does not permit one to determine if this deformation occurred during a post Fairview Valley folding event.

The high-angle faulting and/or folding event which post-dated Fairview Valley age rocks was followed by erosion and deposition of subaerial pyroclastic and interbedded sedmientary rocks of the Sidewinder Group. The Sidewinder Group is in turn cut by some later high angle faults.

TIMING OF STRUCTURAL EVENTS

No radiometric age dates are available on rocks in the immediate vicinity of Quartzite Mountain. Quartz monzonite plutonic rocks from the Victorville Narrows (fig. 1) have been dated by Armstrong and Suppe (1973) as 72± 1.4 m.y. old. These plutonic rocks are probably the same age and part of the same plutonic complex as the granitic to quartz monzonitic rocks of the Quartzite

Mountain area. These plutonic rocks intrude all metasedimentary rocks and structures in this area, and provide the upper age limit for all structural events described from the Quartzite Mountain area.

At Black Mountain, discussed below, the Fairview Valley Formation unconformably overlies distinctive monzonite plutonic rocks, chemically and petrographically identical to plutons dated in the nearby Granite Mountains (fig.1) by Calvin Miller (pers. comm) as 230 ± 8 m.y. old (U/Pb, zircon). This provides a lower age limit for the Fairview Valley Formation. The monzonite pluton unconformably beneath the Fairview Valley Formation at Black Mountain intrudes isoclinally folded calcite marble and severely contact metamorphoses it. Although the marble is too severely recrystallized to identify, it probably represents a portion of the Paleozoic carbonate section exposed nearby within the study area. As the Fairview Valley Formation post-dates F_1 and most likely F_2 in the Quartzite Mountain area, it is possible that the 230 m.y. old monzonites exposed in the Black Mountain and Granite Mountain area may have been coeval with or post-dated one or both of the deformational episodes which affected the older rocks in the Quartzite Mountain area. If coeval, this plutonic event may have provided the thermal regime necessary for the metamorphosm accompanying the deformation in the Quartzite Mountain area. Although the 230 m.y. old monzonite plutons provide a lower age limit for the Fairview Valley Formation, there are no radiometric dates from the Sidewinder volcanic rocks which would provide an upper age limit for this formation. As the Sidewinder volcanic rocks post-date the post-230m.y. Fairview Valley Formation and are intruded by granitic rocks probably associated with the latest Upper Cretaceous intrusive episode in the Quartzite Mountain area, both the volcanic rocks and the Fairview Valley Formation must be Mesozoic in age.

The sequence of events affecting the rocks at Quartzite Mountain are listed in figure 3.

FIGURE 3

SEQUENCE OF EVENTS, QUARTZITE MOUNTAIN AREA

(?) Intrusion of gabbroic dikes

1. Deformation D_1: Folding accompanied by upper greenschist grade metamorphism. Colinear with D_2(?). Prior to or during 230± 8 m.y. old intrusive event(?)

2. Intrusion of meta-hypabyssal (?) igneous rocks. Not clear whether pre- or post-event 1. Northwest trending fault on the northeast flank of Quartzite Mountain.
   D_{2a}: Folding, N40-50W fold axes, fanning fracture cleavage
   D_{2b}: Folding, accompanied by partial regrowth of biotite and muscovite, formation of Quartzite Mountain anticline. Fold axes N40-50W, 30NW, southwest dipping axial planes.

3. High angle faulting: not clear whether pre- or post-Fairview Valley (event 4).

4. Unconformity: deposition of Fairview Valley Formation (Post 230 ± 8 m.y. ago)

5. High-angle faulting of Fairview Valley-older rocks contacts. (Tilting of Fairview Valley and older rocks-due to folding event(?) or to high-angle faulting) Event 3 may have occurred at this time.

6. Unconformity: deposition of Sidewinder Group volcanic rocks.

7. Deformation D_3: minor folding-east-west axes, steep axial planes, crinkle lineation and small folds in Wood Canyon schists. Faulting of Sidewinder Group volcanic and older rocks.

8. Intrusion of 72 ± 1.4 m.y. old batholithic quartz monzonite

GEOLOGY OF THE SIDEWINDER MOUNTAIN - BLACK MOUNTAIN AREA

I. Stratigraphy

INTRODUCTION

About ten miles (17 km) due east of Quartzite Mountain, and across the trace of the Helendale fault is the Black Mountain - Sidewinder Mountain area (fig. 1). Black Mountain is the type locality for the Fairview Valley Formation (Bowen, 1954). Sidewinder Mountain is the type locality for the Sidewinder Group (Bowen, 1954). On the northern side of Sidewinder Mountain, in fault contact with the Sidewinder Group rocks is a structurally very complex roof pendant in granitic rocks. This roof pendant contains metasedimentary rocks ranging in age from the Precambrian-Cambrian Wood Canyon Formation up to possible equivalents of the Mississippian Monte Cristo Limestone.

The rocks of the Sidewinder Mountain-Black Mountain area will be discussed in order of their relative ages, followed by a discussion of the tectonics which have affected these.

LATE PRECAMBRIAN TO PALEOZOIC METASEDIMENTARY ROCKS

General Statement

Exposure of the older Precambrian to Paleozoic metasedimentary rocks are present in three places within the map area (Plate II). The largest exposure lies on the northern spur of Sidewinder Mountain. Here, a structurally highly complex roof pendant in Mesozoic granitic rocks is in fault contact on its south side with Mesozoic volcanic rocks of the Sidewinder group. The roof pendant contains several partial sections of Precambrian to Paleozoic metasedimentary rocks. The oldest unit exposed is the upper part of the Precambrian-Cambrian Wood Canyon Formation, the youngest are possibly equivalent to the Mississippian Monte Cristo Limestone. The partial sections are in fault contact with one another, and tectonic slicing of what were once normal stratigraphic contacts appears to have been prevalent. Similar to problems of correlation at Quartzite Mountain, the actual sequences of rock types rather than their detailed lithologic characteristics and thicknesses, has been the most important criteria for the identification and correlation of the rocks at Sidewinder Mountain to non-metamorphosed strata of the southern Great Basin region. Correlation of the Precambrian Wood Canyon Formation, the Cambrian Zabriskie Quartzite and the Cambrian Carrara Formation to sequences in the southern Great Basin was discussed in the Quartzite Mountain section and will not be discussed in detail below. The Paleozoic carbonate rocks which overlie the Carrara Formation, although generally recrystallized to marbles, can be subdivided into formations typical of platform facies sequences of the southern Great Basin. The Paleozoic carbonate rocks in this roof pendant, however, are not as deformed and recrystallized as the carbonate rocks at Quartzite Mountain. Original bedding and some of the original lithologic characteristics have been preserved locally in some of these units. A composite lithostratigraphic column of these rocks is shown in figure 4. Thickness estimates are only approximate tectonic thicknesses and probably vary considerably from original stratigraphic thicknesses.

Some characteristics of the metamorphic history of these rocks also differs from those affecting rocks described from Quartzite Mountain. Pelitic rocks of the Carrara Formation do not contain a foliation or schistocity but rather hornfels contact metamorphic textures.

South of the Sidewinder Mountain roof pendant is a small outcrop of Cambrian Bonanza King Formation at Tri-Color Quarry (Plate II). Here the Bonanza King Formation is overlain by carbonate conglomerate probably correlative with the Fairview Valley Formation. These older rocks are in fault contact with volcanic rocks of the Sidewinder Group.

At the Black Mountain quarries, coarsely crystalline marbles of Paleozoic (?) age occur unconformably beneath the Fairview Valley Formation. The marbles here are too recrystallized for identification, and they will be discussed only in the section dealing with the Fairview Valley Formation and its relationship to underlying rocks.

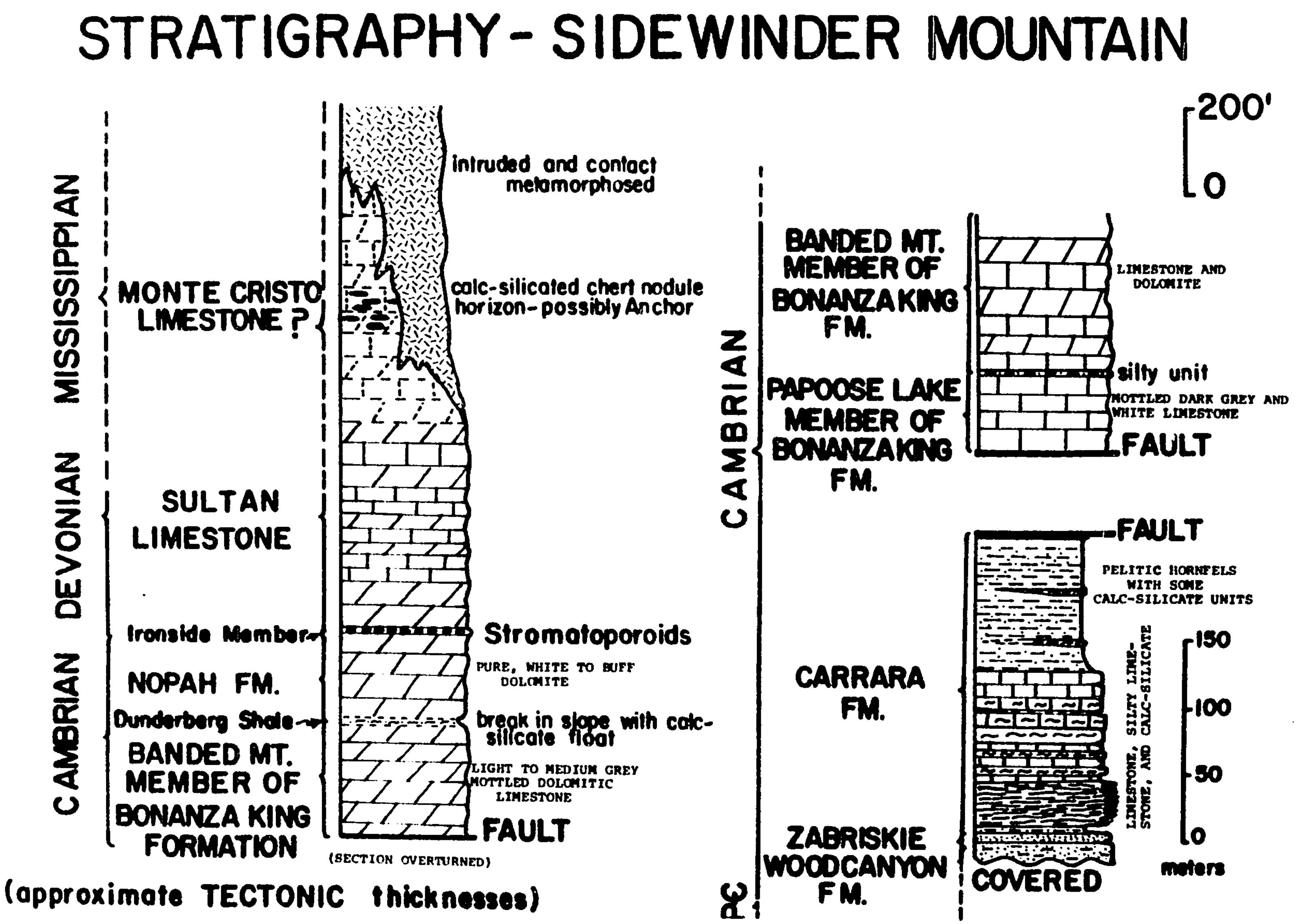

STRATIGRAPHY - SIDEWINDER MOUNTAIN
MISSISSIPPIAN
DEVONIAN
CAMBRIAN
MONTE CRISTO LIMESTONE ?
SULTAN LIMESTONE
Ironside Member
NOPAH FM.
Dunderberg Shale
BANDED MT. MEMBER OF BONANZA KING FORMATION
intruded and contact metamorphosed
calc-silicated chert nodule horizon - possibly Anchor
Stromatoporoids
PURE, WHITE TO BUFF DOLOMITE
break in slope with calc-silicate float
LIGHT TO MEDIUM GREY MOTTLED DOLOMITIC LIMESTONE
FAULT
(SECTION OVERTURNED)
(approximate TECTONIC thicknesses)
CAMBRIAN
PC
BANDED MT. MEMBER OF BONANZA KING FM.
PAPOOSE LAKE MEMBER OF BONANZA KING FM.
CARRARA FM.
ZABRISKIE WOODCANYON FM.
LIMESTONE AND DOLOMITE
silty unit
MOTTLED DARK GREY AND WHITE LIMESTONE
FAULT
FAULT
PELITIC HORNFELS WITH SOME CALC-SILICATE UNITS
LIMESTONE, SILTY LIMESTONE, AND CALC-SILICATE
COVERED
200'
0
150
100
50
0
meters

FIGURE 4

Wood Canyon Formation

Thickness and Lithology: Two small exposures of Wood Canyon Formation are present at Sidewinder Mountain. The first exposure occurs beneath the upright Zabriskie-Carrara sequence at the base of the western side of the mountain (Plate II). The Wood Canyon consists of dark brownish, laminated, fine-grained, impure quartzite. The rocks are covered to the south by alluvium. The second exposure, bound on the southwest by a major high angle fault, is overturned, dips to the southwest, and is underlain by the Zabriskie Quartzite (Plate II). This small sliver of Wood Canyon Formation is primarily composed of dark brown, laminated, fine-grained impure quartzite. Stratigraphically below the Zabriskie, in the saddle of the mountain, the Wood Canyon contains very coarse-grained sandstones which are occasionally cross-bedded. Cross-bedding indicates that the sequence is overturned. Rare vestiges of what may have been *Scolithus* tubes are present in this exposure of Wood Canyon, but these are not as well-developed as at Quartzite Mountain. The two exposures of Wood Canyon Formation at Sidewinder Mountain contain no carbonate or calc-silicated units such as occur near the top of the Wood Canyon Formation at Quartzite Mountain (fig. 2). Because only the uppermost beds of the Wood Canyon are exposed there is no evidence suggesting whether or not carbonate units may have been present lower in the section.

Age and Correlation: In the Sidewinder Mountain area, the limited exposures of the Wood Canyon Formation preclude comparison of these rocks to Wood Canyon sequences elsewhere. The formation was identified on the basis that it underlies clean, vitreous orthoquartzite of the Zabriskie and contains possible vestiges of Scolithus tubes.

Zabriskie Quartzite

Thickness and Lithology: The distinctive pinkish red to white vitreous Zabriskie Quartzite crops out in two places on Sidewinder Mountain. Above the Wood Canyon Formation at the base of the hill (Plate II), it is approximately 20 feet (6 m) thick and is overlain by carbonate and calc-silicate rocks of the Carrara Formation. Its upper and lower contacts are not well exposed. In the saddle of the mountain (Pl. II), the Zabriskie is overturned and is underlain (structurally overlain) by Wood Canyon quartzite and overlain (structurally underlain) by calc-silicate rocks and limestone of the Carrara Formation. At this second exposure, the Zabriskie Quartzite is brecciated and tectonic shearing and slicing is evident along exposed portions of its upper and lower contacts. Along the trend of its outcrop, the Zabriskie varies from about 5-7 feet (2.1m) to about 20 feet (6m) in thickness. A small outcrop of orthoquartzite occurs along the trace of the fault between Carrara and overlying Bonanza King Formation along the south flank of the western portion of the southwest roof pendant, and is possibly a piece of

Zabriskie Quartzite which was incorporated as a tectonic slice along the fault.

Age and Correlation: Like the Zabriskie at Quartzite Mountain, a distinctive orthoquartz composition and stratigraphic position between Wood Canyon clastic rocks and Carrara carbonate and calc-silicate rocks are used as the criteria for recognition of the Zabriskie Quartzite. Although the Zabriskie is severely brecciated and tectonic shearing and slicing along its contacts, the difference in thickness between the Zabriskie here and at Quartzite Mountain may be real and not entirely the result of tectonic thinning. In the southern Great Basin, the Zabriskie Quartzite forms a westward thickening wedge of 0-1000 feet (0-300m) (Stewart, 1970). If the difference in thickness between the Zabriskie of Quartzite Mountain and that of Sidewinder Mountain is real, it would indicate that the Precambrian sequence of Sidewinder Mountain was perhaps deposited in a more cratonal position than was the sequence at Quartzite Mountain.

Carrara Formation

Thickness and Lithology: The Cambrian Carrara Formation is best-exposed along the southern slope of the eastern half of the Sidewinder Mountain roof pendant (Plate II). Across the northwest-trending high angle fault (Plate II) it crops out structurally below the overturned Wood Canyon-Zabriskie Sequence in the saddle of the mountain and is inferred to continue along strike and form the southernmost exposures along the eastern half of the roof pendant where it is overturned and in fault contact on its north side with the Banded Mountain Member of the Bonanza King Formation along the extent of its outcrop (Plate II). Eastward, small bodies of Carrara pelites, still in fault contact with the Bonanza King Formation swing around the eastern tip of the roof pendant and are exposed again to the north (Plate II).

On the south slopes of the eastern half of the roof pendant,where best exposed, the Carrara is about 700 feet (210m) thick (tectonic thickness). Because its upper contact with the Bonanza King Formation is a fault contact which appears to truncate structures within the Carrara sequence, it is uncertain whether most or only a part of the Carrara Formation is exposed here. The portion that is exposed, however, consists of a lower, more calcareous sequence and an upper pelitic sequence. The calcareous sequence is directly above the Zabriskie Quartzite and consists of a thin dark quartzite unit, followed by resistant, banded, greenish calc-silicate rocks which are overlain by interlayered limestone, calc-silicate rocks and pelite. The grey limestone units contain small calc-silicate knots, possibly the vestiges of silicified girvinella or algal balls, which are common to the Carrara Formation in the southern Great Basin area. The thick pelitic unit above the calcareous sequence is a slope-forming, non-resistant, featureless sequence of dark hornfelsed pelitic rocks which do not crop out well. Occasional greenish, more resistant calc-silicate and siltstone units occur within the pelitic sequence. A bright greenish-yellow, mottled, calc-silicate unit occurs at the top of the sequence directly beneath the fault at the top of the Carrara exposures.

Age and Correlation: Its mixed carbonate and pelitic lithology and its position above the Zabriskie Quartzite were the criteria used in the recognition of the Carrara Formation. Presence of the vestiges of algal balls(?) which typify limestone units of the Carrara in unmetamorphosed terrains, strengthens correlation of these rocks with the Carrara Formation elsewhere.

The Carrara Formation at Sidewinder Mountain differs considerably from the Carrara Formation at Quartzite Mountain. The very thick, massive grey limestone unit in the Carrara at Quartzite Mountain is not present in this area. The Sidewinder Mountain section bears certain similarities with the Quartzite Mountain section in that carbonate-rich rocks are present at the base of the formation above the Zabriskie Quartzite and the formation becomes less calcareous upwards. The differences between the Carrara Formation in the two areas may substantiate the observation, based on the extreme differences in thickness of the Zabriskie Quartzite, that the sequences at Quartzite Mountain and at Sidewinder Mountain may have been deposited in somewhat different locations with respect to craton-miogeosynclinal trends within this area.

Bonanza King Formation

Thickness and Lithology: In fault contact with rocks of the Carrara Formation described above, in the western part of the Sidewinder Mountain roof pendant, are three fault slices of carbonate rocks which contain units correlative to portions of the Cambrian Bonanza King Formation. In the uppermost fault slice (Plate II, cross-section A-A' and figure 4) the lowest exposed units of the Bonanza King Formation are distinctive dark grey and white mottled to banded limestone. The exposed portion of this sequence is approximately 215 feet (64.5m) thick (tectonic thickness). Mottling or color-banding in the limestone is interpreted as an artifact of original mottling due to intense burrowing of these carbonate rocks with selective dolomitization of the burrows. Tectonic shearing, flow, and metamorphic recrystallization of these carbonate rocks has not entirely destroyed the mottling caused by original compositional variation, although it might be more properly termed "color-banding" in this area. The dark grey and white mottled to banded limestone unit is overlain by an orange-weathering, silty, calc-silicated unit approximately 5-10 feet (1.5-3m) thick which is overlain by a more heterogeneous sequence of light grey dolomitic limestone, mottled or color-banded limestone, and greyish-white to buff dolomite (377 feet (113m) tectonic thickness). As discussed more fully below, the two units, the lower limestone unit separated by a silty unit from the upper, more heterogeneous limestone and dolomite unit, may be correlated respectively to the lower Papoose Lake Member and the upper Banded Mountain Member of the Cambrian Bonanza King Formation. Parts of the sequence described above are repeated in two lower fault slices (Plate II, cross-section A-A').

Medium grey to light grey banded dolomitic limestone of the Banded Mountain Member of the Bonanza King Formation crops out beneath the Nopah Formation (structurally above), southeast of the fault which juxtaposes the Carrara Formation to this overturned section in the western part of the roof pendant (Plate II, cross-section A-A'), and also along the south side of the eastern part of the roof pendant where it is in fault contact with both the Carrara and Nopah Formations (Plate II). The lithology and appearance of the carbonate rocks in these two areas are identical. Identification of this unit at the first locality was based on its stratigraphic position below the Nopah Formation and higher units. Identification of this unit in the second locality was based on its lithologic similarity to rocks of the first locality.

At Tri-Color Quarry, carbonate rocks of the Banded Mountain Member of the Bonanza King Formation are unconformably overlain by conglomerate probably equivalent with the Fairview Valley Formation. Bedding in the Banded Mountain Member strikes N65E and dips 60 to the northwest. The sequence contains alternating white to buff laminated sugary dolomite and grey dolomitic limestone with some well-preserved grey mottled (burrowed) dolomite at the base of the exposed sequence. Above this sequence is a 4 foot (1.2m) thinly bedded dolomite and calc-silicate unit which is overlain by grey dolomite with chert nodule horizons.

Age and Correlation: Hazzard and Mason (1936) named and described the Bonanza King Formation in the Providence Mountains of California. Palmer and Hazzard (1956) indicated that the Bonanza King Formation possibly ranges from Middle to Upper Cambrian in age. The Bonanza King Formation has been mapped and correlated throughout the southern Great Basin region. Two formal subdivisions, the lower Papoose Lake Member and the upper Banded Mountain Member have been recognized in the Bonanza King Formation and were defined by Barnes and Palmer (1961). The most distinctive feature of the Papoose Lake Member in unmetamorphosed areas is its mottled pattern which consists of rusty orange mottles weathering out on a dark grey background (Gans, 1974). The Papoose Lake Member of the Bonanza King Formation is overlain by a distinctive thin unit of fine-grained silty dolomite which forms non-resistant orange-weathering slopes in an otherwise purer carbonate section (Gans, 1974). The silty unit is the base of the Banded Mountain Member which contains a heterogeneous sequence of light and dark grey dolomite and medium to dark grey mottled dolomite and limestone with occasional chert nodule horizons throughout the section (Gans, 1974).

In working with the metamorphosed equivalents of these units, no single criteria was used to correlate these rocks. Rather, the sequence of lithologies exposed was the most useful criteria for recognition and correlation of this formation: the sequence of distincitive dark grey and white color banded limestone, followed by a silty unit which separates these limestones from an upper, more heterogeneous sequence of limestone and dolomites is remarkably similar to the two-part division of the Bonanza King Formation in unmetamorphosed terrains. Fossils from the overturned sequence at the westernmost tip of the roof pendant, discussed below, provides very important evidence for the assignment of these carbonate rocks to the Cambrian Bonanza King Formation.

Nopah Formation

Thickness and Lithology: Dolomites assigned to the Cambrian Nopah Formation crop out extensively in the area of the Sidewinder Mountain roof pendant (Plate II). The Nopah Formation in this area is a distinctive massive, sugary, buff-weathering white dolomite with only occasional thin calc-silicate stringers. In the overturned sequence in the westernmost part of the roof pendant, grey dolomitic limestone of the upper Banded Mountain Member of the Bonanza King Formation is overlain by 1) a slight break in slope with calc-silicate float, 2) massive buff-weathering dolomite here assigned to the Nopah Formation

(200 feet (60m) tectonic thickness), 3) a 3-5 foot (1-1.5m) thick horizon of stretched stromatoporoids assigned to the Ironside Member of the Devonian Sultan Limestone, and 4) higher dolomites, limestone and dolomitic limestones.

Age and Correlation: Hazzard (1937) named and described the Nopah Formation from the type locality in the Nopah Range of California. He concluded that it was Upper Cambrian in age. Its base is defined by a silty and shaley unit called the Dunderberg Shale Member. In the Nopah Range the Nopah Formation is characteristically grey to dark grey dolomite, but in other localities (such as the New York Mountains (Burchfiel and Davis, in press)) the Nopah Formation is a white dolomite. Gans (1974) has shown that this lighter color may be characteristic of more cratonal facies of the Nopah Formation. In cratonal areas (Frenchman Mountain, Sheep Mountain for example, figs. 17, 18) the Nopah Formation is overlain paraconformably by units of the Middle to Upper Devonian Sultan Limestone.

In the overturned section at Sidewinder Mountain, the break in slope with calc-silicate float between the Banded Mountain Member of the Bonanza King Formation and the overlying buff dolomites very likely represents the Dunderberg Shale Member of the Cambrian Nopah Formation. The fact that the pure, massive, buff weathering, white dolomite proposed to be correlative with the Nopah Formation is overlain by stromatoporoid-bearing rocks assigned to the Middle Devonian Ironside Member of the Sultan Limestone, provides strong evidence for the correlation of the Sidewinder Mountain sequence to Cambro-Devonian platform sequences further to the east.

Ironside Member of the Devonian Sultan Limestone and Higher Units

Thickness and Lithology: Stratigraphically above the overturned unit correlated with the Cambrian Nopah Formation is a 3-5 foot (1-1.5m) thick horizon of stretched, 4-12" (10-30cm) in diameter, calc-silicated stromatoporoids. Stromatoporoid-bearing horizons are also present above buff-colored dolomites of the Nopah Formation in the eastern part of the Sidewinder Mountain roof pendant, although here a bed or beds of stromatoporoids are isoclinally folded and repeated several times (Plate II). The stromatoporoid horizons are the first reported occurrence of fossils in the Sidewinder Mountain area.

The stromatoporoid-bearing horizon in the overturned section on the western edge of the Sidewinder Mountain roof pendant is overlain by approximately 1300 feet (390m) (tectonic thickness) of carbonate rocks which contain 1) dolomite and thinly-layered dolomite and limestone and 2) limestone and dolomitic limestone. This sequence becomes extremely metamorphosed upwards (westward) toward the Mesozoic igneous rocks on the north and west. Near the top of the exposed section, a calc-silicated, chert nodule(?) bearing unit is present.

Age and Correlation: The Sultan Limestone was named and described by Hewett (1931) from localities in the southern Spring Mountains, Nevada, and he reported a late Middle Devonian to early Late Devonian age for the Limestone. Hewett (1931) recognized three members in the Sultan Limestone: 1) the Ironside Dolomite, 2) the Valentine Limestone and 3) the Crystal Pass Limestone. The stromatoporoids of the Ironside Member range from 2-8 inches (5-20cm) in diameter and are almost always chertified. This early diagenetic chertification is probably the reason why these stromatoporoids are preserved as calc-silicated objects in deformed and metamorphosed terrains such as at Sidewinder Mountain. Poorly preserved stromatoporoids may be confused with round algal stromatolites. The distinction between the two is based on the presence of internal structure or chambers between the concentric laminations in stromatoporoids and the lack of these in stromatolitic structures. The author observed that even in unmetamorphosed terrains, chertification of the stromatoporoids has usually destroyed the evidence for internal chambers. Very close inspection of the stromatoporoid-bearing horizon at Sidewinder Mountain, however, indicated that a few of these still had preserved chambers between the concentric laminations and hence correlation of this unit to the Middle Devonian Ironside Member of the Sultan Limestone is considered valid. Recognition of this unit within the Sidewinder Mountain section lends credence to the assignment of lower units in this section to the Cambrian Nopah Formation and the Cambrian Bonanza King Formation.

Units above the Ironside Member of the Sultan Limestone at Sidewinder Mountain are difficult to identify due to their metamorphism by the intrusive rocks of the area. Possibly the thinner bedded dolomites and limestones in the section above the Ironside Member of the Sultan correspond to the Crystal Pass Member of the Sultan which is characteristically thinly bedded to laminated in unmetamorphosed terrains (Hewett, 1931). The calc-silicated chert nodule bearing (?) horizon near the top of the exposed section at Sidewinder Mountain may be correlative with the Anchor Member of the Lower to Middle Mississippian Monte Cristo Limestone, named by Hewett (1931) in the Spring Mountains, Nevada and which is characterized by abundant and distinctive elongated chert nodules. These possible Lower Mississippian carbonate rocks are the youngest metasedimentary rocks of the Paleozoic sequence exposed in the Sidewinder Mountain area.

FAIRVIEW VALLEY FORMATION

General Statement

The Fairview Valley Formation is the first recognized sequence of Mesozoic sedimentary rocks in the Western Mojave with the exception of the Mesozoic Sidewinder Group rocks. The formation was first described by Bowen (1954), was later mapped in detail by Stone (1964), and was mapped by Dibblee (1967). The conclusions of these previous workers all differ somewhat from those presented in this work and will be discussed below.

Thickness and Lithology

The Black Mountain area (Plate II) is the type locality for the Fairview Valley Formation. North of the Riverside Cement Company quarry road, before the main entrance to the quarry, the base of the Fairview Valley Formation is exposed. Here it unconformably overlies monzonite plutonic rocks and to the east overlies unidentified deformed and metamorphosed Paleozoic(?) carbonate rocks which are intruded and contact metamorphosed by the monzonite. The basal contact above the monzonite is well exposed, but to the east this contact may be faulted and is severely mineralized. Bowen (1954) suggested that the Fairview Valley Formation lay unconformably above Oro Grande (Paleozoic(?) of this report) carbonate rocks. Dibblee (1967) suggested an unconformable if not fault contact with the marbles. Stone (1964) mapped the basal contact of the Fairview Valley Formation as a fault contact.

Above the Fairview Valley's basal contact with the monzonite is a spectacular conglomerate containing primarily clasts of the underlying monzonite and marble. The massive conglomerate at Quartzite Mountain assigned to the Fairview Valley Formation is lithologically very similar to this conglomerate.

The Fairview Valley Formation at Black Mountain is approximately 3766 feet thick (1148m). A detailed description of a measured section of the Fairview Valley Formation is included in Appendix I of this study. A simplified stratigraphic column is shown in figure 5. Measured sections of the Fairview Valley Formation are also presented by Stone (1964). The Fairview Valley Formation dips steeply to the northeast and occasionally beds are vertically to slightly overturned. Because of these steep dips, the map view of the Fairview Valley Formation is almost a cross-sectional view. In its eastern area of outcrop, the Fairview Valley Formation consists of a lower heterogeneous sequence of generally fine-grained sedimentary rocks with occasional conglomeratic lenses. Near the top of the formation, this sequence interfingers with a massive grey limestone cobble conglomerate (fig. 6.)

The lower part of the Fairview Valley Formation along the line of the measured section (fig. 6) is a heterogeneous sequence of rocks that includes siltstone, calcareous siltstone and mudstone, sandstone, conglomerate and carbonate rocks. The rocks have been weakly deformed and it is difficult to determine the original sedimentary rock types within the sequence. Most of the rocks in the lower part of the Fairview Valley Formation are fine to very fine-grained calc-silicate hornfels. These fine-grained rocks are generally light green on fresh surfaces and weather orange to orange brown. They are very thinly bedded (1-3cm), thinly bedded (3-10cm) to massive and structureless.

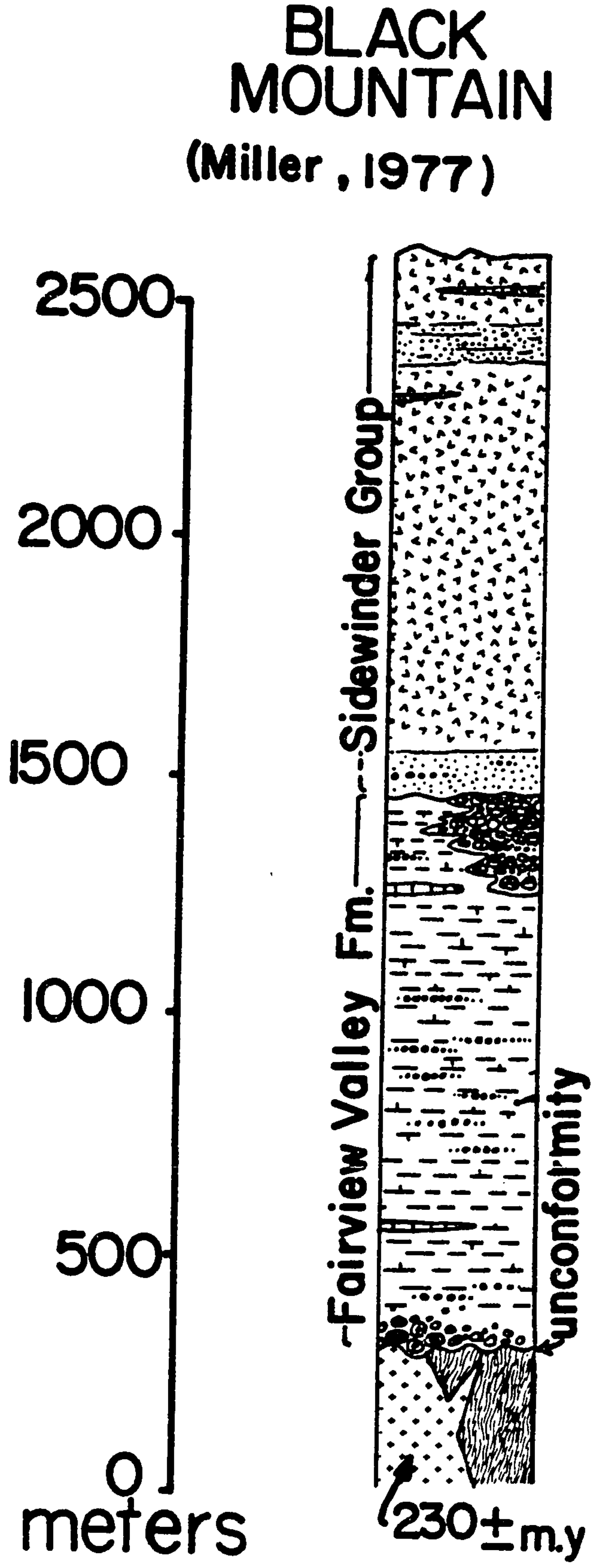

BLACK
MOUNTAIN
(Miller, 1977)
2500
2000
1500
1000
500
0
meters
Sidewinder Group
Fairview Valley Fm.
unconformity
230± m.y

FIGURE 5

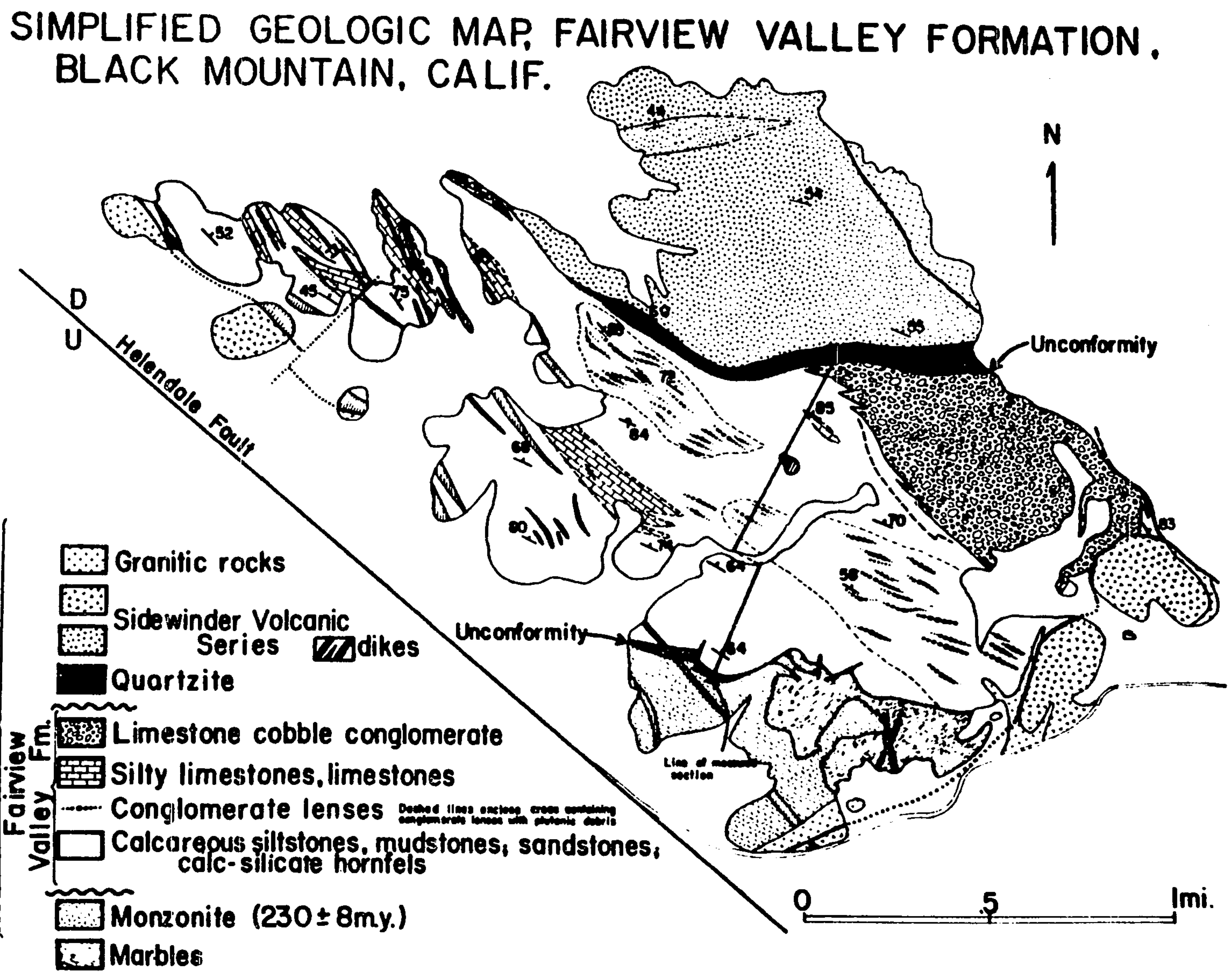

SIMPLIFIED GEOLOGIC MAP, FAIRVIEW VALLEY FORMATION,
BLACK MOUNTAIN, CALIF.
N
Unconformity
Unconformity
D
U
Helendale Fault
Line of
section
48
34
55
50
65
52
45
73
72
84
68
80
74
85
70
64
56
64
83
0
.5
1mi.
MESOZOIC
Fairview Valley Fm.
Granitic rocks
Sidewinder Volcanic Series
dikes
Quartzite
Limestone cobble conglomerate
Silty limestones, limestones
Conglomerate lenses
Dashed lines enclose areas containing conglomerate lenses with plutonic debris
Calcareous siltstones, mudstones, sandstones, calc-silicate hornfels
Monzonite (230 ± 8m.y.)
Marbles

FIGURE 6

No cross-bedding was ever observed in the portion of the Fairview Valley Formation where the section was measured. It is possible that sedimentary structures were present in the fine-grained rocks but have been destroyed by recrystallization occurring during contact metamorphism. Because of the difficulty in determining original sedimentary rock types, the descriptive terms "siltstone/ mudstone", "siltstone" and "sandstone", used in the measured section descriptions, are only qualitative terms. In thin-section, these rocks contain variable amounts of silt-size quartz and minor silt-size plagioclase and potassium feldspar grains in a fine-grained matrix of calc-silicate minerals which include clinozoicite/epidote, microcrystalline quartz, calcite ± tremolite ± garnet ± diopside. Bedding in these rocks is defined by variable percentages of silt-size particles and/or by variable content of siliceous or calcareous (calc-silicate) constituents. The fine-grained rocks in the lower part of the Fairview Valley Formation in this area were originally calcareous siltstone and mudstone marl and silty carbonate rocks.

Occasional sandier strata are interbedded with these finer-grained rocks. The term "sandstone" as used in measured section descriptions refers only to grain size. Thin sections of some of the sandier horizons in the Fairview Valley Formation show these rocks to be arkose, containing large percentages of microcline, orthoclase and plagioclase. Lithic fragments of metaquartzite, chert, microcline +

plagioclase + quartz aggregates, and of volcanic rocks are common in these coarser-grained horizons. Sorting is poor and grains are angular. Some of the sandstone appears to be matrix-supported in thin-section, but evidence from other thin-sections indicates that much of the matrix could be completely recrystallized, altered plagioclase or lithic igneous fragments. Brief thin-section descriptions or observations made fron thin-sections have been included in the measured section descriptions.

Conglomerate lenses, tens of meters in lateral dimension,occur frequently throughout the generally finer-grained rocks of the lower Fairview Valley Formation (Appendix I). Most of the major lenses are indicated on the map by a series of dots. Although most of the clasts in these conglomerates are calcite and dolomitic marble, some conglomerate lenses contain a large percentage of non-carbonate material. Thin-section studies of the non-calcareous clasts indicate that most of these are derived from monzonite plutonic rocks, identical to plutonic rocks unconformably beneath the Fairview Valley Formation. Occasional rhyolitic volcanic clasts, granitic clasts, metaquartzite and chert clasts are also present. Clasts of sheared quartz-microcline-plagioclase-biotite rock are frequently present in some of the conglomeratic horizons. It is possible that these clasts were derived from a sheared Precambrian crystalline terrain. Figure 6 shows the aerial distribution of conglomerate lenses which contain non-carbonate debris. The pattern of these lenticular shaped bodies perhaps indicates different source terrains, or mixed source terrains for different parts of the lower Fairview Valley Formation. Conglomerate lenses in this portion of the Fairview Valley occasionally contain both metamorphosed and unmetamorphosed limestone clasts.

Thermal metamorphism becomes less pronounced toward the top of the measured section, and rock types are easier to recognize: here the sequence consists of predominantly calcareous siltstone and occasional silty limestone. Some of these beds are obviously burrowed, but no other sedimentary structures were observed.

The limestone cobble conglomerate at the top of the section interfingers with the calcareous siltstone to the west and becomes approximately 2250 feet (675m) thick slightly east of the line of the measured section. The limestone cobble conglomerate is somewhat deformed but is only weakly metamorphosed. Bedding in the limestone cobble conglomerate is about .5 -2 feet (.15-.6m) thick and is defined by differences in average clast size. The matrix of the conglomerate is fine-grained silty limestone and calcareous siltstone. Many of the clasts are fossiliferous. Virtually no clasts of marble or igneous rocks are present in the limestone cobble conglomerate member of the Fairview, indicating that the source area for the massive limestone cobble conglomerate was different from the source area which provided conglomeratic material to the lower Fairview.

Presence of unmetamorphosed fossiliferous clasts in the limestone cobble conglomerate is interesting in light of the fact that the Fairview Valley Formation unconformably overlies deformed and coarsely crystalline calcite marbles. The northwesternmost exposures of the Fairview Valley Formation (south of pipeline road, Plate II), are not metamorphosed and original sedimentary structures and lithologies are fairly well preserved. Orange-weathering silty limestone is burrowed and exhibits small-scale herringbone type cross-stratification. Polygonal mudcracks and raindrop(?) imprints were observed in several places here. Some of the laminated silty limestones exhibit wavy and crinkly laminae, perhaps indicative of algal growth. The silty limestone is incised by lenticular channels of limestone cobble conglomerate. Laterally non-continuous, sheet-like deposits of very coarse to coarse-grained arkosic sandstone, interbedded with the silty limestone, are structureless to inversely graded. Thick units of fine-grained, structureless calcareous siltstone are common, these contain large cobbles of limestone floating in a much finer-grained matrix. Lenticular bodies of stretched, relatively pure grey limestone also occur throughout the section. Because the more ductile limestone has been deformed, these units perserve no original sedimentary structures.

No fossils were found within this sequence with the exception of fossil-bearing clasts within the limestone cobble conglomerate. Limestone samples were processed for conodonts,but none were found. Exposures north of Sparkhule in the Quartzite Mountain area,which were correlated with the Fairview Valley Formation,bear marked similarity to the Fairview Valley Formation in this particular area.

Quartzite Unit Above the Fairview Valley Formation

The Fairview Valley Formation is overlain by a unit of quartz-rich sandstone (Plate II). The contact between the Fairview Valley Formation and the overlying quartzite is never well-exposed. In the eastern portion of the Fairview Valley Formation, the upper 10-15 feet (3-5m) of limestone cobble conglomerate right below the contact has been altered and patchily silicified.

An erosional but not necessarily angular unconformity between the Fairview Valley Formation and the overlying quartzite unit is suggested on the basis of:

1. the quartzite unit overlaps various facies of the Fairview Valley Formation, or rests on different units in different places.
2. Along the contact between the two units, sometimes considerable difference in the strike and dip of beds is observed on either side of the contact.
3. The quartzite unit exhibits an extremely different mineralogy from the Fairview Valley sediments: it is characterized by 50-90% very well-rounded to subangular fine sand-size quartz grains, little or no feldspathic debris, and a variable percentage of calc-silicated

matrix material which appears to have been volcanic debris.

4. The quartzite unit contains a few conglomeratic horizons containing carbonate and chert pebbles, but these conglomeratic horizons have a different appearance from conglomerate in the Fairview Valley Formation: clasts are not as fresh and it is possible that they may have been reworked from the upper Fairview Valley Formation deposits.

The quartzite unit is approximately 300 feet (92m) thick and overlain conformably(?) by a minimum of 3000 feet (915m) of welded tuff, pyroclastic rocks and volcanogenic sedimentary rocks of the Sidewinder Volcanic Group. The quartzite unit was mapped as "Oro Grande Series" by Bowen (1954), Dibblee (1967) and Stone (1964). Stone (1964) mapped it as a sliver of Oro Grande bound by faults on either side. The author believes that it lies conformably beneath the Sidewinder Volcanic rocks here as sedimentary units within the overlying volcanic sequence are quartz-rich and exhibit identical thin-section mineralogy.

Fairview Valley Formation Equivalent(?) at Tri-Color Quarry

At Tri-Color quarry, just south of the Sidewinder Mountain roof pendant, medium to thick-bedded dolomite cobble conglomerate, probably deposited as alluvial sediments, unconformably overlie the Cambrian Banded Mountain Member of the Bonanza King Formation. This sequence of conglomerate is described in detail in Appendix II. Because of their unconformable relationship to the underlying, older, metasedimentary rocks, the conglomerate may be correlative with the Fairview Valley Formation. Thin beds of greenish, calcsilicated sandstone interbedded with the dolomite cobble conglomerate of Tri-Color quarry are mineralogically similar to the quartzite which unconformably overlies the Fairview Valley Formation at Black Mountain. It is possible then, that the conglomerate sequence may be a lateral equivalent of the quartzite unit rather that a lateral equivalent of the Fairview Valley Formation.

Depositional Environment of the Fairview Valley Formation

Because of the thermal metamorphism affecting the Fairview Valley Formation, it is often difficult to determine the original rocktypes within the sequence. However, the northwesternmost exposures of the Fairview Valley Formation, although deformed, are only very slightly metamorphosed. Data regarding the depositional environment of the Fairview Valley Formation were obtained primarily from this area.

Small-scale herringbone-type cross-stratification in the silty limestone of the Fairview Valley Formation indicates deposition of these sediments in shallow water with changing current directions. Presence of mudcracks and raindrop imprints indicates subaerial exposure of these sediments. Wavy and crinkly laminations within the silty limestone may be algal laminations. These data indicate that the sediments were probably deposited in very shallow water, possibly in a tidal flat or lacustrine environment. It is not known whether the limestone units interbedded with the silty limestone and calcareous siltstone were originally biogenic limestone or detrital limestone as deformation of these units has destroyed all original sedimentary structures. These limestones contain only minor amounts of quartz silt in their insoluble residue fractions.

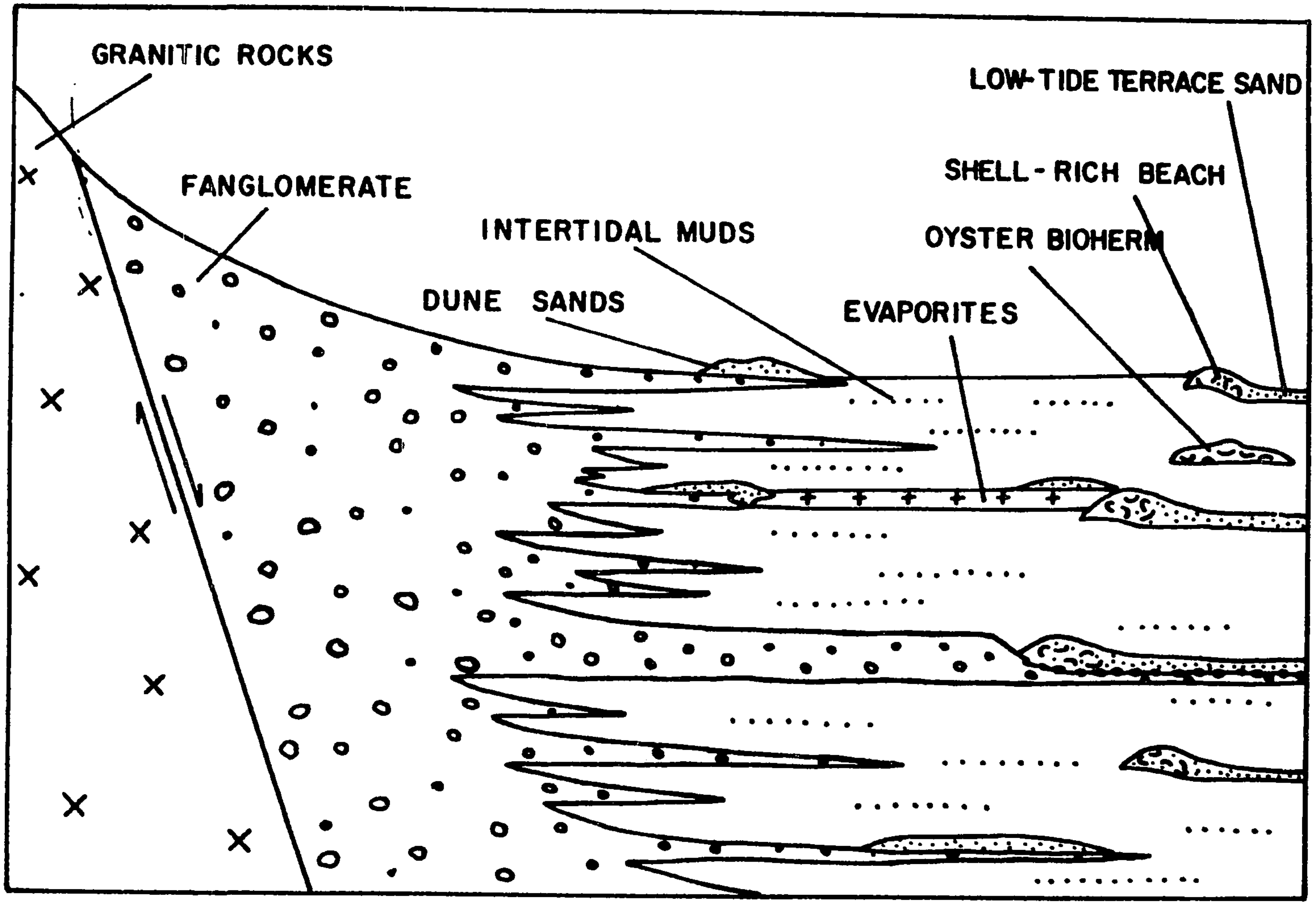
Channels filled with coarse cobble conglomerate are cut into the finer-grained silty limestone, calcareous siltstone and limestone and probably represent stream channels that were cut across a quieter, more stable depositional environment. The stream channel conglomerates contain only limestone clasts, indicating that they were derived from a purely carbonate terrain. Laterally non-continuous, sheet-like deposits of very coarse- to coarse-grained arkosic sandstone, interbedded with the silty limestone, are structureless to inversely graded and probably represent grain flow or debris-flow deposits (Middleton and Hampton, 1973; Hooke, 1967). The arkosic sandstone contains primarily quartz grains, polycrystalline quartz, orthoclase, microcline, plagioclase and metamorphic rock fragments. Volcanic rock fragments and carbonate debris are only a very minor constituent of the arkosic sandstone. The arkosic sandstone must have been derived from a predominantly plutonic-metamorphic terrain.

Structureless, fine-grained calcareous siltstone units with large cobbles of limestone floating in a much finer-grained matrix are also interstratified with the silty limestone. These also were probably deposited by debris-flows.

The massive limestone cobble conglomerate which interfingers to the northeast with finer-grained sediments of the Fairview Valley Formation probably represent an alluvial fan deposit. This is indicated by coarse cobble to boulder size clasts, lack of sorting, and thick to massive bedding which is defined only by differences in average clast size. These qualities are all characteristic of present-day alluvial fan deposits (Hooke, 1967).

It is possible, then, that the Fairview Valley Formation represents the interfingering of alluvial and stream channel deposits with shallow marine (tidal flat?) or lacustrine deposits. A tentative modern analogue for the depositional environment of the Fairview Valley Formation may be similar to that which characterizes northeastern Baja California where tidal flat muds, derived primarily from the Colorado River delta intertongue with coarse alluvial and channel deposits derived from the uplifted peninsular ranges to the west (Walker, 1967). A schematic cross-section showing the interfingering relationship of alluvial and tidal flat sediments in northeastern Baja California is shown in figure 7.

Differences in clast and grain lithology of conglomerate and sandstone within the Fairview Valley Formation, discussed above, indicate either a highly variable and/or a



Diagrammatic cross section showing facies relationships of Recent, Pleistocene, and Pliocene sediments, northeastern Baja California, Mexico (Walker, 1967)

FIGURE 7

changing source terrain for the conglomerate and sandstone within the Fairview Valley sequence.

Age of the Fairview Valley Formation

Bowen (1954) assigned an Upper Permian age to the Fairview Valley Formation. This age assignment was based on the fact that Fairview Valley limestone conglomerate contains fossiliferous clasts up to Lower Permian in age (Bowen, 1954). Stone (1964) mapped the Black Mountain area in detail. His fossil collections from clasts within the Fairview were all Early Permian (Wolfcampian) in age. Bowen reported primarily Mississippian and Permian forms but also reported several Lower Paleozoic forms. Stone (1964) questioned the reliability of identification of the older forms and stated that all the Upper Paleozoic fossils reported by Bowen are compatible with a Wolfcampian age. Stone (1964) also suggested an Upper Permian age for the Fairview Valley Formation. Dibblee (1967) pointed out that the fossiliferous clasts only dated the source rocks, and that the formation could possibly be Mesozoic in age, however, listed it as Permian and Permian(?).

It can be demonstrated that the Fairview Valley Formation rests unconformably above monzonite plutonic rocks. The exposure of the unconformity was either not seen or was mapped as a fault by previous workers (Bowen, 1954; Stone, 1964; Dibblee, 1967). The mineralogy of the monzonite is distinctive in that it contains 30-60% perthitic orthoclase, plagioclase and hornblende, and no modal quartz. The hornblende in this rock is partially altered and may be replacement after pyroxene. Accessory biotite, apatite, sphene and opaques are also present. In outcrop and in hand specimen, the monzonite exhibits a distinctive primary igneous foliation defined by the preferred orientation of the lathe-like-feldspar crystals.

Miller (1976) has done extensive geochemical and geochronologic work on monzonite plutonic rocks in the San Bernardino, Granite and Inyo Mountains. In particular, the monzonite plutons in the Granite Mountains,10-15 km from the Black Mountain area (fig 1), bear strong geochemical similarities with the monzonite below the unconformity at Black Mountain, and Miller (personal communication) suggests they are part of the same plutonic event. The monzonites in the Granite Mountains have been dated (U/Pb, zircon) as 230 ± 8 m.y. old (Miller, pers. comm.). Miller also dated two zircon separates from two of the monzonite clasts from the Fairview Valley conglomerates. He obtained ages of 178 and 235 m.y. for these rocks, and believes that the data yielding the younger age is not reliable (Calvin Miller, pers. comm.). It is most probable, then,that the monzonite beneath the Fairview Valley Formation is approximately 230 m.y. old, coeval with plutons in the nearby Granite Mountains. This provides a lower age limit for the Fairview Valley Formation, and definitely places it within the Mesozoic. An upper age bracket is not yet available for the Fairview Valley Formation: it is overlain unconformably by a quartzite unit which is in turn overlain by more than 3000 feet (900m) of pyroclastic volcanics of the Sidewinder Group. As far as I know, no reliable geochronologic work has been done on rocks of the Sidewinder Group. The Fairview-Sidewinder sequence was then weakly folded and intruded by a series of hypabyssal dikes which were probably feeders for younger Mesozoic volcanic rocks in the area. The youngest granitic rocks in this portion of the Mojave range from 70-80 m.y. old (Armstrong and Suppe, 1973).

Granitic rocks in the Black Mountain area intrude all of the metasedimentary rocks; and therefore, until more radiometric data is available from this area, the upper age bracket for the Fairview Valley Formation can only be said to be Upper Cretaceous. However, since both volcanism and deformation and possibly later volcanism post-date the Fairview Valley Formation, and pre-date possible Late Cretaceous intrusives, it is more likely that the Fairview Valley Formation is either Triassic or Jurassic in age, although an Upper Jurassic or Early Cretaceous age cannot be ruled out at present.

Significance of the Fairview Valley Formation

Deformation, metamorphism, and plutonism in the southern Cordillera spanned most of the Mesozoic (Burchfiel and Davis, 1975). Earlier Mesozoic syn-tectonic deposits are only rarely preserved or exposed within this portion of the orogenic belt. The importance of syn-orgenic deposits is two-fold: 1) they usually stratigrphically date a deformational event and 2) also provide some insight on events occuring during their deposition. The Fairview Valley Formation is the first documented Mesozoic sedimentary sequence of the syn-orogenic type described from the central and western Mojave. The Fairview Valley Formation and the monzonite plutons in this area indicate a major very early(?) Triassic deformational and plutonic event in this area. The Fairview Valley Formation unconformably overlies 230 ± 8m.y. old plutonic rocks that perhaps were syntectonic or post-dated one or both of the biotite-grade metamorphic and deformational events described at Quartzite Mountain. Clasts within the conglomerate of the Fairview Valley Formation consist of both metamorphosed and unmetamorphosed sedimentary rocks, plutonic rocks and volcanic rocks, and possibly Precambrian crystalline rocks. Thus the composition of the conglomerates within the Fairview Valley Formation provides evidence for the erosion of a deformed and variably metamorphosed terrain and verifies an earliest Triassic deformation which was of sufficient magnitude to produce structures which involved Precambrian crystalline basement rocks.

Although no volcanic flows were found within the Fairview Valley Formation, one unit of conglomerate contains volcanic and limestone clasts and could be interpreted as a volcanic mud-flow deposit. Presence of abundant volcanic debris within the Fairview Valley Formation indicates that it post-dated volcanism in this area and may indicate that volcanic activity continued during deposition of the Fairview Valley Formation.

The Fairview Valley Formation also indicates minor tectonic activity within the batholithic belt during or post-dating its deposition. According to the interpretation presented above, the Fairview Valley Formation was slightly uplifted (?), eroded and overlain by a unit of quartzite which is in turn conformably overlain by a sequence of pyroclastics of the Sidewinder Group. Volcanism preceeded, may have occurred during, and certainly post-dated deposition of the Fairview Valley. During volcanic activity, variable uplift occurred. Only after deposition of the overlying pyroclastics, was this package of sedimentary and volcanic rocks folded and intruded by hypabyssal dikes which probably represent or indicate continuing volcanism in this area. Thus the sequence at Black Mountain documents a continuum of deformational and volcanic activity within the volcanic-plutonic arc. Lithologies very similar to the Fairview Valley Formation, and which bear the same relationship to underlying rocks, are found at Quartzite Mountain. This indicates that the Fairview Valley Formation, or similar deposits, although exhibiting extreme lateral facies variation, may have formed fairly extensive deposits in this area of the batholith.

The interpretation of the depositional environment of the Fairview Valley Formation, discussed above, indicates that the Fairview Valley Formation may have interfingered with shallow marine sediments.

SIDEWINDER GROUP

General Statement

Three major sequences of volcanic rocks are exposed in the map area. The relationship between the three sequences is not known as they are separated by faults. The first sequence lies stratigraphically above the quartzite unit which unconformably overlies the Fairview Valley Formation. The second sequence is in fault contact with both the Fairview Valley Formation and the roof pendant of Precambrian to Paleozoic rocks on the northern side of Sidewinder Mountain. The third sequence is in fault contact along a northeast striking, shallowly southeast dipping fault with Fairview Valley Formation and Paleozoic(?) metacarbonate rocks along the quarry road (Plate II). Some small outcrops of Sidewinder Volcanic rocks are also present on the southwest side of the northeasternmost exposures of Fairview Valley sediments.

These three sequences consist predominantly of pyroclastic rocks and minor, interbedded volcanogenic sedimentary rocks. Units that can properly be described as volcanic flows are rare and tend to be more mafic in composition. Most of the pyroclastic rocks are interpreted to be slightly metamorphosed and recrystallized ignimbritic or pyroclastic flows. Only minor thin-section study was done on these rocks and the descriptions below are based primarily on field observations. Bowen (1954) presented detailed petrography on some of the units of the Sidewinder Group. Stone (1964) briefly described the volcanic rocks which overlie the Fairview Valley Formation.

Volcanic rocks of the Sidewinder Group which overlie the Fairview Valley Formation

The quartzite unit above the Fairview Valley Formation is overlain by a minimum of 3000 feet (1000m) of northwest striking, northeast dipping pyroclastic volcanic rocks. This sequence is intruded by later granitic rocks. Volcanic rocks to the north of pipeline road were not mapped in this study but presumably are part of this sequence. The volcanic rocks immediately above the quartzite unit are a sequence of reddish-weathering, pink to white, sheared and recrystallized lithic tuffs. Pieces of volcanic rocks, chert and weathered pumice fragments occur within this unit. In thin section these rocks contain broken feldspar crystals, quartz grains, volcanic rock fragments, and recrystallized glassy(?) fragments in a fine-grained altered and recrystallized groundmass of primarily micaceous minerals. Alignment of micaceous minerals produce the schistosity seen in hand specimen. The volcanic rocks in the sequence above this sheared tuffaceous unit were probably all ignimbrite or pyroclastic flow units. Occasional welded horizons are present. These rocks are in all ways similar to the rest of the volcanic rocks of the

Sidewinder Group exposed in the area although they appear to be more highly recrystallized and exhibit a more pronounced schistocity which trends northwest and dips to the southwest. Near the top of the section, just south of pipeline road, sedimentary sandstone units are interbedded with the volcanic rocks. In thin section the sandstone contains approximately 50% very well rounded to subrounded fine sand-size quartz grains, minor feldspar, and metaquartzite grains in a very fine-grained matrix of predominantly micaceous minerals. The sandstone bears strong petrographic resemblance to the quartzite unit above the Fairview Valley Formation, indicating that the quartzite unit is probably related to the volcanic sequence and not to the underlying Fairview Valley Formation, from which it differs considerably.

Volcanic rocks of the Sidewinder Group at Sidewinder Mountain

A very thick sequence of pyroclastic volcanic rocks is exposed on Sidewinder Mountain, the type locality for the Sidewinder Group. In the area mapped, the exposed section is at least 4000-5000 feet (1200-1500m) thick and continues to the south where it was not mapped in this study. The volcanic rocks form a homoclinal east-west trending, north dipping sequence. No top and bottom indicators were seen in this section, hence it is only presumed to be upright. This sequence of volcanic rocks of the Sidewinder Group is cut by an east-west trending fault which juxtaposes it on the north to the older metasedimentary rocks of the Sidewinder Mountain roof pendant. A small upthrown fault block exposes underlying Fairview Valley and Bonanza King Formation carbonate rocks at Tri-Color quarry (Plate II). To the west, a northwest trending, steeply southwest dipping fault juxtaposes this Sidewinder sequence and rocks of the Fairview Valley Formation in the vicinity of the cement plant (Plate II). Because the contact is a fault here, the relationship of this volcanic sequence to the volcanics which overlie the Fairview Valley Formation is not known. However, this sequence of volcanic rocks, although altered and recrystallized, shows only slight evidence of shearing. To the northwest it is intruded by granitic rocks near Sidewinder Mine (Plate II).

