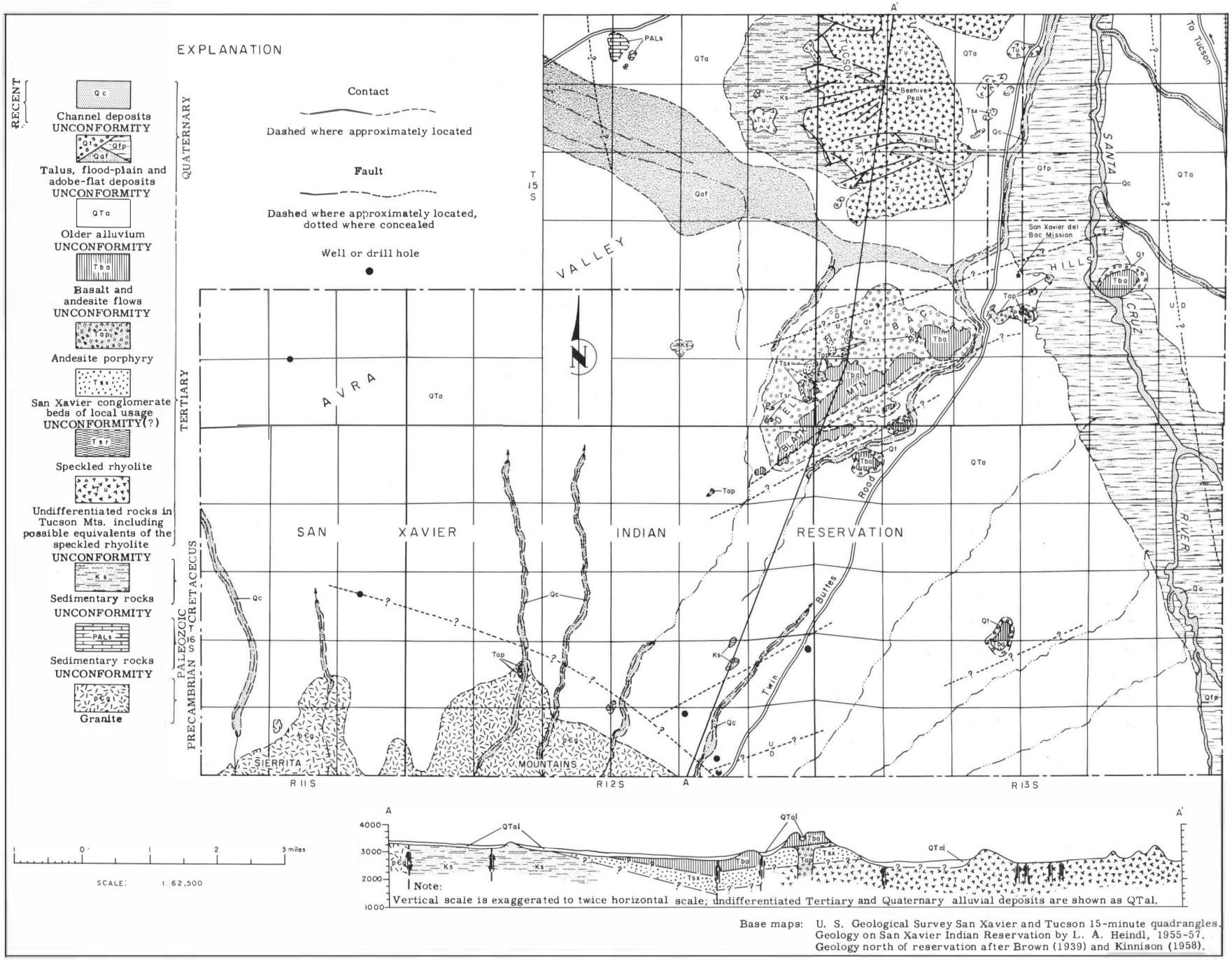

FIGURE 29. Geologic map and cross section of the San Xavier Indian Reservation, Pima County, Arizona.

