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GEOLOGY AND GROUND-WATER RESOURCES OF THE NORTHERN PART OF THE RANEGRAS PLAIN AREA, YUMA COUNTY, ARIZONA

By

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GEOLOGY AND GROUND-WATER RESOURCES OF THE NORTHERN PART OF THE RANEGRAS PLAIN AREA, YUMA COUNTY, ARIZONA

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ABSTRACT

The Ranegras Plain area is part of the Basin and Range province in west-central Arizona.

The report discusses rocks of pre-Cambrian, pre-Cambrian (?), Paleozoic (?), Mesozoic (?), Cretaceous (?), Cretaceous and Tertiary, Tertiary (?), Quaternary (?), and Quaternary age. All the Paleozoic (?) and Cretaceous (?) rocks and parts of the Mesozoic (?), Cretaceous and Tertiary, and Tertiary (?) rocks have been mapped as a unit because they are so intensely faulted that detailed mapping was not practical. Rocks older than Quaternary form the mountain ranges bordering the Ranegras Plain. Quaternary alluvium underlies the broad, gently sloping valley floor to depths of generally a few hundred feet, locally more. Well logs indicate that the underlying Tertiary (?) alluvium exceeds 1,100 feet in thickness.

The structure of the area is controlled by faulting typical of the Basin and Range province, but the major faults are covered by alluvium and are inferred from topographic features.

Ground water occurs in Quaternary and Tertiary (?) alluvium and the best aquifers are in sand and gravel of the Quaternary alluvium. Ground-water movement is, in general, to the northwest.

Recharge to the aquifers is predominantly from stream flow resulting from heavy rains. There is also minor or unevaluated recharge from underflow from Butler Valley to the east, and--since 1948--seepage from irrigation.

Discharge is by pumping and by natural processes of underflow and evapotranspiration. In addition to small domestic and stock wells, only two irrigation wells, in the vicinity of Utting, are in use. No accurate data on pumpage are available.

The safe yield from the ground-water reservoir may be less than 5,000 acre-feet and probably does not exceed 10,000 to 15,000 acre-feet per year.

The quality of ground water ranges from permissible to unsuitable for irrigation purposes. The fluoride content is generally too high for the water to be considered satisfactory for use by young children.

INTRODUCTION

PURPOSE AND COOPERATION

The increased use of ground water in the State of Arizona has called attention to the need for State regulation of the development and use of ground water. Such regulation must be based upon adequate information as to the quantity, quality, and use of the ground water, and on its source and movement. Therefore, the State Legislature in 1939 and in subsequent years has appropriated funds for investigation of the ground-water resources of Arizona. These investigations are made by the Geological Survey, United States Department of the Interior, under a cooperative agreement with the Arizona State Land Department.

Field work in the Ranegras Plain area was done by D. G. Metzger, H. E. Skibitzke, and G. E. Hazen between November 1948 and June 1949, and in February 1950, under the general supervision of S. F. Turner, District Engineer (Ground Water) of the Geological Survey. Water analyses were made by chemists under the general direction of J. D. Hem, District Chemist of the Geological Survey, Albuquerque, N. Mex.

LOCATION

The area included in this investigation is in northern Yuma County, Arizona. It includes the northern part of the Ranegras Plain and is known locally as the "Bouse country" because Bouse is the largest settlement in the area. The area described is bounded on the north by the Bouse Hills, on the east by the Granite Wash Mountains, on the west by the Plomosa Mountains, and on the south by an east-west line at latitude 33° 40', 4 miles south of Hope. The plain extends approximately 25 miles southeast of latitude 33° 40', beyond the area described in this report. The present investigation was limited to the area north of that line because no aerial photographs were available for the area to the south and because all development of ground water for irrigation has been to the north.