Assuming that the sequence is upright, the uppermost exposed units are part of an extensively exposed sequence of lahar or mudflow conglomerates. The mudflows are composed of coarse, rounded, gray dacite cobbles and boulders, derived from volcanic flows or ignimbrites. There is little if any variation in the composition of these clasts. The average size of the clasts of 4-8 inches (10-20cm) but boulders up to four feet (1.2m) are present sporadically throughout the mudflows. Sorting is poor. A weak schistosity is developed in the finer-grained volcanic mud matrix of the conglomerate. This schistosity strikes approximately east-west, with variable but steep dips. Shear planes parallel to the schistosity sometimes cut or offset the more resistant dacite boulders and cobbles and is therefore interpreted as a tectonic foliation and not a primary foliation. The mudflow deposits interfinger laterally (Plate II) with ignimbritic flow rocks similar in composition to the clasts within the mudflow. Occasional thin horizons of laminated, cherty sediments (water-lain tuffs?) occur within this sequence. The mudflow units are underlain by ignimbrites and interbedded sedimentary rocks. Occasional true welded tuffs can be identified within the pyroclastic sequence, but most of these rocks are massive, non-bedded, and exhibit no textures indicative of welding other than an occasional larger (5-15cm) flattened volcanic fragment. All of these rocks are intermediate to felsic in composition.

True volcanic flow units occur sporadically through the section. These contain zoned plagioclase phenocrysts in a recrystallized glassy matrix. All original mafic minerals are altered to chlorite, epidote, and opaque minerals. These minerals also occur throughout the groundmass. The volcanic flow units tend to be more mafic in composition and are probably andesitic. Interbedded sedimentary rocks within this pyroclastic sequence are marroon to purple arkosic sandstone and volcanic sandstone and conglomerate that probably represent stream channel deposits. Another major mudflow sequence is present lower in the section and is underlain by more pyroclastic ignimbrite units.

Other Exposures of the Sidewinder Group

Volcanic rocks exposed to the southeast of the fault along the Quarry road are intermediate composition, massive and structureless flow or ignimbrite units. Similar volcanic rocks are also exposed near the northwesternmost exposures of the Fairview Valley Formation, south of pipeline road. Here they are probably in fault contact with the Fairview Valley Formation.

Age and Correlation of the Sidewinder Group

As mentioned above, there has been no reliable geochronologic work done on the Sidewinder Group. Previous workers (Bowen, 1954; Stone, 1964; Dibblee, 1967) all assigned a tentative Triassic-Jurassic age to the Sidewinder Group, primarily on the basis that it has been intruded by granitic rocks tentatively assigned a Jurassic-Cretaceous age.

At Sidewinder Mountain-Black Mountain, a relative stratigraphic age is available only for the sequence which unconformably overlies the Fairview Valley Formation which is post-230m.y. old, but for which no upper age bracket is yet available. As the rest of the volcanic rocks in the Sidewinder Mountain area are in fault contact with the volcanic rocks which overlie the Fairview Valley Formation their relationship to these volcanic rocks and therefore their relative age relationship, is not known. The volcanic rocks above the Fairview Valley Formation are interpreted to have been involved in the same folding event which folded the Fairview Valley Formation. As this sequence of volcanic rocks exhibits a better-defined schistosity (cleavage) than the rest of the Sidewinder volcanic rocks in this area, it is possible that the rest of the volcanic rocks at Sidewinder Mountain may be younger and post-date the folding event. On the other hand, it is also possible that these may be higher units in a thick volcanic section which overlay the Fairview Valley Formation, and for some reason or another, were not as highly foliated during the folding event.

The correlation between volcanic rocks of the Sidewinder Group at Quartzite Mountain and the volcanic rocks mapped in at the Sidewinder-Black Mountain area is also not clear. At Quartzite Mountain, flat-lying Sidewinder volcanic rocks unconformably overlie steeply dipping Fairview Valley conglomerate. Steep dips in the Fairview Valley conglomerate at Quartzite Mountain may be due to a period of faulting, folding, or both, which occurred prior to the deposition of the Sidewinder Group. At Black Mountain, volcanic rocks which overlie the Fairview Valley appear to rest above a low angle erosional unconformity and appear to be folded with the Fairview Valley Formation, rather than post-date a deformational event.

The fault which juxtaposes Sidewinder Volcanic rocks against Paleozoic(?) marble and the Fairview Valley Formation along the quarry road is intruded by a felsic hypabyssal dike, similar to the rest of the northwest trending felsic hypabyssal dikes which cross-cut the Fairview Valley Formation. Hence these volcanic rocks and this fault predate the intrusion of these dikes. All of the Sidewinder Volcanic rocks in the Black Mountain-Sidewinder Mountain area are intruded by later granitic rocks. As most age dates for youngest granitic rocks within this portion of the Mojave Desert cluster around 70-80 m.y. old (Armstrong and Suppe, 1973), it is most probable that volcanic rocks of the Sidewinder Group are pre-Upper Cretaceous in age.

INTRUSIVE ROCKS

General Statement

Because the igneous rocks in the study area were not the major focus of this report, the discussion of these rocks consists of only a brief description and dewlls primarily on their relative ages. The great variety and ages of the igneous rocks in the Sidewinder Mountain-Black Mountain area were only slightly less bewildering after an entire field season in this area, and certainly deserve more detailed future work. Bowen (1954) described many of the intrusive rocks of this area, but he did not map these in detail. The sequence of intrusive events in the Sidewinder Mountain-Black Mountain area is listed together with the deformational events in figures 10 and 12.

Monzonite

The monzonitic plutonic rocks which occur unconformably beneath the Fairview Valley Formation at Black Mountain are the oldest intrusive rocks in the area mapped. The relationship of these plutonic rocks to the other rocks in the area, and the petrography of the monzonite has been discussed above and will not be discussed here. Briefly, the monzonite is probably cogenetic with earliest Triassic plutons in this region which have been studied in detail by Miller (1976) and which have been dated in the Granite Mountains as 230± 8 m.y. old by Calvin Miller (pers. comm.). Apparently plutons of similar chemistry and age are widespread and occur not only in the Black Mountain-Granite Mountain region but in the San Bernardino and Inyo Mountains (Miller, 1976). These are the oldest Mesozoic intrusive rocks yet known from the Mojave region.

Hypabyssal Dikes Associated With the Sidewinder Group Volcanics(?) (swh)

These dikes intrude the older metasedimentary rocks in the Sidewinder Mountain roof pendant. They are dark green-grey to grey, very resistant to weathering, sheared and foliated, fine-grained, recrystallized dikes. The shearing and foliation present in these rocks differentiates them from the later quartz monzonite porphyry dikes which are discussed below. The Sidewinder(?) dikes are intruded (along the ridge of Sidewinder Mountain) by later undifferentiated quartz monzonite/granitic rocks and alaskite. The rocks on the eastern tip of Sidewinder Mountain (Plate II) consist of foliated metavolcanic rocks. These have been labeled swh on the map although it is not clear whether these are sheared extrusive rocks in fault contact with the metasedimentary rocks or sheared hypabyssal intrusive rocks. Later intrusive rocks obscure the contact relationships here.

Felsite and Intermediate Composition Hypabyssal Dikes (hd)

Two sets of dikes intrude the Fairview Valley Formation at Black Mountain. Felsite dikes intrude the southwestern exposures of the Fairview Valley Formation. These dikes trend approximately N20-40W, are vertical to steeply dipping, and are sub-parallel to the axial plane attitudes of folds in the Fairview Valley Formation (Plate II). Similar rocks are present at the eastern tip of the Sidewinder Mountain roof pendant (Plate II). The felsite dikes exhibit a well-developed flow foliation. Plagioclase, Potassium feldspar and quartz phenocrysts occur in a finer-grained ground mass of myrmekitic feldspar intergrowth and quartz. Minor amounts of biotite and hornblende occur as fine-grained aggregates along foliation planes. These dikes post-date deformation of the Fairview Valley Formation. The dikes cross-cut the basal unconformity of the Fairview Valley Formation and cross-cut the east-northeast-west-southwest trending fault which juxtaposes volcanic rocks of the Sidewinder Group on the south to monzonite and older undifferentiated carbonates to the north along the quarry road (Plate II). This fault and the felsic dike were later intruded by quartz monzonite (Plate II).

The second set of dikes which intrudes the folded

Fairview Valley Formation and the overlying quartzite unit, also trends northwest but their dips are variable. The dikes are very abundant in northeastern exposures of the Fairview Valley Formation beneath the massive limestone conglomerate unit, (Appendix I, measured section of the Fairview Valley Formation) and are conspicuous in the white marble quarry at the entrance to the Southwestern Cement Plant. Only a few of these have been mapped; they are fine-grained, non-resistant to weathering, and are often found only in float. In thin section they consist primarily of plagioclase and hornblende. Variable percentages of quartz and potassium feldspar are present. All of the plagioclase in these dikes is altered, either sericitized or replaced by coarse-grained epidote. The hornblende is light-brown to brown and is often altered to light green tremolitic amphibole along the edges of grains.

As discussed above, it is possible that these two sets of hypabyssal dikes, which intrude the Fairview Valley Formation rocks, represent the continuation of volcanic activity in this area. This volcanic activity post-dated the folding of the Fairview Valley-Sidewinder Group sequence.

Hornblende-Plagioclase Rocks

Dark hornblende-plagioclase rock intrudes carbonate rocks at the western tip of the Sidewinder Mountain roof pendant. In outcrop these rocks often exhibit a layering defined by varying amounts of hornblende and plagioclase and vary from very fine-grained to extremely coarse-grained. Petrographic descriptions and chemical analyses of these rocks (Lamprophyric dike rocks) are discussed by Bowen (1954, p. 73-74). Their age relationship to other intrusives in this area is not clear, but they appear to post-date quartz monzonite (1) and pre-date the quartz monzonite-quartz monzonite porphyry, discussed below.

Undifferentiated Quartz Monzonite/Granitic Rocks

This group of rocks includes a variety of undifferentiated quartz monzonite to granitic rocks which were not mapped in detail. Certain important relative age relationships, however, were established in parts of the area mapped. Briefly, the bulk of the rocks which intrude the older metasedimentary rocks of the Sidewinder Mountain roof pendant to the north consist of quartz monzonite and alaskite. The alaskite (discussed below) is the youngest of the two. Where outcrop patterns of the quartz monzonite and alaskite were complex, these were mapped as undifferentiated alaskite/quartz monzonite. Most of the quartz monzonite (well exposed on the ridge which is crossed by the gas pipeline road) is medium-grained and contains abundant inclusions. This quartz monzonite contains approximately 40-45% plagioclase, 20-25% potassium feldspar, 20% quartz and about 15% biotite and minor hornblende. Accessory opaques, apatite, sphene and zircon are present.

Several dikes labeled qmqr cut the metasedimentary rocks in the Sidewinder Mountain-Black Mountain area.

In the eastern half of the Sidewinder Mountain roof pendant, one of these dikes is intruded along a fault which offsets the Carrara-Bonanza King fault contact (Plate II). This fault also offsets the older quartz monzonite (discussed above) intrusive contact and hence the quartz monzonite porphyry intruded along this fault is younger than the quartz monzonite whose intrusive contact is offset by this fault. An even younger body of alaskite cross-cuts this fault, but it is not clear if it intrudes the quartz monzonite porphyry dike here. The quartz monzonite porphyry dikes contain phenocrysts of plagioclase, quartz, potassium feldspar, and altered biotite and hornblende(?) in a very fine-grained recrystallized glassy matrix which is dark grey in hand specimen. This rock type was discussed in detail by Bowen (1954, p. 68-72). Within the Sidewinder Mountain-Black Mountain area, all gradations exist between these porphyritic dike rocks and their coarser-grained equivalents. This gradation is particularly obvious along the trend of the dike which intrudes the east-west trending fault zone between rocks of the Sidewinder Group and the older metasedimentary rocks of the Sidewinder Mountain roof pendant (Plate II). Here, the quartz monzonite porphyry with recrystallized glassy matrix becomes very coarse-grained in places and weathers to a distinctive rubbly outcrop. In the Black Mountain area, similar porphyritic to coarse-grained quartz monzonite is intruded along faults which juxtapose volcanic rocks of the Sidewinder Group to older metasedimentary rocks, and intrudes rocks of the Sidewinder Group to the south (Plate II). On the southwest side of the Helendale fault, quartz monzonite/granitic rocks, probably part of this same intrusive event are widespread but do not crop out well.

The relative age of the quartz monzonite-quartz monzonite porphyry and the alaskite intrusions is not known, however, these two types of intrusives represent the latest intrusive episodes in the area mapped.

Alaskite

Alaskite intrudes the older metasedimentary rocks of the Sidewinder Mountain roof pendant (Plate II). The distinctive rounded-boulder outcrops of alaskite weather dark brown. These rocks contain approximately 85% perthitic orthoclase, 5-10% quartz, and about 5% plagioclase. Very minor percentages of mafic minerals are entriely altered, and accessory opaques, sphene and zircon are present.

With the exception of the younger quartz monzonite-quartz monzonite prophyry discussed above, to which the relative age of the alaskite is unknown, the alaskite is the youngest, or one of the youngest intrusive rocks in the area mapped.

II. Deformation

GENERAL STATEMENT

Because the Sidewinder Mountain-Black Mountain area is divided into several different structural blocks separated by faults of unknown displacement, it is not always clear how the sequences of events can be correlated between blocks. The deformational events affecting 1) the Sidewinder Mountain roof pendant of older metasedimentary rocks, 2) the Tri-Color quarry area and 3) the Black Mountain area will, for this reason,be discussed separately.

It is understood that the maps and cross-sections which accompany this report (Plate II) should be continually consulted while reading this section. For this reason, repeated reference to these figures has been avoided.

SEQUENCE OF EVENTS IN THE SIDEWINDER MOUNTAIN ROOF PENDANT

The metasedimentary rocks in the Sidewinder Mountain roof pendant are not as penetratively deformed and recrystallized as the older rocks at Quartzite Mountain. The less penetrative nature of the deformation affecting these rocks has better preserved the stratigraphy in this area. Presence of identifiable stratigraphic units has aided in the interpretation of the structures involving these units. But as is often the case, greater quality of data can also cause greater confusion: Some of the structural interpretations presented below are only of a tentative nature as a fuller understanding of the geologic history is precluded by the small extent of the outcrop and the presence of many intrusive rocks in this area. To facilitate descriptions of the sequence of events affecting these rocks, a colored fault map (fig. 8) will be referred to frequently.

One of the earlier events to affect the older metasedimentary rocks of the Sidewinder Mountain roof pendant is interpreted to be an event which caused tectonic slicing of original stratigraphic contacts. This event appears to have caused imbrication and slicing of normal contacts, placing younger rocks on older rocks, tectonically removing portions of the sequence, but preserving the original stratigraphic order. Structures related to this event are present in the eastern half of the roof pendant where three tectonic slices of the Bonanza King Formation are in shallowly dipping fault contact (brown) with the underlying Carrara Formation. The basal fault contact beneath the Bonanza King units cuts across trends of both upper and lower plate rocks. Where the fault is exposed, it is a very narrow shear zone, in places less than an inch thick. Rocks immediately adjacent to this contact are severely sheared parallel to the contact, but the deformation has been plastic and flowage has occurred. Hence this faulting event was not a brittle event (as compared to later faults which cut these rocks) and was probably one of the earliest events to affect this package of rocks with the possible

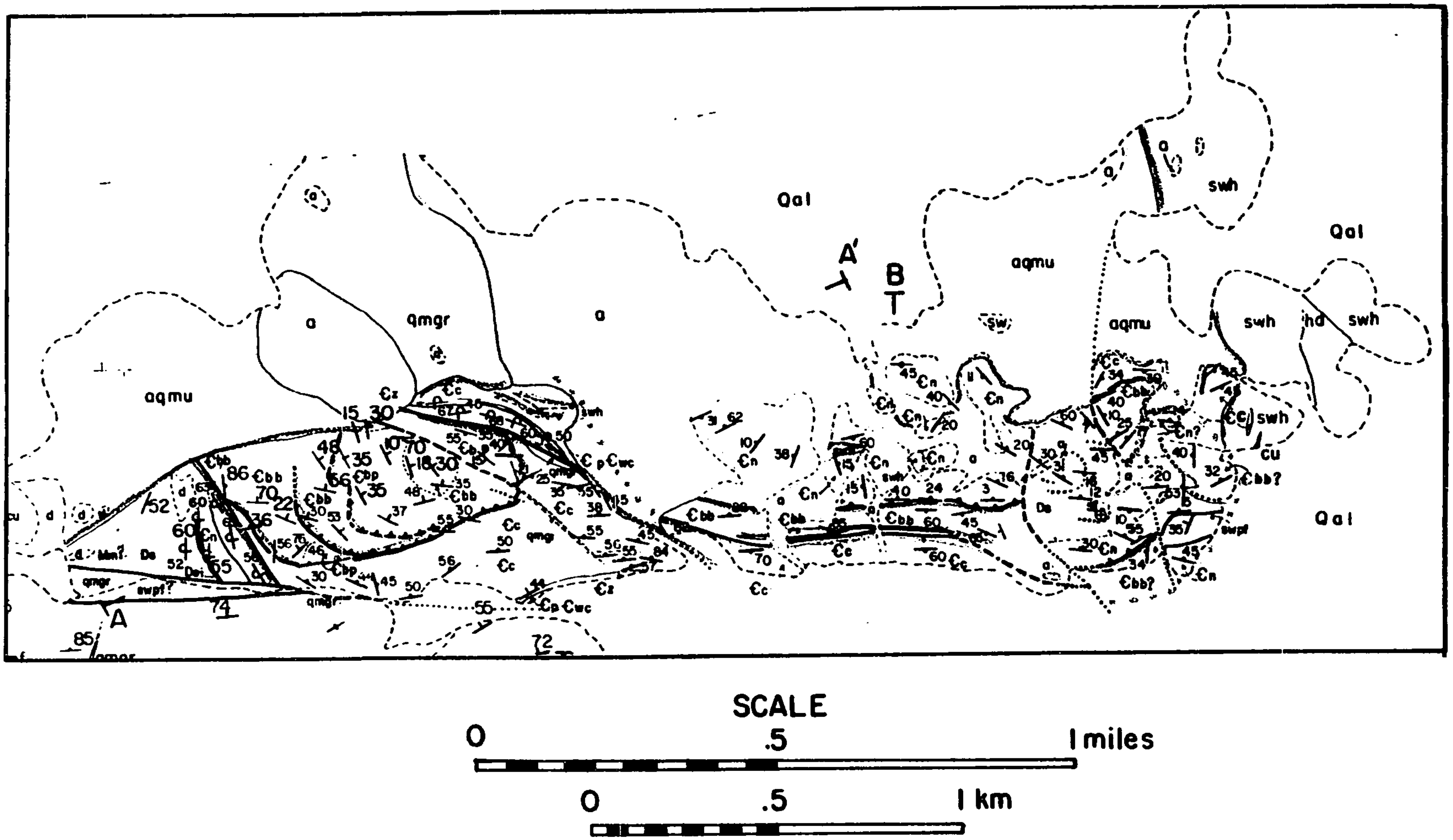

Qal
Qal
Qal
aqmu
aqmu
aqmu
qmgr
a
a
swh
swh
swh
swh
hd
sw
A
A′
B
Ꞓz
Ꞓc
Ꞓbb
Ꞓbp
Ꞓn
Ꞓp
Ꞓwc
Ꞓbb?
cu
De
SCALE
0
.5
1 miles
0
.5
1 km

FIGURE 8

exception of deformation (folding) which may have affected these rocks prior to the slicing event. An earlier folding event is suggested as the fault cuts across units or compositional layering within the Carrara Formation. Perhaps folding of the Carrara was synchronous with the slicing event, the slicing a slightly later result of the continuous deformation of these rocks. Bedding is better preserved in the upper plate Bonanza King Formation; lower plate Carrara rocks appear to be more highly deformed.

The sense of movement on the shallowly dipping fault beneath the Bonanza King Formation is not clear. Bonanza King Formation rocks in the lowest fault slice (Plate II, cross-section A-A') are involved in a medium-scale paired antiform-synform structure which is then cut by the fault. The antiformal axis trends N6E and plunges 31 to the northeast, its axial plane strikes N52W and dips 36 northeast. The sense of overturning on this fold is to the west.

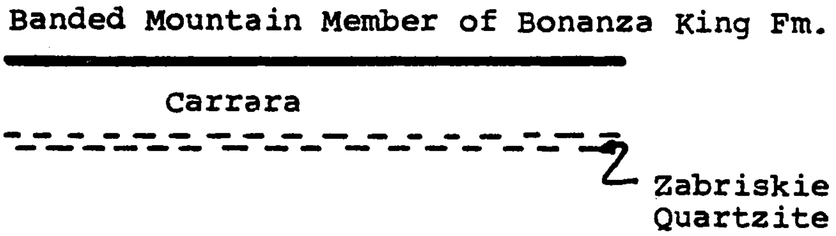
To the east, the Carrara-Bonanza King block is bound by a major northwest trending high angle fault (olive green). The sequence on the east side of this fault seems to belong to a different tectonic block, and the relationship of the two blocks is not clear. The exposures just east of this fault contain an overturned section of Wood Canyon, Zabriskie, and Carrara Formations. This overturned sequence is inferred to be continuous with exposures of Carrara Formation which trend east-west across the front of the mountain in the eastern half of the roof pendant. If this inferrence is correct, the Carrara Formation to the east is overturned and it is in contact (brown) with sugary grey mottled dolomitic marble to the north. The grey dolomite sequence is distinctive and is correlated with the uppermost Banded Mountain Member of the Bonanza King Formation elsewhere in this area. This contact must be a fault contact as the entire Papoose Lake Member and probably most of the Banded Mountain Member of the Bonanza King Formation is missing. The contact dips steeply to the south parallel to compositional layering in the Carrara and parallel to bedding in the Banded Mountain carbonate rocks which also dips steeply to the south. This faulted contact (brown) may be similar to or related to (same age, same fault?) the sliced Carrara-Bonanza King Contact in the block to the west.

The contact between the distinctive dark, hornfelsed Cararra pelites and the Banded Mountain member of the Bonanza King Formation is offset by two faults (yellow) and crops out again on the northeasternmost tip of the mountain, where it still dips to the south. Patchy outcrops of the Carrara Formation in this area appear to fold around the eastern tip of the mountain. The Carrara-Banded Mountain fault contact is interpreted to be folded into a syncline, the limbs of the syncline being semiparallel and south dipping. The field evidence does not rule out the possibility that the structure is anticlinal however, this would imply that the folded fault places older (Carrara) on younger (Banded Mountain) rocks which is not the younger-over-older relationship seen in the adjacent structural block, provided, of course, that the two blocks are related. For this reason the interpretation that the fault contact is folded into a syncline is preferred.

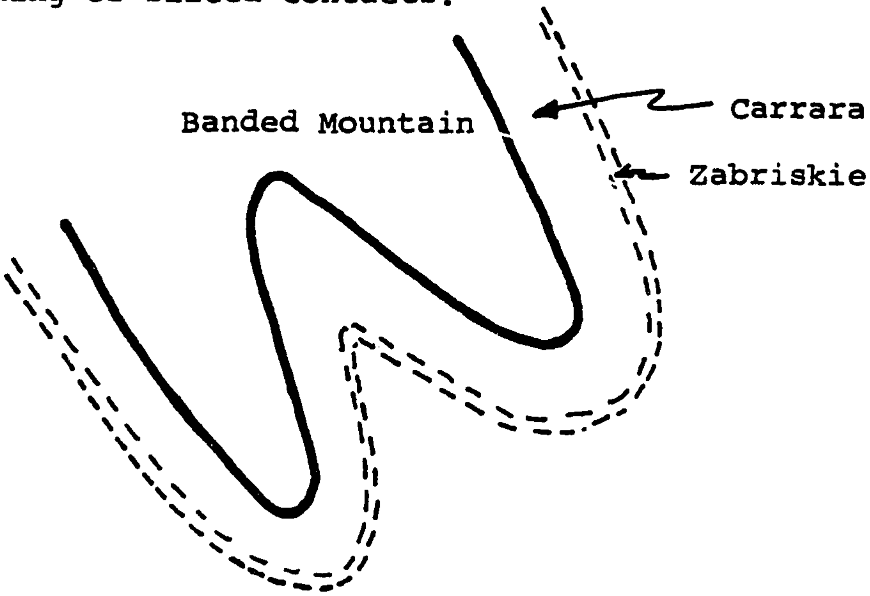
In fault contact (red) with the steeply south-dipping Banded Mountain Member of the Bonanza King Formation are buff-colored dolomites of the Nopah Formation. The Nopah is isoclinally folded about gently north-dipping, east-west trending axial planes. Axial plane foliation and compositional layering in the Nopah Formation are parallel to the low-angle fault which juxtaposes these rocks above steep-dipping Banded Mountain dolomites. Hence the fault parallels structures in the hanging wall and cuts across structures in the foot wall. The Nopah formation is inferred to have been emplaced along a low-angle fault which post-dated folding of the lower plate although this emplacement may have been a later event in a continuing episode of deformation. This fault places younger on older rocks but as the Nopah Formation is more penetratively deformed, it may have come from a structurally lower horizon and emplaced on structurally higher units. A highly schematic interpretation of a series of events which may have produced the geologic relationships described above is shown in figure 9.

FIGURE 9. Highly simplified and schematic interpretation of series of events producing structural relationships seen at Sidewinder Mountain.

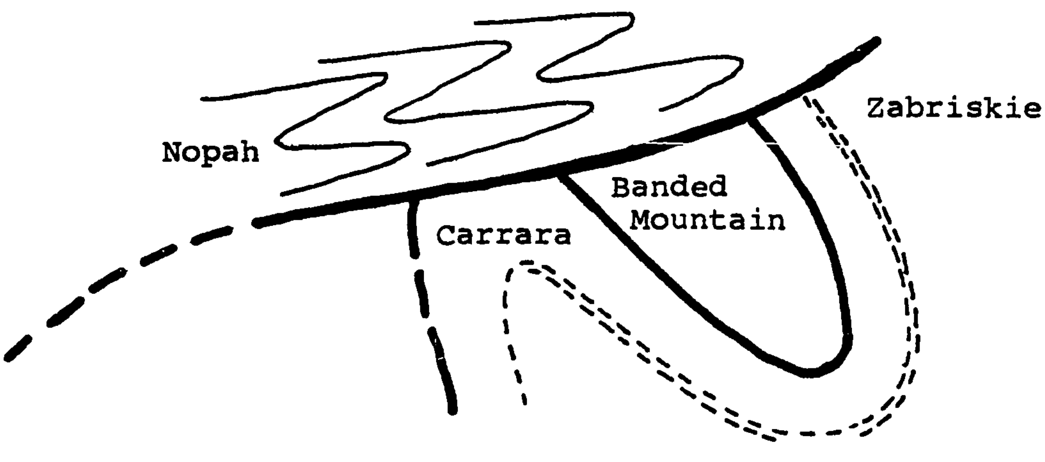
1. Slicing of stratigraphic contacts, placing younger on older rocks, and removing portions of section:



2. Folding of sliced contacts:



3. Emplacement of structurally lower, more deformed Nopah Formation:



Two later high-angle faults (yellow) down-drop to the east a portion of upper plate Nopah Formation. The rocks in this graben are deformed in a similar style to those on the west side of the western fault, but higher units are exposed. Stromatoporoid bearing beds, repeated by folding are present in the upper part of this sequence between the two (yellow) faults. These beds are correlated with the Ironside member of the Devonian Sultan Limestone or perhaps higher stromatoporoid-bearing units within the Sultan.

Across the fault which bounds this graben on the east side (yellow), the Carrara-Banded Mountain fault is again exposed (where it is inferred to fold around). This particular fault block (on the east side of the yellow fault), is very complex. Intrusive rocks have altered the original characteristics, particularly the color, of the carbonate rocks , and it is no longer possible to identify rock units unambigously. There is one stromatoporoid horizon exposed in the northern part of the block (Plate II). Small areas of Carrara pelite and Banded Mountain (?) grey dolomitic marble crop out within the area of buff-colored, Nopah (?)-like dolomite. This complicated map pattern may be explained by the hypothesis of a shallow contact juxtaposing isoclinally folded Nopah and higher units above a folded structure involving Carrara and the Banded Mountain Member of the Bonanza King Formation, being eroded to expose lower plate rocks in fensters. The fact that Nopah(?) carbonate is in contact with both Carrara pelite and Banded Mountain (?) dolomite would be evidence that the fault contact beneath the Nopah crosscuts a folded structure in the underlying rocks.

The sequence of events and the structures described above are believed to be the oldest set of events in this area. It is not clear whether these older structures were formed during a single deformational event as proposed above, or were formed during several distinct deformational events.

Two faults (olive-green) of probably major displacement cut this older set of structures. Both strike northwest and are steeply dipping. One juxtaposes essentially upright but sliced Cambrian Bonanza King and Carrara and an overturned section of Banded Mountain Member of the Bonanza King Formation, Nopah Formation, Sultan Limestone and Mississippian Monte Cristo Limestone(?). The other one of these faults separates the block containing Carrara and Bonanza King from the eastern half of the roof pendant. The significance of these faults is not clear, but most probably represent considerable displacement and must cut previously formed, complex, overturned structures as they juxtapose upright and overturned sequences of similar rocks.

This episode of high-angle faulting was followed by:

a. Possibly the intrusion of hypabyssal dikes associated with(?) extrusion of the Sidewinder Group volcanic rocks (green).

b. Intrusion of undifferentiated quartz monzonite (qmgr) (blue).

c. A period of high-angle faulting (yellow) which is perhaps the same age as the faulting which juxtaposes rocks of the Sidewinder Group of Sidewinder Mountain to the older metasedimentary rocks of the roof pendant.

d. Intrusion of Alaskite (orange) and the intrusion of quartz monzonite perphyry dike rocks along the east-west trending fault which bounds rocks of the Sidewinder Group (?) to the north.

This sequence of events is tabulated in figure 10.

SEQUENCE OF EVENTS IN THE SIDEWINDER MOUNTAIN ROOF PENDANT

1. Folding and metamorphism:
    a) Folding (?)
    b) Slicing of stratigraphic contacts, placing younger on older rocks; portions of section removed by faulting
    c) Folding of sliced contacts
    d) Emplacement of structurally lower(?) more deformed Nopah Formation and higher units

2. High angle faulting. Not clear whether pre- or post-Fairview Valley deposition.

3. Possibly intrusion of hypabyssal dikes associated with(?) extrusion of Sidewinder Group volcanics.

4. Intrusion of Quartz Monzonite (1) (?).

5. High angle faulting of metasedimentary rocks against Sidewinder Group.

6. Intrusion of quartz monzonite porphyry-quartz monzonite, and intrusion of alaskite.

FIGURE 10

SEQUENCE OF EVENTS AT TRI-COLOR QUARRY

At Tri-Color quarry a sequence of older rocks are juxtaposed against younger volcanic rocks of the Sidewinder Group.

Rocks of the Banded Mountain Member of the Bonanza King Formation are deformed and metamorphosed and are overlain unconformably by a sequence of dolomite cobble conglomerate probably correlative with either the Fairview Valley Formation or the quartzite unit which overlies the Fairview Valley Formation.

The sequence of events affecting this block are the following (shown on the colored fault map, fig. 11)

1. Metamorphism and deformation of the Banded Mountain Member of the Bonanza King Formation (brown). Interpret this event to correlate with the formation of the older structures described from the nearby Sidewinder Mountain roof pendant.
2. Erosion and deposition of the Fairview Valley Formation or quartzite unit equivalent (light green).
3. Shearing and flattening of conglomerate beds above the unconformity (Appendix II). This may have resulted from subsequent folding.
4. Unconformity cut by two small high-angle faults of minor displacement (purple).
5. Faulting of this sequence with respect to probably overlying volcanic rocks of the Sidewinder Group and Formation of horst block (dark green).

6. Fault-bounded horst block cut by later faults (yellow), one of which terminates the exposure of the unconformity to the south.

Dibblee (1967) and Bowen (1954) both mapped this later fault continuing for a much greater distance than shown on this map, although both did not put it in the same place. I found no evidence for the fault cutting through the Sidewinder sequence further to the east, although it would not be obvious if it followed bedding in these rocks.

It is possible that 4, 5, and 6 may be equivalent to event 5 (yellow) or younger faults of the Sidewinder Mountain roof pendant fault map.

This sequence of events is tabulated in figure 12.

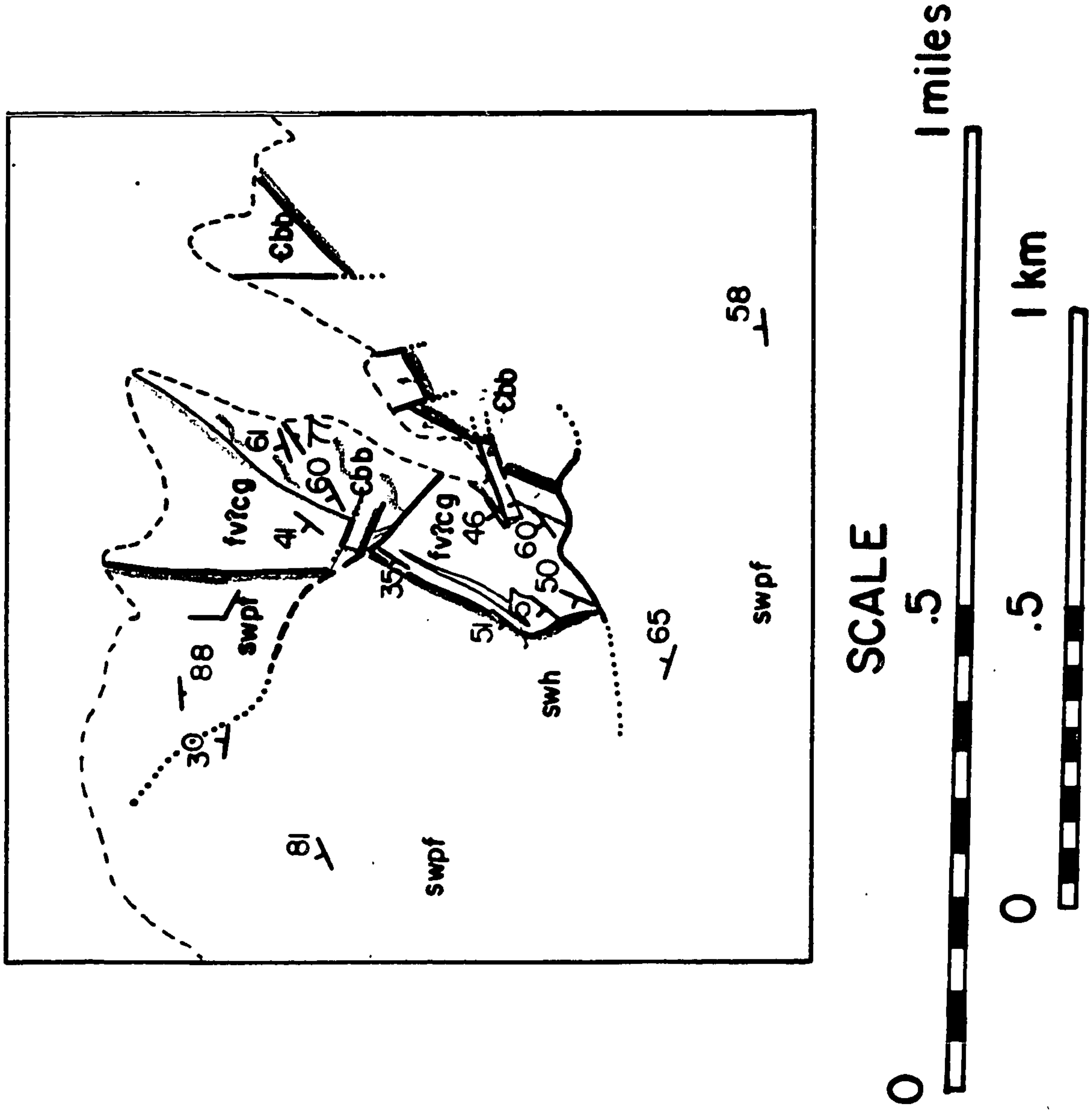

€bb
€bb
€bb
fvp€cg
fvp€cg
swpf
swpf
swpf
swpf
swh
58
61
60
41
46
60
50
35
51
65
88
30
18
SCALE
0
.5
1 miles
0
.5
1 km

FIGURE 11

SEQUENCE OF EVENTS, TRI-COLOR QUARRY

1. Deformation of rocks of the Banded Mountain Member of the Bonanza King Formation.

2. Unconformity; deposition of Fairview Valley equivalent (?).

3. Shearing and flattening parallel to unconformity.

4. Minor high angle faulting.

5. High angle faulting of the Bonanza King Formation and Fairview Valley equivalent(?) sequence against overlying volcanic rocks of the Sidewinder Group.

6. Later high-angle faulting of entire sequence.

FIGURE 12

SEQUENCE OF EVENTS IN THE BLACK MOUNTAIN AREA

At Black Mountain, the post-230m.y. old Fairview Valley Formation unconformably overlies monzonite plutonic rocks which intrude and contact metamorphose coarsely crystalline calcite marble, currently being quarried by the Southwestern Cement Co.

The marble is too deformed and recrystallized to be identified but undoubtedly is part of the older Paleozoic carbonate sequence exposed in this area. The fact that the marble is highly deformed and recrystallized and is intruded by the monzonite which represents a 230m.y. old episode of magmatic activity, indicates that the monzonite post-dates the deformation of this particular marble. This is a critical relationship as it suggests that this older plutonic event was perhaps co-eval with or post-dated the first or both(?) of the two earlier deformations at Quartzite Mountain where no older plutonic rocks are presently exposed.

The relationship of these older plutonic rocks and metasedimentary rocks to the overlying Fairview Valley Formation at Black Montain is similar to that described at both Quartzite Mountain and at Tri-Color quarry. Hence the deformation, metamorphism, and intrusion of this Paleozoic (?) marble is analogous to the F_1 and F_2 folding events at Quartzite Mountain and to the folding and slicing events (events 1a-d) which affected the Sidewinder Mountain roof pendant rocks, and corresponds to the earliest group of events affecting the rocks in this area. At least the earliest of these events would have to have occurred prior to or during the intrusion of the 230 m.y. old plutons in this area and thus may be earliest Triassic in age.

Uplift and erosion post-dated this earliest sequence of events, exposing a variably metamorphosed and intruded terrain. This terrain had been deformed by an event (or events) of sufficient magnitude to form structures involving Precambrian crystalline basement rocks. The Fairview Valley Formation was then deposited on this eroded terrain and the sediments of the Fairview Valley Formation were derived, in a large part, from the continuing erosion of this terrain.

According to the interpretation presented above, the Fairview Valley Formation was probably slightly tilted (?) eroded, and was unconformably overlain by a thin unit of quartzitic sandstone which is conformably overlain by a minimum of 3000 feet (900m) of pyroclastic volcanic rocks of the Sidewinder Group.

This entire sequence was then deformed and folded along northwest-striking, vertical to steeply southwest-dipping axial planes. Fold axes in the Fairview Valley Formation trend northwest and are nearly horizontal. Cleavage associated with this folding event is well-developed in the less contact metamorphosed northwestern exposures of the Fairview Valley Formation. Bedding and cleavage relationships are easily seen in the siltier limestone; purer limestone units are more deformed and bedding has been transposed. In the northwestern exposures of the Fairview Valley Formation, these rocks are involved in an open syncline, and based on bedding attitudes, an open anticline (Plate II) although units involved in the anticlinal structure were not mapped around the hinge zone area, because it is covered by alluvium (Plate II). This anticline-syncline pair apparently dies out along strike because further to the southeast, bedding is steep, vertical or slightly overturned, but tops are consistantly to the northeast. The shortening and deformation represented by this anticline-syncline pair must, therefore, be compensated to the southeast by bedding plane shear, slip, or flattening as there is no indication of a fault between the sequence involved in the folds and the unfolded sequence.

Another anticline-syncline pair is developed in the Fairview Valley Formation beneath its contact with the quartzose sandstone unit (Plate II). Again, this fold pair appears to die out or be compensated by bedding plane slip or flattening to the southeast. Shearing or slippage probably occurred along the unconformity between the quartzite unit and the Fairview Valley Formation: this contact is never exposed, but outcrops of the limestone cobble conglomerate unit near this contact show silification and brecciation. The anticline-syncline couple beneath the unconformity may have been caused by shear along the unconformity during deformation of this package of rocks.

The folding which affected the Fairview Valley Formation is interpreted to have involved the overlying pyroclastic rocks of the Sidwinder Group as the volcanic rocks contain a schistosity which is sub - parallel to axial plane cleavage and foliation within the Fairview Valley Formation.

Previous workers interpreted this folding event differently from the interpretation presented here. Bowen (1954) indicated that the limestone cobble conglomerate unit of the Fairview Valley Formation was folded into a syncline which was faulted against the "Oro Grande" sequence (quartzite unit at the base of the Sidewinder volcanic rocks of this report). Stone (1964) also interpreted the conglomerate unit to be folded into a <u>shallow</u> syncline and faulted against the Sidewinder volcanic rocks with a sliver of "Oro Grande" (quartzite of this report) brought up along the fault. Dibblee (1967) interpreted the conglomerate unit to be folded into a tight, almost isoclinal syncline and in fault contact with the quartzite unit. It is hard to accurately determine bedding attitudes in the massively bedded conglomerate unit and criteria for sedimentary facing are difficult to interpret. Major quarrying of the limestone conglomerate has now made it difficult to investigate most of the conglomerate exposures: quarry walls are steep, and dangerous avalanches are common. Blasting operations are carried out daily. One of the criteria used by previous workers as evidence for a syncline within this carbonate conglomerate unit is the presence of a small outcrop of hornfelsed calcareous siltstone, similar to rocks of the lower Fairview Valley Formation, on the southeast edge of the conglomerate unit (Plate II). This outcrop has been interpreted as repitition of the lower Fairview Valley by the folding of this sequence. I believe that these outcrops of calcareous siltstone interfinger along strike with the cobble conglomerate, and represent the southeastern sedimentary edge of the conglomerate unit. The north-northeast trending fault which cuts the Fairview Valley Formation in this area has rotated the beds within the Fairview Valley Formation; some of these beds now trend to the northeast (Plate II). This fault was not mapped by Bowen (1954), Stone (1964) or Dibblee (1967). The major argument in favor of post-volcanic folding is the fact that axial plane cleavage surfaces within the Fairview Valley Formation are the same as the schistosity in the overlying pyroclastic rocks of the Sidewinder Group.

A series of felsite dikes intrude the folded rocks of the Fairview Valley on the southwestern side of Black Mountain (Plate II). These dikes trend N20-40W, and are subparallel to axial planes of folds in the Fairview Valley Formation. They exhibit a strong flow foliation, show signs of slip along some of their contacts, and some show evidence for forceful intrusion.

Intermediate composition hypabyssal dikes are also common, particularly in the northeastern exposures of the Fairview Valley Formation. These dikes generally strike northwest but have variable dips and are clearly seen to cross-cut cleavage or foliation within the Fairview Valley Formation. These latter dikes rarely cross cut the sandstone unit above the Fairview Valley Formation but do not intrude the overlying volcanic rocks.

The fault which juxtaposes volcanic rocks of the Sidewinder Group against the Fairview Valley Formation and Paleozoic(?) marble along the quarry road dips 30-50 degrees to the east-southeast. The trace of this fault is intruded by a northwest-trending felsite dike similar to the ones which intrude the Fairview Valley Formation to the northwest (Plate II). Hence this fault predates all or part of the intrusion of this dike system. As mentioned above, the relationship of the Sidewinder Group rocks southeast of this fault to the sequence of volcanic rocks above the Fairview Valley is not clear. Sidewinder pyroclastic (?) rocks also are present in contact with the Fairview Valley Formation rocks at the extreme northwest end of Black Mountain (Plate II). If these are pyroclastic volcanic rocks rather than hypabyssal intrusive rocks, they are probably separated from the Fairview Valley Formation by a fault, but, the contact is intruded by a northwest-trending felsite dike.

The steep southwest-dipping, northwest trending fault which juxtaposes the volcanic rocks on Sidewinder Mountain to the Fairview Valley Formation in the vicinity of the cement plant postdates the more shallowly dipping, northeast trending fault along the quarry road. The younger fault possibly continues along the contact between the undifferentiated granitic rocks and Sidewinder volcanic rocks to the northwest as this intrusive contact is very linear, and contains a small sliver of recrystallized marble along its trace (Plate II) which may have been emplaced as a result of faulting. Later, undifferentiated granitic rocks were then intruded along this fault (Plate II).

The intrusion of undifferentiated quartz monzonite/ granitic rocks postdated the major faulting events at Black Mountain as these rocks are intruded along or partly along the older faults. Thus the major faults described above are Mesozoic in age by reference to the argument that the younger intrusive rocks in this portion of the Mojave are all Upper Cretaceous in age (Armstrong and Suppe, 1973). The trace of the recently active, northwest-trending Helendale fault cuts all older rocks and structures in the area. A discussion of the Tertiary faulting and the Helendale fault is presented in a separate section.

The sequence of events affecting the Black Mountain area is tabulated in figure 13.

SEQUENCE OF EVENTS, BLACK MOUNTAIN AREA - Figure 13

1. Deformation/metamorphism of Paleozoic(?) marble.

2. Intrusion of monzonite cogenetic with monzonite dated in Granite Mountains at 230± 8 m.y. old (Calvin Miller, pers. comm).

3. Erosion; deposition of Fairview Valley Formation

4. a) Tilting(?), uplift and erosion; deposition of quartzite unit above Fairview Valley Formation
   b) Deposition of pyroclastic rocks (a) of the Sidewinder Group

5. Folding: N20-30W, vertical to steeply southwest-dipping axial planes; Northwest trending fold axes with near horizontal plunges.

6. Extrusion of younger Sidewinder Group volcanic rocks (post-volcanic rocks (^{a})). These volcanic rocks are less deformed than volcanic rocks (a). Alternatively, volcanic rocks higher in the section above volcanic rocks (a) were, for some reason, not as deformed as volcanic rocks (a).

7. Faulting: East-northeast-west-northwest striking fault juxtaposes volcanic rocks of the Sidewinder Group against Fairview Valley Formation and Paleozoic (?) marble along quarry road. Northwest striking fault which juxtaposes Fairview Valley and Sidewinder Group volcanics along the northwestern exposures of the Fairview Valley.

8. a) Intrusion of N20-40W trending felsite dikes.
   b) Intrusion of intermediate composition dikes (may represent continuing volcanism?)

9. Faulting of younger volcanic rocks of post-Sidewinder (a) age Sidewinder Mountain against Fairview Valley Formation along steep, northwest trending fault. Not clear whether pre or post event 8.

10. Intrusion of undifferentiated quartz monzonite/granitic rocks.

11. Helendale Fault

RECONNAISSANCE GEOLOGY OF THE PIERCE QUARRY AREA

I. Introduction

Accompanying this report is a preliminary geologic map of the Pierce Quarry area (Plate III) which lies to the east of Interstate 15 (figure 1). Due to time constraints, this area was not mapped or studied in detail. The rocks at the Pierce quarry area consist of limestone, calc-silicate rocks, dolomite, and minor quartzite which are present as a roof pendant within undifferentiated intrusive rocks.

II. Metasedimentary Rocks

Although minor orthoquartzite and pure dolomite occur within this roof pendant (Plate III) of metasedimentary rocks, most of the rocks in this area are interlayered grey limestone, cherty limestone, calc-silicate units, dolomitic limestone and minor dolomite.

The northernmost outcrop of limestone, which crops out along the Stoddard Wells Road (Plate III) consists of calc-silicated limestone with abundant elongate chert nodules and is folded about vertical, northwest-trending axial planes. South of this outcrop, limestone and calc-silicated limestone with abundant elongate and small round chert nodules is interlayered with several thick (up to about 6m) silty to sandy calc-silicated units. This sequence of rocks is tightly folded about north-northwest, vertical to steeply southwest dipping axial planes. Plunge of fold axes within this plane are variable but steep. To the south of these outcrops, cherty limestone, calc-silicate rocks and dolomitic limestone become more highly metamorphosed and recrystallized which is also the case for all the carbonate outcrops further to the south in and around the quarries (Plate III). The size of the calcite grains in these rocks is often a centimeter or more in diameter. This recrystallization is undoubtedly due to the various intrusive rocks present in this area.

III. Igneous Rocks

A large body of biotite quartz monzonite crops out in the southwestern portion of the Pierce Quarry map (Plate III). A sample of this intrusion from the Victorville narrows has been dated by Armstrong and Suppe (1973) as 72 ± 1.8 m.y. old (biotite, K-Ar). To the northeast, a large variety of igneous rocks intrude the metasedimentary rocks of the Pierce quarry area. The intrusive relationships of these rocks are well exposed along the steep walls of the quarries. The quarry area was visited only very briefly on a tour given by Pfeizzer Chemical Company. Hornblende-rich amphibolite dikes (similar to those which intrude the Quartzite Mountain metasediments?) are common. Some of the intrusive dikes are similar in hand specimen to the monzonite that lies unconformably beneath the Fairview Valley Formation at Black Mountain. A sample of one of these coarse-grained dikes contains 40-50% plagioclase, 30% potassium feldspar, which occurs as large pink phenocrysts as well as in the groundmass, 10% quartz, 10-20% hornblende, 5% opaques, and accessory zircon and sphene, hence these dike rocks contain a greater amount of quartz and less mafic minerals than the monzonite at Black Mountain. The thin-section of this dike rock shows textures indicative of metamorphic recrystallization and shear zones. These porphyritic quartz monzonite dikes are certainly older than the Upper Cretaceous biotite quartz monzonite which intrudes the metasedimentary rocks to the south as the latter intrusive rock type represents the latest thermal event in the area and cross-cuts all structural trends. Minor, more mafic dikes with plagioclase phenocrysts in an altered dark matrix also intrude the metasedimentary rocks in the quarry area.

To the south, rocks mapped as undifferentiated igneous rocks contain a large percentage of very fine-grained foliated felsic hypabyssal rocks which contain relict feldspar phenocrysts in a very fine-grained recrystallized groundmass and very minor fine-grained hornblende and biotite. This rock type is in all ways similar to the more highly foliated metahypabyssal igneous rocks mapped in the Quartzite Mountain area although here their intrusive relationship to the metasedimentary rocks is more obvious.

IV. Age and Correlation

The intensity of the deformation affecting the metasedimentary rocks of the Pierce quarry area, as well as the variety of igneous rocks types which intrude these is similar to the deformation and intrusive history which characterizes the metasedimentary rocks (Precambrian-Cambrian) in the Quartzite Mountain area. Quartzite, calc-silicate rocks and dolomite in the southernmost exposures of metasedimentary rocks of the Pierce quarry area (Plate III) appear lithologically similar to the Johnnie-Stirling equivalent(?) rocks at Quartzite Mountain or to the undifferentiated meta-carbonate rocks in the Shay Quarry-Dent Mine area of Quartzite Mountain. However, the remainder of the metasedimentary rocks in the Pierce quarry area contain calcite marble and cherty marble which is not similar to rocks in the Quartzite Mountain area. The northwesternmost exposures of metasedimentary rocks in the Pierce quarry area are less recrystallized. Here, the folded sequence of limestone marble and calc-silicate rocks with abundant elongate and small rounded chert nodules and the thick silty to sandy calc-silicated units is distinctly different from any of the Precambrian to Cambrian formations at Quartzite Mountain. This sequence of rocks is also distinctly different from the lower Paleozoic succession at Sidewinder Mountain. The Pierce quarry rocks are also vastly different from rocks of either the Mesozoic Fairview Valley Formation or the rocks of Shadow Mountains. It is most probable that the Pierce quarry rocks represent some part of the late Precambrian to Paleozoic succession but there is not sufficient exposure in the Pierce quarry area to establish the stratigraphic relationship of these rocks to the sequences studied in the Quartzite Mountain and Sidewinder Mountain area. It is the author's opinion that the Pierce quarry exposures, or a portion of these exposures, may contain rocks of Upper Paleozoic age, or metasedimentary rocks which are younger than the older Paleozoic sequence exposed at Sidewinder Mountain. The Pierce quarry rocks bear some similarity to the Mississippian Monte Cristo Limestone or Pennsylvanian-Permian Bird Springs Formation of the eastern Mojave Desert.

GEOLOGY OF THE EASTERNMOST SHADOW MOUNTAINS

I. Introduction

Extensive exposures of metasedimentary rocks and Mesozoic(?) batholithic rocks are present in the Shadow Mountains. The eastern edge of the Shadow Mountains lies approximately 10km west of Quartzite Mountain (fig. 1). The easternmost Shadow Mountains were mapped by Bowen (1956) who placed the metasedimentary rocks of this area in the "Oro Grande" sequence. The entire Shadow Mountains were mapped by Dibblee (1967) who also placed these rocks within the "Oro Grande" sequence. Both of these authors indicated that the carbonate-rich sequence in the easternmost Shadow Mountains was in fault contact with metasedimentary rocks to the west which were subsequently mapped by Troxel and Gunderson (1970) as metasedimentary rocks of questionable Upper Paleozoic (?) age.

The easternmost Shadow Mountains, not mapped by Troxel and Gunderson (1970) was mapped during this study with the expectation that these rocks might represent a younger portion of the Paleozoic miogeosynclinal/cratonic sequence described in the previous sections. It was hoped that the relationship of these rocks to the questionable age metasedimentary rocks to the west could be clarified. It was subsequently established that the eastern and western sequences of metasedimentary rocks are a conformable sequence and are not separated by a fault as indicated by Bowen (1954) and Dibblee (1967). Furthermore, the entire sequence of metasedimentary rocks in the Shadow Mountains bears no resemblance to any of the sequences described from the Quartzite Mountain, Sidewinder Mountain, and Black Mountain area.

II. Stratigraphy

GENERAL STATEMENT

The metasedimentary rocks of the easternmost Shadow Mountains crop out in two small hills (Plate IV) near Highway 395, and more extensively to the west of these hills where they are continuous to the west into the area mapped by Troxel and Gunderson (1970). Small exposures of metasedimentary rocks occur in the alluviated area between the outcrops by the highway and the hills further west. Presumably, this alluviated terrain is entirely underlain by metasedimentary rocks, but because the exposure is poor, it is not clear what the stratigraphic and structural relationship of the rocks of the easternmost exposures is to the units exposed in the western hills.

The metasedimentary rocks in the map area consist of lithologically heterogeneous sequences of pelitic hornfels, dolomite, limestone, interbedded limestone, siltstone, cherty siltstone and calcareous siltstone, minor limestone cobble conglomerate and minor orthoquartzite. These metasedimentary rocks are strongly folded on a mesoscopic scale about north-south trending horizontal fold axes with west-dipping axial planes. The lithologic heterogeneity of these rocks, and the deformation which has affected them has made it extremely difficult to establish a stratigraphic sequence. No sedimentary facing data was found within the area mapped. Although the deformation affecting these rocks has undoubtedly caused tectonic thinning and thickening of units along strike, it is not clear whether the variation of individual units along strike, and some of the pinching out of the units as shown on Plate IV and discussed in the structure section, is entirely tectonic in origin. Possibly some of this variation may be due to original sedimentary facies changes and original lenticularity of individual units. Because of these problems, description of the stratigraphy in this area is discussed in terms of the units developed for the purpose of mapping these rocks; no age relationships are implied.

MAP UNITS phf_1, phf_2, phf_3: PELITIC HORNFELS

Hornfelsed pelitic rocks (phf_1) occur interlayered (?)/ infolded with dolomite, impure dolomite, dolomitic limestone and limestone in the easternmost portion of the map area. A pelitic hornfels unit (phf_2) is present structurally beneath the massive grey marble unit in hills to the west. This unit can be followed from the southern tip of the map northwards where it pinches out. A third pelitic hornfels unit (phf_3) crops out extensively on the westernmost portion of the map area. This latter unit continues to the west where it was mapped by Troxel and Gunderson (1970) as "mh" or hornfels. No correlation of these three pelitic units is implied.

The pelitic hornfels consists of fine-grained, non-resistant, non-foliated, dark reddish brown to light brownish pink, contact metamorphosed or hornfelsed pelitic rocks. These rocks contain the metamorphic assemblage white mica + quartz ± andalusite ± biotite ± chlorite ± minor plagioclase which is characteristic of contact metamorphosed pelitic rocks (Winkler, 1974, p. 197). In thin section the pelitic rocks are non-foliated and exhibit textures typical of contact metamorphism. The dark color of these rocks is due to the presence of 5-10% fine-grained biotite.

MAP UNIT d

Map unit d crops out in the easternmost Shadow Mountains, and contains undifferentiated dolomite, slightly impure dolomite, dolomitic limestone and minor limestone. Siliceous impurities in these rocks have been calc-silicated and white-weathering calc-silicate minerals in lenses, patches and knots are common within these carbonate rocks. Wollastonite, forsterite, and periclase (mostly altered to brucite) are present in some thin sections of these rocks. These rocks are more highly recrystallized than rocks further west in the Shadow Mountains, and these eastern hills also contain more granitic and aplitic dike rocks than further west.

MAP UNIT qtz: QUARTZITE

A quartzite unit is present on the northwestern edge of the eastern Shadow Mountains (Plate IV). The quartzite unit does not crop out well, and although laminations can be seen in pieces of float, no other sedimentary structures were seen. In thin section, the quartzite consists of about 95% recrystallized quartz grains; no original grain boundaries remain. Small scattered tremolite grains form the remaining 5% of these rocks.

MAP UNIT ms

Map unit ms consists of a heterogeneous sequence of interbedded grey limestone, thin-bedded siltstone, silty chert, and calcareous siltstone. Although rocks mapped as unit ms crop out both to the east and west of the thick grey limestone unit (lst) in the western portion of the map, as discussed below, they may not be correlative. One of the most striking features about this map unit is the laminated to very thinly bedded (1-3cm) and thinly bedded (3-10cm) character of the siltstone, silty chert, and calcareous siltstone. Thin sections of the calcareous siltstone indicate that the bedding in these rocks is defined by almost rhythmic alternation of laminae which contain silt-size quartz grains floating in a calcite matrix and laminae which contain silt-size quartz in a finer-grained, more pelitic matrix. Boundaries between the layers are extremely sharp, even in thin section, and where these rocks are well-exposed, the layering does not seem to have been disrupted by processes such as burrowing. More calcareous sub-units within map unit ms are thin to medium-bedded. Thick (up to 100m) limestone sub-units within map unit ms have been mapped separately as "msl". These limestones contain variable percentages of silty and sandier horizons. One bed of deformed limestone cobble conglomerate is present near the base of one of the mapped limestone sub-units. The limestone cobble conglomerate bed is indicated by a series of small triangles on the map. Clasts within the conglomerate are predominantly limestone and silty limestone similar to lithologies within the Shadow Mountain sequence itself. Rare chert and calcareous siltstone cobbles are also present.

One of the more interesting lithologies within map unit ms is the wollastonite-bearing, calc-silicated conglomeratic and/or quartzose beds. These rocks are shown on the map by a series of small circles. They form very resistant, white and brown weathering beds up to approximately four meters in thickness. These beds invariably contain either stretched limestone pebbles in a wollastonite-rich calc-silicate matrix and/or quartzitic layers interbedded with wollastonite-bearing calc-silicate rocks. In thin section the white-weathering resistant calc-silicate rocks contain variable amounts of medium sand-size quartz grains and minor orthoclase grains (5-10% of grains) floating in a matrix of bladed wollastonite, lesser amounts of diopside, and very minor calcite. It appears that most of these grains are detrital in origin, although original grain boundaries are not well preserved. Some of the detrital grains appear to have been polycrystalline quartz aggregates. The quartzitic layers associated with these rocks contain

70-80% recrystallized quartz grains and 5-10% orthoclase grains in a matrix of wollastonite, diopside and calcite. The quartzitic layers were initially probably fairly pure quartz sandstone with minor calcite cement. The wollastonite-rich beds must have had an initial composition of approximately 50% quartz - 50% calcite to have been almost entirely converted to wollastonite.

As can be seen from the map, these conglomeratic and/or quartzose beds are not laterally continuous. They have been tightly folded on a mesoscopic scale and their lack of continuity is probably due to disruption by folding. Occasionally one can follow some of these marker beds around anticlinal and synclinal hinges.

Only one conglomeratic bed within unit ms differed significantly from the ones described above. This is a stretched limestone pebble conglomerate with a calc-silicated calcareous siltstone matrix. Very rare detrital (?) feldspar aggregates were found in a few of many thin sections made of this conglomerate.

MAP UNIT lst

Map unit lst is a massive, fairly pure, grey limestone and dolomitic limestone marble which crops out in the western part of the map area. Very abundant calcite veining in this unit, and the lack of silty layers distinguishes it from the limestone sub-units in map unit ms, but make it very difficult to distinguish and measure structures within the unit itself. Bowen (1954) reported a Pennsylvanian brachiopod from this unit. Although the area of his fossil locality was thoroughly searched for fossil evidence, no fossils were found. Peculiar-looking calc-silicated shapes and forms are common, however, and one receives the impression that this unit may have been quite fossiliferous prior to deformation and metamorphism. This is also true of the more massive limestone sub-units in map unit ms. Abundant evidence of large (3-5 cm in diameter) burrows was seen in unit 1st.

MAP UNIT phfw

Map unit phfw is a somewhat more pelitic lithology than map unit ms and does not contain significant limestone, but does contain beds similar to the wollastonite-bearing calc-silicated conglomerate and/or quartzose beds described above, thus, is lithologically intermediate between the phf and the ms map units.

SUMMARY

In summary, the rocks exposed in the eastern Shadow Mountains consist of a heterogeneous sequence of limestone, dolomite, pelitic rocks, laminated to thin-bedded calcareous siltstone and cherty siltstone, minor limestone cobble conglomerate and orthoquartzite. These rocks are continuous to the west where they have been mapped by Troxel and Gunderson (1970). Because these rocks are strongly folded and also because of their lithologic heterogeneity, it is very difficult to establish their stratigraphic sequence and impossible to estimate the original thickness of the sequence. However, the tectonic thickness of an apparently unrepeated portion of the section (although internally folded) is approximately 5100 feet (1530 m) (Plate IV). Exposures of these rocks to the east (Plate IV) and the large area of outcrop of these rocks to the west (Troxel and Gunderson, 1970) may indicate that the original thickness of this sequence may have been on the order of several kilometers.

The abundance of carbonate rocks within the sequence and the fact that these carbonate rocks contain relict burrowing and abundant relict fossil(?) debris suggests that this sequence was probably deposited under shallow, open marine conditions. Quartzites of fairly high compositional maturity occur sporadically within the sequence and may be indicative of the action of sorting mechanisms which occur in a nearshore environment. It is not clear what sort of environment the laminated to thinly bedded siltstone, silty chert, and calcareous siltstone were deposited in, but it is obvious that these delicate laminations could only have been developed in very quiet water and were not subsequently disrupted by burrowing action of bottom dwelling organisms. Presence of conglomeratic horizons throughout the section indicate either syndepositional erosion or erosion of probably similar lithologic terrains in nearby areas.

