GEOLOGY OF THE SAHUARO LAKE AREA

MARICOPA COUNTY, ARIZONA

by

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ABSTRACT

In the Sahuaro Lake area of Arizona, rocks are identified as belonging to the older Precambrian, possibly the Mesozoic, and to the Cenozoic Eras. The older Precambrian rocks are chronologically separated, from oldest to youngest, into the metavolcanics, a quartz diorite, and the Stewart Granite. The metavolcanics, further sub-divided into the volcanics and the agglomerate, are believed correlative with the Yavapai Schist. Weak foliation is found in the volcanics, strongest at igneous contacts and shear zones. No rocks of younger Precambrian or the Paleozoic age are recognized.

The older Precambrian rocks are intruded by basic and aplite dikes and plugs, Laramide in age. An unconformity separates these rocks from Tertiary ash-flow tuffs which show varying degrees of welding. Limited exposures of basalt which are pre-ash-flow tuff in age are found. A Tertiary conglomerate, probably synchronous with the Gila Conglomerate, occurs as a basin deposit.

In the older Precambrian rocks, a northeast structural trend is evidenced both by orientation of the metavolcanics and the quartz diorite, and the northeast fault contact between these two units. A

northeast shear zone also is present. Laramide structure is indicated by the orientation of sheared basic dikes striking N. 70° W. A normal fault of Cenozoic age has resulted in southeastward tilting of the volcanics of the Goldfield mountains.

It is concluded that the structures found in the older Precambrian rocks resulted from northwest-southeast compressive forces of the Mazatzal Revolution, which culminated in the intrusion of the Stewart Granite. It is believed either that during younger Precambrian and Paleozoic times the area was topographically high, possibly corresponding to the Mazatzal Land proposed by Stoyanow (1936), or that Peleozoic rocks which were deposited later were totally eroded. During the time of the Laramide orogeny, northwest shearing developed with the intrusion of basic and aplite dikes. Extensive volcanism, resulting in deposition of ash-flow tuffs, marks the Tertiary. Faulting, possibly related to the Basin and Range orogeny, brought about tilting of these volcanics.

INTRODUCTION

Location and Accessibility

Sahuaro Lake, created by Stewart Mountain Dam and located in Maricopa County forty miles northeast of Phoenix, Arizona, is the most downstream reservoir in a series of four located on the Salt River. The lake is approximately ten miles long and ranges in width from one mile to less than one-quarter mile.

The thesis area, bounded by lat. 33°35' 33" N and lat. 33° 32' 07" N and long. 111° 34' 00" W and long. 111° 30' 30" W, surrounds the major portion of Sahuaro Lake (Fig. 1). Approximately 13 square miles were studied, encompassing the mountains immediately adjacent to the lake, Stewart Mountain, and the northern one third of the Goldfield Mountains. Access to the lake area is by either the Bee Line Highway (State Highway 87) from Phoenix or the Bush Highway (County Road) from Mesa. Travel is otherwise limited to foot or horseback.

Topography and Physiography

Sahuaro Lake, located in the boundary area between the Basin

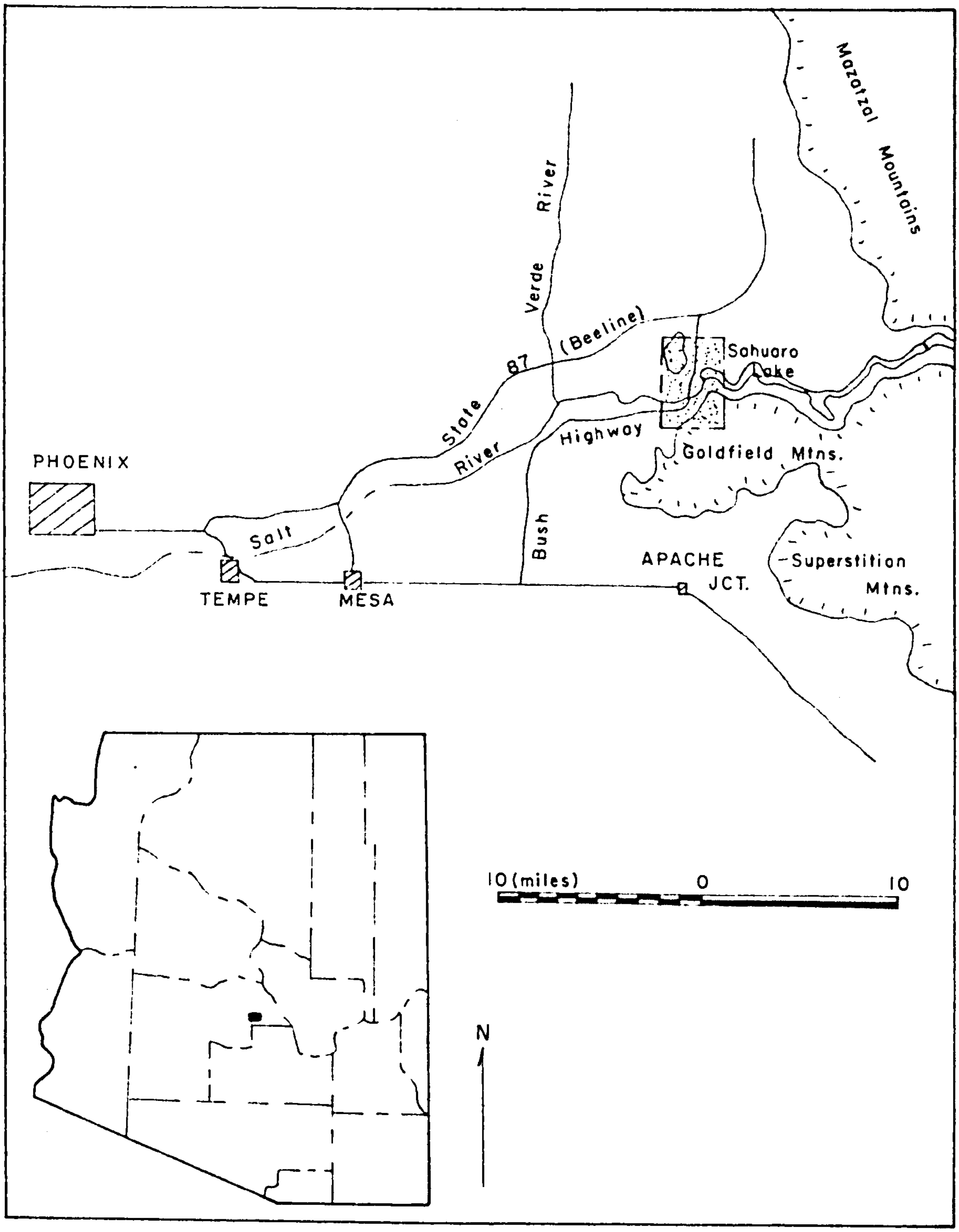

Fig. 1. Location map of the Sahuaro Lake Area

and Range and the Mountain Region (defined by Ransome,1923), typifies the physiographic features of both provinces. Most of the area is mountainous (Fig. 2 and 3), the exception being the Salt River valley which begins at the lake and extends to the southwest.

Physiographically the area is divided into two parts by a northeast-southwest fault escarpment, rising vertically 600 to 800 feet, forming the northwest boundary of the Goldfield mountains. The fault separates rugged mountains on the south from rolling hills and basin topography on the north. The Goldfield Mountains are characterized by vertical faced cliffs and numerous deep canyons. They reach a total elevation of 3250 feet, having a total relief from the valley floor of 1800 feet.

North of the escarpment, terrain is typified by steep slopes covered by erosional cut boulders. Due north of the lake are rolling hills which are part of a large basin which trends westward to the Verde River.

Sahuaro Lake is winding and narrow and bounded by steep canyon walls. These resulted from the cutting of the former channel of the Salt River, controlled in part by the fault escarpment.

Mountains in the area are deeply and well dissected by intermittent streams which flow into the Salt River.

FIGURE 2

Panoramic View of the Sahuaro Lake Area,
Looking East

Figure 2

FIGURE 3

Panoramic View of the Sahuaro Lake Area

Looking South

Figure 3

Climate and Vegetation

Climatically the area is situated in two types of regions: 1. Desert and 2. Steppe. The mixture of the two climates is characterized by low precipitation, high summer temperatures and moderate winters. The average annual rainfall is less than ten inches, the greatest amount usually occurring in late summer and early fall. Temperature in the summer months averages 90 to 95 degrees F. with the winter's temperature 65 to 70 degrees F.

Vegetation for the most part is typical of the Sonoran Desert, consisting of many varieties of cactus, desert brush,and scattered palo verde and mesquite trees. At the higher elevations of the Goldfield mountains, chaparral vegetation is seen.

Method of Study

Approximately 13 square miles of geologic mapping was undertaken. A 1904 U. S. G. S. Ft. McDowell Quadrangle, enlarged to a scale of 1:10560 with a contour interval of 50 feet, was used as a base map. Field locations were determined with the use of a Brunton Compass, altimeter, and aerial photographs where such coverage was available. A petrographic microscope was used in the laboratory to study approximately fifty thin sections of rocks collected in the field. Because of the absence of fossils, age dates of other investigators were used and correlation was made by lithology and stratigraphic position.