CLIMATOLOGICAL DATA

The climate of the Ranegras Plain area is characterised by hot, dry summers and mild winters. No climatological data are available for this area, but U. S. Weather Bureau records have been kept at the nearby towns of Salome and Quartzite. Tables 1 and 2 show that the average annual precipitation at the two localities is 8.56 and 6.04 inches, respectively. The Ranegras Plain area is between Salome and Quartzite, and the average annual precipitation on the area is estimated as 7 inches.

PREVIOUS INVESTIGATIONS

Generalized statements regarding the geology and ground-water resources of the Ranegras Plain area are made in the following reports:

Lee, W. T., Geologic reconnaissance of a part of western Arizona: U. S. Geol. Survey Bull. 352, 1908.

Bancroft, Rowland, Reconnaissance of the ore deposits in northern Yuma County, Ariz.: U. S. Geological Survey Bull. 451, 1911.

Jones, E. L., Jr., and Ransome, F. L., Deposits of manganese ore in Arizona: U. S. Geol. Survey Bull. 710-D, pp. 182-183, 1920.

Bryan, Kirk, Erosion and sedimentation in the Papago country, Ariz., with a sketch of the geology: U. S. Geol. Survey Bull. 730-B, pp. 52-66, 1922.

Ross, C. P., Geology of the lower Gila region, Ariz.: U. S. Geol. Survey Prof. Paper 129-H, pp. 183-197, 1922.

Ross, C. P., The lower Gila region, Ariz.: U. S. Geol. Survey Water-Supply Paper 498. 1923.

Darton, N. H., A résumé of Arizona geology: Univ. Arizona, Arizona Bur. Mines Bull. 119, pp. 221-223, 1925.

Wilson, E. D., Cunningham, J. B., and Butler, G. M., Arizona lode gold mines and gold mining: Univ. Arizona, Arizona Bur. Mines Bull. 137, pp. 134-135, 1934.

Turner, S. F., and others, Pumpage and ground-water levels in Arizona in 1946: U. S. Geol. Survey (mimeographed), 1948.

Turner, S. F., and others, Pumpage and ground-water levels in Arizona in 1947: U. S. Geol. Survey (mimeographed), 1949.

Turner, S. F., and others, Pumpage and ground-water levels in Arizona in 1948: U. S. Geol. Survey (mimeographed), 1949.

GEOLOGY AND ITS RELATION TO GROUND WATER

FIELD WORK AND MAPS

The geologic work was of a reconnaissance nature because the time available and the purpose of the investigation did not warrant more detail. The geologic mapping was done entirely on contact prints of aerial photographs, as no accurate maps of the area were available. The photographs were made in part by the U. S. Army and in part specifically for this project. The base map (pl. 1) was prepared from photographs, township plats, and U. S. Coast and Geodetic Survey Data.

LAND FORMS AND DRAINAGE

The Ranegras Plain is part of the Basin and Range province,[1] which occupies a large part of the southwestern United States. The land surface of the plain slopes gently northwest (see pls. 2 A and B). Bouse Wash and its tributaries constitute the drainage system of the area.

The plain is bordered on the north by the Bouse Hills, on the east by the Granite Wash Mountains, and on the west by the Plomosa Mountains. Both the Granite Wash Mountains and the Plomosa Mountains have gently rolling slopes on the east. Their western slopes, however, are extremely sharp and rugged. The Bouse Hills are considerably lower and less rugged than the other mountains in the area.

The area drained by Bouse Wash includes: (1) Butler Valley, (2) the extreme western part of McMullen Valley through Granite Wash Pass, and (3) the Ranegras Plain. An aerial reconnaissance of the area revealed that the drainage in the southern part of the Ranegras Plain is the reverse of that shown on the old maps of the area, and that the drainage area is much greater than it was assumed to be by Bancroft.[2]

1/ Fenneman, N. M., Physiographic divisions of the United States: Assoc. Am. Geographers Annals, vol. 6, pp. 19-98, 1916.