GEOLOGY OF THE SAN XAVIER INDIAN RESERVATION, ARIZONA

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INTRODUCTION

Individual mountain ranges in the Basin and Range country in southwestern Arizona are alined in north-south chains which are separated by troughlike basins. Much of the discussion of basin-and-range structure has concerned the relationships of the ranges to the basins, but there has been comparatively little discussion regarding the broad saddles or passes where individual mountain ranges of a single chain are in juxtaposition. This report describes the geology of the San Xavier Indian Reservation in central Pima County, Ariz. (fig. 55), which straddles such an area between the northernmost exposures of consolidated rocks in the Sierrita Mountains and the southernmost exposures in the Tucson Mountains.

Geography

The San Xavier Indian Reservation (fig. 29) is about 10 miles southwest of Tucson, immediately north of the Pima mining district. The reservation ranges in altitude from about 3,800 feet in the Sierrita Mountains along the southern boundary, to about 2,450 feet where the Santa Cruz River leaves the reservation at the northeast corner. Most of the reservation consists of broad slopes, or bajadas, descending from the Sierrita Mountains to the Santa Cruz and Avra Valleys. The gradient of the bajadas within the reservation ranges from about 75 to 150 feet per mile. Black Mountain, a lava-capped mesa, is the most conspicuous feature within the reservation, rising about 1,000 feet above its base to an altitude of 3,703 feet. It is the largest feature of the Del Bac Hills, which are in the northeastern part of the reservation. The Del Bac Hills extend for about 7 miles along a N. 60° E. trend and are exposed on both sides of the Santa Cruz River. The eastern part of the San Xavier Reservation is drained by the Santa Cruz River and the west side drains into Avra Valley, whose drainage joins the Santa Cruz River about 20 miles northwest of Tucson.

Acknowledgments

The work upon which this report is based was done by the U. S. Geological Survey for the Bureau of Indian Affairs as part of an investigation of the groundwater resources of the Papago Indian Reservation. The American Smelting and Refining Co. has generously allowed the use of data on some of its exploratory drill holes, and helpful discussions with Messrs. Kenyon Richard, J. H. Courtright, and J. E. Kinnison of its staff are gratefully acknowledged.

ROCK UNITS

The land surface in the San Xavier Indian Reservation is largely formed by alluvium -- in an area of 110 square miles, there is only about 7 square miles of exposed bedrock. Most of the bedrock is Precambrian granite of the Sierrita Mountains and is exposed in the southwest corner of the reservation. The Del Bac Hills are a southern extension of the Tucson Mountains and are composed of Tertiary rocks. Mesozoic and Tertiary rocks crop out in three other small areas on the reservation.

25-Heindl-San Xavier

Rocks exposed on the San Xavier Indian Reservation range in age from Precambrian to Quaternary. Pre-Tertiary units consist of Precambrian granite and Mesozoic sedimentary rocks; Tertiary units consist of volcanic, intrusive, and alluvial rocks; and Quaternary units are composed entirely of alluvial deposits.

Pre-Tertiary Rocks

Precambrian granite (Mayuga, 1942), which may include some younger intrusives, crops out in the southwest corner of the reservation. In part, the granite has been extensively sheared, foliated, and cut by thin pegmatitic dikes. Mesozoic rocks of probable Cretaceous age (Kinnison, 1958) crop out in two isolated areas. One small hill, about 2 miles west of Black Mountain, is composed of olive-green siltstone, mudstone, silty arkose, and some dark limestone. Two small hills, about 3 miles south of Black Mountain, are composed of altered white medium- to coarse-grained arkose. Altered arkose and fine-grained olive-green mudstone containing noticeable amounts of pyrite and hematite were encountered in test holes drilled in secs. 24 and 26, T. 16 S., R. 12 E.

Paleozoic and Mesozoic sedimentary rocks crop out south and north of the reservation (Brown, 1939; Mayuga, 1942; Kinnison, 1958).

Tertiary Rocks

In the Tucson Mountains, probable Tertiary volcanic, intrusive, and sedimentary rocks consist mostly of rhyolite and andesite, with minor amounts of alluvial and lacustrine deposits (Kinnison, 1958; 24). These rocks are older than all Tertiary units exposed on the San Xavier Indian Reservation, except possibly the speckled rhyolite. The Tertiary units in the Tucson Mountains are not differentiated on figure 29.

