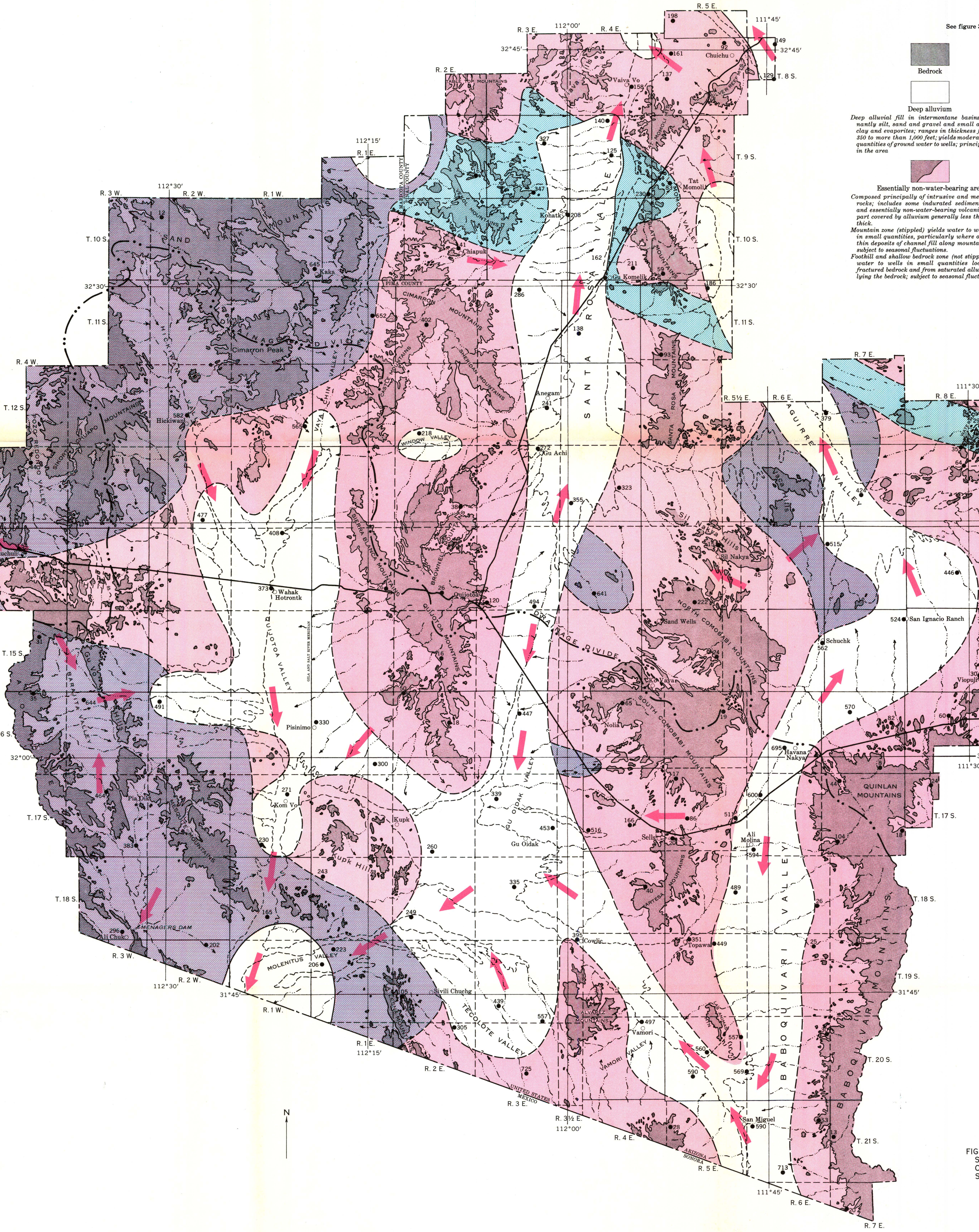

EXPLANATION

See figure 3 for illustration of mountain and foothill and shallow bedrock zones

Bedrock

Deep alluvium

Deep alluvial fill in intermontane basins; predominantly silt, sand and gravel and small amounts of clay and evaporites; ranges in thickness from about 350 to more than 1,000 feet; yields moderate to large quantities of ground water to wells; principal aquifer in the area

Essentially non-water-bearing area

Composed principally of intrusive and metamorphic rocks; includes some indurated sedimentary rocks and essentially non-water-bearing volcanic rocks; in part covered by alluvium generally less than 350 feet thick.