2/ Bancroft, Howland, Reconnaissance of the ore deposits in northern Yuma County, Ariz.: U. S. Geol. Survey Bull. 451, pl. 1, 1911.

The surface drainage in the Granite Wash Mountains presents a physiographi problem. The drainage divide is not in the hard rocks of the mountains but in the alluvial fill on the eastern side. The extreme southern part of Butler Valley, for example, drains westward through the mountains rather than northward to Cunningham Wash. The drainage divide between McMullen Valley and the Ranegras Plain is in the alluvial fill approximately 2 miles west of Salome and not in the mountains at Granite Wash Pass, as would be expected. The drainage of the eastern part of McMullen Valley is to the southwest. Two miles east of Salome the drainage swings abruptly to the southeast and follows this course through the Harquahala Mountains into Centennial Wash. Ross[3/] postulates that the drainage of McMullen Valley probably was originally through Granite Wash Pass and that headward erosion by Centennial Wash captured the drainage.

[3/] Ross, C. P., The lower Gila region, Ariz.: U. S. Geol. Survey Water-Supply Paper 498, pp. 39-40, 1923.

The most prominent wash in the Bouse Hills drains southwest into Bouse Wash. The channel cuts through volcanic rocks instead of alluvium 2½ miles southeast of Bouse. This course possibly represents the downward continuation of a channel that originated on a higher alluvial surface. A remnant of this surface still exists as a ridge paralleling the channel on the south side.

GEOLOGIC HISTORY

Gneiss and schist, regarded as pre-Cambrian in age, are the oldest known rocks in the area. These rocks form the backbone of the Plomosa Mountains and the northern part of the Bouse Hills. During pre-Cambrian time granite was intruded into the rocks and the area was eroded to form a surface of low relief. The area was then covered by advancing sease in which thick deposits of sediments were laid down. The sediments were later metamorphosed to form the slates, quartzites, schists, and recrystallized limestones that are now exposed in the Granite Wash Mountains. By the end of pre-Cambrian time, erosion again had reduced the land surface to one of low relief.

Limestone and quartzite in the Bouse Hills and in the north part of the Plomosa Mountains are tentatively assigned Paleozoic age. They indicate that the area was again covered by seas during that time.

The absence of any rocks that can be identified as Triassic or Jurassic suggest that the region was uplifted and subject to erosion during early Mesozoic time.

Later in Mesozoic (?) time, magmas intruded the rocks and crystallized to form the granitic rocks now exposed in the Granite Wash Mountains and in the complex area in the northern Plomosa Mountains. Still later the sea again advanced upon the land and conglomerate, shale, and limestone were deposited. These rocks are exposed in the northern Plomosa Mountains. Interbedded tuff deposits indicate the beginning of the volcanic activity that took place during Cretaceous and Tertiary time.

Cretaceous and early Tertiary time was characterized by volcanic activity and the formation of various types of volcanic rocks. The flows ranged in character from basic to acidic, the basic type being heavily predominant. Most of the flows were of the quiet type that issued from fissures, but there are deposits of ash, tuff, and agglomerate which indicate explosive activity during this period. The mountain locally known as Four Peaks, 6 miles southwest of Bouse, appears to be a volcanic neck and was possibly the source of some of the ejecta. Intervals during which vulcanism was interrupted and deposition of sedimentary materials occurred are marked by a few beds of sandstone.

Toward the end of the major vulcanism, uplift and block faulting gave the mountain masses the general trends they have today. A period of vigorous erosion was started, the highlands were reduced, and the debris was deposited in the lowlands. A conglomerate marks the deposition and consolidation of the first products of this erosion.

During late Tertiary time at least 1,100 feet of sand and clay of estuarine or lacustrine origin was deposited in the area. Some vulcanism occurred during this period, as shown by the water-deposited ash and bentonitic clay near Bouse.

During the Quaternary period vulcanism diminished and the lava flows were thin. Tilted Quaternary basalt flows give evidence of continued earth movements.