On the San Xavier Indian Reservation, Tertiary volcanic and sedimentary rocks crop out in the vicinity of Black Mountain and consist, apparently in ascending order, of speckled rhyolite, an alluvial conglomerate locally known as the San Xavier conglomerate beds, andesite porphyry, and thin flows of basalt and andesite. These units were mapped together as Tertiary or Quaternary(?) basalt or shown covered by Quaternary alluvium by Brown (1939). A composite stratigraphic section of the Tertiary rocks follows.

Composite section of Tertiary rocks exposed at Black Mountain in secs. 30 and 31, T. 15 S., R. 13 E., and sec. 36, T. 15 S., R. 12 E.

	Feet
Top of section:	
Erosion surface.	
Basalt and andesite:	
2. Volcanic flows: gray and red-brown to black, weathering brown to black; individual flows 20 to 40 feet thick.....	400±
1. Basal conglomerate and sandstone: includes basal conglomerate, composed of andesite porphyry boulders, grading upward into a muddly angular-pebble conglomerate; a middle laminated sandy mudstone; and an upper cinder sandstone, composed of coarse-sand- to granule-sized fragments.....	0-15

Erosion surface.

Andesite porphyry:

1. Volcanic flows and dikes: gray-brown to red-brown; phenocrysts of plagioclase to three-fourths of an inch; matrix, glassy to aphanitic and cryptocrystalline; highly fractured and in part well-oxidized; thick dike forms resistant walls and flows form moderately steep slopes; thickness refers to flow rocks only..... 150±

San Xavier conglomerate beds of local usage:

1. Conglomerate: light pinkish-brown; fragments range from sand to boulder size and are angular to subangular; generally thin- to thick-bedded (2 inches to 2 feet); lenticular; shows some scour and fill and fluvial cross-bedding; firm, bonded by clay and silt; fragments mainly of arkose, rhyolite, and crystal tuff, with some blue-green limy mudstone in lower part; matrix of similar materials with considerable amounts of feldspar and quartz; weathers to gentle slopes..... 450±

Base covered.

Intrusive(?) speckled rhyolite.

Composite thickness..... 1,000±

The speckled rhyolite crops out west of Black Mountain in several small areas, all of which are completely surrounded by alluvium and lie topographically lower than the other Tertiary rocks. The rhyolite is dark gray, is finely crystalline and contains bright biotite and quartz phenocrysts, and is tentatively considered to be intrusive because it shows no features of extrusive rocks. It is texturally so unlike the biotite rhyolite described from a few miles north in the Beehive Peaks (Brown, 1939; Kinnison, 1958) that no correlation can be suggested at this time, although they appear at about the same stratigraphic position. That the speckled rhyolite lies at a lower elevation than the alluvial conglomerate suggests that it is lower stratigraphically than the conglomerate, but this cannot be demonstrated. Nowhere was the speckled rhyolite seen cutting the overlying rocks.

The so-called San Xavier conglomerate beds crop out in discontinuous patches on the north side of Black Mountain and on the southeast slopes of the Tucson Mountains. On the south side of Black Mountain, their presence is suggested by float fragments. This alluvial conglomerate is made up of fragments of Cretaceous (?) arkose, siltstone, and mudstone, and Tertiary rhyolite and andesite which are similar to those described by Brown (1939) and are commonly of pebble size but may be as large as small boulders. Individual beds are lenticular and contain scour-and-fill structures. The base is nowhere exposed, but the unit appears to overlie older volcanic rocks on the east side of the Tucson Mountains and may overlie the speckled rhyolite at Black Mountain. The maximum exposed thickness is about 450 feet.

The age of the San Xavier conglomerate beds is not known, but they are younger than the Tertiary volcanic rocks to the north (Brown, 1939) and older than the andesite porphyry which intrudes and overlies them. East of Tucson, Brennan (1957) recognized a formation that he considered to be of possible middle Tertiary age, and

it includes flows of andesite porphyry similar in texture to those of Black Mountain. Tentatively, the San Xavier conglomerate beds are considered to be of similar age.

