THE STRATIGRAPHY AND STRUCTURE OF THE RECREATION REDBEDS, TUCSON MOUNTAIN PARK, ARIZONA

by

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ABSTRACT

The Recreation redbeds present a problem in complex Cretaceous(?) stratigraphy in an area which has been deformed by faulting and minor folding. The original Recreation redbeds formation consisted of only a sandstone-siltstone member. It has now been expanded to include a volcanic conglomerate member and a tuff member. These new members were originally part of another formation.

The Recreation redbeds-Amole arkose relationship was found to be conformable and gradational through the volcanic members of the redbeds.

Two thrust faults border the area. A large block of Recreation redbeds moved eastward, onto the Amole arkose, along the eastern one. The western fault brought Amole arkose up on to the middle part of the redbeds.

Andesite and basalt intrusives apparently used the faults as

channels, where they intruded and deformed the sediments. The unusual folded structure on southern Brown Mountain is possibly due to the lifting action of these intrusions.

The Amole granite forms the northern intrusive border of the Recreation redbeds. Latite dikes intrude the formation along west-northwest fractures. Carbonate material has been introduced into local permeable parts of the formation. Mineralization is present as limonite and quartz in north-northwest fractures.

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INTRODUCTION

LOCATION, EXTENT AND ACCESS

The Arizona-Sonora Desert Museum, about 20 miles west of Tucson on the west side of the Tucson Mountains, is located centrally in the area of this report (Pl. I). This area, in the Tucson Mountain Park Recreational Area, is situated in Secs. 1, 6, 7, and 8, T. 14 S., R. 11 E.; and Secs. 35 and 36, T. 13 S., R. 11E., on United States Geological Survey, San Xavier Mission, Arizona, and Cortaro, Arizona, Quadrangle maps.

Access is by all weather asphalt and dirt roads. The Gates Pass Road comes directly over the Tucson Mountains and the Ajo and Kinney Roads come around the southern end of the Range.

OBJECTIVE

This study was originally undertaken to reveal the stratigraphy and structure of the Recreation redbeds (W. H. Brown, 1939) and their relation to the upper Cretaceous(?) Amole arkose. Reconnaissance showed, however, that an additional area, Brown Mountain or the Piedmontite Hills, as large as that occupied by the original Recreation, would have to be included because the rocks of this additional area are closely related to the redbeds. No claim is made to finality. Problems

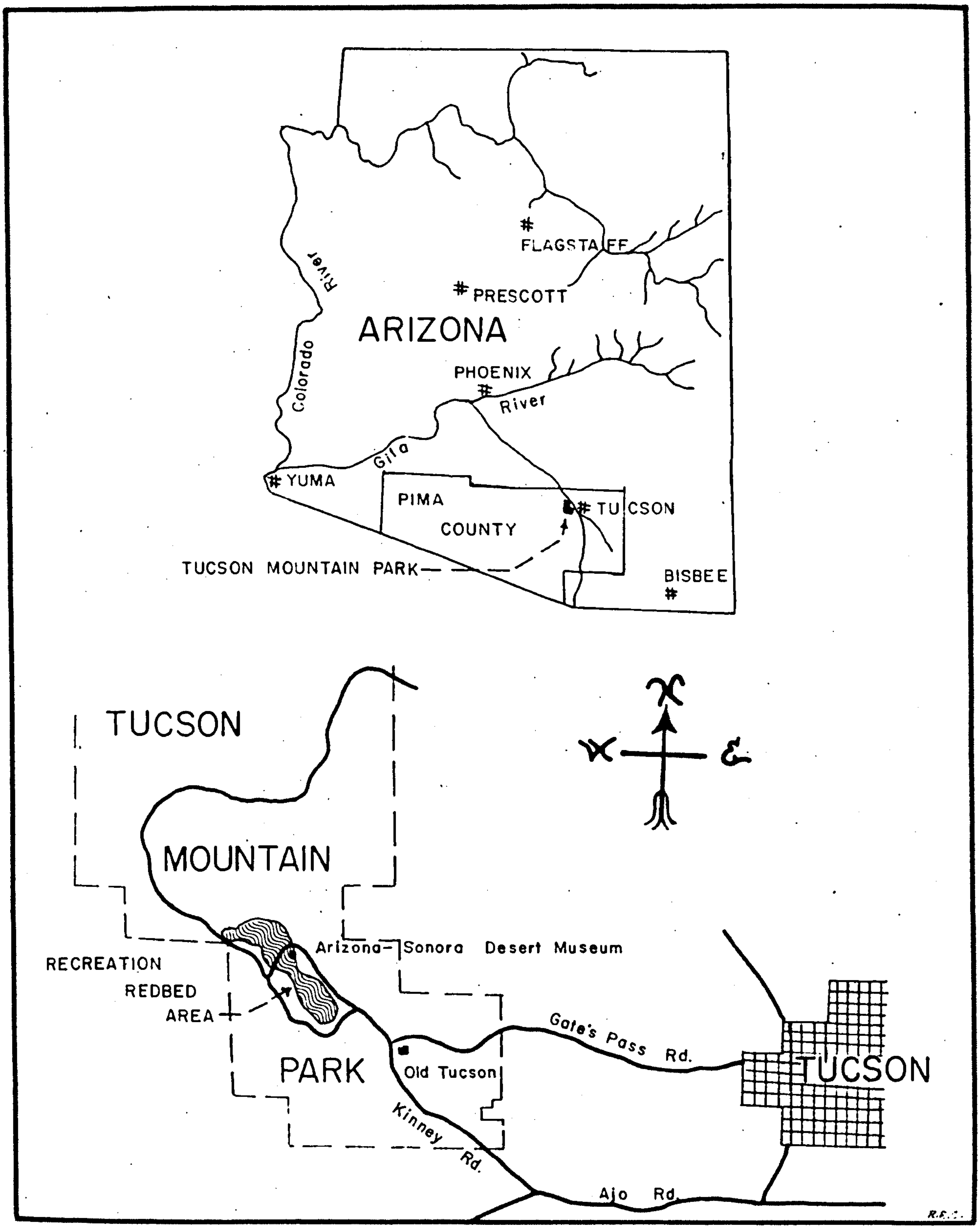


Plate I. Sketch map showing the location of the Recreation redbeds.

in sedimentation and detailed structure remain unstudied, but it is felt that a worthwhile beginning has been made.

TOPOGRAPHY, CLIMATE AND VEGETATION

The Red Hills and Brown Mountain (Pl. III) are the most prominent topographic features. They are separated by a broad, westward sloping, highly dissected bajada-pediment. The highest point to the north is in the Red Hills, approximately 3,150 feet above sea level. The Red Hills are connected to the Tucson Mountains proper, to the east, by a long ridge while Brown Mountain is isolated. Several large washes traverse the area. Westward, the surface slopes gradually away into the Avra Valley.

The climate is typical of southern Arizona; hot, moist summers and dry, temperate winters. The vegetation is Sonoran. Giant Saguaros, Cholla, Ocotillo, Palo Verde and Mesquite are most abundant.

PREVIOUS WORK

This area has never been studied in detail before, but it has been included in several general surveys of the Tucson Mountain area. Of these, that by W. Horatio Brown (1939) was probably the most thorough.

Since only maps with a scale of 1:62500 were available, base maps were prepared by enlarging United States Geological Survey maps to approximately 1 in. = 300 yds. and 1 in. = 100 yds. Soil Conservation Service aerial photographs were used to supplement these.

ACKNOWLEDGMENTS

Many people contributed material and aid in various ways to this thesis. Of these, I should like to especially thank Dr. Evans B. Mayo, Dr. John F. Lance, and Dr. Robert L. Dubois, all of the Department of Geology, University of Arizona.

I am also indebted to Mr. William H. Woodin, Director of the Arizona-Sonora Desert Museum, and his staff, Mr. Severo H. Samoyoa, present Superintendent of the Tucson Mountain Park, and Mr. Joseph F. Carithers, previous Superintendent of the Park, for their many courtesies.

STRATIGRAPHY

GENERAL

The stratigraphic units in the Red Hills-Brown Mountain area appear to be, from oldest to youngest, the Recreation redbeds proper, the sandstone-siltstone, volcanic conglomerate, and tuff members; the Amole arkose; the Andesite and Basalt intrusives; the Amole granite; the Silver Lily latite dikes; and the Quaternary alluvium (Pl. III).

The apparently oldest rocks of the redbed sequence are found in the northwestern Red Hills area and the younger in the southwestern Brown Mountain area. A fairly complete section, with the exception of the bottom of the Recreation redbeds which is buried, can be seen by traversing the Red Hills from west to east and then traversing Brown Mountain from north to south. The uppermost part of the section can be seen in limited outcrop to the west of the southern part of Brown Mountain. This peculiar arrangement results from thrust faulting, minor folding and erosion. The stratigraphy is complicated and somewhat obscured in the upper units by these structures and the lack of continuous exposures.

FORMATIONS

Sedimentary Rocks

Recreation Redbeds Kr

This formation comprises most of the rocks in the area of study. It is made up of three units: the sandstone-siltstone member, the volcanic conglomerate member and the tuff member. The sandstone-siltstone member is red in color, is apparently the oldest of the three and is the unit for which the formation was named, W. H. Brown (1939). The other two members seem to be younger than or possibly of the same age as part of the sandstone-siltstone member. The tuff is actually found as layers or lenses within the conglomerate, but these are large and distinct enough to be mapped and discussed separately. These two members are what W. H. Brown mapped as Cretaceous volcanics. He placed them directly below the Recreation redbeds, in the geologic column, and accounted for their present position by a fault. This fault will be discussed later. The present work has fairly definitely shown that these volcanic rocks are above the original Recreation redbeds or possibly contemporaneous with them (Fig. 1).

If the traverse mentioned previously is made, the following sequence of rocks may be seen.