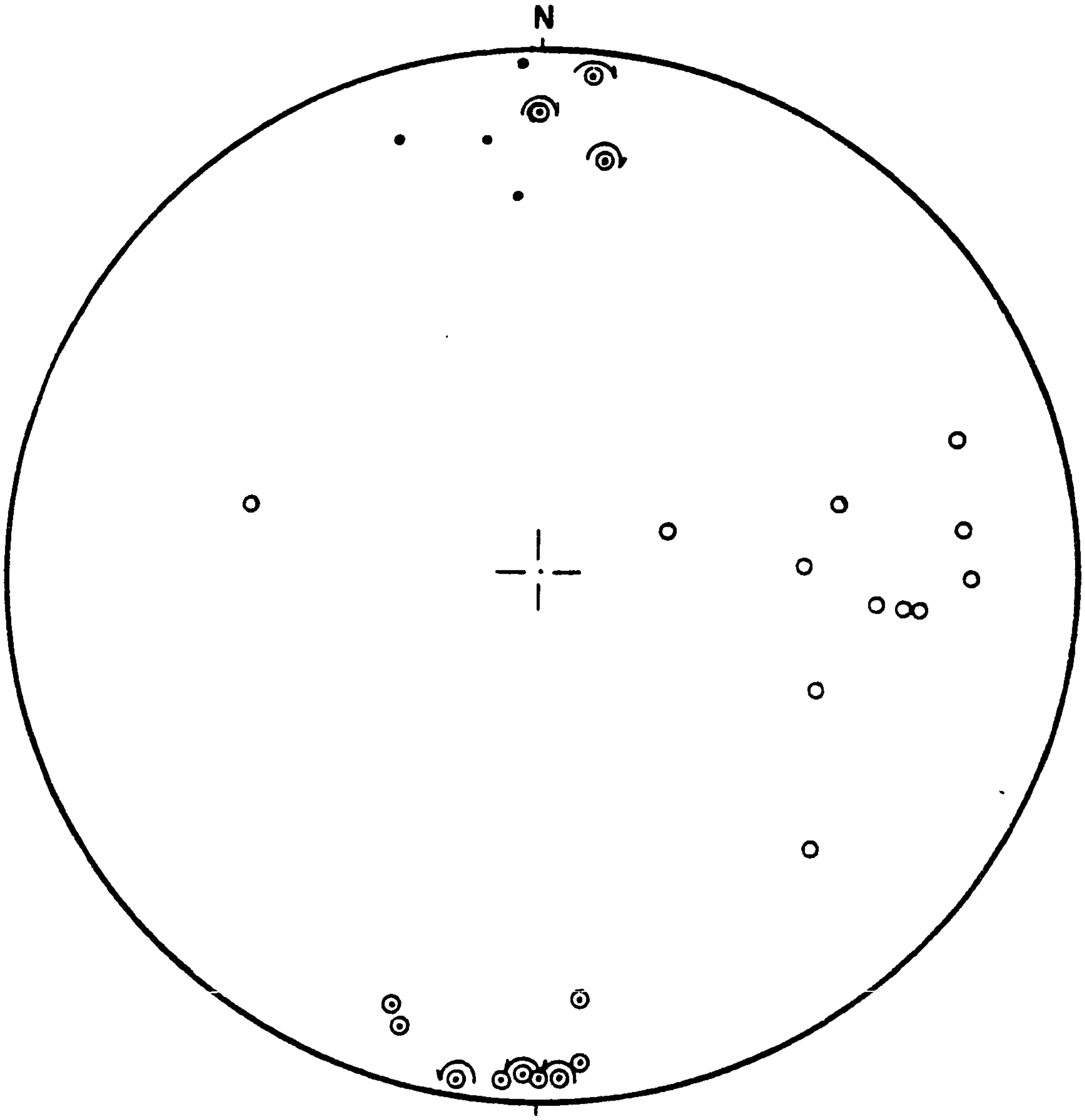
If the lateral variability of units in the Shadow Mountains is not entirely due to tectonic causes alone but reflects original lenticularity of units, this fact, together with the fact that conglomeratic horizons exist throughout the section, may indicate that the deposition of these rocks occurred in an environment which was somewhat tectonically unstable.

III. Structure

The sequence of rocks in the eastern Shadow Mountains has been tightly folded on a mesoscopic scale about north-south trending, near horizontal fold axes with west-dipping axial planes. Mesoscopic folds measured on the east side of the map unit lst are east-vergent (fig. 14). No folds were measured to the west of this unit as exposure was poor. There is sufficient outcrop and thin section evidence to demonstrate that these rocks have been subjected to only one penetrative deformation. Although the more ductile carbonate rocks have been isoclinally folded and bedding has been transposed in these units, more resistant lithologies exhibit well defined bedding and cleavage. Thin sections of tight fold hinges in silty limestone beds indicate that delicate sedimentary layering is preserved and can be followed around the hinges of these folds

West of the map area, the rocks mapped by Troxel and Gunderson (1970) are involved in a series of north-south trending map-scale folds. In the western part of the area mapped in this report, it is not clear if map unit ms has been repeated by folding or if it represents two different

FIGURE 14



SHADOW MOUNTAINS

⊙ Fold axes

○ Poles to axial planes

• S_{0x1} lineations

units. It is the author's opinion that this sequence is probably continuous and that it has not been folded. Although tectonic thinning and thickening has undoubtedly caused units to pinch out in this area, some of the lithologic changes along structural strike may represent original stratigraphic facies changes and may indicate original lenticularity of units within the Shadow Mountain sequence: Unit phf_2, structurally beneath the massive grey marble unit lst, is not repeated on the west side of the marble unit as would be expected if map unit ms was repeated by folding (Plate IV). Unit phf_2 does, however, pinch out northward along strike. Two east-west striking hi-angle faults cut the sequence of rocks in the western portion of the map area (Plate IV). The southern normal fault offsets the west-dipping contact between map unit ms and unit phf_3 westward on the north side of this fault, indicating that this fault has relatively downdropped rocks to the south. The sense of movement on the northern normal fault is unknown as on the northern side of this fault, unit phf_3 is in contact with map unit phfw rather than map unit ms. Whatever the sense of movement on this fault, the presence of this new unit north of the fault suggests either facies changes take place or units are lenticular (tectonic or sedimentary) in a direction at some angle to the plane of the map. It is possible, then, that the absence of the massive grey limestone unit lst on the north side of the fault is also due to lenticularity of this unit in the third dimension.

IV. Metamorphism and Igneous Rocks

The sequence of metasedimentary rocks in the eastern Shadow Mountains is strongly contact metamorphosed. The contact metamorphism in this area post-dates the deformational event which folded this sequence as metamorphic textures of these rocks are hornfels contact metamorphic textures. There is no evidence from thin section studies which indicates that these rocks were significantly metamorphosed during the folding event itself.

The presence of wollastonite in units of appropriate composition is indicative of pyroxene-hornfels facies of contact metamorphism with temperatures in excess of 500°C (Winkler, 1974). Wollastonite also indicates that the metamorphism of these rocks occurred at shallow crustal levels. Even at the highest temperatures attained in regional metamorphism, calcite and quartz are generally stable and react only when either the CO_2-rich fluid phase has been considerably diluted by H_2O or the presence of the CO_2-rich fluid phase has been low as in shallow metamorphism (Winkler, 1974). In the Shadow Mountains, wollastonite-bearing beds are interstratified with calcareous siltstone which often contain only quartz, calcite and tremolite, and which appear to be of much lower metamorphic grade. This can only indicate that a highly variable distribution of the H_2O and the CO_2 volatile phases existed within these rocks during metamorphism.

Presence of periclase altered to brucite in dolomites of the easternmost Shadow Mountains also indicates very high temperatures of shallow level contact metamorphism (Winkler, 1974). The decomposition of dolomite to periclase and calcite is more probably at lower fluid pressures or shallow crustal levels: At partial pressure of $C0_2$=1, the dissociation temperature is 820°C at 1000 bars, 760°C at 500 bars and 700°C at 250 bars (1 km) (Winkler, 1974). The dissociation of dolomite can take place at appreciably lower temperatures only if the partial pressure of $C0_2$ in the fluid phase is very small. For example, if some mechanism has been effective locally in diluting the liberated CO_2 with H_2O; in this case the lowest possible temperature this reaction can take place is at 600°C (Winkler, 1974).

Only a few east-west trending granitic to aplitic dikes intrude the Shadow Mountains metasedimentary rocks, in the western portion of the map area. In the easternmost hills, north-south trending and east-west trending granitic to aplitic dikes are more abundant. To the west of the area mapped in this report lies a very large plutonic terrain consisting of primarily quartz monzonite, minor granite and minor hornblende diorite-hornblende gabbro (Troxel and Gunderson, 1970; Rogers, 1967). To my knowledge, no radiometric dates on these rocks have been published. It is probable that the granitic and aplitic dike rocks in the map area are associated with the intrusion of the plutons to the west of here. This large plutonic terrain (and its possible extension to the east beneath the metasedimentary rocks) may have provided the high temperatures for the contact metamorphism of the Shadow Mountains metasedimentary sequence.

V. Sequence of Events in the Eastern Shadow Mountains

The first documented event to affect the rocks of the Shadow Mountains is the deformational event which tightly folded these rocks about north-south trending near-horizontal fold axes with west-dipping axial planes. These rocks were then subjected to pyroxene-hornfels grade contact metamorphism. Intrusion of granitic to aplitic dike rocks may have occurred in conjunction with this thermal event. The two east-west striking hi-angle faults which cut the rocks in the map area do not offset any granitic dikes so it is not clear if these predate or post-date intrusion of the dikes. However, several of the dikes have east-west trends possibly controlled by the trends of faults in this area; hence the faulting possibly predated the intrusion of the dikes. This sequence of events is summarized in figure 15.

FIGURE 15

SEQUENCE OF EVENTS

SHADOW MOUNTAINS

1. Folding: north-south trending near horizontal fold axes, west-dipping axial planes
2. a) Contact metamorphism
   b) East-west to west-northwest high angle faulting
   c) Intrusion of granitic to aplitic dikes

VI. Problems Concerning the Age and Correlation of the Shadow Mountains Metasedimentary Rocks

Bowen (1954) and Dibblee (1967) assigned the rocks in the Shadow Mountains to the "Paleozoic Oro Grande sequence". It has been established that the "Oro Grande" sequence of the Victorville region actually consists of strata that are correlative with miogeosynclinal and platform facies sequences of the southern Cordillera and range from Late Precambrian to Mississippian(?) in age. The rocks in the Shadow Mountains bear no resemblance to this sequence. Data from the San Bernardino Mountains (Hollenbaugh, 1970) indicates that Paleozoic carbonate rocks, probably correlative with Cordilleran miogeosynclinal units may be as young as Pennsylvanian. Furthermore, the Paleozoic carbonate sequence in the San Bernardino Mountains apparently contains no terrigenous material (Hollenbaugh, 1970; Stewart and Poole, 1975). The limestone cobble conglomerate unit within the Fairview Valley Formation at Black Mountain contains abundant Wolfcampian-age fossiliferous clasts (Stone, 1964). Together, this information indicates that miogeosynclinal/platform carbonate deposition probably continued uninterrupted in the Victorville region at least into the Lower Permian, although careful mapping and correlation of the San Bernardino Paleozoic carbonate sequence will be necessary in order to fully substantiate this hypothesis. According to the data presented in previous sections, Cordilleran miogeosynclinal and platform affinity rocks in this region were first deformed and metamorphosed prior to or during a 230 ± 8 m.y. old intrusive event. If these interpretations are correct, there are, then, no sedimentary rocks of Precambrian to Upper Paleozoic age in the Victorville and San Bernardino Mountains area which obviously correlate to the lithologically distinctive Shadow Mountains sequence.

Bowen (1954), reported a Pennsylvanian brachiopod from map unit lst. I and many others searched diligently for fossils at Bowen's locality but found none, although peculiar-looking calc-silicate shapes and objects are common in the limestone units in the Shadow Mountains. The limestone at Bowen's fossil locality is so recrystallized that it is difficult to believe that it yielded an identifiable brachiopod. Troxel and Gunderson (1970) assigned a questionable Upper Paleozoic (?) age to the Shadow Mountains metasedimentary rocks. Troxel found no fossils or indications for the age of these rocks and said Bowen lost the brachiopod after it had been identified (Troxel, pers. comm., 1976). Poole (1974) visited the Shadow Mountain area and suggested that the Shadow Mountains rocks represented southernmost exposures of the Mississippian Antler clastic wedge. As the Shadow Mountains metasedimentary rocks contain a large percentage of carbonates and contain no flysch-like units, Poole's suggestion is unlikely.

The metasedimentary rocks in the Shadow Mountains have been penetratively deformed only once, contact metamorphosed once, and intruded by only a few granitic to aplitic dikes. This sequence of events is in sharp contrast to the multiple deformations, multiple intrusions and contact metamorphic episodes which the known Late Precambrian to Paleozoic rocks have undergone within the other areas mapped during this study. The deformational and intrusive history of the Shadow Mountains rocks is more similar to the sequence of events affecting the younger Mesozoic Fairview Valley Formation. This strictly negative evidence suggests that the Shadow Mountains metasedimentary rocks may be Mesozoic in age.

Determination of the age of these rocks is very crucial in terms of understanding the geologic and paleogeographic history of this portion of the Mojave Desert. If these metasedimentary rocks are Paleozoic in age, they must represent an assemblage or facies different from the miogeosynclinal/cratonic Paleozoic carbonate sequence of the Victorville and San Bernardino region.

In the Lane Mountain quadrangle, north of the Calico Mountains (fig. 17) and mapped by McCullough (1952), a sequence of metasedimentary and metavolcanic rocks are exposed which is called the Coyote Group (McCullough, 1952). The Coyote group has a composite thickness of over 26,000 feet (7800 m) (McCullough, 1952). Parts of this sequence were briefly looked at by the author and some of the units here bear a strong lithologic resemblance to the

Shadow Mountains sequence. In light of what is presently known about the tectonic, volcanic and plutonic history of the southeastern Cordillera, the presence of metavolcanic rocks within the Coyote Group would indicate that this sequence of rocks is Mesozoic. However, McCullough (1952) reported a Paleozoic age for at least part of the Coyote Group based on poorly preserved circular crinoid stem joints near the middle of the section. Therefore, the problems posed by the Shadow Mountains sequence may not be restricted only to the Shadow Mountains area; similar metasedimentary rocks with similar problems of age-assignment may be more widespread in this western part of the Mojave Desert.

Comparison of the Shadow Mountains sequence to the known Mesozoic sedimentary rocks of the Victorville region (Fairview Valley Formation) is uninformative. Although the Fairview Valley Formation may have interfingered with open marine sediments as suggested above, and it is possible that it may have been a lateral equivalent of the Shadow Mountain sequence,this hypothesis is really untenable as it is difficult to reconcile the abundance of igneous and volcanic debris within the Fairview Valley Formation and the lack of similar debris within the Shadow Mountain sequence. Small percentages of orthoclase within Shadow Mountain quartzites and very rare feldspar aggregates of detrital (?) origin in a pebble conglomerate bed in the Shadow Mountains provides the only meagre evidence to the contrary. A careful petrographic study of conglomeratic and sandstone beds in the rest of the Shadow Mountains mapped by Troxel and Gunderson (1970) could possibly result in some evidence which would determine if the Shadow Mountains sequence post-dated plutonism and volcanism in this area, which in turn would most likely indicate a Mesozoic age for these rocks.

In summary, the fact that the Shadow Mountains rocks have undergone only one penetrative deformation argues in favor of these rocks being younger than the Precambrian-Mississippian(?) rocks studied in this report.

CENOZOIC FAULTING

The Shadow Mountain-Victorville-Sidewinder Mountain area lies in the south central part of the Mojave structural block. The wedge-shaped Mojave block is bound to the north by the left-lateral Garlock fault and to the southwest by the right-lateral San Andras fault system.

Northwest striking right lateral faults dominate the late Cenozoic to Holocene structure of the Mojave block. This set of faults has been attributed to considerable distortion of the Mojave block resulting from an approximately 30 degree counterclockwise rotation of the Mojave block by shearing along parallel northwest-trending faults which were originally north-striking (Garfunkle, 1974). Cummings (1976) argues that the northwest-striking faults in the Mojave block are the better developed set of a conjugate fault system which parallel the bounding Garlock and San Andreas faults and are due to north-south compression of the Mojave block. Davis and Burchfiel (1973) interpret the Garlock fault as an intracontinental transform structure which separates a northern crustal block distended by Late Cenozoic basin and range tectonics from a southern, Mojave block, much less affected by dilational tectonics and do not believe the left-lateral Garlock fault is conjugate to the right-lateral San Andreas in a regional strain pattern of north-south shortening and east-west extension as suggested by Cummings (1976). Cummings (1976) hypothesis is also incompatible with Garfunkle's (1974) analysis which suggests that the crustal shearing in the Mojave block resulted from the position of this crustal element between regions of crustal spreading in the Great Basin and those in the continental borderland and the Salton Trough. Accomodation of lateral variations of crustal spreading between these two areas was accomplished by shearing of the Mojave region (Garfunkle, 1975).

In the map area, the Helendale fault (fig. 1) is the only major northwest-trending fault belonging to this system. The Helendale fault can be traced from approximately three miles south of Granite Peak in the San Vernardino Mountains (Rogers, 1967 - San Bernardino map sheet) across Lucerne Valley and northwest towards Helendale into the vicinity of Kramer Hills (Bowen, 1954). Recent movement with the development of scarps in alluvium is evident along this fault in the Black Mountain area. Strike-slip movement along this fault was suggested by Bowen (1954) as the downthrown side of the fault alternates along strike (northwest of Helendale, downthrown side to the west; Black Mountain area, downthrown side to the east).

Understanding the Mesozoic deformational trends in this portion of the Mojave and correlation of rock types, structural events, and deformational trends across the Helendale fault between Black Mountain-Sidewinder Mountain and Quartzite Mountain are important aspects of this study. For this reason, before reconstructing Mesozoic events in this area, it is necessary to demonstrate

1. the extent of Tertiary rotation of structural trends

east of the Mojave and north of the Garlock fault.

2. The magnitude of right-lateral strike-slip displacement along the Helendale fault between the Black Mountain area and Quartzite Mountain area.

Studies of the geology both north and south of the Garlock fault do not favor Garfunkle's (1974) interpretation of a 30 degree counterclockwise rotation of fault blocks within the Mojave area. Smith (1962) documented 65km of left-lateral offset along the Garlock fault by matching extensive dike swarms on either side of the fault. The dikes are uncommon, distinctive rock types, have near-vertical dips and are at a high angle to the trend of the Garlock, and are thus good indicators of offset (Smith, 1962). The dikes north of the Garlock in the Argus range, strike N40-50W; their presumed southward continuation is offset to the Granite Mountains to the east where the dikes strike N5-20W (Smith, 1962). Smith (1962) interprets the 20-45 degree discrepancy between the trends of the dikes on either side of the Garlock as the result of clockwise horizontal rotation of the Mojave block, in part due to about 20 degrees change in the trend of the Garlock fault between Spangler Hills and the Granite Mountains. Smith and others (1968) described a thrust fault in the southern Slate Range to the north of the Garlock where cataclasized Mesozoic granitic rocks and gneisses of Pre-Cambrian age overlie Mesozoic metavolcanic and granitic rocks along a west dipping (30-40 degrees) thrust called the Layton Wells thrust. Davis and Burchfiel (1973), in reconnaissance studies in the eastern Granite Mountains south of the Garlock, found a major thrust fault which they regard as the 56-64km offset extension of the Layton Wells thrust. Here, sheared and phylonitized crystalline rocks overlie Mesozoic metavolcanics along a west-dipping (40 degree) thrust contact about three miles south of the Garlock fault, indicating little or no relative rotation of Mesozoic structures north and south of the Garlock fault.

Garfunkle (1974) suggusts 10-15 km of right-lateral slip along the Helendale fault in the Mojave block by matching the southernmost exposures of the Sidewinder Group volcanic rocks in the Sidewinder Mountain area to the southernmost exposures of the volcanics northwest of the fault. In light of the complex geology of this area as well as the fact that rocks of the Sidewinder Group contain no distinctive units that may be correlated, their outcrop pattern alone provides a very poor, if not meaningless, criterion for slip along the Helendale. On the southwest side of the trace of the Helendale fault near Black Mountain, monzonitic plutonic rocks crop out which are identical to those unconformably below the Fairview Valley Formation on the northeast side of the fault near the Black Mountain quarries. In both places, the rocks are intruded by distinctive felsite dikes. Uplifted alluvium on the southwest side of the fault consists almost entirely of debris derived from the Fairview Valley Formation. Although certainly not conclusive, the presence of identical rocks types on either side of the Helendale fault indicates that strike-slip movement along it may have been minor (less than 1 km?). Dibblee's (1964) geologic map of the Lucerne Valley quadrangle also indicates only minor strike-slip movement along this portion of the Helendale: an outcrop of granodiorite containing pendants of older metamorphic gneisses (P€?) is cut by the Helendale fault, but movement here seems primarily dip-slip (Dibblee, 1964). Along the north slope of the San Bernardino Mountains, movement along the Helendale has been almost entirely dip-slip (Dibblee, 1964; Tyler, 1975).

Garfunkel (1974) also suggests right-lateral offset of the metasedimentary rocks of the Shadow Mountains from those in the Quartzite Mountain area, although no fault has been mapped separating these two areas. As the metasedimentary rocks of the Shadow Mountains are not the same age as those of Quartzite Mountain, there is little basis for postulating right-lateral slip between these two places.

Garfunkle's (1974) calculated value of a 30 degree counterclockwise rotation of the Mojave block is dependent on a "K" value which is directly related to the amount of right-lateral movement along the northwest-trending faults of the Mojave block. The higher the "K" value, the larger the magnitude of counterclockwise rotation of the Mojave block with respect to structural elements north of the Garlock.

In summary, geologic evidence does not seem to warrant 30 degree counterclockwise rotation of structural trends south of the Garlock fault with respect to trends north of the Garlock (Smith, 1962; Davis and Burchfiel, 1973), and there seems to be only minor (less than 1 km (?)) strike-slip movement along the length of the Helendale fault and certainly not 10-15 kilometers of right-slip movement as postulated by Garfunkle (1974).

CORRELATION OF DEFORMATIONAL EVENTS

I. Introduction

Discussions presented above suggest that not only some of the stratigraphy, but the style of deformation and thermal history is variable between the areas mapped for this study. There are no clearcut answers to exactly why this is true and the vast expanses of alluvium which separate these areas only makes this question more difficult to answer.

The areas mapped occur essentially as roof pendants in late Mesozoic batholithic rocks. The roof pendant rocks have undergone a long, complex deformational and thermal history probably beginning at about 230 ± 8 m.y. ago and continuing to about 70 m.y. ago. Upper Cretaceous and Tertiary erosion and Tertiary faulting has also played an important but not well understood role in the history of this area.

Because of this complex history, there are many inherent problems involved in the correlation of both stratigraphic sequences and deformational events between widely separated terrains. The first of these is the possibility that the deformational history of this area may have involved significant juxtaposition of rocks by Mesozoic age thrust faulting. Although there does not seem to be thrust faults of significant magnitude exposed in the Victorville region, thrust faulting has been an important element of Mesozoic deformation further to the east in the southeastern Cordillera fold and thrust belt. To the southwest, in the

San Bernardino Mountains, rocks similar to those in the Victorville region have been involved in large eastward overturned folds cored by Precambrian crystalline rocks and these folds are cut by thrust faults of unknown magnitude (Tyler, 1975). Hence it is very possible that the exposures of metasedimentary rocks in the Victorville area may have been juxtaposed by thrusing, and their present positions may not reflect their original paleogeographic positions with respect to each other.

Secondly, there is evidence in all the areas studied for various episodes for Mesozoic high-angle faulting. If this high angle faulting has been superimposed on thrust faults we do not see, geological relationships become extremely complex. Even if high angle faults do not cut major thrust faults, there is certainly evidence that high-angle faults cut previously formed complex structures. Large displacement high-angle faulting could easily juxtapose rocks from different structural levels.

At least the older metasedimentary rocks have been repeatedly affected by thermal events due to continuous or episodic plutonism and volcanism, the spatial-temporal relations of which have been largely obscured by latest phases of plutonic intrusion. As the transition from brittle to ductile behavior of rocks is dependent strongly on thermal regime, high-angle faulting of sequences involved in such a complex thermal history might easily expose rocks of highly variable deformational styles and metamorphic history.

Rotation of previously formed structural trends during periods of high-angle faulting is also likely to have occurred.

The result of this complex structural and intrusive history is that one is left only with small pieces of a formerly much more extensive terrain however, it is strongly felt that these pieces do tell approximately similar stories and it is primarily the details of this story which are not clear.

II. Correlation

Figure 16 presents the correlation of the major events in the various areas mapped. This is a generalized chart; more detailed information is presented in the discussions of the individual areas. The generation of such a chart has the inherent problem of possibly correlating events which do not, in fact, correlate. On the other hand, it aids in more precisely determining the problems of correlation This entire study was aimed primarily at understanding the metasedimentary sequences in this area and their relationship to one another. Certainly, these will initially tell more about the geologic history of an area than any other study. However, since these metasedimentary rocks occur within a complex batholithic terrain, study of the metasedimentary rocks must be coupled with an understanding of the ages of intrusive events and the volcanic rocks associated with the intrusives. The usefulness of such a chart would certainly be improved by mapping and geochronologic work in both the intrusive and metavolcanic rocks within this area. Specifically, figure 16 points out: 1) the need for geochronologic work on dikes and intrusive rocks which cut the metasedimentary sequences, and 2) the importance of understanding both the stratigraphy and geochronology of the Sidewinder Group volcanic rocks-clearly, the volcanic rocks appear to be different ages in different places, but the number of volcanic extrusive groups having different ages in unknown. On the other hand, certain fundamental relationships are seen in more than one place and when the age of these are bracketed in the future by geochronologic work, will undoubtedly give an important absolute time scale for events in this area.

EVENT I

Event I (figure 16) includes deformation, metamorphism intrusion, and volcanism. This event is bracketed below by the youngest sediments involved in the first deformation affecting this area, which in the Victorville region is Mississippian(?) (Sidewinder Mountain) or perhaps Later Paleozoic (?) (Pierce quarry area). More indirect evidence suggests that carbonate deposition probably continued uninterrupted in this area at least into Lower Permian times. The discovery of an earliest Triassic monzonitic plutonic event in this area, occurring approximately 230 ± 8 m.y.ago (Calvin Miller, 1976, pers. comm.), which may have provided

MAJOR EVENTS		SHADOW MOUNTAINS	QUARTZITE MOUNTAIN		PIERCE QUARRY AREA
IX. CENOZOIC FAULTING					Present
VIII. INTRUSION OF LATER BATHOLITHIC ROCKS		Contact metamorphism (age unknown) (Event 2)	Present (Event 8, 72 ± 1.4 m.y., (Armstrong and Suppe, 1973)	? D3 folding ?	Present 72 ± 1.4 m.y. (Armstrong and Suppe, 1973)
VII. HIGH ANGLE FAULTING: SIDEWINDER GROUP VOLCANICS AGAINST OLDER ROCKS		Age of metasedimentary rocks and age of deformation not known	Present (Event 7)		
VI. EROSION AND DEPOSITION OF LATER SIDEWINDER VOLCANICS			Present (Event 6)		
V. POST-FAIRVIEW VALLEY FORMATION:	HIGH-ANGLE FAULTING		Present (Event 5)		
	FOLDING		Present (?)		
IV. UNCONFORMITY, DEPOSITION OF QUARTZITE UNIT AND OVERLYING PYROCLASTICS VOLCANIC ROCKS (*)					
III. UNCONFORMITY DEPOSITION OF FAIRVIEW VALLEY FORMATION			Present (Event 4)		
II. HIGH-ANGLE FAULTING (NOT CLEAR IF PRE-FAIRVIEW VALLEY OR PART OF EVENT IV)			Present (Event 3)		
I. DEFORMATION, METAMORPHISM, INTRUSION, VOLCANISM: BEGINNING PRIOR TO OR DURING 230 ± 8 m.y. INTRUSIVE EVENT (CALVIN MILLER, PERS. COMM.) AND CONTINUING UP TO DEPOSITION OF FAIRVIEW VALLEY FORMATION			D_2a,b (Event 2) folding, faulting D_1 (Event 1) folding, upper Greenschist grade metamorphism Intrusion of amphibolite dikes?	Intrusion of meta-hypabyssal igneous rocks?	Folding, metamorphism

FIGURE 16. CORRELATION OF EVENTS BETWEEN AREAS

BLACK MOUNTAIN	TRI-COLOR QUARRY	SIDEWINDER MOUNTAIN		
Present (Event 11)				
Present (Event 10) age (?)		Present (Event 6) age (?)		
Present (Event 9)	Present	Present	Intrusion of hypabyssal dikes (Event 3)	Intrusion of quartz monzonite (1) (Event 4)
Intrusion of felsite dikes (Event 8) 2) Faulting of Volcanics (Event 7) 1) Either deposition of more volcanics or volc-volcanics above (a) less deformed (Event 6)				
Present (Event 5)	Present (?) (Event 3)			
Present (Event 4)	Present (Event 2) Possibly III or IV, depending on whether conglomerate unit is Equivalent to Fairview Valley or to quartzite unit.			
Present (Event 3) overlies monzonite				
		Present (Event 2)		
-Intrusion of Monzonite cogenetic with 230 + 8 m.y. old intrusive episode -Deformation/metamorphism of Paleozoic(?) marble	Deformation, Metamorphism	Deformation/metamorphism: a. folding (?) b. slicing c. folding d. thrust(?) faulting or more slicing		

the thermal regime for the upper greenschist grade metamorphism at Quartzite Mountain is suggested to have accompanied or slightly post-dated the first deformation affecting the older Precambrian-Paleozoic rocks in this area. The upper age bracket for event I is the deposition of the Fairview Valley Formation. The Fairview Valley Formation post-dates the 230 m.y. old plutonic episode, but the length of time between this event and the deposition of the Fairview Valley Formation is unknown as the age of the Fairview Valley Formation is not closely bracketed. It is probable that the Fairview Valley Formation post-dates two deformational events of significant magnitude at Quartzite Mountain, however it is not known if these two deformations were closely spaced in time. The Fairview Valley Formation post-dates an involved sequence of folding and tectonic slicing at Sidewinder Mountain-Tri-Color quarry. Presence of plutonic debris of almost entirely monzonitic derivation and the general lack of abundant quartz monzonitic to granitic debris may indicate that the Fairview Valley Formation was not deposited long after the 230 m.y. old plutonic event. The Fairview Valley Formation also postdated and perhaps was deposited synchronously with volcanism as it contains significant volcanic debris.

EVENT II

Event II is represented by high-angle faulting of the older deformed metasedimentary rocks. Field evidence does not permit establishing whether high-angle faults occurred before or after deposition of the Fairview Valley Formation and actually belong to event IV. As the Fairview Valley Formation rocks overlie Paleozoic rocks exhibiting different deformation and thermal histories (Quartzite Mountain and Tri-Color quarry), this may suggest that high angle faulting, thrust faulting, variable erosion, or a combination of these occurred prior to deposition of the Fairview Valley Formation. High angle faults of this event may have considerable displacement. At Sidewinder Mountain (event 2), these faults juxtapose upright and overturned sequences indicating that they must cut previously formed complex structures and perhaps have displacements on the order of several hundred meters.

EVENT III

Event III includes erosion and deposition of the Fairview Valley Formation. As discussed above, the Fairview Valley Formation places an upper limit on event(s) I. The unconformable relationship of the Fairview Valley Formation is exposed at Tri-Color quarry, Black Mountain (where it overlies monzonite and undifferentiated meta-carbonates) and at Quartzite Mountain. Fairview Valley deposits are thought to represent interfingering of alluvial fan and stream channel conglomerates with very shallow water marine (tidal flat?) or lacustrine deposits. Fairview Valley deposits are present at least 15 or more kilometers apart at Quartzite Mountain and Black Mountain, indicating that the Fairview Valley Formation may have been an extensive deposit.

Biogenic (?) limestone within the Fairview Valley Formation and its inferred tidal flat(?) environment of deposition may suggest that the Fairview Valley Formation interfingered with open marine deposits. As indicated in figure 16, the age of the Shadow Mountain sequence and the age of the deformation of this sequence is unknown. However, if the Shadow Mountain sequence is Mesozoic in age, it is tentatively suggested that these rocks may have been deposited prior to or during Fairview Valley deposition.

EVENT IV

Event IV (figure 16) is present with certainty only at Black Mountain and involves uplift, tilting(?) and erosion of Fairview Valley Formation deposits and deposition of a quartz-rich unit above the unconformity. The quartz-rich unit is the basal unit of the overlying pyroclastic volcanics of the Sidewinder Group. It is questionable if this unconformity is of major significance because only after deposition of the volcanic rocks were the Fairview Valley and Sidewinder rocks folded and this unconformity may be associated with or caused by the beginning of post-Fairview Valley volcanic activity. If the conglomerate at Tri-Color quarry is equivalent to the quartzite unit (as indicated by similar petrology of intercalated sandstones), this unit would have been deposited directly on the older deformed and metamorphosed substratum in the Tri-Color quarry area.

EVENT V

The Fairview Valley Formation and unconformably overlying pyroclastic volcanic rocks at Black Mountain were weakly folded about N20-30W-trending axes. Because outcrops of Fairview Valley Formation are not as extensive in the other areas, no structural data for this event is available from these places. At Tri-Color quarry, the basal beds of the Fairview Valley (?) conglomerate have undergone shear and flattening parallel to the unconformity (Appendix II). This strain may have been produced during event V. At Quartzite Mountain, Fairview Valley conglomerate units dip steeply to vertically and are overlain by volcanic rocks of the Sidewinder Group. These steep dips could have been caused by folding and/or post-Fairview Valley high-angle faulting. Silty limestone and limestone cobble conglomerate of the Fairview Valley Formation at Sparkhule Mountain are sheared and flattened parallel to bedding. This deformation may have taken place during event V.

Post-Fairview Valley faulting associated with or postdating this folding event is not obvious at Black Mountain, but certainly occurred at Tri-Color quarry (minor), Quartzite Mountain and Sparkhule Mountain. Faults formed at this time are normal(?) faults which downdropped Fairview Valley sediments with respect to older metasedimentary rocks.

EVENT VI

The sequence of events followed event V becomes complex and difficult to unravel because of the poorly understood spatial-temporal relations of volcanism, plutonism, and deformation is this area. At Quartzite Mountain, event VI is represented by the erosion of tilted and/or folded rocks of the Fairview Valley Formation and the deposition of the gently dipping Sidewinder Group volcanic rocks. These gently dipping volcanic rocks must be younger than the volcanic rocks which overlie the Fairview Valley Formation at Black Mountain as the latter volcanic rocks are folded with the Fairview Valley rocks whereas at Quartzite Mountain the volcanic rocks overlie a profound angular unconformity.

Post-dating the folding of the Fairview Valley Formation at Black Mountain, rocks of the Fairview Valley were faulted against volcanic rocks of undetermined age (event 7, Black Mountain). It is not clear if these volcanic rocks are a higher part of the Sidewinder Group volcanic sequence deposited unconformably above the Fairview Valley Formation and for some reason are somewhat less deformed, or if they represent a post-folding sequence of volcanic rocks perhaps equivalent to the sequence at Quartzite Mountain. The hypabyssal dikes which intrude the Fairview Valley Formation at Black Mountain intrude the fault contact between Fairview Valley rocks and these later(?) volcanic rocks. Possibly the hypabyssal dikes represent feeder dikes for continuing volcanism in this area and they, instead, may be similar in age to the volcanic sequence at Quartzite Mountain. The relative time relationship of other hypabyssal dikes possibly associated with extrusion of portions of the

Sidewinder Group volcanic rocks in the Sidewinder Mountain roof pendant (event 3) and the intrusion of the quartz monzonite (1) (Event 4, Sidewinder Mountain) are largely unknown (fig. 16).

EVENT VII

Whatever the relative age of the Sidewinder Group volcanic rocks that have been faulted against the Fairview Valley Formation at Black Mountain, high-angle faulting of these rocks with respect to older rocks occurred at Black Mountain, Tri-Color quarry and Sidewinder Mountain. Faulting of Sidewinder Group volcanic rocks with respect to older rocks also occurred at Quartzite Mountain and Sparkhule Mountain prior to the intrusion of quartz monzonite/ granitic rocks in these two areas.

EVENT VIII

Quartz monzonite-quartz monzonite porphyry is intruded along and adjacent to many of the faults of event VII at Black Mountain, and place an upper limit on the age of these faults. The quartz monzonite-quartz monzonite porphyry represents one of the latest intrusive eqisodes in the Sidewinder Mountain-Black Mountain area. Bodies of alaskite cut across these faults at Sidewinder Mountain.

At Quartzite Mountain and at Pirece quarry, granitic quartz monzonitic dikes probably associated with the 72 ± 1.4 m.y. old (Armstrong and Suppe, 1973) quartz monzonite batholithic rocks intrude all structures. Intrusion of the granitic to aplitic dikes in the Shadow Mountains probably occurred at this time. The third deformation D_3 (event 7) at Quartzite Mountain probably occurred slightly prior to this latest intrusive event.

EVENT IX

The recently active northwest trending Helendale fault cuts all older structural trends in the Black Mountain area. Cenozoic faulting was discussed in detail in the preceding section. A north-northwest trending fault cuts the 72 ± 1.4 m.y. old biotite quartz monzonite in the Pierce quarry area.

DISCUSSION AND CONCLUSIONS

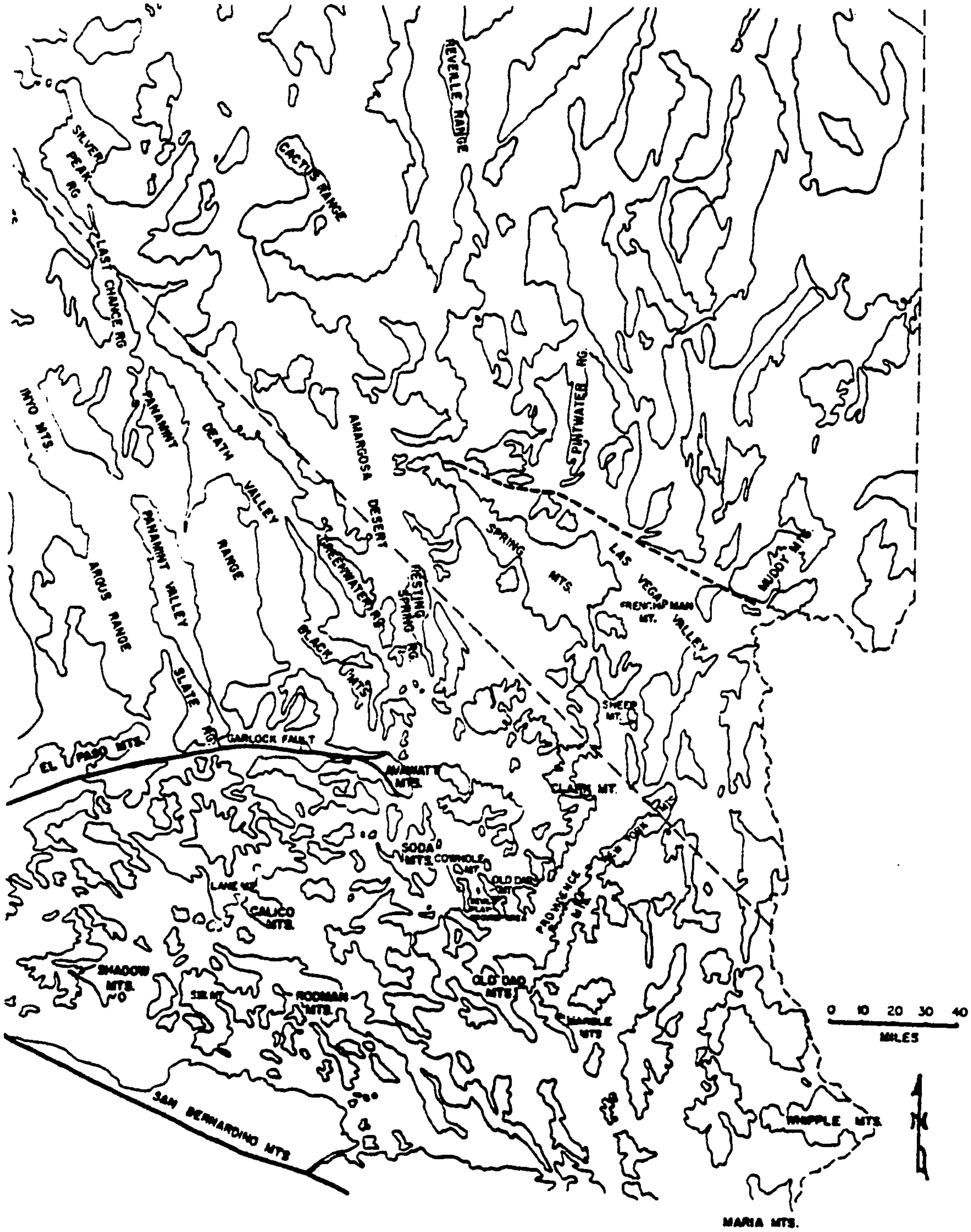
I. Conclusions Regarding Precambrian-Paleozoic Paleogeography

INTRODUCTION

Late Precambrian and Paleozoic rocks of the Cordilleran continental margin (geosyncline) form a westward thickening wedge of sedimentary rocks in the southern Great Basin region (Stewart, 1970). Facies boundaries and isopachs of these rocks are well understood in this region but the southern continuation of these trends is not well understood, because the Mesozoic magmatic arc cuts across the older continental margin in this region (Hamilton, 1969; Burchfiel and Davis, 1972, 1975).

Southernmost exposures of miogeosynclinal and cratonal or platform-facies rocks of the Cordilleran continental margin occur in the New York Mountains (Burchfiel and Davis, in press),Devil's Playground area (Dunne, 1972, 1977; Novitsky-Evans, in prep.), Providence and Marble Mountains (Hazzard and Mason, 1936) (fig. 17). Much further to the south, highly deformed platform facies rocks are exposed in the Maria Mountains (Hamilton, 1964, 1971) (fig. 17). To the west of these localities, miogeosynclinal rocks are exposed in the Soda Mountains (Grose, 1959). The exposures of Late Precambrian and Paleozoic rocks in the Sidewinder Mountain-Quartzite Mountain area lie more than 100 kilometers to the west-southwest of exposures of the same rocks in the Soda Mountains. No rocks belonging with certainty to this

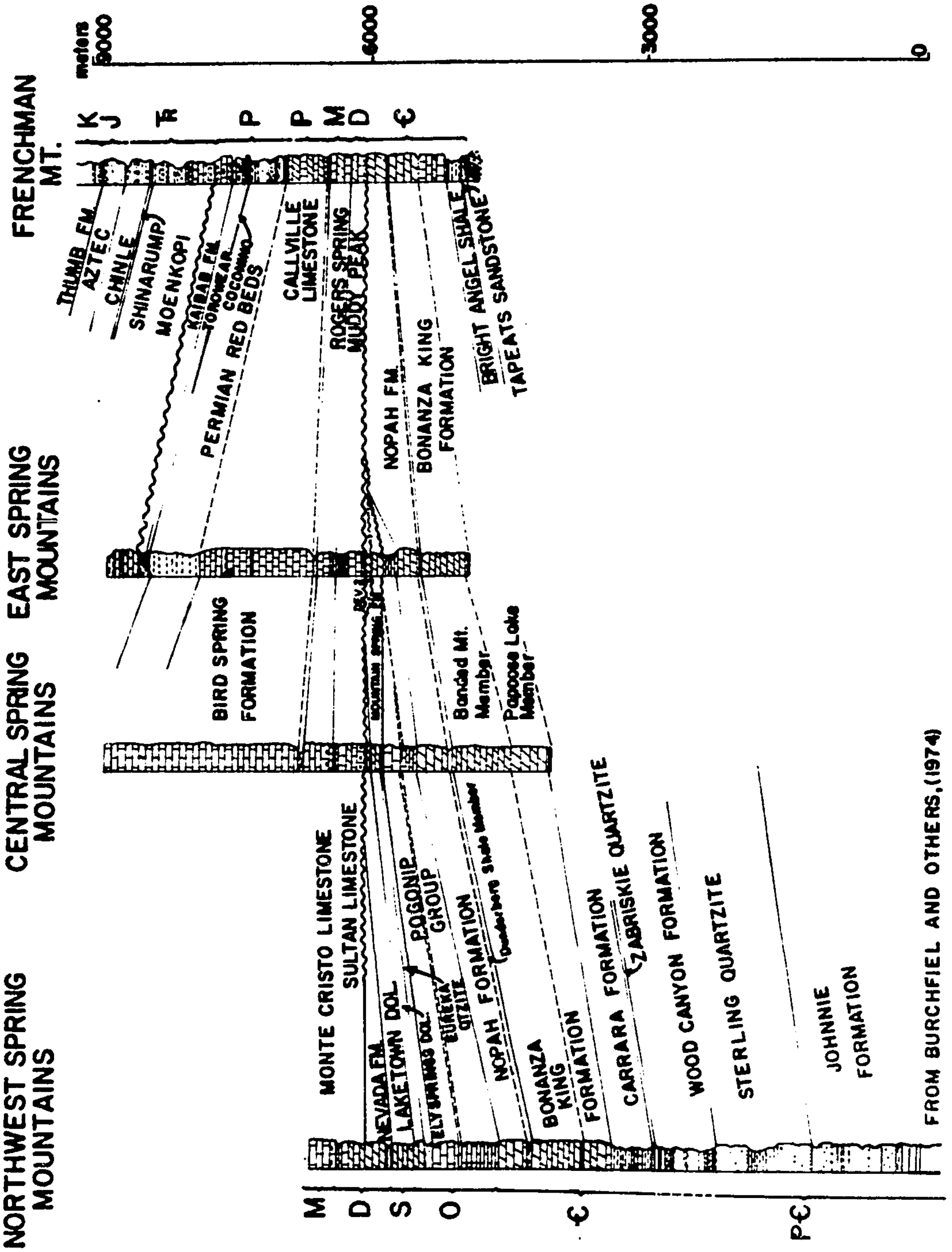
FIGURE 17. Index map of the Mojave Desert region showing localities discussed in text.



sequence are found between these two areas.

Hamilton (1969) suggested that miogeosynclinal rocks of the Cordilleran continental margin continued to the southwest through the Mojave Desert and that the western edge of the continental margin was truncated during a Permo-Triassic event. Stewart and Poole (1975) were the first to verify the presence of Late Precambrian and Cambrian miogeosynclinal rocks in the San Bernardino and Quartzite Mountain area, substantiating the hypothesis of Hamilton (1969).

Crucial to understanding the trend of Cordilleran continental margin through the Mojave region is the ability to establish whether rocks of the Quartzite Mountain-Sidewinder Mountain area and San Bernardino Mountains belong to cratonal facies or to miogeosynclinal facies of the Cordilleran continental margin. An east-southeast to west-northwest cross section across the miogeosyncline in the Spring Mountains, Nevada, is shown in figure 18 (from Burchfiel and others, 1974), and indicates that distinctive differences exist between sequences in cratonal, transitional and miogeosynclinal positions. One of the distinguishing characteristics of Paleozoic cratonal facies sequences is that Middle Devonian rocks rest paraconformably on Upper Cambrian rocks. To the west and northwest, Ordovician, then Silurian and Early Devonian rocks appear at this unconformity (fig. 18). Late Precambrian and Early to Middle Cambrian terrigenous rocks of the Cordilleran miogeosyncline



FROM BURCHFIEL AND OTHERS,(1974)

FIGURE 18. Representative stratigraphic columns from the Spring Mountains, Nevada, and Frenchman Mountain, demonstrating the change from a cratonal sequence to a geosynclinal sequence. From Burchfiel and others (1974)

form a wedge thickening to the northwest, reaching thicknesses of more than 3000 m in the Death Valley area, and which thin to only 100-200 m eastward on the craton (Stewart, 1970). Generally, cratonal sequences exhibiting the Cambro-Devonian paraconformity contain only a thin, basal section of terrigenous rocks that is probably only Early and Middle Cambrian in age (Stewart, 1970) (fig. 18). Paleozoic miogeosynclinal sequences which contain Ordovician, Silurian and Early Devonian units added along the Cambro-Devonian paraconformity contain a fully developed Late Precambrian and Early to Middle Cambrian terrigenous sequence (fig. 18).

In portions of the eastern Mojave, however, the distinction between miogeosynclinal and cratonal or platform facies sequences is not as clear: The sequence of Late Precambrian and Paleozoic rocks in the Devil's Playground area (Novitsky-Evans, in prep.; Dunne, 1972) and that of the Providence Mountains (Hazzard, 1954; Stewart, 1970) contain later Precambrian units of miogeosynclinal affinities overlain by a cratonal Paleozoic sequence exhibiting the Cambro-Devonian paraconformity. This is due to the cross-cutting of Late Precambrian-Cambrian isopachs and facies boundaries (Stewart, 1970) by isopachs and facies boundaries of the Early Paleozoic rocks (Gans, 1970) in this portion of the eastern Mojave Desert. The facies boundary or depositional hinge line between Late Precambrian-Cambrian terrigenous rocks of the thicker miogeosyncline sequence and those of the thinner, Middle to Upper Cambrian cratonal sequence trends north-south in the eastern Mojave (Stewart, 1970). Isopachs for cratonal facies rocks of this age also trend north-south (for instance, the Zabriskie=70'isopach, figure 19) but isopachs for the thicker parts of the Late Precambrian-Cambrian miogeosynclinal sequence trend more southwesterly (Stewart, 1970) (fig. 19). The work of Gans (1970, 1974) in the Goodsprings District, Nevada, has demonstrated that the facies boundary or depositional hinge between Lower Paleozoic cratonal rocks and Lower Paleozoic miogeosynclinal rocks trends more westerly in this area (Fig. 27, p. 79a, Gans, 1970) across the north-south facies boundary of the earlier terrigenous rocks. To the east-southeast of the Nopah range, a generally progressive off-lapping of Ordovician units occurs between the Upper Cambrian Nopah Formation and the Middle Devonian Sultan Limestone until Middle Devonian rocks rest paraconformably upon Upper Cambrian rocks (Gans, 1970). The Cambro-Devonian paraconformity is widely developed on the craton to the east of here. It is for this reason that the sequences of rocks in the Devil's playground area (Novitsky-Evans, in prep.; Dunne, 1972, 1977) and Providence Mountains (Hazzard, 1954; Stewart, 1970) contain Late Precambrian and Cambrian strata of miogeosynclinal facies which are overlain by cratonal facies Paleozoic rocks. In this area, then, presence of later Precambrian and Cambrian terrigenous units of miogeosynclinal affinities alone does not necessarily imply that a particular sequence of rocks had miogeosynclinal

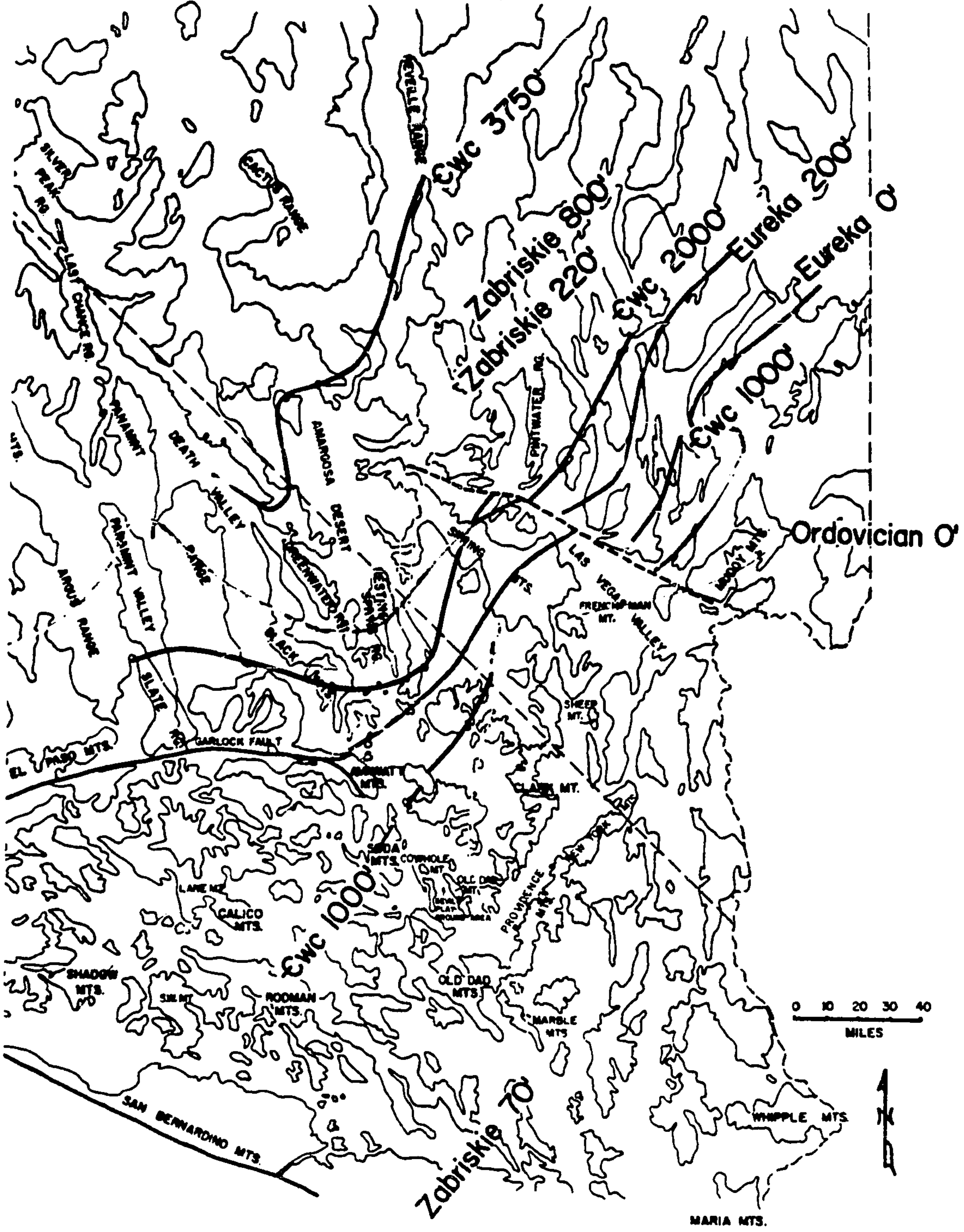


FIGURE 19. Selected isopachs for the Precambrian-Cambrian Wood Canyon Formation, Cambrian Zabriskie Quartzite, and Ordovician Eureka Quartzite in the Mojave region. From an unpublished compilation by B.C. Burchfiel and includes data from Stewart (1970) and Ross (1974).

affinities during the Paleozoic. Determination of the presence or absence of the Cambro-Devonian paraconformity is necessary in order to establish whether sequences in the Mojave Desert had cratonal or miogeosynclinal affinities during the Paleozoic.

LATE PRECAMBRIAN TO PALEOZOIC ROCKS OF THE VICTORVILLE REGION

It is known that older Precambrian crystalline basement rocks exist in the southwestern portion of the Mojave Desert. These rocks are exposed in the Ord Mountains and in the San Bernardino Mountains (Rogers, 1967) (fig. 1). In the San Bernardino Mountains, the Late Precambrian Stirling Quartzite rests depositionally upon these older rocks (Tyler, 1975). In the Victorville region, there are no exposures of strata in depositional contact with Precambrian crystalline basement, thus the stratigraphy of the basal part of the Late Precambrian succession is unknown. The oldest Late Precambrian metasedimentary rocks exposed in this area is the sequence of dolomite, orthoquartzite, and calc-silicate rocks tentatively assigned to Precambrian Johnnie-Stirling equivalent(?). At Quartzite Mountain, a complete sequence of rocks is exposed which correlates to the Precambrian-Cambrian Wood Canyon Formation, Cambrian Zabriskie Quartzite, Cambrian Carrara Formation and some unknown portion of the Cambrian Bonanza King Formation. At Quartzite Mountain, the base of the exposed Wood Canyon Formation sequence is a fault, and it is probable that only the upper of three members of the Wood Canyon Formation are present. The upper Wood Canyon Formation at Quartzite Mountain contains a thick dolomitic unit typical of that developed in miogeosynclinal facies Wood Canyon in the southern Great Basin region and which apparently is not present in cratonal units equivalent to the Wood Canyon Formation (Stewart, 1970; Diehl, 1974). Unfortunately, the deformation and metamorphism of the carbonate rocks above the Carrara Formation at Quartzite Mountain has obliterated all original characteristics of these rocks and determination of the stratigraphic succession of the Lower Paleozoic carbonate rocks is impossible here.

The Late Precambrian-Paleozoic sequence is again exposed to the east of Quartzite Mountain, at Sidewinder Mountain. Tectonic slicing of stratigraphic contacts has occurred in this area and the stratigraphic section (Plate V) is a composite section which is cut by many faults of unknown displacement. Portions of the sequence from the Precambrian-Cambrian Wood Canyon Formation up to possible Mississippian age rocks are exposed at Sidewinder Mountain. Only the uppermost beds of the Wood Canyon Formation are present and hence comparison of these rocks to the Wood Canyon Formation of Quartzite Mountain is not possible. It is felt that the extreme difference in thickness of the Zabriskie Quartzite of Sidewinder Mountain to that of Quartzite Mountain (6m vs. 90m), and the lithologic differences in the Cambrian Carrara Formation of both places (Plate V) cannot be due to tectonic causes alone. These differences most probably reflect the fact that these two sequences were not deposited in the same paleogeographic position with respect to Cordilleran miogeosynclinal trends and suggests that the Quartzite Mountain sequence may have been a more basinward equivalent of the Sidewinder Mountain sequence at least during Upper Precambrian and Lower Cambrian times. Nevertheless, the Wood Canyon Formation, Zabriskie Quartzite, and Carrara Formation of Sidewinder Mountain are lithologically distinctive units correlative with later Precambrian-Cambrian miogeosynclinal rocks of the southern Great Basin.

Rocks stratigraphically above the Cambrian Carrara Formation at Sidewinder Mountain are not as metamorphosed as the carbonate rocks which overlie the Cambrian Carrara Formation at Quartzite Mountain and consist of parts of the Papoose Lake Member and Banded Mountain Member of the Cambrian Bonanza King Formation, Cambrian Nopah Formation, paraconformable Middle Devonian Ironside Member of the Sultan Limestone, and higher units possibly correlative with the upper Sultan Limestone and Mississippian Monte Cristo Formation. Unfortunately, it is not known whether the deformed carbonate rocks at Quartzite Mountain contain units higher than the Bonanza King Formation and hence impossible to know whether the Quartzite Mountain sequence at one time contained the Cambro-Devonian paraconformity present at Sidewinder Mountain. Generally speaking, however, the sequences in these two areas are correlative and are what remain of an older Precambrian-Paleozoic stratigraphic succession and paleogeography which has been dismembered and tectonized in a way which is not well understood. Less complete pieces of this older sequence of rocks are present at scattered localities in the Victorville region (Plate I, II, III).

Lithologic columns of the rocks at Sidewinder Mountain and at Quartzite Mountain are shown in Plate V together with a stratigraphic section of the later Precambrian-Cambrian rocks of the Gold Mountain-Baldwin Lake area of the San Bernardino Mountains measured by Tyler (1975). No implications regarding original paleogeographic positions of these three areas is implied in Plate V. Thickness of strata (with the exception of the Carrara Formation) in the Gold Mountain-Baldwin Lake area may represent original thicknesses as these rocks are much less recrystallized and deformed than correlative strata in the Victorville area (Tyler, 1975). The Wood Canyon Formation in the San Bernardino Mountains does not contain an upper calcareous unit (Tyler, 1975). The presence of a fairly thick dolomitic unit in the upper Wood Canyon of Quartzite Mountain may reflect more basinward deposition of these strata with respect to the rocks in the San Bernardino Mountains. Tyler (1975) felt that the Precambrian-Cambrian sequence in the San Bernardino Mountains best correlated with the sequence of rocks in the Winters Pass thrust plate in the Clark Mountains, California, and suggested that this correlation places the San Bernardino Mountain section near the eastern margin of the Cordilleran miogeosyncline. Stewart and Poole (1975) correlated the San Bernardino Mountain section with the Providence Mountains, California, sequence, but disregarded the great thickness of Stirling Quartzite exposed on Gold Mountain (Tyler, 1975).

Tyler (1975) did not map or study the stratigraphy of the Lower Paleozoic carbonate sequence above the Bonanza King Formation in the San Bernardino Mountains. Locally, these rocks have yielded Mississippian and Pennsylvanian fossils (Hollenbaugh, 1970). Study of the carbonate rocks in the San Bernardino Mountains will be necessary before it can be established whether these represent a Paleozoic cratonal sequence containing the Cambro-Devonian paraconformity, or whether these rocks represent Paleozoic strata of miogeosynclinal affinities. There do not seem to be any terrigenous clastic units within the carbonate sequences in the San Bernardino Mountains (Hollenbaugh, 1970; Stewart and Poole, 1975), suggesting that at least the Ordovician Eureka Quartzite (fig. 18) is probably absent in this area. This would at best indicate a transitional position for these rocks (fig. 18).

CORRELATION OF LATE PRECAMBRIAN-PALEOZOIC SEQUENCES IN THE VICTORVILLE REGION TO SEQUENCES IN THE EASTERN MOJAVE DESERT

Presence of the Cambro-Devonian paraconformity at Sidewinder Mountain indicates that this sequence was deposited in a cratonal position, not a miogeosynclinal position during the early Paleozoic. Presence of units correlative to the Precambrian-Cambrian Wood Canyon Formation, Cambrian Zabriskie Quartzite, and Cambrian Carrara Formation of miogeosynclinal affinities strongly suggests that the Sidewinder Mountain sequence may have been deposited in a similar setting with respect to Cordilleran continental margin trends as were the sequences in the eastern Mojave which contain both the Cambro-Devonian paraconformity as well as upper Precambrian-Cambrian units of miogeosynclinal affinities. It is thought that the sequences in the Devil's Playground area (Novitsky-Evans, in prep.) and Providence Mountains (Hazzard, 1954; Stewart, 1970) of the eastern Mojave Desert are most similar to the sequence exposed at Sidewinder Mountain. These sections are shown in Plate V. It should be emphasized, however, that only the uppermost beds of the Wood Canyon Foramtion are present at Sidewinder Mountain, so the amount of section present below these is not known, and that the faults which juxtapose higher units and the Carrara Formation have unknown displacements.

Also shown in Plate V is a stratigraphic column of the cratonal sequence exposed in the New York Mountains, California. The New York Mountain section contains a thin cratonal basal terrigenous unit equivalent to the Tapeats Sandstone and Bright Angel Shale. The terrigenous unit is overlain by a cratonal Paleozoic section. This stratigraphic column from Burchfiel and Davis (in press), has been included in Plate V to demonstrate that just to the south and east of the Paleozoic craton-miogeosynclinal boundary in this part of the eastern Mojave Desert, cratonal facies Paleozoic rocks contain units that are more straightforwardly correlated to miogeosynclinal units rather than to units of the Grand Canyon sequence (i.e. Frenchman Mountain section, fig. 18) (Burchfiel and Davis, in press).

The Cambro-Devonian paraconformity present in the Sidewinder Mountain section indicates that during the Paleozoic at least, this area of the Mojave Desert was part of the platform or craton, not the miogeosyncline. Figure 19 indicates that the Ordovician=0 isopach for miogeosynclinal rocks of the Cordilleran continental margin may be extrapolated further to the southwest from the Avawatz Mountains region and must lie some undetermined distance north of Sidewinder Mountain. This would suggest that the rocks in the San Bernardino Mountains, to the southeast of the inferred Ordovician=0 isopach (fig. 19) ought to contain a cratonal Paleozoic section as does the sequence at Sidewinder Mountain. Future work in the Paleozoic section of the San Bernardino Mountains, then, would test this hypothesis.

Isopachs and facies boundaries for rocks of the Cordilleran miogeosyncline trend north-northeasterly in Nevada and begin to swing more westerly in the Mojave Desert region of California (figure 19). The data from Sidewinder Mountain in the Victorville region substantiates a more westwardly trend of facies boundaries and isopachs through the

Mojave Desert region. There is also no indication that the platform miogeosynclinal boundary swings southeastward again as shown on many paleogeographic maps (Stewart and Poole, 1974; Poole, 1974, Schweickert, 1976). Furthermore, rocks of the Victorville area constitute the westernmost exposures of the cratonal and miogeosynclinal rocks of the Cordilleran continental margin with the possible exception of rocks in the Salinian block (Wiebe, 1970) on the western side of the San Andreas fault. Thus the data from the Victorville region strongly supports truncation of the western edge of the continent proposed first by Hamilton (1969) and later by Burchfiel and Davis (1972, 1975).

II. Timing of Deformational Events and Relationship to Regional Tectonics

LACK OF EVIDENCE IN VICTORVILLE REGION FOR ANTLER EVENT

The Late Devonian-Early Mississippian Antler orogeny culminated in the emplacement of the Robert's Mountain thrust in western Nevada. This thrust belt shed an apron of Mississippian clastic rocks eastward from the thrust complex; carbonate sedimentation continued uninterrupted further to the east in the miogeosynclinal terrain (Silberling and Roberts, 1962; Poole, 1974). Poole (1974) suggested that the Mississippian clastic wedge extended southward to the San Andreas fault, and suggested that the rocks of the Shadow Mountains (fig. 1) represented the southernmost exposures of this clastic wedge. As discussed above, the

Shadow Mountain sequence contains a large percentage of carbonates and no flysch-like units characteristic of the Antler clastic wedge. Poole's suggestion is hence unlikely, particularly in light of the unknown age of the Shadow Mountains sequence and the possibility that these rocks may be Mesozoic rather than Paleozoic in age. Furthermore, the Paleozoic carbonate sequence in the San Bernardino Mountains contains Mississippian and Pennsylvanian age rocks and does not contain terrigenous clastic units (Hollenbaugh, 1970). The Antler clastic wedge, if it did continue to the south or to the southwest, must lie somewhere to the north of the Victorville region. Similarly, rocks deformed during the Late Devonian-Early Mississippian Antler event must also lie further to the north.