Andesite porphyry crops out in the Del Bac Hills. Along the north face of Black Mountain it occurs as a flow, or flows, between the San Xavier conglomerate beds and the overlying basalt and andesite flows. At the west end of Black Mountain it occurs as a thick dike cutting the San Xavier conglomerate beds. Small, isolated exposures of andesite porphyry intruding granitic rocks along the southern boundary of the reservation may be the same rock, and andesite porphyry was encountered at a depth of 210 feet in a test hole drilled about 2 miles west of Black Mountain.

The andesite porphyry, to which Brown (1939) refers as a basalt porphyry, is a coarsely porphyritic andesite, ranging in color from grayish brown to dark maroon, the more altered portions tending to be gray. The prominent tabular andesine phenocrysts are up to three-fourths of an inch long and give the rock a distinctive appearance regardless of whether they are fresh, altered, or completely eroded away. As Brown (1939) noted, at the west end of Black Mountain the andesite porphyry is clearly crosscutting the alluvial conglomerate and has a flow structure characteristic of a dike. Elsewhere, however, it lies more or less conformably between the alluvial conglomerate and the overlying basaltic and andesitic flows and is either a sill or a flow, probably a flow. The maximum thickness of the andesite porphyry is about 150 feet.

A thick sequence of basaltic and andesitic flows forms the upper part of Black Mountain and some of the smaller hills to the east and south. Similar volcanic rocks also were encountered in one drill hole in sec. 26, T. 16 S., R. 12 E. This sequence of flows rests on an erosion surface that cuts across the andesite porphyry and probably the alluvial conglomerate also. The flows are gray to black on fresh surfaces, weather brown to black, and are 20 to 40 feet thick. They weather readily into large, angular blocks which almost completely mantle the underlying formations. The maximum thickness below the present erosion surface is about 450 feet on Black Mountain and about 700 feet on the hill east of the Santa Cruz River.

Late Tertiary and Quaternary Alluvial Rocks

In the greater part of the San Xavier Indian Reservation the land surface is underlain by alluvial deposits of several types which range in age from probably late Tertiary to Quaternary. These deposits have been divided into the following units: 1) Older alluvium of probable late Tertiary and Quaternary age, which includes the deposits that underlie the broad slopes, or bajadas, of the Santa Cruz and Avra Valley basins; 2) talus deposits which mantle the steep flanks of Black Mountain and other high hills, 3) flood-plain deposits of the Santa Cruz River, 4) adobe-flat deposits, all of Quaternary age; and 5) Recent stream-channel deposits.

In this region, there is a wide variety of floodwater deposits, and it is helpful to distinguish between three of the major types -- those deposited along definite channels, those spread over broad flats of low gradient, and those laid down in ephemeral playa lakes. In this paper the term "flood plain" is restricted to streams that even in flood are confined to definite channels, and "flood-plain deposits" are generally heterogeneous, poorly to fairly well sorted, and lenticular. "Adobe flats" are the broad, nearly flat central or lower parts of desert basins formed by the deposition of sandy clay and silt from sheet floods (Bryan, 1922). Playas are the shallow basins at the lowest points in desert basins and are filled at irregular intervals by broad, shallow sheets of water called "playa lakes." Playa deposits laid down in these ephemeral lakes are fine grained and moderately well bedded, and

are probably most readily distinguished by the presence of evaporite deposits. Flood plains, adobe flats, and playas grade into each other, and their deposits interfinger.

The alluvium of probable Tertiary and Quaternary age, although generally obscured by lag gravel resulting from reworking, was penetrated in well borings and is considered to underlie a large part of the reservation. This older alluvium is composed of materials derived mainly from the Sierrita Mountains. In its upper part it consists almost wholly of granitic debris, but well cuttings show an increase in amount of sedimentary and volcanic rock particles with depth. The base of the unit is not exposed. Wherever the alluvium has been penetrated by drill holes on the slopes of the Sierrita Mountains, a zone about 20 feet thick resting on the bedrock is well cemented by caliche. Above the caliche zone the older alluvium is essentially unconsolidated. Neither the base of the unit nor the caliche zone has been recognized in borings along and east of the Santa Cruz River. South of Black Mountain, the older alluvium has an average thickness of about 200 feet and appears to have been deposited on a moderately rolling surface. This surface had shallow northeast-trending valleys separated by ridges, portions of which are now exposed as small hills. Southeast and northwest of the reservation, well logs indicate that the older alluvium is at least 700 feet thick; possibly only the upper part of it is equivalent to the 200 feet of deposits on the higher slopes.