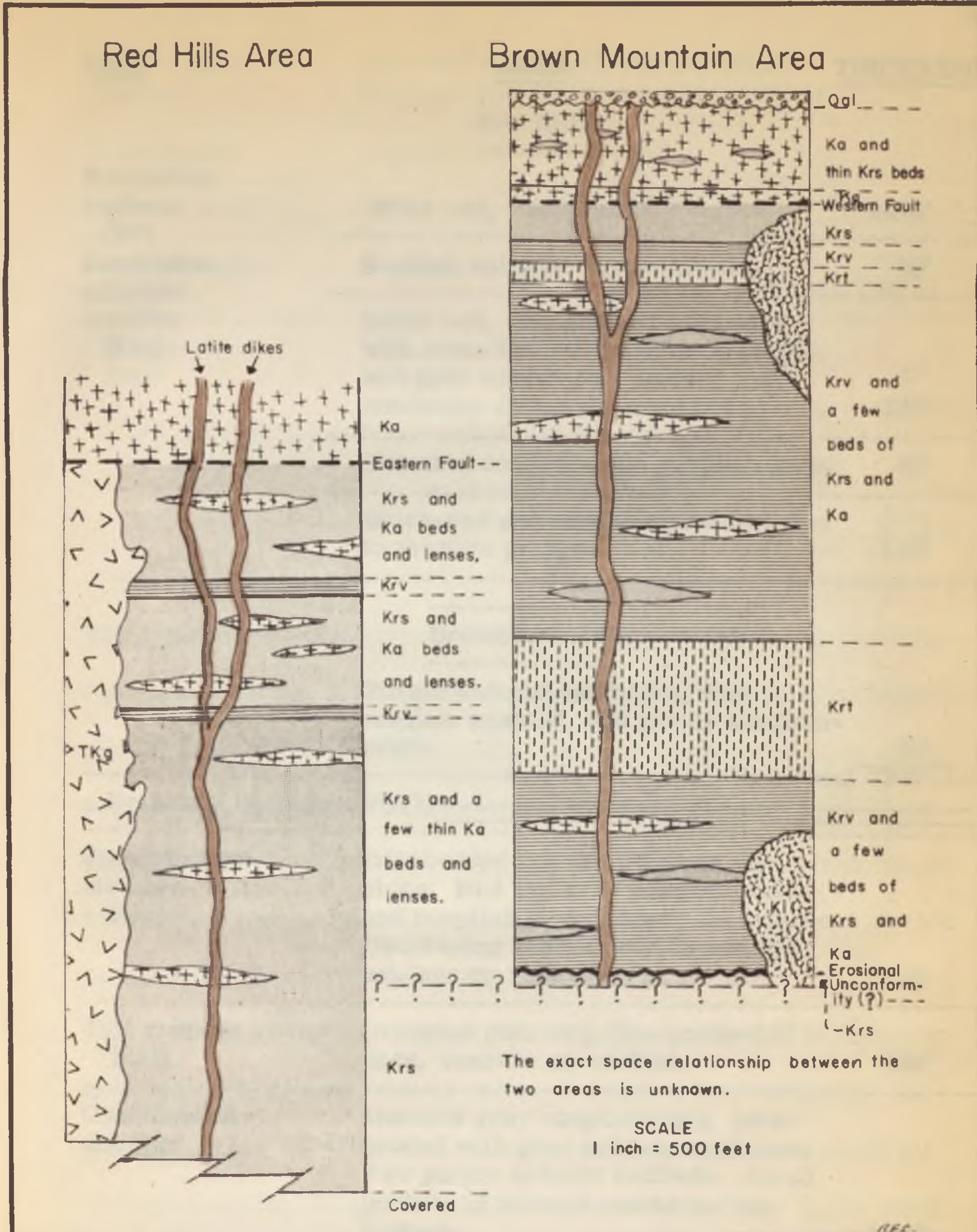


Figure 1. Columnar Section of the Recreation Redbeds Area.

UNIT	AREA	THICKNESS
	Red Hills	
Recreation redbeds (Kr) Sandstone-siltstone member (Krs)	Brick red, fine grained sandstone.	1440'
	Reddish volcanic conglomerate.	20'
	Brick red, fine grained sandstone with some lenses and beds of purple and gray sandstone. Bedded gray sandstone definitely arkosic and thin.	380'
	Volcanic conglomerate purplish gray.	40'
	Brick-red and purple sandstone, fine to medium grained.	380'
	Brown Mountain	
	Purple and red sandstone, fine to medium grained, and purple conglomerate.	30'
	Krs Total	2290'
= Erosional unconformity(?)		
Conglomerate member (Krv)	Interbedded red and purple sandstone. Red and gray conglomerates and purplish gray arkosic sandstones. Decreasing redbeds and increasing arkoses up section.	665'
Tuff member (Krt)	Orangish pink tuff, fine grained at base, coarser up section.	450'
Conglomerate member	Massive gray conglomerate, interbedded with gray arkosic sandstone. Few purple arkosic redbeds. Small pockets of arkosic sandstone and redbeds.	1295'
Tuff member	Orangish pink tuff.	25'

Conglomerate member	Gray and purple arkosic sandstone. Several large reddish purple redbeds.	65'
Tuff member	Orangish pink tuff beds.	?
= Thrust fault(?)		
Conglomerate member	Redbeds, purple and orange.	135'
	Krv and Krt Total	2635'-
Amole arkose (Ka)	Massive gray arkose beds with a few pebbles.	45'
	Interbedded arkoses, greenish buff arkosic sandstone, greenish brown fine grained sandstone and few thin purple-brown redbeds.	360'
	Ka Total	405'

This generalized stratigraphic column appears to show a gradational change from redbeds to arkose, accompanied by impressive volcanic admixtures. East of the Red Hills, the Recreation appears to grade directly into the Amole by increase in amount of arkose and with no appreciable amount of volcanic material. The two formations therefore seem to be conformable, although at no place in the area can the redbeds be traced without break into the arkose.

The questions have been asked whether the rocks in this area are right side up and which is older, the Recreation redbeds or the Amole arkose. The succession is definitely normal as is shown by extensive and beautifully developed cross-bedding (Fig. 2), by small filled channels, by the gradational relationship between the two units, and by the occurrence of redbed material in the arkose.

Figure 2. Cross-stratification in the sandstone-siltstone member. The upper brick-red bed is characteristic of the unit. The lower bed is arkosic and has red grains on the bedding surfaces.

FIGURE 2

No fossils have been found in the Recreation. On stratigraphic evidence, the formation has been tentatively dated as upper Cretaceous by previous workers. Part of this evidence is based on the comformability of the overlying Amole arkose which has been assigned to the upper Cretaceous on the basis of uncertain fossil evidence (W. H. Brown, 1939, p. 719). Perhaps pollen analysis could reveal the age of the formation.

Southern Arizona is covered with redbed outcrops, many of which may correlate with the Recreation, however, the only redbeds that the author feels safe in definitely correlating with these are in the area mapped by R. L. Whitney (1957), on the northeastern side of the Tucson Mountains. This correlation is based on a study of hand specimens and thin sections of the redbeds in Whitney's area, where perhaps part of the volcanic conglomerate member is also present. Mr. Whitney describes arkosic-volcanic conglomerate beds interbedded with the redbeds and arkosic beds. Localities, with rocks similar to the Recreation redbeds, are: the Waterman Mountains, N. E. McClymonds (1957); the Montosa Canyon area, J. F. Sulik (1957); the East-Central Huachuca Mountains, W. H. Weber (1950); and the Empire Mountains, F. W. Galbraith (1949). Until much more detailed work has been done on the redbeds of southern Arizona, correlation between these localities will not be possible.

Sandstone-siltstone member Krs. - This, the basal member, is a fine-grained, brick-red sandstone-siltstone which is both massive and thinly bedded. Thin sections disclose it to be composed of closely packed quartz grains varying in size from 1/2 mm to less than 1/16 mm. While there is little cement of any kind, there is much iron oxide which is responsible for the red color.

Several local color variations occur. A purple sediment is commonly found in the coarser grained lenses. Possibly this color is related to dilution by arkosic material for this variety becomes increasingly more common toward the upper part of this member. Because of local reduction of the iron oxide white semispherical spots appear in the redbeds. Adjoining the andesite and basalt intrusions the redbeds may be represented by a white spotted orange quartz sand.

Joints in the redbeds strike approximately 20 to 45 degrees NW and dip 75 to 90 degrees NE and SW. At some localities, such as the upper south face of the big red hill, the rock is so highly fractured that only splinters remain. On the flanks of the little red hill, to the northwest of the Red Hills proper, the fractures are more widely spaced and the rocks stand in vertical outcrop giving the appearance that beds are on end, whereas actually the bedding dips about 28° NE. These fractures are found more closely spaced in the massive variety of redbed. Further, the joints seem to be associated with the redbeds only and do not traverse the other rocks; thus, a small pocket or layer of redbeds in the volcanic conglomerate member may be intensely fractured while the surrounding material will be unjointed.

The sandstone-siltstone member is typical of the Red Hills area and forms the brick-red outcrops there (Fig. 3). It is also found in the Brown Mountain area, but here the purple variety is most common. Here the red sediments are usually restricted to local beds and lenses and fragments or pockets in the matrix of some of the volcanic conglomerates.

Volcanic conglomerate member Krv. - The rocks of this member of the Recreation redbeds are found interstratified with and above the sandstone-siltstone member (Fig. 4). In this conglomerate member, the gradational relation of the redbeds to the Amole arkose is revealed. The member is composed of a variety of rock types, principally volcanic, interbedded and intermixed with sandy redbed and sandy arkosic material. The redbed material decreases and the arkose increases in amount up section.

Two color varieties compose this unit. One of these is reddish purple in color, the other is grayish brown or yellow. These colors are determined essentially by the matrix, the coarse material being relatively uniform in composition throughout. Often the two types of matrix are mixed, imparting a purplish gray cast to the exposures.

The grayish brown or yellow matrix is most common and is composed mostly of quartz and feldspar together with many volcanic fragments, both of fine grain and phorphyritic. This matrix is often very arkosic. Many of the feldspars are somewhat weathered. The

Figure 3. The Red Hills from Brown Mountain. Redbeds dip eastward. Buff streaks to the right are debris from west-northwest trending latite dikes. Arizona-Sonora Desert Museum compound is in right center.

