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U. S. Geological Survey

GEOLOGY OF THE TUCSON QUADRANGLE, ARIZONA

By

B. N. Moore and C. F. Tolman, Jr., with contributions by B. S. Butler

and R. M. Hernon

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Contents

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Geography

Location and topography

The Tucson thirty-minute quadrangle is in Pima County, southeastern Arizona, between latitudes 32°00' and 32°30'N. and longitudes 110°30' and 111°00'. It lies between the Santa Cruz and San Pedro Rivers on the eastern border of what Ransome, (Globe folio, p. 1; Ransome, USGS Prof. Paper 98K, pp 133-135), termed the Desert Region, an area of rugged mountains which rise from broad irregular basins. This region, which drains to the Gila River, was known to the early Spaniards as Pimeria'Alta and later was called the Papagueria or Papago country.

The dominant topographic features are the wide basin in which Tucson is situated, with deep reentrants into the mountains along the principal tributary streams; the Santa Catalina Mountains to the north; and the Rincon and Tanque Verde Mountains to the southeast. Most of the quadrangle drains to the Santa Cruz River, a portion of which lies within its western border, but the northeastern part of the quadrangle drains to the San Pedro River, farther northeast.

Communications

Tucson, the business and cultural center of the region, is just within the western border of the quadrangle about midway between the northern and southern boundaries. Roads radiate from the city to small settlements and ranches. U. S. Highway 80 crosses the Tucson basin in a southeasterly direction, linking the city with Phoenix to the northwest and Bisbee and Douglas to the southeast, with connections to points farther east and west. U. S. Highway 89, which is coextensive with U. S. Highway 80 north of Tucson, extends southward to the Mexican border at Nogales. State Highway 84 connects Tucson with western Arizona. A good highway crosses the Santa Catalina Mountains to Oracle and a fair road extends through the pass between the Santa Catalina and Rincon Mountains to Redington. Oracle is north, and Redington is east, of the quadrangle. Tucson is the junction of the main line of the Southern Pacific Railroad and the Mexican branch of that railroad and also has two principal air fields.

Industries

Stock raising has been the main agricultural activity within the quadrangle, though irrigation has long been practiced in the valley of the Santa Cruz River both here and in neighboring areas. There has been a growing tendency for the more accessible ranches to be taken over and developed mainly for residential purposes, with incidental stock raising. There has been and still is considerable mining activity in the region tributary to Tucson but the only district within the quadrangle that has attained much production is the Control area at Marble Peak near the north boundary of the quadrangle.

Remains of a civilization that preceded the Indians who were here when the Spaniards came are widespread and give the region an archaeological interest.

Tucson is the site of the State University of Arizona, and the surrounding area contains numerous private schools

Climate and vegetation

The climate and vegetation are controlled largely by differences in altitude. In the flat, arid area around Tucson, the summers are hot although modified by a rainy season from July to September, while the winters are mild and sunny. For a limited area on the higher mountains the summers are cool with considerable rain, while the winters are moderate with considerable snow.

The vegetation varies, as a result of the great differences in altitude, temperature, rainfall, and soil, from the cactuses and desert shrubs of the low areas to the forests of fir and pine on the high mountains. This environment has produced, within a range of a few miles, a vegetation of great diversity, probably including about 1,100 species. The fauna is as rich and varied as the vegetation, ranging from deer and mountain sheep in the mountains to the rodents and reptiles in the low areas.

Basis of the report

The present report is a summary of the work of several geologists. The quadrangle was studied geologically in 1911 and 1912 by C. F. Tolman, Jr., associated with Theodore Chapin, R. W. Moore, and M. M. Carpenter, and a preliminary draft of his report was submitted in 1914. At intervals from 1930 through 1938, Bernard N. Moore worked in the area for the Geological Survey but resigned before his report could be put in shape for publication. Since then B. S. Butler, assisted by R. H. Hernon, checked certain features of the geology of the quadrangle in the field. A report was prepared, of which the present one is a condensed summary. Data on the Control copper mining district is from an unpublished report by N. P. Peterson and S. C. Creasey of the U. S. Geological Survey. A report on ground water conditions in the Tucson quadrangle, by S. F. Turner of the Geological Survey, is to be published in the geologic map series of the Survey, and data on ground water are consequently omitted from the present report.

Rocks

The rocks of the Tucson quadrangle include igneous, sedimentary, and metamorphic varieties, and range in age from early pre-Cambrian to Recent. Available data on each of the mapped units are summarized.

Pre-Cambrian rocks

Pinal schist (pGs):- Small patches of highly schistose sedimentary rock, which are here correlated with the Pinal schist of Ransome (U. S. Geol. Survey Prof. Paper 98K, 1916, p. 135), crop out near the southeastern border of the Santa Catalina Mountains, just north of the western tip of the Tanque Verde Mountains, and in several areas just beyond the borders of the quadrangle. Where not infiltrated by granitic material, most of the rock is silvery gray, sericitic schist with green chloritic metacrysts. It varies markedly in texture, and its foliation generally parallels bedding planes. The schist is intruded by pre-Cambrian granitic rock and overlain unconformably by beds of the Apache group (pre-Cambrian).

Oracle granite (pGo):- The granitic rock of a large mass that extends into the northwestern part of the Tucson quadrangle was called Oracle granite by C. F. Tolman in his manuscript report. The name was taken from the village of Oracle 10 miles north of the northern border of the Tucson quadrangle and has come into common use locally (Schwartz, G. M., 1945; Peterson, N.P., 1938, p. 8), although hitherto not formally defined. It is adopted here for the rock of the large mass that extends from the type locality near Oracle into the Tucson quadrangle, on and near Samaniego and Oracle Ridges and appears in isolated outcrops at widely spaced intervals to the south and southeast. Some of the outlying masses consist of the gneissic facies of the granite that is locally distinguishable (pΘog).

The Oracle granite varies considerably in different localities. Near Oracle, where it is comparatively unaffected by metamorphism, it is a coarse-grained, nearly white rock with large phenocrysts of potash feldspar in a groundmass of microcline, orthoclase, alkali plagioclase, quartz, biotite and accessory minerals. In other places hornblendite, gabbro, and hornblende granite are included. In many places the rocks are crushed and altered, contain schlieren and, on the margins, igneous material intimately permeates the host rocks. A few of the more distinctly gneissic parts of the granitic complex are distinguished on the map as the gneissic facies (pΘog). As the Oracle granite is intrusive into the Pinal schist and is unconformably overlain by the Apache group it is pre-Apache in age.

Apache group (pΘa):- Representatives of the Apache group are on the summits and northern slopes of the Santa Catalina Mountains. In the original field work in the Tucson quadrangle all six formations formerly included in the group (Ransome, Prof. Paper 98K, pp 144) were mapped together. Where possible, the Troy quartzite has been distinguished on the present map in accord with Darton's discovery that the Troy is of Cambrian age and the other five formations formerly grouped with it are of pre-Cambrian age (Darton, N. H., 1925, p. 36, Darton, N. H. and others, Geologic Map of Arizona 1924). Some Troy quartzite may remain in the Apache group as mapped but, if so, the areas occupied by it are so small as to be of slight significance. In ascending order the Apache group as now defined includes, in the Tucson quadrangle, (1) the Scanlan conglomerate (10 to 25 feet thick), a basal conglomerate containing small cobbles and pebbles of quartzite and vein quartz in an arkosic matrix, locally metamorphosed to massive white quartzite; (2) the Pioneer shale (150 feet thick), with black shale in the lower part, fine-grained arkose in the middle, and black shale in the upper part, grading upward into the Barnes conglomerate; (3) the Barnes conglomerate (0 to 25 feet thick), containing large cobbles and small boulders of quartzite and chert in an arkosic matrix, grading upward into the Dripping Spring quartzite, and locally represented only by pebbles and sandy shale at the base of that unit; (4) the Dripping Spring quartzite (10 to 15 feet thick) consisting of thin-bedded, fine-grained, locally pebbly arkosic quartzite; (5) the Mescal formation (75 feet or more thick), the equivalent of the Mescal limestone of other areas in Arizona, here consisting of sandy calcareous shale, commonly rendered micaceous and schistose through metamorphism and locally impregnated by intrusive rock.

Cambrian sedimentary rocks

Troy quartzite (Ꞓt):- In common with the other Paleozoic sedimentary rocks in the quadrangle, the Cambrian formations are named in accordance with Ransome's usage, with the exception already noted, that the Troy is now included in the Cambrian system. The Troy of Ransome has been subdivided by Stoyanow (1936, pp. 474-476) under several names.