Fieldwork commenced in the spring of 1965 and was completed in the spring of 1966. Approximately three and a half months were spent in the field.

Purpose of Investigation

The Sahuaro Lake Area, which lies in the Mountain Region between the Transition Zone and the Basin and Range Province, is a complex of igneous, metamorphic, and sedimentary rocks about which little has been published. The purpose of this investigation is to contribute information on the structure and petrology of this complex and to the knowledge and understanding of the Mountain Region in central Arizona.

Acknowledgments

The writer wishes to express appreciation to Dr. S. R. Titley for his interest and encouragement given during this investigation. Especial appreciation is extended to William Rehrig and Dr. Earl Lovejoy for their participation in field trips and discussions. The critical reading of the manuscript by Professors Dr. Spencer R. Titley, Dr. Joseph F. Schreiber, and Dr. Gilbert is appreciated.

GEOLOGIC SUMMARY

All of the rocks found in the Sahuaro Lake area, with the exception of a conglomerate, are of igneous or volcanic nature. All can be assigned to four age designations: older Precambrian, possible Laramide, Tertiary, and Quaternary.

The metavolcanics (subdivided into the volcanics and the agglomerate), a quartz diorite, and a granite are assigned to the older Precambrian. Of possible Laramide age are basic and aplite dikes. The Tertiary period is marked by a basalt, a group of ash-flow tuffs (subdivided into red, brown and yellow flows), and a conglomerate. Sands, silts, and gravels make up the Quaternary deposits.

The metavolcanics are believed to be the oldest rocks in the area, and outcrop in the central portion of the area on the east and west side of Sahuaro Lake. The volcanics comprise the most extensive formation of the metavolcanic group. They are overlain by an agglomerate, which strikes N.45° E, and dips from 15 to 48 degrees southeast. Contact relationship between the volcanics and the agglomerate is gradational.

In the central portion of the area, the metavolcanics lie in fault contact with a quartz diorite. This fault contact is irregular and sharp, dipping steeply to the south. No fault gouge has developed, but a strong foliation, the result of shearing, is found in both rocks at the contact, diminishing approximately 30 feet from it on either side. Contact exposures are limited because of the presence of a thin veneer of alluvium.

No definite field evidence was seen for distinguishing the relative age relationship of the metavolcanics and the quartz diorite. However, thin sections at the contact reveal that the rocks of the metavolcanics have undergone recrystallization, whereas the quartz diorite exhibits no such evidence. It therefore seems probable that the metavolcanics are pre-quartz diorite, since the latter also would have been affected by the same conditions causing metamorphism if the quartz diorite were pre-metavolcanic.

Intruding both the metavolcanics and the quartz diorite is a granite referred to, for the purposes of this study, as the Stewart Granite. Since it is believed to be older Precambrian (Moore and Peirce 1957), it follows that both the metavolcanics and the quartz diorite also may be older Precambrian.

The granite outcrops primarily in the west and northwest portions of the area, although some is found east and south of the lake.

It lies in contact with the metavolcanics in the northeastern and western portions of the area. Exposures of the contact between the metavolcanics and the Stewart Granite are limited, but where observed, the metavolcanics exhibit strong shearing, with a well developed foliation paralleling the contact and extending as far as 20 feet from it. The granite is unaffected. On the east side of the lake there is a shear zone which has developed in both the metavolcanics and the Stewart Granite, adjacent to their contact. In the Butcher Jones Beach area on the north side of the lake, a dike of Stewart Granite approximately 30 feet in width cuts the metavolcanics, indicating that the Stewart Granite post-dates it.

The quartz diorite is intruded by and almost entirely bounded by the Stewart Granite. The contact is sharp and well defined, in general dipping steeply. The quartz diorite at the contact is extremely sheared, with the development of a strong foliation marked by the stringing out of the micas and feldspars. Foliation parallels and is best developed at the contact, extending usually only 20 to 30 feet from it. The granite also cuts the quartz diorite as dikes and small veinlets.

Based on reconnaissance observations, the Stewart Granite is believed to extend eastward to the west slope of the Mazatzal Mountains and is equivalent to the granite found there, described by Wilson (1939). Wilson suggests that the granite of the Mazatzals may correlate with the Bradshaw Granite of the Bradshaw Mountains and the Ruin granite of the Globe district. The Stewart Granite also extends southwestward beyond the Usery Mountains.

Intruding the metavolcanics, the quartz diorite, and the Stewart Granite are sheared basic dikes, outcropping as small ridges or knolls and trending north 70 degrees west. Several were found to strike north 15 to 25 degrees west and north 45 degrees east. Relative age of the basic dikes was definitely established, although it was impossible to ascertain actual age. Since the dikes cut the older Precambrian Stewart Granite, quartz diorite and metavolcanics, they are reasonably either younger or post-Precambrian. They are definitely pre-Tertiary, since they are unconformably overlain by Tertiary ash-flow tuffs. The author, however, feels that these dikes are of Laramide origin because: 1. The Laramide in Arizona is characterized by east-west and north-south shear breaks and denotes a period of extensive igneous activity and 2. These basic dikes dominantly exhibit this distinctive Laramide shear trend.

In all instances, the dikes exhibit a strong foliation which strikes parallel to their trends and which usually dips steeply to the northeast or vertically. The foliation generally continues for several feet into the contact rock. Stringers and lenses of white quartz paralleling the foliation are found associated with the dikes; one large quartz vein, varying from 10 to 30 feet in thickness and having a length exceeding 600 feet, is seen on the south slope of Stewart Mountain.

A few basic plugs similar in composition to the dikes are found in the area.

Aplite, occurring both as dikes and plugs, intrudes all of the older Precambrian units. These are believed to be post-basic dike in age; this is suggested by the observation of several aplite dikes cutting basic dikes. Outcropping is found primarily in the Stewart Granite. Two dominant strike directions were noted: 1. N. 50° to 55° E. and 2. N. 30° to 40° W. The dikes dip from steep to vertical. Aplite plugs outcrop as small knolls, ranging in diameter from less than 20 feet to greater than 150 feet.

On the north side of Sahuaro Lake, lying unconformably over the Stewart Granite, a narrow band of basalt outcrops. Stratigraphically above it is the yellow flow 1 of the Goldfield Volcanics. The contact between these two units is obscured by extensive cover.

Lying unconformably over the metavolcanics, the Stewart Granite, and the basalt are ash-flow tuffs, herein named the Goldfield Volcanics after the mountains in which they predominantly outcrop. The flows, which have undergone varying degrees of welding, are tilted from 20 to 30 degrees toward the southeast, as a result of a normal fault. This fault creates an 800 foot escarpment, the most prominent structural feature of the area. Locally, flow dips may be in excess of 60 degrees, due to underlying topography. Age of the Goldfield Volcanics is believed to be Tertiary (Moore and Peirce, 1957).

At the contact between the Goldfield Volcanics and the metavolcanics, very little erosional material is present, but fragments of the latter, ranging in size from small pebbles to boulders, are incorporated into the first few feet of the basal flow. Some baking is evidenced by the change in color of the metavolcanics from a bluish gray to black. Width of this baking zone varies from several inches to about one foot.

The contact between the Goldfield Volcanics and the Stewart Granite is sharp, marked by a well developed erosional surface. Sands, gravels and boulders, all of a granitic nature, are found incorporated in the basal unit of these volcanics. The zone of assimilation varies from several feet to less than 6 inches in thickness. Generally a thin veneer of erosional material separates the zone of assimilation and the granite.

A Tertiary conglomerate outcrops in a basin located north of Sahuaro Lake, overlying, for the most part, the Goldfield Volcanics, the Stewart Granite and the metavolcanics.

East of Butcher Jones Beach, however, a flow of the Goldfield Volcanics is seen lying unconformably over some Tertiary conglomerate. The conglomerate at this location consists of a bed measuring approximately 20 feet in thickness, and it in turn lies unconformably over the metavolcanics. Over this sequence the bulk of the Tertiary conglomerate is deposited. Because of this relationship and because of the assigned

Tertiary age of the Goldfield Volcanics, the conglomerate thus appears also to be Tertiary. It is probably synchronous with the Gila Conglomerate.

The conglomerate, where deposited on topographic highs, dips 20 to 40 degrees north. In the basin it dips 2 to 5 degrees north.

The Quaternary is represented by silts, sands and gravels found in stream drainages, on gentle slopes, and in the Salt River channel.

DESCRIPTION OF THE ROCKS

Older Precambrian Rocks

Metavolcanic Unit

The metavolcanic unit, older Precambrian in age, is a group which is subdivided into the volcanics and the agglomerate. The metavolcanics are the oldest rocks in the area. Outcropping is confined to the central portion of the region, occurring on the east and west side of Sahuaro Lake. These rocks have undergone weak to moderate recrystallization.