Long alluvial ridges considerably higher than the present valley floor probably represent remnants of alluvial surfaces that existed during the Pleistocene epoch. Erosion resulting from uplift or climatic changes, or both, gradually reduced these higher land surfaces to the present level of the plain.

Recent alluvium is represented by the sands and gravels in the washes that drain the area.

STRUCTURE

Faulting played an important part in the formation of the mountains that border the Ranegras Plain. Most geologists believe that the main structural feature of the Basin and Range province is block faulting, the mountains representing horsts and the valleys representing grabens. Most of the major bounding faults are covered by alluvium and can be inferred only from topographic features.

Faulting in the Ranegras Plain area probably started with the pre-Cambrian granitic intrusions and has continued until the present time. The greater part of the recognizable faulting undoubtedly occurred during Cretaceous and Tertiary time. Faulting within the mountain masses shows a predominantly northwest trend, corresponding with the structural trend of the region. The Ranegras Plain itself is elongated northwest.

The northern Plomosa Mountains and the isolated hills northwest of Bouse are structurally complex. The rocks have been so severely faulted and folded that much detailed work would have to be done to work out more than the general structural features. Four miles west of Bouse, for example, pre-Cambrian gneiss and schist are faulted against limestones of Cretaceous (?) age. The gneiss also forms the hanging wall in a reverse fault against limestone and quartzite tentatively assigned Paleozoic age. West of Bouse the contact between bedrock and alluvium forms a conspicuous, almost straight line that probably reflects a major bounding fault.

In the southwestern part of the area the Plomosa Mountains are composed of volcanic rocks dipping southwest. Gentle folding is reflected in the gradually curving strike of the lava flows. A prominent fault parallels the mountain front on the northeast side. It is visible for approximately 4 miles along the strike.

To the northwest, near Ibex Mountain, is another fault that curves in a broad arc in an approximate north-south direction. The trace of this fault is easily seen on aerial photographs.

In the northern part of the Granite Wash Mountains are topographic features that probably indicate fault control. These features include a ridge extending northwest from Salome Peak and a large wash to the southwest that parallels the ridge.

Fault structure is displayed in the row of volcanic hills south of Hope. In this area two periods of faulting can be distinguished. During late Tertiary time the Cretaceous and Tertiary volcanic rocks were tilted to the southwest. Basalt of probable Quaternary age flowed over them, and again the hills were tilted to the southwest. The dip of the older volcanics is 18°; the dip of the basalt is 8°. A similar series of volcanic rocks was observed south of U. S. Highway 60-70 in the Plomosa Mountains. Detailed work might prove that the rock of the two areas could be correlated.

PEDIMENTS

Rock pediments, as described by Bryan[4]/ were observed in various places

4/ Bryan, Kirk, Erosion and sedimentation in the Papago country, Ariz.: U. S. Geol. Survey Bull. 730-B, pp. 52-65, 1922.

along the mountain borders. They are usually formed on granitic rocks, an exception being the pediment near Vicksburg which is formed on metamorphic rocks. The largest pediment areas are: (1) along the northern border of the Bouse Hills, (2) along the southeastern and eastern borders of the Bouse Hills, (3) northwest of Ibex Mountain in the Plomosa Mountains, and (4) along the southwestern border of the Granite Wash Mountains.

ROCK DESCRIPTIONS

Pre-Cambrian and pre-Cambrian (?) rocks

Rocks regarded as pre-Cambrian in age include metamorphic and granitic rocks in the Bouse Hills and Plomosa Mountains and metamorphosed sedimentary rocks in the Granite Wash Mountains.

The gneiss that constitutes the backbone of the Plomosa Mountains is possibly the oldest rock in the area. It is locally schistose. It is impermeable except where fractured. Although wells drilled in fracture zones might yield small quantities of ground water, the gneiss is considered of little value for the storage or transmission of water.