The Troy quartzite (172 feet thick) is mapped on the northeastern slopes of the Santa Catalina Mountains. The thin-bedded quartzite in its lower part is succeeded upward by more massive cross-bedded and pebbly quartzite overlain by thin-bedded quartzite that grades upward into arenaceous shale. The Troy rests in apparent conformity on the Mescal formation, although in other places in Arizona an angular unconformity has been reported.

Bolsa quartzite (Ꞓb):- In the southeast corner of the quadrangle the Apache group and Troy quartzite are absent and beds correlated with the Bolsa quartzite of the Bisbee region (Ransome, Prof. Paper 21, pp. 28-30) rest in apparently depositional contact on the Rincon Valley granite (pre-Cambrian). The Bolsa quartzite of this locality consists of thin-bedded arkosic quartzite overlain by coarse, red, vitreous quartzite, locally conglomeratic. The thickness is variable with a maximum of about 150 feet. The formation is conformably overlain by the Abrigo limestone. The Troy quartzite and the coarse red part of the Bolsa quartzite are similar in stratigraphic relations, and east of the Tucson quadrangle they appear to grade into each other.

The Rincon Valley granite is called Cretaceous (?) on p. 11 and in the legend(?)!

Abrigo limestone (Ga):- Beds correlated with the Abrigo limestone, (Ransome, Prof. Paper 21, pp 30-33) rest in apparent conformity on the Troy and Bolsa quartzites. In a section measured just north of the quadrangle border, they consist, in ascending order, of 258 feet of thin-bedded green limy shale and shaly and micaceous limestone with fucoid markings, 31 feet of red, rusty-weathering quartzite, locally white, 159 feet of thin-bedded limestone and limy shale, and 162 feet of sandy limestone, a total of 610 feet.

Devonian, Carboniferous and Permian(?) strata

Martin limestone (Dm):- Narrow, faulted bands of rock correlated with the Martin limestone (Ransome, Prof. Paper 98K, p. 145) in both the northeastern and southeastern parts of the quadrangle overlie the Abrigo unconformably. The formation shows marked variation in detail. It is as much as about 350 feet in thickness and consists in different places of grey limestone, rusty-brown stromatoporoid reefs, sandy limestone, black and pink shale, and quartzitic sandstone, and is regarded as of Devonian age, an assignment which is supported by the presence of *Atrypa reticularis* and other fossils. A few patches of rock, mostly marbleized limestone, whose correlation is uncertain, are mapped as limestone of Carboniferous or Devonian age, undifferentiated (CDl). In addition, small areas are so intensely metamorphosed that their age and original character are unknown (ums).

Escabrosa limestone (Ce):- The principal exposures of the beds here correlated with the Escabrosa limestone (Ransome, Prof. paper 21, p. 42) are low on the northeastern slopes of the Santa Catalina Mountains, but there are fault blocks containing beds of this formation in the southeastern part of the quadrangle also. The formation is about 400 feet thick, consists of dark blue, thick-bedded limestone, in part marbleized, and is regarded as of Mississippian age.

Naco limestone (Cn):- Beds correlated with the Naco limestone (Ransome, Prof. Paper 21, p. 44) are similar in distribution to the Escabrosa limestone, on which they rest unconformably. The formation where measured in Edgar Canyon is 908 feet thick and consists of blue, crystalline limestone in beds 10 to 15 feet thick separated by pink and green shaly limestone strata 10 to 15 feet thick. The Naco limestone in southeastern Arizona was originally regarded as containing beds of both Pennsylvanian and Permian age but in recent usage has been restricted to rocks of Pennsylvanian age. This usage is followed in the present report so far as information permits, but it is possible that small amounts of Permian rocks have been included with the Naco on the map.

Permian(?) rocks (Psl):- Southeast of Vail narrow strips of siliceous shale and limestone with lenticular conglomerate beds containing pebbles of chert and jasperoid at the base are exposed. These rocks may be equivalent to the basal part of the Permian beds in the Empire Mountains south of the Tucson quadrangle (Galbraith, F. W., 1940, pp.1927).

Mesozoic stratified rocks

Cretaceous sedimentary rocks (Ksl):- Cretaceous strata crop out in the northeastern, central, and southeastern parts of the quadrangle. They probably aggregate several thousand feet in thickness, and include conglomerate, sandstone, and shale, which in many places are moderately metamorphosed. Where the rocks are metamorphosed, limestone pebbles are drawn out into flat lenses or plates but quartzite pebbles tend to retain their shapes. Fossils found along the northern border of Rincon Valley are reported by J. B. Reeside, Jr., to suggest an Upper Cretaceous age. He states that they are definitely post-Paleozoic and doubts that they could belong even to the Lower Cretaceous. Fossils have not been found in the other strata mapped as Cretaceous, and correlations have been made on the basis of lithologic character and stratigraphic relations. Some rocks of Permian(?) age may be included with the Cretaceous beds.

Cretaceous or early Tertiary intrusive rocks

Diabase (di):- There are numerous diabase dikes and sills, only the largest of which are mapped. The principal exposures are low on the northeast slopes of the Santa Catalina Mountains, but smaller intrusions are widely distributed throughout the quadrangle. The diabase is black to dark green and of variable texture. Much of it is porphyritic and some is schistose. Some contains olivine, some is olivine-free, and other representatives contain quartz; but all three of these varieties may occur in a single sill. Most of the diabase has been so changed that serpentine, uralitic hornblende, and other alteration products have largely replaced the original constituents.

The diabase was regarded by Tolman as of post-Paleozoic age, and some of it cuts Paleozoic and Cretaceous strata. Diabase is intruded by porphyritic quartz diorite in Buehman Canyon. The relations between the diabase and the andesite described below is not clear, but the diabase is thought to be slightly older. Thus, much of the diabase in the quadrangle is probably of Cretaceous age. However, like similar rocks in other parts of the State, some of the diabase may be of the same age as the Apache group.

Andesite (an):- The bodies of somewhat schistose andesite east of Oracle Ridge are extensions of a larger and less metamorphosed mass that intrudes Cretaceous strata north of the quadrangle boundary. The originally glassy matrix of the schistose rock within the quadrangle is devitrified; its plagioclase phenocrysts are partly altered to quartz and mica, and the hornblende and augite are chloritized. The andesite is clearly not older than Cretaceous, and its lithologic resemblance to effusive Cretaceous rocks in neighboring regions suggests a genetic relation to these flows.

Quartz diorite (Tld) and related schistose rock (Tldp):- Near Marble Peak there is an irregular stock of quartz diorite that is somewhat porphyritic and, in certain zones, is indistinctly schistose. It consists of a dark, fine-grained, granitoid rock containing saussuritized plagioclase, albite, quartz, microcline, biotite, epidote, and sphene. A similar but more porphyritic and decidedly more schistose rock has been mapped in the vicinity of Buehman Canyon. These two rocks cut Paleozoic strata and are thought to belong to the assemblage of granitic intrusions that consolidated in late Cretaceous or early Tertiary time.

Rincon Valley granite (Trg):- The granitic rock that underlies much of Rincon Valley and forms other exposures farther south is here named the Rincon Valley granite. It is a coarse-grained, greenish granite composed of sericitized potash feldspar, some oligoclase, interstitial quartz with chloritized biotite, small amounts of altered augite, and such accessories as magnetite, sphene and apatite. It intrudes Cretaceous strata.

Santa Catalina granitic complex (Tcg-Tcpg):- The central core of the mountain mass that comprises the Santa Catalina and Rincon Mountains consists of a batholith and its envelope of altered gneissic rocks, which together may be referred to as the Santa Catalina granitic complex. Some of the granitic rock of the batholith is intrusive into older rocks, but in most places the distinctly granitic material (Tcg) grades into gneissic rock (Tcpg). Tolman separated the complex into a dominantly granitic part and a dominantly gneissic part. This separation has been followed on the map, but it should be understood that in general there is no distinct boundary between the two kinds of rocks. Both kinds include many varieties that are not distinguished on the map. In addition to these two kinds of dominantly granitoid rocks there are metamorphosed and partially permeated masses of originally sedimentary rock (Tcgn). The rocks of the complex, especially the gneissic varieties, cut and grade into most of the sedimentary formations present in the quadrangle, including those of Cretaceous(?) age. They also cut Oracle granite and a number of smaller intrusive bodies, including dacite regarded as of Tertiary age.

The granitic rock of the complex is commonly a light gray rock varying in texture from fine to coarse in different areas and is in general of simple mineral composition; quartz, orthoclase, plagioclase, and varying amounts of biotite and muscovite are the common minerals, while in numerous places small red garnets are a minor constituent. In the hand specimen the rock has a typical granitic texture, but in large fresh outcrops such as road-cuts the granite has a distinct gneissic appearance. The obscure gneissic texture grades into the strongly gneissic texture of the outer portions of the complex.