Volcanics

The volcanics comprise the most extensive formation of the metavolcanics. They lie in fault contact with the quartz diorite, are intruded by the Stewart Granite, and are overlain by the agglomerate and the Goldfield Volcanics.

Megascopically, the volcanics are dacitic, but it is difficult to determine their exact composition owing to extreme shearing and recrystallization of the rocks. Generally they are porphyritic, with feldspar and quartz occurring as phenocrysts. In shear zones, the rocks vary from well foliated with strongly oriented phenocrysts to phyllitic or schistose.

In thin section, the volcanics range in composition from dacites to rhyolites. For the most part they are porphyritic with the phenocrysts composing approximately 25 to 35 percent of the rock, ranging up to 2 mm in size. Some aphanitic varieties are seen. All the samples studied exhibit a foliation which varies in intensity depending on sample location. Samples collected which have no apparent megascopic foliation show a weak foliation in thin section.

In the samples collected from the shear zones, the fabric is strongly oriented due to the streaking-out of the micas and to the alignment of the feldspar phenocrysts parallel to their long axes. Many of the phenocrysts have granulated edges, the apparent result of rolling. The matrix, which ranges from sub-microscopic to very fine grained, has undergone recrystallization. This is evidenced by the interpenetration relationship of the feldspar and quartz grains. Little recrystallization of the phenocrysts is apparent.

Samples located other than at the shear zones exhibit a folia tion which is sub-megascopic to microscopic. Foliation is marked by the weak to moderate alignment of the micas, with only occasional alignment of the feldspar phenocrysts. The matrix, as before, is fine-grained, exhibiting evidence of recrystallization (Fig. 4).

FIGURE 4

Photomicrograph of Recrystallized "Volcanics" of the Metavolcanic Unit. (A), recrystallized matrix of quartz, orthoclase and plagioclase. (B), partially recrystallized plagioclase phenocryst. Weak orientation to fabric can be seen. Crossed nicols.

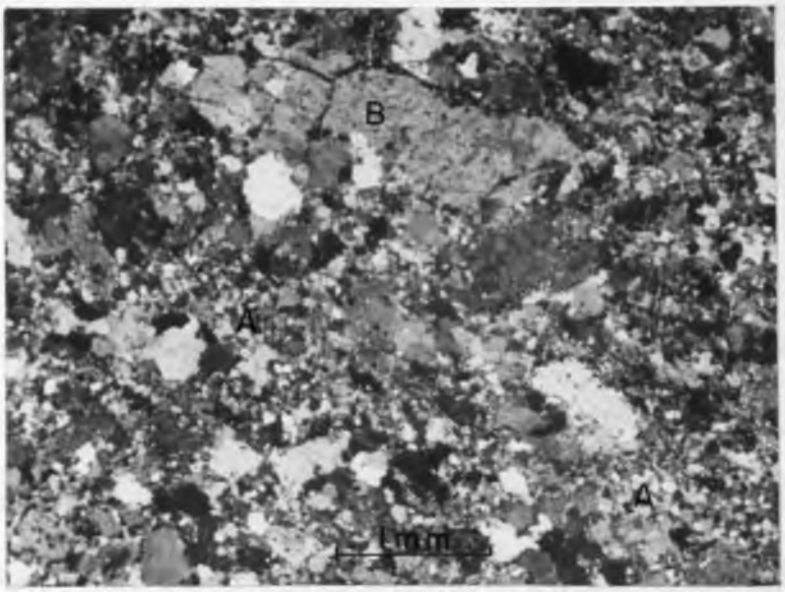

Figure 4

Plagioclase of composition An_{30-34} constitutes over 75 percent of the phenocrysts, with orthoclase and quartz making up the remainder. The crystals are subhedral to anhedral, mostly untwinned, and are weakly to moderately altered to clay. Plagioclase also is found in the matrix as anhedral untwinned crystals. Quartz makes up anywhere from 15 to 35 percent of the rocks and exists dominantly in the matrix. A few crystals of volcanic quartz are seen as phenocrysts. Orthoclase, moderately altered to clay, is found as subhedral phenocrysts and as anhedral grains in the matrix. Biotite and muscovite constitute up to 20 percent of the rock.

Agglomerate

The agglomerate unit of the metavolcanics overlies the "volcanics". It outcrops primarily on the east side of Sahuaro Lake and occurs sporadically in the central portion of the area. Contacts between the volcanics and the agglomerate are gradational and vague. Because the matrix and color of the two units are so similar, contacts can be distinguished only by the presence of pebbles, which occur randomly within 50 to 100 feet of the actual agglomerate unit.

The agglomerate, which is light tan to gray in color, contains a consistent distribution of pebbles throughout. These pebbles, which make up approximately 70 percent of the rock unit, megascopically appear to be volcanic in composition. They are well to sub-rounded and range up to three inches in diameter. Some fragmental material less than 1/2 inch in dimension occurs in the matrix.

In the agglomerate, two types of pebbles are megascopically distinguishable on the basis of color and apparent composition: 1. a light tan pebble and 2. a dark gray to black pebble. Both types have been recrystallized.

The light tan pebbles are porphyritic to granitic in texture and appear to be rhyolitic as they contain phenocrysts of quartz and orthoclase. Biotite is also found. The granitic-textured pebbles are probably a result of a more intense recrystallization.

The dark gray pebbles have a basic composition and contain phenocrysts of plagioclase.

Surrounding both types of pebbles is a finely crystalline matrix of quartz, plagioclase, and orthoclase. Sericite is also present.

In thin section, the agglomerate is composed of volcanic pebbles and fragments surrounded by a dacitic matrix. The pebbles and matrix are intensely recrystallized, as is evidenced by the sutured relationships of the mineral constituents (Fig. 5).

The pebbles analyzed range from basic to rhyolitic and are finely crystalline with scattered phenocrysts of quartz and feldspar.

The dacitic matrix surrounding the pebbles is composed of quartz, orthoclase, plagioclase, and sericite. These minerals are finely crystalline and range up to 1/4 mm in size. Phenocrysts of

FIGURE 5

Photomicrograph of Recrystallized Agglomerate of the Metavolcanics. (A) Recrystallized matrix of quartz, orthoclase and plagioclase. (B) Recrystallized pebbles. Crossed nicols.

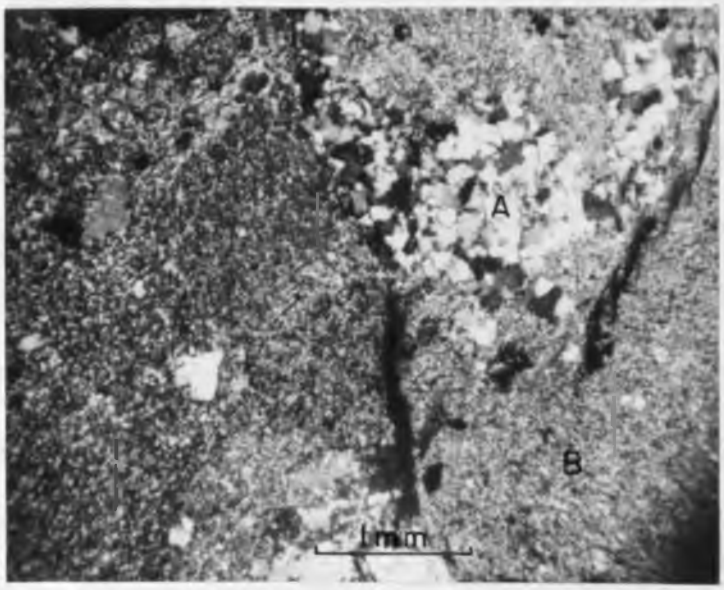

Figure 5

feldspar and quartz are also found. These range up to 1 mm in size. Quartz occurs dominantly in the matrix as small anhedral grains and as veinlets which cut small pebbles and fragments. Plagioclase, composition An_{28-30}, occurs as subhedral to anhedral grains, mostly untwinned, and ranging up to 1 mm in size. The phenocrysts are largely composed of this mineral. Orthoclase is found as anhedral grains in the matrix. Sericite is present in small wisps which are found along the edges of the pebbles and fragments.

Proposed Correlation

Much of the metavolcanics sequence in the area has undergone such extensive shearing and recrystallization that megascopic identification of the parent rock is extremely difficult. For the following reasons, however, these rocks are believed originally to have been volcanics, possibly flows:

1. The presence of a relict porphyritic texture.
2. The occurrence of subhedral feldspar crystals as phenocrysts, indicating igneous origin.
3. The occasional but unmistakable appearance of graphic quartz.
4. The weakly recrystallized phenocrysts in a completely recrystallized matrix.

Since these metavolcanics appear to be truly volcanic in origin, and since they have been shown to be older Precambrian (intrusion of the older Precambrian granite into the metavolcanics), these rocks may be correlative with the Yavapai Schist. As Anderson (1951) remarked, there is danger in any attempt at distant correlation between the older Precambrian rocks because of the repetitious character of the andestic and rhyolitic flows, tuffs and tuffaceous sediments. It is nevertheless conjectured that the metavolcanics possibly may be correlative with Wilson's (1939) Red Rock Rhyolite of the Mazatzal Mountains, which consists of rhyolitic flows and minor amounts of agglomerate. Further work no doubt would have to be done to substantiate this inference.