FIGURE 3

Figure 4. Volcanic conglomerate, redbed, tuff succession on northwestern tip of Brown Mountain. These rocks are relatively low in the conglomerate section.

FIGURE 4

grains are fine to coarse and subrounded. Locally, this matrix is a nearly pure quartz sand, relatively free from feldspars and volcanics. Conglomerate with the grayish brown or yellow matrix (Fig. 5) is usually found on Brown Mountain.

The reddish purple matrix (Figs. 6 and 7) is not as common as the other type. It is most often seen on the north end of Brown Mountain and in the Red Hills. Red sandstone and reddish purple volcanic fragments are the main constituents of this matrix, which is very poorly sorted and appears to have been deposited rapidly. The texture is somewhat coarser than that of the grayish type. Roundness of grains is approximately the same.

The matrices are similar in that they contain many grains or small fragments with the same lithology as the enclosed pebbles, cobbles or boulders of the conglomerate. The small fragments may amount to 50 or 60 percent of the matrix.

The coarse material of the conglomerate varies in size and composition. The pebbles, cobbles and boulders range from less than 1 inch to greater than 24 inches with an average being around 2 to 4 inches. They vary from angular to well rounded, the majority being subrounded to subangular. At any given location, one degree of roundness will usually prevail. In one or two localities, the conglomerate is very coarse with nearly all the boulders over 12 inches in smallest diameter. At these places, the matrix is very fine grained and composes an unusually

Figure 5. Grayish arkosic volcanic conglomerate showing color, texture and mottling.

FIGURE 5

Figure 6. Reddish volcanic conglomerate. Matrix is redbed and red volcanic material.

FIGURE 6

Figure 7. Detail of reddish volcanic conglomerate in the Red Hills. Poorly sorted with pebbles of various lithologies, including redbeds.

FIGURE 7

small percentage of the entire rock. Massive outcrops of this rock, at least 15 feet thick, are found on northern and north central Brown Mountain immediately below the large tuff outcrop. The rock may have been emplaced as a mud flow.

The lithology of the pebbles, cobbles and boulders is as follows:

Andesite -	Dense with porphyritic varieties of various colors, most commonly red or black.
Quartzite and Quartz -	Finely crystalline and massive usually yellow, gray or white in color. Many have weathered pitted surfaces and are stained with iron.
Others --	Fine grained volcanics of undetermined composition; yellow, red, brown or black in color. Badly weathered granite and arkose. A very few redbed fragments. A few pieces of limestone and shale.

These pebbles, cobbles and boulders often appear to be weathered around the edges, especially in the conglomerate with the grayish arkosic matrix.

No particle count was attempted, but relative abundance of the various rock types was roughly estimated. The andesites are the most important, composing possibly 70 to 80 percent of the coarse material in the lower reddish matrix while perhaps no less than 40 to 50 percent in the upper grayish matrix. The quartzite and quartz are next in abundance, although usually restricted to the upper parts of the unit, composing about 10 to 20 percent of the coarse material. The fine-grained volcanics are present in amounts equal to the quartzite and quartz. The other rocks are scarce, making up only 5 to 10 percent of the coarse material, at most.

Interbedded with these volcanic conglomerates are numerous beds of grayish arkosic sandstone and redbed sandstone that vary in thickness and lateral extent. The thickness ranges from a few inches to 10 feet. Due to lensing out and to burial by talus, the average distance a bed can be traced is approximately 10 to 20 yards. The redbeds can be found throughout the conglomerate unit and locally even in the overlying Amole arkose. High in the section, they are scarce, their place being increasingly occupied by arkosic beds.

In addition to beds, or lenses, of red sandstone, pockets of redbed material only a few feet across are distributed at random in the conglomerate. They are most abundant at the north end of Brown Mountain.

Exposures of these conglomerates have mottled gray-brown surfaces obscured by black desert varnish. Even the freshly broken surfaces are mottled and difficult to study. Also, the conglomerate varys rapidly in texture, color and lithology both horizontally and vertically. The sandstone beds have no unusual characteristics to differentiate one from another. Moreover, as previously mentioned, they are lenses with limited lateral extent. All these features make it difficult to discuss the nature and structure of the conglomerate.

A measured section through part of this unit is included in the appendix. Unfortunately, this section represents only the specific area in which it was measured. Because of the rapid change in color, texture and lithology, two sections only a short distance apart could be measured in the same horizon and each show a different sequence.

Tuff member Krt. - This rock is found intercalated with the volcanic conglomerate at several horizons. The tabular body on the north and central western slopes of Brown Mountain (Fig. 8) is the largest and was the most studied. This rock is a very fine grained pinkish orange or white faintly banded tuff. Throughout, it carrys numerous red volcanic fragments, principally andesite.

The thin sections disclose abundant shards of partly devitrified glass, a few plagioclase fragments, a few quartz fragments and several streaks of piedmontite. The piedmontite is orientated parallel to the primary layering which is disclosed by the preferred orientation of flattened glass shards. It seems to be much more common in the upper part of the unit which is most obviously pink.

The structure of the tuff is obscure. The lower parts have a fine rhyolitic texture while the coarser upper parts have a granitic texture. The gradation is not uniform throughout. This structure, although not entirely conclusive, suggests deposition from nuées ardentes.

There are two dominant fracture systems in the tuff. One is parallel to the bedding or layering about N 30° E with 25° SE dip. The other is about parallel to the general fracture pattern prevailing in the area, N 20° W and 70 to 90° SW-SE dip. In either case, the fractures are fairly wide spaced, usually several inches to several feet apart.

Figure 8. Brown Mountain from road to the west. Light colored outcrops are the tuff member; volcanic conglomerates are above and below. Crest of the Tucson Mountains in background.

FIGURE 8

The tuff member is restricted to the Brown Mountain area except for one small exposure east of the Red Hills along the fault contact with the Amole arkose.

Amole Arkose Ka

This formation, as previously stated, seems to overlie conformably the Recreation redbeds. The principal exposures of the Amole lie east of the area of this study. However, two limited exposures are in the western part of the area. The larger of these is in the wash and on the small hill west of southern Brown Mountain. The other is about 25 yards west of the basalt intrusion (Pl. III). Several thick arkosic beds were mapped in the Recreation redbeds and many more too thin and local to map were seen. These layers of arkose, as mentioned earlier, disclose the gradational relationship of the Recreation to the Amole.

The Amole arkose in the area usually consists of interbedded coarse gray arkose, fine to coarse gray arkosic sand, gray and greenish brown quartz sand, and pale purplish or brownish red sandstones. The coarser materials sometimes include layers with pebbles up to 4 inches in size. The finer materials are usually laminated. Good cross-bedding is expressed locally. The bedding is revealed by concentrations of dark purplish red sand grains and iron oxide fragments on the bedding surfaces. Most of the finer greenish beds are highly fractured. A measured section of the southern arkose area is included in the Appendix.

The northern arkose outcrop, near the basalt intrusion, is much smaller than the southern one. However, it appears to contain the same sequence of beds as the southern one. Both exposures appear to be in the hanging wall of a westward dipping thrust which separates them from the main body of sediment to the east.

Quaternary Alluvium Qual.

Alluvium laps onto the older sediments on the western and southern sides of the area and, with local exceptions, thinly covers the ground between the Arizona-Sonora Desert Museum and Brown Mountain. Unfortunately, this covered interval is critical for the relationship between the sandstone-siltstone and volcanic conglomerate members of the Recreation redbeds. The accompanying maps show this covered interval as underlain by the sandstone-siltstone member.

The alluvium is a heterogeneous collection of fragments from all the earlier sediments and igneous rocks. It is usually buff colored with the surface reddish due to the abundance of redbed fragments. The texture ranges from fine sand to coarse conglomerate. In general, pebbles, cobbles and boulders prevail. The alluvium forms a bajada over an eroded pediment. It should afford excellent material for studies of transportation and deposition in an arid region.

Along the washes, the larger fragments are occasionally embedded in massive caliche deposits. In some areas, where a wash crosses one of the older sedimentary or igneous rocks, calcite has precipitated in all the cracks and indentations. This is particularily noticeable in washes around the scoreaceous basalt intrusion.

Igneous Rocks

Andesite and Basalt Intrusives Ki

These intrusions are located in the central and southern parts of the thesis area. The andesites are found only to the south of the east-west museum road while the basalt is found north of this road.

The andesites are generally medium gray or brownish gray rocks, porphyritic with large plagioclase crystals. These crystals are locally orientated in planes. Of the several andesite intrusions, the pair west of the north tip of Brown Mountain is the most interesting and easiest to study. Here the andesite seems to be of two ages. The southern, presumably older outcrop, near the small dam (Pl. II) has been somewhat deformed in the solid. The more northern and apparently younger intrusion is an elongate body that has pushed up under the sandstone-siltstone member of the redbeds apparently lifting these sediments and forcing them aside. It is considered significant that the deformation of the sediments is much the most severe along the eastern side of the intrusions on the trace of an inferred thrust fault. Dr. Evans B. Mayo, of the Geology Department, is currently making a study of this locality.

The small andesite intrusion at the south end of Brown Mountain is somewhat different than the one just discussed. It is greenish black with reddish spots. It too has distorted the overlying sediments, and as discussed later is particularly interesting because of the suggestion it gives as to the structure of Brown Mountain.

The texture and lithology of the andesite body in the flat area, west of the southern end of Brown Mountain, is very much like the one at the north end of the Mountain. Its structure is unknown and the intrusion is interesting only because of its location.

The basalt intrusion is larger than any of the andesites. It is black except along the edges where it contacts the sediments. Here it is often green or brown and the altered sediments are of similar color. The basalt is moderately scoreaceous and has numerous calcite veins and amygdules.

This intrusion apparently has contorted and altered the surrounding sediments even more than have the andesites. On the north edge, the sediments were highly mobile, either because of the heat and solutions or because they were poorly consolidated, or both. Gas from the basalt seems to have bubbled up through them leaving vesicles. Moreover, the presently more resistant beds have been highly contorted with little evidence of shear.