The part of the complex mapped as gneiss includes two principal varieties; one a medium-coarse-grained rock resembling a sheared granite, the other an augen gneiss with crushed porphyroblasts of feldspar that are in places several inches in length surrounded by fine-grained material rich in biotite. In lighter-colored facies the biotite is replaced by feldspar and quartz.

In rocks that have suffered only incipient replacement the feldspar grains are arranged in bead-like strings of crystals or augen along bedding planes or other permeable lines. Where the process has proceeded further the crystal aggregates have enlarged and coalesced with similar adjacent ones to form bands of pegmatitic material that generally follow the schist planes or bedding of the replaced rock, but locally cross the structure. The mineral composition of the gneiss in which replacement ceased at an early stage depends on the character of the rock that was replaced, and varies greatly, but in the advanced stages the gneiss, irrespective of the character of the original rock, tends to consist dominantly of feldspar, quartz, and mica with accessory minerals among which red garnet is common. The effects of crushing are present in all of the gneiss but are especially conspicuous in the coarse pegmatite facies.

Cenozoic stratified rocks

Pantano formation (Tp):- Tertiary sedimentary rocks with interbedded volcanic material crop out around the margin of the basin in which Tucson lies and probably underlie the basin. They were named the Pantano formation in the manuscript report on the Tucson quadrangle by C. F. Tolman. This name, although unpublished, has attained wide usage among the geologists of Arizona and is here adopted. The formation is extensively exposed along and east of the headwaters of Pantano Wash, from which the formation name has been taken. Both sedimentary (Tp) and volcanic (Tv) rocks are included.

The sedimentary rocks, thought to be about 2,000 feet thick, include bedded sands and crudely sorted conglomerates with some mudstone, rare beds of gypsum, and tufa. Dark red fanglomerate (a variety of conglomerate) predominates. In the lower part of the formation the pebbles are of limestone, altered limestone, volcanic rocks, and some quartzite, whereas at higher horizons gneiss similar to that now being eroded from the Santa Catalina Mountains predominates. Small areas near fault contacts with the Catalina granitic complex are silicified.

The volcanic part of the formation is interbedded with the sediments at various horizons. The volcanic rocks are well exposed in Sentinel Peak (west of Tucson), Sahuarito Butte, Twin Hills, and near Irene Station, and consist largely of basalt, andesite commonly olivine-bearing, with minor quantities of rhyolitic tuff. In a few places intrusive necks and dikes of rhyolite and basalt have been recognized but not separately mapped.

The Pantano formation is thought to have been laid down on an irregular surface and much of the material in it was derived from nearby hills. It is not merely the older part of the fill in the present basin but formerly covered much of the region as an uneven blanket of varied character. The relations of the formation to the other rocks of the quadrangle indicate that it is of Tertiary age.

Pliocene lake beds (QTa):- Terraces and portions of the pediments throughout the lowland areas of the quadrangle are carved to a considerable extent from soft, coarse-grained sandstone, pebbly sand and sandy conglomerate that in the northeast corner of the quadrangle are co-extensive with lake beds in the valley of the San Pedro River that have yielded Pliocene fossils (Gidley, pp 119-121).

Older alluvium (Qoa):- Portions of the pediment north of old Fort Lowell on the southwest side of the Santa Catalina Mountains retain sufficient old alluvium to be mapped. In other localities the remnants of similar material are so thin and scattered that they have not been discriminated from the somewhat similar material on which they lie. The old alluvium consists mainly of gravel. Some of it may be as old as the lake beds near the San Pedro River but some of it is younger.

Younger alluvium (Qal):- The floodplains and lower terraces along the modern streams are floored with younger alluvium, and the principal deposits of this kind have been mapped. The younger alluvium is largely, if not entirely, of Recent age.

Structure

The first clearly recorded structural deformation affecting Paleozoic and younger rocks occurred in the Mesozoic era. Unconformities and the absence of representatives of several of the Paleozoic and early Mesozoic systems suggest that warping and regional uplifts may have interfered with sedimentation, but no evidence of marked folding or faulting is known. At some time in the long interval between the deposition of the Permian(?) beds and those of Cretaceous age faults of easterly trend were formed. One of the more prominent of these is the Geesman fault that extends from north of Marble Peak into Geesman Canyon and is interpreted as a normal fault that dips 50° south. The faulting during the Mesozoic was accompanied by uplift and possibly by folding. The result was that in some areas the Paleozoic rocks were deeply eroded before the Cretaceous beds were laid down.

After the Cretaceous strata were laid down widespread and diverse intrusive activity took place. The principal product of this activity is the Santa Catalina granitic complex, which comprises both granite and a variety of gneissic rocks, thought to have been produced through the permeation of stratified rocks of different kinds by granitic material. The gneissic rocks are banded, in part because of survival of original sedimentary structures, and both the granitic and the gneissic material in the complex are foliated and exhibit linear features. In a broad way, as the map shows, the gneissic structures trend northwest, parallel to the trend of the mountain mass, and over much of this area dip northeast. There are a number of departures from the prevailing attitude, which may result from folding.

The next episode in the structural history was marked by thrust faulting. The trace of the main thrust surface or sole extends from near Cross Hill, close to the southern border of the quadrangle, through the hills south of Agua Verde Creek into the Rincon Valley and thence along the southern base of the Tanque Verde Mountains. Farther northwest the thrust is exposed at the base of Agua Caliente Hill but along most of the base of the Santa Catalina Mountains the thrust is concealed by alluvium. The dip is from 10° to 40° to the south and west. Rocks that range in age from the Pinal schist (pre-Cambrian) to the Pantano formation (Tertiary) are affected by the faulting. The rocks along the thrust plane are brecciated and locally silicified. There are a number of subsidiary thrust planes, particularly in the area south of Agua Verde Creek. Drag folds and tear faults are probably present. The thrust faults may have extended to the crest of the mountain pass.

Late in the history of the region the mountains were elvated to their present level as a result of broad doming accompanied by faulting. The strong fault at the base of the Santa Catalina Mountains northwest of Pusch Ridge, as well as a number of others in the quadrangle, may have been formed during this uplift.

Geomorphology

The geomorphic features of the Tucson quadrangle are typical of the arid areas of southern Arizona; rocky mountains rise abruptly from broad basins with extensive rock floors or pediments bordering the mountains. A notable difference from some desert areas, however, is the absence of the prominent alluvial fans where streams emerge from the mountains.

Geomorphic forms of late origin seem to have resulted from broad doming of the Santa Catalina-Rincon Mountain area during recurrent elevations interspersed with intervals of quiet. During the quiet periods the processes of erosion were essentially similar to those now in operation with the result that the stream valleys broadened into amphitheaters and pediments around the ranges. In detail, these features were modified by the character and structure of the rocks, just as they are at present. Erosion progressed to various stages and the resulting land forms are preserved to different degrees at different altitudes in the mountains and in the rolling country that forms the higher part of the main range. At present the streams in and near the mountains are cutting rather than depositing, and the rock pediments and gentle alluvial slopes that extended out from the range are cut by narrow steep-walled arroyos. This is especially conspicuous on the northwest east slope extending down to the San Pedro River.

A feature of the basin containing Tucson is the position of the main streams. The Santa Cruz River and Rillito Creek are near the mountain fronts rather than in the axis of the basin. This seems to be the result of sediments deposited by streams from the Empire and Santa Rita Mountains, south of the quadrangle.

Economic Geology

Mineral deposits

The Santa Catalina Mountains have been prospected in numerous localities, but mines have been developed in but few. The vicinity of Marble Peak on the north side of the range has been the most productive area, and copper has been the principal metal. There has also been some production from the Pontotoc mine on the south side of the range about one mile east of the Pima Canyon road.

The Marble Peak area has been described by Peterson and Creasey (U. S. Geological Survey unpublished report, Stratégic Minerals). Marble Peak is composed of highly metamorphosed sedimentary rocks, ranging in age probably from Apache time to the Pennsylvanian, into which have been intruded diorite and quartz diorite. Near the contact with the intrusive rocks the sedimentary strata have been strongly metamorphosed and replaced, largely by garnet, epidote and quartz. Locally associated with these minerals is sufficient copper sulphide to make an ore.

The most productive mines have been the Geesman and Daily mines at the northeast point of the Marble Peak area near the Control station on the Mt. Lemmon road. The mineral deposits in this area are associated with minor folds and faults in the sedimentary rocks. In other localities as at the Stratton claims on the south side and the Hartman claims on the northwest side of Marble Peak, the deposits are some distance from the intrusive contact.

In the contact zone and near the intrusive rock there is some scheelite, but there has been little production of tungsten. There has been some prospecting for gold.

The value of recorded metal production from 1937 to 1945, mostly copper, is $811,705.00.