Talus deposits are best exposed on the flanks of Black Mountain whose slopes can be divided into an upper, steeper part and a lower, more gentle part. Within short distances, the lower slopes merge with the gentle gradient of the bajada. Locally, there is essentially no development of the lower slopes and the steep slopes of the mountain flanks form an abrupt angle with the bajada. The upper slopes of the talus deposits are steep, about 35^{o}, and are bare of vegetation. They are formed by unconsolidated blocks of volcanic rock weathered from the andesite and basalt flows capping Black Mountain. The lower slopes are less steep, as low as 6^{o}, and are sparsely covered by desert vegetation. The lower slopes are underlain by the same material as the upper slopes, but the material contains large amounts of fragments smaller than boulders and is well cemented by caliche. Lenses of talus material grade into and interfinger with surrounding alluvial deposits. The deposits of the upper and lower slopes are continuous, but those of the upper slopes are in the process of being accumulated and those of the lower slopes are being eroded.

Flood-plain deposits lie along the main course of the Santa Cruz River and are about 1-1/2 miles wide except where they are sharply constricted passing between the easternmost Del Bac Hills. The extent of the flood plain is clearly marked by dense vegetation. Only the top 20 feet or so of the flood-plain deposits are exposed; the total thickness may be as much as 150 feet. The uppermost deposits consist of weakly consolidated mudstone and siltstone and minor amounts of sand and gravel. According to well logs, the unexposed lower part contains a higher proportion of sand and gravel. Near the volcanic rocks of the Del Bac Hills the flood-plain deposits interfinger with blocky talus deposits. Coarse deposits are more common along the central part of the flood plain, although gravel beds also occur near the margins.

Adobe-flat deposits are well developed in the pass between Black Mountain and the main mass of the Tucson Mountains and extend northwestward into the Avra Valley. These deposits are composed predominantly of reddish-brown silt and sand and contain small amounts of gravel. They are now in the process of being eroded by sheet wash, and the upper surface is being reworked to some extent by wind action.

Channel deposits along the Santa Cruz River and its principal tributaries are the only Recent deposits mapped separately. Deposits now in the process of transportation but not separately mapped are talus slides; the top few millimeters of the adobe-flat deposits, being reworked by wind and sheet wash; the unconsolidated lag gravel mantling the older alluvium; and channel deposits along small washes.

STRUCTURE

Three principal fault trends are recognized in the area. They are about N. 60° E., about N. 60° W., and about north-south. The N. 60° E. faults are exposed at the south end of the Tucson Mountains (Brown, 1939; Kinnison, 1958) and the N. 60° W. and north-south trends are inferred from the outcrop pattern and relative altitudes of exposures.

Faults having the N. 60° E. trend are well developed, and Mayuga (1942) reported them south of the reservation. They can be seen to displace all rocks older than Quaternary except the granite. In the Tucson Mountains the cumulative effect of many small N. 60° E. faults appears to be a downthrow to the south, but the Black Mountain block is a horst of small displacement, broken by some transverse faulting. South of Black Mountain, a downdropped block appears to lie between the outcrops of Cretaceous rocks 3 miles south of Black Mountain and the southernmost drill hole along the southern boundary, where the Twin Buttes Road leaves the reservation. Andesite flows were encountered below the older alluvium in this hole, in contrast to the test hole a quarter of a mile north, in which Cretaceous(?) rocks were encountered below the older alluvium, suggesting a stratigraphic throw involving possible local equivalents of older Tertiary volcanic rocks, the San Xavier conglomerate beds of local usage, and the andesite porphyry. This downdropped block may be a continuation of the general structural lowering to the south. The N. 60° E. faulting was active prior to the extrusion of the basalt and andesite flows because the andesite porphyry dike in Black Mountain was apparently emplaced along it (Brown, 1939).