Gneiss of pre-Cambrian age appears as a small outcrop in the central part of the Bouse Hills. The gneiss has been intruded by granite and is schistose along the contact. The gneiss is coated with dark "desert varnish," and from a distance the hills have the appearance of being capped by basalt.

Intrusive rocks of probable pre-Cambrian age crop out northwest of Ibex Mountain. The intrusive rocks are syenite cut by a dike complex. The syenite is composed of orthoclase and biotite and is coarse-grained and locally gneissoid. It has been cut by dikes to such an extent that the dikes cover a greater surface area than the syenite. The dikes are extremely fine-grained and are of both the acidic and basic types. Although there are no known wells in those rocks, wells sunk in fracture zones or along dikes might produce small quantities of ground water.

Granite regarded as pre-Cambrian in age, yet younger than the previously described rocks, crops out in an extensive area in the eastern and northeastern parts of the Bouse Hills. The granite is medium- to coarse-grained and white to gray in color. It is composed of orthoclase, quartz, and varying amounts of the subordinate basic minerals, principally biotite. It is locally gneissoid. The granite is cut by many fine-grained aplitic and diabasic dikes from a fraction of an inch to 4 feet in width. The granite is considered of little value for the storage or transmission of ground water because it is practically impermeable.

Metamorphosed sedimentary rocks, tentatively assigned pre-Cambrian age, are exposed in an extensive area in the Granite Wash Mountains. The metamorphosed sedimentary rocks are probably younger than the metamorphic rocks in the Plomosa Mountains, and it is possible that they may be, in part, Paleozoic in age. Darton[5] assigned some of the metamorphosed limestones in this area

[5] Darton, N. H., A résumé of Arizona geology: Univ. Arizona, Arizona Bur. Mines Bull. 119, p. 223, 1925.

to the Paleozoic. The metamorphosed sedimentary rocks are principally mica schist and smaller amounts of slate, quartzite, and recrystallized limestone. They dip, generally northeast, from 20° to 60°. Many variations in the dip and strike pattern are caused by faulting and minor folding. The schist is relatively impermeable except along fractures and is considered of little hydrologic importance. The slate, quartzite and limestone are dense and compace except where fractured, and their value as aquifers is questionable. Wells in fracture zones in the limestone might yield small quantities of ground water.

Paleozoic (?) sedimentary rocks

Small outcrops of limestone and quartzite of Paleozoic (?) age occur throughout the areas of the sedimentary and igneous complex shown on plate 1. These rocks, as well as other rock units in the complex areas, have been subjected to intricate faulting and folding and the relations between the various rock types are so complicated that it was impossible to map the units separately in the limited time available for the investigation.

The Paleozoic (?) limestone is gray, massive, and crystalline and is interbedded with a fine-grained quartzite. Ross[6] states, "near the Little

[6] Ross, C. P., The lower Gila region, Ariz.: U. S. Geol. Survey Water-Supply Paper 498, p. 184, 1923.

Butte mine . . . are limestones lithologically similar to those at the Socorro mine, in the Harquahala Mountains, and hence progagly Paleozoic." Darton[7]

[7] Darton, N. H., A résumé of Arizona geology: Univ. Arizona, Arizona Bur. Mines Bull. 119, pp. 218-219, 1925.

mentions limestone and quartzite strata that "resemble strata in which Carboniferous fossils have been found" (at the Harquahala Mine). It is probable that rocks of similar age were deposited in the Ranegras Plain area. No fossils were found during this investigation.

The limestone and quartzite of Paleozoic (?) age are not regarded as important sources of ground water, as the rocks are relatively impermeable. Wells sunk in fracture zones might yield small quantities of ground water.

Mesozoic (?) rocks

Intrusive rocks

Intrusive rocks regarded as Mesozoic (?) in age include: (1) a granite laccolith, (2) a stock of biotite granite and quartz monzonite, (3) a diabase stock, and (4) acidic and basic dikes. All these crop out in the Granite Wash Mountains. Also included is granite observed in the Plomosa Mountains and in the isolated hills northwest of Bouse. This granite was not mapped with the Mesozoic (?) intrusive rocks but is included in the sedimentary and igneous complex areas shown on the map (pl. 1).