Building materials

The rocks of the area have not been used extensively for building stones, though the basalt boulders from Sentinel Peak are popular in Tucson for foundations.
were 50 years ago

Sand, gravel, and clay from the river deposits have long been used as building materials. The basalt of Sentinel Peak is a source of crushed rock.

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EXPLANATION

QUATERNARY

Late Tertiary or early Quaternary

Qal

Younger alluvium

Qoa

Older alluvium

QTa

Alluvium, including lake beds in San Pedro Valley

TERTIARY

Early Tertiary

Tp

Pantano formation
(Red sands and conglomerates of continental origin.)

LATE CRETACEOUS OR EARLY TERTIARY

Silicified matter

Tv

Volcanic rocks of Pantano age
(Basalt, rhyolitic tuffs, rhyolite)

Tcg

Catalina granite

Tcpq Tcgn

Trg

Rincon granite
(May include granites of two ages)

Tld	Tldp

Leatherwood quartz diorite
(Tldp, schistose quartz
diorite porphyry sills.)

an

Andesite
(In part schistose)

di

Diabase
(Probably of two ages)

LATE CRETACEOUS OR EARLY TERTIARY

This is Ksl of the map. Make consistent in accord with whatever Goddard prefers. C?R

Ksl

Redshale, limestone conglomerate,
limestone, sandstone
(in part metamorphosed)

CRETACEOUS

(?) PERMIAN AND PENNSYLVANIAN

Cn

PCn	Psl

Naco limestone
(Limestone with thin interbeddedd
shales. Psl, Permian (?) shale and
limestone with basal jasperoid
conglomerate in southeastern part.)

PERMIAN (?) AND CARBONIFEROUS

Mississippian

Ce

Escabrosa limestone
(Limestone, cliff-forming.)

CARBONIFEROUS

CDl

Limestone of Carboniferous
or Devonian age, undifferentiated,
(Partly metamorphosed.)

DEVONIAN

Dm

Martin limestone
(Limestones and sandstones)

CAMBRIAN

Upper Cambrian

Ꞓa

Abrigo limestone
(Thin bedded shaly, limestone,
some quartzite.)

INSERT Ꞓb

PRE-CAMBRIAN

Late pre-Cambrian
and Cambrian

Ꞓt | Ꞓb Ꞓt
p Ꞓ a

Apache group (pre-Cambrian) and
Ꞓt, Troy quartzite (mid-Cambrian) in north;
Ꞓb, Bolsa quartzite (Cambrian) in south.

TERTIARY

Tcpg

Gneissic Catalina granite and pegmatite
(Contains little host rock)

Tcgn

Catalina gneiss
(Contains much host rock of
pre-Cambrian to Cretaceous age.)

PRE-TERTIARY

ums

Metamorphosed sedimentary rocks
of unknown age.

pЄo	pЄog

Oracle granite
Oracle gneissic granite, pЄog

pЄs

Pre-Cambrian schist
(Includes Pinal schist)

PRE-CAMBRIAN

Strike and dip of foliation of gneisses

30°

Bearing and plunge of lineation

16°

Strike and dip of foliation
and plunge of lineation

30°
16°

Substitute
New Geologic
~~Map Symbols~~
on map for
these symbols.

Piece 1 of map, in 3 pieces

-c)
. 275
. 11...

Ground Water in the Tucson quadrangle, Arizona

By S. F. Turner

Introduction

The ultimate development of the Tucson quadrangle depends chiefly on the extent to which its greatest natural resource - water - can be made available for continuing beneficial use. For the last several years the downward trend of the water level has indicated that the use of ground water has exceeded the safe annual yield. This is a serious situation because, at present, all the water for municipal, industrial, and agricultural purposes must be supplied from ground-water sources.

The following statements concerning the ground-water resources of the quadrangle are based on studies made by the U. S. Geological Survey in cooperation with the Corps of Engineers, U. S. Army,[1] and on continuing

[1] Turner, S. F., and others, Ground-water resources of the Santa Cruz River Basin: U. S. Geological Survey (mimeographed) 84pp., May 14, 1943.

studies of the area in cooperation with the Arizona State Land Commissioner.

Occurrence of Ground Water

The principal ground-water supplies in the quadrangle are found in the Tertiary and Recent sands and gravels of the valley fill, although several springs issue in the outcrop areas of the limestones and other hard rocks.

Springs

Although the total amount of water derived from springs in the area is very small compared with the amount of water pumped from wells, the springs are so situated that their supplies are important. The large springs are derived from limestones or from the Recent valley fill where the underflow of streams is forced to the surface by a narrowing of the fill.

Springs of normal temperature

One of the largest springs of the area is known as the Day Spring on the north bank of Agua Verde Creek in the NW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 9, T. 16 S., R. 17 E. This spring has a flow that varies with rainfall, from a minimum of 5 gallons a minute to a maximum of 200 gallons a minute. It probably derives its water supply from limestone, as indicated by the chemical analyses (see table of analyses), although the apparent source is a brecciated fault zone between the Bolsa quartzite and granite. The temperature of the water from the spring was 65^{o} F. in 1941. 7/10

Several small springs in and near the quadrangle derive their supply from faulted limestone blocks. These springs are located at or near the lowest elevation where the limestone blocks are exposed, usually along the bounding fault on the down dip side of a block. One small spring of this type in a branch of Geesman Canyon (T. 11 S., R. 16 E.) is locally known as the "PD Spring". It was used to supply water for the early development of the group of Control Mines. Hartman Spring, 1 mile northwest and probably of similar origin, provides the present supply for the Control Mines.

There are many small springs that derive their supply from faults and fractures in the schists and granites. Typical of these is Taylor Spring in the Rincon Mountains (NW$\frac{1}{4}$ sec. 4, T. 15 S., R. 17 E.), which supplies the Taylor Ranch house through a 2 inch pipeline. The flow was estimated as 15 gallons a minute on April 1, 1941. It was reported that this flow diminishes in dry seasons but has never failed. Springs of similar nature in Soldier and Sycamore Canyons, in the Santa Catalina Mountains, were improved to provide a part of the water supply for the Federal prison camp.

Several large springs in the Tucson quadrangle are located where the underflow of the principal streams is forced to the surface by a narrowing of the Recent stream fill or by a ground-water dam. Typical of these is the spring developed by the Evans School along Tanque Verde Wash (NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 5, T. 14 S., R. 16 E.). The flow of this spring is known to range from zero after long droughts to a measured maximum of 3 second-feet on February 5, 1942. The temperature at that time was 59° F. The water was of very good quality (see table of analyses). A similar spring occurs where U. S. Highway 80 and the Southern Pacific Railroad cross Pantano Wash near Irene. At this place the wash is sometimes locally called Ciénega Wash. Creek The underflow of the wash is forced to the surface at this point by a narrowing of the fill, which is in a channel cut in lava. According to stream-flow records obtained at this locality, the flow was never less than 1-3/4 second -feet from July 1940 to March 1941. A part of this flow is developed by an infiltration gallery (SE¼ sec. 14, T. 16 S., R. 16 E.) and used for irrigation by the Rancho del Lago. The water was of very good quality (see table of analyses). Ground water is also forced near the surface along the channel of the Santa Cruz River near Sahuarita Butte. This water has been developed by infiltration galleries owned by the U. S. Indian Service and Midvale Farms.

<u>Warm springs</u>

There are two warm springs in the quadrangle--Agua Caliente and Cebodilla. Both of these springs are in areas where a thin veneer of fill overlies schist or granite, and both are near the major fault zone that bounds the Santa Catalina Mountains. Agua Caliente Spring (SW¼SE¼ sec. 20, T. 13 S., R. 16 E.) is on the southeast side of Agua Caliente Wash. The spring has been improved by the construction of a spring house, by installation of a centrifugal pump that lifts water to an elevated storage tank to supply the ranch, and by a ditch leading to a swimming pool and irrigation storage reservoir. The flow was measured as 150 gallons a minute on February 5, 1942, and it is reported to be constant. The temperature was 86° F., which is 16° to 20° warmer than normal for this area. The water is not heavily mineralized (see table of analyses).

The Cebodilla Spring is on the north bank of Tanque Verde Wash (SE¼NE¼ sec. 3, T. 14 S., R. 16 E.). The water flows from many seeps in a swampy area and is developed by drainage ditches and one shallow well, The total discharge was 40 gallons a minute on February 5, 1942. This spring also is reported not to vary in flow. The temperature in February 1942 was 81° F. in the warmest seep. This water has a somewhat higher mineral content than that of the Agua Caliente Spring (see table of analyses).