Quartz Diorite

A quartz diorite of older Precambrian age outcrops just north of the Salt River as a lens-shaped body pinching out to the east and west. It is intruded by and almost entirely bounded by the Stewart Granite and also comes in fault contact with the volcanics of the metavolcanics group.

Megascopically, this quartz diorite appears to be a dark green, medium grained quartz diorite. Quartz exists an anhedral, transparent grains, ranging up to 2 mm in diameter. Plagioclase occurs as subhedral to anhedral white grains ranging up to 6 mm in length. A few of the surfaces, when studied with a hand lens, show polysynthetic twinning. Biotite and hornblende make up the mafic minerals which constitute approximately 20 percent of the rock. Biotite is present as shiny black flakes with a rather irregular outline. The books have an average length of less than 1 mm. Hornblende occurs as subhedral grains less than 2 mm in length.

Microscopically, the older Precambrian quartz diorite is a holocrystalline, medium grained, hypidiomorphic granular quartz diorite, composed of quartz, feldspar, biotite, hornblende and sericite. Quartz comprises 8 to 10 percent of the rock, existing as anhedral grains which show undulatory extinction. Average grain size is less than 1 mm. Plagioclase of composition An_{34-36} as determined by the Michel Lévy method is the dominant feldspar. The grains are subhedral to anhedral, ranging in size up to 5 mm. A few crystals are zoned but generally are well twinned. The plagioclase exhibits weak to moderate alteration to sericite. Orthoclase occurs as anhedral grains ranging less than 1 mm in size. These are untwinned, perthitic, and exhibit weak clay alteration. Biotite is the dominant mafic mineral comprising some 8 percent of the rock, with hornblende averaging less than 5 percent. Biotite is light brown to dark brown, and occurs as patches or subhedral flakes.

Stewart Granite

The most prominent rock unit in the area representing the older Precambrian, and the one most extensively mapped, is the Stewart

Granite. Stewart Mountain, after which, for the purposes of this study, the granite is named, is entirely composed of this rock unit. The granite intrudes the metavolcanics and the quartz diorite, and is intruded by aplite and basic dikes and plugs. Lying uncomformably over the granite are the Goldfield Volcanics.

The Stewart Granite is a light tan in color, and megascopically appears to vary from a coarse-grained granite to a granite porphyry. The more porphyritic phases occur dominantly in the Stewart Mountain area, while the coarse-grained type is found in the areas surrounding the quartz diorite. The quartz appears as anhedral, smoky to transparent grains ranging up to 4 mm in diameter. The potash feldspar occurs as subhedral to anhedral flesh-colored grains exhibiting a perthitic texture. In the coarse grained phases, the orthoclase ranges up to 8 mm in length, with the average length approximately 6 mm. In the porphyry phases, this mineral ranges up to 35 mm in length with an average length of about 15 to 20 mm, forming phenocrysts. Carlsbad twinning is readily observed on many crystals. Plagioclase occurs as subhedral to anhedral white grains averaging 4 to 5 mm in length. Polysynthetic twinning can be seen with the aid of a hand lens. Biotite is present as shiny greenish-black books ranging up to 5 mm in size.

In thin section, the Stewart Granite is a granite composed of quartz, orthoclase, plagioclase, biotite, chlorite, sericite, apatite and sphene. The quartz, which comprises 15 to 20 percent of the rock, shows two distinct periods of crystallization. The first period was contemporaneous with the initial crystallization of the granite and formed interstitial anhedral grains averaging less than 1 mm to 2 mm in size. A second period of quartz crystallization is evidenced by small quartz veinlets cutting the formerly crystallized quartz and feldspar grains (Fig. 6). The quartz grains in the veinlets have an igneous texture, suggesting that the quartz is either a product of late-stage crystallization or is of a secondary source. All the quartz has moderate to strong undulatory extinction. Plagioclase of composition An_{32-34} is the dominant feldspar in the groundmass. The grains are anhedral to subhedral, averaging 1 to 2 mm in length. The plagioclase is moderately to strongly altered to sericite. Orthoclase exists as subhedral to anhedral grains and largely composes the phenocryst portion of the porphyritic phases of the granite. The grains are generally untwinned, perthitic and exhibit weak alteration to clay. Biotite occurs as wisps to subhedral flakes, showing a very weak alteration to chlorite. Apatite and sphene are present as accessory minerals.

Laramide Rocks

Basic Dikes

The basic dikes are found almost exclusively in the northwestern portion of the area, outcropping as narrow bands ranging in width from less than two feet to greater than 100 feet. They are found

FIGURE 6

Photomicrograph of Stewart Granite Showing Two Periods of Quartz Crystallization. (A), late stage quartz veinlets cutting orthoclase crystal, (B), and primary quartz crystal, (C), Crossed nicols.

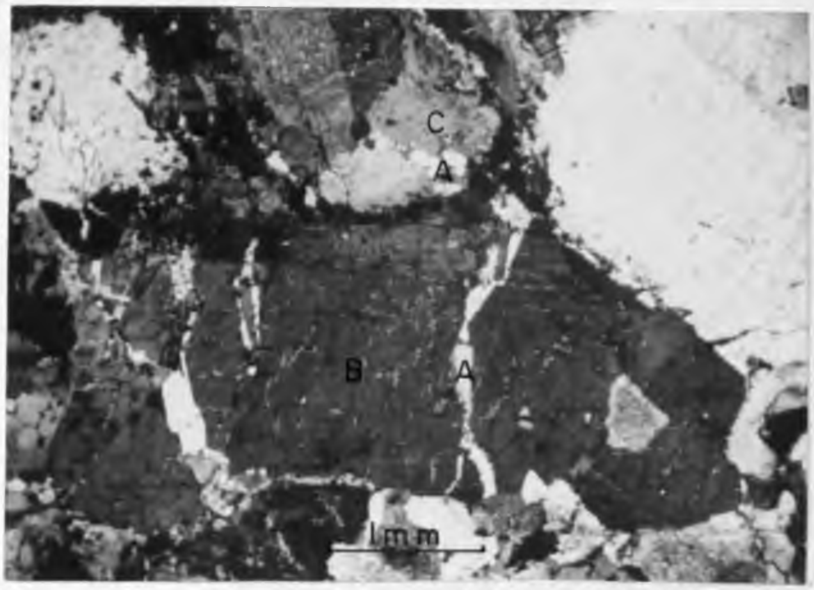

Figure 6

intruding the Stewart Granite, quartz diorite and metavolcanics.

Megascopically, the dikes, dark green in color, appear to be basic in composition. Texturally, they range from very fine grained to aphanitic, with a few feldspar and quartz crystals occurring as phenocrysts. The mafic minerals, which comprise approximately 90 percent of the rock, are composed of biotite and hornblende. Feldspar and quartz account for the remaining 10 percent.

Microscopically, the composition of the basic dikes is a quartz diorite approaching a quartz gabbro. The mineral constituents are biotite, hornblende, quartz, and plagioclase.

In the non-foliated samples analyzed, the dikes are very fine grained, having a non-oriented fabric (Fig. 7). Hornblende is the dominant mafic constituent, comprising anywhere from 40 to 80 percent of the rock, with biotite accounting for 20 to 30 percent. Average grain size of the mafic minerals is less than one-half millimeter. In some specimens studied, hornblende is in such quantities that the rock could be called a hornblendite. Plagioclase, composition An_{44-46}, appears as subhedral to anhedral grains averaging less than one-half millimeter in size. Few crystals are twinned. Quartz occurs in the matrix as anhedral grains.

The foliated samples have a mylonitic texture as exhibited by a strongly oriented fabric. This is characterized by the streaking out

FIGURE 7

Photomicrograph of Non-Foliated Basic Dike. Unoriented fabric is illustrated by random arrangement of hornblende (A) and biotite (B) crystals. (C) plagioclase and quartz grains in matrix. Uncrossed nicols.

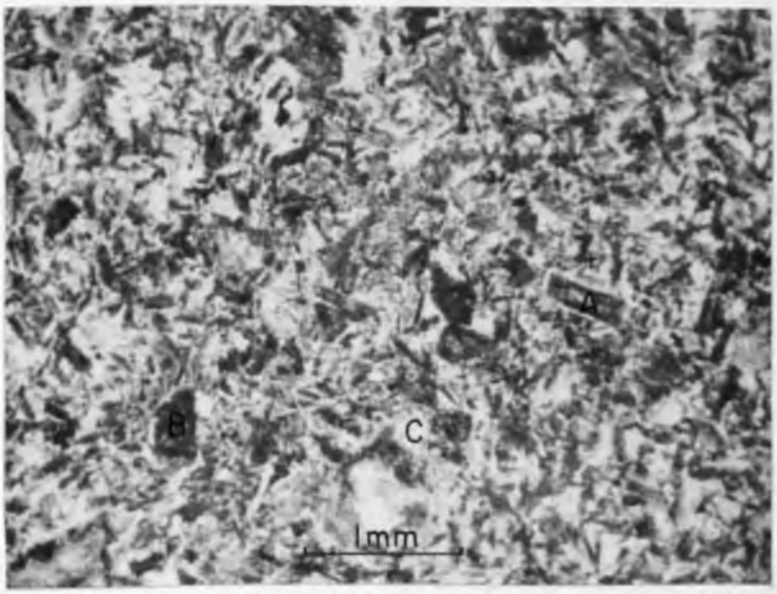

Figure 7

of the mafic minerals and the reduction in grain size of the mineral constituents (Fig. 8). The biotite and hornblende occur as minute grains, less than one-tenth millimeter in size, exhibiting a strongly preferred orientation. The quartz and plagioclase, whose average grain size is less than one-quarter millimeter, are fractured and granulated.