PERMO-TRIASSIC TRUNCATION

Data from the Victorville region indicates that this part of the Mojave was part of the Paleozoic craton, not the miogeosyncline, and that the boundary between the two facies lies at some undetermined distance north of Sidewinder Mountain. This further substantiates, Hamilton (1969), and Burchfiel and Davis' (1972, 1975) concept of a truncation event which removed some unknown portion of the western margin of the continent, but there is not any obvious evidence from the Victorville region that indicates exactly where and when this truncation took place. Presumably the truncation occurred somewhere to the west of any elements on the western side of the San Andreas fault that may be matched with the geology of this portion of the Mojave Desert.

The earliest plutonic activity presently documented in the Victorville region of the Mojave Desert has been dated at 230 ± 8 m.y. old (Calvin Miller, pers. comm.). Presumably these plutons (and the accompanying deformation in this area) were related to the inception of subduction along the western edge of the continent which probably could only have taken place after the truncation occurred. Indirect evidence from the Black Mountain area (fig. 1), where conglomerates contain fossiliferous clasts of Lower Permian limestone, indicates that platform carbonate sedimentation probably continued uninterrupted in this region at least into Lower Permian times. If it can be demonstrated that the Paleozoic succession in the San Bernardino Mountains contains rocks correlative to or younger than the Pennsylvanian-Permian Bird Spring Formation and that these rocks are in all ways similar to miogeosynclinal/cratonic strata further to the east (fig. 18), the age of the youngest rocks of this sequence will help provide a lower age limit for the truncation event.

MESOZOIC DEFORMATION, RELATIONSHIP TO EVOLUTION OF SOUTHEASTERN CORDILLERA

The first deformation in the Victorville region is suggested to have occurred somewhat prior to or during the emplacement of 230 ± 8 m.y. old plutons (Calvin Miller, pers. comm.). These are the earliest plutonic rocks yet known from the Mojave region and presumably this magmatic episode places an upper limit on the age of inception of subduction along this portion of the western continental margin. Burchfiel and Davis (in preparation) place the earliest deformational events occurring in the southeastern Cordillera into the Latest Tirassic to Early Jurassic age bracket. Structures of this age are present over a broad terrain between the Inyo-Panamint ranges and the Clark Mountain area, California, and extend through the eastern Mojave region (Burchfiel and Davis, in prep.). Two plutons dated at 190 and 200 m.y. cut east vergent structures in the Clark Mountains (Burchfiel and Davis, 1971). Although the lower limit of deformation is not well established, Burchfiel and Davis believe that these structures formed in the Triassic, and most likely in Middle or Late Triassic. Because the late Early Triassic Moenkopi Formation is involved in the first deformational events occurring in this region, deformation is believed to have begun at the earliest during Middle Triassic times (Burchfiel, pers. comm.). This would indicate that the first deformational event further to the west, in the Victorville region, may have occurred somewhat earlier than the earliest documented deformational events in the southeastern Cordillera fold and thrust event. This earlier deformation in the Victorville region may be a significant event of wide extent: In the San Bernardino Mountains, monzonitic plutons are present which are chemically and mineralogically distinct from younger calc-alkaline batholithic rocks of California and instead are extremely similar to plutons in the Granite Mountains dated at 230 ± 8 m.y. (Calvin Miller, 1976). The monzonitic plutons in the San Bernardino Mountains appear to cross-cut earlier formed structures in the Precambrian-Paleozoic metasedimentary rocks. About 220 ± 10 m.y. ago, the Mount Lowe-Parker Mountain pluton was emplaced in the central San Gabriel Mountains with accompanying deformation of the adjacent Precambrian rocks (Silver, 1971). The offset equivalents of these 220 ± 10 m.y. old plutonic rocks are probably present on the southeastern side of the San Andreas fault in the Chocolate Mountains (Dillon, 1975), suggesting that this earliest Triassic belt of deformation and plutonism may have extended many kilometers to the southwest of Victorville.

The trends of structures in the Victorville area formed during this earlier deformational event are not clear. Evidence suggests that the first folding event at Quartzite Mountain may have been colinear with northwest-trending folds of the second deformational event which affected these rocks, but it is not certain that these trends were not rotated during later Mesozoic events. The northwest trending eastward overturned folds in the San Bernardino Mountains (Tyler, 1975) may have formed during earliest deformational events in this region. These data would suggest that the earlier plutonic and deformational event was precursor to the northwesterly trending later Mesozoic batholithic belt which cut across the older southwest-trending Precambrian-Paleozoic paleogeography, and which reflects the trend of the modified, truncated margin (Burchfiel and Davis, 1975).

Deformational events of significant magnitude occurring between the Middle Jurassic and early Late Cretaceous post-date the earlier Late Triassic to Early Jurassic group of deformational events in the southeastern Cordillera (Burchfiel and Davis, in prep.). There is as yet insufficient data from the Victorville region to bracket the time of older Mesozoic deformational events in this area (fig. 16): The first deformation in the Victorville area is suggested to have occurred prior to or during a 230 ± 8 m.y. old plutonic event. The post-230 m.y. old Fairview Valley Formation appears to post-date two folding events at Quartzite Mountain, although it is not known if these two events were closely spaced in time. At Sidewinder Mountain-Tri-Color quarry, Fairview Valley equivalent rocks post-date an involved sequence of folding and tectonic slicing which affected later Precambrian to Mississippian (?) age rocks. It is not known whether this sequence of events represents one continuous deformation or several distinct deformational events. Until the age of the Fairview Valley Formation is more precisely known, it provides a poor upper limit on the age of the pre-Fairview Valley deformations.

The Fairview Valley Formation and overlying volcanic rocks of the Sidewinder Group in the Black Mountain area were subsequently folded about northwest trending fold axes. At Quartzite Mountain, Fairview Valley Formation conglomerate is unconformably overlain by probably younger volcanic rocks of the Sidewinder Group. A later (D_3, event 7, fig. 3), east-west trending weak folding event affected the rocks of Quartzite Mountain. This event probably occurred slightly prior to the intrusion of 72 ± 1.4 m.y. old (Armstrong and Suppe, 1973) batholithic quartz monzonite plutons which cross-cut all structural trends in this area. Figure 16 indicates that at least two, and possibly three or more periods of Mesozoic high-angle faulting occurred in the Victorville region. The magnitude and significance of these high angle faulting episodes is not clear. There is evidence for at least three episodes of volcanism in the Victorville region (fig. 16), and possibly more may be present.

Thus, although it is clear that the first deformation in the Victorville area occurred prior to or during intrusion of 230 m.y. old plutons, the timing of later Mesozoic events is not well understood but the geology of this area reflects many episodes of tectonic, plutonic and volcanic activity throughout the Mesozoic prior to the intrusion of Late Cretaceous batholithic rocks (Fig. 16).

Earliest to Late Mesozoic plutonic rocks of the Victorville region were emplaced into older Precambrian continental crust overlain by a sedimentary sequence containing Paleozoic platform-facies carbonate rocks. The northwest-trending

Mesozoic magmatic arc cut across the older trends of the Cordilleran continental margin paleogeography in this region (Fig. 19). Northwest-trending structures in the San Bernardino Mountains (Tyler, 1975), and perhaps (if not rotated by later deformational events) northwest-trending structures in the Quartzite Mountain area, as well as later northwest-trending folds in the Fairview Valley Formation at Black Mountain, which were formed during the development of the Mesozoic magmatic arc, reflect the geometry of the Mesozoic arc in this region, as do the structural trends of the Southern Cordillera in general (Burchfiel and Davis, 1975). However, the origin of east-west trending(?) structures at Sidewinder Mountain, east-west trending deformation at Quartzite Mountain, and north-south trending structures in the Shadow Mountains is not clear. It is strongly felt that the complex geology of this region, the lack of continuous exposure, and the present lack of data concerning the timing of deformational and intrusive events as yet precludes 1) a clear cut analysis of the aerial extent and geometry of Mesozoic deformational events, and 2) the spatial-temporal relationship of deformation to plutonism and volcanism in this area.

Crystalline debris in the Fairview Valley Formation, probably derived from Precambrian crystalline basement rocks provides indirect evidence that the earlier, pre-Fairview Valley Formation deformation(s) produced structures which exposed Precambrian crystalline basement. Northeast vergent folds cut by thrusts in the San Bernardino Mountains involve Precambrian crystalline rocks (Tyler, 1975) and hence indicate that Mesozoic deformation in this region was one characterized by basement involvement.

Deformation of platform-facies rocks, basement involvement in Mesozoic structures, and the superposition of earliest Mesozoic deformational events by later Mesozoic deformational events in the Victorville region most probably reflect the controlling influence of the developing Mesozoic magmatic arc in a way grossly similar to that described by Burchfiel and Davis (in preparation), and discussed in the introduction of this report, which caused the particular style and tectonic development of the southeastern Cordilleran fold and thrust belt. The Victorville area, however, lies west of the eastern Cordilleran fold and thrust belt, and further into the magmatic arc. Several differences are noted below between the tectonic history of these two areas which may reflect the different positions of these two areas with respect to the development of the Mesozoic batholithic belt:

1. The geology of the Victorville area indicates significant deformation and plutonism occurred in earliest Triassic time, prior to the first deformational events (Middle to Upper Triassic) recorded in the southeastern Cordilleran fold and thrust belt (Burchfiel and Davis, in prep.).

2. The geology of the Victorville area records a more

involved history of volcanic and plutonic activity.

3. Mesozoic high-angle faulting episodes may have been more prevalent in the Victorville region than in the southeastern Cordilleran fold and thrust belt. Burchfiel and Davis (in press) record two high-angle faulting episodes both in the New York Mountains and Clark Mountains, California. Mesozoic high angle faulting in the Victorville region has been grouped into three major episodes (fig. 16), although the time relationships of these are not at all clearly understood, and more episodes may be present. The nature and significance of these high angle faults is not understood; possibly they related to the history of volcanic and plutonic activity in this area.

4. Data is insufficient to know whether thrust faults of large displacement are present in the Victorville region as has been documented for the southeastern Cordilleran fold and thrust belt (Burchfiel and Davis, 1975, in press; in prep.). None are exposed in the areas mapped.

5. There may be significant thickness of Mesozoic sedimentary rocks (discussed in the following section) in the Victorville region, the significance of which is not yet understood.

III. Conclusions Regarding Mesozoic Paleogeography

FAIRVIEW VALLEY FORMATION

Fairly extensive exposures of Mesozoic volcanic rocks and lesser exposures of known Mesozoic age sedimentary rocks are exposed in the Victorville region.

These provide an important key to unravelling the Mesozoic tectonic history of this area.

At its type locality at Black Mountain, the approximately 4000 feet (1200m) thick Fairview Valley Formation consists of a very heterogeneous sequence of conglomerate and finer-grained metasedimentary rocks which exhibit extreme lateral facies variation. It is surprising, then that equivalent rocks are found at Tri-Color quarry (Plate II), at Quartzite Mountain (Plate I), and at Sparkhule Mountain (Plate I), more than 15 kilometers apart. At all of these places, it can be demonstrated that the Fairview Valley Formation rests with angular unconformity on the older Precambrian-Paleozoic platform/miogeosynclinal rocks. Presence of the Fairview Valley Formation at these scattered localities suggests that at one time these rocks may have formed deposits of maybe significant aerial extent.

It is clear that the Fairview Valley Formation postdates at least one major deformational and plutonic-volcanic event in this area, and at Black Mountain, the Fairview Valley Formation overlies monzonite probably cogenetic with 230 ± 8 m.y. old plutons in the nearby Granite Mountains (Calvin Miller, pers. comm.). However, it is not clear what the time-span was between the 230 m.y. old plutonic event and the deposition of the Fairview Valley Formation, as presently, no upper age bracket is available for the Fairview Valley Formation. It is suggested that it may be Triassic or Jurassic in age, however, an Upper Jurassic or Lower Cretaceous age cannot be presently ruled out. Plutonic debris within the Fairview Valley Formation is almost entirely monzonitic in composition. The lack of more quartz-rich debris within the Fairview Valley Formation, characteristic of later plutons in this area, is striking. Hence it is possible that the Fairview Valley Formation may have been deposited fairly early in the Mesozoic, possibly during the Triassic

The metasedimentary sequence at Black Mountain documents a continuum of deformational and volcanic events within the trend of the Mesozoic batholithic belt: Conglomerate within the Fairview Valley Formation provides evidence for the erosion of a deformed and variably metamorphosed terrain, and verifies an earliest Triassic deformation. The Fairview Valley Formation post-dated some volcanism in this area, may have been deposited during a time of volcanic activity, and was post-dated by volcanic activity. During or after its deposition, the Fairview Valley Formation was tilted(?), uplifted, eroded and overlain by a quartz-rich unit which is in turn conformably overlain by a sequence of pyroclastic volcanics of the Sidewinder Group. After deposition of the overlying pyroclastic rocks, this package of sedimentary and volcanic rocks was folded and intruded by hypabyssal dikes which probably represent continuing volcanism in this area.

In the southern part of Nevada, Mesozoic sedimentation is represented by marine sandstone and limestone of the Lower Triassic Moenkopi Formation. Middle Triassic to Cretaceous rocks are clastic non-marine sedimentary rocks. These non-marine sedimentary rocks interginfer with volcanic and volcaniclastic strata of a "western volcanic suite" in the area of Soda Mountains (Grose, 1959). It is commonly assumed that during Mesozoic times, an entirely volcanic terrain lay to the west of the Soda Mountains (Grose, 1959; Stanley and others, 1971). The Fairview Valley Formation in the southwestern Mojave indicates that non-volcanic Mesozoic sedimentary rocks may have formed significant deposits. The interpretation of the tidal flat (?) depositional environment of parts of the Fairview Valley Formation may indicate that it interfingered with shallow marine sediments. Plate IV shows several sequences of Mesozoic sedimentary and volcanic rocks from within the adjacent to the magmatic arc in the eastern Mojave Desert, together with a stratigraphic column of the Mesozoic metasedimentary sequence at Black Mountain. It is possible that Mesozoic sedimentary units in the Victorville area may be in part time-equivalent to sedimentary sequences of the eastern Mojave. However, it must be kept in mind that the tectonic environment within and adjacent to a developing magmatic arc is one characterized by time and space transgressive volcanism, plutonism, and deformation. Thus one might expect similar age rocks to exhibit different characteristics in different places, and similar rock types to have different ages in different places. This is apparent in the Victorville region where rapid facies changes occur within the Fairview Valley Formation; volcanic rocks of the Sidewinder Group have different ages in different places; and, if Mesozoic, the age and relationship of the Shadow Mountains sequence is unknown. These complex relationships also characterize the Mesozoic sequences in the eastern Mojave Desert:

In the New York Mountains, California, a 300m sequence of pale green calc-silicate and quartzites unconformably (?) overlies the Pennsylvanian-Permian Bird Springs Formation and is unconformably overlain by Mesozoic metavolcanic and metasedimentary rocks (Plate VI) (Burchfiel and Davis, in press). The age of these rocks is uncertain, but they have been tentatively correlated to the Lower Triassic Moenkopi Formation although Burchfiel and Davis recognize the possibility that this unit may represent a local Mesozoic formation not present in sequences to the north or west. In the Cowhole Mountains, the Late Triassic(?) - Early Jurassic Aztec Sandstone unconformably overlies allochthonous rocks (Plate IV) (Novitsky-Evans, in prep.). It is not entirely clear in this area if the "Lower Volcanic Unit" (Plate VI) which underlies the Aztec in the Devil's Playground area (Dunne,1972; 1977) also post-dates emplacement of allochthonous rocks or is pre-thrusting (Novitsky-Evans, in prep.), and in the nearby Soda Mountains, Lower Triassic Moenkopi equivalent rocks grade upwards into a volcanic sequence (Grose, 1959) which may be equivalent to the Lower Volcanic sequence of the Devil's Playground area (Plate VI) (Dunne, 1972, 1977). According to Grose (1959), however, this volcanic sequence contains sandstone units lithologically identical to the Aztec sandstone throughout the section (Plate VI), and so here there seems to be no evidence of pre-Aztec(?) age thrusting. Whether these sandstones are really time-equivalent to the Aztec Sandstone in the nearby Cowhole Mountains is entirely unclear. It is interesting to note that quartzose horizons in the pyroclastic Sidewinder Group sequence above the Fairview Valley Formation at Black Mountain contain 50-90% very well - rounded to subangular fine sand-size quartz grains in a fine-grained matrix of altered volcanic debris, and obviously relfects derivation from two different sources. Could this mature quartz sand be indicative of deposition of the shallow marine and aeolian Upper Triassic(?) -Lower Jurassic Aztec, or Aztec-like sands further to the east, dispersed westward and southward by mechanisms of aeolian and marine transport such as described by Stanley and others (1971)? The answer to this question is unknown, and it is emphasized again that in correlating Mesozoic strata in the Mojave Desert, the unstable Mesozoic tectonic framework of this area must be kept in mind.

Mesozoic deposits are scarce in the Mojave region, but where present, provide a highly sensitive and extremely important stratigraphic documentation of tectonic activity and paleogeography in this region. Thus it is probable, when sequences such as the Fairview Valley Formation, and the Shadow Mountain sequence (discussed below) are more closely bracketed in time a far more coherent picture of the paleogeography within the developing southern Cordillera magmatic arc will emerge.

SPECULATIONS CONCERNING THE SHADOW MOUNTAINS SEQUENCE, "MYSTERY ROCKS OF THE MOJAVE"

Problems concerning the age assignement of the Shadow Mountains sequence were discussed fully in a previous section of this report. Briefly, the metasedimentary rocks of the Shadow Mountains are unlike the platform/ miogeosynclinal facies rocks in the Victorville region, and there are probably no sedimentary rocks of Upper Precambrian to Upper Paleozoic age in the Victorville and San Bernardino Mountains region which obviously correlate with the lithologically distinctive Shadow Mountains sequence. In light of this problem, one is faced with two alternatives. Either these rocks are Paleozoic in age such as suggested by Bowen (1954) on the basis of one Pennsylvanian brachiopod, and represent a facies very much different from the miogeosynclinal/cratonic Paleozoic carbonate sequence of the Victorville-San Bernardino Mountain region and the eastern Mojave Desert, or else these rocks are Mesozoic in age. If these rocks are Paleozoic in age, it is not clear how they would relate to the interpretation presented above of the geologic history of this region. They might be related to pre-Triassic events occurring along the western edge of the continental margin which are presently not understood.

Although severely contact metamorphosed, the Shadow Mountains rocks appear to have not undergone the complex deformational and thermal history of the Late Precambrian to Mississippian (?) rocks in the Victorville area. Although they are strongly folded, the Shadow Mountains rocks appear to have undergone only one penetrative deformation. Possibly these rocks could have been deposited during the Mesozoic, prior to the deposition of the Fairview Valley Formation or else may represent a lateral, open marine, equivalent of the Fairview Valley Formation. The strongest argument against this latter suggestion is the apparent lack of plutonic and volcanic debris within the Shadow Mountains sequence which would expectably be present if this sequence of rocks post-dated earliest Triassic plutonic and volcanic activity in this area.

The lateral variability of units within the Shadow Mountain sequence may not be entirely tectonic but reflect original lenticularity of sedimentary units. Conglomeratic beds occur throughout the Shadow Mountains section. The conglomerate horizons contain clasts similar to lithologies within the Shadow Mountains sequence itself and must inidcate either syndepositional erosion or erosion of probably similar lithologic terrains in nearby areas. These facts probably indicate that the deposition of the Shadow Mountains sequence occurred in an environment which was at least in part tectonically unstable. This contrasts sharply with the depositional framework of platform and miogeosynclinal rocks of the Cordilleran continental margin as this sequence of rocks contains distinctive units which can be correlated over thousands of square miles in the Great Basin region. Therefore, if the Shadow Mountains sequence is Paleozoic, these rocks were deposited in a tectonic framework probably significantly different from that which controlled the deposition of the southeastern Cordilleran margin platform and miogeosynclinal rocks.

If the Shadow Mountains rocks are Mesozoic, as suggested in this report, they may provide some reason for believing that the formation of Mesozoic depositional basin(s) was an important part of the geologic history of parts of the Mojave Desert, although the tectonic controls and reasons for this are not yet understood.

As mentioned previously, rocks of the Shadow Mountains sequence bear certain lithologic resemblance to portions of the metasedimentary sequence in the Lane Mountain quadrangle mapped by McCullough (1952, 1954, 1960). McCullough (1954) reports more than 25,000 feet (7500m) of apparently conformable strata in this area of which he claims at least half are Paleozoic in age. This section, the Coyote group, contains 60% metamorphosed clastic sedimentary rocks and 24% metavolcanic rocks, minor marble and lime-silicate hornfels (McCullough, 1954). The Coyote group rests depositionally on approximately 1000 feet (300m) of hornblende-biotite-oligoclase schist, possibly the dynamothermally metamorphosed equivalent of latite or latite tuff (McCullough, 1952). Thick meta-arkose units characterized by detrital feldspar and accessory detrital zircon and tourmaline, and the local occurrence of granitioid pebbles in meta-conglomerate suggest that the source of these sediments was an area containing granitic or metamorphic rocks (McCullough, 1954). McCullough has apparently discovered poorly preserved pelecypods in the Lane Mountain area which suggest a Late Triassic age (<u>in</u> Grose, 1959, p. 1526) but the relationship of the pelecypod-bearing rocks to the Coyote group is not known.

As discussed above, to the east of the Lane Mountain quadrangle, in the Soda Mountains, the first recorded signs of volcanism are the andesitic component in sands of rocks equivalent to the Triassic Moenkopi Formation (Grose, 1959). To the southwest of the Lane Mountain quadrangle, in the Victorville region, the earliest known plutonic activity and occurred approximately 230 ± 8 m.y. ago (Calvin Miller, 1976, pers. comm.). Therefore, from what is presently known about the geology of the Mojave Desert region, the presence of metavolcanic rocks and granitic debris within the Coyote Group at Lane Mountain, and its depositional base on meta-latite or latite tuff(?) would indicate that these rocks are Mesozoic in age.

If these rocks and possibly the Shadow Mountains sequence are Mesozoic in age, it certainly is not clear why significant thicknesses of Mesozoic rocks would be present in this part of the Mojave Desert. If the 25,000 feet (7500m) of section in the Lane Mountain quadrangle is not repeated or thickened, this certainly represents an astounding thickness of strata and would indicate significant subsidence of this area during Early Mesozoic times. The thickness of the Shadow Mountain sequence is not known, but the tectonic thickness of an apparently unrepeated portion of the section (although internally thickened by folding) is approximately 5,100 feet (1530m) (Plate IV). Exposures of these rocks to the east (Plate IV) and the large areas of outcrop of these rocks further to the west (Troxel and Gunderson, 1970) may indicate that considerable thickness of metasedimentary rocks are present in this area as well.

APPENDIX I

MEASURED SECTION
FAIRVIEW VALLEY FORMATION
AT
BLACK MOUNTAIN

Measured from the base upwards

MEASURED SECTION - FAIRVIEW VALLEY FORMATION

Description	Thickness in feet (meters)
Monzonite intrusive rock	
Unconformity	
Limestone (marble) conglomerate, pebble to small cobble-size clasts in light green calc-silicate hornfels matrix. Lower foot of section is highly sheared, shear plane N77W,66NE, parallel to bedding higher in section	1 (.3m)
Cobble conglomerate with angular clasts of white and light grey coarsely crystalline calcite marble up to 50cm in longest diameter. Matrix is light green calc-silicate fine-grained hornfels. Minor epidotized clasts of underlying monzonite	2 (.6m)
Interbedded fine-grained calc-silicate hornfels (bedding 5-30cm) and two thin, sheared marble conglomerate layers	4 (1.2m)
Conglomerate containing clasts of predominantly plutonic (monzonite) and volcanic rocks, and minor (less than 1%) carbonate clasts. Unsorted with clasts up to 50cm at base of unit. Average cobble size is 15-20cm, clasts are well-rounded to angular in a matrix of finer-grained material; both clasts and matrix are strongly epidotized. Vugs with euhedral quartz fillings common. Clasts become smaller upwards, at 30'(10m) within this unit clasts are 10cm or less in diameter, at 40'(12m) within unit, clasts are 5-8cm in diameter, and are matrix-supported. Matrix consists of small (1cm) pebbles and finer material. Conglomeratic horizons near the top of this unit are interbedded with finer, bedded, material with some sandy horizons	105 (31.5m)
Fine-grained greenish calc-silicate hornfels	15 (4.5m)
Conglomerate unit, same as above	15 (4.5m)
Fine-grained greenish calc-silicate hornfels	4 (1.2m)
Cummulative feet(meters)	146(44.5)

Conglomerate	1 (.3m)
Sandstone with calc-silicate hornfels matrix	7 (2.1m)
Fine-grained, greenish, calc-silicate hornfels	15 (4.5m)
Conglomerate, maximum clast size about 3cm, clasts are both angular and rounded and are matrix-supported, interfingers laterally with fine-grained very thinly bedded calc-silicate siltstones/mudstones with small conglomeratic lenses	8 (2.4m)
Fine-grained very thinly bedded calc-silicated siltstones/mudstones with small conglomeratic lenses	3 (.9m)
Conglomerate, pebble to small cobble-size clasts of igneous and volcanic rocks	5 (1.5m)
Fine-grained greenish calc-silicate siltstone and sandstone	40 (12m)
Covered interval. Float of above lithology and of fine-grained greenish calc-silicated very thinly bedded siltstones/mudstones	160 (48m)
Coarse sandstone. Thin section: grains predominantly lithic fragments of meta-quartzite , recrystalized chert; quartz grains, in matrix of epidote/ clinozoisite, fine-grained quartz, tremolite, and white mica	5 (1.5m)
Fine-grained greenish calc-silicated very thinly bedded to thin bedded siltstones/mudstones with occasional more quartzose and sandier horizons. Beds are 1-2cm thick, as much as 8-10cm thick. Thin section: Laminations on mm scale, laminae are often lenticular, lithology is a calc-silicated probably formerly slightly calcareous mudstone with variable amounts of quartz silt	245 (73.5m)
Sandstone with thin conglomeratic lense	5 (1.5m)
Cummulative feet (meters)	685 (208.8m)

Fine-grained greenish calc-silicate, very thinly to thin bedded in places and non-bedded or massive in places, siltstones/mudstones. 20 feet (6m) above base of this unit is a 15cm thick conglomeratic horizon containing fine-grained limestone (un-metamorphosed) clasts. 55 feet (16.5m) above base of unit, siltstones grade into sandier lithology: coarse sand-size grains (K-spar, microcline, quartz and plagioclase) in a finer calc-silicated matrix	65 (19.5m)
Greenish calc-silicate very thinly bedded to non-bedded or massive siltstones/mudstones	30 (9m)
Conglomerate: angular carbonate clasts (up to 4-5cm in diameter). Conglomerate is clast-supported with a calc-silicated, finer grained matrix	5 (1.5m)
Very fine-grained, white-weathering lithology, occasionally very thinly bedded with occasional limestone clasts. Thin section mineralogy: dolomite, fine-grained calc-silicate minerals, silt-size quartz grains	15 (4.5m)
Green-weathering dark-grey sandstones and siltstone. Thin section: immature volcanogenic sandstone, containing much volcanic rock fragments, feldspar grains	30 (9m)
Fine-grained greenish, calc-silicated, very thinly bedded (1-3cm) siltsones/mudstones with occasional sandier horizons	30 (9m)
Covered interval. Float of above lithology	25 (7.5m)
Igneous intrusion	
Covered interval, float of thinly bedded siltstones	130 (39m)
Cummulative feet (meters)	1015 (309.4)

Very fine-grained, white-weathering lithology (dolomitic) with tubular(?) structures 1-1.5 cm in diameter which are more resistant than matrix (more strongly calc-silicated burrows?)	10 (3m)
Fine-grained, greenish, calc-silicated siltstones/mudstones	175 (52.5m)
Coarse-grained sandstone, contains coarse sand-size quartz grains, metaquartzite fragments, microcline, plagioclase, volcanic rock fragments, in a much finer-grained calc-silicate matrix	2 (.6m)
Greenish, calc-silicated very thinly bedded siltstones/mudstones	103 (30.9m)
(offset of measured section 50feet (15m) NW along strike of bedding)	
Covered Interval; float of fine-grained, greenish calc-silicated siltstones	90 (27m)
Stretched limestone cobble conglomerate, calc-silicate matrix	5 (1.5m)
Fine-grained, greenish, calc-silicated siltstones/mudstones	25 (7.5m)
Fine-grained, greenish, calc-silicated, thinly bedded siltstones/mudstones with small (1-1.5cm) silicified burrows (?), and thin interlayered greyish-white weathering dolomitic calc-silicates	15 (4.5m)
Cummulative feet (meters)	1440 (439m)

Fine-grained, greenish, calc-silicated, very thinly bedded siltstones/mudstones.. 18
(5.4m)

Limestone cobble conglomerate.................. 2
(.6m)

Fine-grained, greenish, calc-silicated, very thinly bedded siltstones/mudstones............................ 20
(6m)

Greyish-white weathering dolomitic calc-silicated lithology with brownish-black weathering irregular calc-silicate stringers.................. 15
(4.5m)

Fine-grained, greenish to white weathering calc-silicated siltstones, thin to very thin bedding seems disrupted in places (perhaps by burrowing?). Thin carbonate rich beds and lenses common; abundant thin carbonate conglomerate layers.................................. 30
(9m)

Fine-grained, greenish to white weathering massive calc-silicate hornfels with occasional very thinly bedded horizons......................... 15
(4.5m)

Cummulative feet (meters) 1540
(469.4m)

Stretched carbonate cobble conglomerate	5 (1.5m)
Very thinly beddedcalc-silicated unit with small channels and lenses of carbonate cobble conglomerate. Small (1cm) calc-silicated burrows prevalent	13 (3.9m)
Channel conglomerate with carbonate clasts	3 (.9m)
Very thinly bedded calc-silicated calcareous unit with small channels and lenses of carbonate cobble conglomerate	24 (7.2m)
Channel conglomerate, carbonate clasts up to 10cm in longest diameter, contains clasts of both marble and limestone, some clasts are armoured	7 (2.1m)
Very thinly bedded calc-silicated calcareous unit with small channels and lenses of carbonate cobble conglomerate. 3 feet (.9m) below top of unit, increase in the amount carbonate conglomerate	35 (10.5)
Massive conglomerate with clasts of relatively fine-grained grey limestone and about 5% igneous clasts in a finer-grained calc-silicate matrix	20 (6m)
Fine-grained, light green to white , massive calc-silicated dolomitic unit thinly bedded in places and with occasional sandier horizons. Unit contains three 2feet (.6m) thick lenses of pebble conglomerate with igneous and carbonate clasts which pinch out along strike	105 (31.5m)
Limestone (recrystallized)	3 (.9m)
Fine-grained, light green to white massive calc-silicate hornfels, thinly bedded in places, occasional sandier horizons. One 3'(.9m) thick conglomerate unit 7'(2.1m) from top of unit which contains both carbonate and igneous clasts	67 (21.1m)
Conglomerate containing primarily marble clasts, some igneous clasts, in a finer-grained calc-silicate matrix	3 (.9m)
Cummulative feet (meters)	1825 (556.3m)

Fine-grained, greenish calc-silicate, massive, lenses out along strike	2 (.6m)
Conglomerate, containing clasts of marble and igneous rocks	5 (1.5m)
Fine-grained, greenish, clac-silicated massively bedded siltstones containing occasional thin horizons of carbonate cobble conglomerate	70 (21m)
Interbedded limestone(recrystallized), calc-silicate hornfels, and sandy horizons	5 (1.5m)
Fine-grained calc-silicate structureless hornfels	5 (1.5m)
Interbedded limestone(recrystallized), calc-silicate hornfels and sandy horizons	5 (1.5m)
Fine-grained, calc-silicate massive hornfels with thin limestone(recrystallized) horizons	20 (6m)
Conglomerate with clasts of carbonate, one containing crinoidal hash, and igneous rocks. Thin beds of calc-silicate hornfels and limestone interstratified with the conglomerate	45 (13.5m)
Fine-grained, greenish, calc-silicate hornfels with conglomeratic, very thinly bedded siltstone and sandy horizons. Thin section of coarse sandy unit contains poorly sorted, poorly rounded K-feldspar, microcline, quartz and plagioclase grains; meta-quartzite fragments and sheared quartz-microcline-plagioclase aggregates in finer-grained calc-silicated matrix	55 (16.5m)
Conglomerate containing clasts of marble, some with relict crinoid fragments, altered igneous clasts and clasts of very coarsely recrystallized marble in finer-grained calc-silicate matrix	15 (4.5m)
Fine-grained, greenish, massive calc-silicate hornfels	35 (10.5m)
Conglomerate containing clasts of carbonate and igneous rocks in finer-grained, calc-silicate matrix	5 (1.5m)
Cummulative feet (meters)	2092 (637.6m)

Fine-grained, greenish, calc-silicated massive siltstones with occasional units of sand-size particles	115 (34.5m)
Intermediate composition dike rock	
Fine-grained, greenish , calc-silicated massive siltstones with occasional units of sand-size particles	20 (6m)
Intermediate composition dike rock	
Fine-grained, greenish, calc-silicated massive siltstones with occasional units of sand-size particles	95 (28.5m)
Intermediate composition dike rock	
Fine-grained, greenish, calc-silicated massive siltstones with occasional units of sand-size particles	30 (9m)
Conglomerate: clasts consist of igneous rocks, chert, and fine-grained calcareous siltstone, up to 40cm in longest diameter. No carbonate clasts. Matrix consists of fine-grained hornfels	10 (3.0m)
Fine-grained, greenish, calc-silicated, massive, siltstones with occasional very thinly bedded to thinly bedded horizons and some sandier units	55 (16.5m)
Intermediate composition dike rock	
Fine-grained, greenish, calc-silicated massive siltstones with occasional very thinly bedded to thinly bedded horizons and some sandier units	45 (13.5m)
Intermediate composition dike rock	
Fine-grained, greenish, calc-silicated massive siltstones with occasional very thinly bedded to thinly bedde horizons and some sandier units	40 (12.0m)
Intermediate composition dike rock	
Cummulative feet (meters)	2502 (762.6m)

Fine-grained, greenish, calc-silicated massive siltstones with occasional very thinly bedded to thinly bedded horizons and some sandier units	35 (10.5m)
Intermediate composition dike rock	
Fine-grained, greenish, calc-silicated massive siltstones, slightly more calcareous than the rocks in sequence below	45 (13.5m)
Limestone and silty limestone	5 (1.5m)
Intermediate composition dike rock	
Calcareous siltstones thinly bedded with grey limestone	10 (3m)
Fine-grained calc-silicate, massive hornfels; some silty laminations, some thin limestone layers	40 (12m)
Intermediate composition dike rock	
Fine-grained, calc-silicated, siltstones with greyish-white limestone layers containing disturbed silty laminations	45 (13.5m)
Very thinly bedded to thinly bedded siltstones and silty limestones with occasional limestone layers. About 70'(21m) above base of unit, silty limestones are burrowed (1-2cm in dia.)	110 (33m)
Grey limestone layer, tectonically stretched	1 (.3m)
Calcareous siltstones (burrowed) and occasional limestone layers, thinly bedded to massive	32 (9.6m)
Fine-grained, greensih, calc-silicate hornfels, very thinly bedded to massive	32 (9.6m)
Lense of limestone cobble conglomerate	1 (.3m)
Calcareous siltstones, thinly bedded to massive with rare limestone conglomerate stringers and thin limestone layers	180 (54m)
Cummulative feet (meters)	3038 (956m)

Calcareous siltstones, becoming more calcareous toward top of unit and becomes more grey-weathering rather than orange-weathering like the more silty calcareous siltstones	145 (43.5m)
Lense of limestone cobble conglomerate	5 (1.5m)
Calcareous siltstones and silty limestones	20 (6m)
Limestone cobble conglomerate	5 (1.5m)
Intermediate composition dike rock	
Silty limestone	5 (1.5m)
Limestone cobble conglomerate with one thin silty lens. Bedding in conglomerate is about 1/2-1' (.15-.3m) thick and is defined by differences in average clast size; matrix is silty limestone/calcareous siltstone	30 (10m)
Limestone cobbles floating in silty limestone matrix	5 (1.5m)
Limestone cobble conglomerate	5 (1.5m)
Silty limestone, pinches out to SE	10 (3m)
Limestone cobble conglomerate with a 1' (.3m) siltstone layer 10' (3m) from base of unit which pinches out to SE	30 (9m)
Calcareous siltstone with some limestone cobbles	8 (2.4m)
Limestone cobble conglomerate with a few thin siltstone lenses. Bedding is 1/2 to 2 feet thick (.15-.6m) and is defined by differences in average clast-size. Matrix is silty limestone/calcareous siltstone. Upper 10-15'(3-4.5m) of conglomerate unit exposed is patchily altered to a more siliceous(chert) material, some of which appears brecciated	460 (135.0m)
UNCONFORMITY	
Cummulative feet (meters)	3766 (1148m)

UNCONFORMITY

Covered interval. Float of quartz-rich lithology described above. Thin section: 50% fine sand-size quartz grains , varying from very well rounded to angular, and are strained. 50% matrix consists of clinozoicite-epidote-tremolite-quartz, much of which may be calc-silicated, recrystallized lithic fragments	165 (49.5m)
Quartzite. Along strike is a lense of limestone pebble conglomerate. Top of unit is very thin bedded	30 (9m)
Limestone cobble conglomerate	3 (1m)
Quartzite with a 6inch (.15m) chert pebble conglomerate 30 feet (9m) from base of unit	105 (31.5)
Cummulative feet (meters)	303 (92.4m)

Quartzite unit is overlain (presumably conformably) by approximately 3000 feet (914.4m) minimum of welded tuffs, pyroclastics and volcanogenic sediments of the Sidewinder Series.

APPENDIX II

MEASURED SECTION

FAIRVIEW VALLEY EQUIVALENT (?)

TRI-COLOR QUARRY

Measured from the base upwards

Description	Thickness in feet (meters)
Meta-dolomites of the Cambrian Banded Mountain member of the Bonanza King Formation.	
UNCONFORMITY	
Dolomite cobble conglomerate, clasts are angular, unsorted, average 5-10" (.15-25cm) in longest diameter, up to 2' (60cm) in longest diameter. Bedding is massive. Bottom of unit is sheared up to 4-5' (1.2-1.5m) above unconformity, flattening has been sub-parallel to the contact. Grades upwards into undeformed, angular clasts. Matrix is finer grained, greenish, calc-silicate hornfels	55 (16.5m)
Better bedded dolomite cobble conglomerate. Clast-size averages 6-8"(15-18 cm) at base to 2-6" (5-15cm) at top of unit. Largest clasts 1.5' (45cm) in diameter. Bedding defined by alternating layers of large and small clasts. Matrix is finer-grained, greenish, calc-silicate hornfels	50 (15m)
Fine-grained sandstone/siltstone with calc-silicate hornfels matrix	1.5 (.45m)
Dolomite cobble conglomerate	225 (67.5m)
Fine-grained sandstone/siltstone with calc-silicate hornfels matrix	5 (1.5m)
Dolomite cobble conglomerate	4 (1.2m)
Fine-grained sandstone/siltstone with calc-silicate matrix with thin lenses of dolomite cobble conglomerate	22 (6.6m)
Covered interval	14 (4.2m)
Fine-grained sandstone/siltstones with calc-silicate matrix. Thin section: 80% grains, mostly subrounded fine sand-size quartz grains (grain growth around grain boundaries), minor microcline grains in matrix of epidote and tremolite	20(6m)

Covered interval. Float of fine-grained sandstones/siltstones with calc-silicate matrix	49 (14.7m)
Fine-grained sandstones/siltstones with calc-silicate matrix; dolomite conglomerate lense at same horizon along strike. Thin section of coarse-grained sandstone: Grains-recrystallized chert, tremolite/actinolite -epidote clumps, extremely altered plagioclase grains, orthoclase, orthoclase+quartz aggregates, metaquartzite fragments, some ghost outlines of lithic(?) fragments. Both matrix and grains recrystalized to felty aggregates of tremolite/actinolite and epidote.	
offset of measured section along strike of beds to NE	
Dolomite cobble conglomerate with some calcite marble clasts	9 (2.7m)
Fine-grained sandstone/siltstones with calc-silicate hornfels matrix	2 (.6m)
Dolomite cobble conglomerate	3 (.9m)
Fine-grained sandstones/siltstones with calc-silicate matrix; one bedding surface has ripple marks. Thin section: sub-rounded fine to very fine sand-size quartz grains and minor feldspar grains floating in a matrix composed primarily of fibrous tremolite growing in radial clusters, epidote and finer grained quartz, feldspar, epidote	35 (10.5m)
offset of measured section along strike of beds to NE	
Dolomite cobble conglomerate	4 (1.2m)
Fine-grained sandstone/siltstone with calc-silicate matrix; one 10' (3m) dolomite conglomerate lense	20 (6m)
Dolomite cobble conglomerate	2 (.6m)
intermediate composition dike rock	
offset of measured section along strike of beds to NE	
Dolomite cobble conglomerate	33(10.5)

Fine-grained sandstone/siltstone with calc-silicate hornfels matrix	2 (.6m)
Dolomite cobble conglomerate	20 (6m)
Covered interval	50 (15m)
Sandstone eith calc-silicate matrix with chert pebbles	5 (1.5m)
Covered interval; float of greenish sandstone with calc-silicate matrix, with chert pebbles	55 (16.5m)
offset of measured section along strike of beds to NE	
Dolomite pebble conglomerate	15 (4.5m)
Sandstone with occasional chert pebbles	30 (9m)
Dolomite pebble conglomerate. Bedding 1-3 inches (2-8cm), clasts .5-1 inch (1-3cm) in diameter	30 (9m)
FAULT	
Cummulative feet (meters) total thickness	760.5 (231.8m)

REFERENCES CITED

American Commission on Stratigraphic Nomenclature, 1961, Code of Stratigraphic Nomenclature, Am. Assoc. Petroleum Geol. Bull., v.45, p. 645-665.

Armstrong, R.L. , and Suppe, J., 1973, Potassium-Argon geochronometry of Mesozoic igneous rocks in Nevada, Utah, and southern California, Geol. Soc. America Bull. v. 84, p. 1375-1392.

Barnes, H., and Palmer, A.R., 1961, Revision of stratigraphic nomenclature of Cambrian rocks, Nevada Test Site and vicinity, Nevada, U.S. Geol. Survey Prof. Paper 424-C, p. C100-C103.

Burchfiel, B.C., and Davis, G.A., 1971, Clark Mountain thrust complex in the Cordillera of southeastern California: Geologic summary and field trip guide, Calif. Univ. Riverside Campus, Miscellaneous Contributions no. 1, p. 1-28.

Burchfiel, B. C., and Davis, G. A., 1972, Structural framework and evolution of the southern part of the Cordilleran orogen, western United States, American Jour. Sci., v. 272, p. 97-118.

Burchfiel, B. C., and Davis, G. A., 1975, Nature and controls of Cordilleran orogenesis, western United States: Extensions of an earlier synthesis, American Jour. Sci. v. 275-A, p. 363-396.

Burchfiel, B. C.,and Davis, G.A., in press, Geology of the Slaughterhouse Spring-Sagamore Canyon area, New York Mountains, California, Geol. Soc. America Bull.

Burchfiel, B. C., Fleck, R., Secor, D. T., Vincelette, R. R., and Davis, G. A., 1974, Geology of the Spring Mountains, Nevada, Geol. Soc. America Bull., v. 85, p. 1013-1022

Bowen, O.E., 1954, Geology and Mineral Deposits of the Barstwo Quadrangle, San Bernardino County, California, Division of Mines, State of California Department of Natural Resources, Bull. no. 165

Bowen, O. E. , and Ver Planck, W. E., 1965, Stratigraphy, structure and mineral deposits in the Oro Grande Series near Victorville, California, California Division of Mines and Geology, Spec. Report no. 84.

Cummings, D. , 1976, Theory of plasticity applied to faulting, Mojave Desert, southern California, Geol. Soc. America Bull., v. 87, p. 720-724.

Davis, G. A. , and Burchfiel, B. C., 1973, Garlock fault of southern California-an intercontinental transform structure, Geol. Soc. America Bull., v. 84, p. 1407-1422.

Dibblee, T.W., Jr., 1960a, Preliminary geologic map of the Apple Valley quadrangle, California, U.S. Geological Survey Mineral Investigations Field Studies Map , no. MF232, scale 1:62,500.

Dibblee, T.W. Jr., 1960b, Preliminary geologic map of the Shadow Mountain quadrangle, Los Angeles and San Bernardino Counties, California, U.S. Geological Survey Mineral Investigations Field Studies Map, no. MF227, scale 1:62,500.

Dibblee, T.W. Jr., 1960c, Preliminary geologic map of the Victorville quadrangle, California, U.S. Geological Survey Mineral Investigations Field Studies Map, no. MF229, scale 1:62,500.

Dibblee, T. W. Jr., 1964, Geologic map of the Lucerne Valley quadrangle, San Bernardino County, California, U.S. Geol. Survey Misc. Geol. Investigations Map, no. I426.

Dibblee, T. W. Jr., 1967, Areal Geology of the Western Mojave Desert, California, U.S. Geol. Survey Prof. Paper 522, 153p.

Diehl, P., 1974, Stratigraphy and sedimentology of the Wood Canyon Formation, Death Valley area, California, in Guidebook:Death Valley Region, California and Nevada, Geol. Soc. America Cordilleran section meeting field trip no. 1, Death Valley Publishing Co., Shoshone, California, p. 37-48.

Dillon, J. , 1975, Geology of the Chocolate and Cargo Muchacho Mountains, southeasternmost California , Geol. Soc. America Abs. with Programs, v. 7, no. 3, p. 311.

Dunne, G. C. , 1972, Geology of the Devil's Playground area, eastern Mojave Desert, California (Ph. D. thesis) Rice University, 79p.

Dunne, G. C. , 1977, Geology and structural evolution of Old Dad Mountain, Mojave Desert, California, Geol. Soc. America Bull., v. 88, p. 737-748.

Ferguson, H. G. , and Muller, S. W. , 1949, Structural geology of the Hawthorne and Tonopah quadrangles, Nevada, U. S. Geol. Survey Prof. Paper 216, 55p.

Gans, W. T. , 1970, the detailed stratigraphy of the Goodsprings Dolomite, southeastern Nevada-California (Ph.D. thesis): Rice University, Houston, Texas, 87p.

Gans, W. T. , 1974, Correlation and redefinition of the Goodsprings Dolomite, southern Nevada and eastern California, Geol. Soc. America Bull., v. 85, p. 189-200.

Garfunkel, Z. , 1974, Model for the Late Cenozoic tectonic history of the Mojave Desert, California, and for its relation to adjacent regions, Geol. Soc. America Bull., v. 85, p. 1931-1944.

Grose, L. T. , 1959, Structure and petrology of the northeast part of the Soda Mountains, San Bernardino Co., California, Geol. Soc. America Bull., v. 70, p. 1509-1548.

Hamilton, W. , 1964, Geologic map of the Big Maria Mountains NE quadrangle, Riverside Co., California and Yuma Co.,Arizona, U.S. Geol. Survey quadrangle map GQ-350, scale 1:24,000.

Hamilton, W. , 1969, Mesozoic California and the underflow of the Pacific mantle, Geol. Soc. America Bull., v. 80, p. 2409-2430.

Hamilton, W. , 1971, Tectonic framework of southern California, Geol. Soc. America Abs. with Programs, v. 3, no. 2, p. 130-131.

Hamilton, W., and Meyers, W. B., 1966, Cenozoic tectonics of the western United States, Rev. Geophysics, v. 4, p. 509-549.

Hazzard, J. C. , 1937, Paleozoic section in the Nopah and Resting Springs Mountains, Inyo Co., California, California Jour. Mines and Geology, v. 33, p. 273-339.

Hazzard, J. C. , 1954, Rocks and structure of the northern Providence Mountains, San Bernardino County, California, California Div. Mines Bull. 170, p. 27-35.

Hazzard, J. C. , and Mason, J. F. , 1936, Middle Cambrian formations of the Providence and Marble Mountains, California, Geol. Soc. America Bull., v. 47, p. 229-241.

Hershey, O. H. , 1902, Some crystalline rocks of southern

California, American Geologist, v. 29, p. 273-290.

Hewett. D. F. , 1931, Geology and ore deposits of the Goodsprings quadrangle, Nevada, U. S. Geol. Survey Prof. Paper 162, 172p.

Hollenbaugh, K. M. 1970, Geology of a portion of the north flank of the San Bernardino Mountains, California, Geol. Soc. America Abs. with Programs, v. 2, no. 2, p. 103.

Hook, R. LeB. , 1967, Processes on arid-region alluvial fans, Jour. Geology, v. 75, p. 438-460.

McCulloh , T. H., 1952, Geology of the southern half of the Lane Mountain quadrangle, California (Ph.D. thesis) University of California, Los Angeles, 180p.

McCulloh , T. H., 1954, Problems of the metamorphic and igneous rocks of the Mojave Desert, California, California Div. Mines Bull. 170, p. 13-24.

McCulloh , T. H. , 1960, Geologic map of the Lane Mountain quadrangle, California, U. S. Geol. Survey open file map, scale 1:48,000.

Middleton, G. V. , and Hampton, M. A. , 1973, Mechanics of flow and deposition in turbidites and deep water sedimentation, Soc. Econ. Paleon. and Miner. Short Course, Pacific Section SEPM, Los Angeles, California, p. 1-38.

Miller, C. F., 1976, Alkali-rich monzonites, southern and central California-a unique magmatic episode?, Geol. Soc. America Abs. with Programs, v. 8, no. 3, p. 395-396.

Miller, W. J. , 1944, Geology of parts of the Barstow quadrangle, San Bernardino Co., California, Am. Ass. Petroleum Geol. Bull., v. 42, p. 1812-1844.

Novitsky-Evans, J. M., in preparation, Geology of the Cowhole Mountains, California (Ph.D. thesis): Rice University, Houston, Texas.

Palmer, A. R. , and Hazzard, J. C. , 1956, Age and Correlation of Cornfield Springs and Bonanza King Formations in southeastern California and southern Nevada, Am. Ass. Petroleum Geol. Bull., v. 46, p. 2494-2499.

Poole, F. G. , 1974, Flysch deposits of the Antler foredeep, western United States, <u>in</u> Dickinson, W. R. , ed., Tectonics and Sedimentation, Soc. Econ. Paleon. and Miner. Special Publication 22.

Rogers, T. H. , 1967, Geologic map of California, scale 1:250,000, San Bernardino Sheet, California Division of Mines and Geology.

Ross, R. J., Jr. , 1964, Middle and Lower Ordovician formations in southernmost Nevada and adjacent California with a section on paleotectonic significance of Ordovician sections south of the Las Vegas shear zone by R. J. Ross Jr., and C. R. Longwell, U. S. Geol. Survey Bull. 1180-C, p. C1-C101.

Ross, R. J. Jr. , 1964, Relations of Middle Ordovician time and rock units in basin ranges, western United States, Am. Assoc. Petroleum Geol. Bull., v. 48, p. 1526-1554.

Schweickert, R. A. , 1976, Early Mesozoic rifting and fragmentation of the Cordilleran orogen in the western U.S. A., Nature, v. 260, p. 586-591.

Silberling, N. J., and Roberts, R. J. , 1962, Pre-Tertiary stratigraphy and structure of northwestern Nevada, Geol. Soc. America Spec. Paper 72.

Silver, L. T., 1971, Problems of crystalline rocks of the Transverse Ranges, Geol. Soc. America Abs. with Programs, v. 3, no. 2, p. 193-194.

Smith, G. I. , 1962, Large lateral displacement on the Garlock fault, California, as measured from offset dike swarm, Am Assoc. Petroleum Geol. Bull, v. 46, p. 85-104.

Smith, G. I., and Ketner, K. B. , 1970, Lateral displacement on the Garlock fault, southeastern California, suggested by offset sections of similar metasedimentary rocks, U. S. Geol.Survey Prof. Paper 700-D, p. D1-D9.

Smith, G. I. , Troxel, B. W. , Gray, C. H., Jr., and von Huene, R. E. , 1968, Geologic reconnaissance of the Slate Range, San Bernardino and Inyo Counties, California, California Division of Mines and Geology Spec. Report 96, 33p.

Speed, R. C. and Kistler, R. W. , 1977, Correlations between pre-Tertiary rocks of the Great Basin and the Sierra Nevada, Geol. Soc. America Abs. with Programs, v. 9, no. 4, p. 505-506.

Stanley, K. O., Jordan, W. M. , and Dott, R. H. Jr., 1971, Early Jurassic Paleogeography, western United States, Am. Assoc. Petroleum Geol. Bull., v. 55, p. 10-20.

Stewart, J. H. , 1970, Upper Precambrian and Lower Cambrian strata in the southern Great Basin, California and Nevada, U. S. Geol. Survey Prof. Paper 620, 205 p.

Stewart, J. H. , and Poole, F. G. , 1974, Lower Paleozoic and uppermost Precambrian Cordilleran miogeosyncline, Great Basin, western United States, in Dickinson, W. R., ed., Soc. Econ. Paleon. and Miner. Spec. Publication 22, p. 28-57.

Stewart, J. H. and Poole, F. G., 1975, Extension of the Cordilleran miogeosynclinal belt to the San Andreas fault, southern California, Geol. Soc. America Bull., v. 86, p. 205-212.

Stone, W. D. , 1964, Geology of the Black Mountain area, Apple Valley quadrangle, California (M. A. thesis): University California Riverside.

Troxel, B. W. and Gunderson, J. N. , 1970, Geology of the Shadow Mountains and northern part of Shadow Mountains SE quadrangles, western San Bernardino Co., California, California Division of Mines and Geology, Preliminary Report 12.

Tyler, D. L. , 1975, Stratigraphy and structure of the Late Precambrian-Early Cambrian clastic metasedimentary rocks of the Baldwin Lake area, San Bernardino Mountains, Ca-ifornia (M.A. thesis): Rice University, Houston, Texas, 50 p.

Walker, T. R. , 1967, Formation of red beds in modern and ancient deserts, Geol. Soc. America Bull., v. 78, p. 353-368.

Wiebe, R. A., 1970, Pre-Cenozoic tectonic history of the Salinian block, western California, Geol. Soc. America Bull., v. 81, p. 1837-1842 .

Winkler, H. G. F. , 1974, Petrogenesis of Metamorphic Rocks, New York, Springer Verlag N.Y. Inc., 237p.

Wright, L. A. , Troxel, B. W. , Williams, E. G. , Roberts, M. T. , and Diehl, P. E. , 1974, Precambrian sedimentary environments of the Death Valley Region, Eastern California, in Guidebook: Death Valley Region, California and Nevada, Geol. Soc. America Cordilleran Section meeting field trip no. 1, Death Valley Publishing Co., Shoshone, California, p. 27-35.

EXPLANATION

Quaternary

Qal
Alluvium

Qoal
Older alluvium

METASEDIMENTS

Mesozoic

sw
Sidewinder Group volcanic rocks

fv
Fairview Valley formation:
Mfv$_1$: massive conglomerate with plutonic, volcanic and metasedimentary clasts
Mfv$_2$: calcareous siltstones, silty limestones
Mfv$_3$: carbonate cobble conglomerate

Cambrian

Єbk
Bonanza King Formation

Єc
Carrara Formation:
Єc$_2$: upper schistose and calc-silicate unit
Єc$_1$: lower limestone unit

Єz
Zabriskie Quartzite

re-Cambrian

pЄwc
Wood Canyon Formation:
pЄwcd: dolomite unit

pЄsj?

IGNEOUS

L. Mesozoic

g
late Mesozoic granitic r

Mesozoic?

mh
meta-hypabyssal igneou

CONTACTS

definite, approxi

FAULTS

high angle faults

FOLDS

overturned antic

zone of alteration, cont

BEDDING

20 39
strike and dip of b

20
strike and dip of
inclined, vertical

GEOLOGIC

EOUS

g

Mesozoic granitic rocks, undifferentiated

h

-hypabyssal igneous rocks

CONTACTS

definite, approximate, inferred or concealed

FAULTS

high angle faults

FOLDS

overturned anticline

of alteration, contact metamorphism

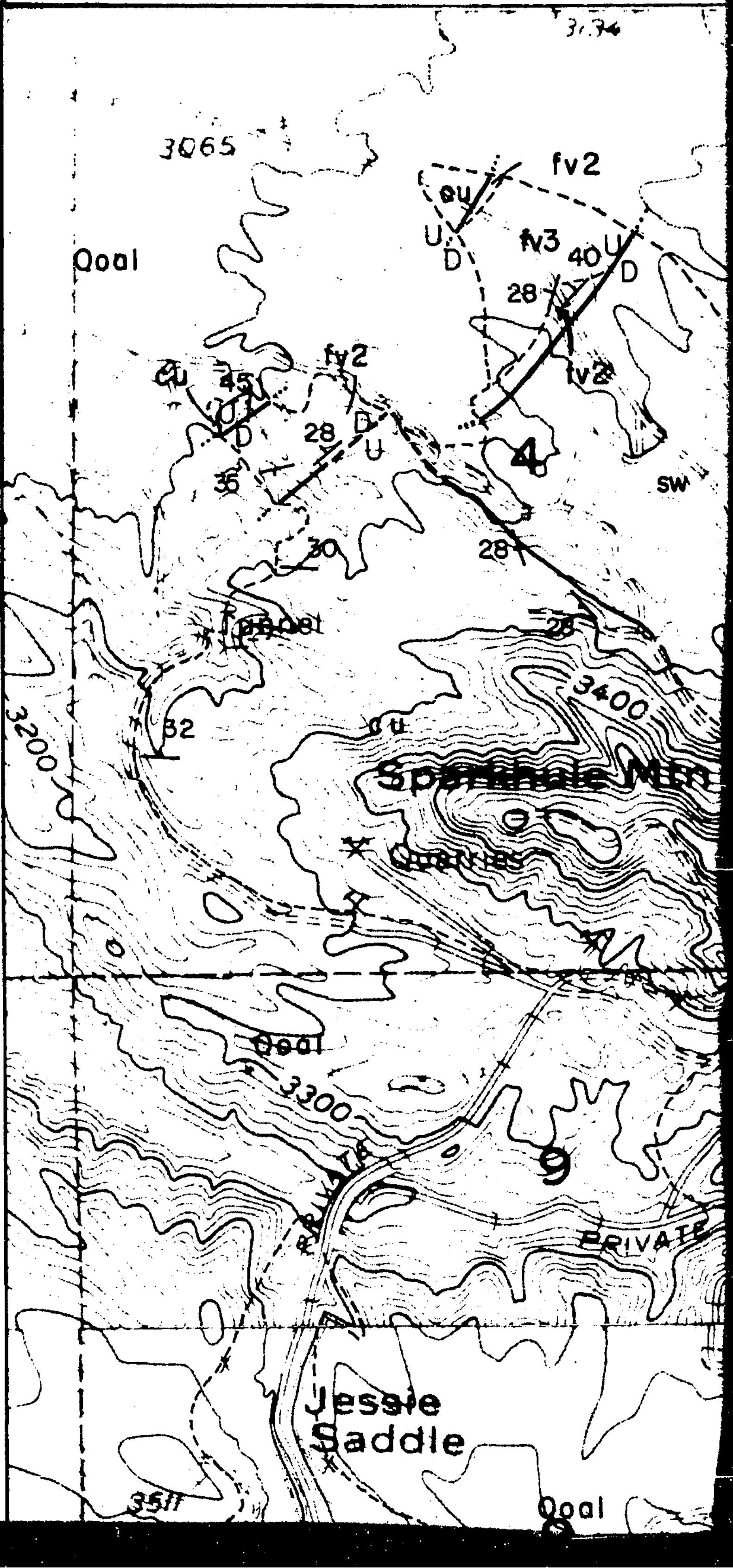
BEDDING

20 39

strike and dip of bedding: upright, overturned

20

strike and dip of compositional layering: inclined, vertical



OGIC MAP OF QUARTZIT

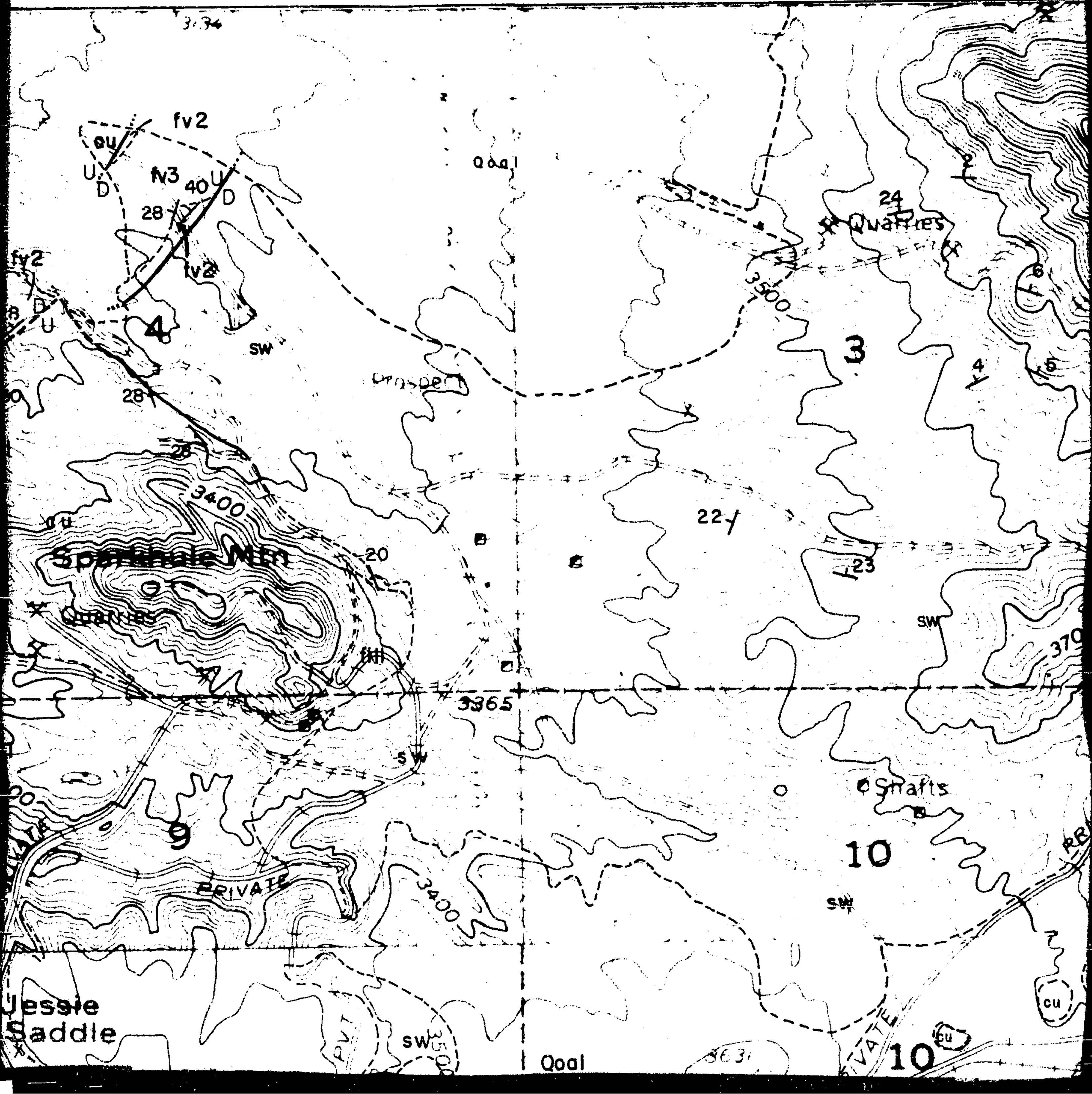
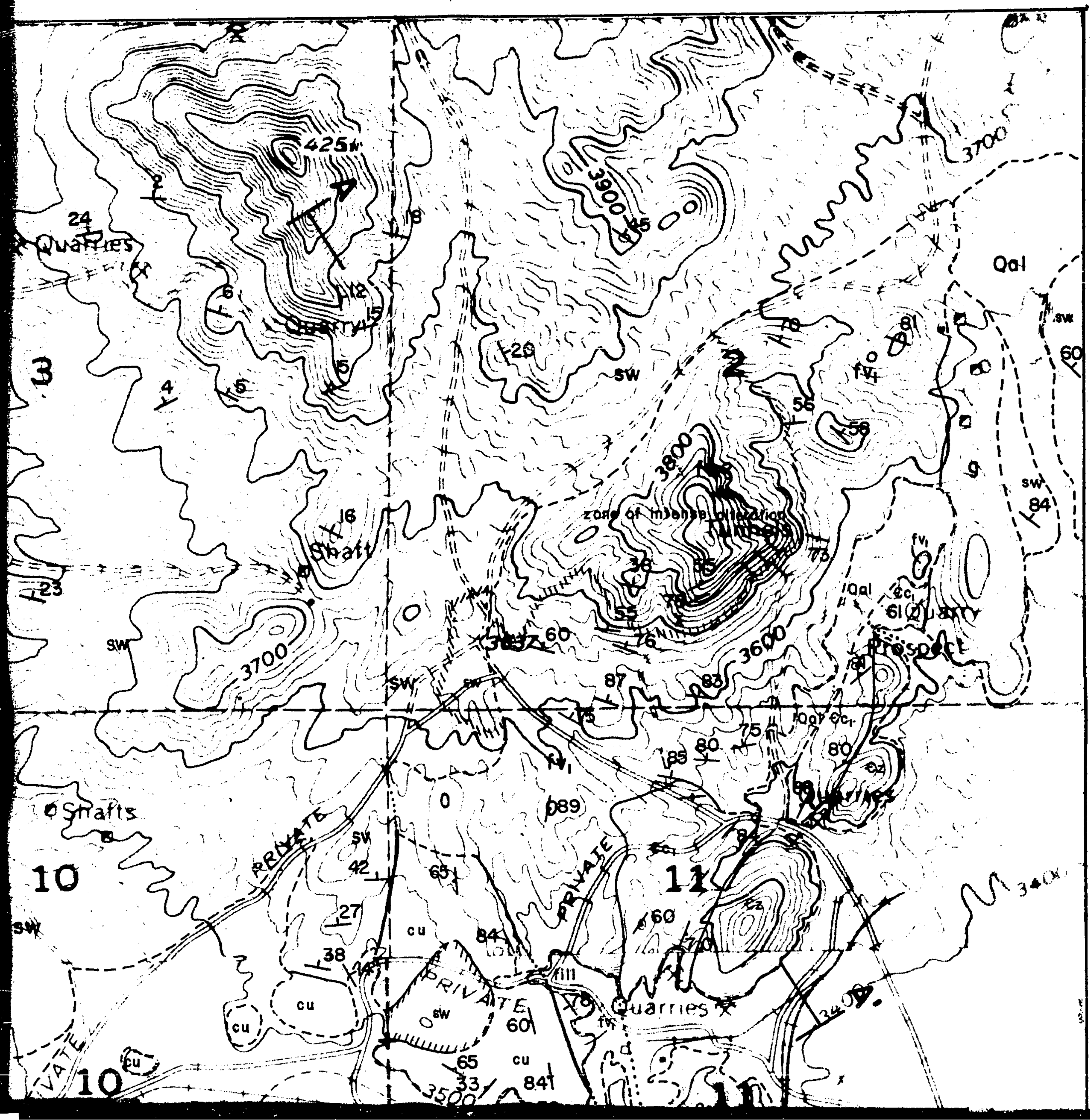


PLATE IA

ARTZITE MOUNTAIN



Zabriskie Quartzite

pre- Cambrian

ЄpЄwc

Wood Canyon Formation:
ЄpЄwcd: dolomite unit

pЄsj?