The sediments adjacent to the intrusion on the east dip steeply under it. This would seem to indicate that the structure of this intrusion is similar to that of the andesite to the south (Pl. II and Fig. 14).

Both intrusions appear to be in the hanging wall of the same thrust fault and they both are elongated northward. Apparently the basalt was accompanied by more heat than the andesites. All that can be said about the age of the basalt and andesites is that they are definitely post Amole arkose, hence, late Cretaceous or younger.

Amole Granite TKg.

This granite is in intrusive contact with the sandstone-siltstone member of the Recreation redbeds, north of the Red Hills. It is a coarse grained yellowish rock composed essentially of quartz, feldspar and biotite crystals. There is no alteration or discoloration in the redbeds at the contact. Moreover, no deformation attributable to the intrusion is visible in the sediments, even though several apophyses of the granite extend into the redbeds. It is difficult to see how so large an intrusive body could be emplaced without causing any changes in the sediment.

At some distance from the contact, there is evidence of static metamorphism of the sediments. It is not certain whether this occurred at the time of intrusion or later, for the fluids used fractures, or fractured areas, as channels. Thin sections of these sediments reveal recrystallized secondary overgrowths of quartz and plagioclase and also some garnet(?) and epidote. One small, very highly fractured area of the redbeds, about 30 feet square, is altered green, apparently by the introduction of chlorite.

The Amole granite is obviously younger than the Cretaceous sediments and it may be a "Laramide" intrusion.

Silver Lily Dikes Ti

These dikes, named by W. H. Brown (1939), cross the Recreation redbeds in the Red Hills area and on southern Brown Mountain. They are in general latite porphryies, although they locally may be monzonites. They are buff colored when fresh, but weather dark brown. Quartz and feldspar, usually plagioclase, phenocrysts are common in the fine variety. In the coarse rocks, these minerals form the ground mass, along with some biotite and hornblende.

The texture of these dikes is usually porcelain-like, with exceptions where a dike is especially wide and the texture becomes granitic. The widths of the dikes range from 5 to 30 feet.

The dikes exhibit excellent flow surfaces and cleave parallel to them. The flow surfaces are usually parallel to the sides. The dikes occupy a set of fractures which parallel the major fracture planes in the Cretaceous-Tertiary granite. The orientation is approximately N 55 - 65° W, dipping 65° SW (Fig. 9).

The adjoining sediments are often altered brown by the dike, but there seems to be no deformation of the adjacent bedding.

These dikes may be the youngest igneous rocks in the area as

Figure 9. One of the Silver Lily latite dikes in the Amole arkose east of the Recreation redbeds. This dike crosses the redbed-arkose contact and continues over the Red Hills.

FIGURE 9

they intrude all the sediments and occupy a fracture system that probably already existed in the granite. Outside the thesis area, they intrude Tertiary volcanics.

Carbonate Alteration

This alteration is present throughout the area in small patches, flush with the ground. It is found only in highly permeable rocks, either highly fractured redbeds or porous conglomerates, and is gradational in nature as evidenced by the progressive change of color from unaltered to altered rock. The originally red sediments are progressively changed to reddish gray, grayish white and whitish pink or orange. The last stage looks a great deal like the tuff member of the Recreation redbeds. In thin section much calcite appears whereas the original rock has little or none. Detrital quartz, plagioclase and orthoclase were seen in addition to the secondary sericite and calcite crystals. The matrix is probably very fine grained calcite and sericite. A small amount of epidote is also present. This rock is possibly the result of low grade thermal metamorphism related to intrusive action.

Mineralization

The mineralization is represented by limonite and quartz veins in a series of north-northwest fractures. Limonite is also found disseminated throughout the rock in the fault zone along the east side of the area. Most of the veins are only a few inches wide and a few inches to a few feet long. Two of the limonite veins are up to 400 feet long and one quartz vein, on the southwestern slopes of Brown Mountain, is over 1,200 feet long. The quartz, in this vein, has been introduced along a fracture and may have replaced pieces of the redbed wall rock. The vein is rather unusual as one-half of it is a quartz-redbed breccia while the other is mainly silicified wall rock. For some reason, the silica migrated into the west wall of the fracture only. The other wall is unaffected (Fig. 10). For some reason, the three larger veins are not oriented parallel to the strike of the veins.

Such minerals as malachite, calcite, and azurite are present in very small amounts. Around 1930, the entire area was prospected in some detail, most of it being staked for claims. There are a few small exploration holes, but no large workings. Surface indications do not encourage the hope for economic mineral deposits.

Figure 10. Composite vein west of Brown Mountain. The right-hand portion is quartz and redbed fragments; the left-hand portion is silicified redbeds.

FIGURE 10

STRUCTURE

GENERAL

The Red Hills-Brown Mountain area has the eastward tilt common to most of the Tucson Mountains. The average dip of the bedding in the area is 25° NE or SE (Figs. 3 and 8). The westward dipping faults, probably thrusts, displace the sediments and folding is usually restricted to the vicinities of these faults and the intrusions. The structure of Brown Mountain may have been considerably modified by concealed intrusions, whereas, apparently, that of the Red Hills was not.

FAULTS

Two large faults, both of which separate the Recreation redbeds from the Amole arkose are found in the area. One follows the eastern side of the area and the other lies along the western side.

Eastern Fault

The eastern fault begins under the alluvium somewhere southeast of Brown Mountain and continues northwestward until it reaches the north end of the Mountain, where it turns northeastward and curves behind the Red Hills and into the Amole granite. This is the fault that

W. H. Brown (1939) continued northwestward from Brown Mountain to disappear under the alluvium just north of the basalt intrusive. This author found no evidence for so extending this fault, though he did find fairly definite evidence that the fault turned northeast at the picnic area near the north end of the mountain. Brown mistakenly believed that the volcanic conglomerate in the Brown Mountain area was stratigraphically below the Recreation redbeds. With this belief, he could only account for the present position of the conglomerate by extending the fault as he did.

Perhaps this eastern fault is more properly called a crush zone. At no place can a large fault surface or the actual fault contact of the redbeds and the arkose be seen. The fault, if such it be, is usually expressed as a brecciated, sheared and crumpled zone of varying width, usually seen in the arkose and not in the redbeds (Fig. 11). This zone is relatively easy to trace as it is mineralized by disseminated limonite. Numerous small tear faults with limonitic gouge, occur along it. There are also several horses or slices along the fault zone. The largest of these is east of Brown Mountain.

There is no direct evidence of the direction of movement. The stratigraphy indicates that the western side rode up over the east. This would make it a thrust fault. The redbeds on the west side steepen somewhat near the fault, while the sediments on the east are intensely crumpled and sheared for as much as 100 yards east of the contact. These

Figure 11. Shatter breccia of Amole arkose along the eastern fault zone. The breccia is cemented by a network of calcite.

FIGURE 11

observations plus the irregular surface trace of the zone suggest a thrust.

The displacement along the zone is probably limited to a few hundred feet. The fact that abundant arkosic material is found on the redbed side of the fault zone and that some redbed material is found on the arkose side, seems to indicate that the upper limits of the Recreation redbeds and lower limits of the Amole arkose are not separated by any great distance. Moreover, if the fault were of great magnitude, it would seem that definite fault surfaces would be better developed.

This is a very steep zone, usually dipping 50° to 70°. The dip is either east or west, depending on the location along the zone, which obviously overturns in places. In the King Canyon Wash, just northeast of the Museum, several of the small faults in the zone can be traced vertically as they overturn. Their dip in the wash is westward, changing to eastward with increasing elevation.

Western Fault

This fault is not even as well exposed as the one to the east. Most of it is covered by alluvium. Where it can be seen, it is restricted to a zone only a few feet wide. It is located by an abrupt reversal of the dip, from east or southeast to southwest (Fig. 12). During the early days of this study, it was thought that the southwestward dipping sediments represented the west flank of an anticline, of which Brown Mountain was the east flank. The abrupt change in rock type, the failure of

Figure 12. The western slope of Brown Mountain, looking south. West dipping arkoses on low ridge in center are in hanging wall of the western fault. Rocks higher on the slope dip southeastward. The light colored exposures are of the tuff member, underlain by dark mudflow(?) conglomerate.

FIGURE 12

recognizable beds to cross the supposed crest, the very abrupt change of dip and the almost impossible crookedness of the supposed axis all indicated that an anticline was not the best solution. All the above features plus the presence of a shear zone, visible in some places along the inferred trace, suggest a thrust fault. It is best seen on the north and east side of the ridge formed by the west end of the latite dike that crosses Brown Mountain (Pl. IV).

This fault appears to dip westward at an angle of 30° or less, but the dip cannot be measured directly. The hanging wall seems to have moved eastward carrying the Amole arkose over the Recreation redbeds. The thrust plane seems to have sliced into the Recreation because the arkose now rests on the volcanic conglomerate member somewhere near its base, whereas, normally the arkose rests on the top of the conglomerate. Cross-sections AA' through DD' suggest the structure.

The stratigraphic throw is unknown, but cannot be very great because the overlying Amole arkose contains several redbed layers that would be in place just above the top of the volcanic conglomerate. The horizontal displacement is not known, but it could be considerable.

At several places along the fault, several small intensely deformed masses of limestone are present. It is suggested that these foreign appearing bodies were squeezed upward along the fault plane to their present position.

It appears as if the northernmost andesite intrusion and the basalt intrusion have come in along this fault. Evidently the intrusives bulged up as they neared the surface causing the sediments to crumple. Both intrusions have structures that suggest this type of emplacement.

FOLDS

Two kinds of folds are present in the area. One of these is closely associated with the eastern fault, while the other appears to be related to intrusions that have risen along both faults.

Folds of the first kind were briefly mentioned in the section dealing with the eastern fault. As stated in that section, the folds are most pronounced in the Amole arkose. The Recreation redbeds are usually merely tilted downward into the fault, as if the beds had been dragged. This is most noticeable along Brown Mountain where the dips of redbeds often increase near the fault.