Mountain zone (stippled) yields water to wells locally in small quantities, particularly where overlain by thin deposits of channel fill along mountain valleys; subject to seasonal fluctuations.

Foothill and shallow bedrock zone (not stippled) yields water to wells in small quantities locally from fractured bedrock and from saturated alluvium overlying the bedrock; subject to seasonal fluctuations

Limestone area

Composed principally of Paleozoic limestone; includes small areas of essentially non-water-bearing rocks; in part covered by alluvium generally less than 350 feet thick.

Mountain zone (stippled) locally yields water to wells in small to large quantities from solution openings in limestone and fractures.

Foothill and shallow bedrock zone (not stippled) may yield water to wells in small to large quantities from solution openings in limestone, fractures, or from overlying saturated alluvium

Water-bearing volcanic area

Composed in part of permeable andesitic and basaltic flows and breccias and in part of impermeable rhyolitic and latitic pryoclastic and flow rocks; in part covered by alluvium less than 350 feet thick; locally includes essentially non-water-bearing rocks.

Mountain zone (stippled) locally yields small, and may yield large quantities of water to wells.

Foothill and shallow bedrock zone (not stippled) locally yields small, and may yield large quantities of water to wells from volcanic rocks and overlying alluvium; in specific instances yields small quantities of water to wells from intrusive rocks underlying volcanic rocks

?

Generalized contact

Solid along deep alluvial-fill aquifer where yield is more than 200 gpm; dashed where yield of more than 200 gpm is probable and queried where yield of more than 200 gpm is possible.

Contacts between mountain and foothill and shallow bedrock zones are inferred by visualizing a generalized line between the central parts of the ranges and the discontinuous hills marginal to them

Drainage divide between Gila and Sonoyta Rivers

General direction of ground-water movement

●272

Well, shaft, or test hole showing depth to water, in feet below land surface

FIGURE 2. MAP OF PAPAGO INDIAN RESERVATION SHOWING GENEARLIZED GROUND-WATER AREAS, PRINCIPAL DRAINAGE DIVIDE, DIRECTION OF GROUND-WATER MOVEMENT, AND DEPTH TO WATER AT SELECTED POINTS

SCALE 1:250 000

4 2 0 4 8 12 16 20 MILES

Reservation boundaries and surveyed township lines compiled from U.S. Geological Survey 15-minute topographic maps and original surveys from the files of the U.S. Bureau of Land Management. Unsurveyed township lines protracted in consultation with Bureau of Land Management and Arizona State Land Department. Map compiled by Ruth S. Allison, 1955–57

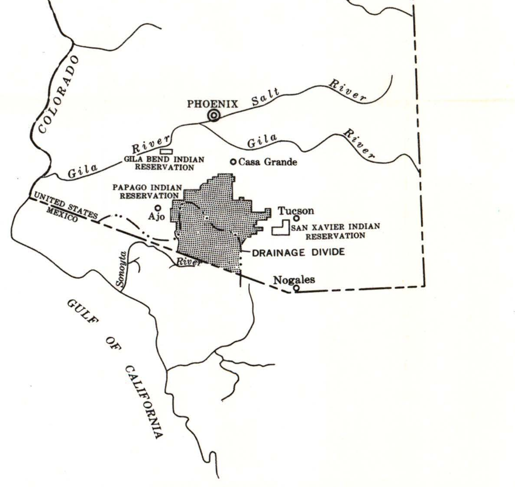

FIGURE 1. MAP OF ARIZONA AND NORTHERN MEXICO SHOWING PAPAGO INDIAN RESERVATION AND PART OF THE DRAINAGE DIVIDE BETWEEN THE GILA AND SONOYTA RIVERS

Bedrock outlines and drainage lines by L. A. Heindl, M. E. Cooley, and O. J. Cosner, 1955–58

INTRODUCTION

This atlas summarizes information obtained during the ground-water investigation of the Papago Indian Reservation made by the U.S. Geological Survey in cooperation with the Bureau of Indian Affairs. It also refers to small-area studies made under separate cooperative agreements with the U.S. Public Health Service for local water supplies. The principal purpose of the investigation was to evaluate the ground-water resources of the reservation in terms of potential irrigation supplies, the location of water for range and stock wells, and the location of suitable water for domestic, community, and public-service supplies.