Stirling Quartzite- Johnnie Formation equivalent (?)

cu

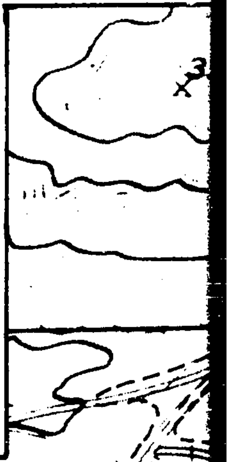
undifferentiated meta-carbonate rocks

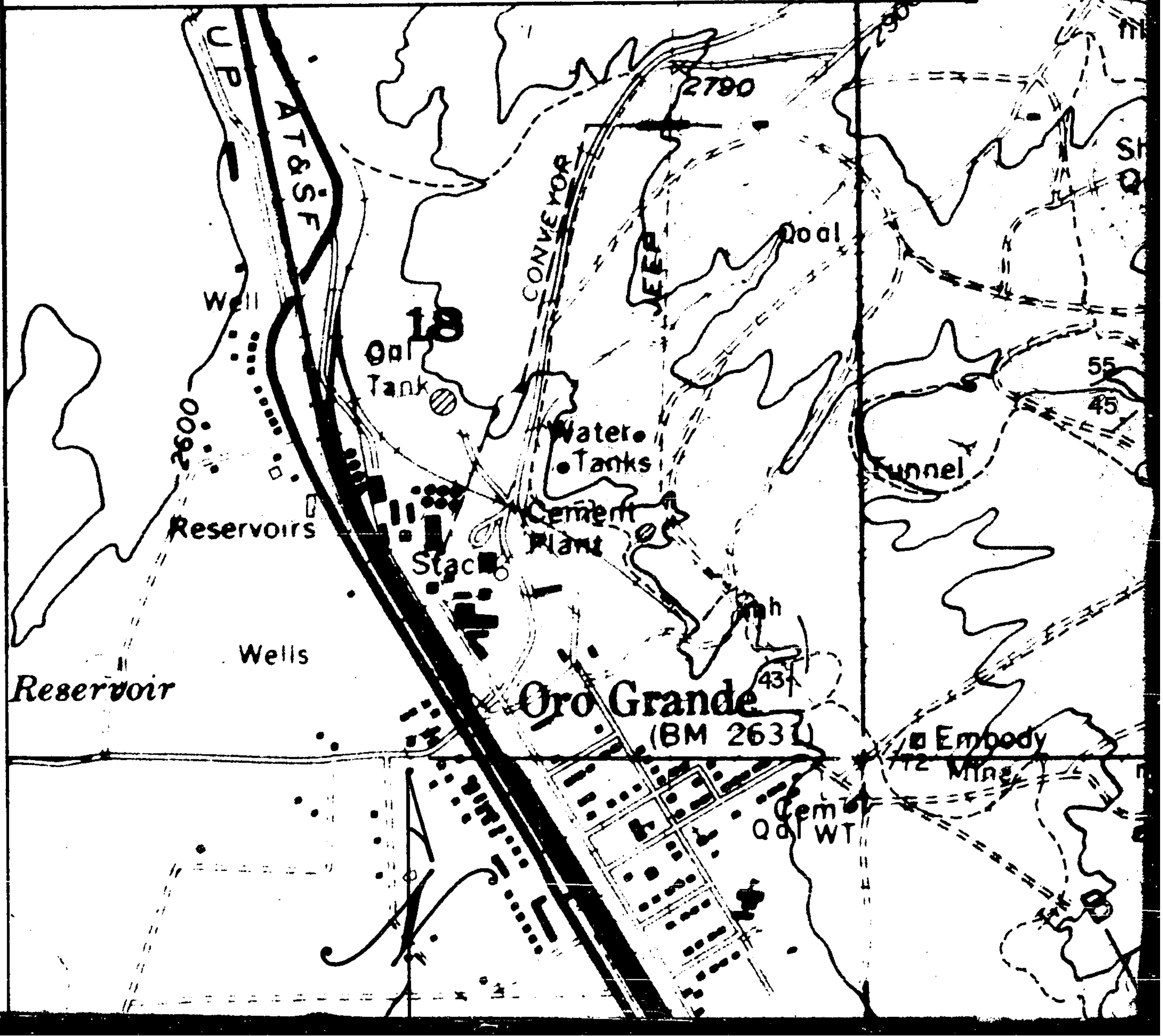
20

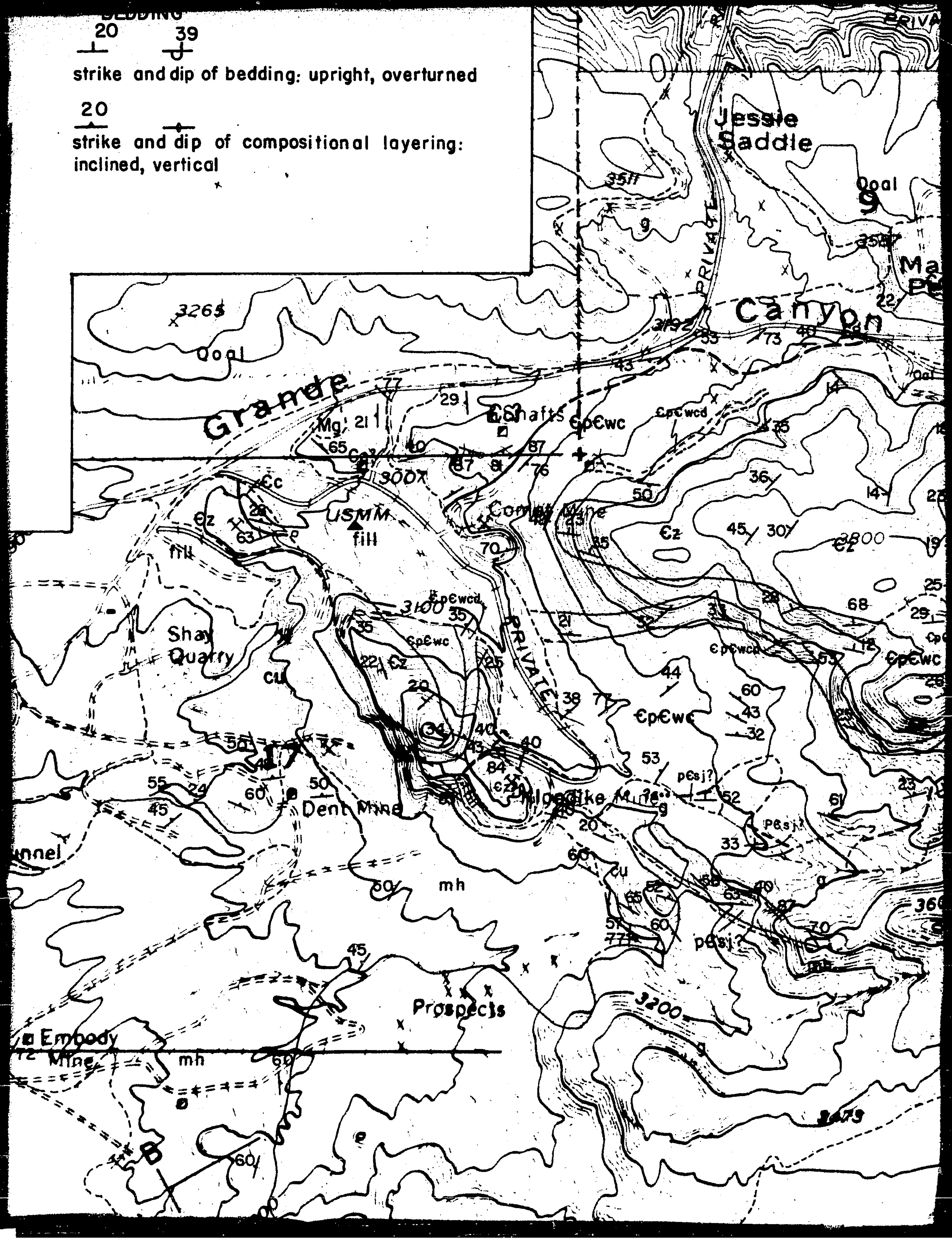
strike and di

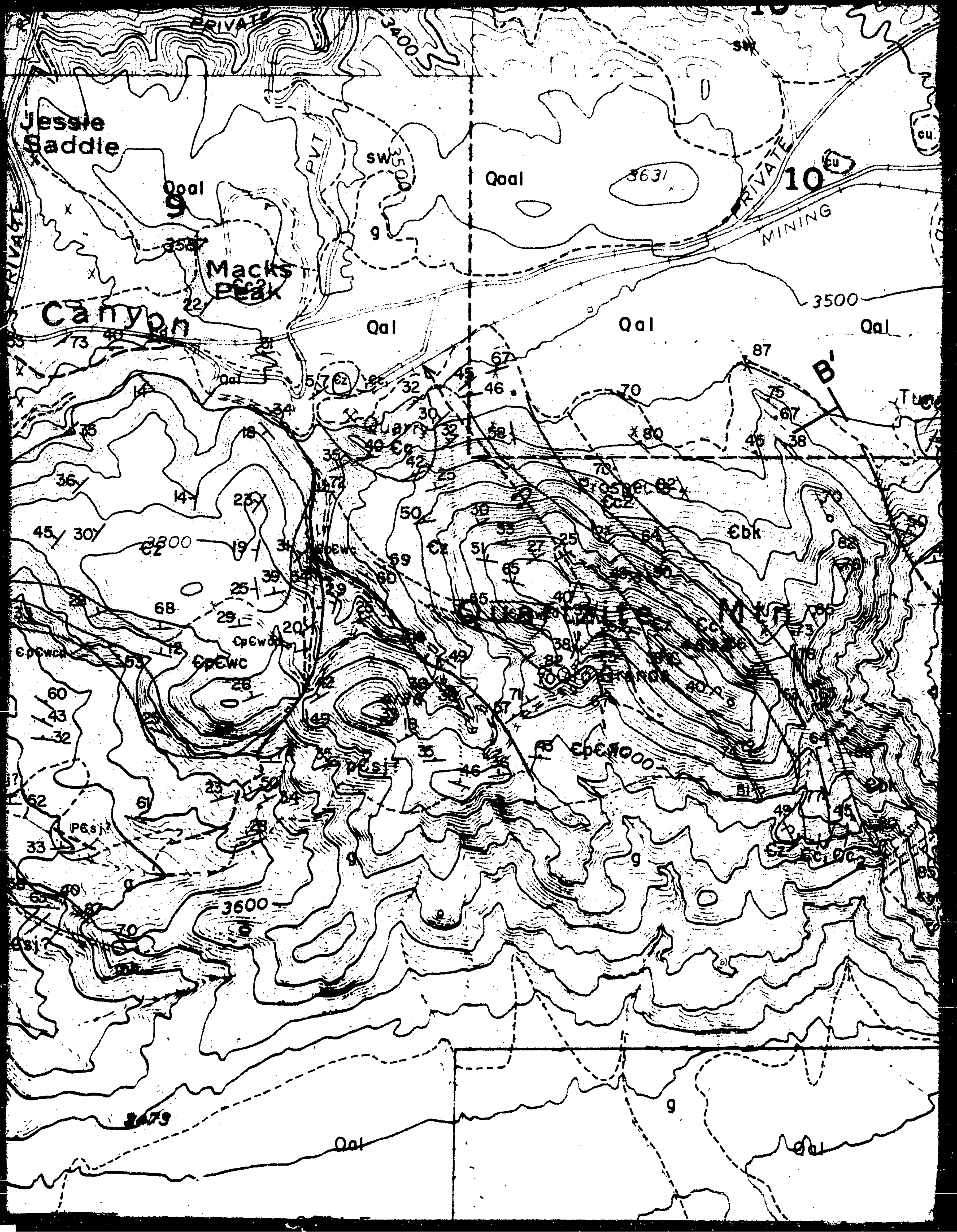
20

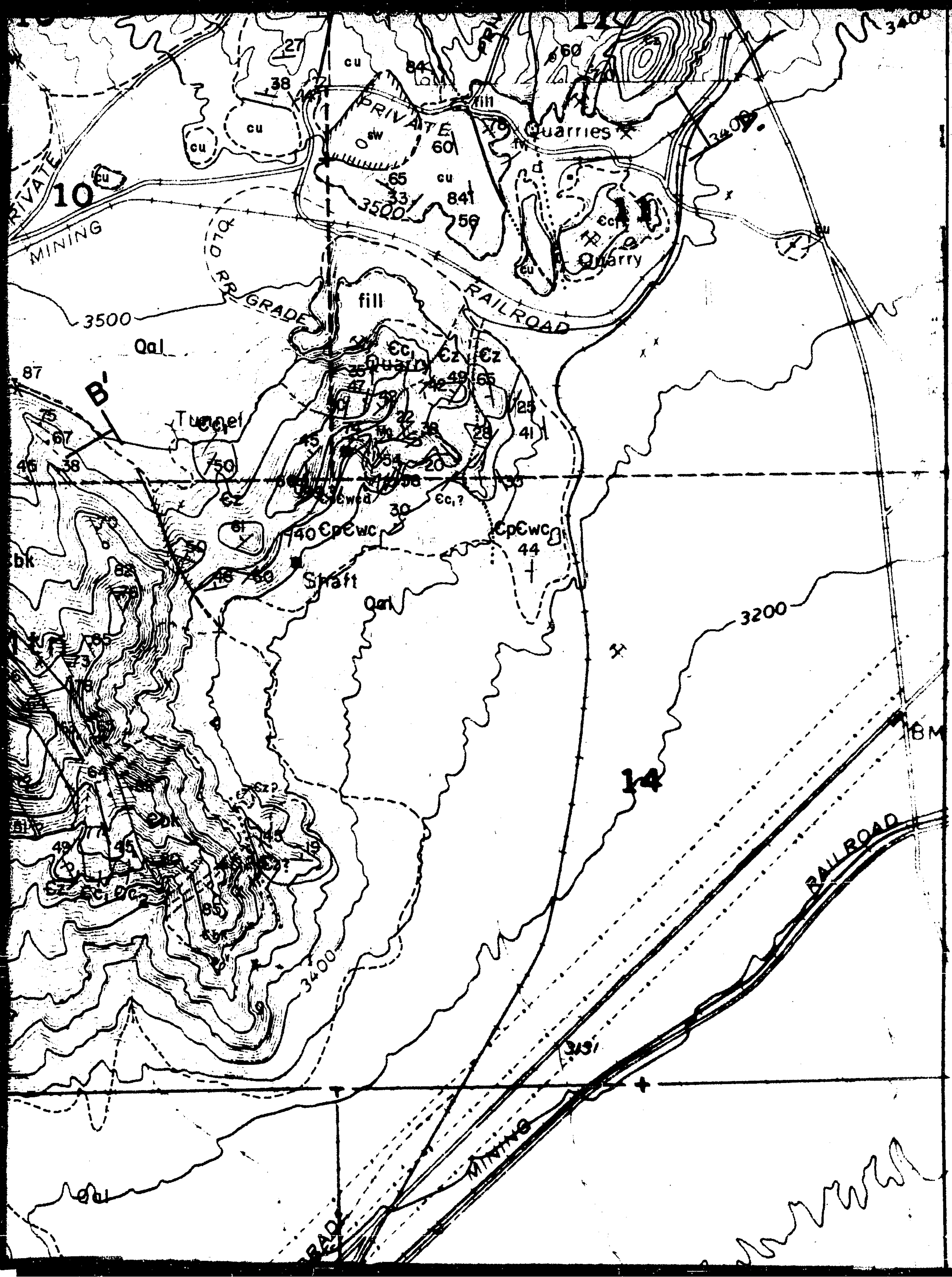
strike and di
inclined, vert

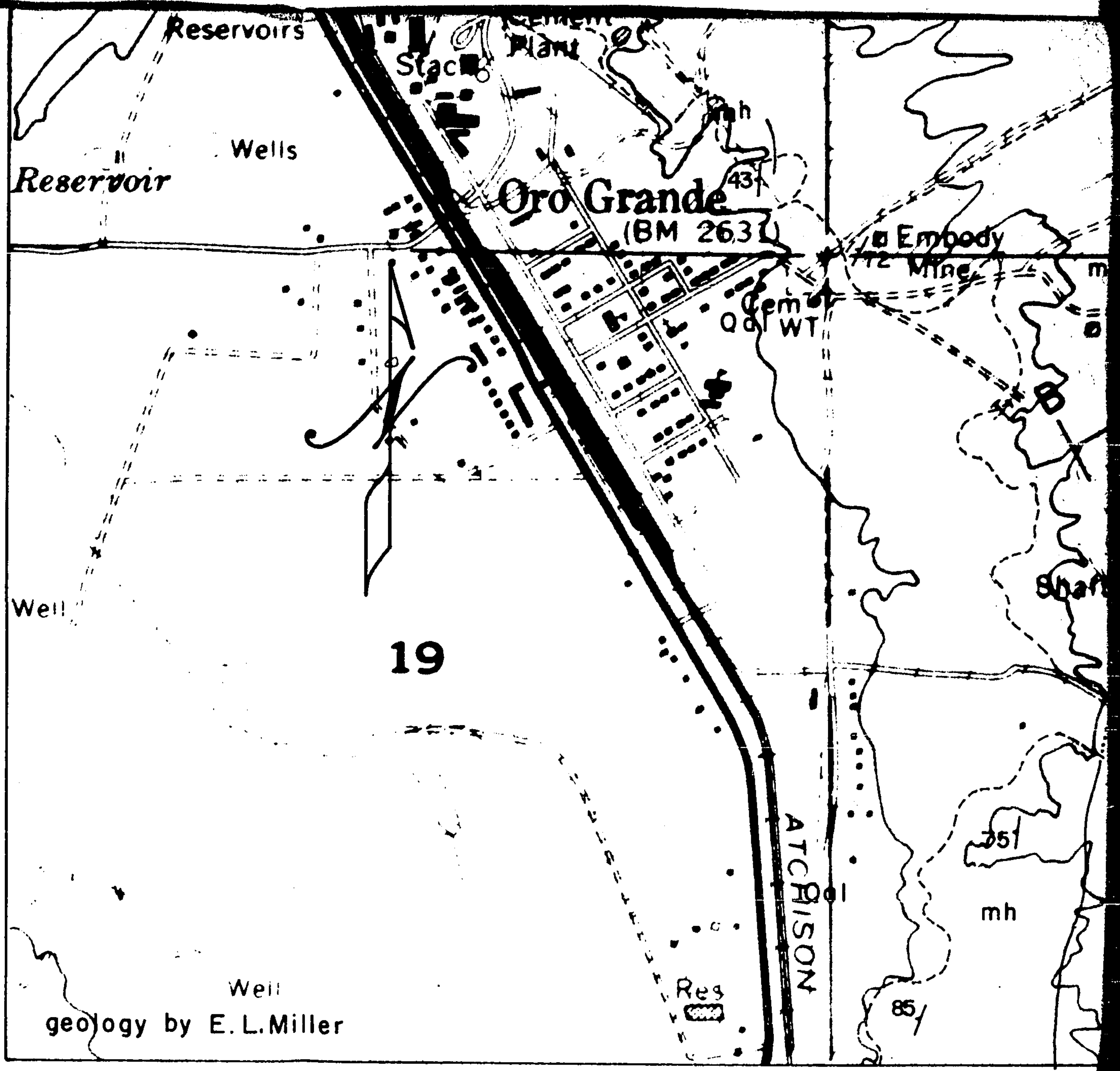


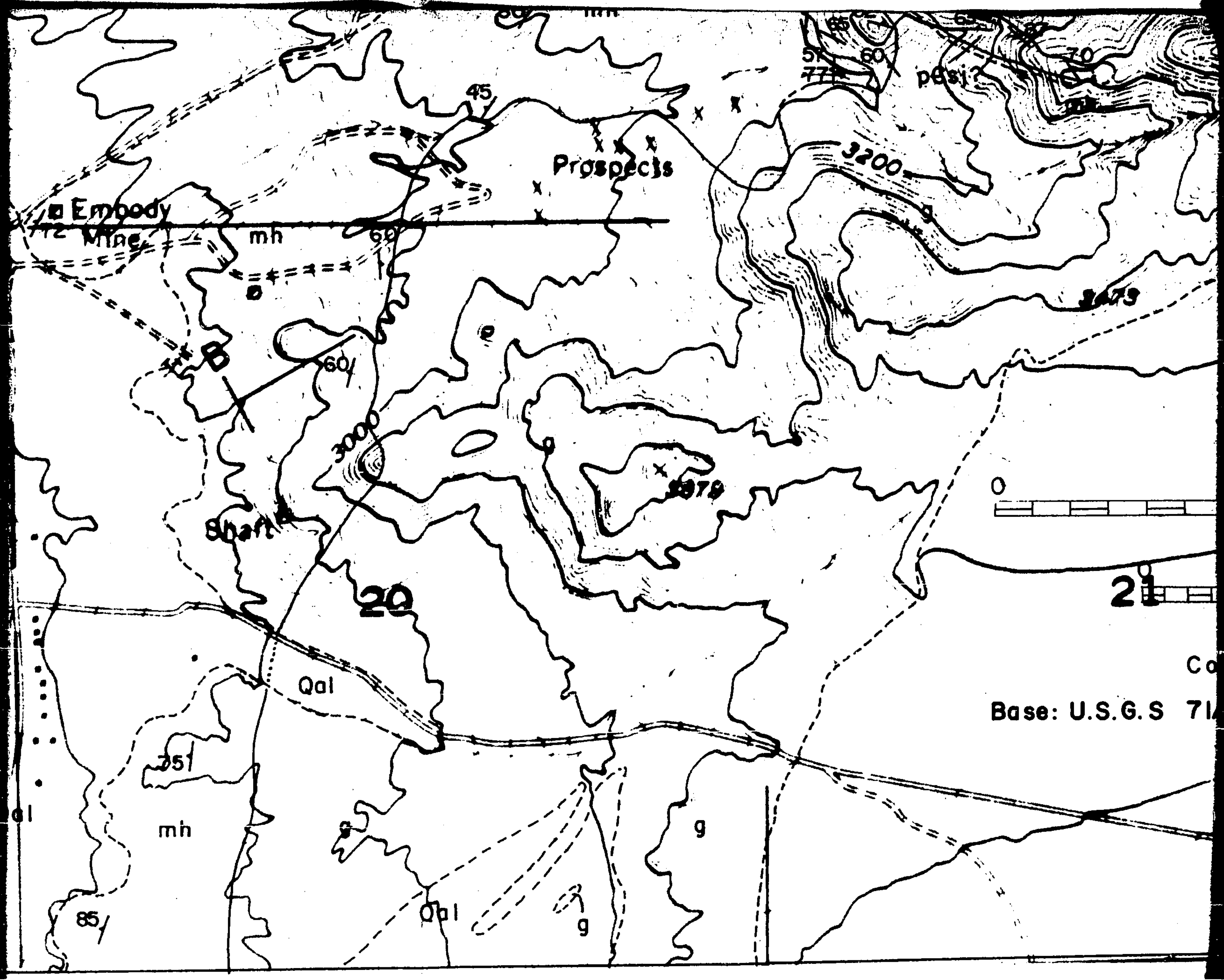



BEDDING
20
39
strike and dip of bedding: upright, overturned
20
strike and dip of compositional layering: inclined, vertical
Jessie Saddle
Canyon
Grande
Qoal
3265
3511
3192
3587
9
g
Shafts
€p€wc
€p€wcd
Mg
€c
€z
USMM
fill
Comet Mine
PRIVATE
3007
3100
3800
Shay Quarry
cu
17
Dent Mine
Klondike Mine
p€sj?
mh
Prospects
3200
Embody Mine
tunnel
B
3473


PRIVATE
3400
sw
Jessie Saddle
Qoal
9
PVT
sw
3500
g
Qoal
3631
PRIVATE
10
cu
MINING
3587
Macks Peak
22
Canyon
Qal
Qal
3500
Qal
87
B'
Tung
Quarry
Єz
Prospect
Єbk
Єz
3800
Quartzite Mtn
ЄpЄwc
ЄpЄwcd
ЄpЄwc
pЄsj
ЄpЄwc
4000
Єbk
pЄsj?
g
g
g
3600
g
3475
Qal
Qal

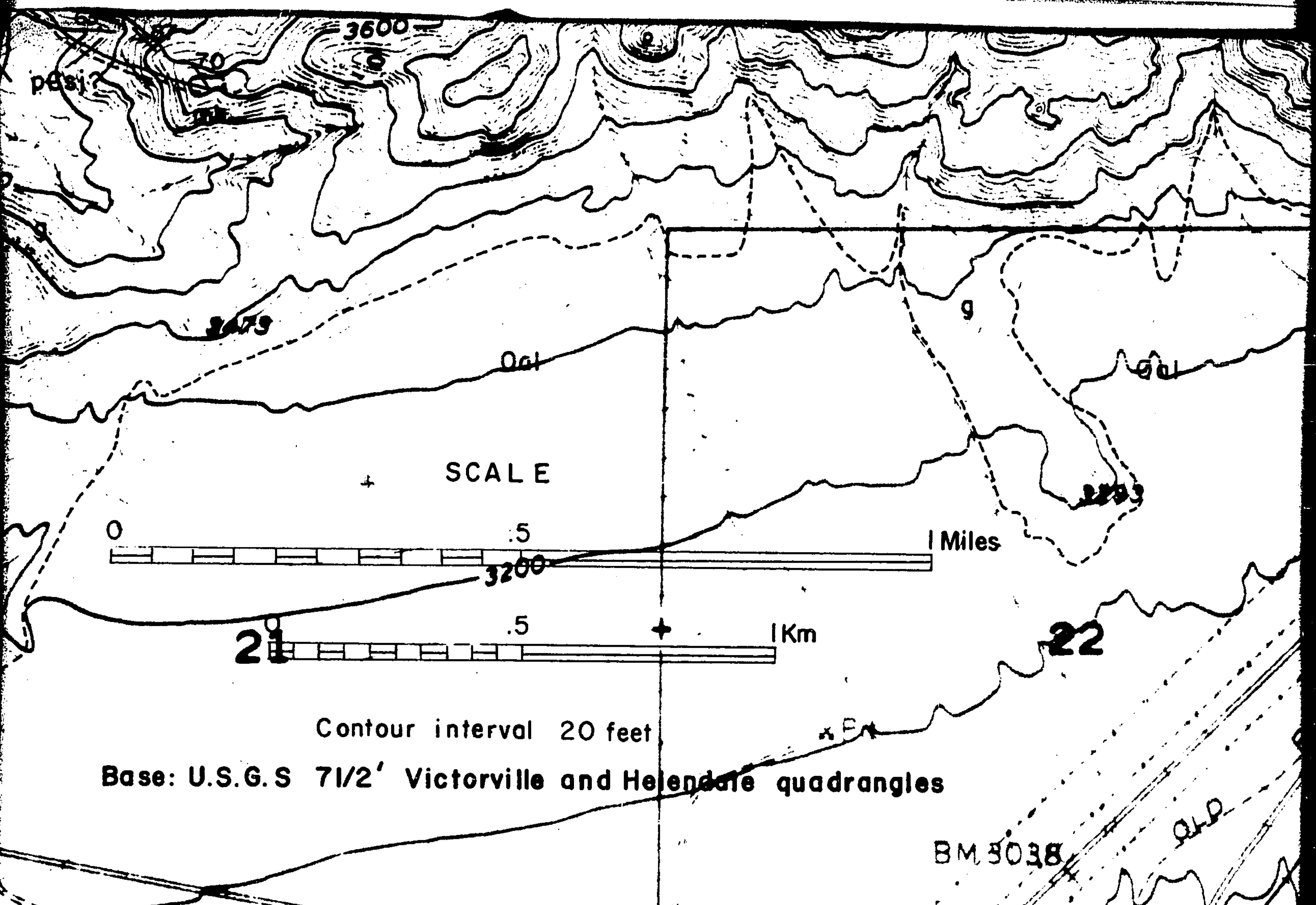

PRIVATE
10
MINING
cu
27
38
84
60
70
fill
PRIVATE
sw
60
76
Quarries
3400
65
33
3500
84
56
OLD RR GRADE
RAILROAD
Єcr
11
Quarry
fill
3500
Qal
87
B'
Tunnel
Єc1
Єz
Quarry
35
47
49
65
42
50
22
38
28
41
75
67
46
38
750
54
20
Єcwcd
Єc1?
Єz
30
61
40
ЄpЄwc
ЄpЄwc
44
50
46
60
Shaft
Qal
bk
70
3200
85
73
Єbk
Єz?
45
19
49
Єz
Єc1
Dc
3400
85
14
BM
RAILROAD
3131
MINING
Qal
ROAD


Reservoirs
Cement Plant
Stack
mh
Wells
Reservoir
Oro Grande
43
(BM 2631)
Embody Mine
72
m
Cem
Qal WT
B
Shaft
Well
19
75
Qal
mh
ATCHISON
Well
Res
85
geology by E. L. Miller



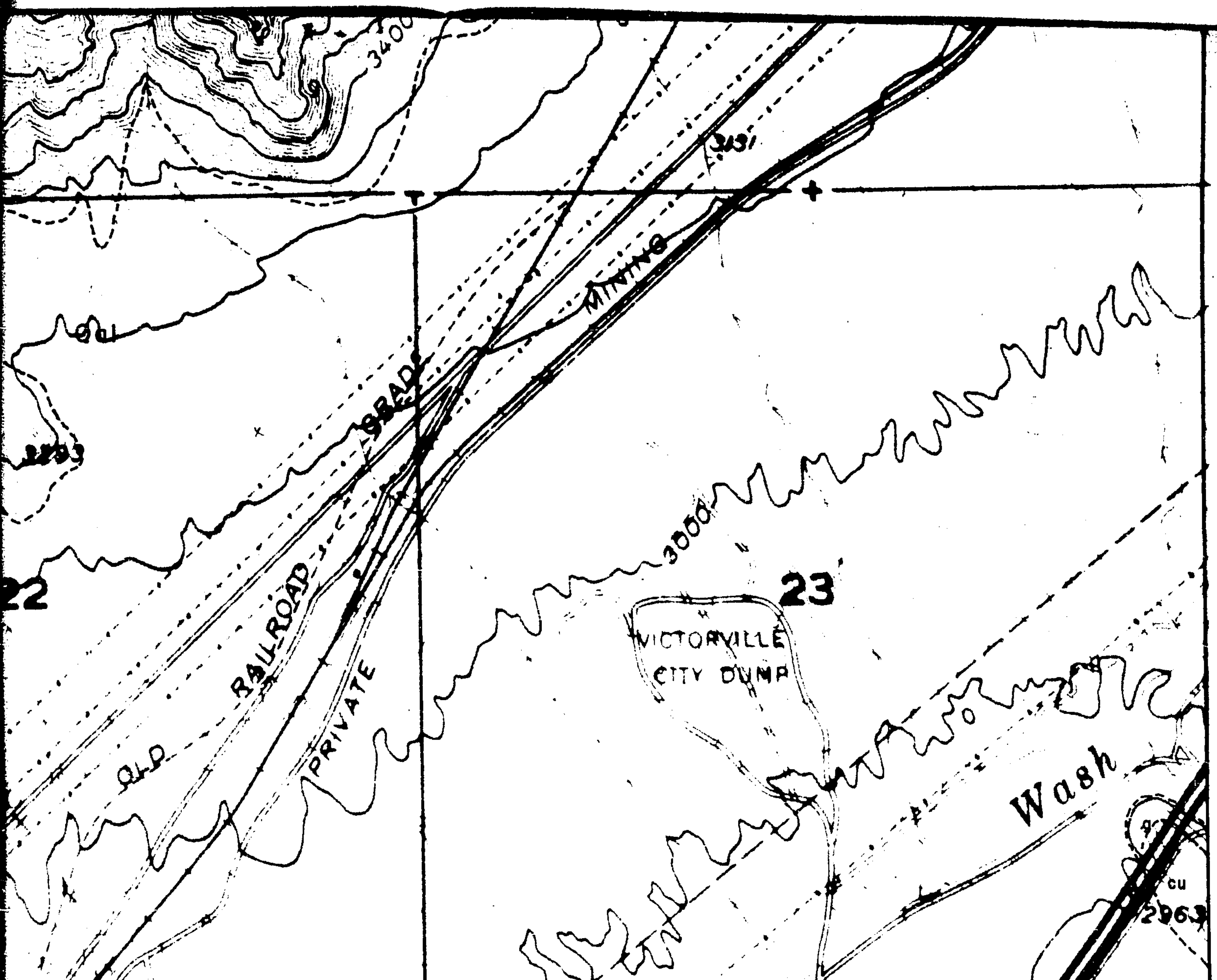
Co

Base: U.S.G.S 71

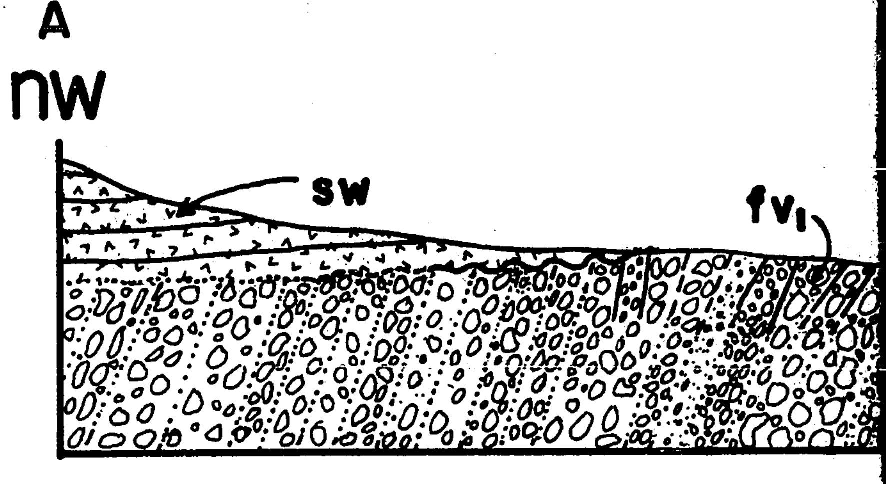


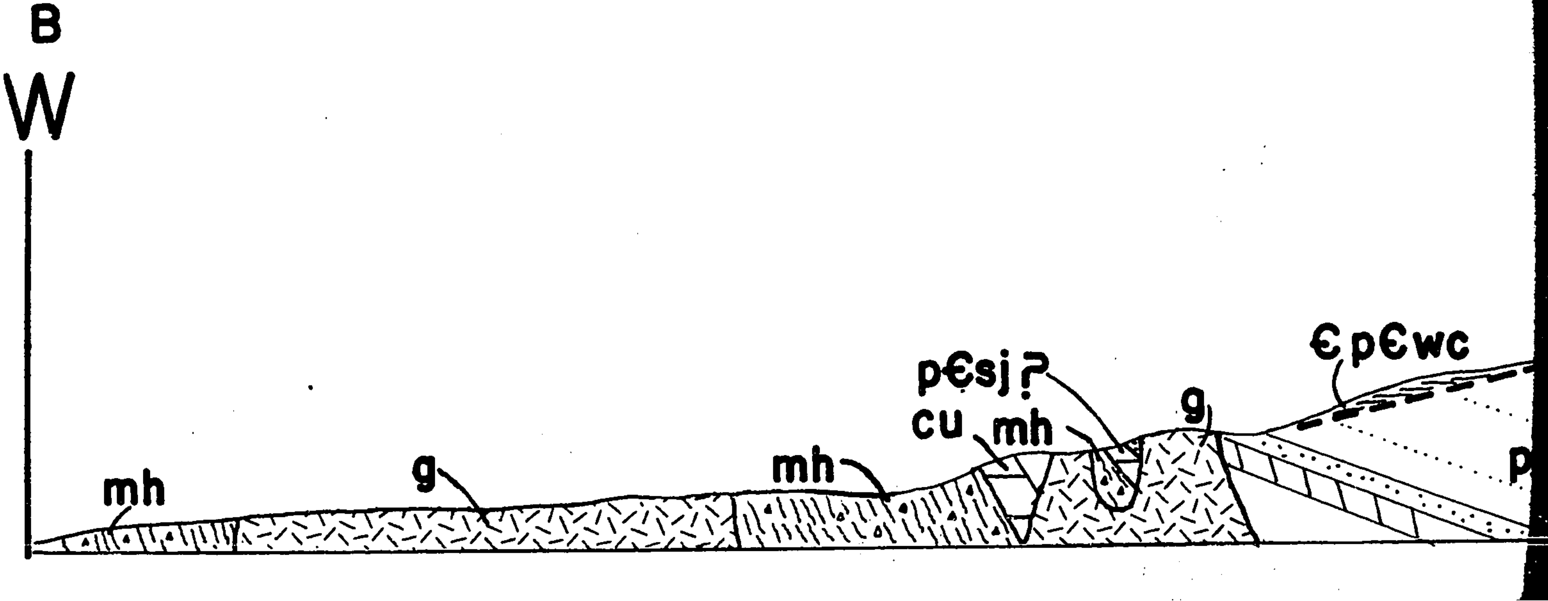
Contour interval 20 feet

Base: U.S.G.S 71/2′ Victorville and Helendale quadrangles

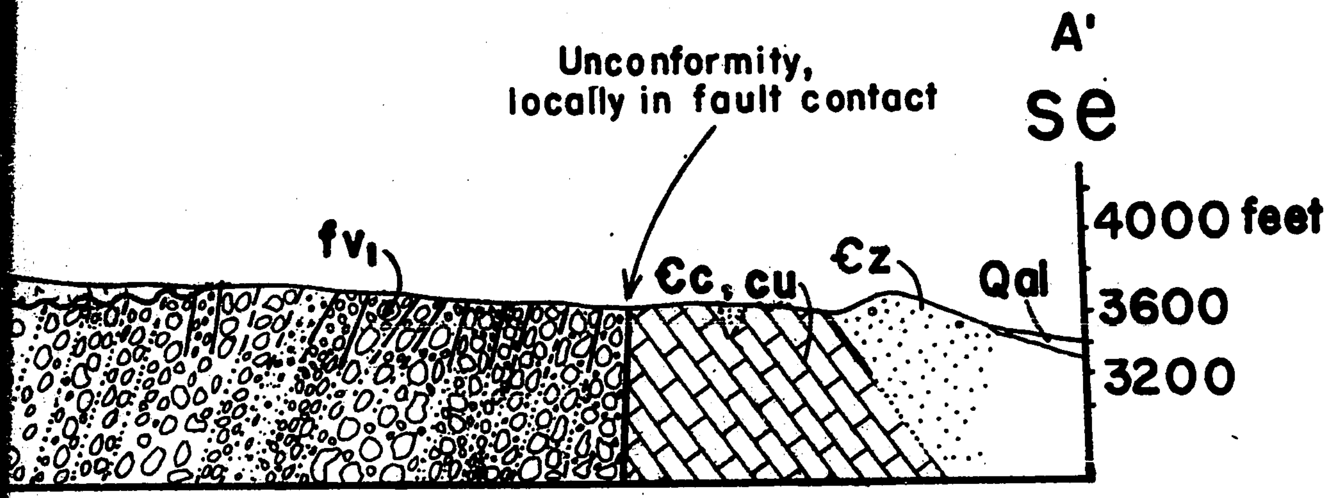

3400
3131
MINING
GRADE
OLD RAILROAD
PRIVATE
22
23
3000
VICTORVILLE CITY DUMP
Wash
cu
2963

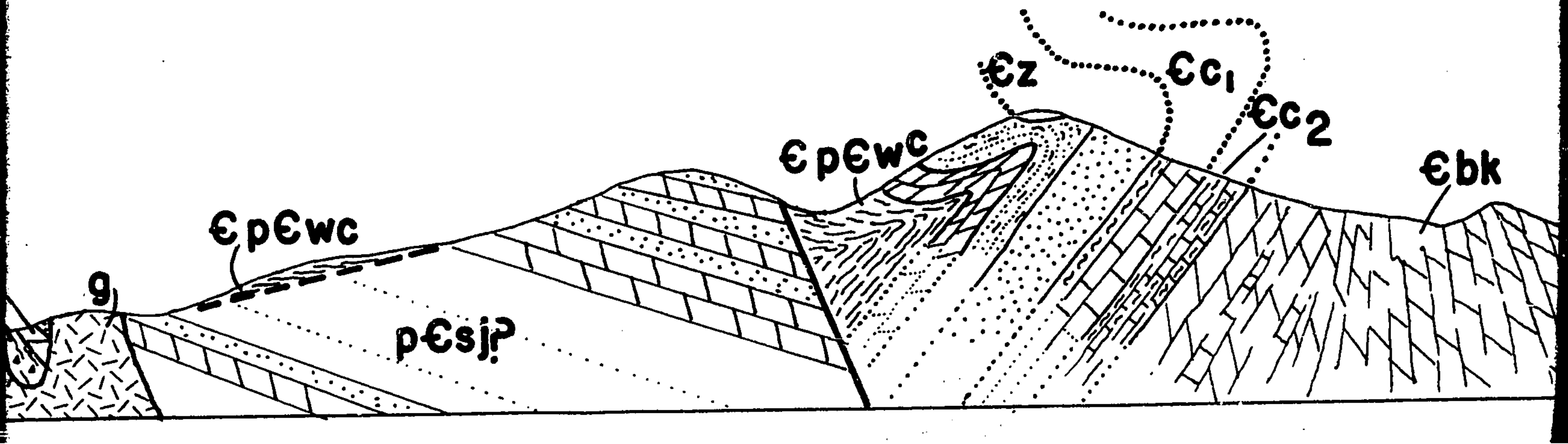
GEOLOGIC CROSS-SECTIO



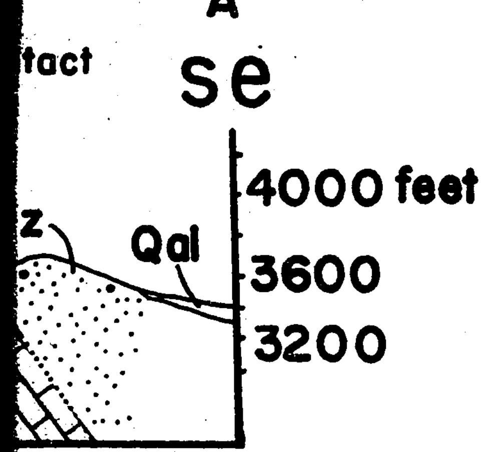


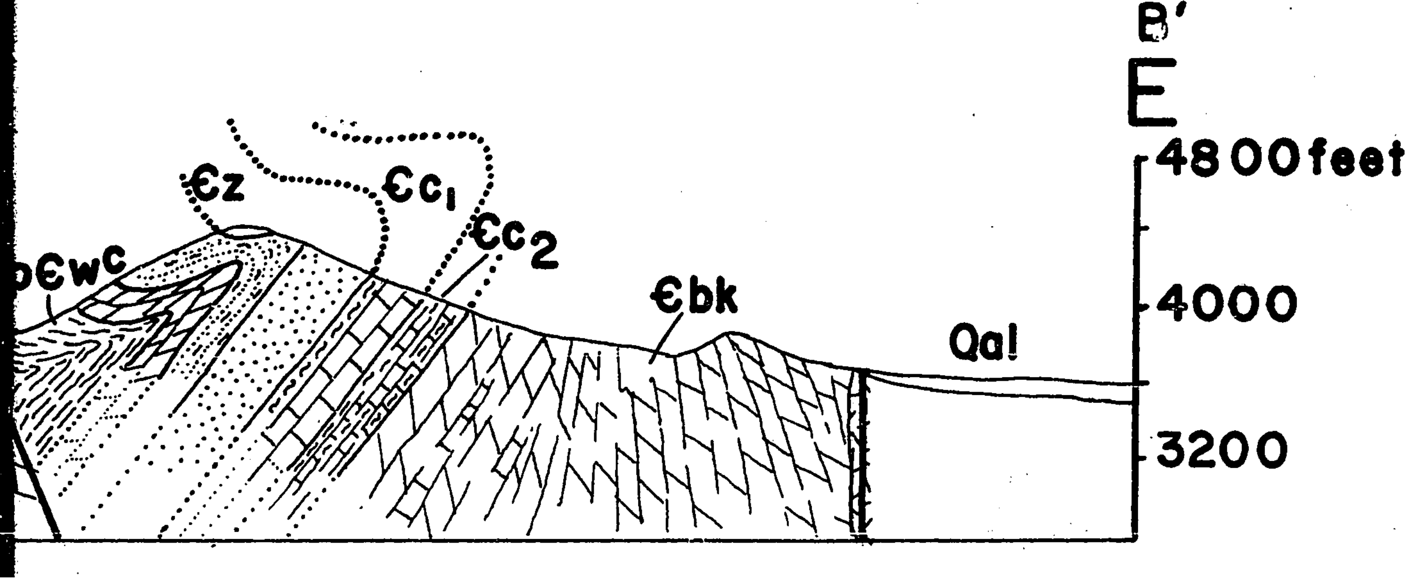
-SECTIONS, QUARTZITE MOUNT

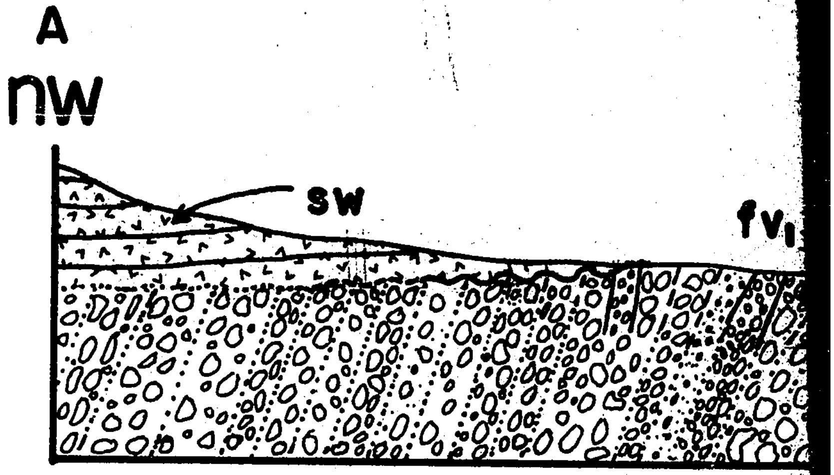




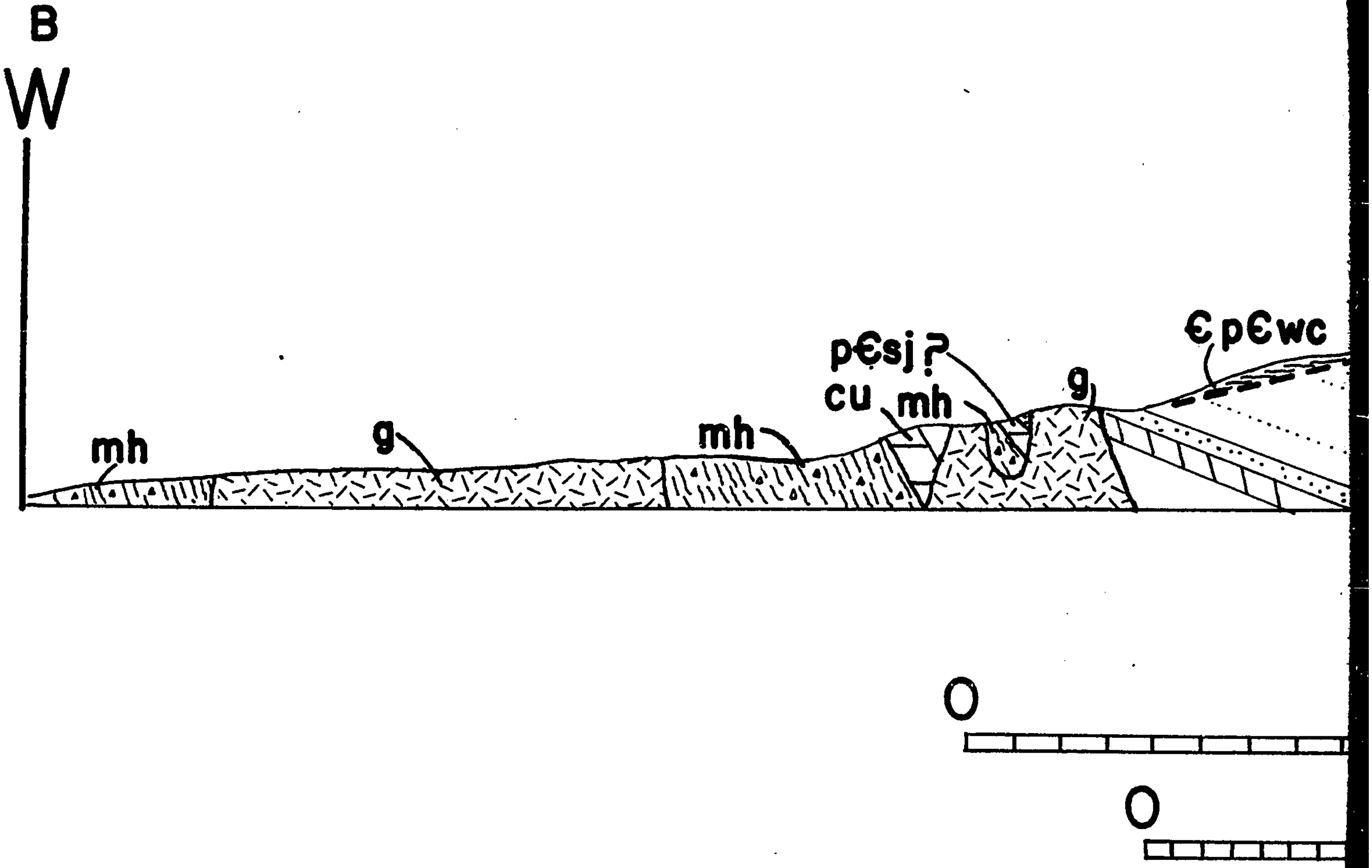
RTZITE MOUNTAIN



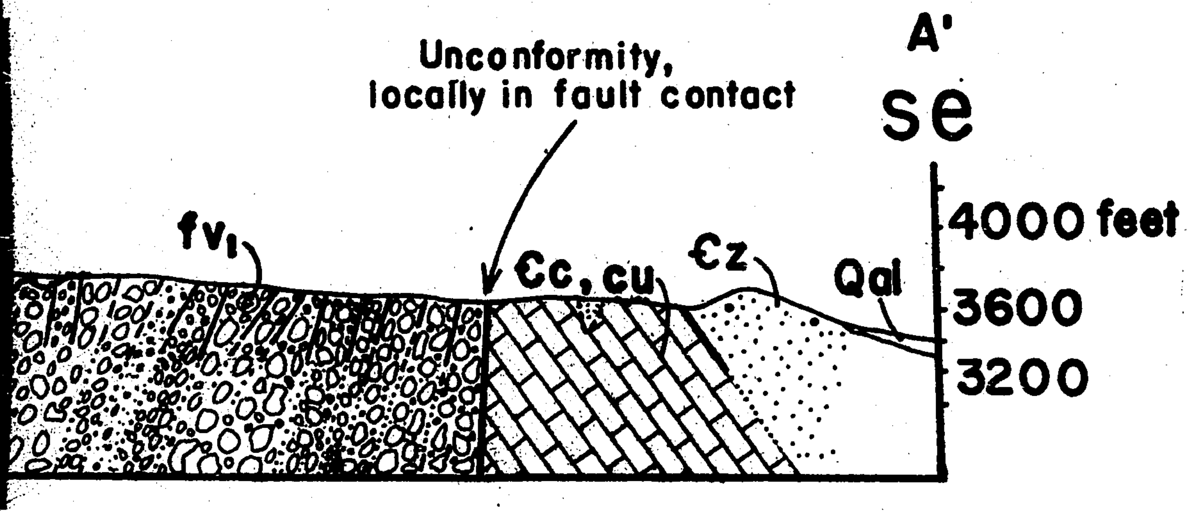


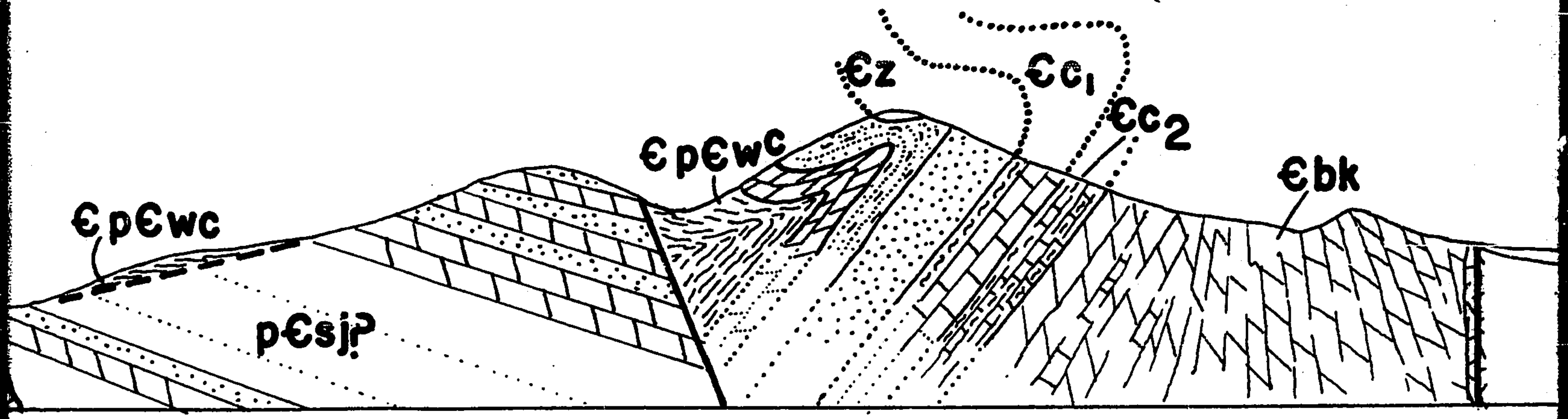


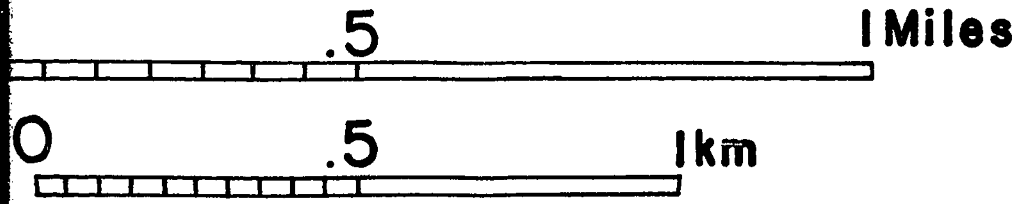
A
nw
sw
fv1



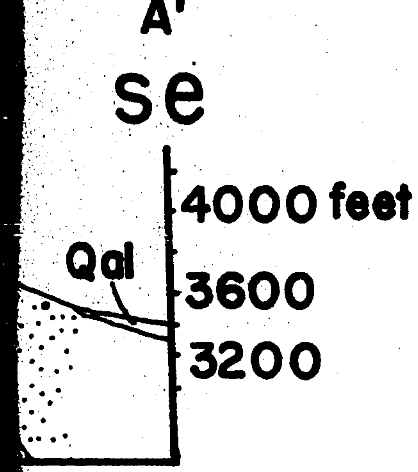
B
W
mh
g
mh
pꞒsj ?
cu
mh
g
Ꞓ pꞒwc
0
0


A'
se
Unconformity, locally in fault contact
fv1
€c, cu
€z
Qal
4000 feet
3600
3200


€z
€c1
€c2
€p€wc
€p€wc
€bk
p€sj?