Aplite Dikes

Although outcrops of the aplite are found primarily in the Stewart Granite, it intrudes and is confined to all of the older Precambrian units. It occurs both as dikes and plugs. The dikes range in width from less than 6 inches to greater than 40 feet, while the plugs outcrop as small knolls, and range in diameter from less than 20 feet to greater than 150 feet.

Megascopically, the aplite bodies are light tan to rusty brown in color and exhibit two types of textures: 1. aplitic and 2. porphyritic with an aplitic groundmass. Compositionally they appear to be granitic.

In the aplitic phases, quartz appears as transparent, anhedral grains ranging up to less than 1 mm in diameter. Orthoclase occurs as flesh colored grains, subhedral to anhedral. The plagioclase grains, which exhibit occasional polysynthetic twinning, are white and are subhedral to anhedral. Biotite is the mafic mineral, which constitutes less than 3 percent of the rock.

FIGURE 8

Photomicrograph of Sheared Basic Dike Illustrating Its Mylonitic Fabric and Reduction of Grain Size of the Mineral Constituents. Uncrossed nicols.

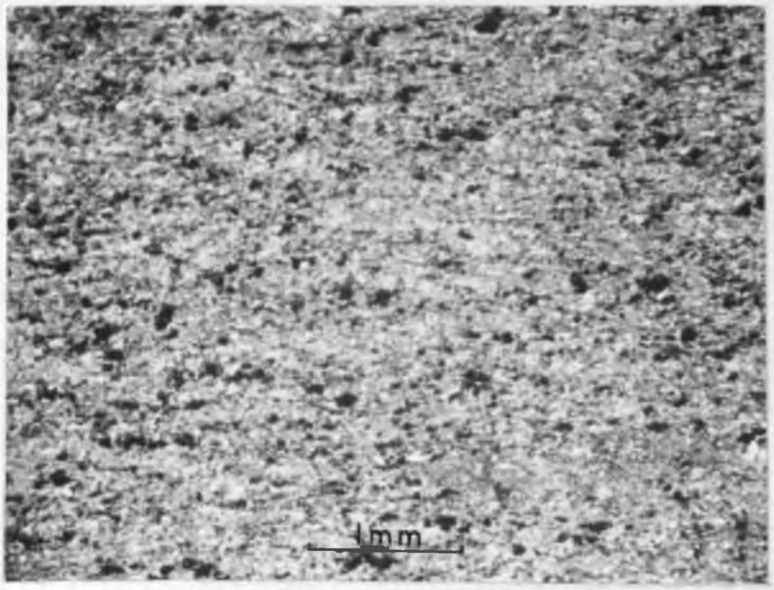

Figure 8

In the porphyritic phases, quartz and feldspar constitute the phenocrysts, comprising less than 6 percent of the rock. These phenocrysts range up to 5 mm in size. The matrix is identical with that found in the aplitic phases.

In thin section, the aplite is compositionally an alaskite. Quartz comprises 40 to 45 percent of the rock, occurring as anhedral grains less than one-half millimeter in size. A few phenocrysts range up to a maximum 2 mm in diameter. The plagioclase, composition An_{22-24}, appears as subhedral to anhedral grains averaging one-half millimeter in size. Phenocrysts may range up to 2 mm in length, and show moderate to strong alteration to sericite. Few crystals are twinned. Orthoclase is largely anhedral, exhibiting a weak clay alteration. Biotite makes up less than 2 percent of the rock. Some microcline is present as anhedral grains.

Tertiary Rocks

Basalt

On the north side of Sahuaro Lake, lying unconformably over the Stewart Granite, a narrow band of basalt outcrops. Stratigraphically above it is the yellow flow 1 of the Goldfield Volcanics. The contact between the yellow flow and the basalt is obscured by extensive cover.

Megascopically, the basalt shows a reddish-brown color on a weathered surface, with a fresh surface displaying a bluish-gray color.

Plagioclase, a pyroxene, and an unidentifiable reddish brown mineral, comprise the phenocrysts. These, ranging up to 3 mm in size, make up less than 2 percent of the rock. The plagioclase is subhedral, with occasional polysynthetic twinning observable.

Viewed microscopically, the basalt is composed of plagioclase, augite and iddingsite (Fig. 9). The plagioclase, composition An_{46-48}, occurs as lath-shaped crystals comprising approximately 98 percent of the rock. Most have albite twinning, with a few of the larger crystals exhibiting peripherial zoning. They range from less than one-tenth millimeter to 1 mm. The augite, which comprises less than 2 percent of the rock, occurs as phenocrysts ranging up to 1 mm in size. Iddingsite is scattered sparingly throughout the matrix as crystals ranging up to 1/2 mm in size. The iddingsite is an alteration product of olivine, being pseudomorphic after it. Several crystals of olivine are seen which are rimmed by iddingsite.

Goldfield Volcanics

The Goldfield Volcanics, named for the purpose of this paper after the mountains in which they predominantly outcrop, are ash-flow tuffs which have undergone varying degrees of welding. They lie uncomformably over the metavolcanics, the Stewart Granite and the basalt, and their age is believed to be Tertiary (Moore and Peirce 1957).

FIGURE 9

Photomicrograph of Basalt. (A) Plagioclase crystals. (B) Augite crystals. Crossed nicols.

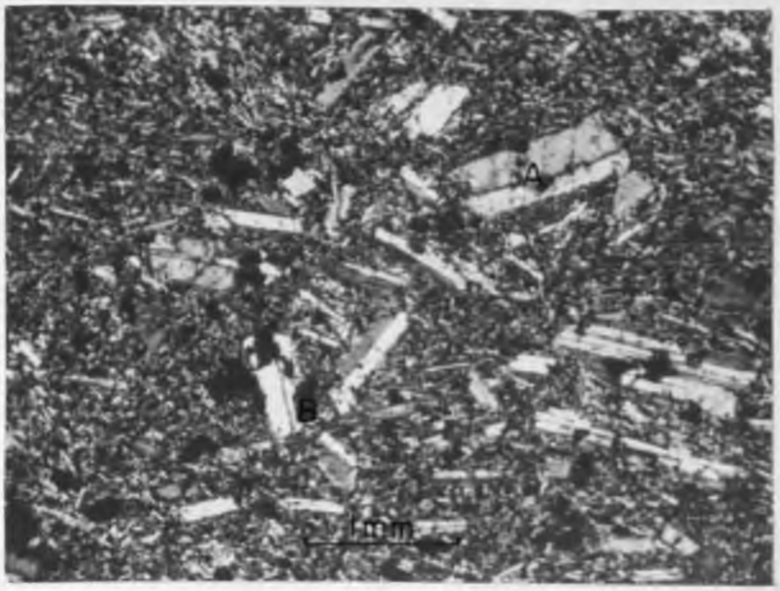

Figure 9

Individual flows of the Goldfield Volcanics are subdivided into three categories, differentiated on the basis of actual color and composition, and done in order to illustrate the structural relationship of the Goldfield Mountains to the rest of the area. The volcanics are placed into three divisions: 1. Red Flow; 2. Brown Flows; and 3. Yellow Flows. The latter two were then further subdivided into individual flows, alphabetically for the brown flows and numerically for the yellow flows. This more detailed subdivision was based on inferred stratigraphic position and contact relationships. Since the only difference among the different sub-flows of the color groups is found in their varying amounts of glass content, their rock description is treated as a whole.

Red Flow

The red flow outcrops in the central portion of the area south of the Salt River. It forms the basal unit of the Goldfield Volcanics in this area, lying unconformably over the Stewart Granite. Lying stratigraphically above is the C flow of the brown flows. The contact between the C flow and the red flow is sharp, marked by a color change from reddish brown to light brown.

Megascopically, the red flow appears to be a reddish-brown tuff, with fragmental material less than 4 mm in size enclosed in a glassy matrix. Occasionally a glass phenocryst is observed. Numerous vesicles are present, in general partially filled with quartz. A dark green mafic mineral also can be seen.