The deformation in the Amole arkose is far more intense than in the redbeds. The arkose beds are crumpled and twisted for as much as 100 yards east of the contact area. The folds appear to be small and very tight. Many have ruptured crests. The least resistant beds are highly sheared and the more resistant ones fractured and contorted. The true relationship of these folds to the fault zone is not entirely clear.

No obvious, primary sedimentary structures were found, therefore, the facing of the beds could not be determined. Two possibilities exist: the arkose may turn down under the fault zone and the volcanic conglomerate; or it may turn back up away from the zone and eventually over the conglomerate. Both cases may exist, but the second possibility appears more likely (Fig. 13).

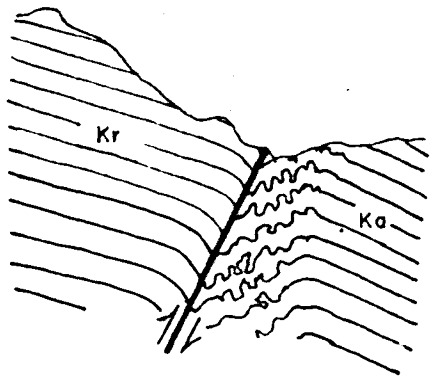
There does not seem to be much folding associated with the western fault except near the intrusions along it. As previously mentioned, these intrusions appear to have lifted the sediments and thrust them aside. In addition, there is especially intense deformation along the eastern side of the andesite (Pl. II) supposedly caused by the western thrust. Here again, there are two possible interpretations of the deformation (Fig. 14).

Although the basalt intrusion to the north is not as well exposed as the andesite, it appears to have the same structure, to have deformed the sediments in a similar manner, and to be similarly related to the western thrust.

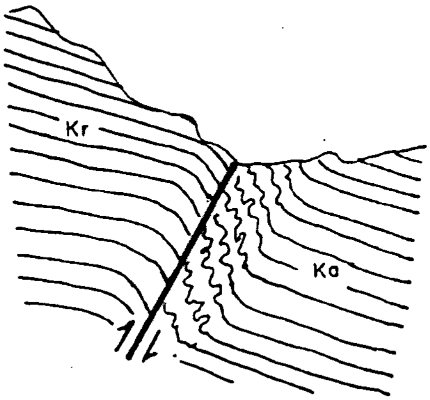
Immediately to the east of the andesite intrusion (Pl. II) lies the northern tip of Brown Mountain. This low ridge is composed of both southeastward and southwestward dipping strata. It would seem that the western thrust fault must pass through the ridge and a branch of it may do so, but the evidence is not convincing. The fault is probably located in the wash that separates the ridge from the intrusion. Intense local deformation suggests this.

The strata on Brown Mountain do not conform to the northwesterly strike and the northeasterly dip common to the Red Hills and nearby areas.

W E



Amole arkose beds turned under.

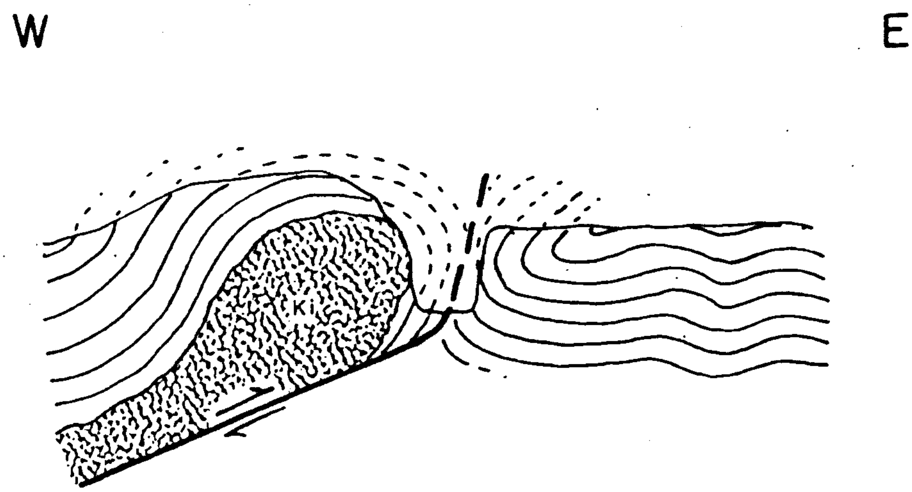


Amole arkose beds turned up.

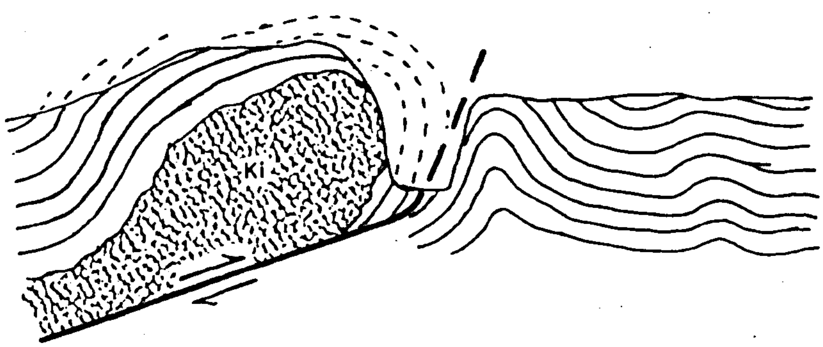
Alternative relationships between the bedding and the fault zone.

(Sketches not to scale.)

Figure 13. Sketch sections of the Eastern Fault Zone.



Beds turned up.



Beds turned under.

Alternative relationships between the bedding, the intrusion and the fault.

(Sketches not to scale.)

Figure 14. Sketch sections of the Northern Andesite Intrusion and the Western Fault.

It seems as though on Brown Mountain the bedding is flattened and warped out of the "normal" attitude. There appears to be no faulting on the mountain itself and the two main faults on either side do not seem to be directly related to this deformation. Intrusions appear to offer the best suggestion as to the origin of the Brown Mountain structure.

The smaller of the two andesite intrusions on the southwestern slopes of the mountain seems to have pushed up through and under the massive conglomerates. The beds above the intrusion are flat while some of those along the sides are up-ended to a nearly vertical position (Fig. 15). Immediately east of the intrusive outcrop is a thick conglomerate containing a highly sheared and contorted red sandstone-siltstone bed. The conglomerate itself has been sheared and contorted to some degree.

The larger southwestern andesite exposure is below the mountain on the floor of the desert. The outcrops of this intrusion are few and nearly flush with the surface. The andesite appears to have been eroded considerably. Originally, it probably rose quite a few feet higher and was surrounded by sediments that now are gone. The few bedding attitudes obtainable around this mass are flat and twisted out of the "normal" pattern. They fit in well with the ones higher on the mountain.

These structures may be small scale examples of the larger Brown Mountain structure. The structure associated with intrusions along the western fault zone appear to strengthen this suggestion. The

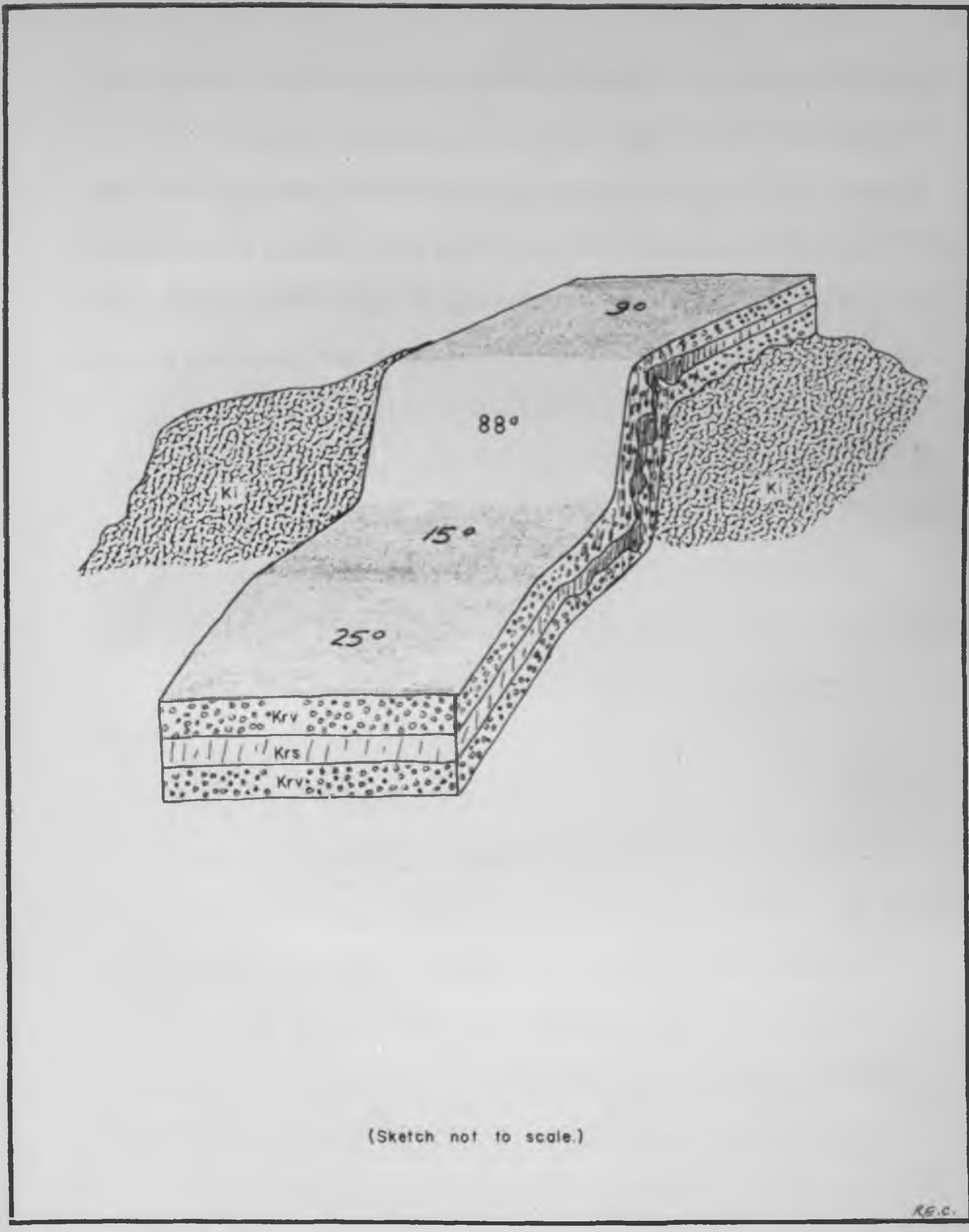


Figure 15. Diagrammatic sketch of the small Andesite Intrusion on southern Brown Mountain.

small intrusions may be upward projections of a larger one at depth.