The atlas makes available to the public and other interested parties a summary in graphic form of information that supplements the tables of well records, chemical analyses of ground water, and drillers' logs (Heindl and Cosner, 1961), which were published separately. The tables include much of the information upon which this atlas is based. The atlas describes ground-water occurrence on the Papago Indian Reservation only generally and is not intended as a guide to individual well locations.

The Papago Indian Reservation has an area of about 4,300 square miles in south-central Arizona (fig. 1). Most of the reservation is in Pima County, but small parts of it are in Maricopa and Pinal Counties. The area is in the Basin and Range province and includes parts of four chains of mountain ranges and three major alinements of troughs and basins. Most of the ranges and basins trend north-south, but there are many local deviations from this predominant trend.

The climate is semiarid. The precipitation, which is almost entirely rainfall, is divided about equally between the hard, local summer showers and more gentle regional winter storms. Total annual precipitation ranges from about 5 inches in the southwestern part of the reservation to about 20 inches in the Baboquivari Mountains. The small amount of precipitation and the abundant sunshine result in a high rate of evaporation, estimated to be about 8 to 10 times the average rainfall. Summer runoff and runoff after occasional winter storms are commonly in the form of sheet wash and floods of short duration.

About 8,000 Papago Indians live on the reservation part of the time, but the full-time population is probably about 4,000. The economy is based largely on cattle grazing, supplemented by farming of small areas irrigated by pumping of ground water or diversion of floodwater.

GROUND-WATER OCCURRENCE

The Papago Indian Reservation is divided here into four ground-water areas (fig. 2). In each of these areas, ground water occurs under generally distinctive conditions which are primarily controlled by the local geology but modified by the local topography.

The four ground-water areas are differentiated on the water-bearing characteristics of their principal rock types. These areas are composed of (1) essentially non-water-bearing materials largely comprised of granitoid and metamorphic rocks but also including some indurated sedimentary and volcanic rocks; (2) locally water-bearing Paleozoic limestone; (3) locally water-bearing volcanic rocks; and (4) generally water-bearing alluvial deposits.

The rocks, except for some of the alluvial deposits, have been structurally deformed at different times. In late Tertiary time the region was warped and faulted into high-standing and depressed areas. The present topography of mountain chains and troughlike valleys has resulted from this structural deformation and associated erosion and deposition.

The topography of the region comprises three principal elements. These are (1) the mountains; (2) the intermontane basins; and (3) the belts of foothills and of shallow bedrock that form zones between the main parts of the mountains and the basins. The foothills are composed of low rolling hills of bedrock separated by only small amounts of alluvium along transecting valleys. Farther away from the mountains, the foothills give way to slopes covered by a shallow alluvial apron within which bedrock is exposed from place to place. The alluvial apron thins toward the mountain areas and thickens toward the basins, merging with the deep alluvial deposits (fig. 3). The first three ground-water areas include mountains and belts of foothills and shallow bedrock; the fourth ground-water area is entirely within the basins.

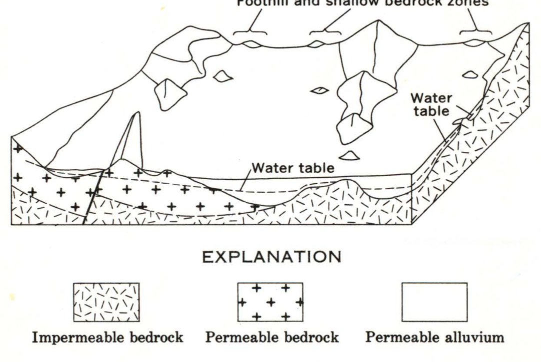

FIGURE 3. SKETCH SHOWING PRINCIPAL TOPOGRAPHIC ZONES AND GENERALIZED RELATIONSHIPS OF SURFACE AND BURIED TOPOGRAPHY TO THE WATER TABLE IN RELATIVELY PERMEABLE AND IMPERMEABLE BEDROCK AND PERMEABLE ALLUVIUM. THE MOUNTAINS AND AREAS OF DEEP ALLUVIUM IN THE INTERMONTANE BASINS ARE NOT IDENTIFIED ON THE SKETCH