In thin section, the red flow is an ash-flow tuff composed of 40 to 50 percent rock fragments enclosed in a devitrified matrix. The fragments exhibit no distortion, indicating lack of welding, and are poorly sorted (Fig. 10). Tridymite, the result of devitrification, comprises the matrix, and also fills vesicles. Augite occurs as an occasional phenocryst and as small laths scattered randomly throughout the matrix.

Brown Flows

The brown flows comprise the greatest part of the Goldfield Volcanics, forming units that measure up to 600 feet in thickness. Each unit appears to be the composite of several ash-flows or welded tuffs.

Occurring randomly throughout the brown flows are the yellow flows. Contacts between these units are gradational and marked only by the color change from brown to yellow. Adjacent to the contacts, glass fragments which range up to one foot in diameter are commonly found in both formations. These fragments have a perlitic texture, are gray in color and are oblong to sub-rounded in shape. Lithophysae ranging up to one-half inch in diameter also are found randomly throughout both volcanic units.

FIGURE 10

Photomicrograph of the Red Flow of the Goldfield Volcanics. (A) Fragments, non-distorted and poorly sorted. (B) Vesicles partially filled with tridymite. (C) Devitrified matrix. Uncrossed nicols.

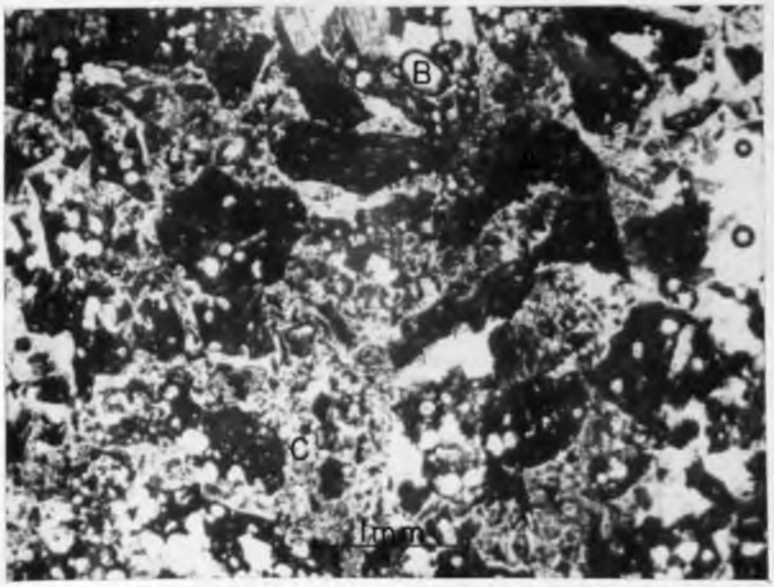

Figure 10

The brown flows contain lenses of hyaline material, which range in thickness from several feet to greater than 30 feet.

Megascopically, the brown flows appear andesitic in composition. They are light brown to reddish brown in color. For the most part, excluding the hyaline lenses, they appear to be of uniform fine-grained texture, although in some units rock fragments measuring up to 1 inch in diameter are found. Plagioclase exists as white phenocrysts ranging up to 5 mm in size. Biotite is found as scattered flakes less than 3 mm in size. The matrix ranges from holohyaline to hemicrystalline.

In thin section, the brown flows appear to be ash-flow tuffs of andesitic composition which have undergone varying degrees of welding. In the fine-grained specimens studied, texture is characterized by phenocrysts of plagioclase scattered throughout a devitrified cryptocrystalline matrix. The plagioclase crystals, composition An_{28-30}, are subhedral, range up to 6 mm in size, and comprise less than 10 percent of the rock. A few exhibit albite twinning and peripheral zoning. Biotite is the dominant mafic mineral, comprising less than 3 percent of the rock. Hornblende is present as euhedral to subhedral grains less than one millimeter in size. Minor quartz as phenocrysts is noted (Fig. 11).

Samples analyzed from the hyaline lenses have a weak eutaxitic structure and exhibit characteristics of extreme welding (Fig. 12 and 13).

FIGURE 11

Photomicrograph of Fine-Grained Specimen Collected From the Brown Flows. (A) Phenocrysts of plagioclase. (B) Hornblende. (C) Biotite. (D) Devitrified matrix. Uncrossed nicols.

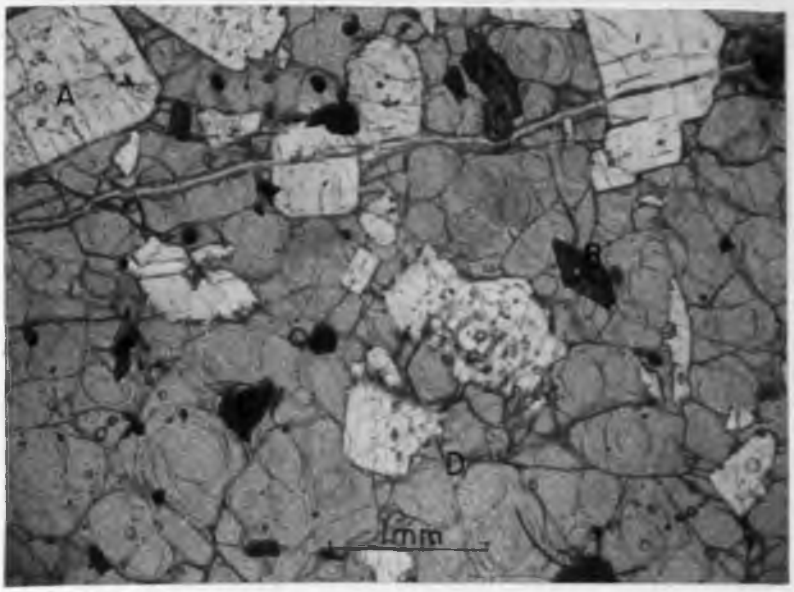

Figure 11

FIGURE 12

Photomicrograph of Sample Collected From Hyaline Lens of the Brown Flows. (A) Axiolitic structure developed in the devitrified products. (B) Spherulites. Crossed nicols.

FIGURE 13

Photomicrograph of Sample Collected From Hyaline Lens of the Brown Flows. (A) Plagioclase phenocryst. (B) Spherulites. (C) Devitrified matrix.

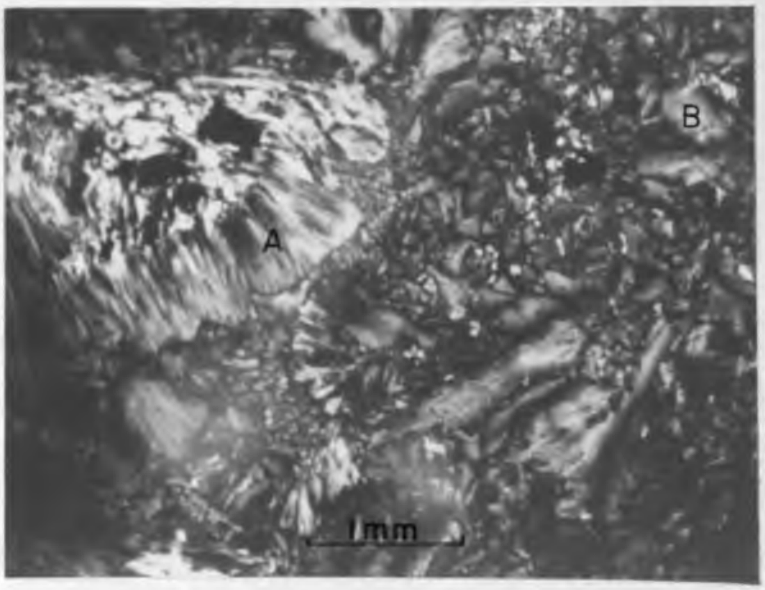

Figure 12

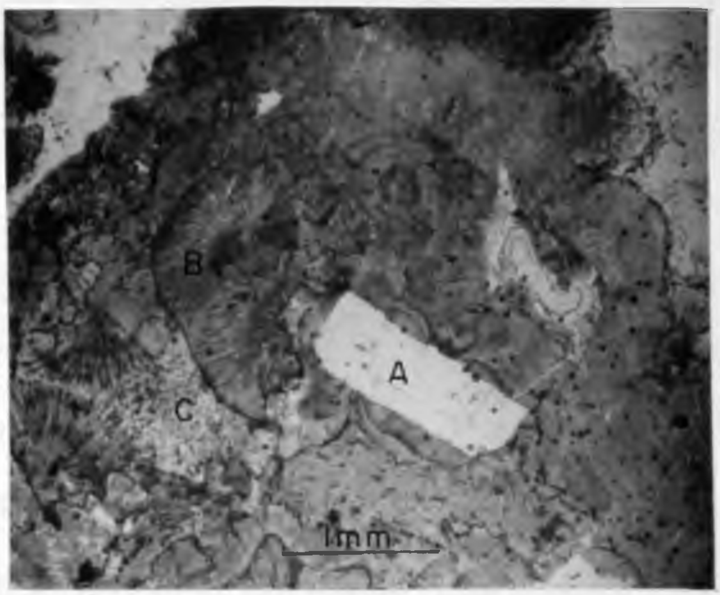

Figure 13

Yellow Flows

As is true with the brown flows, the yellow flows outcrop primarily in the Goldfield Mountains, but there also are several exposures of yellow flows located on the north side of Sahuaro Lake. One of these forms vertical cliffs, lies unconformably over the metavolcanics, Stewart Granite and the basalt, and is believed to be an isolated erosional remnant of yellow flow 1.