Shallow water-bearing beds of Quaternary age

The shallow water-bearing beds of Quaternary age are the principal water-bearing beds in the quadrangle. They have a thickness of about 100 feet along the Santa Cruz River and about 60 feet along Rillito and Pantano Washes. The City of Tucson pumps about half of its supply from wells in these beds along the Santa Cruz River, and most of the water used for irrigation in the quadrangle is produced from wells tapping this supply. The uppermost materials described in the following well log are typical Quaternary beds.

City of Tucson well. NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 35, T. 14 ~~N~~ S., R. 13 E., on east bank of Santa Cruz River and 3$\frac{1}{2}$ miles south of Tucson Post Office. Drilled well, diameter 16 inches, equipped with 25 horsepower electric motor and turbine pump. Reported production 1,000 gallons a minute with 10 feet of drawdown.

Driller's log

Material	Thickness in Feet	Depth in Feet
Black soil	17	17
Fine sand	8	25
Sand and gravel	5	30
Dry gravel, boulders, yellow clay	7	37
Clay, sand, gravel, and boulders with water	8	45
Yellow clay and coarse sand	5	50
Gravel and boulders with water	2	52
Yellow clay, gravel, and boulders	5	57
Loose sand and gravel with water	2	59
Yellow clay, gravel, and boulders	17	76
Black clay, gravel, and boulders	4	80
Gray clay, gravel, and boulders	5	85
Yellow clay, gravel, and boulders	20	105
Sand, gravel, and boulders with water	3	108
Clay and loose red sand	6	114
White shale	1	115
Yellow clay, sand, gravel, and boulders	3	118
Loose sand, gravel, and boulders with water	3	121
Clay, gravel, and boulders	19	140
Sand and gravel with little clay	4	144
Clay, sand, and gravel	63	207

The locations of most of the wells and springs are shown on plate________.

Sources of recharge.--The shallow water-bearing beds are recharged principally by infiltration from flash floods on the Santa Cruz River and its tributary washes--Pantano Wash, Rillito Creek, and Cañada del Oro. The major part of the water lost from the flood flows in these washes is recharged to the ground-water reservoir. The coarse materials of the stream beds permit rapid infiltration of the water and little return to the surface by capillarity after flood flows have ceased, and thus an unusually small part of the flows is lost by evaporation. Evaporation from the surface of each flood flow itself is small, owing to the short duration of the flow. Moreover these areas support few phreataphytes (plants which draw water from the water table) and hence little water is lost by transpiration. Evaporation losses are greater, however, when the flood flows are large enough to spread out over the flood plains or into many vegetation-filled channels. At such times losses occur both from evaporation and from transpiration by vegetation.

Experiments to determine the amount of evaporation from a wetted stream bed of a typical desert stream were conducted in Queen Creek, about 80 miles north of Tucson./ These experiments showed that the evaporation from the

/Babcock, H. M., and Cushing, E. M., Recharge to ground water from floods in a typical desert wash, Pinal County, Arizona: A. Geophysical Union Trans., pp. 49-56, 1942.

wetted stream bed was approximately equal to the evaporation from free water surfaces for the first 36 hours but subsequently it decreased very rapidly.

To sum up, it can be assumed that most of the water lost from stream flows in the sand and gravel-bottomed channels is recharged to the ground-water bodies, but that most of the water lost on the flood plains and in the shallow, silty channels is evaporated or transpired.

A study was made of the amount of water lost from the flood flows in the

Santa Cruz Basin during 1941. During that year, however, the flows were below average and the figures therefore are not indicative of the average losses that would occur in normal years. It was computed [1] that

[1] Turner, S. F. and others, op. cit., p. 46.

in 1941 the loss from flood flows to the ground-water reservoir and to evapotranspiration in the reach of the Santa Cruz River between Continental (25 miles south of Tucson) and Tucson was 1,700 acre-feet of water, and in the reach between Tucson and Rillito (18 miles north of Tucson) it was 2,500 acre-feet.

In Pantano Wash 7,000 acre-feet of water was lost between a gaging station near Irene and one near Tucson (NE¼NW¼ sec. 6, T. 14 S., R. 15 E.). Between the gaging station on Pantano Wash near Tucson and the one on Rillito Creek near Tucson (NE corner of sec. 23, T. 13 S., R. 15 E.) 4,000 acre-feet of water was lost.

In Rillito Creek 15,000 acre-feet of water was lost between the gaging station near Wrightstown (NE corner of sec. 31, T. 13 S., R. 15 E.) and that near Tucson, and 12,000 acre-feet of water was lost between the gaging station on Rillito Creek near Tucson and that on the Santa Cruz River at Rillito.

In Cañada del Oro 7,000 acre-feet of water was lost.

The preceding computations indicate that about 4,200 acre-feet of water was lost from the surface flow of the Santa Cruz River between Continental and Rillito, about 11,000 acre-feet from flows originating in Pateno Wash, about 27,000 acre-feet from flows originating in Rillito Creek, and about 7,000 acre-feet from flows in Cañada del Oro. It is believed that the major part of the water lost recharged the ground-water reservoir, as most of the flood flows were small enough to remain within the main channels of the streams.

The rate of infiltration on Rillito Creek was found to be greatly affected by the depth to water below the stream bed. In the upper reach of Rillito Creek, which has the capacity to absorb large quantities of the surface flow, infiltration takes place rapidly when the runoff occurs after the water table has been depressed by a prolonged drought or a season of heavy pumping. After the first large flood or period of prolonged flow, however, the water table in the immediate vicinity rises to the level of the creek bed, and subsequent flows pass over the saturated bed with comparatively small losses. In the lower reach, where the depth to the water table is greater, the total flood losses were larger, as a larger volume of sediments must be filled before the water table is brought to the level of the creek bed.

In the smaller washes and in the fractured rocks in the mountain areas some recharge occurs as a result of seepage from streams. Little or no recharge occurs, however, from precipitation falling on the desert area. Dr. Forrest Shreve

Shreve, Forrest, Rainfall, runoff and soil moisture under desert conditions: Assoc. Am. Geographers Annals, pp. 150-151, Sept. 1934. Vol. 24, No. 3.

stated that near Tucson:

> "It is still more doubtful if any of the rain falling on the flood-plain reaches the ground water by penetrating the soil surface of the plain. It is only the runoff, reaching the channel of the river which may contribute to the ground-water supply."

The water derived from the shallow beds generally is moderately mineralized.

Deep water-bearing beds, probably of Tertiary age.

Deeper water-bearing beds have been tapped by wells belonging to the City of Tucson and by many industrial and irrigation wells. The water from this source is preferred by laundries and other industries requiring water of lower hardness than that found in the shallow beds. The following well descriptions are typical for wells that penetrate the deeper water-bearing beds.

City of Tucson well. NE¼NW¼ sec. 8, T. 14 S., R. 14 E., about 3½ miles south of Rillito Creek and 3/4 mile east of the University of Arizona campus. Drilled well, diameter 20 inches, equipped with 100 horsepower electric motor and turbine pump. Reported production 1,000 gallons a minute.

Driller's log

Material	Thickness in Feet	Depth in Feet
Caliche	7	7
Packed sand	18	25
Gravel and sand	40	65
Gravel and boulders	10	75
Gravel and sand	5	80
Red clay	5	85
White sand	18	103
Red packed sand	8	111
White sand	11	122
Hard packed sand	3	125
White sand	5	130
Hard cemented boulders	3	133
Hard sand shell	2	135
White sand	5	140
Sand shell	3	143
Loose white sand	7	150
Red packed sand	10	160
Water, gravel, and boulders	31	163
Packed sand	7	170
Hard sand	3	173
Packed sand and gravel	12	185
Loose fine sand	2	187
Packed sand, gravel, and clay	3	190
Sticky sand and clay	5	195
Hard cemented sand	35	230
Packed red sand	5	235
Packed white sand	2	237
Packed red sand	3	240
Cemented sand shell	2	242
Cemented boulders	4	246
Packed sand	9	255
White sand and clay	5	260
Hard sand shell	10	270
Sticky sand and clay	5	275
Cemented boulders	2	277
Hard cemented sand	13	290
White clay, gravel, and sand	6	296
Hard brown sand	19	315
Packed white sand	10	325
Packed red sand	5	330
Hard brown sand	10	340
Dirty sand	2	342
Hard brown sand	14	356
Sandstone	4	360
Packed sand with hard shell	15	375
White sticky sand	15	390

Driller's log of City of Tucson well-Cont.