If the above reasoning is correct, then it seems as though magmas have utilized both eastern and western fault zones as channels. Approaching the surface, they appear to have expanded, lifting and tilting the sediments (Fig. 16). In this way the "abnormal" Brown Mountain pattern may have originated.

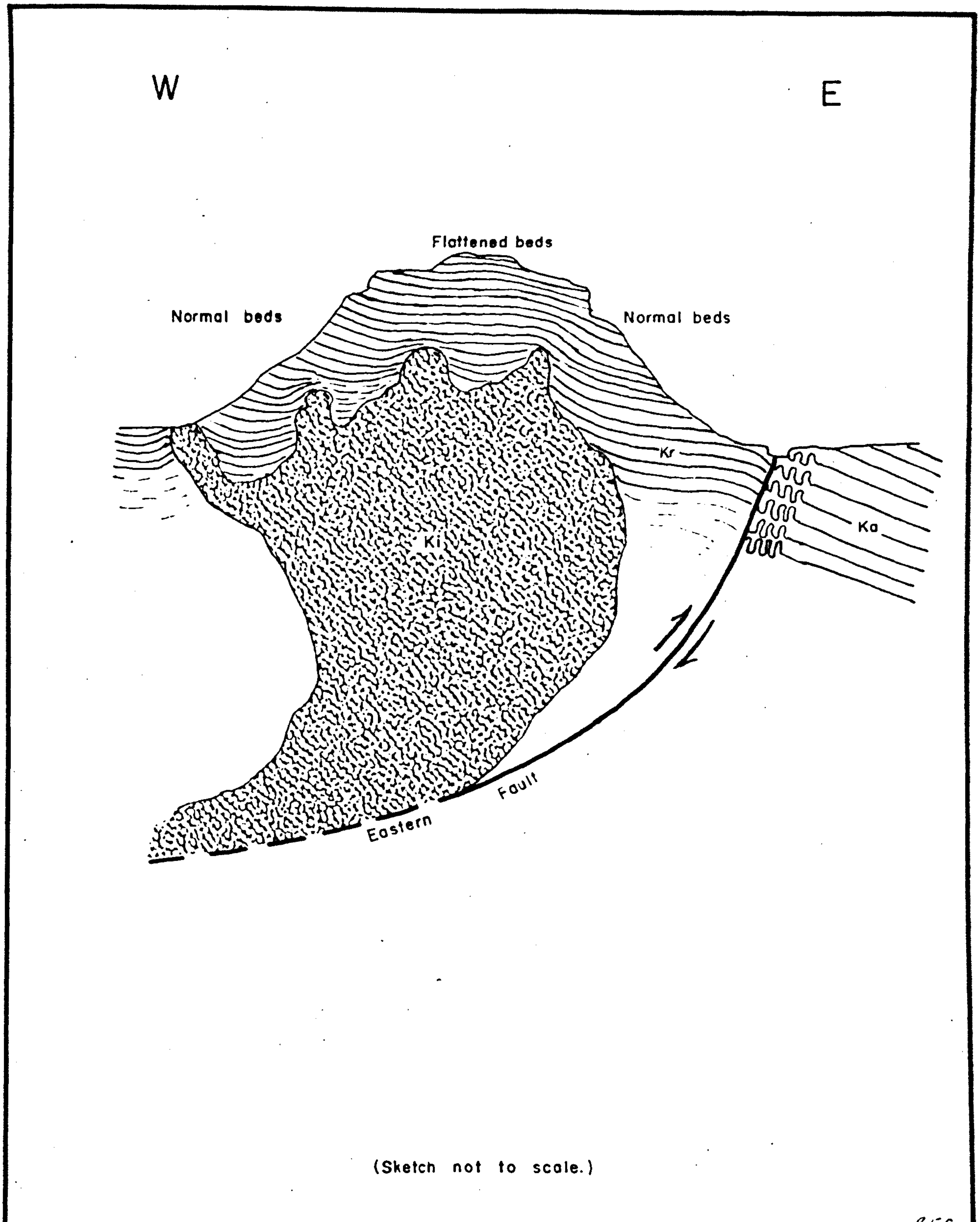


Figure 16. Sketch section of the possible relationship of the intrusions to southern Brown Mountain.

GEOLOGIC HISTORY

GENERAL

The geologic history of this area is fairly complex. The source and depositional environments apparently changed rapidly and often as indicated by the presence of intermixed redbeds, arkoses and volcanics in the area of study.

According to P. D. Krynine's (1949) classification of redbeds, the sandstone-siltstone member of the Recreation may be classified as a primary redbed. This type of quartz-iron oxide sediment indicates tectonic stability in the source area where there is rapid erosion of residual red deposits on a peneplained granitic terrain, under warm humid climatic conditions. Deposition of primary redbeds evidently may occur under almost any climatic condition. However, rapid burial in an oxidizing environment seem to be necessary to preserve the red color. They are probably deposited on flat alluvial plains in temporary lakes or sluggish streams. Aridity does not seem to be a prerequisite, but may be rather common.

Arkoses are often associated with redbeds and evidently have much the same source and depositional environments. They are developed under conditions of rapid erosion of a granite body and rapid burial close by.

Large amounts of coarse volcanic material suggest renewed tectonic activity in the source area and increased sedimentation in the depositional area.

Non-marine, moderately shallow, arid and oscillatory basins apparently prevailed in southeastern Arizona during the Cretaceous. The Recreation redbeds were probably deposited on the edge of one of these basins under near-shore conditions or on an alluvial plain sloping into it.

DEPOSITIONAL AREA

The sandstone-siltstone member of the Recreation redbeds was deposited in this basin relatively slowly and in shallow water. Occasionally, a greater influx of water would bring in slightly coarser material such as arkosic sands and small pebble conglomerates. These interbeds of coarser material became more arkosic and numerous as time progressed. The area was slightly above sea level at times and small cut and fill channels were formed.

Following this, part of the sandstone-siltstone member was eroded. Small scale examples of this can be seen in the small cut and fill channels found on the north end of Brown Mountain. At the same time the water influx greatly increased bringing with it huge amounts of volcanic material and some redbed and arkosic material. Evidently something like a huge cut and fill channel formed in part of the older redbeds. Most of the evidence for this is found on the northernmost part of Brown Mountain below the northern summit. This was seemingly on the edge of the cut and fill area. This is indicated by the abrupt horizontal change from an area of red sandstone and siltstone to an area of intermixed red conglomerates, sandstone lenses, and redbed pockets, where there is no appreciable faulting. In the wash that borders Brown Mountain on the north, this is quite evident. The pockets of red sandstone-siltstone are conspicuous. Apparently some of them were formed when parts of the old redbeds were under cut and dropped into the channel. Others appear to have been formed as red muds from the source area filled in depressions in the conglomerates. Besides accounting for the mixed up nature of the sediments on Brown Mountain, this large cut and fill depression accounts for part of the lower volcanic conglomerate member being on the same horizon as the upper sandstone-siltstone member. Moreover, this different environment probably accounts partly for the general attitude of beds on Brown Mountain, which is different than that of the Red Hills.

The volcanic conglomerate member was deposited under these cut and fill conditions on a minor erosional unconformity. Most of the time the inflow of water was high, but occasionally it tapered off, as the sandstone units were interbedded in the conglomerate (Fig. 4). During certain periods, there may have been mud flows; as some of the massive conglomerate beds are difficult to explain otherwise. These conglomerates immediately preceed tuff deposits of probable nuées ardentes origin and suggest some preliminary disturbance. As time progressed, the volcanic conglomerate contained increasing amounts of arkosic material, and small amounts of redbed material still were carried into the area, derived both from the erosion of the sandstone-siltstone member and from the original source. Eventually, the volcanic material was exhausted and only arkosic material was deposited along with a very small amount of redbed material. Finally only arkosic material was deposited.

Following deposition, faulting and folding then took place. During this orogenic period the eastern fault and then the western fault developed in the Red Hills-Brown Mountain area. Intrusion of the basalt and andesite and folding of parts of Brown Mountain seem to have closely followed the faulting. The Amole granite probably was intruded after this. Then the whole area of the Tucson Mountains was then apparently tilted eastward. The Silver Lily dikes and the mineralization then followed. According to W. H. Brown (1939), all the structures and rock units were present by the end of the Tertiary. The only thing still to be accomplished was the formation of the present topographical surface.

SOURCE AREA

The source area of the sediments may have been relatively close. The environment at the source appears to have changed drastically during uplift and erosion. During the deposition of the sandstone-siltstone member, an old oxidized surface may have been removed. After much of this surface had been eroded, volcanism commenced in the source area. Much andesitic material was produced and occasional eruptions seem to have resulted in nuées ardentes, probably rhyolitic or dacitic in composition. This volcanic area was rapidly eroded and continued uplift and deeper erosion cut into a granitic terraine which shed large amounts of arkosic material. Eventually most of the volcanic material was depleted and only the granitic portion remained. Throughout this entire sequence, redbed material was continually supplied in lessening amounts. The sources were probably small remnants of the original old oxidized surface and some of the earlier deposited redbeds near the depositional area. Finally the original source was exhausted and the nearby source probably buried so that no more redbed material was available to contaminate the arkoses.