Megascopically, the yellow flows are andesitic in composition and have a yellow to yellowish-tan color. They are porphyritic, with plagioclase occurring as phenocrysts in a hemicrystalline aphanitic matrix. These phenocrysts range up to 5 mm in size and are white. Biotite and hornblende are the mafic minerals constituting less than 3 percent of the rock.

Lenses of glassy material are not common, although some occur (Fig. 14), but bands of lithophysae and glass fragments are abundant.

In thin section, the yellow flows are andesitic in composition. Plagioclase, composition An_{28-30}, occurs as phenocrysts forming approximately 15 percent of the rock. The matrix, which is holohyaline, exhibits varying degrees of devitrification. The products of devitrification are cryptocrystalline and have an axiolitic structure. Spherulites ranging up to 2 mm are not uncommon in the matrix. Biotite, found as books ranging up to 2 mm in size, is the dominant

FIGURE 14

Photomicrograph of Hyaline Specimen Collected From the Yellow Flows. (A) Spherulites. (B) Devitrified matrix. (C) Plagioclase crystal. Uncrossed nicols.

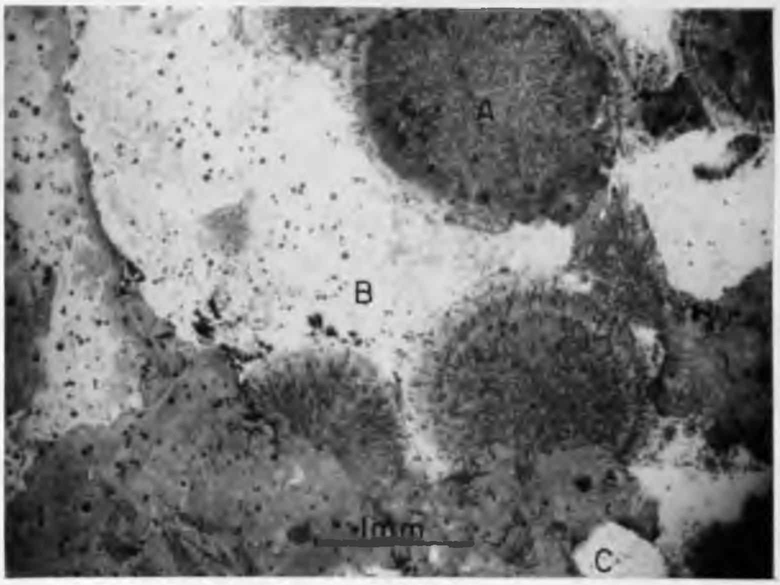

Figure 14

mafic mineral. Trace hornblende is present.

Conglomerate

A conglomerate of Tertiary age outcrops in a basin located north of Sahuaro Lake. For the most part it overlies the metavolcanics, the Stewart Granite and the Goldfield Volcanics.

The conglomerate is poorly consolidated, light tan in color, and contains scattered pebbles, cobbles and boulders. Fragmental material makes up to 40 percent of the rock and is granitic to volcanic in composition. The fragments are angular to well-rounded, and range in size from less than 1 inch to greater than 2 feet. The matrix is dominantly sand size, but silt and gravel-sized particles also are found. Composition of the matrix is granitic to volcanic, depending on proximity to the source area. Generally the matrix appears to be of a composition similar to that of the Goldfield Volcanics. Stratification is delineated by the differing concentrations of fragmental material and interformational beds of sand, gravel and silt.

STRUCTURE

The older Precambrian rocks of the Sahuaro Lake area exhibit a dominant northeast structural trend. This is evidenced by the northeast orientation of the metavolcanics and the quartz diorite, and by the northeast trend of a fault which separates these two units. This fault is marked by a zone of extensive shearing in both the metavolcanics and the quartz diorite which varies in width from 30 to 40 feet. No fault gouge is present, but mechanical deformation is shown by the strong orientation of the micas and feldspars, paralleling the contact. Relative displacement along this fault could not be determined, but it is felt by the author that it is a reverse fault. The presence of the large amount of shearing associated with the fault, the fact that the fault occurs in older Precambrian rocks, and that the closing of the older Precambrian period is characterized by compressive forces give basis to this conclusion.

Another structural feature found in the older Precambrian rocks appears in the contact area between the metavolcanics and the Stewart Granite on the east side of Sahuaro Lake. Here is found a zone of shearing, 100 to 800 feet in width, which strikes N 40° E and dips vertically to 75° southeast. Most of the shear zone is marked only by a strong foliation in both rock units, but adjacent to their contact, greatest mechanical deformation of the rocks is displayed. Here both the metavolcanics and the granite have been so intensely deformed that texturally they are phyllitic to schistose. Away from the contact, the shear zone is clearly marked by the parallel orientation of the mafic minerals and the individual mineral constituents of the rocks. In this area the granite contains phenocrysts of orthoclase which have a strongly preferred orientation parallel to the foliation found in the granite. Many appear to have been rolled.

This shear zone, because it is so extensive and well defined and because of its northeast orientation, seems to be the consequence of compressive stresses probably initiated during the younger Precambrian and continuing over a long period of time.

The older Precambrian rocks are cut by a series of N-S and W-NW trending shear fractures. For the most part, these are occupied by basic and aplite dikes. The basic dikes occur mainly in the W-NW trending fractures, although a few are found to have a north-south trend. The dikes are sheared and in general exhibit a strong foliation which strikes parallel to the trend of the dikes, usually dipping steeply to the northeast or vertically. The foliation generally continues for several feet into the contact rock. In the larger dikes, their central portions vary from weakly foliated to non-foliated.

The aplite dikes for the most part are found to have a N-S to NE trend, and exhibit no shearing.

The principal feature of structure in the area is a fault escarpment which is the result of a normal fault. Exposures of the fault are limited, but where they can be observed the fault strikes N 65° to 70° E and dips 70 to 72 degrees south. The fault zone varies in width from less than one foot to greater than 3 feet, sharply separating the Goldfield Volcanics on the south from the Stewart Granite on the north. Developed in the fault zone is a fault gouge. Hematite staining is common. The Stewart Granite located on the footwall of the fault exhibits strong shearing as far as 10 feet from the fault plane. The Goldfield Volcanics show little effects of shearing, but slickensides, plunging 20 to 25 degrees to the east, are well developed on the fault plane. Maximum vertical displacement is believed to exceed 800 feet, as is shown by the stratigraphic shifting of yellow flow 1. Apparent relative movement involved a rotation of the south block toward the east, with reference to the north block. This has resulted in the uplifting of the Goldfield Volcanics, tilting them 20 to 30 degrees to the south. Little apparent rotational movement of any kind has taken place on the north block, as is evidenced by the flat-lying flows of flow 1 of the yellow flows.

A minor fault, paralleling the major normal one, is found in the Goldfield Volcanics on the east side of Sahuaro Lake. It appears to have developed sympathetically to the normal fault.

Jointing in the older Precambrian rocks displays a predominant N 20° W and N 85° E trend, dipping steeply to vertical. In the Tertiary volcanics, the dominant joint trend is N 30° W, with a minor N-S and E-W development.

Some primary folding is found in the Goldfield Volcanics, the apparent result of underlying topography.

GEOLOGIC HISTORY

During the initial period of the older Precambrian, the Sahuaro Lake area of Arizona was marked by great vulcanism, which resulted in the formation of the metavolcanics. Undoubtedly there was crustal unrest which caused deformation, but this is obscured today. Following the period of vulcanism, recrystallization took place in the volcanics which had been formed. The exact cause of this cannot be determined, nor can the exact time of intrustion of the quartz diorite into the area, although it is apparent the quartz diorite is of younger age than the metavolcanics. It is here conjectured that the quartz diorite was faulted into contact with the metavolcanics, resulting from the northwest-southeast compressive forces characterizing the Mazatzal Revolution. Evidence of such development is apparent in the northeast orientation of the metavolcanics and the quartz diorite. Culmination of the Mazatzal Revolution was marked by a period of granitic activity. Apparently the Stewart Granite was associated with this period.

No rocks representative of the younger Precambrian, Paleozoic or Mesozoic Eras are found in the area. Since Paleozoic rocks are found in the transition zone in the central portion of Arizona, their absence in the Sahuaro Lake area possibly can be explained in one of two ways: 1. Rocks representing the Paleozoic were deposited and then later completely eroded, or 2. The area was topographically high during the younger Precambrian and most of the Paleozoic Eras, possibly corresponding to Stoyanow's Mazatzal Land (1936).