In this report shallow alluvium generally includes that which is 350 feet deep or less, or that in which the water table is at or near the base of the alluvium. Generally, the shallow alluvium has a saturated thickness or a permeability insufficient to yield water in amounts adequate for irrigation. This yield is set arbitrarily at 200 gpm (gallons per minute). Available data indicate that any alluvial deposit capable of sustained yield of more than 200 gpm to a well is part of the deep alluvial aquifers.

The ground-water areas and zones and their boundaries are highly generalized, and, because of local variations in rock type and structure, conditions at any particular place within any ground-water area may differ considerably from those considered to be typical. The contacts between the mountain and foothill zones are not shown on the accompanying map but can be inferred by visualizing a generalized line between the bedrock and the alluvium-covered areas.

ESSENTIALLY NON-WATER-BEARING AREAS

Mountain Zone.—The essentially non-water-bearing mountain areas include most of the ranges on the reservation, excluding only those composed largely of Paleozoic limestone or younger volcanic rocks. The bedrock of these areas includes granitoid and metamorphic rocks of early Precambrian, probably Mesozoic, and early Tertiary ages, indurated sedimentary rocks of late Precambrian, Cambrian, Cretaceous(?), and early Tertiary ages, and volcanic rocks of Cretaceous(?) and early(?) to middle(?) Tertiary age. The sedimentary rocks are composed predominantly of well-cemented clastic materials, although some limy deposits also are included. The volcanic rocks are composed of rhyolitic to andesitic fragmental rocks, in part reworked and redeposited, lava, and some associated intrusive bodies. Locally, particularly along the main stream courses, the bedrock is partly covered by thin coarse channel deposits.

Water occurs principally in fractures in the indurated rocks, in interstitial openings, or in the thin channel deposits. In the indurated rocks, water occurs along dikes and fault zones. In the channel deposits, the water tends to be concentrated where the channels cross favorable fractures, dikes, and faults in the bedrock and where the deposits thicken locally at changes in the course of the channel, at stream junctions, and at places where the gradients flatten. In short, the local concentrations of water in the mountain zone are controlled by the structure of the bedrock and by favorable location in relation to runoff, even where the water is obtained from the channel deposits.

The wells and some springs in the essentially non-water-bearing mountain areas are either in narrow valleys, washes, or ravines, or, more rarely, directly on the mountain slopes. The wells may be located directly on the bedrock or on the thin channel debris overlying the bedrock. Water is obtained from either the fractured bedrock, the channel fill, or both, and is generally obtained from depths of less than 50 feet and rarely from depths of more than about 300 feet. Only small amounts of water are obtained from most of the wells—the production generally is sufficient to sustain only a few head of stock or a few families of Indians. Available data indicate that productivity fluctuates only slightly with the type of rock involved but varies considerably within the same rock type, depending on the degree of fracturing. Productivity and water levels fluctuate seasonally in response to rainfall, and many wells go dry between periods of precipitation. A few wells in the areas yield as much as 25 gpm, but such yields usually are not sustained for long periods of time.

The igneous and metamorphic rocks and the indurated sediments composed of sandstone and quartzite commonly contain small amounts of water where they are located favorably in relation to runoff and the water table—that is, along the larger stream courses. A specialized locus for wells and springs in some areas is along fault zones. The fault zones act either as conduits or barriers to the movement of ground water, bringing the water to points at or close to the surface. Concentration of vegetation marks such places in many areas.