.5
1 Miles
0
.5
1 km

PLAT


A'
se
4000 feet
Qal
3600
3200

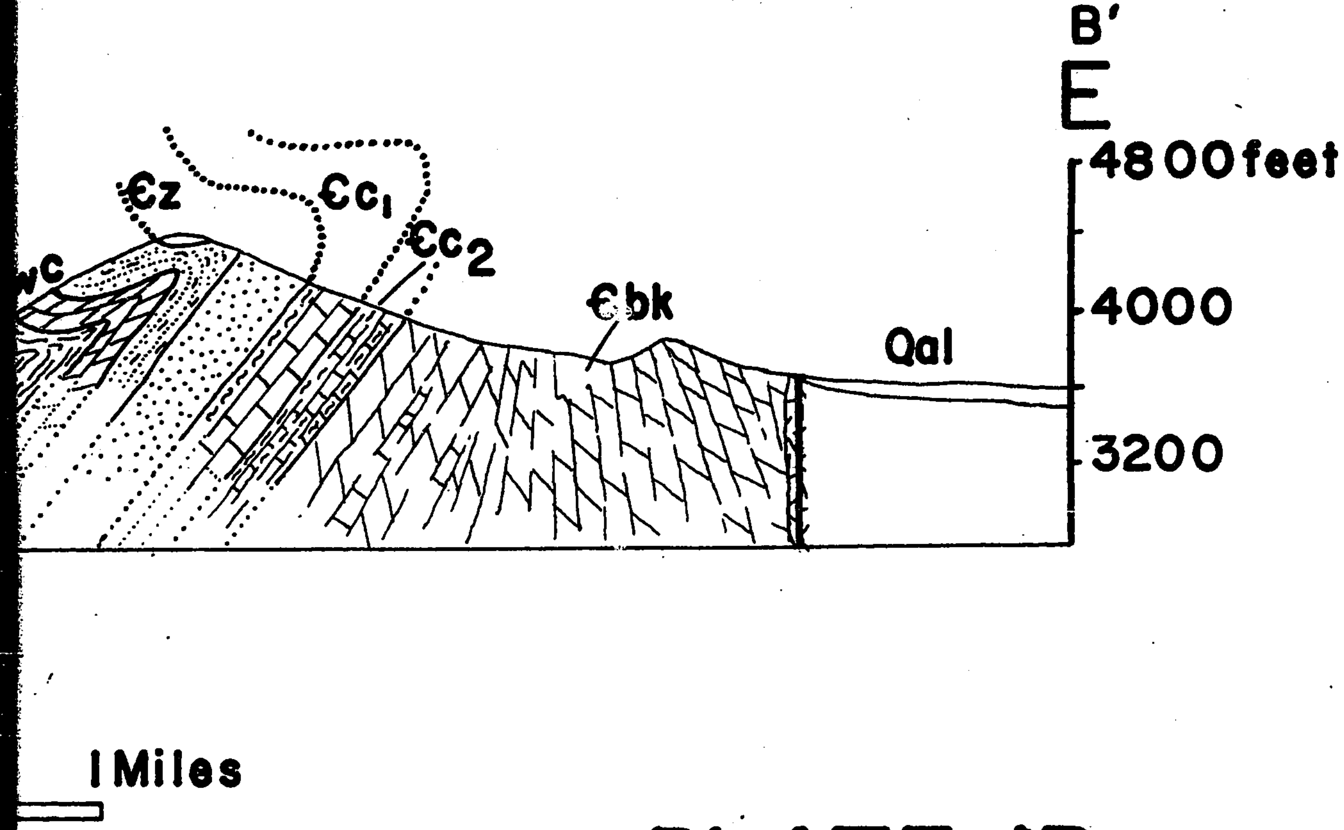
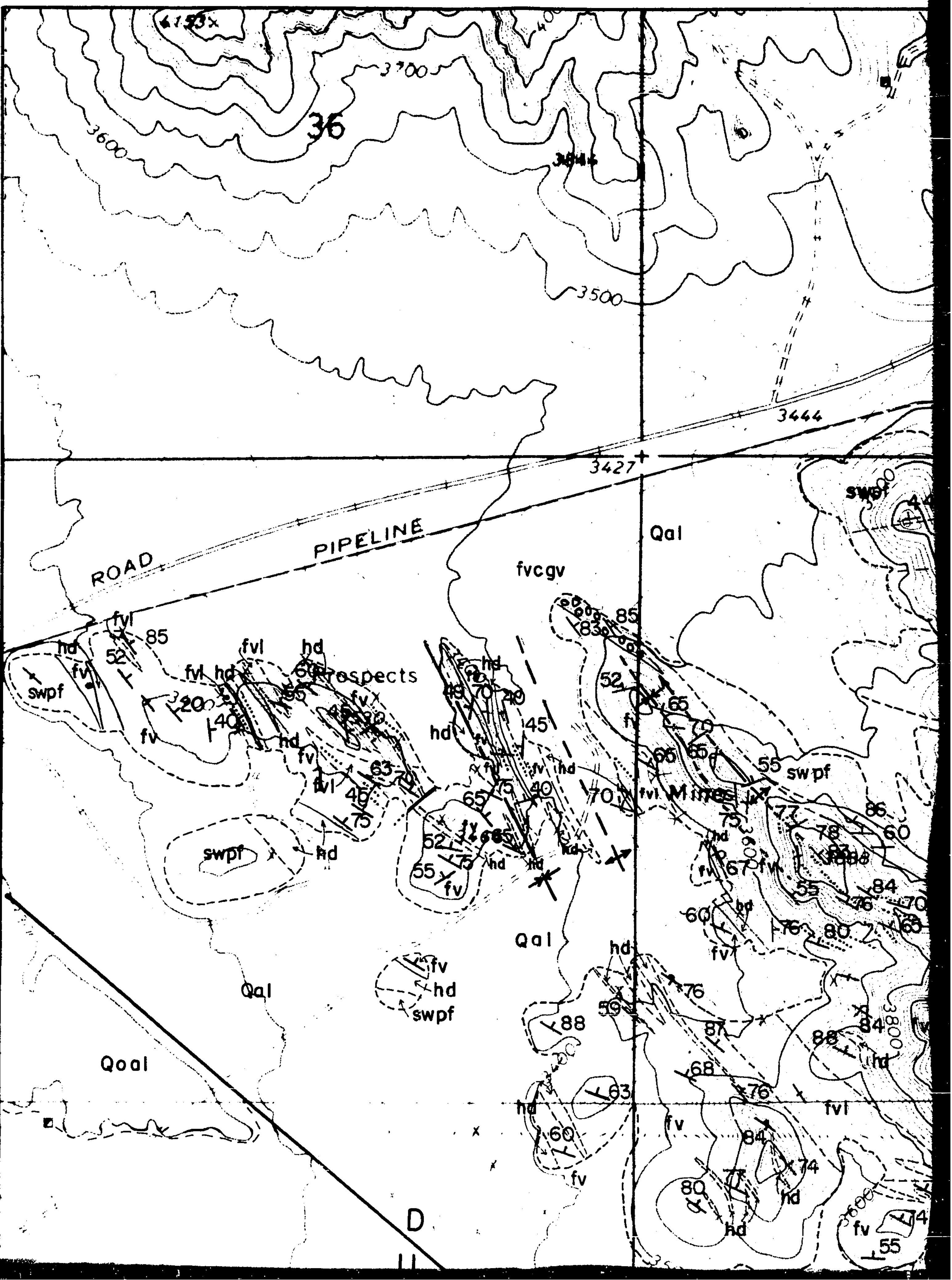
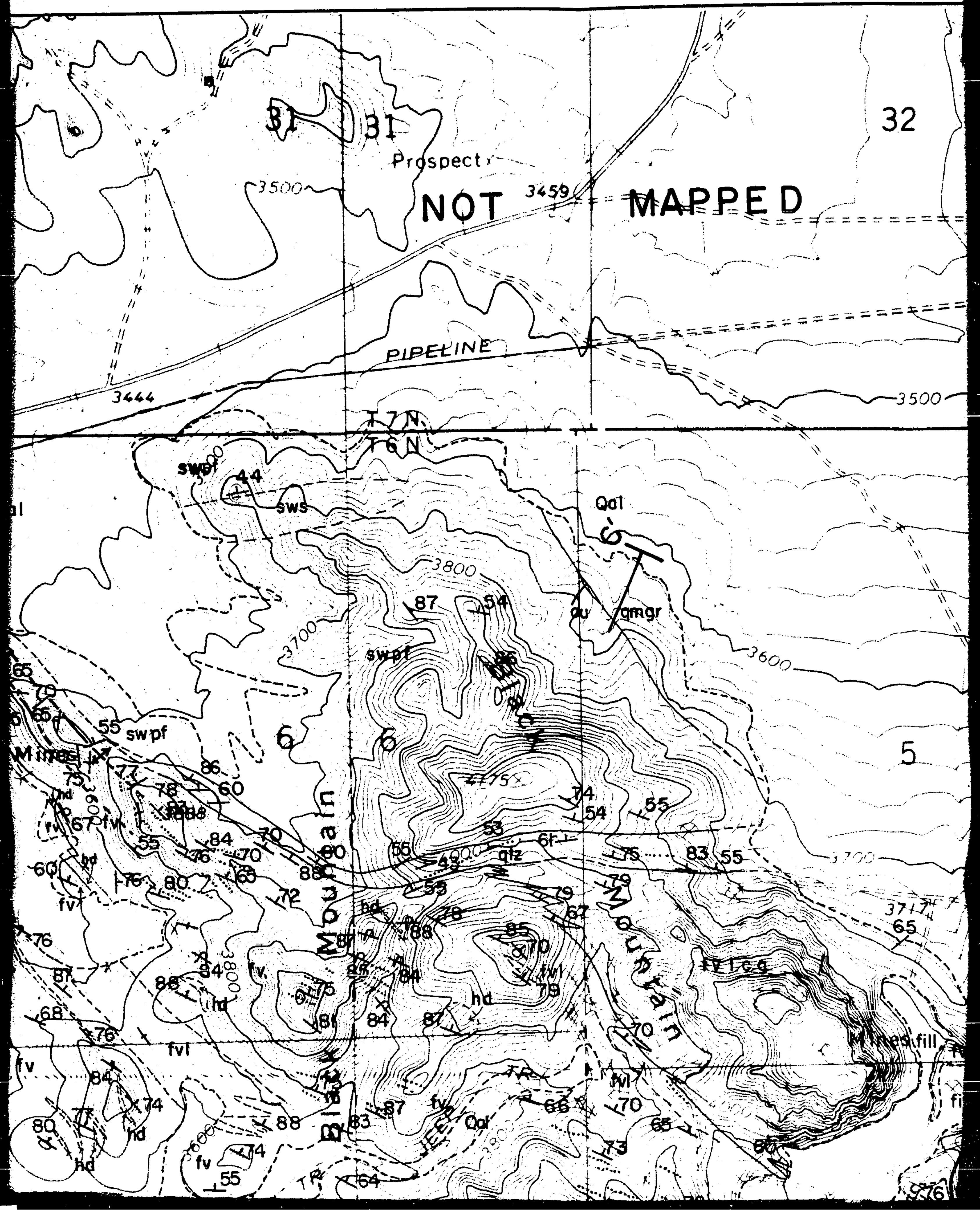
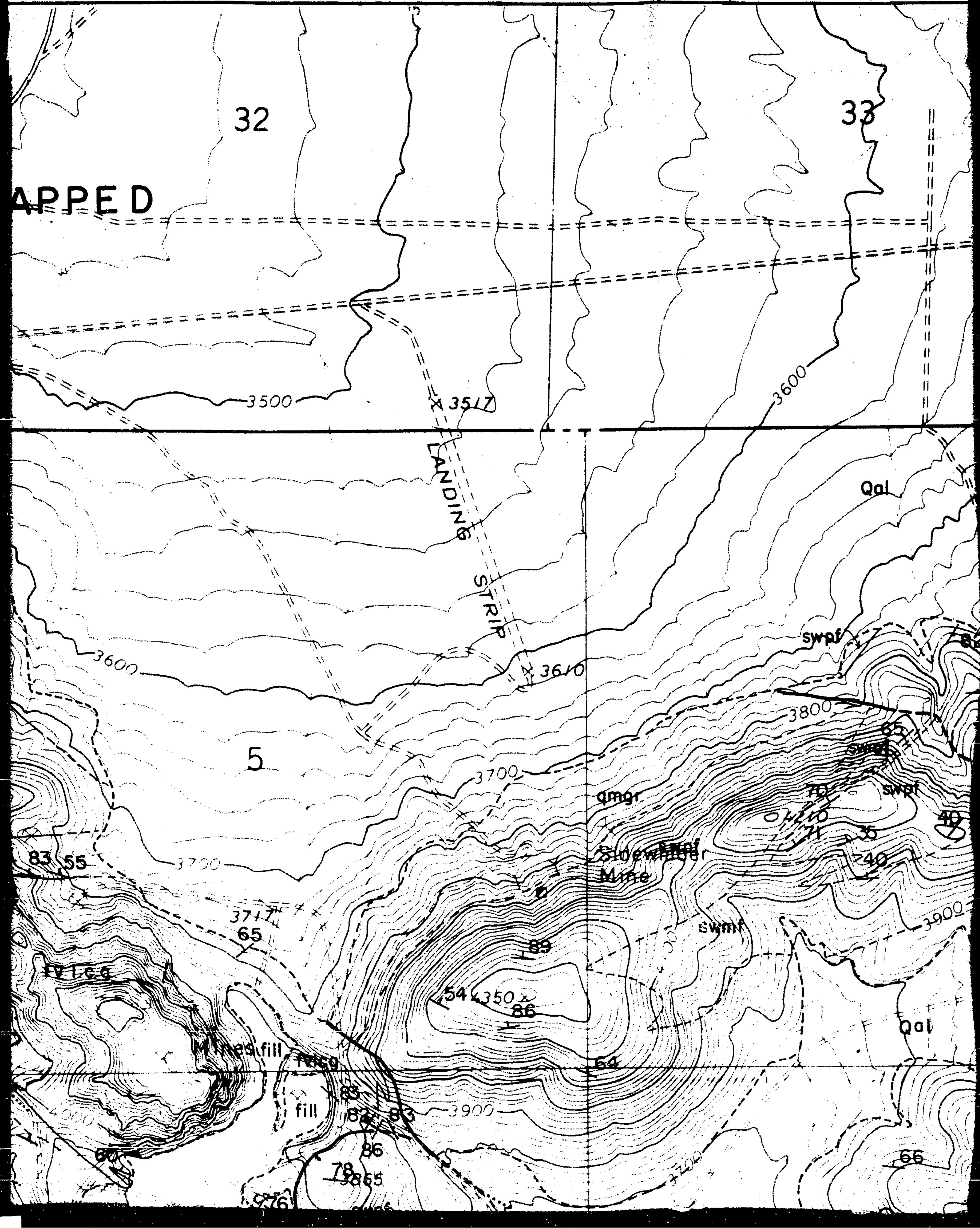

B'
E
4800 feet
Єz
Єc1
Єc2
wc
Єbk
4000
Qal
3200
1 Miles

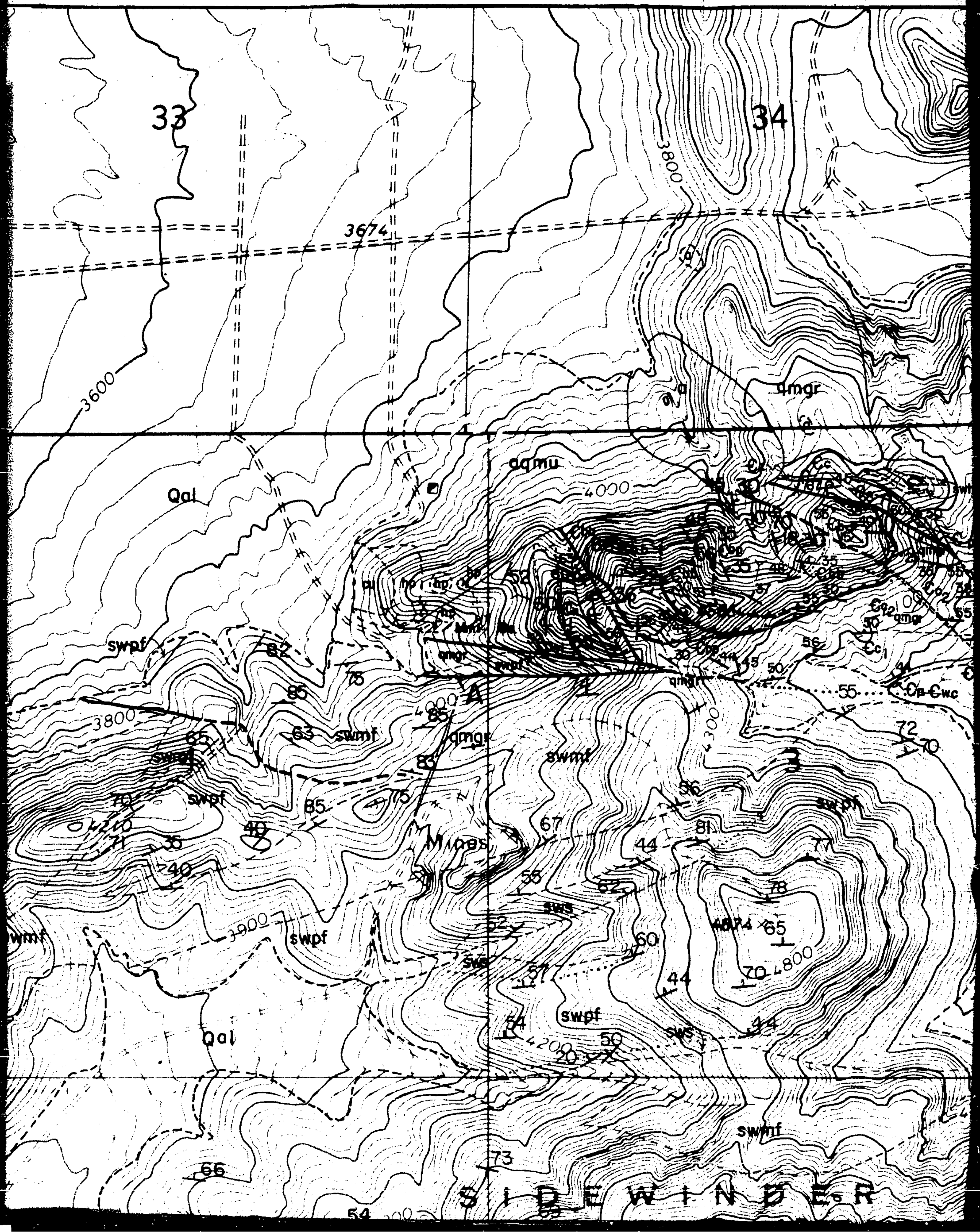
PLATE IB

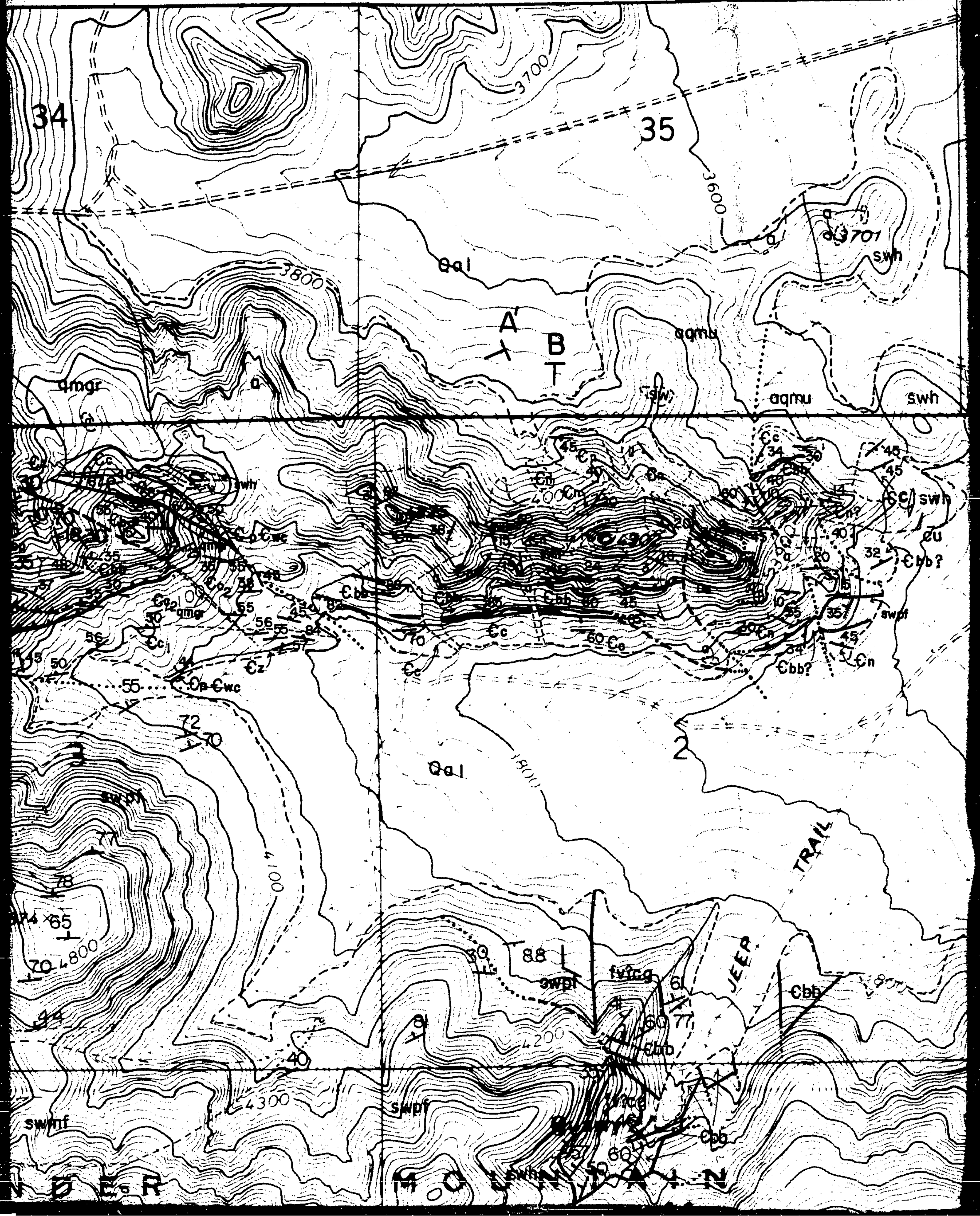


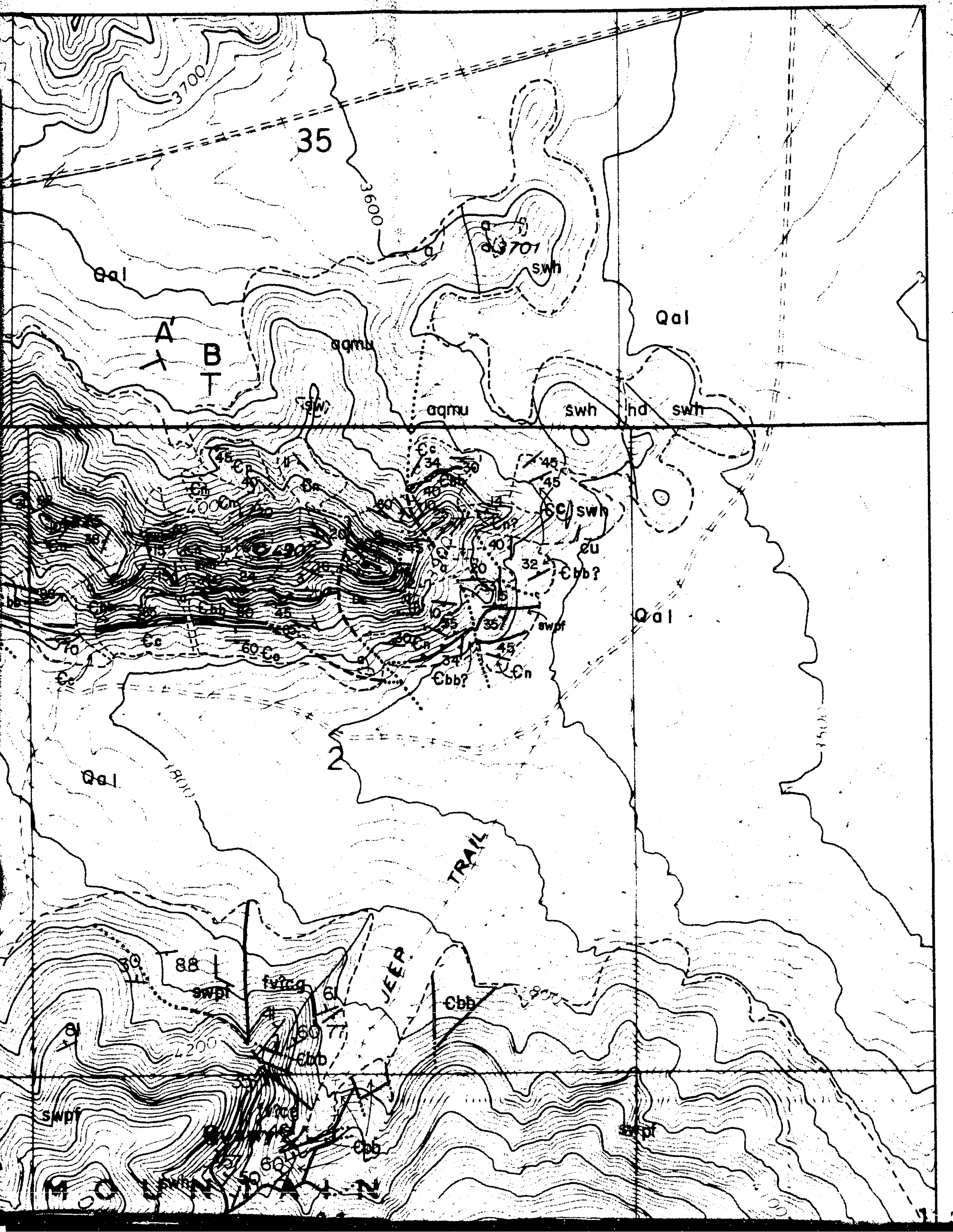
4153
3700
36
3600
3644
3500
3444
3427
ROAD
PIPELINE
Qal
fvcgv
swpf
fvl
hd
fv
prospects
Mines
Qoal
D
85
52
20
40
55
45
63
70
75
65
83
77
78
86
60
84
76
80
88
59
87
68
74
3800
3600

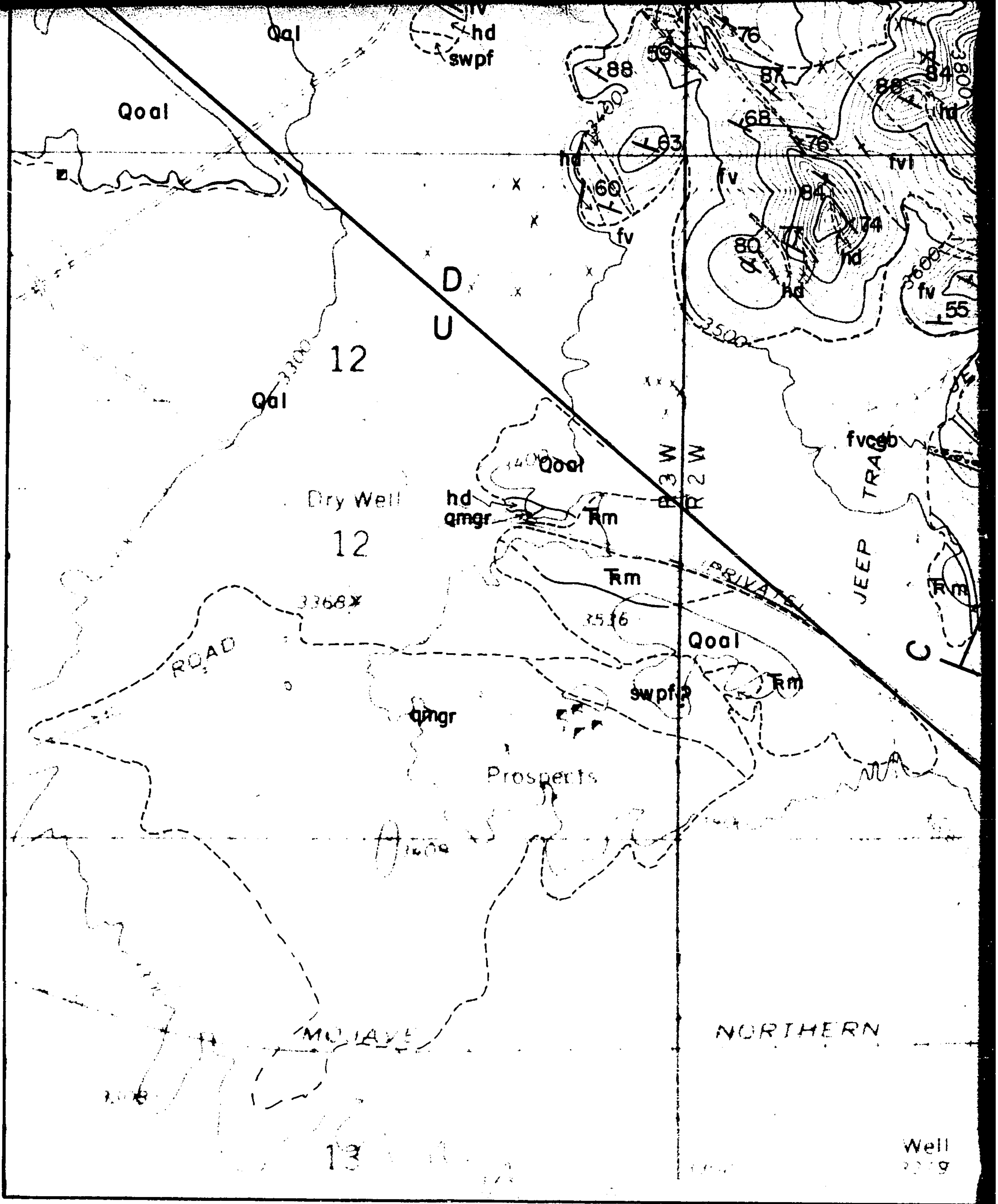

31
31
32
Prospect
3500
3459
NOT MAPPED
PIPELINE
3444
3500
T7N
T6N
swpf
44
sws
Qal
3800
au
qmgr
3700
swpf
3600
6
6
5
Mines
swpf
55
86
60
hd
fv
67
fvl
74
54
55
53
qtz
Mountain
Mountain
3700
3717
65
fvlcg
hd
3800
fv
hd
hd
fvl
Mines fill
fvl
fv
fv
JEEP TR
Qal
3600
hd
fv
55
64
66
70
65
73
76


32
33
APPED
3500
3517
LANDING STRIP
3600
Qal
swpf
3610
3800
65
5
3700
qmgr
70
4210
71
35
40
Sidewinder Mine
83
55
3700
3717
65
Tvica
89
54
3350
86
swmf
3900
Qal
Mines fill
fill
83
82
83
86
64
3900
4000
60
78
3865
76
66
3700


33
34
3800
3674
3600
Qal
aqmu
qmgr
4000
swpf
swmf
sws
A
1
3
Mines
4210
4674
4800
4200
3900
Cp Cwc
SIDEWINDER

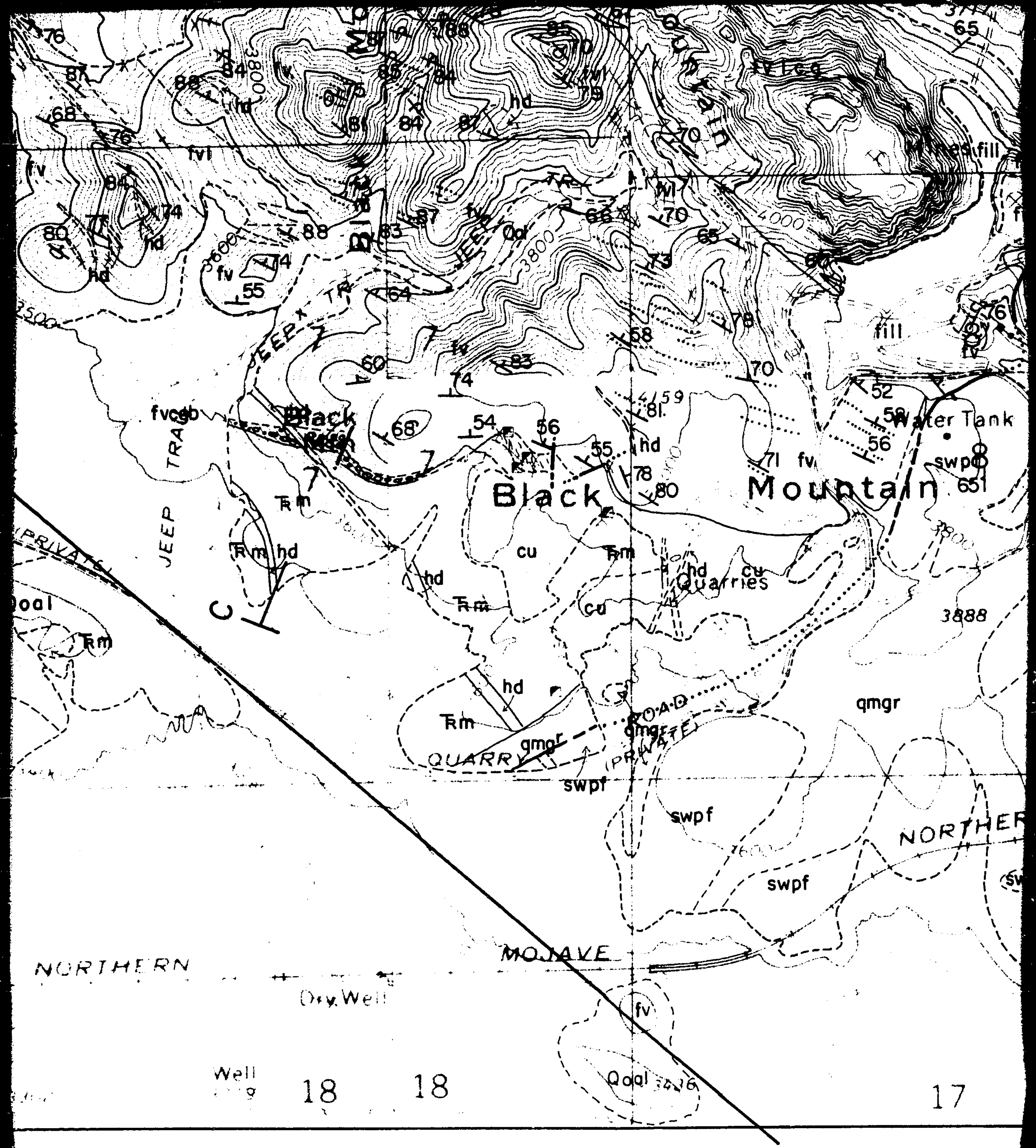

34
35
3
2
3700
3600
3701
3800
Qal
A
B
aqmu
swh
qmgr
a
Ꞓc
Ꞓbb
Ꞓn
Ꞓz
Ꞓp Ꞓwc
Ꞓc₁
Ꞓo₂
Ꞓbb?
Ꞓn?
Ꞓu
swpf
4000
4800
4200
4300
fv?cg
JEEP
TRAIL
swpf
swhf
swh
N B E R
M O U N T A I N


3700
35
3600
a
a
3701
swh
Qal
A'
B
aqmu
sw
aqmu
swh
hd
swh
Qal
45
Ꞓn
Ꞓn
Ꞓn
4000
Ꞓc
34
Ꞓbb
30
40
45
45
Ꞓc
swh
14
Ꞓn?
40
Ꞓu
32
Ꞓbb?
Ꞓn
36
Ꞓbb
Ꞓbb
Ꞓc
60
Ꞓc
45
Ꞓc
Ꞓn
34
Ꞓbb?
45
Ꞓn
35
swpf
Qal
2
Qal
3800
TRAIL
JEEP
30
88
swpf
fv?cg
61
60
77
81
4200
Ꞓbb
Ꞓbb
swpf
Ꞓbb
swpf
60
M O U N T A I N



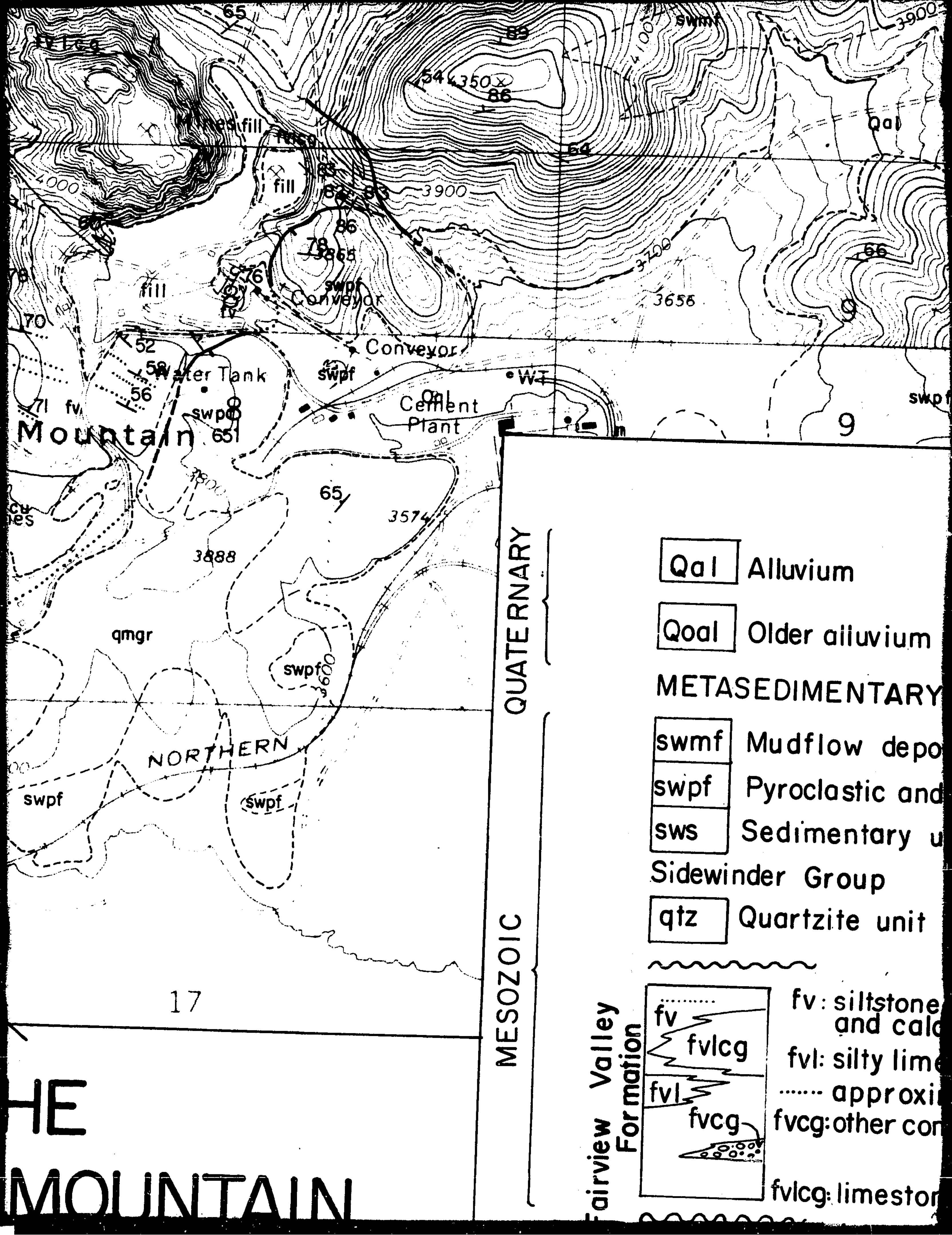
GEOLOGI

BLACK MOUNTAIN-



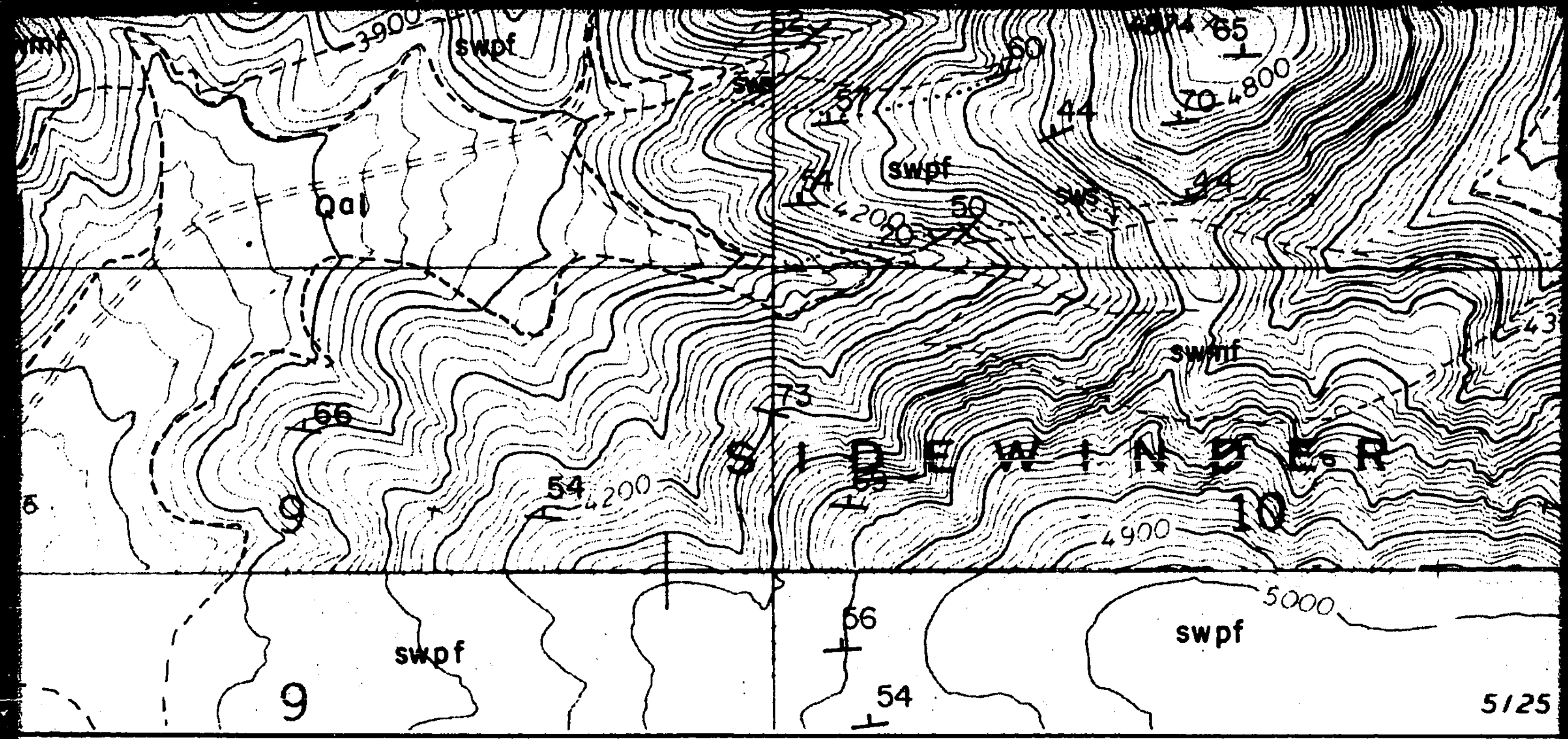
OLOGIC MAP OF THE

TAIN-SIDEWINDER MOUNT


fvlcg
Mines
fill
fvlcg
fill
fill
fv
Conveyor
Conveyor
Water Tank
swpf
swpf
swpf
Qal
Cement Plant
WT
Mountain
651
3900
3700
3656
3865
4000
4350
3574
3888
3600
qmgr
swpf
NORTHERN
swpf
swpf
swmf
Qal
swpf
9
9
8
17
65
89
54
86
64
83
82
83
86
78
76
60
70
52
58
56
71
66
65
QUATERNARY
MESOZOIC
Qal Alluvium
Qoal Older alluvium
METASEDIMENTARY
swmf Mudflow depo
swpf Pyroclastic and
sws Sedimentary u
Sidewinder Group
qtz Quartzite unit
Fairview Valley Formation
fv
fvlcg
fvl
fvcg
fv: siltstone
and calc
fvl: silty lime
approxi
fvcg: other con
fvlcg: limestor

HE

MOUNTAIN



EXPLANATION

Qal Alluvium

Qoal Older alluvium

ETASEDIMENTARY ROCKS

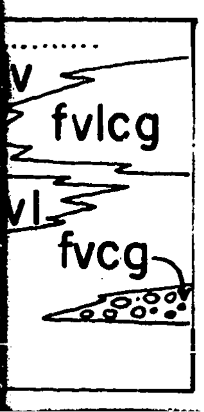
wmf Mudflow deposits

wpf Pyroclastic and flow units

ws Sedimentary units

idewinder Group

qtz Quartzite unit



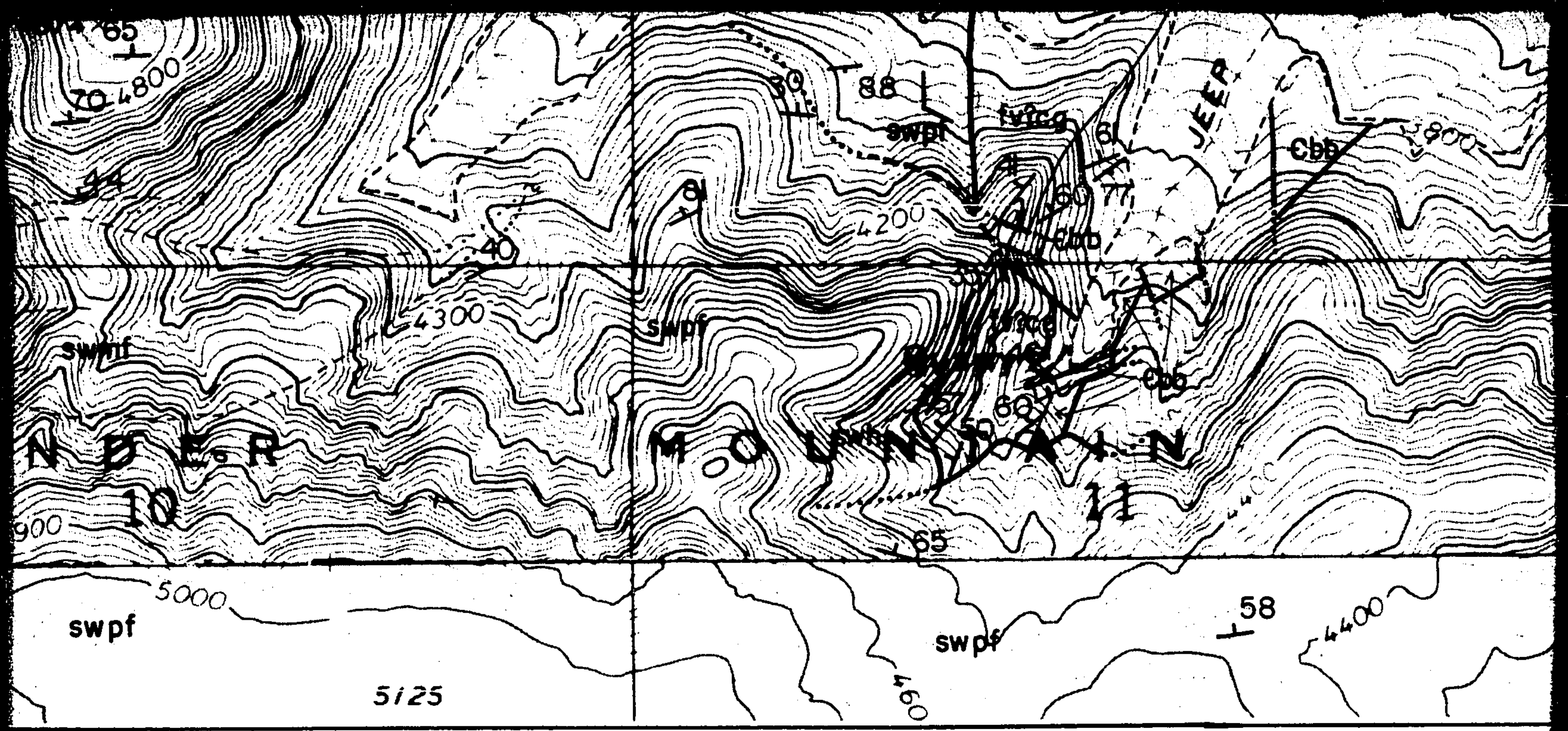
fv: siltstones, calcareous siltstones and mudstones, sandstones, and calc-silicate hornfels.

fvl: silty limestones, limestones

······ approximate location of some major conglomerate lenses

fvcg: other conglomerates: fvcgv-volcanic mudflow
fvcgb-basal conglomerate

fvlcg: limestone cobble conglomerate



ANATION

istones,sandstones,

conglomerate lenses
dflow
omerate

INTRUSIVES

MESOZOIC

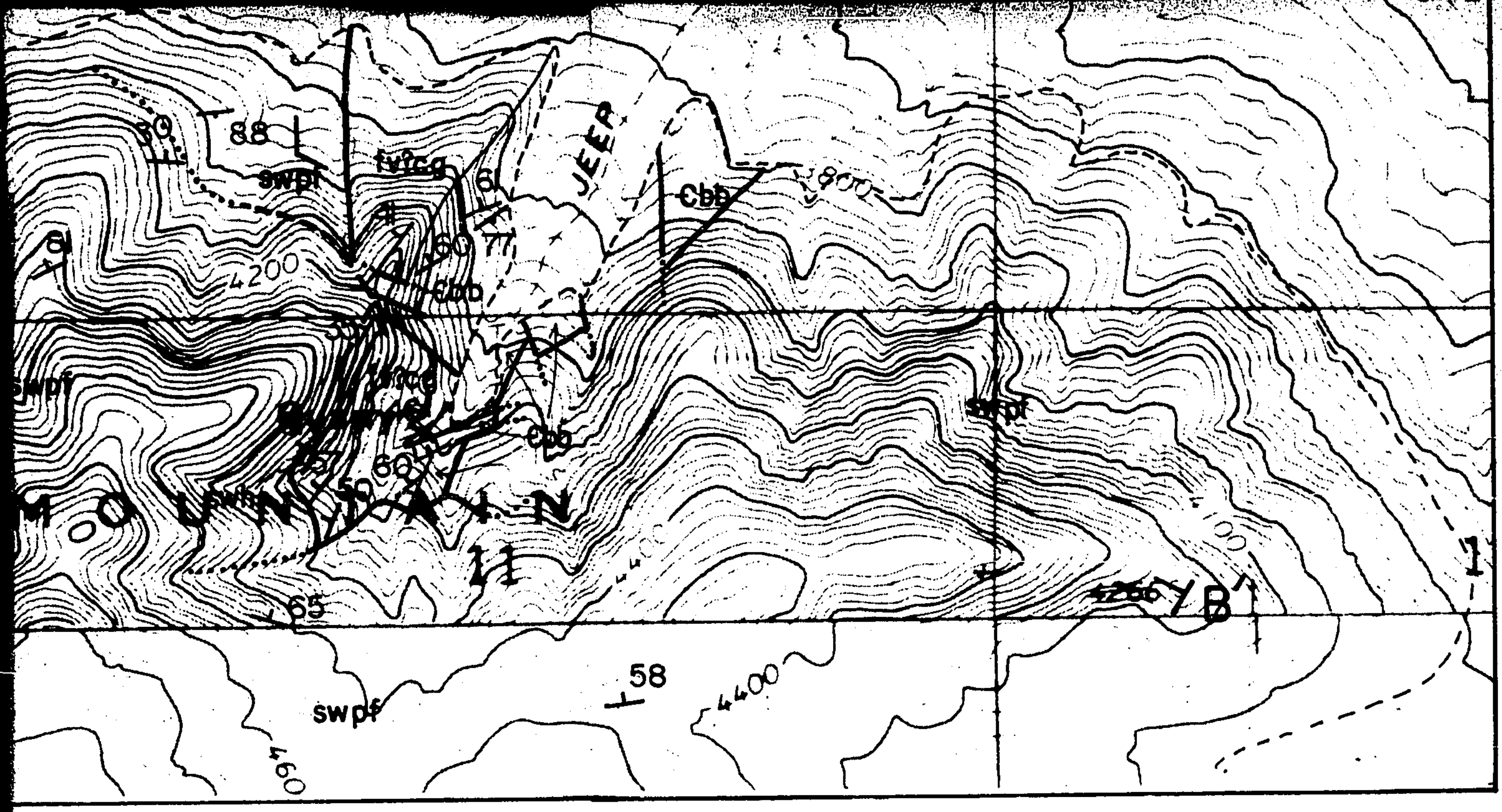
a	alaskite
aqmu	undifferentiated alaskite and quar
qmgr	undifferentiated quartz monzoni
hp	hornblende-plagioclase rock
hd	felsic and intermediate hypabys
swh	hypabyssal dikes associated with

L. Triassic

TRm	monzonite

CONTACTS

definite, approximate, inferred or conc

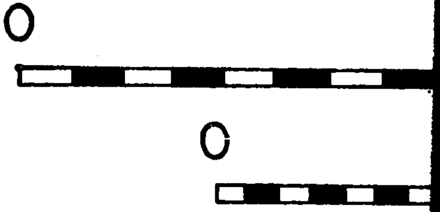


INTRUSIVES

	a	alaskite
	aqmu	undifferentiated alaskite and quartz monzonite
	qmgr	undifferentiated quartz monzonite/ granitic rocks
	hp	hornblende-plagioclase rock
	hd	felsic and intermediate hypabyssal dikes
	swh	hypabyssal dikes associated with Sidewinder Group (?)
L. Triassic	TRm	monzonite

CONTACTS

GEOLOGI
BLACK MOUNTAIN-S
A

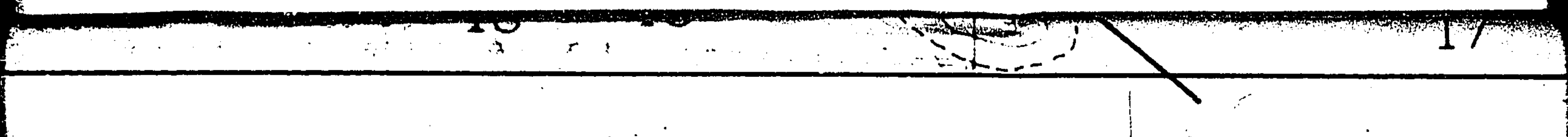


contour

base: U.S. Geologi
Apple Valley N., St
quad

Geology by E.

PLATE IIA



OLOGIC MAP OF THE TAIN - SIDEWINDER MOUNT AREA

N

SCALE

0 .5 I miles

0 .5 I km

contour interval: 20 feet

base: U.S. Geological Survey 7 1/2' Turtle Valley,
Apple Valley N., Stoddard Well, and Fairview Valley
quadrangles

Geology by E.L. Miller, 1976

17

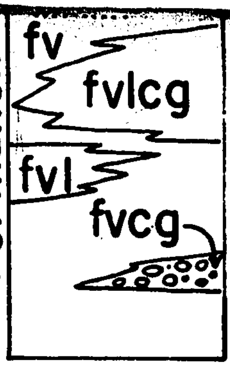
THE MOUNTAIN

es

ey,
ley

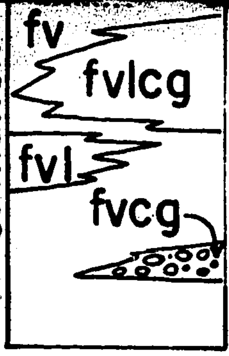
MES

Fairview Valley Formation



and c
fvl: silty li
······· appro
fvcg: other c
fvlcg: limes

Dev. Miss.	Mm?	Monte Cristo L
Dev.	Ds Dsi	Sultan Li
Cambrian	€n €nd	Nopah For
	€bb €bp	Bonanza King
	$€c_{1,2}$	Carrara Forn
	€z	Zabriskie Qu
p€	€p€wc	Wood Canyon
Paleoz.(?)	cu	Undifferentia



v: siltstones, calcareous siltstones and mudstones, sandstones and calc-silicate hornfels.

fvl: silty limestones, limestones

······· approximate location of some major conglomerate lenses

fvcg: other conglomerates: fvcgv-volcanic mudflow
fvcgb-basal conglomerate

fvlcg: limestone cobble conglomerate

Mm?	Monte Cristo Limestone(?)
Ds Dsi	Sultan Limestone Dsi: Ironside Member, ······ stromatoporoids
€n €nd	Nopah Formation €nd: Dunderberg Shale Member
€bb €bp	Bonanza King Formation €bb: Banded Mountain Member €bp: Papoose Lake Member
$€c_{1,2}$	Carrara Formation, lower calcareous(1) and upper pelitic(2) ur
€z	Zabriskie Quartzite
€p€wc	Wood Canyon Formation
cu	Undifferentiated

astones, sandstones,

conglomerate lenses
udflow
lomerate

...... stromatoporoids

Member

in Member
Member

upper pelitic(2) unit

L. Triass | TRm | monzonite

CONTACTS

definite, approximate, inferred or conc

FAULTS

thrust fault: barbs on upper plate

high angle faults

BEDDING

20 30 ⊕

strike and dip of bedding: inclined, overt

FOLIATION

20

strike and dip of inclined, vertical foliat

▨ zone of alteration

L. Triass

TRm monzonite

CONTACTS

——— - - - ·········

definite, approximate, inferred or concealed

FAULTS

▼▼▼ ▾ ▾ ▾ ·······

thrust fault: barbs on upper plate

——— — — — ·········

high angle faults

FOLDS

anticline, syncline

BEDDING

┴20 ┴30 ┼ ⊕

strike and dip of bedding: inclined, overturned, vertical, horizontal

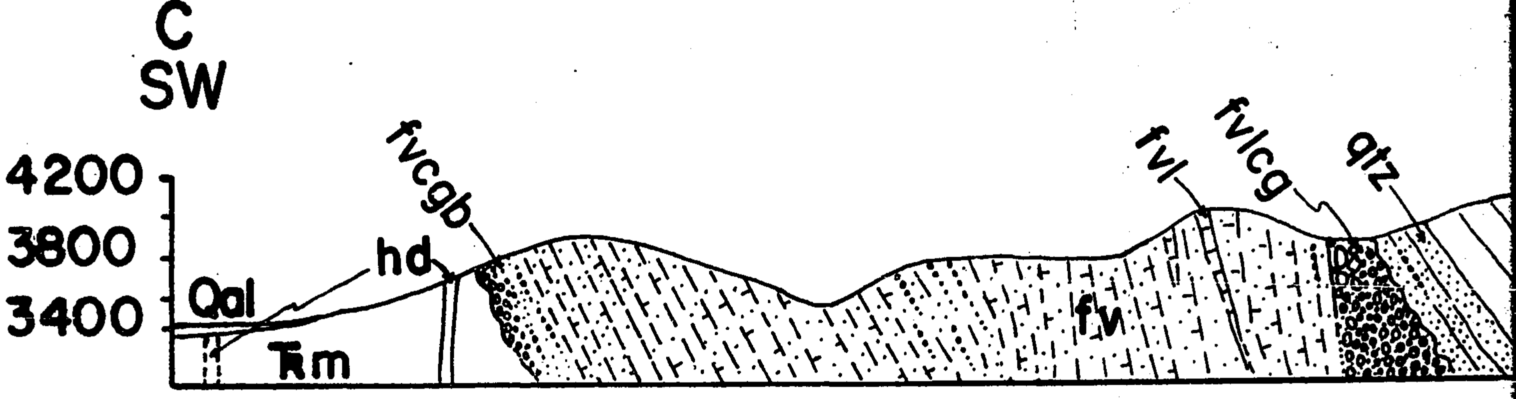
FOLIATION

▲20 ✦

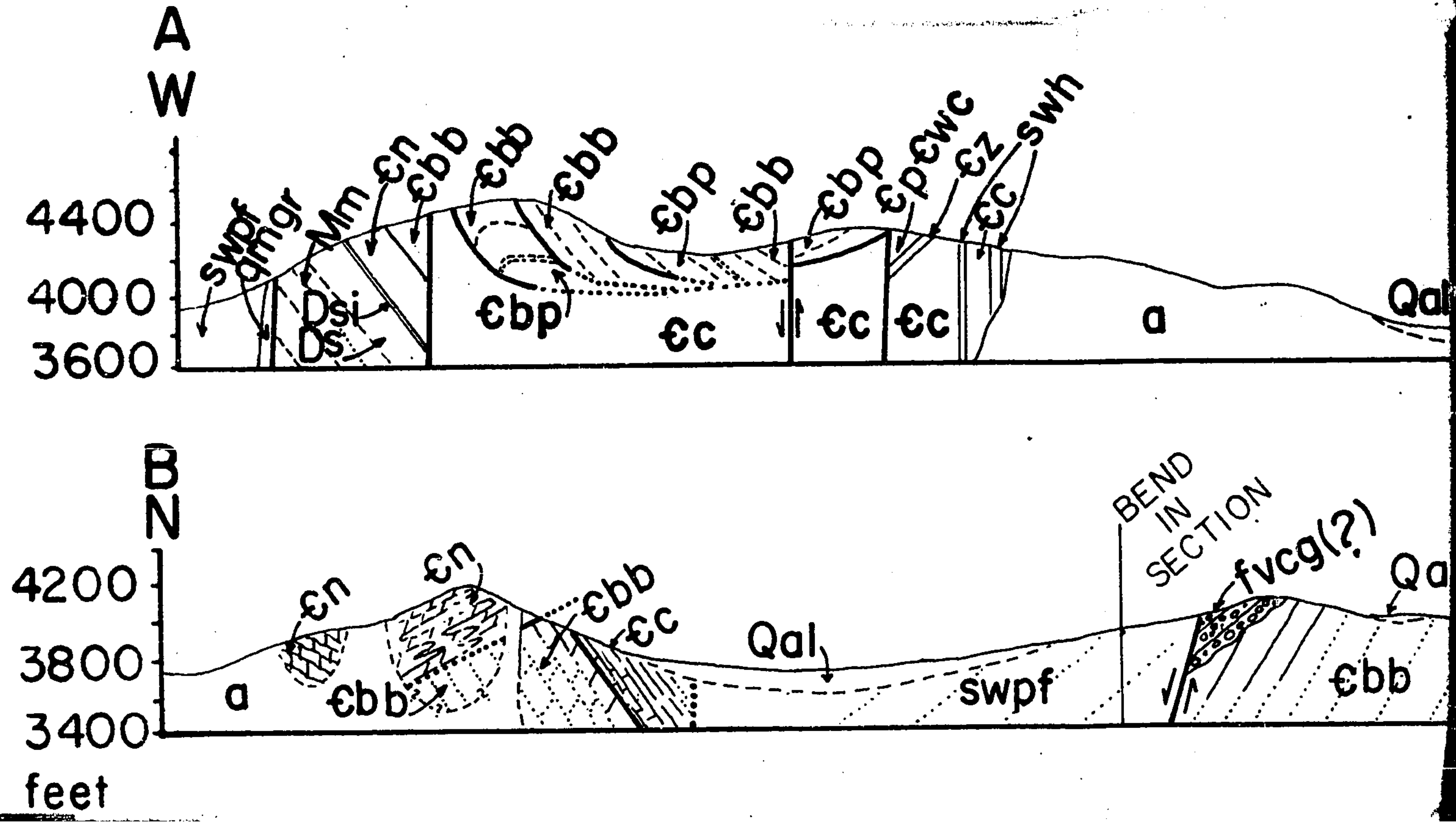
strike and dip of inclined, vertical foliation

▨ zone of alteration

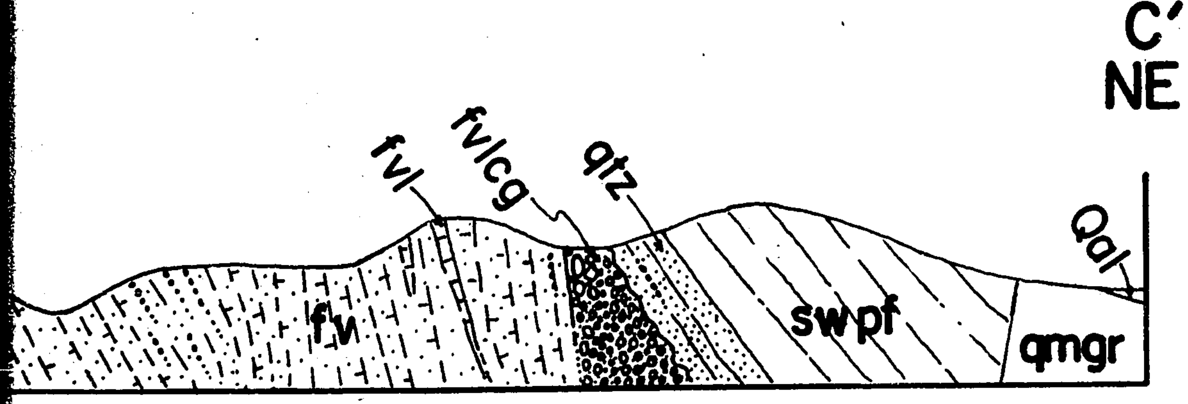
GEOLOGIC CROSS SE
BLACK MOUNTAI



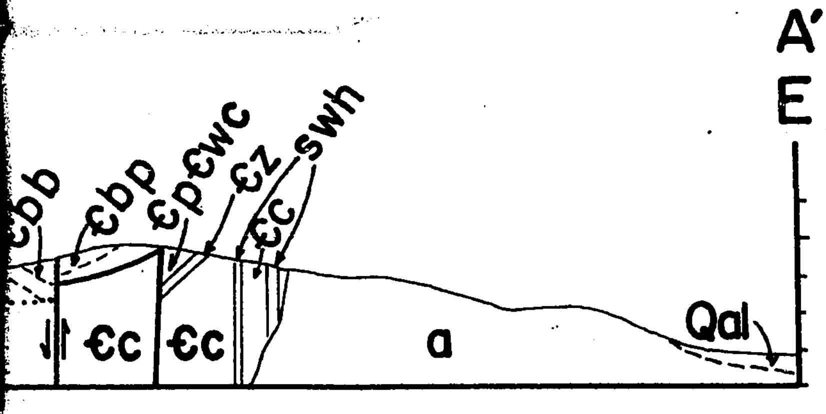
GEOLOGIC CROSS SE
SIDEWINDER MOUN

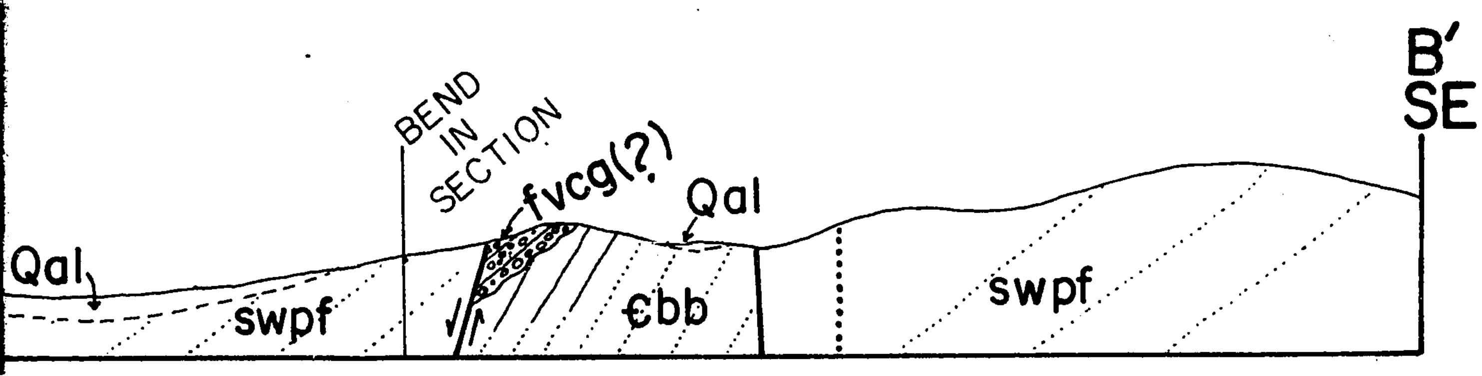


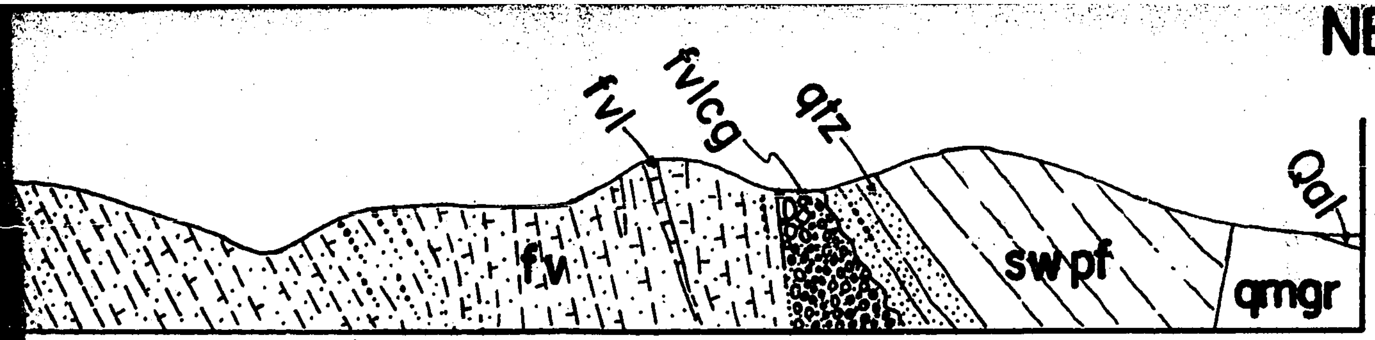
GIC CROSS SECTION
LACK MOUNTAIN



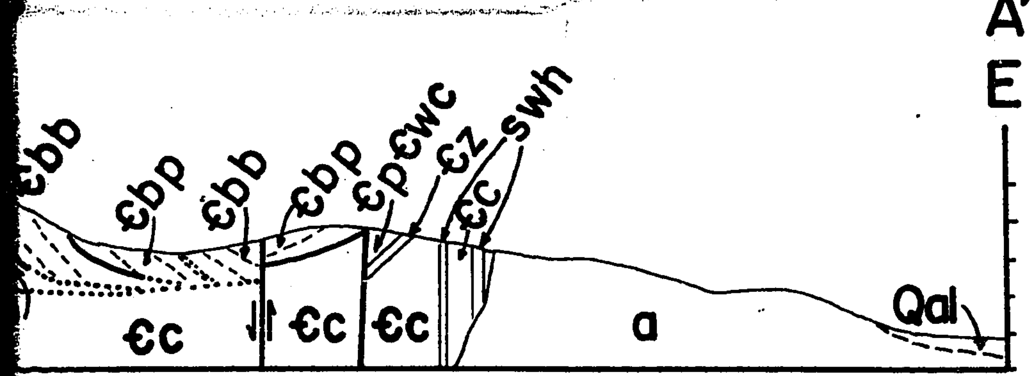
GIC CROSS SECTIONS
WINDER MOUNTAIN

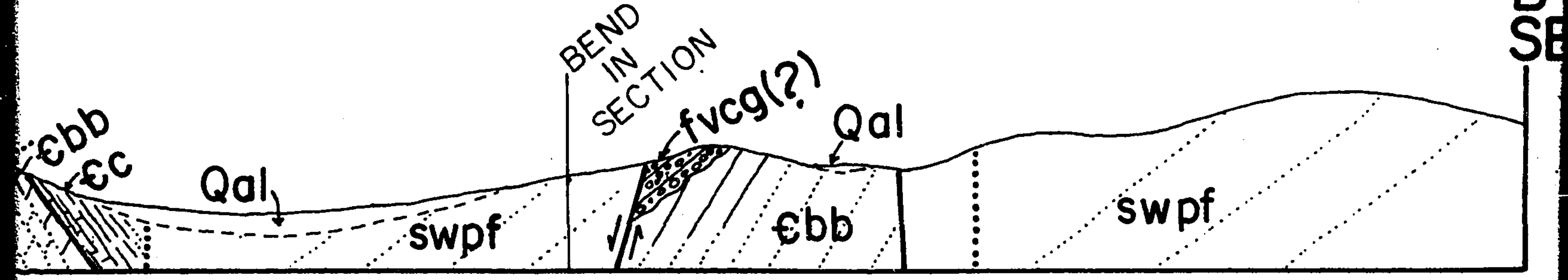






OLOGIC CROSS SECTIONS
SIDEWINDER MOUNTAIN





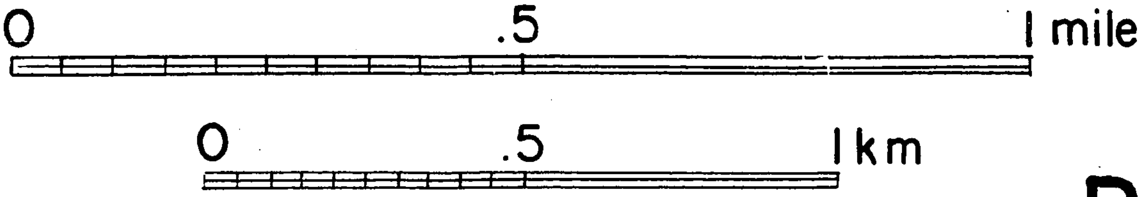


PLATE IIB

PLATE III

PRELIMINARY GEOLOGIC MAP
PIERCE QUARRY AREA
VICTORVILLE QUADRANGLE, CALIF.