Although definite Mesozoic age cannot be attributed to rocks in the area, it is established fact that during the Laramide Revolution, northwest folds developed throughout much of Arizona, with the development of shear breaks of a general E-W and N-S trend. Some local deviations exhibited trends to N 70° W and N 20° E (Wilson 1962). It seems probable that initial shear breaks of the Laramide provided structural weaknesses in the older Precambrian rocks for later intrusion of the basic dikes, since these dikes dominantly trend N 60° to 70° W. Reoccurrence of compressive forces resulted in later shearing of these dikes. The aplite dikes, which mainly trend north-northeast, probably were introduced in the late stages of Laramide granitic activity.

During the Tertiary, another period of vulcanism occurred in central Arizona which resulted in the deposition of ash-flow tuffs found in the Goldfield Mountains and also in the Superstition Mountains. The basalt possibly is related to the initial stages of this same vulcanism. These ash-flow tuffs seem to have resulted from a period of continuing volcanic activity, as is suggested by the gradational contacts between the flow units. Although there was initial deposition of the Tertiary conglomerate preceding the vulcanism that formed the Goldfield Volcanics, the major portion of this conglomerate definitely was deposited after it. During the Cenozoic, the Goldfield Volcanics were tilted as a result of a N 70° E normal fault, possibly related to the Basin and Range orogeny. Recent erosion resulted in the development of sand and gravels in stream drainages and valleys.

SUGGESTIONS FOR FURTHER STUDY

In Central Arizona, especially in Maricopa County, there is need for a more detailed petrologic and structural study, particularly in the correlation of the older Precambrian rock units. A detailed petrographic and chemical study of the metavolcanics found in the Sahuaro Lake area and Wilson's Yavapai Group in the Mazatzals would shed light on their correlative aspects.

A geochemical age-dating study of the older Precambrian rocks of the Sahuaro Lake area would establish definite age relationships between these rock units and other Precambrian units of Central Arizona. Age identity of the quartz diorite and the metavolcanics could be clarified by these methods. Possibly the quartz diorite represents a period of igneous activity which is pre-Mazatzal Revolution. Age of the basic and aplite dikes also would be clarified.

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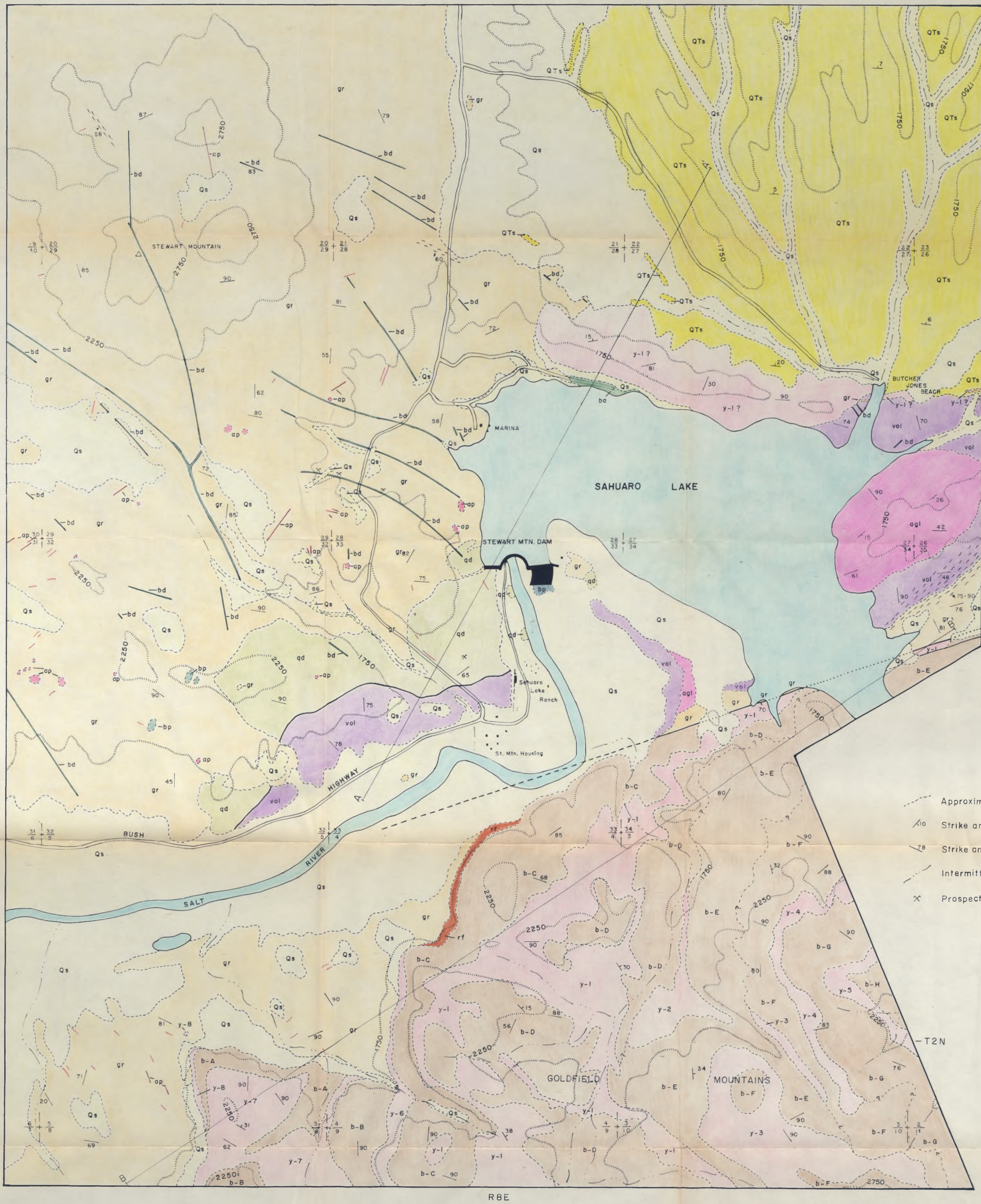


1 0 1/2 1 Miles

Scale 1:10,560
Contour interval 500 feet
1966

EXPLANATION

QUATERNARY

Qs — Silt, sand, and gravel

TERTIARY

QTs — Conglomerate, sand, and gravel

Ash-flow tuffs (andesites)

b-A / y-1 — Brown flows (b-A, B ⋯ H); Yellow flows (y-1, 2 ⋯ 8)

rf — Red flow

ba — Basalt

LARAMIDE ?

ap — Aplite
Plugs
Dikes
>10' in width
<10' in width

bd / bp — Basic dikes and plugs

OLDER PRECAMBRIAN

gr — Granite

qd — Quartz diorite

agl / vol — Metavolcanics
Agglomerate (agl)
Volcanics (vol)

SYMBOLS

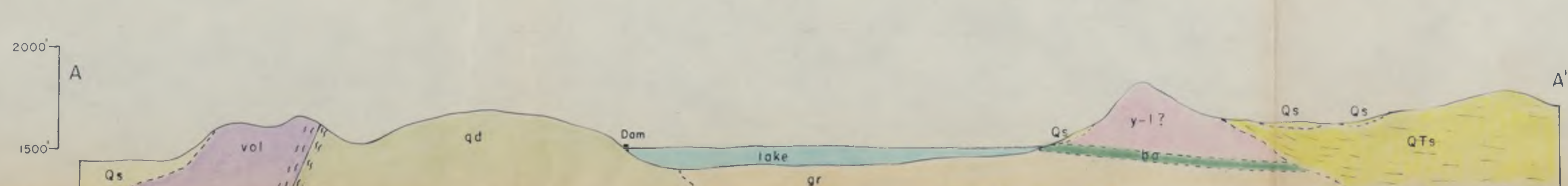
Approximate contact
Strike and dip of beds
Strike and dip of joints
Intermittent stream
Prospect pit
Fault, showing dip
Approximate fault location
Fault, concealed
Shear zone, showing dip
Section corner

GEOLOGIC MAP
OF THE
SAHUARO LAKE AREA
MARICOPA COUNTY, ARIZONA

BY

Harvey S. Durand

1 – Pocket



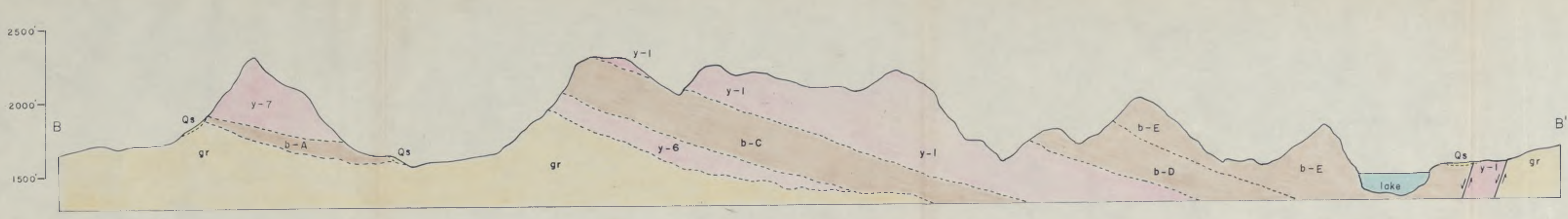


PLATE I