Material	Thickness	Depth
Red sticky sand	10	400
Hard cemented sand	10	410
Cemented sand and boulders	5	415
Hard sand shell	15	430
Loose sand	7	437
Cemented boulders	13	450
White packed sand	10	460
Red packed sand	5	465
Cemented boulders	10	475
White sand boulders	5	480
White cemented sand	15	495
Red cemented sand	15	510

Davis-Monthan Air Field well. SE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 35, T. 14 S., R. 14 E., about 6$\frac{1}{2}$ miles south of Rillito Creek and 5 miles west of Pantano Wash. Drilled well, diameter 16 inches, equipped with electric motor and turbine pump. Reported production 1,000 gallons a minute with 23 feet of drawdown.

Driller's log

Material	Thickness in Feet	Depth in Feet
Topsoil	2	2
Hard cemented caliche	30	32
Cemented sand and clay	18	50
Hard cemented caliche	3	53
Sand and clay	15	68
Hard cemented clay gravel	6	74
Cemented sand and clay	7	81
Hard cemented sand	4	85
Cemented sand and clay	8	93
Hard cemented clay gravel	17	110
Sandy clay	7	117
Hard cemented clay gravel	8	125
Cemented sand and clay	34	159
Hard sandy clay	9	168
Hard sandy clay gravel	23	191
Cemented sand clay and gravel	13	204
Clay and sand	13	217
Cemented sand and gravel	141	358
Sand and clay	5	363
Hard cemented sand and gravel	35	398
Cemented sand, gravel, and clay	3	401
Hard cemented sand and gravel	4	405

Sources of recharge.--The deep beds are recharged by water that first seeps into the shallow water-bearing beds along the stream channels, as described above, and thence moves into the deeper horizons. The recharge occurs principally from Pantano, Rincon, and Tanque Verde Washes along the edges of the Rincon and Tanque Verde Mountains.

The Pantano formation is not a good water-bearing formation in most areas. Several wells drilled in this formation in the foothills of the Santa Catalina Mountains northeast of Tucson have produced little if any water. A well drilled by the Southern Pacific Railroad to a depth of 1,380 feet near Pantano produced only a few gallons a minute. The Southern Pacific Railroad also drilled two wells at Esmond, 1,480 and 883 feet deep, respectively. One of these wells produced about 50 gallons a minute with a drawdown of 78 feet. Two wells near Rita, about 2 miles west of Esmond, drilled to depths of 404 and 412 feet, respectively, produced about 50 gallons a minute each with a 40-foot drawdown. Thus the capacities of the deep wells near Tucson are very large in comparison to those of typical wells in the Pantano formation. There are two possible explanations. One is that the deeper beds near Tucson do not belong to the Pantano formation. The other, which is believed to be more probable in view of the existing well logs and physiographic data, is that the present course of Pantano Wash is relatively recent, that formerly both Pantano Wash and Rincon Creek flowed westward in various channels beneath the site of Tucson, and that the more permeable gravel beds represent the old alluvial deposits of these or similar creeks. The quality of the water from the deeper beds is usually very good. It is only moderately mineralized and is much softer than the shallow water. In a few places warm mineralized water has been obtained from deep wells near the western and southwestern edges of Tucson. These are near comparatively young volcanic rocks and this warm mineralized water is probably related to the volcanic activity.

History of development of ground water.

When the first Europeans explored the Upper Santa Cruz River valley, they found a steady flow in the Santa Cruz River, as well as marshes and lakes in the river valley. Since that time the steady and constantly increasing use of water has caused these surface supplies to disappear and the ground-water level to decline many feet below the surface.

There are many evidences of the changes produced since pioneer days by the declining water level. The original village of Tucson was on the west bank of the Santa Cruz River, near malaria-infested swamps. Today no swamps exist along the Santa Cruz. In 1881 a shallow lagoon existed on land adjoining the northwest corner of the city, but this lagoon has now disappeared. (Before the Civil War a dam was built on the Santa Cruz River south of Tucson, creating Silver Lake, large enough for swimming and canoeing. This dam was washed out by a flash flood in 1892 and the lake back of it was destroyed.) This is not a change produced by the declining water level, unless it can be said that a lake could not be maintained now.

Before the ground-water supplies were developed, little water was available for domestic and industrial use. In the early days water was sold by the bucketful in the town, and baths were taken at the downtown bathhouses. It was not at all unusual for a railroad or mining community to depend on water supplies hauled 10 to 100 miles in tank wagons or railroad cars. Prior to 1890 the City of Tucson obtained its entire water supply by means of gravity pipelines, constructed of wood, which took water from the Santa Cruz River 5 miles south of the city. A few years later the supply was supplemented by wells in the valley near the river. Today there are about 50 municipal and industrial wel supplying water to the urban area.

Irrigation by diverting surface flow from the Santa Cruz River began on the lands near San Xavier Mission about 1698, soon after the Jesuit Padres established themselves there. Although irrigation has continued to increase since that time, it did not become extensive enough to deplete the surface flow of the Santa Cruz River until after 1903. In that year a report by the Governor of Arizona stated that the Santa Cruz River supplied water for irrigation throughout the year but that during the dry seasons the supply was inadequate. He also stated that a sub-current of water existed in the Santa Cruz River, capable of supplying sufficient water for irrigation on a small scale. As proof of it he reported that a rancher in the valley near Tucson irrigated 50 acres of alfalfa with water pumped from a depth of 22 to 38 feet.

The irrigated acreage increased steadily until in 1939, according to the Federal Census, 33,995 acres was irrigated in Pima County, mainly by water pumped from wells along the Santa Cruz River and Rillito Creek. The result of this, according to the Federal Census, has been to increase the pumping lift from 38 feet to 65 feet in Pima County During the last 30 years.

Discharge.

Pumping by the City of Tucson for domestic and industrial use, as well as pumping by many industries from their own wells, and by ranchers for irrigation and domestic and stock purposes, accounts for a large part of the discharge of water from the area. Irrigation requires the largest amount of water, and municipal and industrial uses together rank second. The locations of most of the larger wells are shown on the accompanying plate, but no attempt has been made to show all the small wells used solely for domestic and stock purposes.

The quantity of water pumped in the Tucson area was between 25,000 and 30,000 acre-feet in 1942, somewhat less than one-third of the total water pumped from the Santa Cruz Basin in Pima County. The quantity of water pumped for irrigation varies from year to year, depending upon the amount of precipitation and runoff in the area.

Natural discharge from the area occurs through evaporation and transpiration by phreatophytes and also as underflow from the area. No figures on the amount of water discharged naturally are available at this time.

Fluctutations of water level.

Figure _______ shows the graphs of water-level fluctuations in three typical wells in the Tucson quadrangle.

Well 2823, located in the NE¼SW¼ sec. 28, T. 13 S., R. 14 E., is about 500 feet north of Rillito Creek. Because of the coarseness of the water-bearing material in this vicinity and the proximity of the well to Rillito Creek, the effects of recharge and pumping in the vicinity are quickly registered by the well. The graph shows that the principal recharge usually occurs in the winter from flows originating in the higher parts of the Santa Catalina Mountains, and also indicates that there is a small amount of recharge from summer floods.

Well 4156, located in the SW¼SE¼ sec. 7, T. 14 S., R. 15 E., is about 1¼ miles west of Pantano Wash. This well is relatively deep and is distant from heavily-pumped wells. However, because this well taps the deep water-bearing beds that are penetrated by some wells in Tucson, the relatively small fluctuations the water level show the effects of long-time withdrawals and recharge in this vicinity. The water level declined 3.4 feet between September 22, 1939, and September 27, 1946, the period of record.

Well 4379, located in the SE¼NW¼ sec. 35, T. 14 S., R. 13 E., is about 600 feet east of the Santa Cruz River. This well is near city of Tucson wells and irrigation wells. The graph shows that the water level in this well shows both fluctuations due to pumping and those due to recharge from flood flows in the Santa Cruz River. The water level declined 11.1 feet between September 29,1939, and October 11, 1946, the period of record.

The continuous downward trend of the water levels shown in the accompanying graphs, together with the downward trend indicated by water-level measurements in many other wells in the quadrangle, indicate that the amount of water now being withdrawn from the water-bearing beds of the Tucson quadrangle greatly exceeds the annual safe yield from these beds.

Although disastrous results are not to be expected in the near future, it is evident that, if the development of the area is to continue, water from some outside source must be brought into the area. The building of carefully planned small structures on side washes could augment the natural recharge to some extent, but sites have not been found for large structures that could fully satisfy future needs.

- Sources -

1. Peirce, F.L., 1958, Structure and petrography of part of the Santa Catalina Mountains: Unpub. Ph.D. dissertation, Univ. of Ariz., Tucson.
2. Wallace, R.M., 1954, Structures at the northern end of the Santa Catalina Mountains, Arizona: Unpb. Ph.D. dissertation, Univ of Ariz.
3. Banerjee, A.K., 1957, Petrology and structure of the Oracle granite, Pinal County, Arizona Unpb. Ph.D. dissertation, Univ. of Arizona.