EXPLANATION

Quaternary

Qal

Alluvium

/ Contact: definite, approximate

/ Fault, high angle

20 Strike and dip of bedding, not kno
whether upright or overturned

20 Strike and dip of compositional layering

METASEDIMENTS

Paleozoic(?)

d	qtz	ls

Undifferentiated pre-Mesozoic metasediments, variably contact metamorphosed by multiple intrusive events

d: dolomite

qtz: quartzite

ls: grey limestone, cherty limestone, calc-silicate units, dolomitic limestone, and minor dolomite

IGNEOUS

Cretaceous

Kqm

Biotite quartz monzonite

iu

Undifferentiated Mesozoic intrusive rocks, includes considerable meta-hypabyssal volcanics and hornblende-rich intermediate dike rocks which intrude metasediments

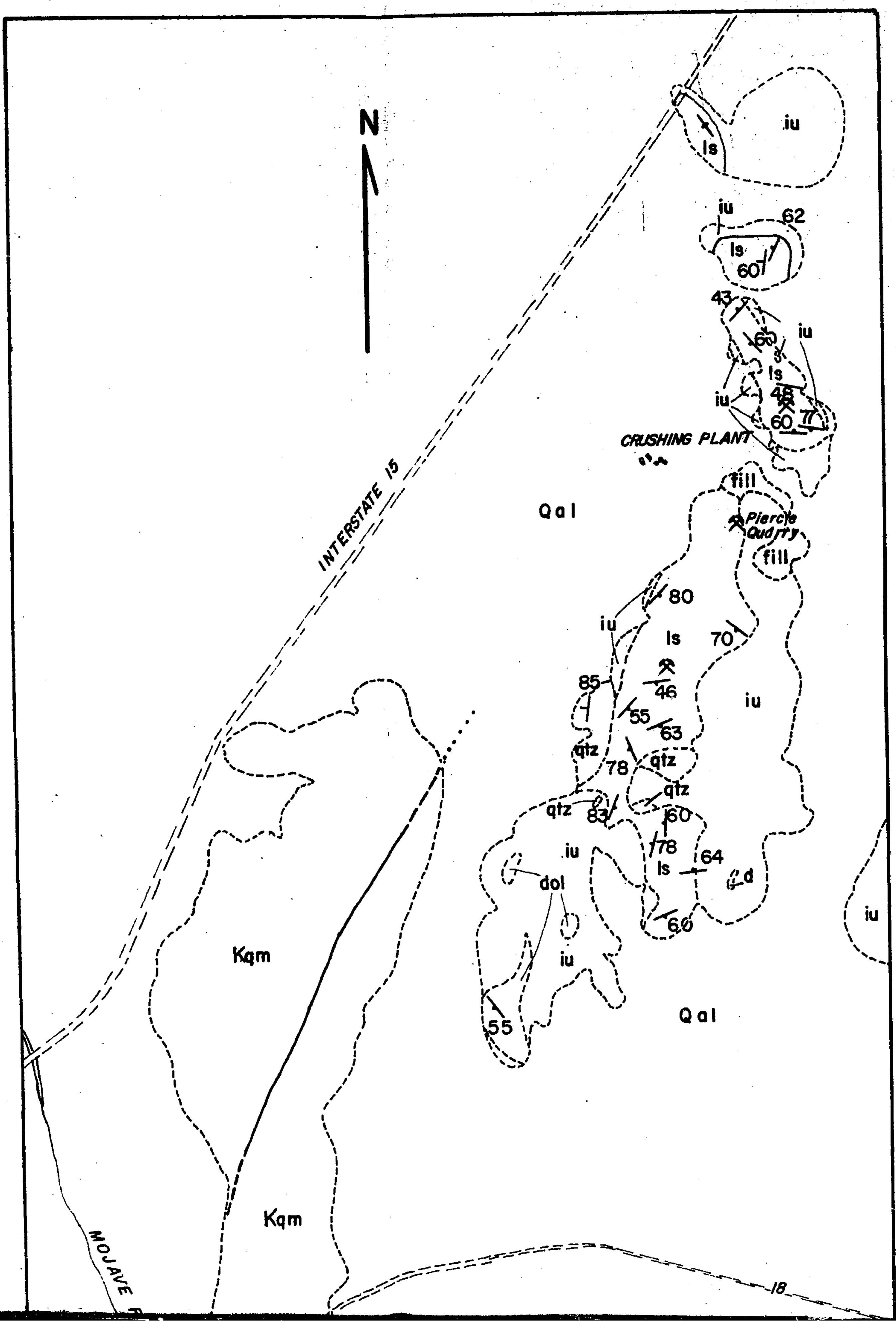
F.

nate

not known
rned

sitional

estone,



EXPLANATION

Quaternary

Qal	Alluvium

╱	Contact: definite, approximate
╱	Fault, high angle
20	Strike and dip of bedding, not known whether upright or overturned
20	Strike and dip of compositional layering

METASEDIMENTS

Paleozoic(?)

d	qtz	ls

Undifferentiated pre-Mesozoic metasediments, variably contact metamorphosed by multiple intrusive events

d: dolomite
qtz: quartzite
ls: grey limestone, cherty limestone, calc-silicate units, dolomitic limestone, and minor dolomite

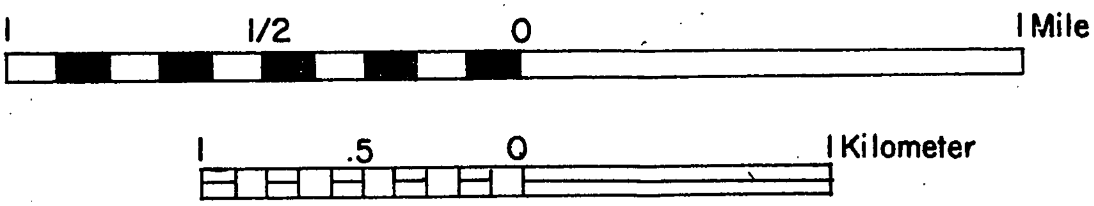
IGNEOUS

Cretaceous

Kqm	Biotite quartz monzonite

iu	Undifferentiated Mesozoic intrusive rocks, includes considerable meta-hypabyssal volcanics and hornblende-rich intermediate dike rocks which intrude metasediments

SCALE



Contour interval 20 feet

Base: U.S.G.S. 7 1/2' Victorville quadrangle hown

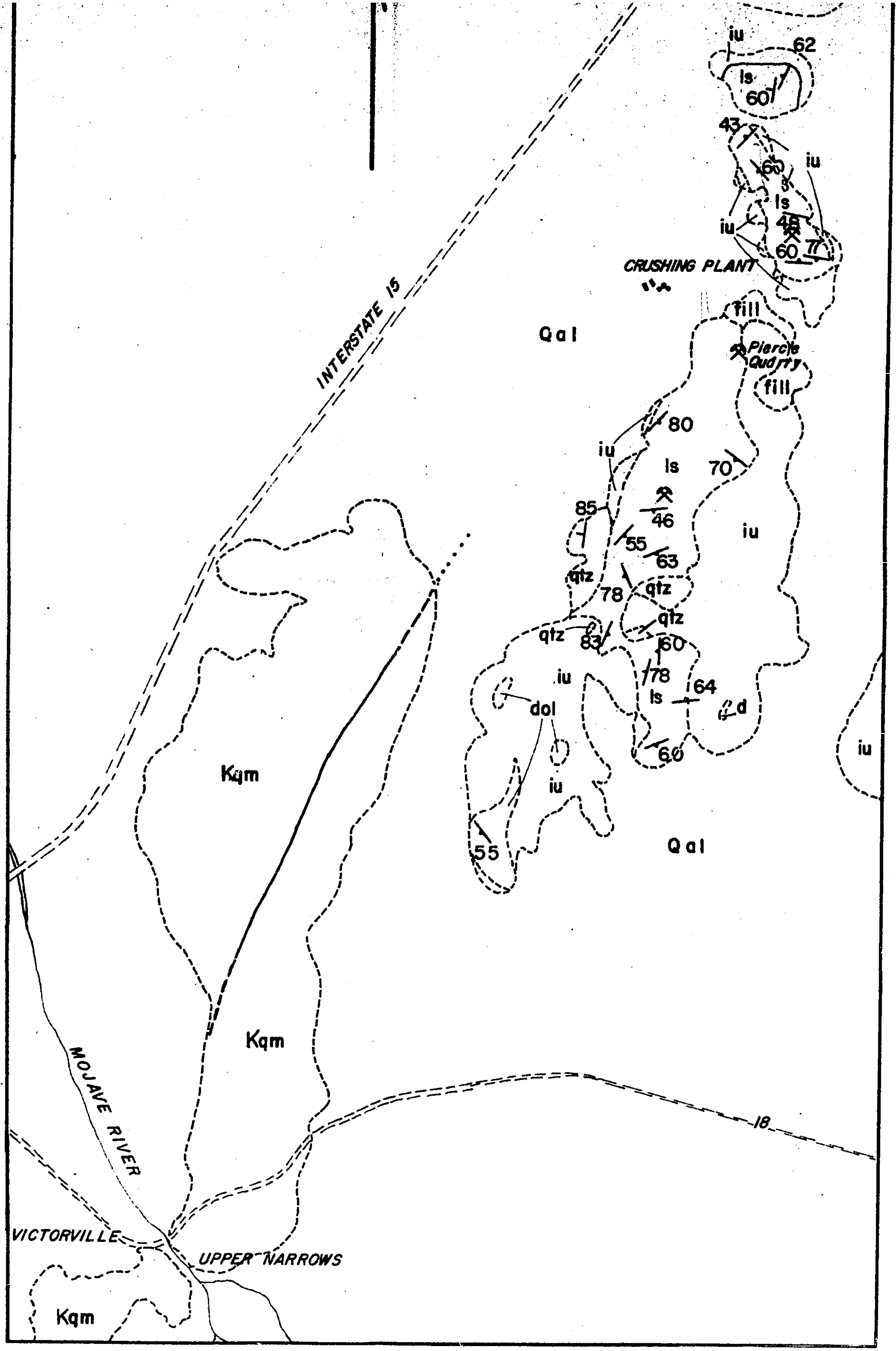
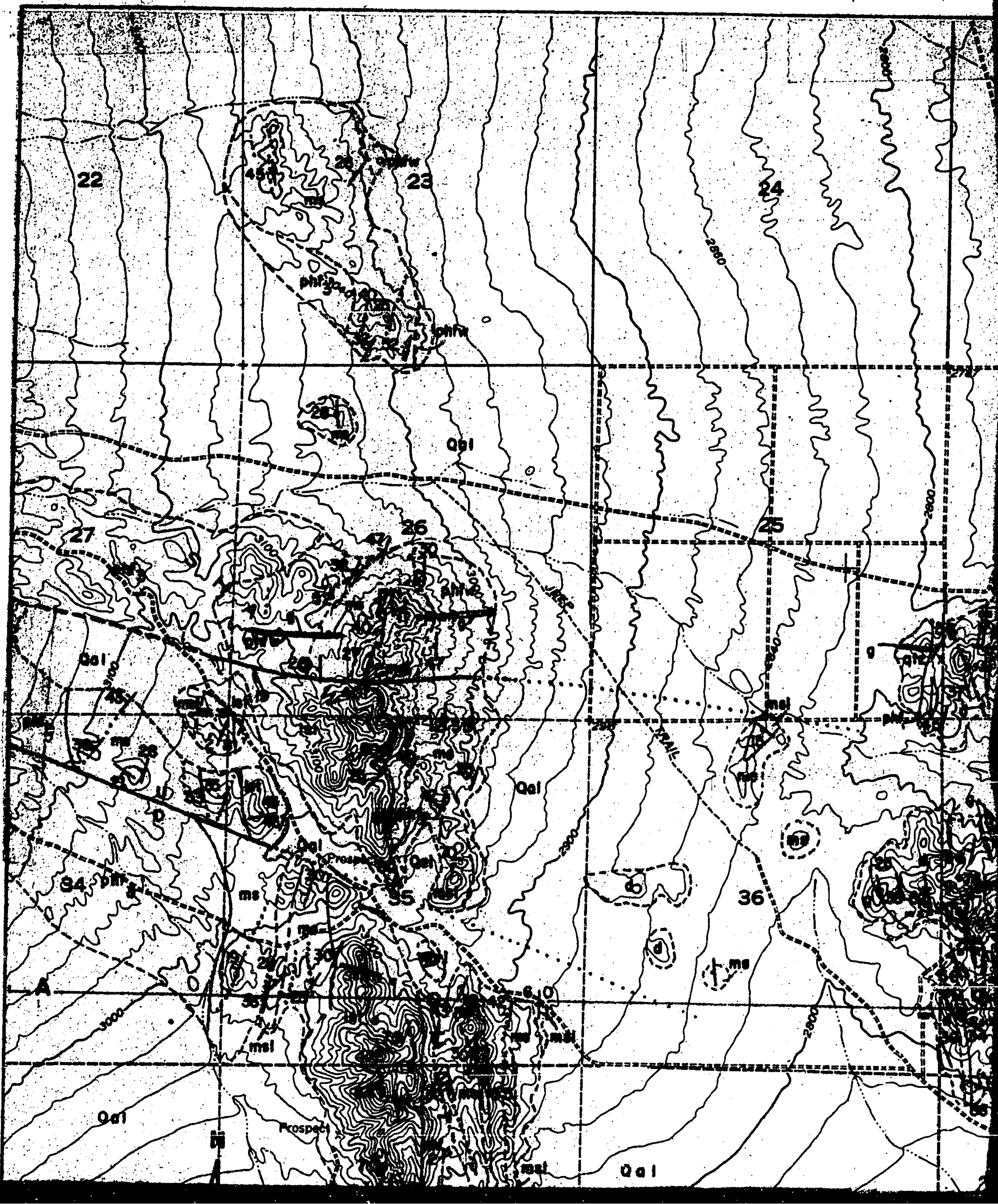
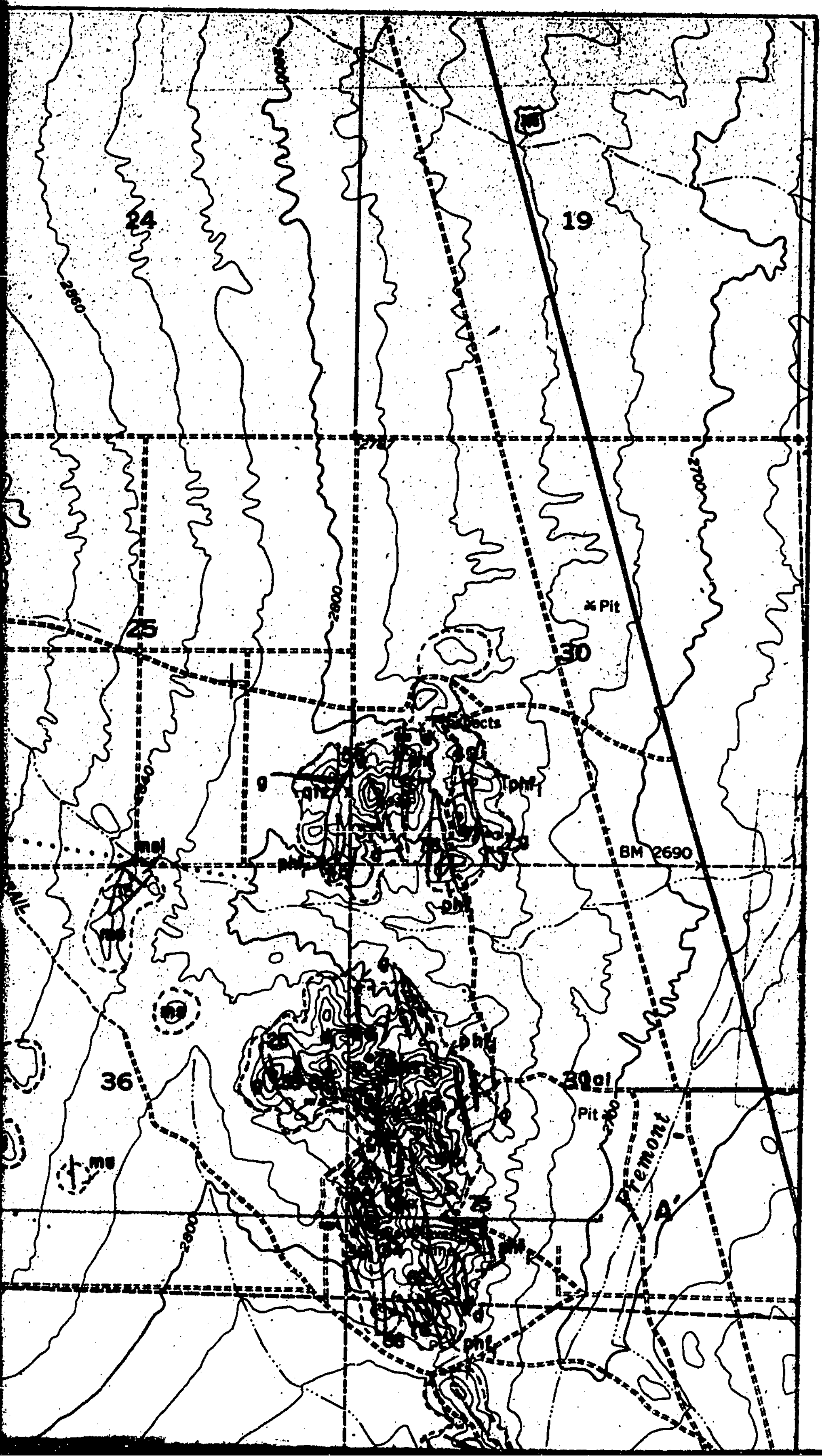

iu
62
ls
60
43
60
iu
ls
48
iu
60
77
CRUSHING PLANT
fill
Pierce Quarry
fill
Qal
INTERSTATE 15
80
iu
ls
70
85
46
iu
55
63
qtz
78
qtz
qtz
qtz
83
60
iu
78
64
ls
dol
d
60
iu
iu
55
Qal
Kqm
Kqm
18
MOJAVE RIVER
VICTORVILLE
UPPER NARROWS
Kqm

PLATE IV


22
23
24
25
26
27
34
35
36
Qal
ms
msl
phfw
2860
2900
3000
3100
JEEP
TRAIL
Prospect
A
d
g

GEOLOGIC MAP O
VICTORVILL



Quaternary

Qal

Alluvium

METASEDIMEN

Age not known

phf$_3$

Pelitic hornfels:
generally unfoliat

phfw

Pelitic hornfels
and/or quartzos

lst

Massive grey lim

phf$_2$

Pelitic hornfels:
generally unfoli

ms **msl**

Interbedded grey l
major limestone
bearing calc-sil

qtz

Quartzite

d

Dolomite, slightl

OLOGIC MAP OF THE EASTERNMOST SHADO
VICTORVILLE NW QUADRANGLE, CALIFORN

Quaternary

Qal

Alluvium

METASEDIMENTS

Age not known

phf3

Pelitic hornfels: fine-grained, non-resistant, contact metamorphosed pelitic rocks, generally unfoliated and with variable quartz content

phfw

Pelitic hornfels with occasional wollastonite-bearing calc-silicated conglomeratic and/or quartzose horizons

lst

Massive grey limestone (marble) and dolomitic limestone, extensive calcite veining

phf2

Pelitic hornfels: fine-grained, non-resistant, contact metamorphed pelitic rocks, generally unfoliated and with variable quartz content

ms **msl**

Interbedded grey limestone, thin-bedded siltstones, silty cherts and calcareous siltstones(m
major limestone units (msl); minor limestone cobble conglomerate (▴▴▴), and wollaston
bearing calc-silicated conglomeratic and/or quartzose horizons (⋯⋯)

qtz

Quartzite

d

Dolomite, slightly impure dolomite, dolomitic limestone and minor limestone (mar

MOST SHADOW MOUNTAINS,
GLE, CALIFORNIA

Contacts: dashed where approximately
located or inferred, dotted
where covered

High angle faults: dashed where approximately located or inferred, dotted where covered

metamorphosed pelitic rocks,
t

Strike and dip of bedding, not known
whether upright or overturned

ing calc-silicated conglomeratic

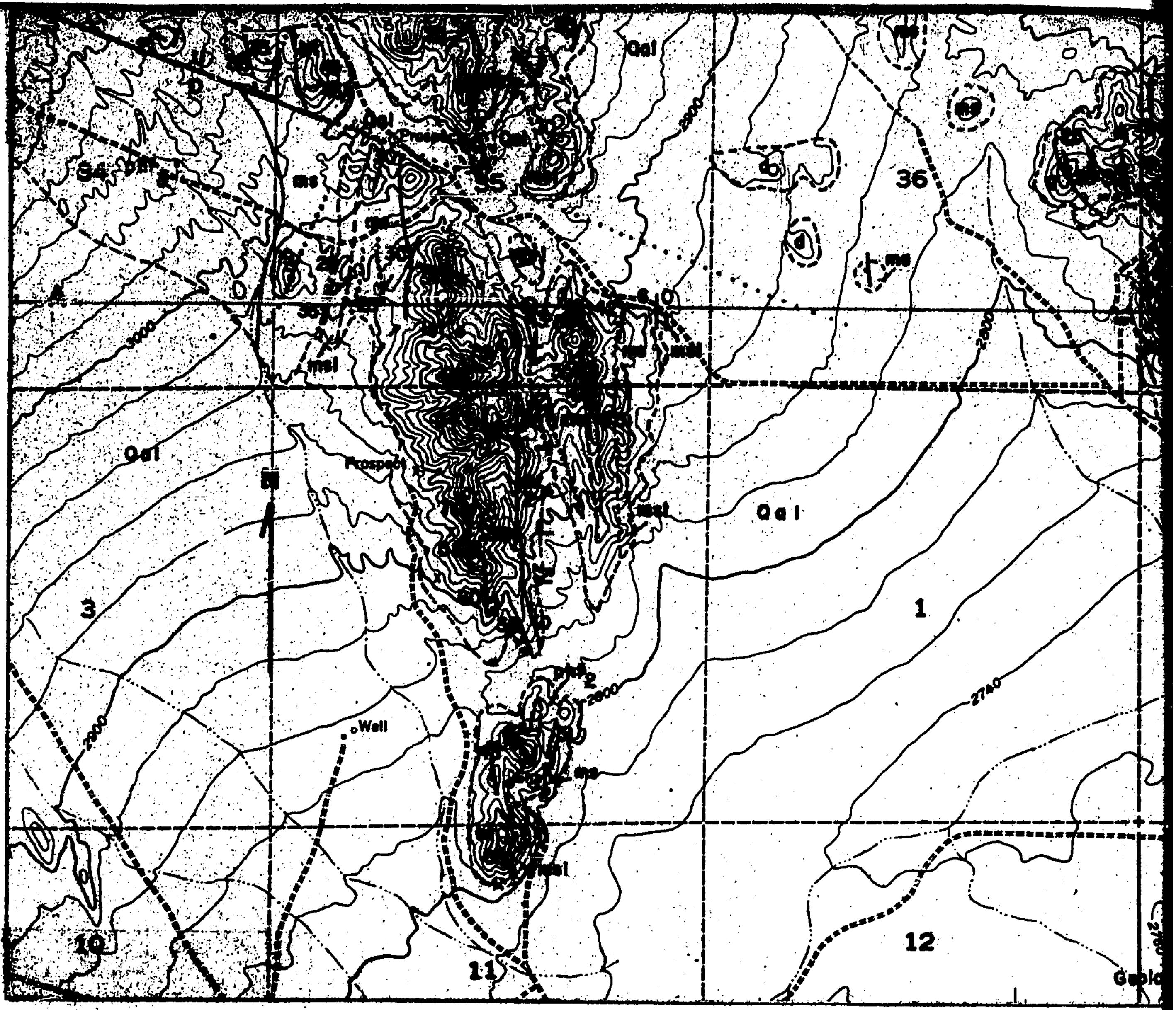
Strike and dip of compositional
layering

ne, extensive calcite veining

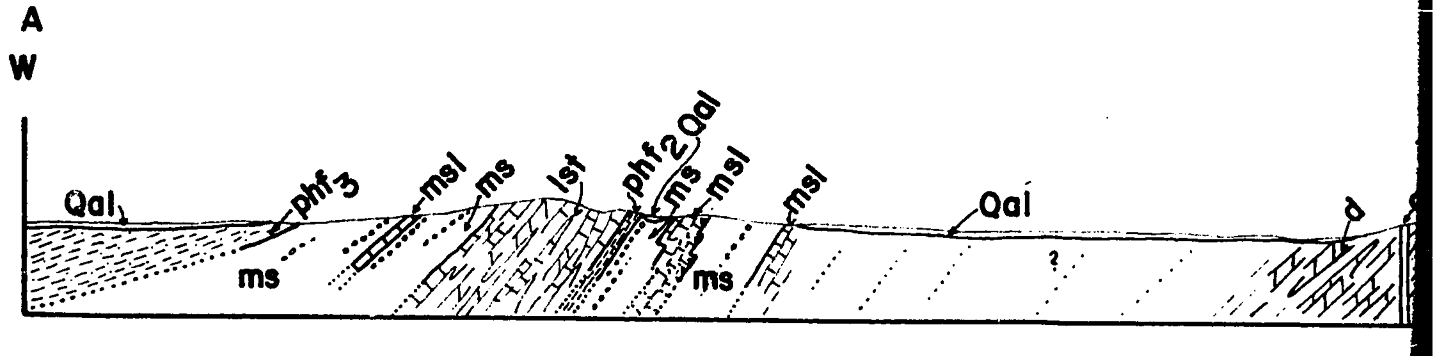
metamorphed pelitic rocks,
ontent

cherts and calcareous siltstones (ms);
conglomerate (▲▲▲), and wollastonite-
tzose horizons (∘•••)

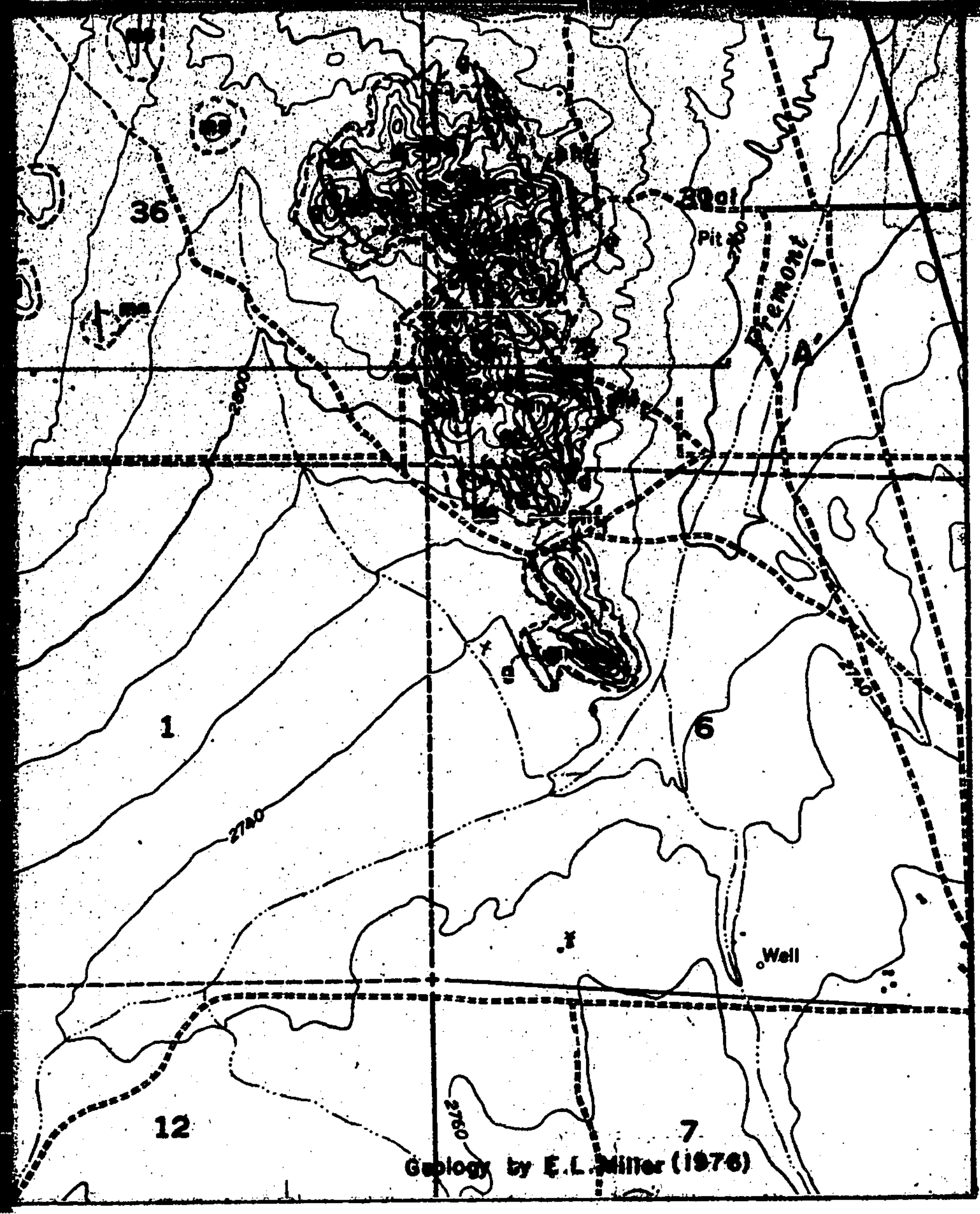
tone and minor limestone (marbles)



Qal
34
phf
35
36
ms
Qal
msl
3000
Qal
Prospect
3
1
Qal
msl
phf2
2800
2740
Well
ms
msl
10
11
12
Geolo



A
W
Qal
phf3
msl
ms
lst
phf2
Qal
ms
msl
msl
Qal
d
ms
ms
?



Geology by E.L. Miller (1976)

generally unfo

Age not known

ms msl

Interbedded grey l
major limestone
bearing calc-sil

qtz

Quartzite

d

Dolomite, slightly

phf$_1$

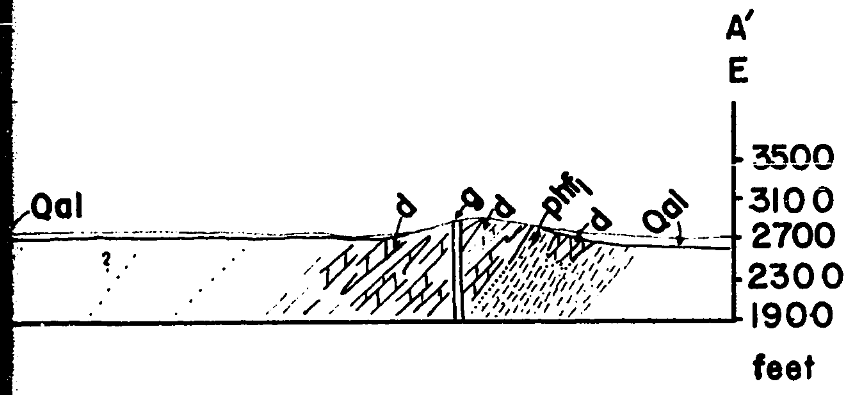
Pelitic hornfels:
generally unfoli

Late Mesozoic?

IGNEOUS

g

Granitic and ap



generally unfoliated and with variable quartz content

Age not known

ms **msl**

Interbedded grey limestone, thin-bedded siltstones, silty cherts and calcareous siltstones(ms
major limestone units (msl); minor limestone cobble conglomerate (▴▴▴), and wollastonit
bearing calc-silicated conglomeratic and/or quartzose horizons (····)

qtz

Quartzite

d

Dolomite, slightly impure dolomite, dolomitic limestone and minor limestone (marble

phf_1

Pelitic hornfels: fine-grained, non-resistant, contact metamorphosed pelitic rocks,
generally unfoliated and with variable quartz content

1

Late Mesozoic?

IGNEOUS

g

Granitic and aplitic dike rocks

Base map

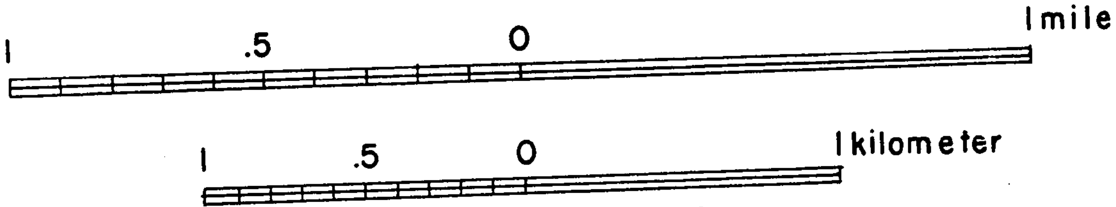
nt

rts and calcareous siltstones(ms);
glomerate (▲▲▲), and wollastonite-
se horizons (••••)

e and minor limestone (marbles)

metamorphosed pelitic rocks,
tent

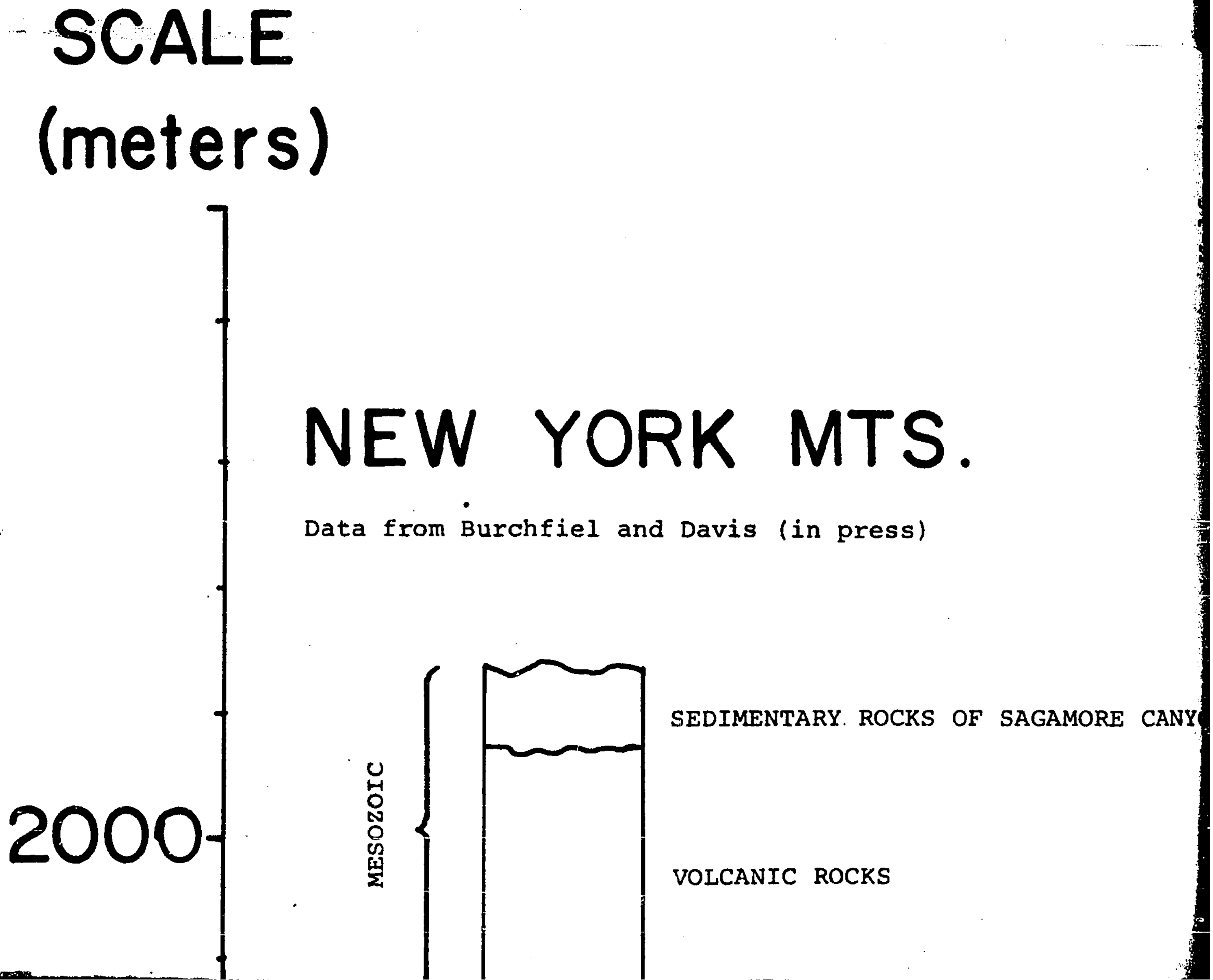
SCALE



contour interval 20 feet

Base map: U.S. Geological Survey 7 1/2' Victorville NW quadrangle

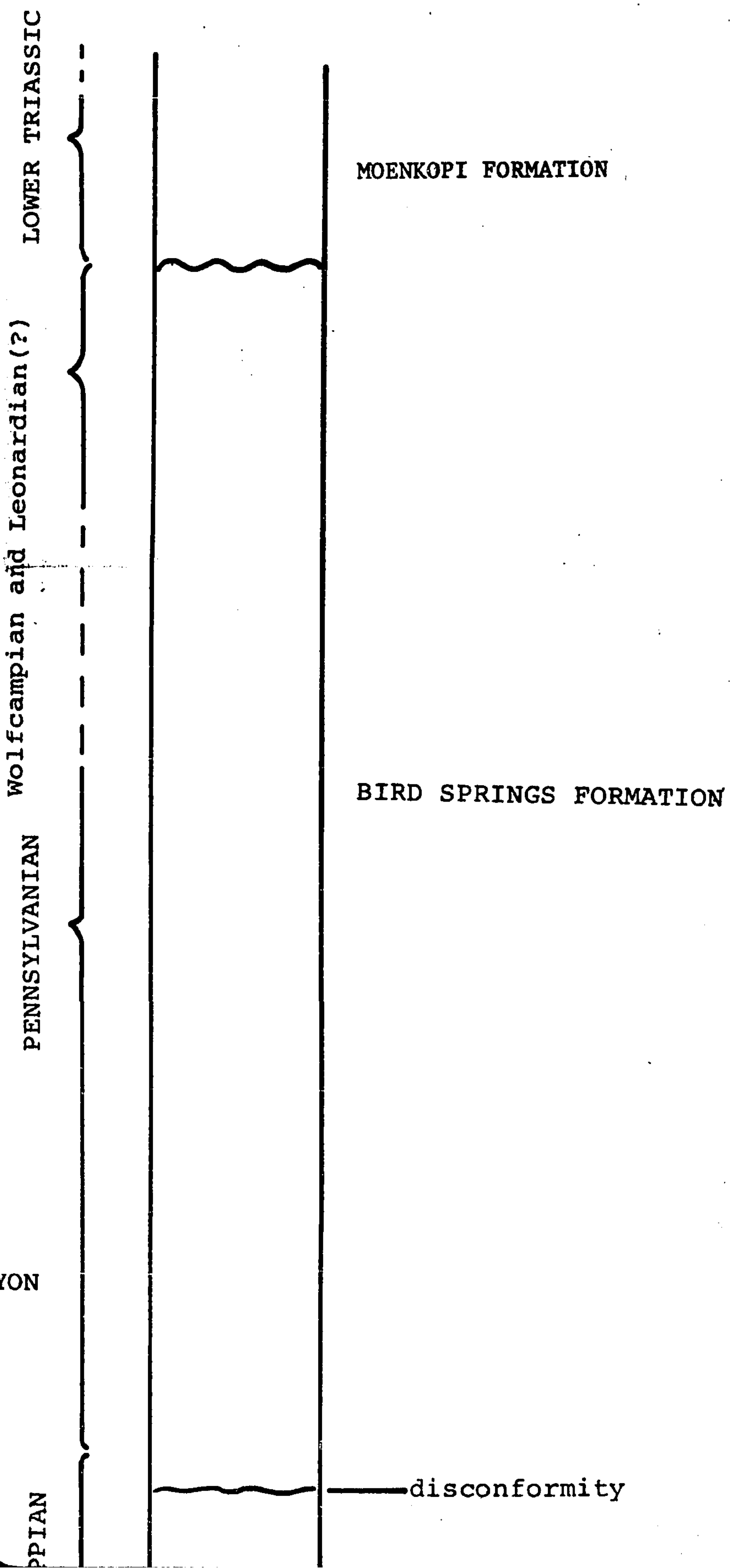
PR



Data from Burchfiel and Davis (in press)

PROVIDENCE MTS.

Data from Hazzard (1954)
and Stewart (1970)



MTS.

in press)

ARY ROCKS OF SAGAMORE CANYON

ROCKS

COV

Data fr

TS.

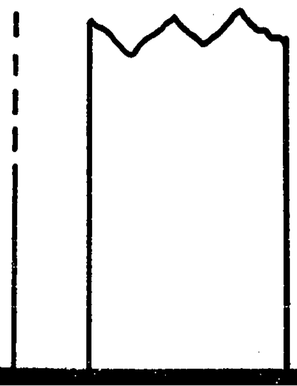
ION

FORMATION

nity

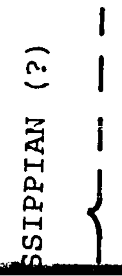
COWHOLE MTS.

Data from Novitsky-Evans, in preparation



SIDEW

(This



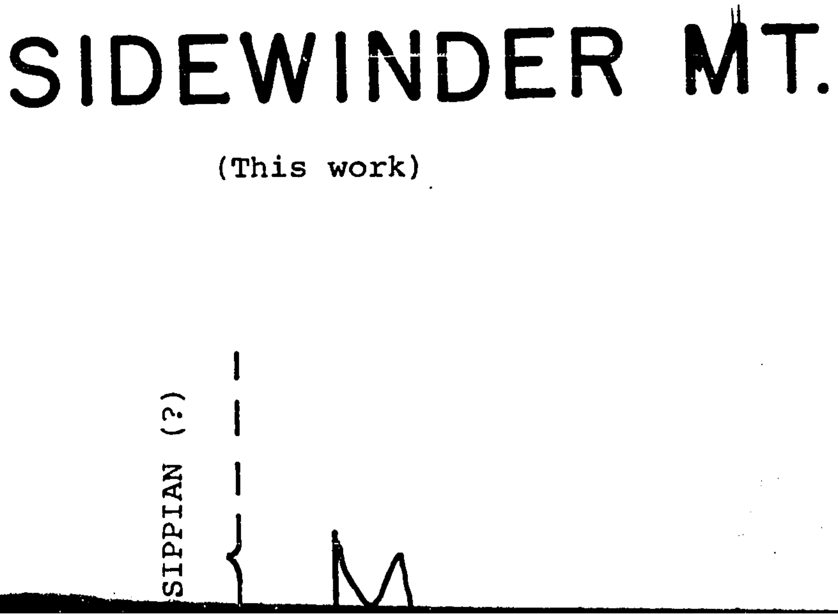
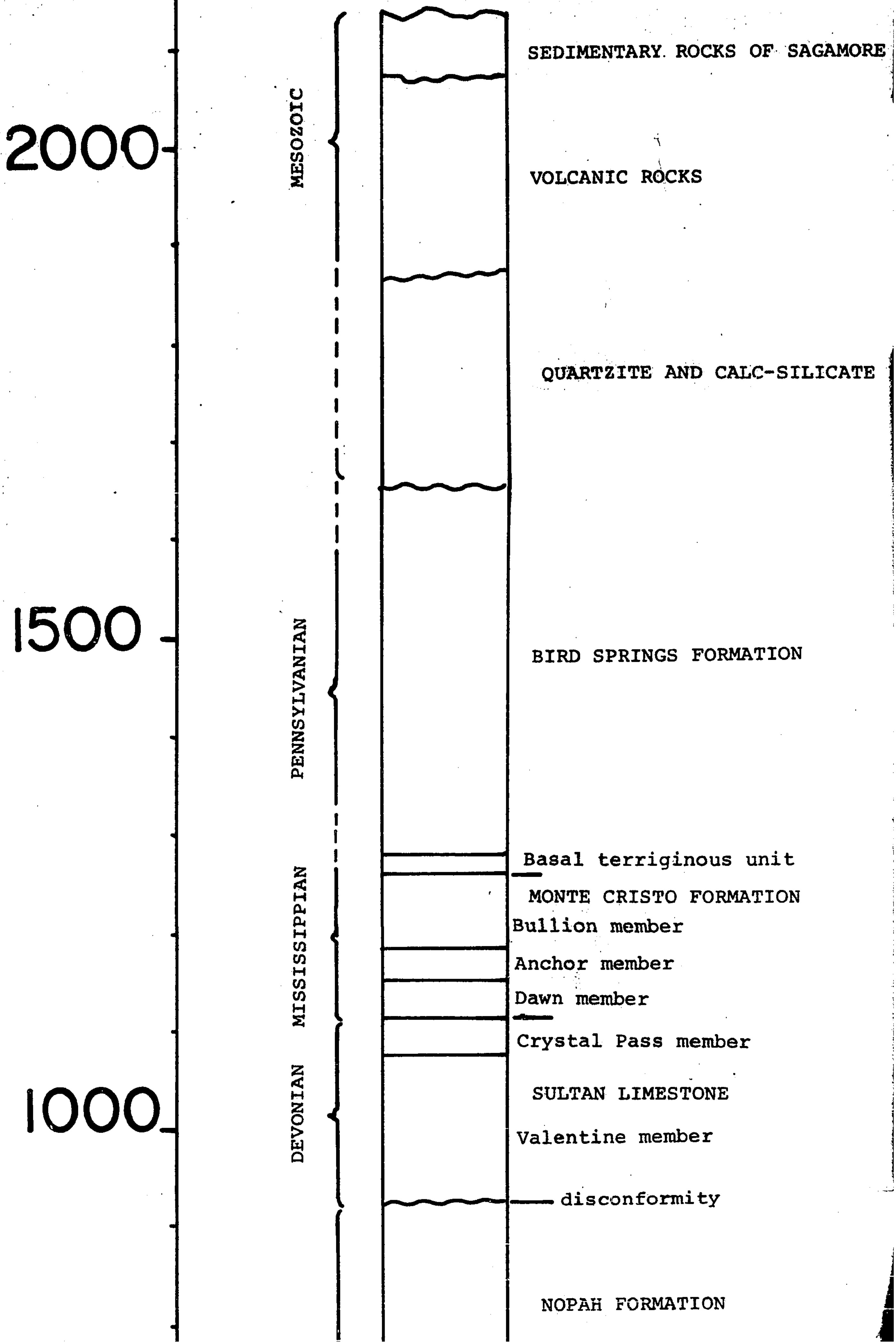
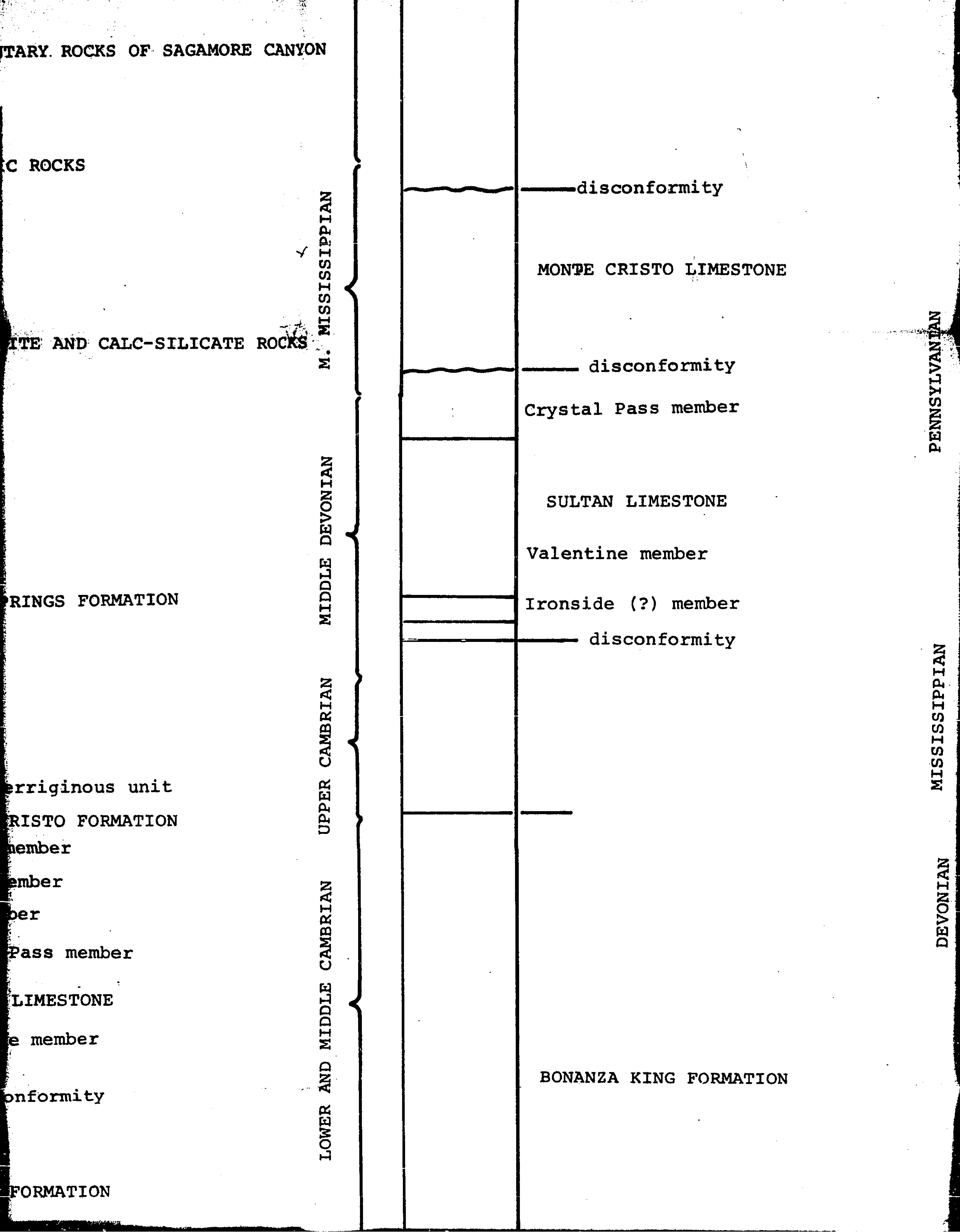
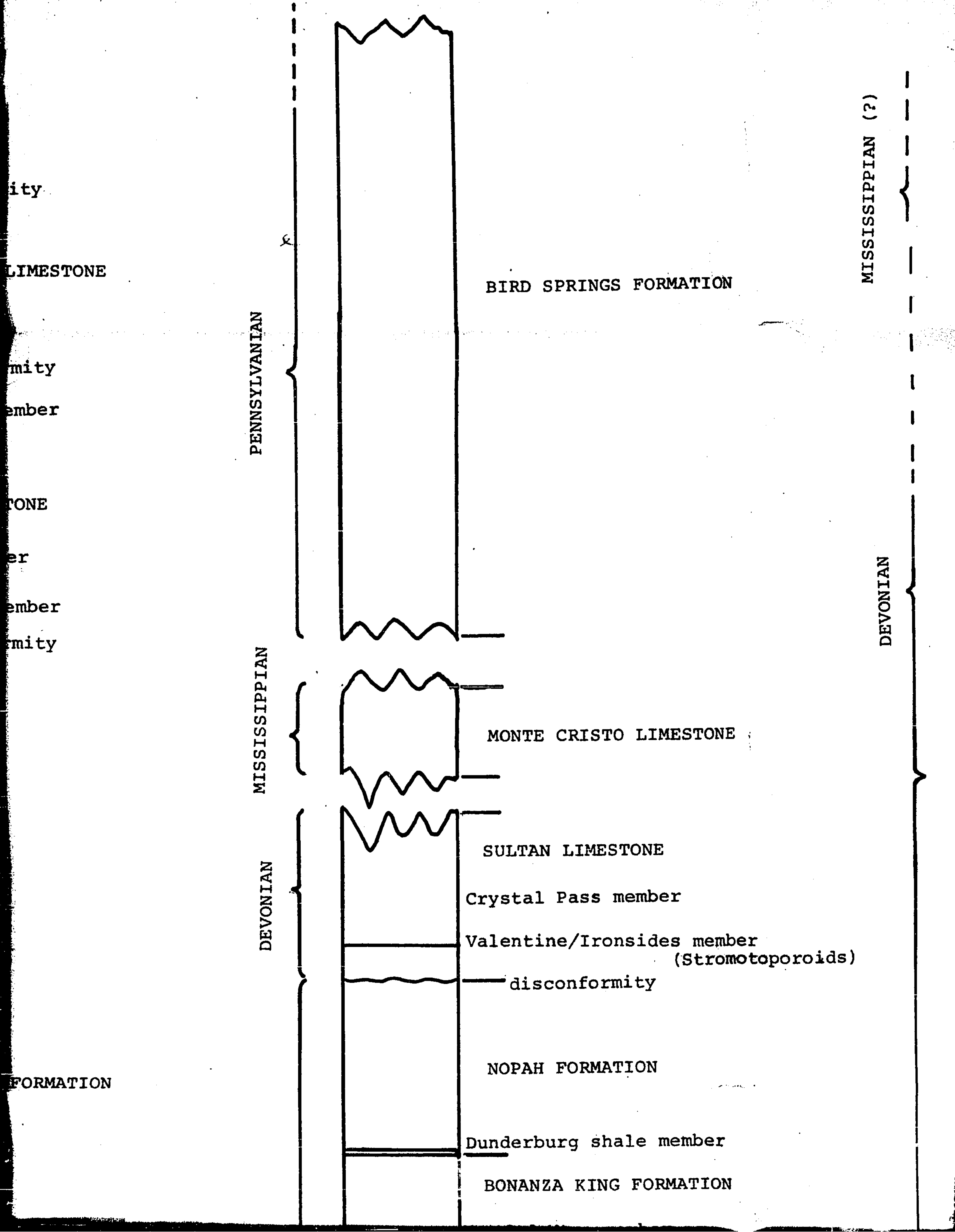
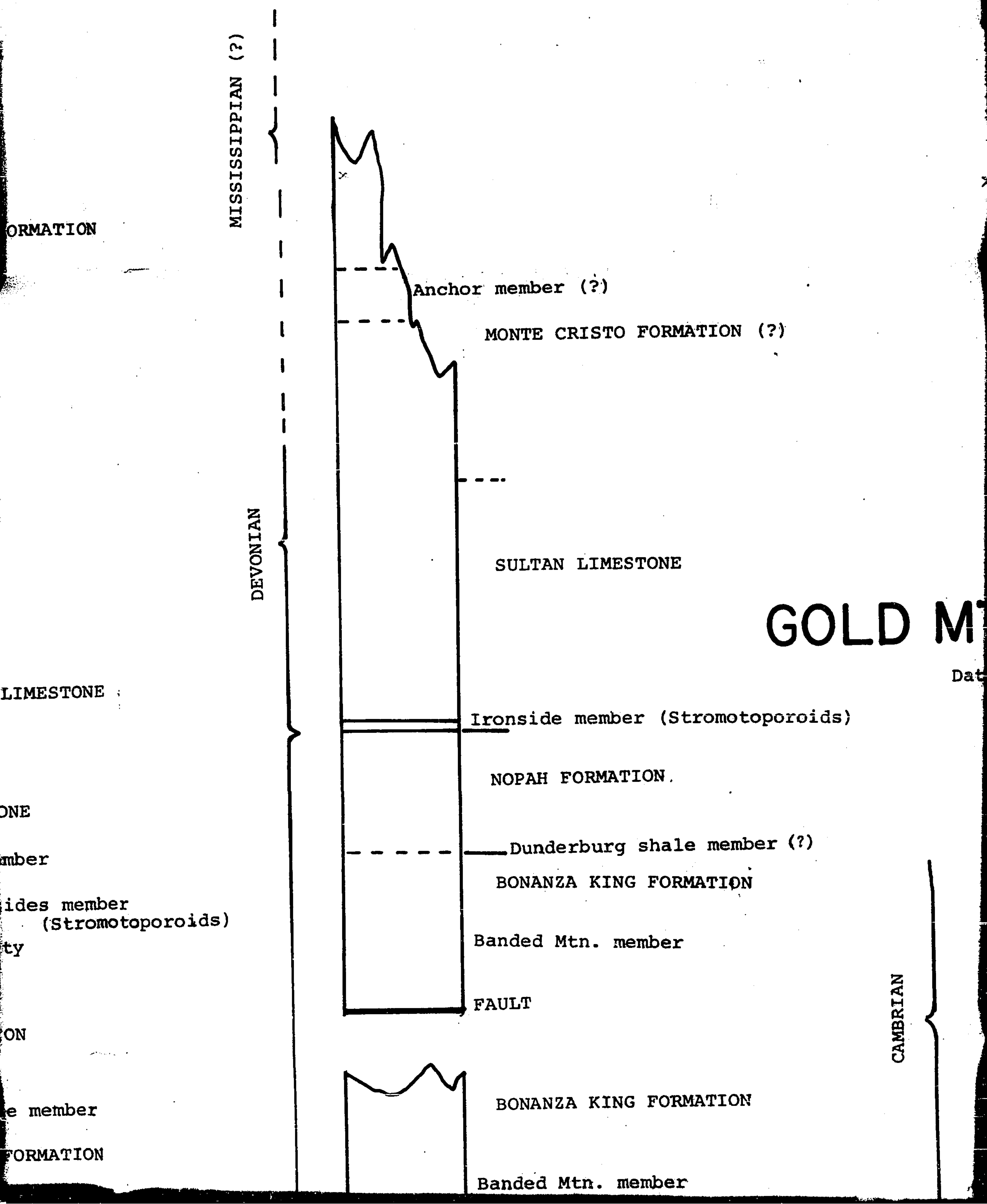

SIDEWINDER MT.
(This work)
SIPPIAN (?)
M

PLATE V


2000
1500
1000
MESOZOIC
PENNSYLVANIAN
MISSISSIPPIAN
DEVONIAN
SEDIMENTARY ROCKS OF SAGAMORE
VOLCANIC ROCKS
QUARTZITE AND CALC-SILICATE
BIRD SPRINGS FORMATION
Basal terriginous unit
MONTE CRISTO FORMATION
Bullion member
Anchor member
Dawn member
Crystal Pass member
SULTAN LIMESTONE
Valentine member
disconformity
NOPAH FORMATION


TARY ROCKS OF SAGAMORE CANYON
C ROCKS
ITE AND CALC-SILICATE ROCKS
RINGS FORMATION
erriginous unit
RISTO FORMATION
member
ember
ber
Pass member
LIMESTONE
e member
onformity
FORMATION
M. MISSISSIPPIAN
MIDDLE DEVONIAN
UPPER CAMBRIAN
LOWER AND MIDDLE CAMBRIAN
disconformity
MONTE CRISTO LIMESTONE
disconformity
Crystal Pass member
SULTAN LIMESTONE
Valentine member
Ironside (?) member
disconformity
BONANZA KING FORMATION
PENNSYLVANIAN
MISSISSIPPIAN
DEVONIAN

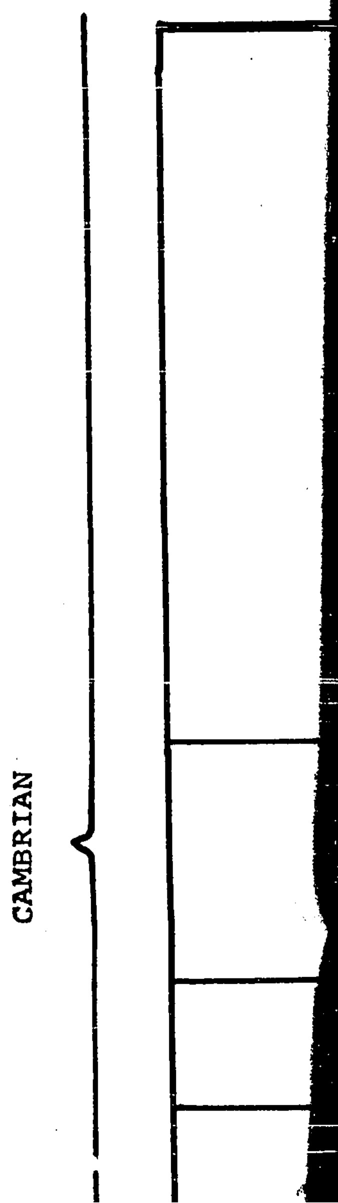

ity
LIMESTONE
mity
ember
TONE
er
ember
mity
FORMATION
PENNSYLVANIAN
MISSISSIPPIAN
DEVONIAN
BIRD SPRINGS FORMATION
MONTE CRISTO LIMESTONE
SULTAN LIMESTONE
Crystal Pass member
Valentine/Ironsides member
(Stromotoporoids)
disconformity
NOPAH FORMATION
Dunderburg shale member
BONANZA KING FORMATION
MISSISSIPPIAN (?)
DEVONIAN


ORMATION
LIMESTONE
ONE
mber
ides member
(Stromotoporoids)
ty
ON
e member
FORMATION
MISSISSIPPIAN (?)
DEVONIAN
Anchor member (?)
MONTE CRISTO FORMATION (?)
SULTAN LIMESTONE
GOLD M
Dat
Ironside member (Stromotoporoids)
NOPAH FORMATION
Dunderburg shale member (?)
BONANZA KING FORMATION
Banded Mtn. member
FAULT
CAMBRIAN
BONANZA KING FORMATION
Banded Mtn. member

ON (?)