Foothill and Shallow Bedrock Zone.—Ground water in the foothill and shallow bedrock zone adjoining the mountains in the non-water-bearing areas occurs principally in the alluvium and, to a lesser extent, in the bedrock under conditions similar to those in the mountains themselves. In general, the water occurs at the base of the alluvium or in the upper, fractured part of the bedrock and may be obtained from either or both sources. The situation is exemplified by the occurrence of ground water in the vicinity of Sells (Coates, 1954).

Wells in this zone are generally permanent, and their yields are adequate for domestic, small-community, and stock purposes, although they are subject to seasonal and long-term fluctuations. The most favorable locations are those that are (1) near or along large washes which provide seasonal recharge from runoff; (2) in bedrock that is well fractured; and (3) in the thicker and coarser alluvium.

In this zone, drilling deeply into the bedrock is inadvisable unless deep fracturing is evident. A well nearly 1,000 feet deep near Sells produced only about 15 gpm, all of which appeared to come from the top 200 feet. The bedrock is virtually impermeable below the topmost fractured areas, and the water-table tends to reflect the bedrock topography.

LIMESTONE AREAS

Mountain Zone.—The limestone areas are principally in the northeastern part of the reservation, where limestone crops out in discontinuous ranges and hills. The areas as shown also include some quartzite and indurated sandstone, and smaller amounts of intrusive, metamorphic, and volcanic rocks. For the most part the volcanic rocks in the area are above the water table and, except in the westernmost part of the area, those that occur below the surface are generally impermeable. Most of the information concerning water from limestone rocks on the reservation comes from records and reports of abandoned mines. Some of the mines were reported to contain considerable quantities of water; one mine, which was pumped intermittently over a period of 5 years, yielded about 700 gpm. Reported water levels in the mines generally appear to be concordant with the water table in the adjacent alluvial valleys.

The limestone exposed in the reservation is predominantly of late Paleozoic age. It occurs in thin to massive beds, ranging in composition from limestone to dolomite interbedded with muddy and sandy limestone to limy shale and sandstone strata. The limestone has been deformed intensely and intruded by small stocks, dikes, and sills. Locally it is extensively fractured. Many of the fractures have been enlarged by solution to form channels and cavities, but in part the fractures have been sealed by secondary deposition of limy and muddy material. Water in all the mines and reports of extensive pumpage from some of them in the past suggest that fractures and solution channels also occur below the water table and that they may be widespread. However, the bodies of ground water in different parts of the limestone may not be interconnected, and, furthermore, because the mines are commonly in extensively faulted and fractured areas, the local bodies of ground water may be compartmentalized. Thus the sustained yield of individual wells may be limited by the quantities of water stored within localized compartments, augmented by small amounts of seasonal replenishment.

Foothill and Shallow Bedrock Zone.—The foothill and shallow bedrock zone in the limestone areas is similar topographically and hydrologically to the foothill and shallow bedrock zone adjacent to the mountains in the non-water-bearing areas, except for one major difference. Near the non-water-bearing mountain areas, it is inadvisable to drill into bedrock below the fractured zone; whereas in the limestone areas it is considered possible to obtain moderate yields from wells in the limestone at depths concordant with the water table in the adjacent alluvial valleys, provided the limestone penetrated is sufficiently channeled.

WATER-BEARING VOLCANIC AREAS

Mountain Zone.—The western third of the reservation is composed largely of late Tertiary volcanic rocks. They consist largely of basaltic and andesitic flows and silicic pyroclastic deposits. In addition, two small areas of similar volcanic rocks are delineated in the central and eastern parts of the reservation. The basaltic and andesitic flows are highly permeable in many places because of well-developed vesicularity, a high degree of fracturing, and the widespread development of brecciated zones between the flows. Some pyroclastic deposits are poorly permeable and may act as local confining beds or form the base of local perched water tables. Other pyroclastic deposits, such as cinder cones and cinder beds, may be highly permeable. The "water mine" near Ajo and adjacent wells obtain their water from andesitic cinder and breccia deposits. In most areas, the base of the late Tertiary volcanic sequence is composed of less permeable intrusive, sedimentary or older volcanic rocks.