Cretaceous arkose and Tertiary volcanic rocks are known to exist under the older alluvium within half a mile of the granitic rocks exposed along the southern boundary of the reservation. The altered and mineralized appearance of the Cretaceous rocks might suggest that an intrusive contact exists between the two units, but the granite is Precambrian (Mayuga, 1942). A thick section of Paleozoic rocks immediately south of the reservation eliminates the possibility of a depositional contact, however, unless some extraordinary erosional relationships are called upon. Consequently, a N. 60° W. structural zone is postulated along the northeast front of granite exposures. There is no known evidence of the N. 60° E. trend in the granitic rocks, and tentatively it is suggested that movement along the N. 60° W. trend is somewhat younger than the N. 60° E. trend. It is suggested also that the structural zone trending N. 60° W. marks the structural boundary between the Sierrita and Tucson Mountains.

Well logs show that the thickness of alluvium ranges from about 200 feet to more than 500 feet within short distances beyond the outer limits of small hills flanking the Tucson and Sierrita Mountains on both the Santa Cruz and Avra Valley sides. Northwest of Black Mountain, water-level altitudes along this zone show a sudden drop from about 2,500 to about 2,000 feet above sea level. These sudden changes are interpreted to indicate the presence of large north-south-trending frontal faults or fault zones separating the basin-and-range blocks. There is no evidence from this area that shows clearly whether the north-south-trending faults are younger,

older, or contemporaneous with movement along the N. 60° E. or N. 60° W. fault zones.

POST-CRETACEOUS GEOLOGIC HISTORY

A summary of the post-Cretaceous history of the San Xavier Indian Reservation depends heavily on evidence from adjoining areas, and I have drawn freely on the work of Bryan (1922; 1925), Brown (1939), Mayuga (1942), and Kinnison (1958).

Before the extrusion of Tertiary volcanic rocks in this area, all existing units were deformed, intruded, and, in part, eroded. The area was covered by a thick sequence of rhyolitic and andesitic volcanic rocks, which may have thinned to the south. Extrusion was accompanied by local intermittent sedimentation and intrusion and mineralization. The Tucson Mountains area was elevated to expose Cretaceous and Tertiary rocks to erosion, while through drainage was either blocked or sufficiently impeded to allow the accumulation of the San Xavier conglomerate beds. During this time the Sierrita Mountains either were comparatively low or were covered with rocks similar to those exposed in the Tucson Mountains. The San Xavier conglomerate beds probably extended over a larger part of the area than did the later alluvium of Tertiary and Quaternary age, but the shape and extent of their basin are not known. Movement along N. 60° E. -trending faults occurred, possibly not for the first time, and along some of them andesite porphyry dikes broke through to the surface and spread as flows over the San Xavier conglomerate beds.

The extrusion of the andesite porphyry was followed by erosion, or deposition and erosion. The onset of further extrusive activity apparently buckled the andesite porphyry into a surface having sufficient relief to allow it to supply boulder-sized debris which was soon buried by thin flows of basalt and andesite.

After the extrusion of the thin andesite and basalt flows and before the deposition of the alluvium of Tertiary and Quaternary age, movement along the N. 60° W. and north-south faults defined the present structural relationships between the Sierrita and Tucson Mountains and the depressed areas flanking them.

Contemporaneously with or after this deformation, through drainage was re-established, probably to the north, and extensive erosion occurred, stripping much of the land to a surface about 200 feet lower than what is seen today. A thin mantle of alluvial material moved across this surface, sufficiently slowly and over a long enough period of time to have developed a thick caliche zone immediately above the bedrock.

Through drainage was again interrupted or retarded and local base levels were established to allow for the accumulation of alluvium in the basin to elevations as high as 150 feet above the present surface along the foothills of the Sierrita Mountains. The source of this alluvium as it occurs in the reservation area was now the Sierrita Mountains. Further reinstatement of through drainage led to the development of the present general degradational cycle. Within this cycle, the Santa Cruz River established itself on the west side of the Santa Cruz Valley, cut its way down through the older alluvium, and superimposed itself across the Del Bac Hills. The Santa Cruz River continued its incisement to about 100 feet below its present channel, forming a valley which it has since partly refilled with flood-plain deposits. The present channel and the gullying across the adobe flats presumably date from the middle 1880's.