QUARTZITE

(This work)



GOLD MT. - BALDWIN LAKE

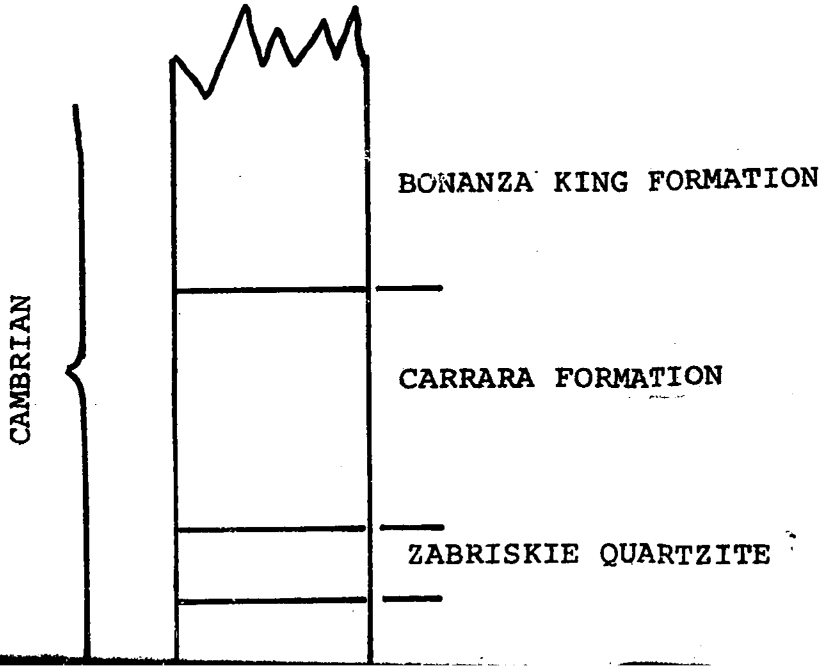
Data from Tyler (1975)

otoporoids)

mber (?)

ON

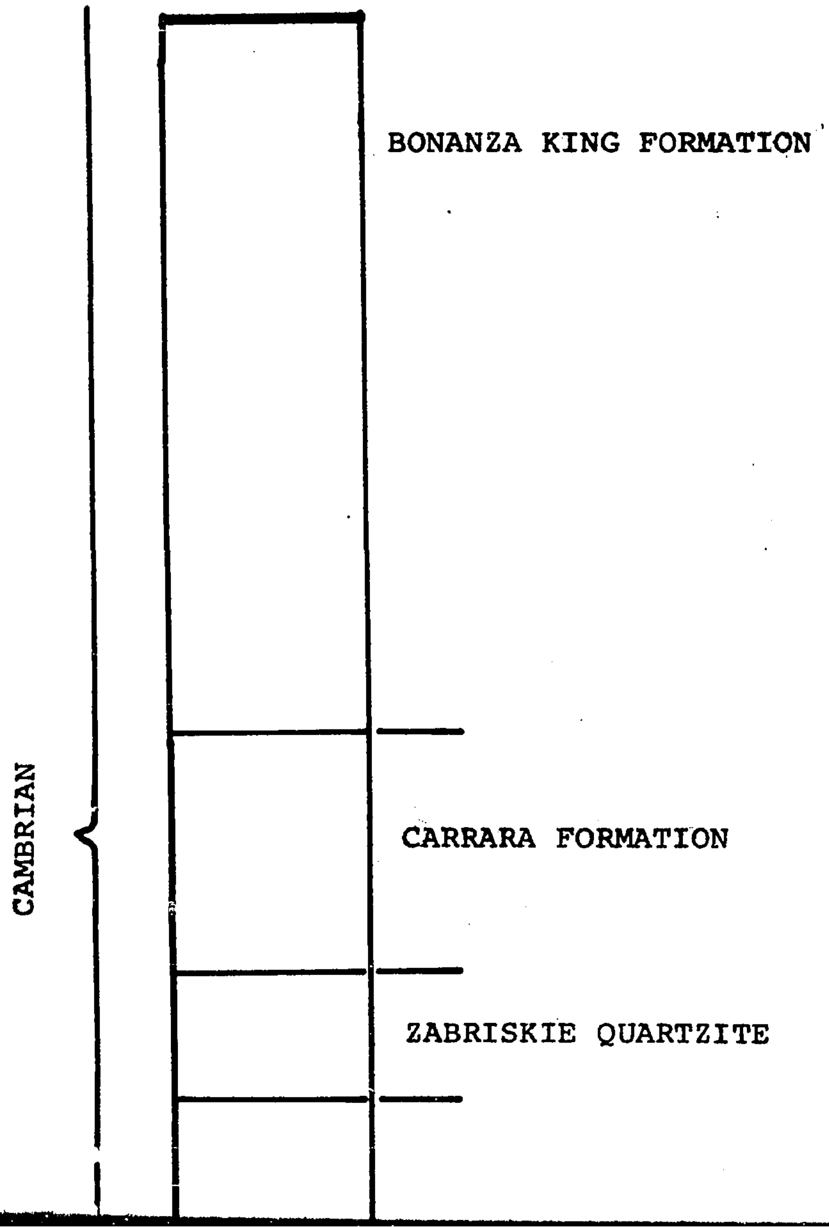
ON



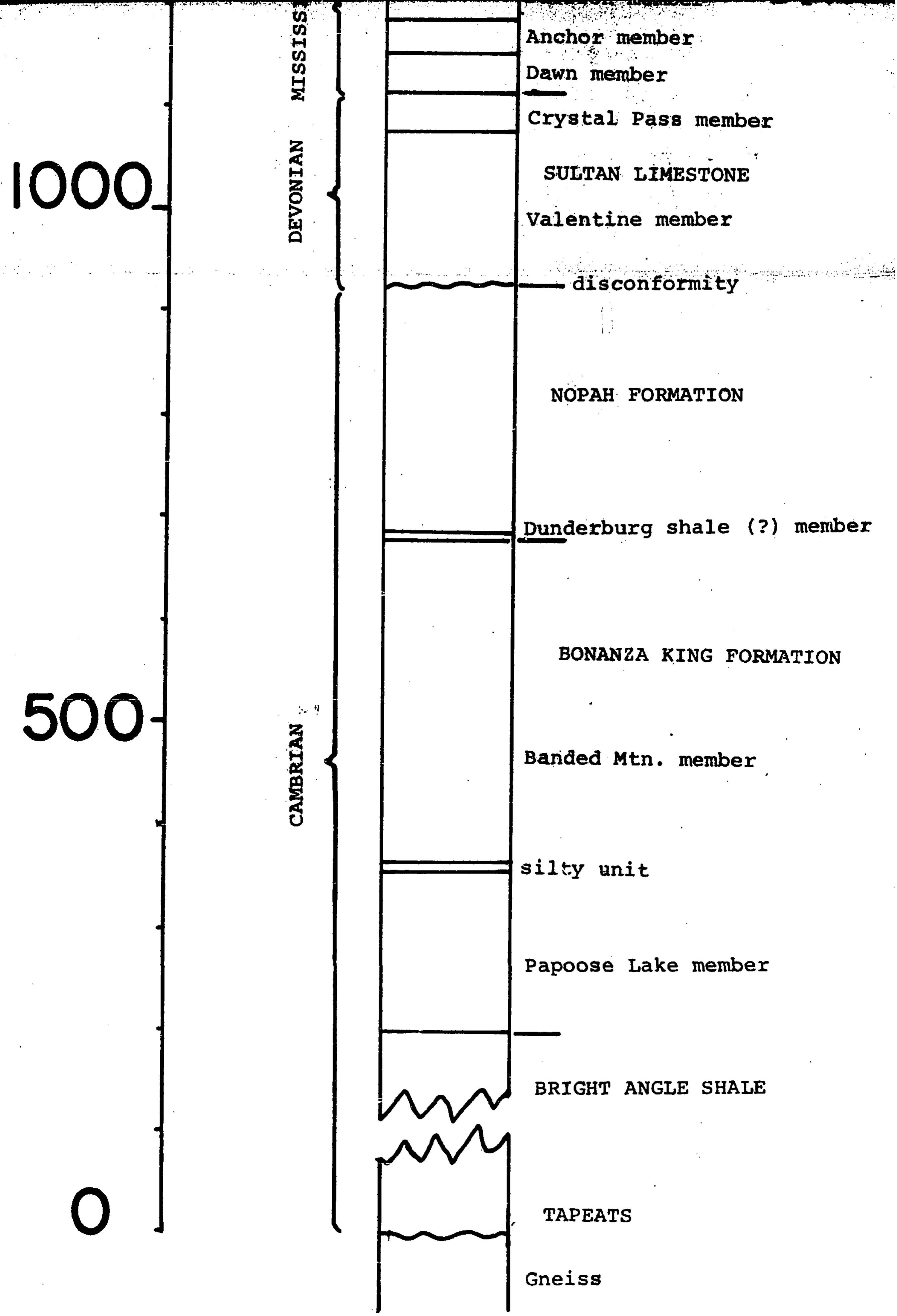
QUARTZITE MT.

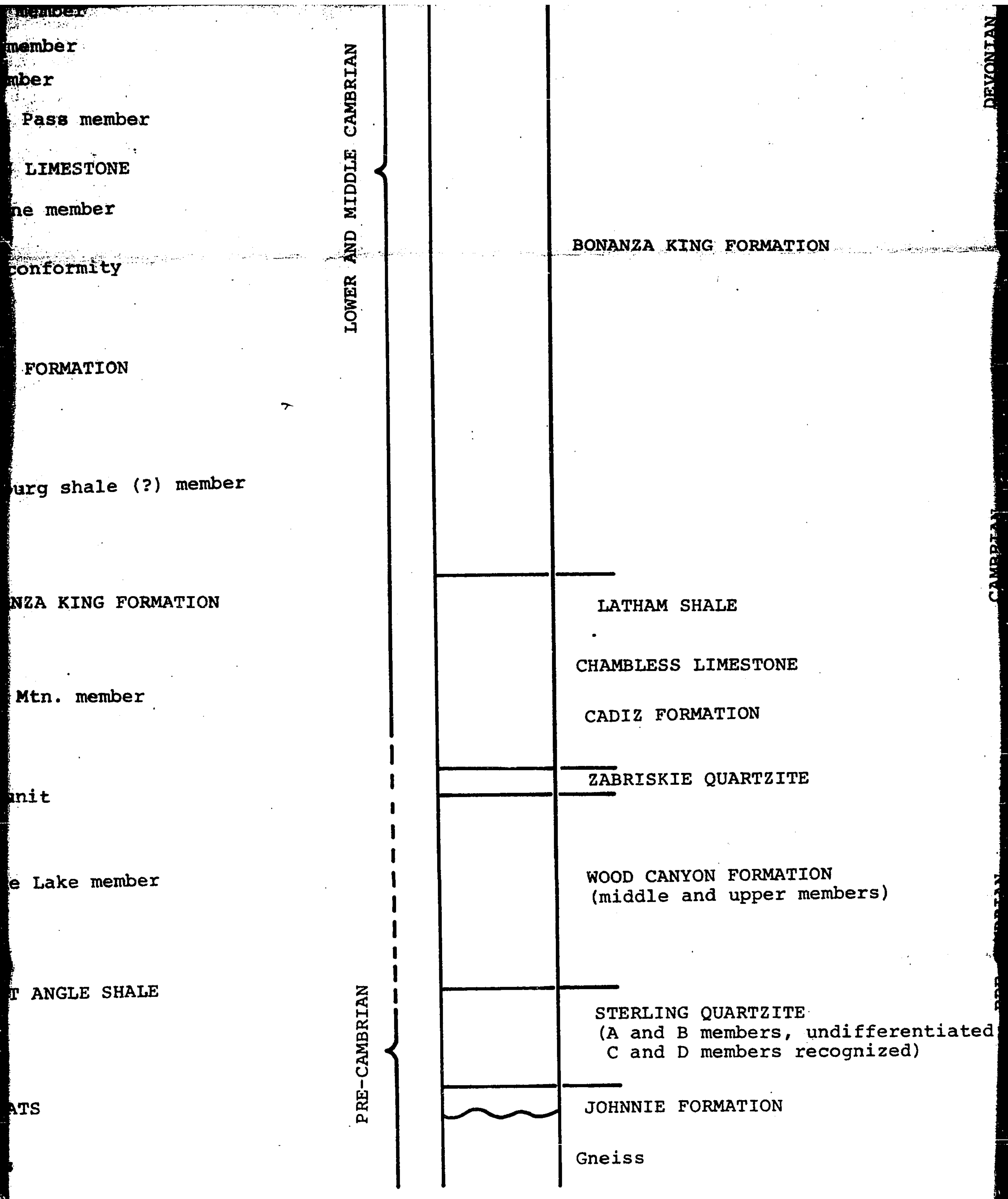
(This work)

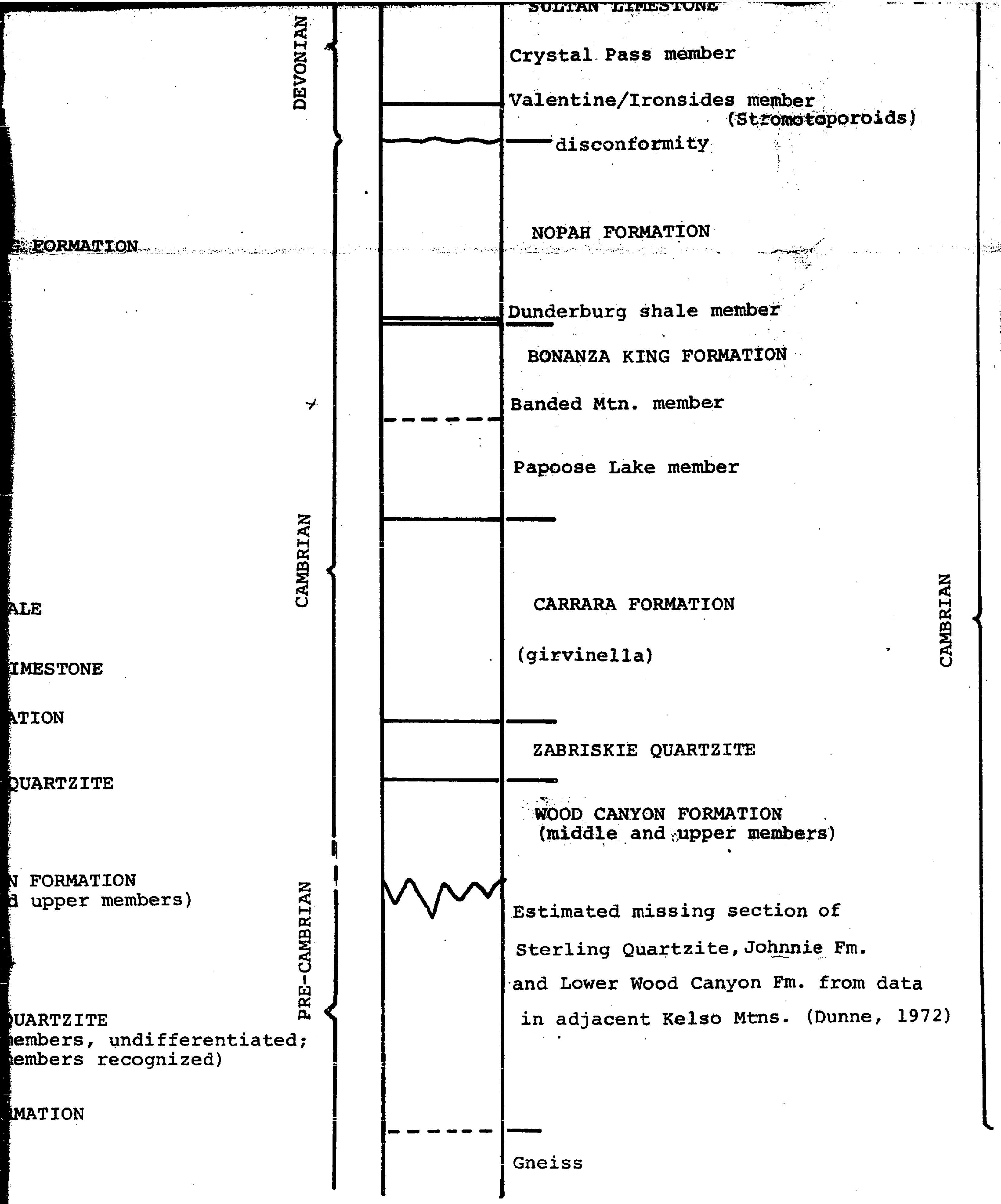
LAKE

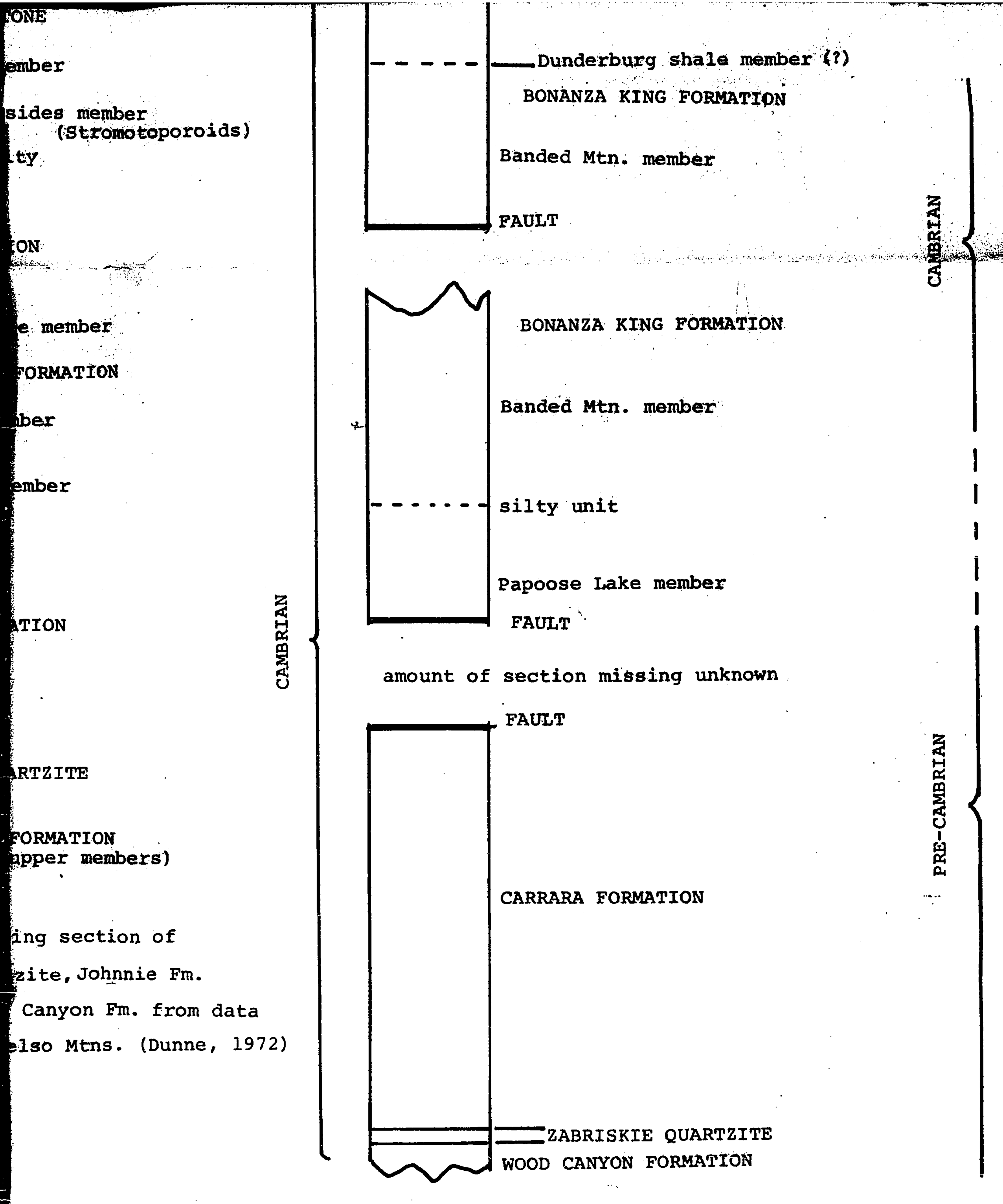


ON

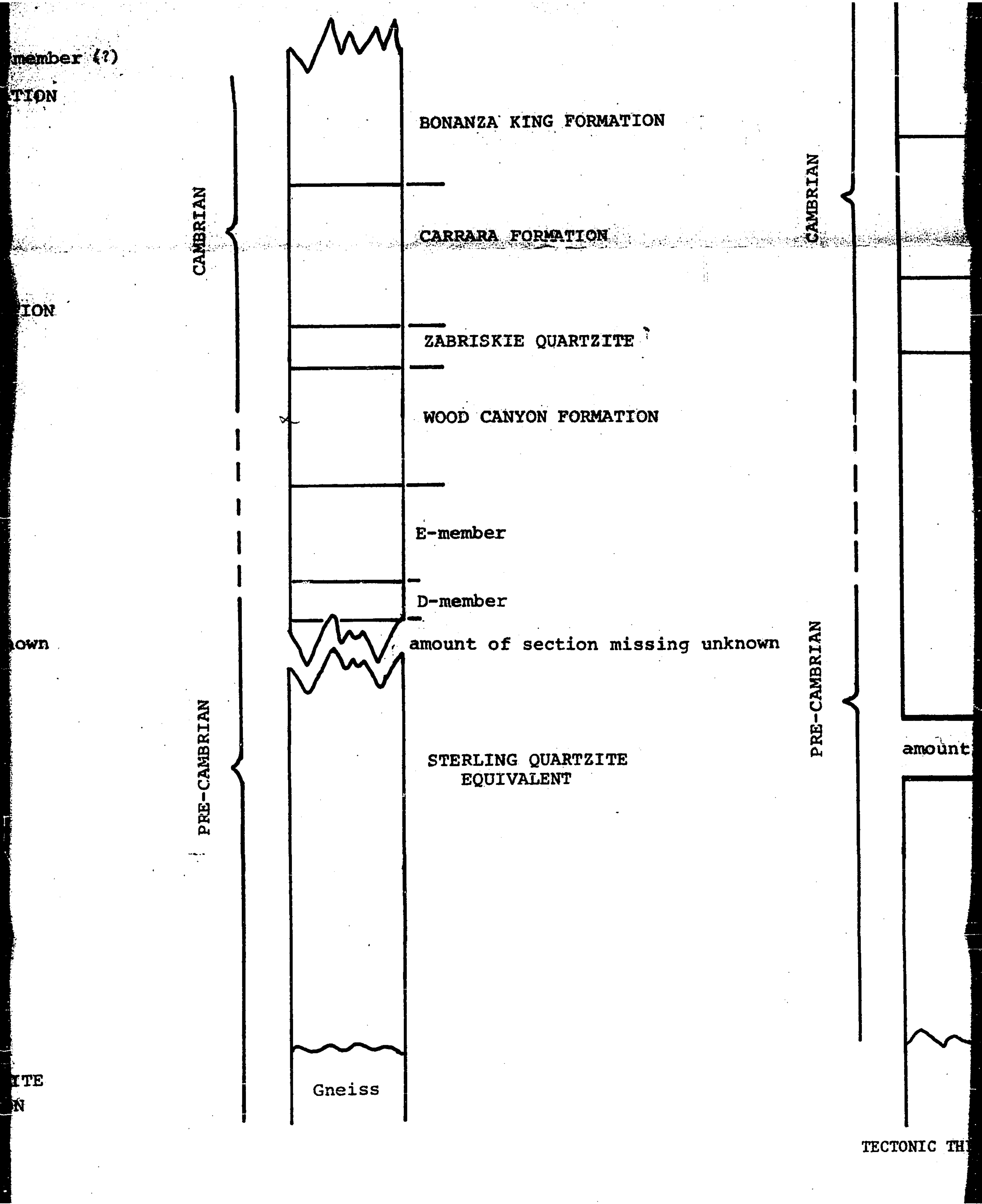

1000
500
0
MISSISS
DEVONIAN
CAMBRIAN
Anchor member
Dawn member
Crystal Pass member
SULTAN LIMESTONE
Valentine member
disconformity
NOPAH FORMATION
Dunderburg shale (?) member
BONANZA KING FORMATION
Banded Mtn. member
silty unit
Papoose Lake member
BRIGHT ANGLE SHALE
TAPEATS
Gneiss

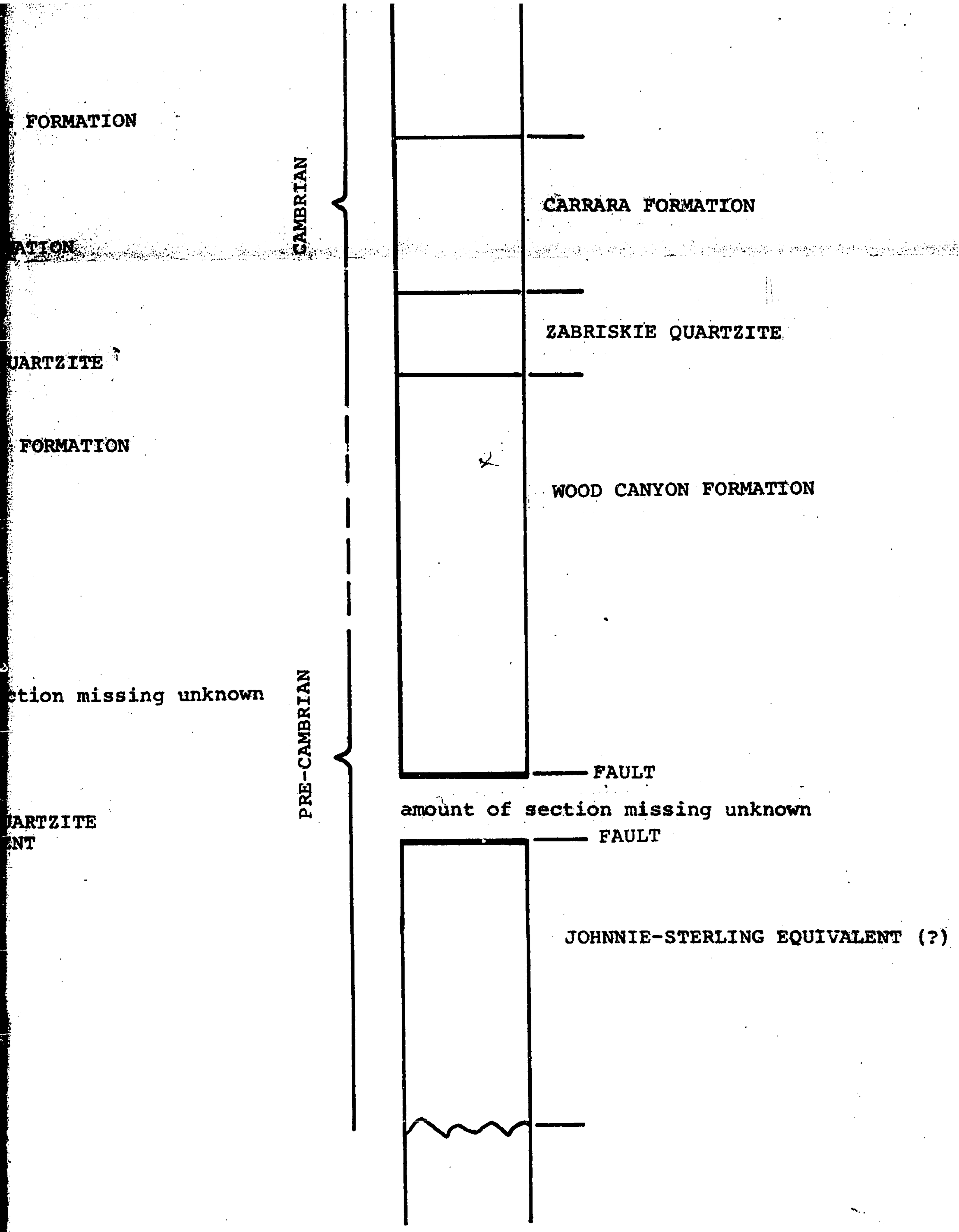

member
mber
Pass member
LIMESTONE
ne member
conformity
FORMATION
urg shale (?) member
NZA KING FORMATION
Mtn. member
nit
e Lake member
T ANGLE SHALE
ATS
LOWER AND MIDDLE CAMBRIAN
PRE-CAMBRIAN
BONANZA KING FORMATION
LATHAM SHALE
CHAMBLESS LIMESTONE
CADIZ FORMATION
ZABRISKIE QUARTZITE
WOOD CANYON FORMATION
(middle and upper members)
STERLING QUARTZITE
(A and B members, undifferentiated
C and D members recognized)
JOHNNIE FORMATION
Gneiss
DEVONIAN


SULTAN LIMESTONE
Crystal Pass member
Valentine/Ironsides member
(Stromotoporoids)
disconformity
DEVONIAN
NOPAH FORMATION
FORMATION
Dunderburg shale member
BONANZA KING FORMATION
Banded Mtn. member
Papoose Lake member
CAMBRIAN
CARRARA FORMATION
(girvinella)
ALE
IMESTONE
ATION
ZABRISKIE QUARTZITE
QUARTZITE
WOOD CANYON FORMATION
(middle and upper members)
N FORMATION
d upper members)
PRE-CAMBRIAN
Estimated missing section of
Sterling Quartzite, Johnnie Fm.
and Lower Wood Canyon Fm. from data
in adjacent Kelso Mtns. (Dunne, 1972)
UARTZITE
embers, undifferentiated;
embers recognized)
MATION
Gneiss
CAMBRIAN



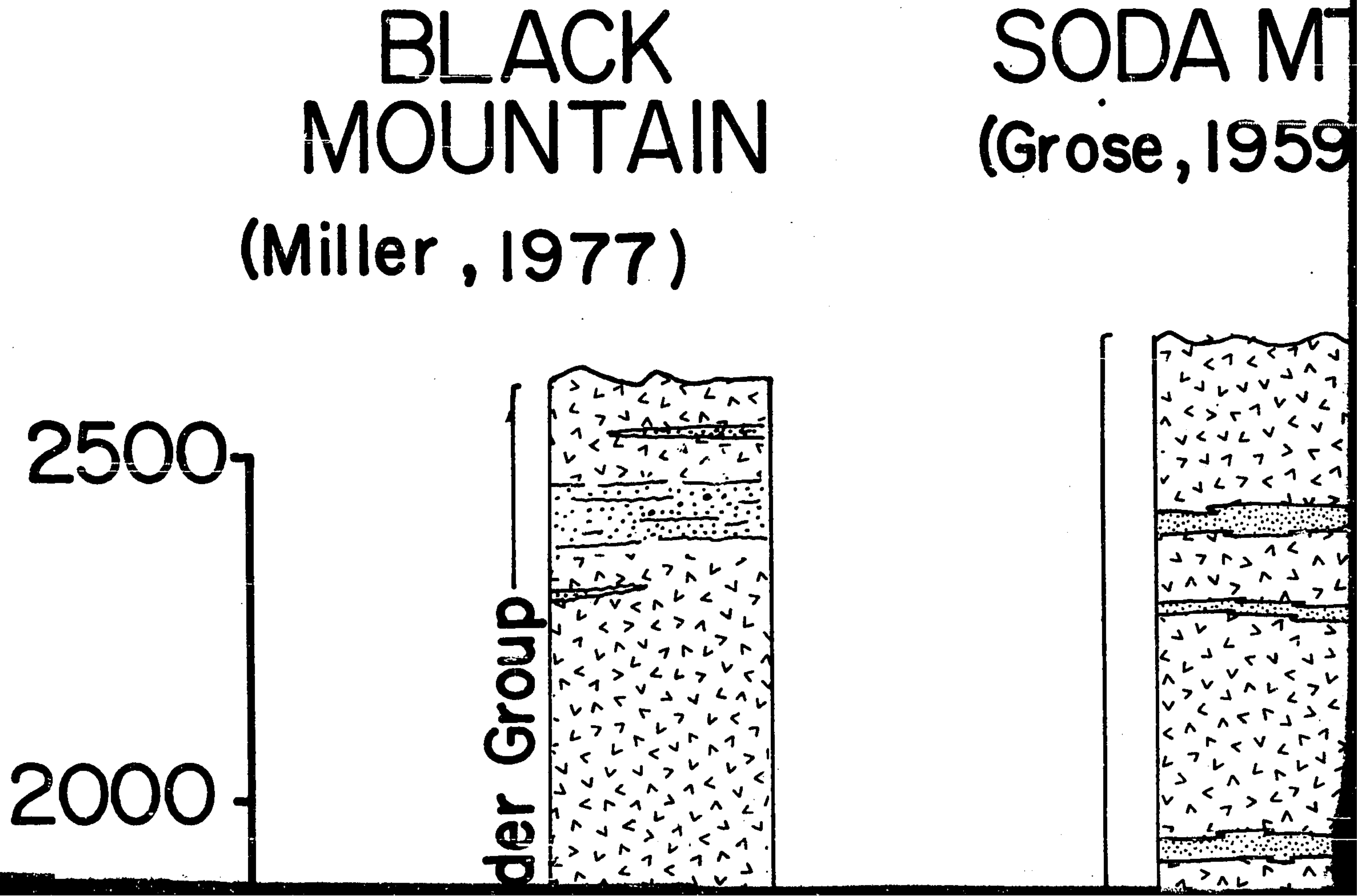
TECTONIC THICKNESSES ONLY


member (?)
TION
ION
own
ITE
N
CAMBRIAN
PRE-CAMBRIAN
BONANZA KING FORMATION
CARRARA FORMATION
ZABRISKIE QUARTZITE
WOOD CANYON FORMATION
E-member
D-member
amount of section missing unknown
STERLING QUARTZITE
EQUIVALENT
Gneiss
CAMBRIAN
PRE-CAMBRIAN
amount
TECTONIC TH



TECTONIC THICKNESSES ONLY

COMPARISON OF
BLACK MOUNTA
FORMATIONS OF
D

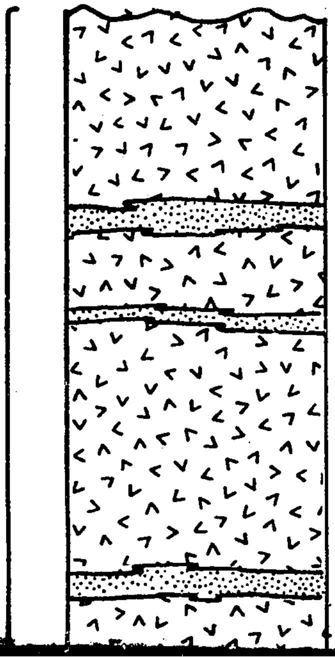


SON OF MESOZOIC ROCK
OUNTAIN WITH MEZOZO
ONS OF THE EASTERN
DESERT

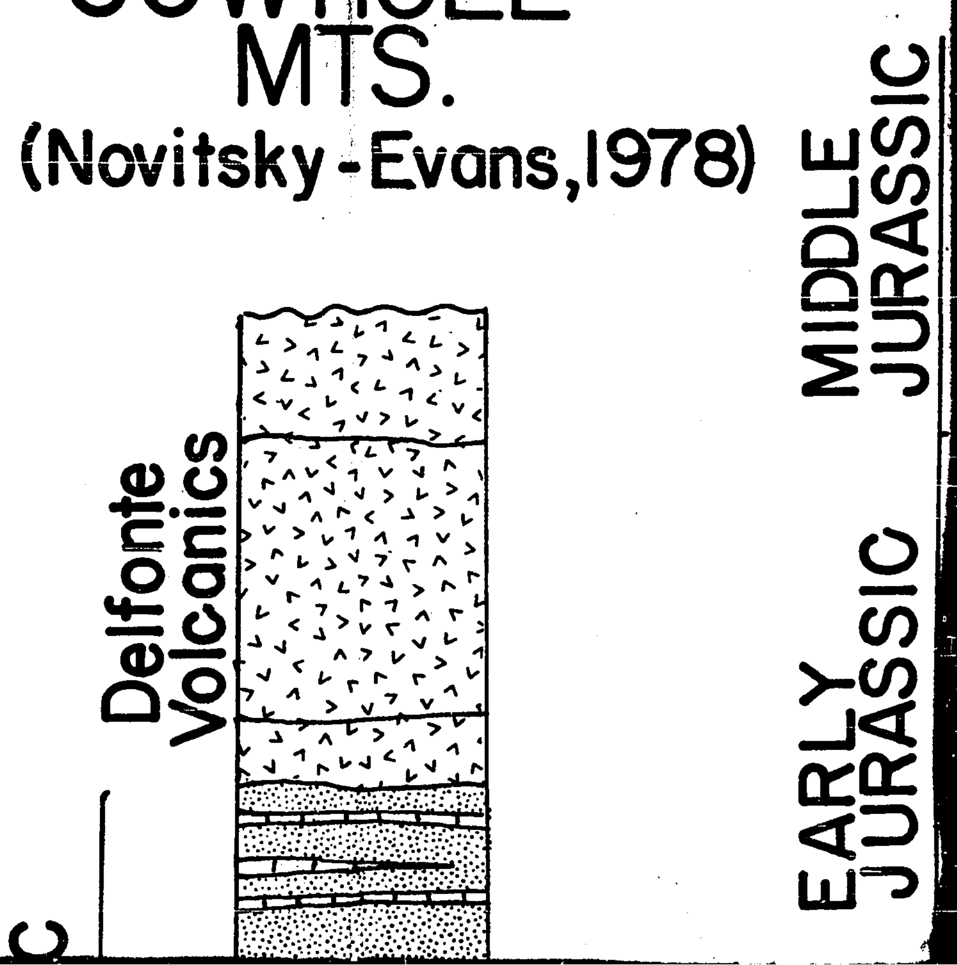
DE

(Du

SODA MTS.
(Grose, 1959)



COWHOLE MTS.
(Novitsky-Evans, 1978)

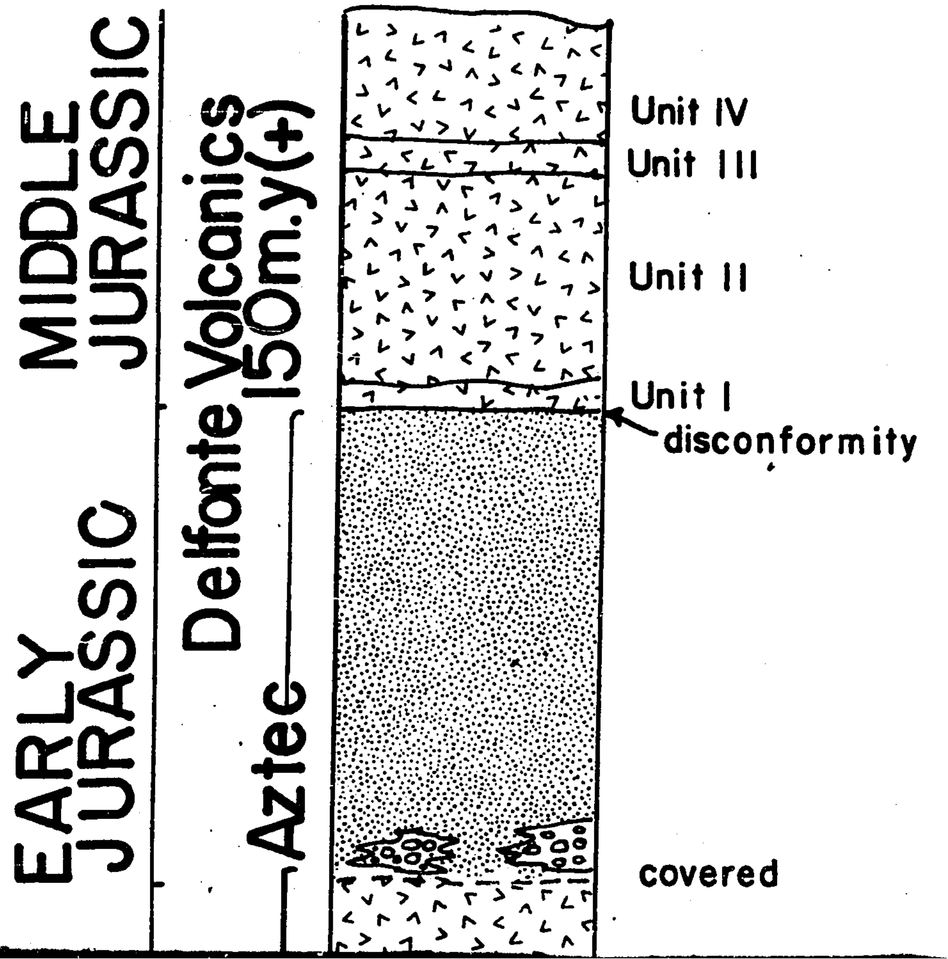


C ROCKS AT
EZOZOIC
TERN MOJAVE

DEVIL'S PLAYGROUND
(Dunne, 1972, 1977)

LE

ns, 1978)



PL

OUND

mity

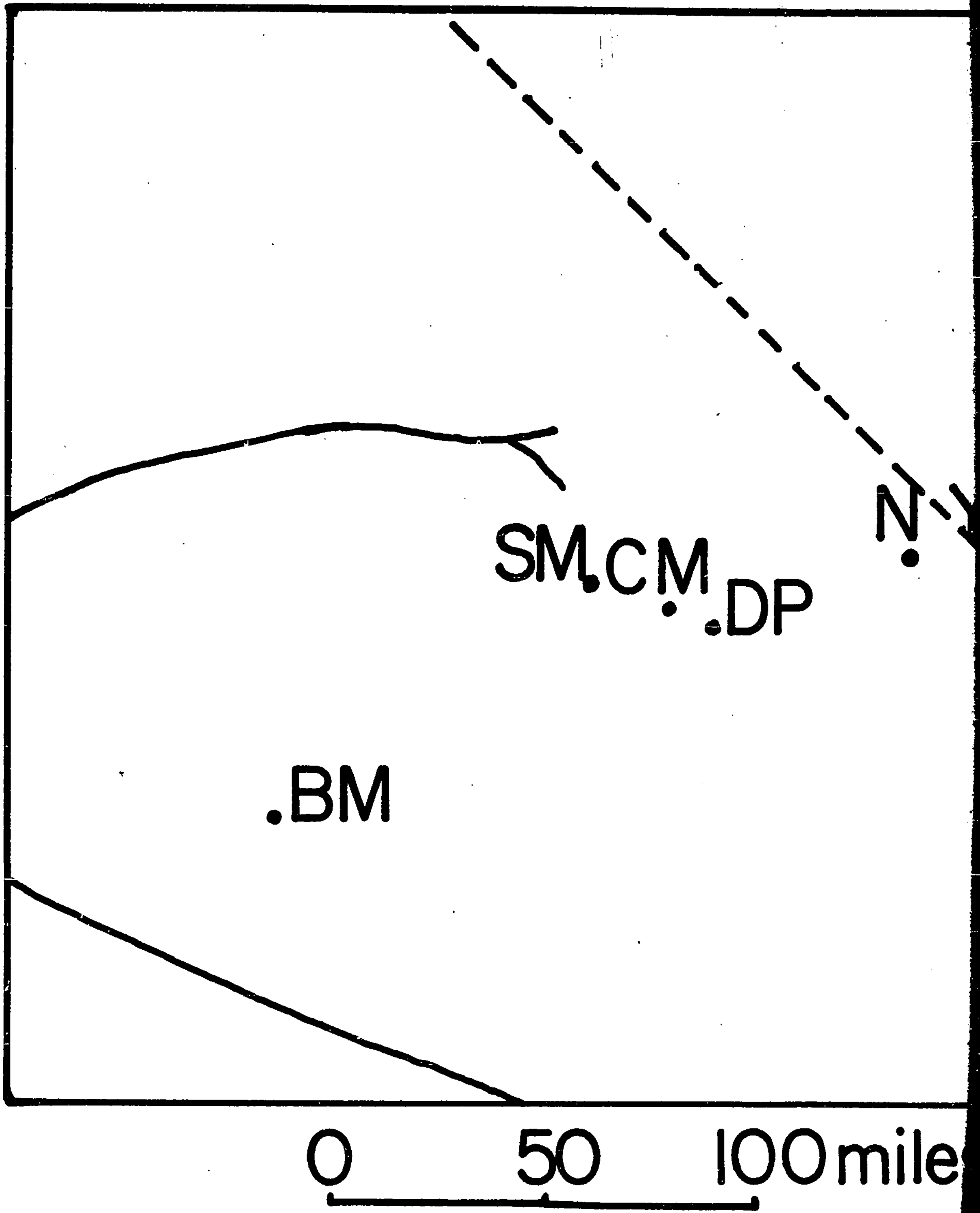
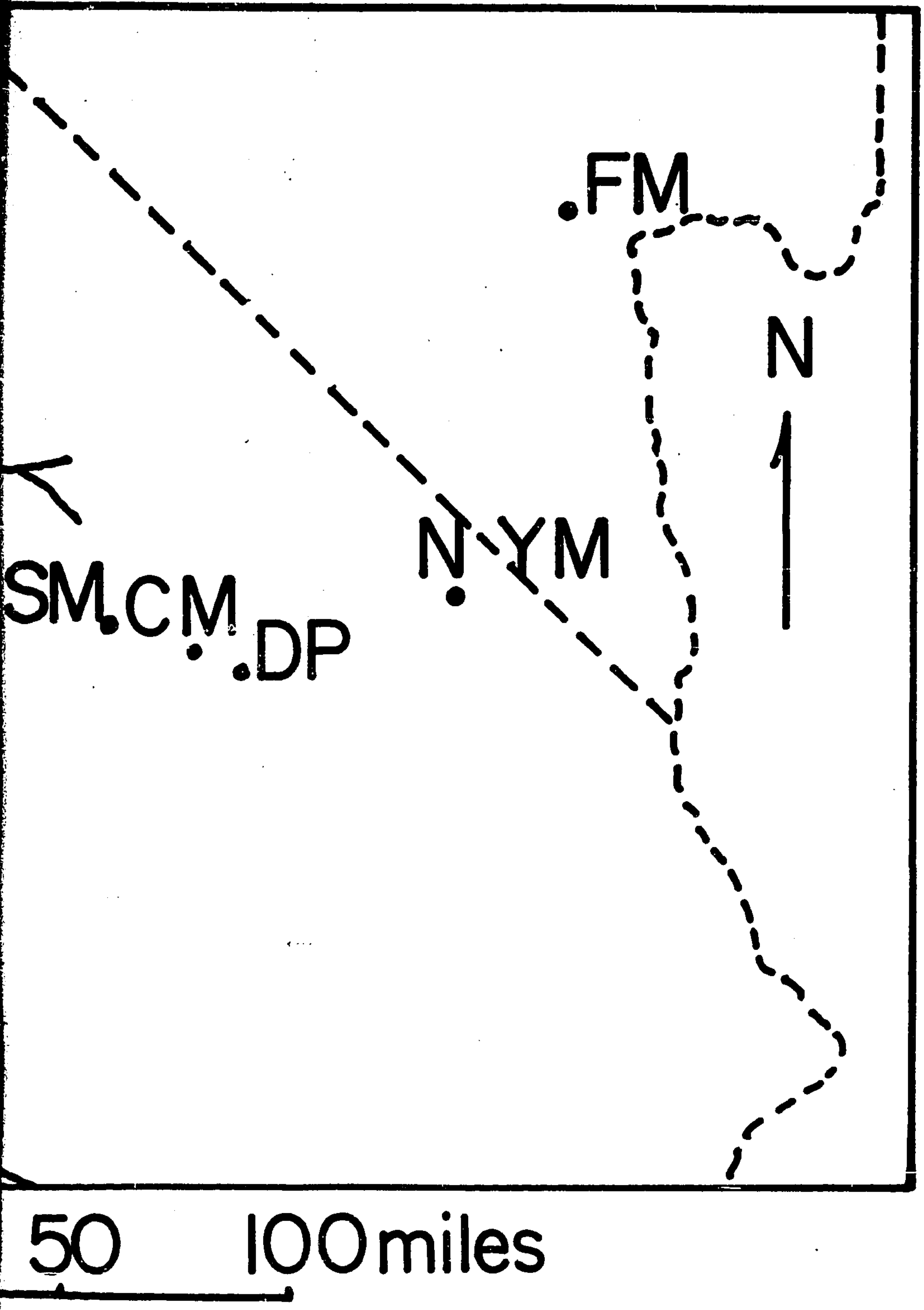
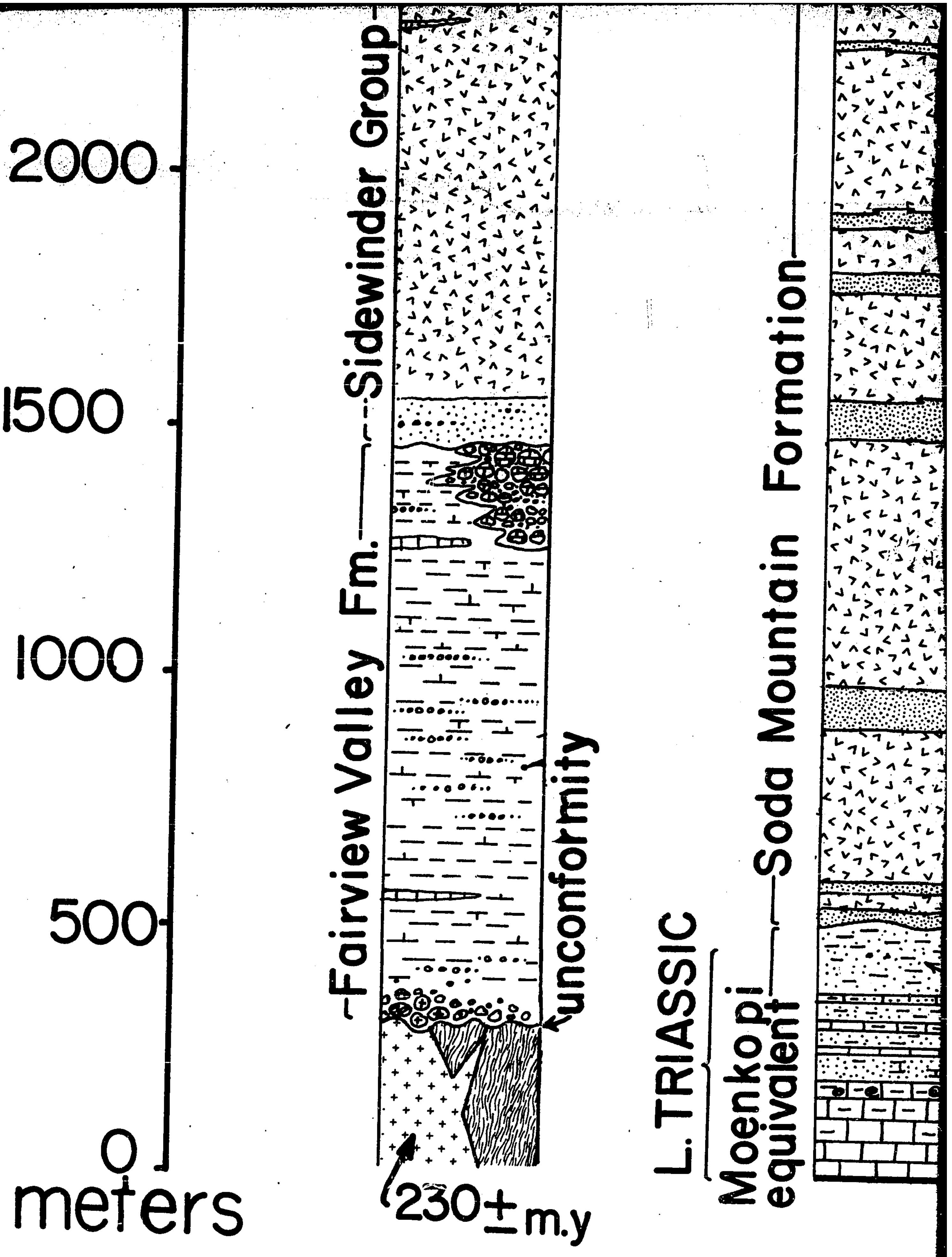
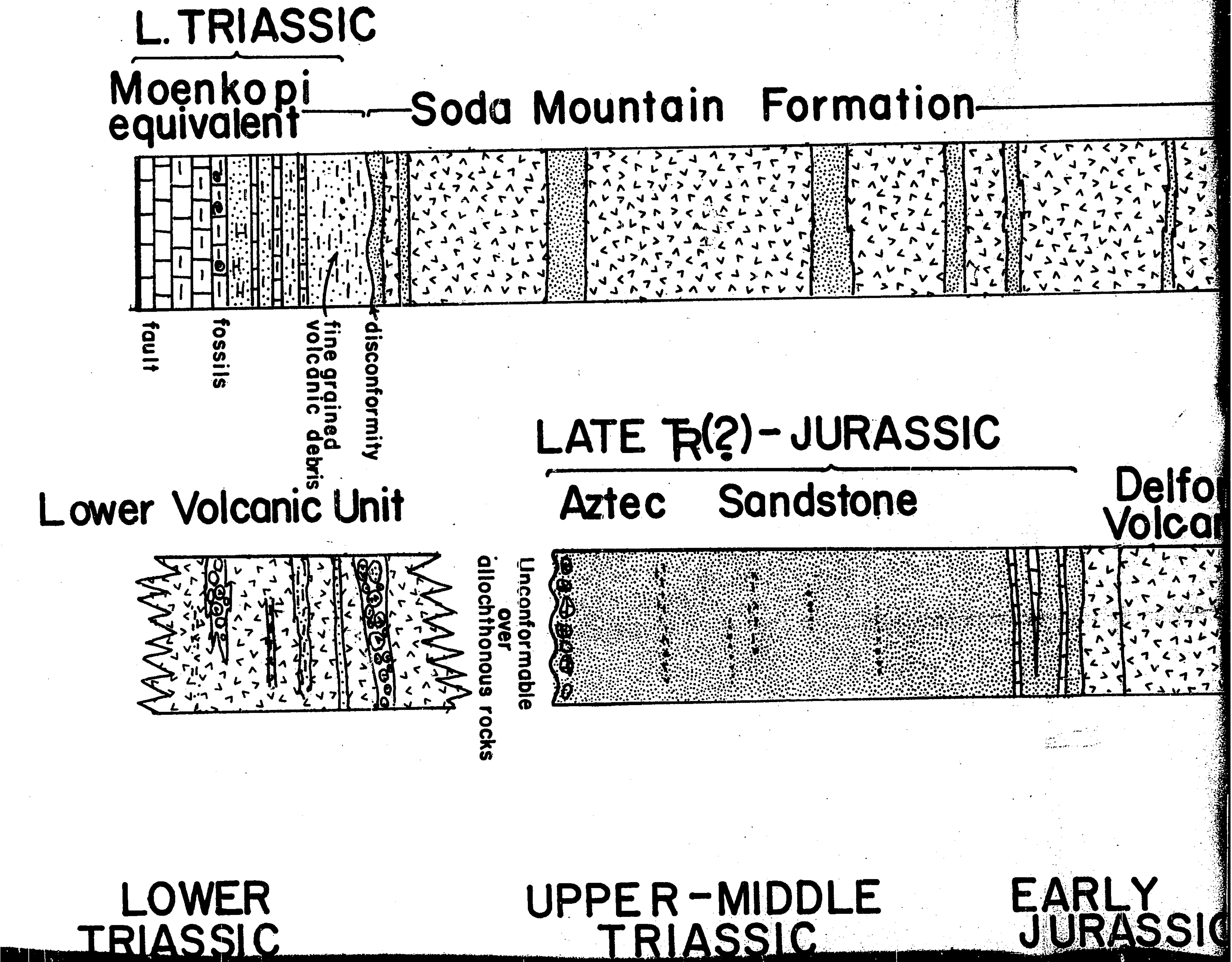
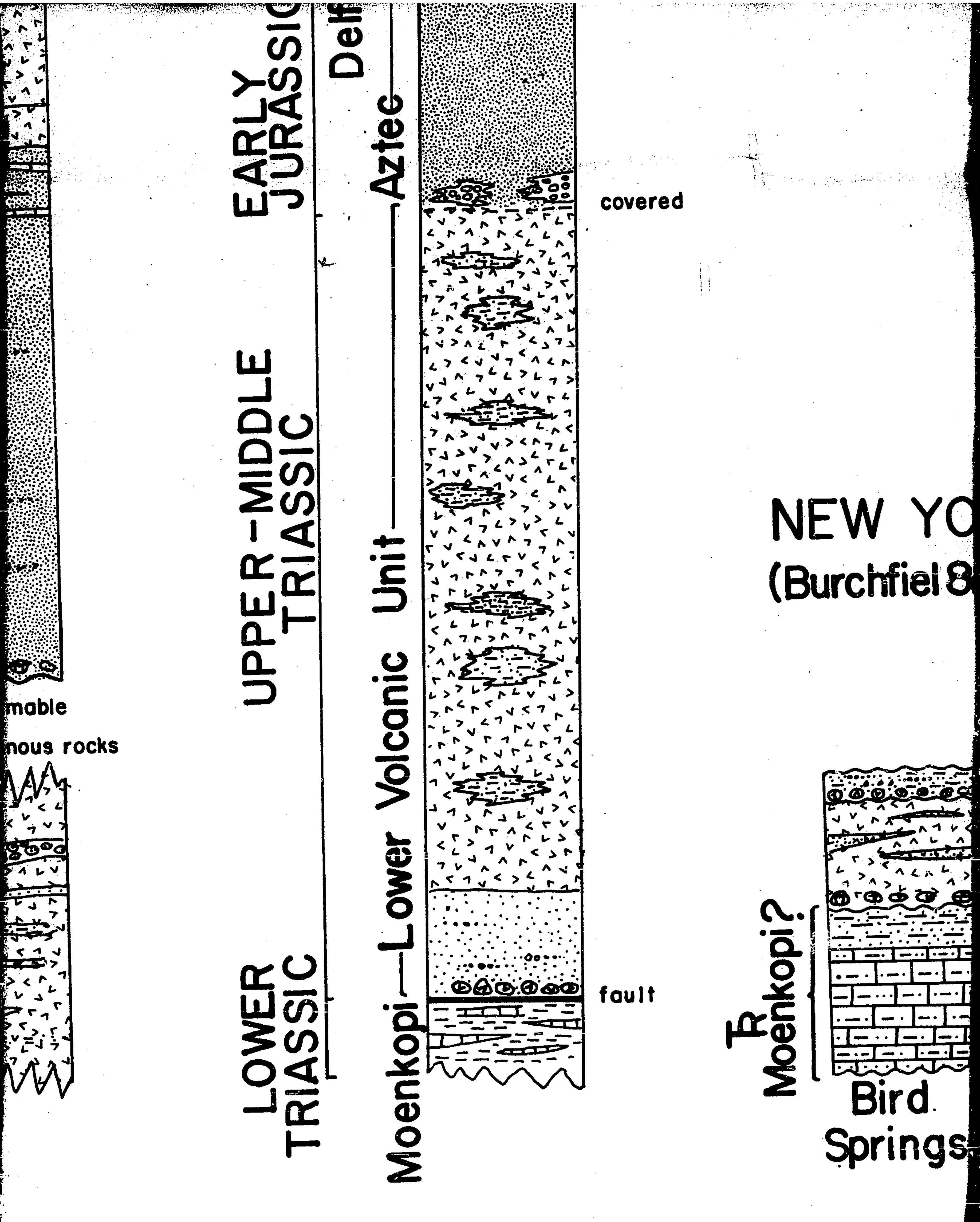


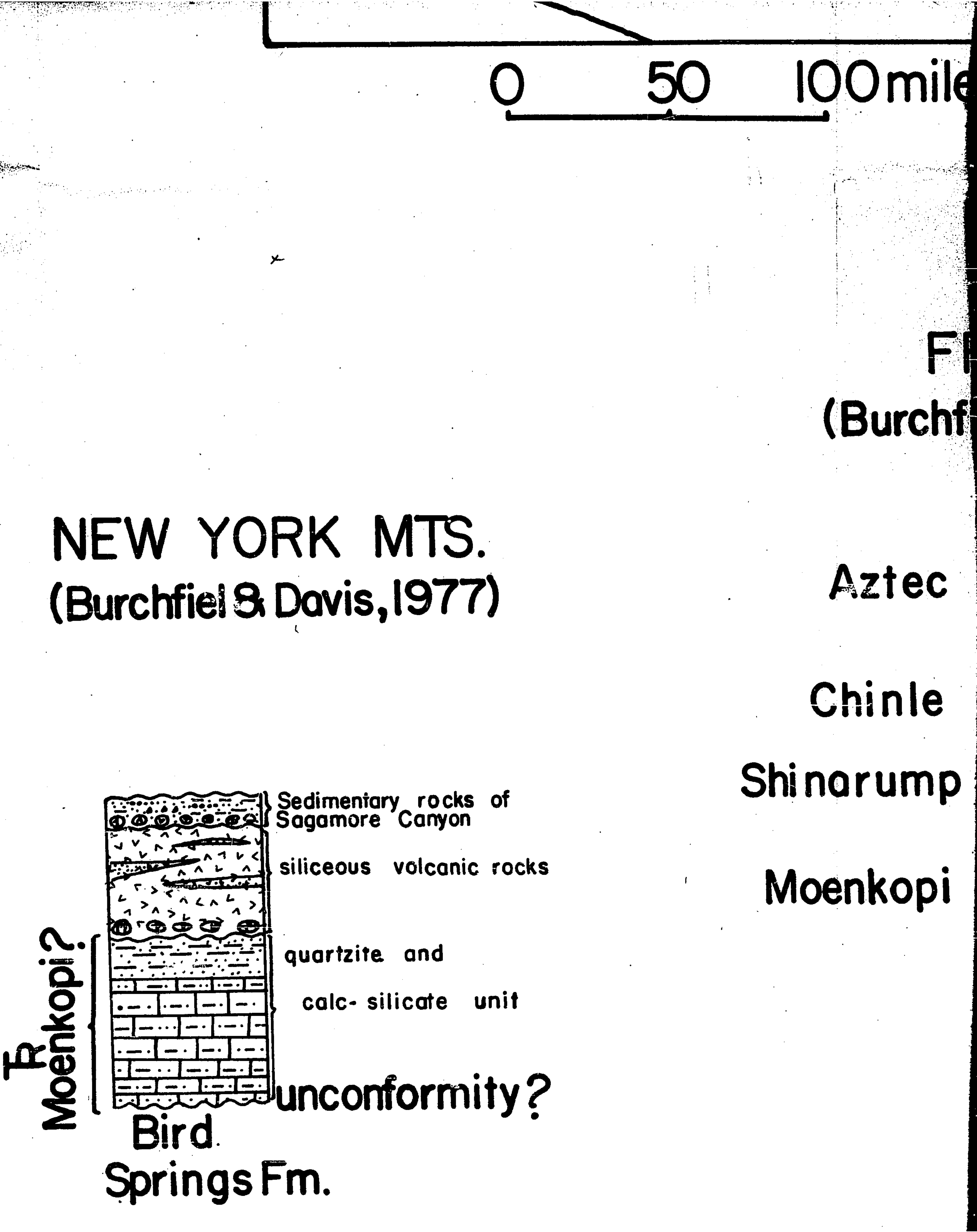
PLATE VI

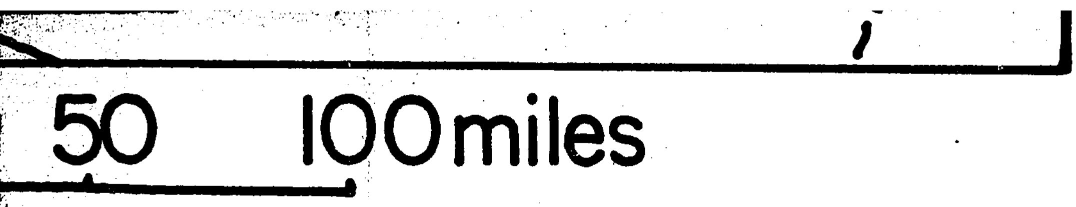



2000
1500
1000
500
0
meters
Sidewinder Group
Fairview Valley Fm.
unconformity
230± m.y
Soda Mountain Formation
L. TRIASSIC
Moenkopi equivalent


L. TRIASSIC
Moenkopi equivalent
Soda Mountain Formation
fault
fossils
fine grained volcanic debris
disconformity
LATE TR(?) - JURASSIC
Aztec Sandstone
Delfo
Volca
Lower Volcanic Unit
Unconformable over allochthonous rocks
LOWER TRIASSIC
UPPER-MIDDLE TRIASSIC
EARLY JURASSI


EARLY JURASSIC
Delf
Aztec
covered
UPPER-MIDDLE TRIASSIC
Lower Volcanic Unit
mable
nous rocks
LOWER TRIASSIC
Moenkopi
fault
NEW YO
(Burchfiel 8
Ꞧ Moenkopi?
Bird Springs


0
50
100 mile
Fl
(Burchf
NEW YORK MTS.
(Burchfiel & Davis, 1977)
Aztec
Chinle
Shinarump
Moenkopi
Sedimentary rocks of Sagamore Canyon
siliceous volcanic rocks
quartzite and calc-silicate unit
unconformity?
Ṝ Moenkopi?
Bird Springs Fm.



FRENCHMAN MT.

(Burchfiel and others, 1974)