The late Tertiary volcanic rocks in the mountains contain small amounts of ground water locally. Small amounts of ground water also occur in mountain valleys in permeable volcanic material. In some valleys in the mountains, seeps along fractured zones, in part related to faults, yield enough water for domestic or stock purposes. In general, flows from springs and water levels in shallow wells in the volcanic areas fluctuate widely in response to seasonal rainfall and runoff.

Foothill and Shallow Bedrock Zone.—The foothill and shallow bedrock zone in the late Tertiary volcanic areas is used here to include alluvial valleys of moderate size within the volcanic area, such as the Barajita, Kaka, and the upper part of the Hickiwan Valleys, in addition to the zones marginal to the mountains. These and similar valleys within volcanic areas are comparatively shallow and ground water beneath their surfaces is contained in the alluvial deposits and the underlying volcanic rocks. Locally, as at Hickiwan, the water table is so deep that water is obtained from granitoid rocks underlying the volcanic rocks.

Over most of the shallow bedrock zones in the late Tertiary volcanic areas, the depth to water is more than 300 feet and may be as much as 650 feet. The available water levels from wells in these areas indicate that the water table in the late Tertiary volcanic rocks is essentially concordant with the water table in the adjacent alluvial valleys. This concordant relationship within the reservation is in sharp contrast to the relationship between the water levels on the reservation and those in the valleys west of the reservation, which are several hundred feet lower.

The yields of wells tapping late Tertiary volcanic rocks are variable largely because sufficiently permeable zones are not everywhere present or interconnected. Similar rocks in other parts of Arizona yield from a few to several thousand gallons per minute to wells, and the yields vary tremendously within short distances. In several areas, holes drilled in volcanic rocks have been reported to be "dry," because the water table was below the depth at which drilling stopped. Locally the water table is below the base of the late Tertiary volcanic sequence, and the small yields of wells in these areas is due to the low permeability of the underlying material and not to the lack of permeability in the volcanic rocks.

DEEP ALLUVIAL VALLEYS

The central parts of most of the basins on the Papago Indian Reservation are underlain by thick alluvial aquifers, except where local buried bedrock barriers are present. In some areas the bedrock barriers are so deep as to have no noticeable effect upon the movement of ground water; in others they constrict the movement of ground water and funnel it through channels that are narrow compared to the width of the valleys. Many of the apparently isolated deep-aquifer areas shown on the map are probably not as isolated as shown; they may be connected by narrow channels similar to the one between the Tat Momoli and Silver Reef Mountains demonstrated by geophysical probing in the Chuichu area (Skibitzke and Yost, 1951; Yost, 1953).

The deep alluvial aquifers are outlined in three patterns—solid lines, dashed lines, and dashed lines with queries—according to the probable ability of the included area to yield water to wells in amounts sufficient for irrigation. These areas are outlined without regard to depth to water, which in the deep alluvial basins ranges from about 100 to about 600 feet.

Ground water is used, or is considered to be sufficient, for irrigation in five areas on the reservation. These are: (1) east of Chuichu, where about 1,200 acres is being irrigated; (2) the Santa Rosa Valley northeast of Kohatk, where pumping tests indicated potential yields of 1,000 gpm with drawdowns of about 50 feet; (3) the west-central part of Tat Momoli Valley along the reservation boundary, southeast of which commercial irrigation is now practiced; (4) the east end of the panhandle in T. 14 S., R. 11 E., which is in Avra Valley, an extensively irrigated basin; and (5) the Molenitus Valley in the southwestern part of the reservation, where quantities of water adequate for irrigation recently have been proved.

Information gained from examination of well cuttings and from bailing tests suggests that two other areas probably have sufficient ground water for irrigation development, but more adequate testing is needed for proof. These are Window Valley and the south-central part of Gu Oidak Valley. The rest of the areas that are outlined as part of the deep alluvial aquifers probably would yield water in sufficient quantity for irrigation development also. The alluvium in these areas is tapped only by wells of small yield equipped with windmills, but, because of the topographic setting and the fact that the alluvium is thick, potential yields of wells may be much greater. Thorough testing of the alluvium, however, should precede its development to pump irrigation.