CONCLUSIONS

From the study of the Red Hills-Brown Mountain area, several conclusions appear to follow:

(1) It seems that the rocks on Brown Mountain, except the intrusions, are, at least in part, equivalent to the Recreation redbeds. Evidence for this is redbed deposition in the volcanic conglomerates. Channeling of the redbeds and the presence of redbed fragments in the conglomerates suggests the possibility of a somewhat later age for some of the conglomerate, but the presence of conformably overlying Amole arkose above the conglomerate greatly weakens this suggestion.

(2) In accord with the above, it is suggested that the coarse sandstones, volcanic conglomerates, and tuffs of Brown Mountain be regarded as a volcanic conglomerate member and a tuff member of the Recreation redbeds.

(3) The Recreation redbeds proper seem to have been laid down on an alluvial plain, or perhaps in a shallow basin. Fine grained red sandstones and red siltstones alternate regularly, suggesting seasonal or other cyclic deposition. Very few conglomerate layers interrupt this regular sequence.

(4) The coarse sandstones and volcanic conglomerates may have

been deposited along the course of a major stream, entrenched into the surface on which the redbeds were being deposited. Channeling observed in the redbeds strengthens this impression. Apparently, the channel or valley was followed at times by mudflows, and by nuées ardentes.

(5) At some time after deposition of the Recreation redbeds and the overlying Amole arkose was completed, it seems that the redbeds and conglomerates were pushed upward and eastward into and over the arkose. At the same time, perhaps, the arkose and some of the upper part of the conglomerates were thrust over the bulk of the conglomerate-tuff succession. As a result, the rocks of Brown Mountain now appear to be bounded by thrust faults to east and west.

(6) Subsequent to the thrusting, it is known that the western thrust fault was utilized by intrusions that lifted and spread the sediments. Evidence suggests that the eastern thrust also was so utilized. If this is correct, it may explain the peculiar structure found on Brown Mountain. The layers of conglomerate and tuff may have been arched or domed above a large intrusive mass not yet exposed by erosion. The evidence of hydrothermal alteration shown by some of the Brown Mountain rocks seems to support such a conclusion.

(7) The present eastward dip of strata over much of the area may result from the late Tertiary(?) block faulting (Brown, 1939, p. 754).

SUGGESTIONS FOR FURTHER RESEARCH

It would seem that much additional, useful information could be gained from petrological and sedimentational studies of the rocks of this thesis area. Possibly the mapping of additional structural detail would be helpful, but it is thought that the structural mapping is already fairly complete.

Possibly the redbeds contain material for pollen analyses. If so, a check could be obtained on the supposed upper Cretaceous age of these sediments. Obviously, any research method would be welcome that could render more definite the dating of these rocks.

APPENDIX —— MEASURED SECTIONS

SECTION A

Big Red Hill, southwest face, strike approximately N 50° E.

Top of Hill and Section		Feet
Recreation redbeds		
Sandstone-siltstone member		
1.	Mottled red and brownish red fine grained sandstone.	27
2.	Grayish red and brownish red fine grained sandstone.	5
3.	Reddish brown fine grained sandstone.	31
4.	Grayish brown fine grained sandstone with numerous quartz veins present.	7
5.	Brick-red fine grained quartz-iron oxide sandstone, massive and thin bedded. Some portions brownish red colored.	210
6.	Dark brownish red small pebble conglomerate which has had silica introduced causing a chert-like surface.	3
7.	Brick-red fine grained quartz-iron oxide sandstone, massive and thin bedded.	31
8.	Grayish yellow or brown volcanic conglomerate. Coarse arkosic matrix with pebbles averaging 2 to 3 inches in diameter. Purplish bedding surfaces are present in small lenses and pockets.	7
9.	Brick-red fine grained sandstone interbedded with coarser gray arkosic sands. Beds only a few inches thick.	14
10.	Grayish yellow or brown volcanic conglomerate like that at location No. 8.	16

11.	Brick-red fine grained quartz-iron oxide sandstone, finely interbedded with small gray fine grained arkosic sands.	83
12.	Grayish brown or purple volcanic conglomerate intermixed with coarse grained gray arkosic sandstone. Conglomerate matrix similar to sandstone with pebbles averaging 1 to 2 inches in diameter. A few cobbles up to 12 inches.	14
13.	Brick-red fine grained quartz-iron oxide sandstone, finely bedded and massive.	47
14.	Orangish red fine grained quartz-iron oxide sandstone, massive with little bedding.	21
15.	Brick-red fine grained quartz-iron oxide sandstone, finely bedded and massive.	21
16.	Reddish orange speckled medium fine grained quartz-iron oxide sandstone.	14
17.	Brick-red fine grained quartz-iron oxide sandstone, mostly massive.	123
18.	Gray medium fine grained arkosic sandstone.	2
19.	Brick-red fine grained quartz-iron oxide sandstone, massive and thin bedded.	21
20.	Gray medium fine grained arkosic sandstone with a few purplish bedding surfaces.	1
21.	Brick-red fine grained quartz-iron oxide sandstone, massive and thin bedded.	31
22.	Gray medium fine grained arkosic sandstone.	1
23.	Brick-red fine grained quartz-iron oxide sandstone, massive and thin bedded.	168
24.	Grayish red coarse grained arkosic sandstone.	10
25.	Brick-red fine grained quartz-iron oxide sandstone, massive and thin bedded.	210

26.	Reddish gray medium fine grained arkosic sandstone.	1
27.	Brick-red fine grained quartz-iron oxide sandstone, massive and thin bedded.	11
28.	Reddish gray medium fine grained arkosic sandstone with purplish bedding surfaces.	3
29.	Brick-red fine grained quartz-iron oxide sandstone, massive and thin bedded, partly covered by alluvium.	42

Quaternary alluvium

SECTION B

Southern end of Brown Mountain, strike approximately N 7^{o} E.

Top of Hill and Section	Feet
Recreation redbeds	
Tuff member	
Light pinkish yellow or white tuff. Occasional fragments of andesite and streaks of piedmontite.	50
Volcanic conglomerate member	
1. Intercalated orangish red to purplish gray fine grained sandstone and purplish gray arkosic conglomerate. The sandstone is a quartz-iron oxide sediment with large quartz crystals and has a speckled appearance. The conglomerate pebbles are about 2 to 3 inches in diameter.	60
2. Latite dike about 3 feet wide.	---
3. Purplish gray to buff massive conglomerate very poorly sorted. Pebbles and cobbles are subangular to subrounded and average about 2 to 4 inches in diameter with a few up to 12 inches.	48
4. Red quartz-iron oxide sandstone bed, moderately contorted.	15
5. Purplish gray massive and conglomerate very similar to that at location No. 3. Intercalated with it are lenses of arkosic sandstone with occasional stringers of small pebbles parallel to the bedding.	108
6. Intercalated grayish purple to green conglomerates, fine grained purple and gray arkosic sands and orangish red quartz sand. The conglomerates have a red arkosic matrix with up to 20 percent feldspar. The purplish gray sands show purple bedding surfaces.	25
7. Dark greenish gray andesitic intrusion with small plagioclase and biotite crystals, limited in lateral extent to approximately 20 feet.	5

8. Purplish red conglomerate with a very fine grained matrix of quartz and red fragments of unknown composition. The coarse material is subangular to subrounded and ranges in size from 0.1 to 3 inches. Several small limonite veins traverse the section and the rocks are thinly covered by alluvium. 98

9. Purplish red conglomerate, very similar to that at location No. 8, interbedded with small fine grained moderately fractured brick-red sandstones. Small quartz veins are fairly common.

Quaternary alluvium

SECTION C

Wash south of small hill to the west of Brown Mountain. Section follows wash, W to E.

Top of Section	Feet
Quaternary alluvium	
Amole arkose	
1. Buff, fine to coarse grained arkosic sandstones interbedded with small greenish quartz sandstones.	39
2. Greenish brown, highly fractured fine grained quartz sandstone.	11
3. Buff, coarse grained quartz-arkose sandstone.	11
4. Green fine grained quartz sandstones interbedded with highly fractured greenish quartzites.	67
5. Gradational change from green quartz sandstone to grayish buff quartz sandstone. The green sandstone is finer than the buff and there are several stringers of small pebbles parallel to bedding.	24
6. Olive green highly fractured, very fine grained quartz sandstone alternating with nonfractured beds of the same material and with several small buff gray coarse grained sandstones.	200
7. Olive green very fine grained sandstone-siltstone with abundant quartz and feldspar crystals on the bedding planes. Purplish spots, probably redbed material, in the lower part of the bed.	49
8. Dark purplish brown quartz-iron oxide fine grained sandstone with abundant quartz and feldspar crystals.	10
9. Greenish brown fine grained sandstone with large fragments of quartz and feldspar, alternating fractured and unfractured beds.	23
10. Purplish brown fine grained sandstone with abundant quartz and feldspar fragments.	4

11.	Green very fine grained sandstone, unfractured.	64
12.	Interbedded fine and coarse grained buff-gray arkosic sandstone. Purple sand grains and quartz and feldspar fragments indicate the bedding planes. A few lenses and pockets of pebbles averaging 2 inches in diameter are present.	10
13.	Green fine grained quartz sandstone.	7
14.	Grayish purple fine grained quartz sandstone interbedded with grayish arkosic sandstone. Abundant large quartz and feldspar fragments and stringers of small pebbles are present.	23
15.	Grayish green very fine grained quartz sandstone-siltstone beds moderately fractured.	15
16.	Buff-gray coarse arkose with several fine grained gray sandstones and a few randomly scattered pebbles up to 3 inches in diameter. Excellent large scale cross-bedding.	5
17.	Grayish purple fine grained sandstones, moderately fractured.	12
18.	Grayish purple medium coarse grained arkosic sandstone with thin purplish black sandstone beds grading into a very coarse gray arkose which shows bedding and has beds of small pebbles. Several beds of coarse volcanic conglomerate are interbedded with the arkose in the lowest part of this unit.	80
19.	Red sandstone-siltstone bed. Massive with no bedding.	4
20.	Alternating purple, red and buff-gray medium coarse grained sandstone with dark red bedding surfaces.	35
21.	Purplish buff arkosic sandstone with pebbles scattered throughout.	16
22.	Reddish purple-gray coarse grained quartz sandstone with dark purple bedding.	8
23.	Purplish red fine grained massive sandstone.	45

Probable fault covered by alluvium.