(Over for Legend.)

Analyses of samples of water from wells and springs in the Tucson quadrangle, Pima County, Arizona.
Analyses by J. D. Hem, U. S. Geological Survey. (Parts per million except specific conductance.)

Name or owner	Location	Date Sampled	Specific conductance ($K \times 10^5$ at 25°C)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Total dissolved solids (calculated)	Total hardness as $CaCO_3$
Pantano Wash	T. 16 S., R. 17 E. SW¼SE¼ sec. 19	Mar. 27, 1941	76.0	92	28	42	331	221	12	6.	509	345
Pantano Wash	SE¼ sec. 19	Apr. 22, 1941	75.9	90	27	47	241	213	13	-	509	336
Aqua Verde Creek	NW¼NE¼ sec. 8	Mar. 31, 1941	18.0	24	7.0	6.8	71	34	7	-	114	89
Rincon Creek	T. 15 S., R. 17 E. SE¼ sec. 10	Mar. 30, 1941	9.9	6.0	4.8	10	20	29	7	-	67	35
Rincon Creek	SW¼NE¼ sec. 16	Mar. 27, 1941	11.7	14	6.6	4.0	38	30	6	-	79	62
Day Spring	T. 16 S., R. 17 E. NW¼SW¼ sec. 9	Mar. 27, 1941	51.8	87	14	18	327	29	9	0.9	319	275
Infiltration Gallery	T. 16 S., R. 16 E. SE¼SE¼ sec. 14	Apr. 22, 1941	64.1	76	24	34	214	164	11	-	414	288
Evans School Spring	T. 14 S., R. 16 E. NE¼SE¼ sec. 5	Feb. 5, 1942	20.6	22	6.8	11	72	35	8	-	114	83
Aqua Caliente Spring	T. 13 S., R. 16 E. SW¼SE¼ sec. 20	Feb. 5, 1942	80.1	32	6.1	141	205	176	30	6.5	493	105
Cebodilla Spring	T. 14 S., R. 16 E. SE¼NE¼ sec. 3	Feb. 5, 1942	116	34	5.5	223	183	339	45	9.6	746	108
Southern Pacific Railroad Davis-Monthan Air Field well	T. 15 S., R. 15 E. NW¼SE¼ sec. 27	Mar. 27, 1941	36.1	43	10	25	174	45	9	-	218	148
City of Tucson shallow wells 1/	T. 14 S., R. 14 E. SE¼NE¼ sec. 35	Mar. 23, 1941	38.3	45	10	24	172	53	7	-	224	153
City of Tucson deep wells 1/	South side	Sept. 1931	-	74	14	67	275	124	21	-	468	242
	North side	Sept. 1931	-	36	4.5	42	166	43	12	-	237	108

1/ Collins, W. D., Lamar, W. L., and Lohr, E. W., The industrial utility of public water supplies in the United States, 1932: U. S. Geol. Survey Water-Supply Paper 658, p. 41, 1934.

See other card
for additional legend

O?gc		
K(?)	Cretaceous(?) conglomerate & arkose.	
Ce	Mississippian Escabrosa ls.	
Dlo	Devonian Lower Ouray ss.	
Dm	Devonian Martin lst.	
€a	Cambrian Abrigo limest.	
€t	Cambrian Troy Quartzite	
p€m	Mescal limestone	Apache Gp.
p€ds	Dripping Spring qzt	Apache Gp.
p€pi	Pioneer fm.	Apache Gp.
p€s	Samaniego granite	Older Pre-cambrian
p€o	Oracle granite	Older Pre-cambrian
p€p	Pinal schist	Older Pre-cambrian

Structure Elements

86 Foliation (planar parallelism of minerals and inclusions) in Oracle and Samaniego granites.

54 Foliation (bedding?) in Pinal schist.

Fault

TQgc Pleistocene(?) Gila cong.

Tmd Tertiary(?) meta-diorite

db db- diabase - age (?)

EXPLANATION

◎	Irrigation or industrial Well
○	Observation Well
♀	Spring
/	Gaging Station
⟵--------	Infiltration Gallery, flowing

--Legend-Tucson Quadrangle-

● Private irrigation well-electric

● Municipal ~~and~~ or Industrial well-electric

● Miscellaneous

● U.S. ~~I.S.~~ [illegible]

● Infiltration gallery

○ Spring

● Observation well

⊙ Unused irrigation well
Well with windmill or small power pump
Rope and bucket or hand power pump well, [illegible]
Unused well

(705)
R2go
[no 1164]

49-1

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

ARIZONA
(PIMA COUNTY)
TUCSON QUADRANGLE

ENGRAVED DEC.1904 BY U.S.G.S.

E.M.Douglas, Geographer.
T.M.Bannon, Topographer in charge.
Topography by R.T.Evans, H.H.Hodgeson, J.E.Blackburn, Chester Irvine, E.R.Bartlett, and D.F.Moor
Triangulation by T.M.Bannon.
Surveyed in 1904.

APPROXIMATE MEAN DECLINATION 1904

Scale 1/125000

Contour interval 100 feet.
Datum is mean sea level.
(Readjustment indicates that elevations on this map should be increased 13 feet.)

DIAGRAM OF TOWNSHIP

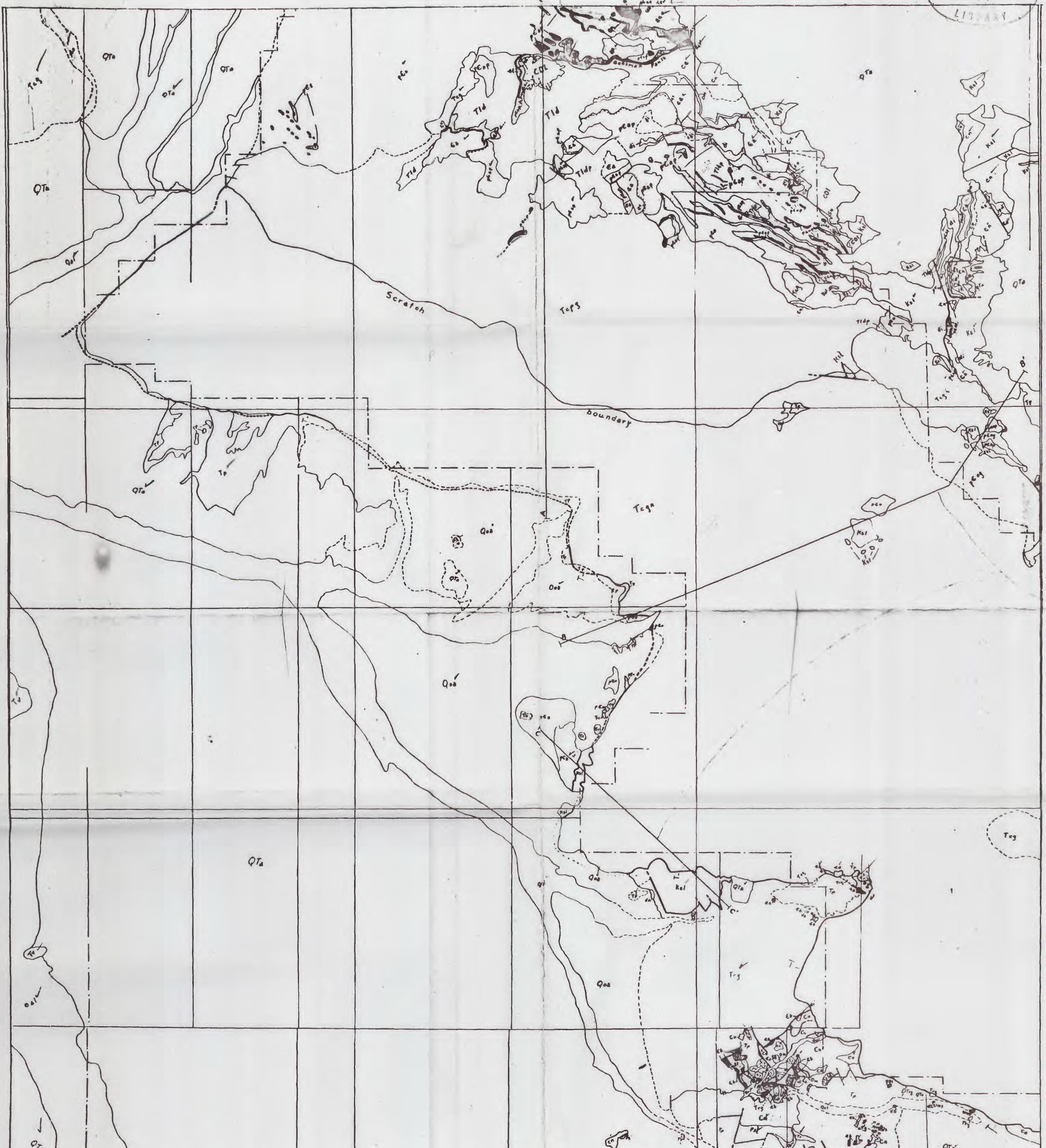
6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Edition of 1905, reprinted 1932
Polyconic projection.