MOVEMENT OF GROUND WATER

The Papago Indian Reservation is drained principally by the Gila River to the north and the Sonoyta River to the south. (fig. 1). Ground water moves largely along the axes of the valleys in those drainage systems. The surface-water and approximate ground-water divides generally coincide, as shown on figure 2. The movement of ground water is controlled primarily by differences in relief and the permeability of the alluvial deposits and secondarily by the configuration and permeability of buried bedrock. The influences of these factors are indicated in the following examples. Ground water west of the Baboquivari Mountains moves south, up Baboquivari Valley, around the south end of the Las Animas Mountains, and then northwest and west to join the south-moving ground water under San Simon Wash into the Sonoyta River valley in Mexico. In the vicinity of Sells, the water in the valley between Sells and the South Comobabi Mountains moves westward and is about 400 feet higher in altitude than the water in Baboquivari Valley, which moves southward. Here is a clear example of the control of the water by the shape, altitude, and impermeability of the underlying bedrock. The second example is the previously mentioned concordance of water-table altitudes in alluvial intermontane basins and the adjacent volcanic rocks, as east of the Ajo Mountains, and in adjacent limestone rocks, as east of the Vekol Mountains. This concordance suggests that the flow of water from these volcanic and limestone areas into the alluvium is reasonably free. Undoubtedly, where conditions are favorable, ground water also moves locally from the alluvium into the limestone and volcanic rocks. The large arrows of figure 2 show the general directions of movement of ground water on the Papago Indian Reservation.

CHEMICAL QUALITY

Water from wells on the reservation generally meets the chemical-quality limits suggested for domestic and public-supply used by the U.S. Public Health Service, with one exception—the fluoride content. About 25 percent of the wells sampled yielded water of more than 1.5 ppm (parts per million), the maximum suggested for domestic use. Water in the southwestern quarter of the reservation, where volcanic rocks are dominant, generally contains greater concentrations of fluoride than waters from other ground-water areas. Dissolved-solids content generally is less than 700 ppm and increases as the water moves downgradient. Sodium, calcium, bicarbonate, and chloride are the predominant constituents.

Chemical analyses of water samples collected on the Papago Indian Reservation are given in tables compiled by Heindl and Cosner (1961).

Ground water is used successfully for irrigation on the reservation, although its quality is considered to be only moderately suitable. Most of the water shows high SAR (sodium-adsorption ratio) and medium to high sodium and salinity hazards. Water of this type may be used to irrigate crops with moderate salt tolerance, particularly where the soils are well drained. However, continued success will depend on good management practices and proper use of chemical amendments. This is also true of other parts of southern Arizona.

The only known highly mineralized water is from two wells, one drilled and one dug, in the extreme southwest corner of the reservation. Water from these wells contains nearly 5,000 ppm of dissolved solids and has a composition that suggests its salt content is derived from evaporites.

REFERENCES CITED

Coates, D. R., 1954, Memorandum on ground-water investigations in the Sells area, Papago Indian Reservation, Pima County, Arizona: U.S. Geol. Survey open-file report, 6 p.

Heindl, L. A., and Cosner, O. J., 1961, Hydrologic data and drillers' logs, Papago Indian Reservation, Arizona, with a section on chemical quality of the water, by L. R. Kister: Ariz. State Land Dept. Water Resources Rept. no. 9, 116 p.

Skibitzke, H. E., and Yost, C. B., Jr., 1951, Location of sites for irrigation wells near Chiu Chuischu, Papago Indian Reservation, Pinal County, Arizona: U.S. Geol. Survey open-file report, 6 p.

Yost, C. B., Jr., 1953, Geophysical and geological reconnaissance to determine ground-water resources of Chiu Chuischu area, Papago Indian Reservation, Arizona: U.S. Geol. Survey open-file report, 25 p.

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—62015

SUMMARY OF OCCURRENCE OF GROUND WATER ON THE PAPAGO INDIAN RESERVATION, ARIZONA

By
L. A. Heindl, O. J. Cosner, H. G. Page, C. A. Armstrong, and L. R. Kister

1962

HYDROLOGIC INVESTIGATIONS
ATLAS HA-55

For sale by U. S. Geological Survey, price 50 cents