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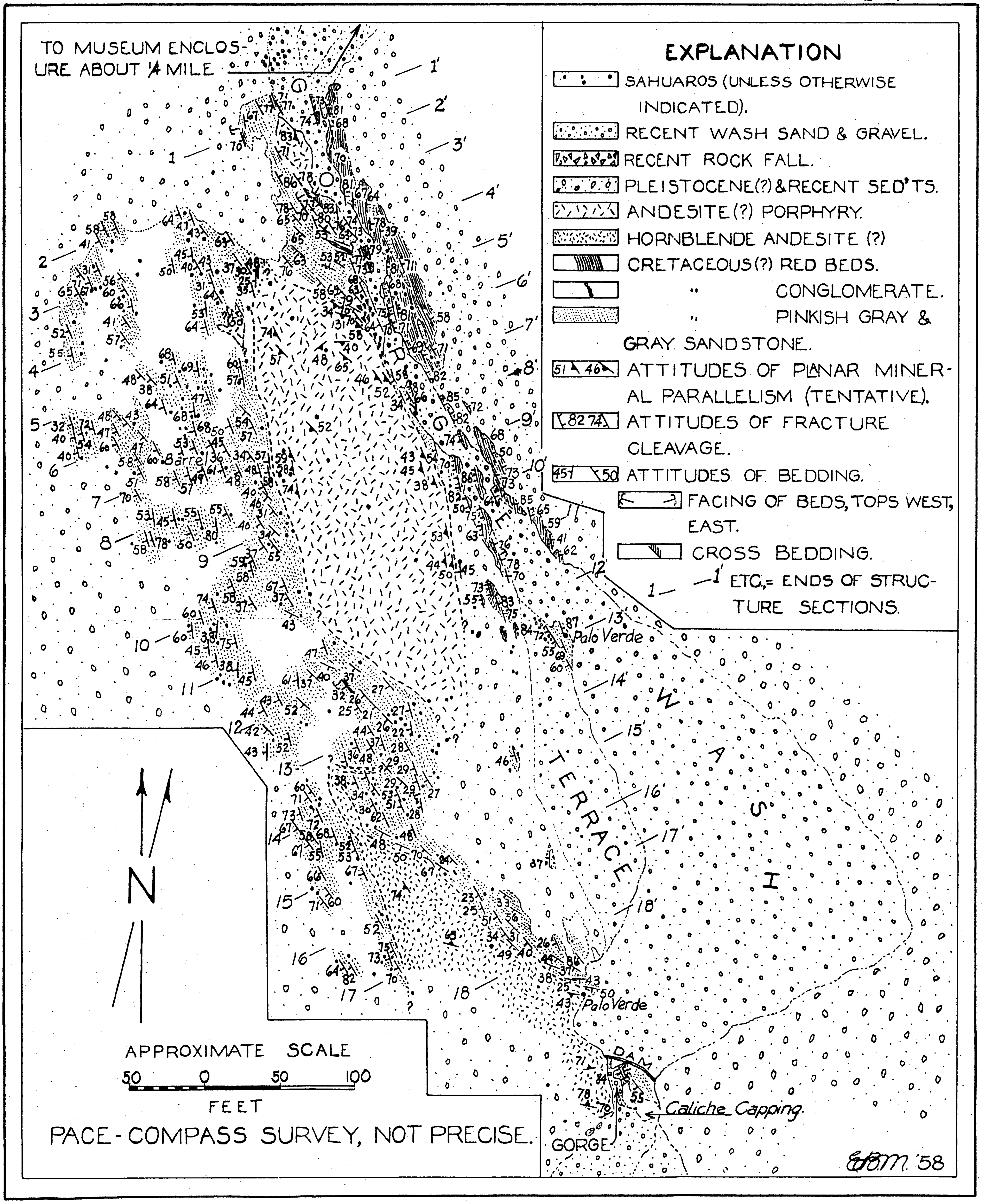
#4 PLATE 11



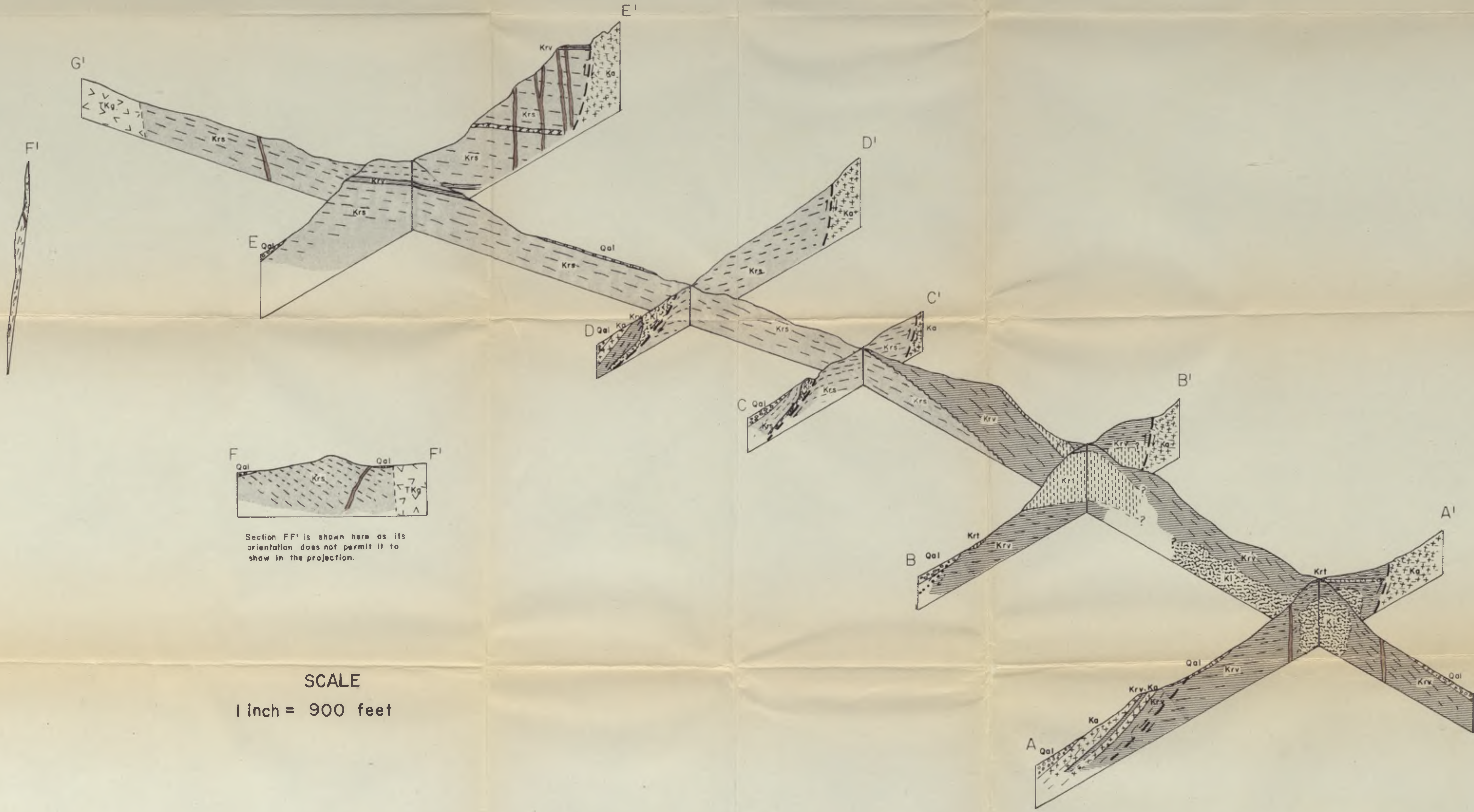
STRUCTURE MAP OF ANDESITE INTRUSIVES AND SEDIMENTS SOUTHWEST OF ARIZONA-SONORA DESERT MUSEUM

PLATE V

CROSS-SECTIONS THROUGH THE RED HILLS-BROWN MOUNTAIN AREA

BY

ROBERT E. COLBY



Section FF' is shown here as its orientation does not permit it to show in the projection.

SCALE
I inch = 900 feet

R.E.C. '58

PLATE III


GEOLOGIC MAP OF THE RECREATION REDBEDS
BY
ROBERT E. COLBY
LEGEND
SEDIMENTARY ROCKS
IGNEOUS ROCKS AND MINERALIZATION
RECENT-(?)-PLEISTOCENE
TERTIARY
CRETACEOUS (?)
Alluvium
Carbonate alteration
Quartz
Limonite
Silver Lily latite dikes
Amole granite
Andesite and Basalt intrusives
Amole arkose
Recreation redbeds
Tuff memb.
Volcanic conglomerate memb.
Sandstone-siltstone memb.
Limestone Squeezed in along faults
SCALE
1 inch = 900 feet
0 900 1800 2700 feet
CONTOUR INTERVAL 50 FEET
SYMBOLS
Dip and Strike
"Strike" of horizontal beds
Fracture zones Dip usually vertical, or nearly so.
Faults, probably thrusts Rightside up and overturned.
Inferred faults
Contacts
Inferred contacts
Contacts with alluvium
Roads, paved
Roads, dirt
Trails
Location of cross-sections
N
RED HILLS
BROWN MOUNTAIN
ARIZONA-SONORA DESERT MUSEUM
WELL
Section 35
Section 36
Section 1
Section 12
Section 7


PLATE IV
GEOLOGIC MAP OF THE RECREATION REDBEDS
BROWN MOUNTAIN AREA
BY
ROBERT E. COLBY
N
SCALE
1 inch = 300 feet
0 300 600 900 feet
CONTOUR INTERVAL 50 FEET
FOR LEGEND AND SYMBOLS SEE PLATE III
2750
R.E.C. '58