TUCSON, ARIZ.

Omit all three lines of sections and the structure sections themselves

49-1

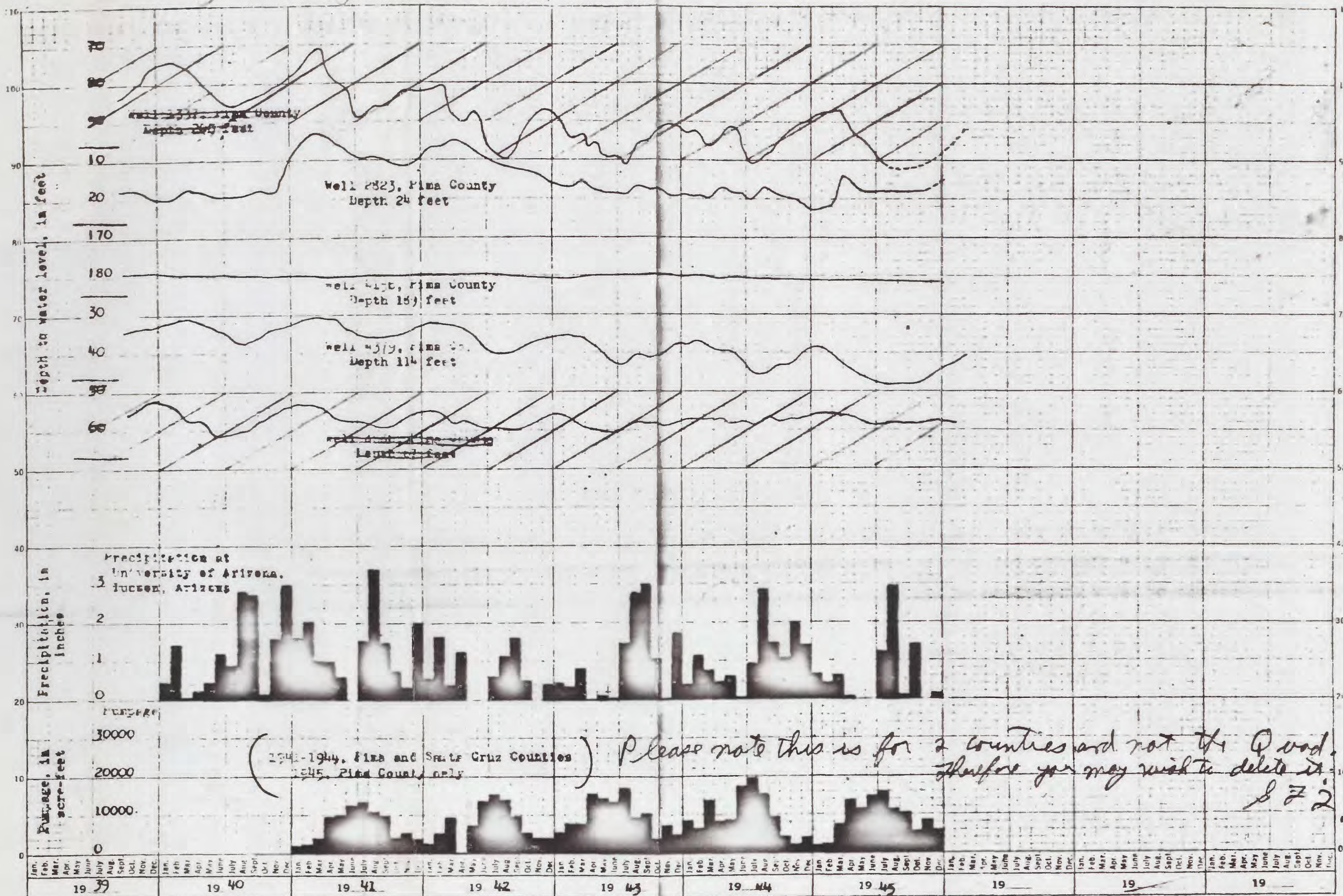


Omit all three lines of sections and the structure sections themselves

(700)
R290
[no. 1164]

U.S. Geological Survey [Reports - Open file series]

PLEASE REPLACE IN POCKET IN BACK OF BOUND VOLUME



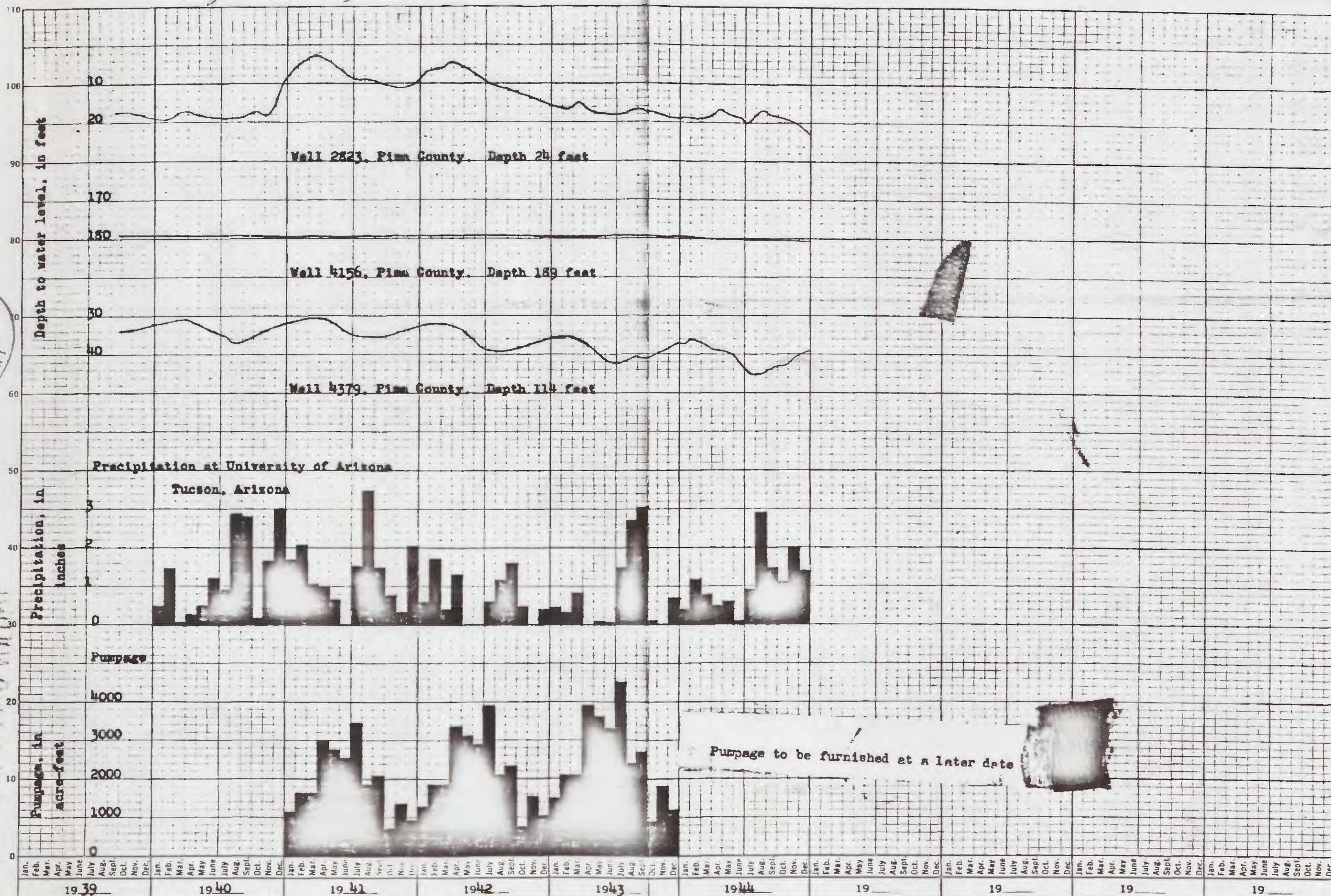
Please note this is for 2 counties and not the Quad. Therefore you may wish to delete it.
S. Z. 2.

Figure .- Graphs showing fluctuations of water level in observation wells in the Santa Cruz Valley, Pima County, Arizona

(200)
R290
no. 1164

U.S. Geological Survey [Reports - Open file series]

49-1



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