The intrusive rocks in the Granite Wash Mountains were assigned by Bancroft[8] to the Mesozoic (?) era. He states:

8/ Bancroft, Howland, Reconnaissance of the ore deposits in northern Yuma County, Ariz.: U. S. Geol. Survey Bull. 451, p. 23, 1911.

> The age of the large and massive granite . . . is not known. Certainly it is younger than the pre-Cambrian strata through which it cuts. Because of the fact that so many granite intrusions have taken place in the Pacific States in Mesozoic time, this one is assigned temporarily to that era, no fossils having been found in the area either to substantiate or disprove the correctness of the assignment.

No evidence was found during this investigation to change his designation.

The granite in the Plomosa Mountains and in the isolated hills northwest of Bouse is regarded as Mesozoic (?) in age on the basis of lithological similarity to the younger granites of southern Arizona that have been referred to the Mesozoic (?).[9]

9/ Wilson, E. D., Geology and mineral deposits of southern Yuma County: Univ. Arizona, Arizona Bur. Mines Bull. 134, p. 28, 1933.

The laccolith in the Granite Wash Mountains, T. 6 N., Rs. 14 and 15 W., is a coarse-grained biotite granite composed of orthoclase feldspar, quartz, and biotite. It weathers to a tan color. The base of the laccolith is plainly discernible. At one locality, 7 miles N. 15° E. from Vicksburg, the metamorphic rocks strike N. 70° W. and dip 35° to 40° NE under the granite. The top of the laccolith is difficult to trace because it highly metamorphosed the overlying rock.

Coarse-grained biotite granite and quartz monzonite crop out over a large area on both sides of U. S. Highway 60-70 in the vicinity of Granite Wash Pass. This may be part of the same general intrusion that formed the laccolith farther north. The biotite granite occupies the center of the outcrop area, and the quartz-monzonite occurs around the circumference. The biotite granite weathers grayish tan and in a crumbling uneven manner.

A diabase intrusive is exposed 1 mile northeast of Hope. The rock is composed of plagioclase phenocrysts in a basic ground mass. It is slightly schistose in places and is of sufficient size to be classed as a small stock.

Dikes of fine-grained aplite and diabase occur as intrusives in the granite laccolith. The dikes have a general northwest trend and are as much as 200 feet in width. The granite-monzonite stock is cut by small pegmatite dikes, by fine-grained light-colored dikes of quartz and orthoclase, and by basic dikes of a dark-green color. No evidence was found to assign these dikes to a definite age group. For convenience, they are classed with the Mesozoic (?) intrusive rocks.

The granite in the Plomosa Mountains and in the isolated hills northwest of Bouse is coarse-grained and locally gneissoid. It is pink but has a greenish tinge caused by weathering. Outcrops of the granite occur within the sedimentary and igneous complex areas shown on the map (pl. 1) but were not separately mapped.

The Mesozoic (?) intrusive rocks are impermeable except where fractured and are considered of little value for the storage or transmission of water.

Cretaceous (?) sedimentary rocks

Conglomerate, shale, and limestone of Cretaceous (?) age occur only within the sedimentary and igneous complex areas shown on plate 1. The basal conglomerate of Cretaceous (?) age is an arkosic sandy conglomerate. It is generally grayish white, although locally it is reddish brown. The coarse-grained white matrix is composed of orthoclase feldspar, quartz, and some mica, orthoclase being the predominant mineral. The rounded, conglomeratic aggregate is composed of granite, gneiss, quartzite, and fine-grained basic igneous rocks. No stratification was observed. The unweathered rock is well consolidated but the matrix weathers easily, leaving the surface covered with rounded pebbles.

The shale and limestone strata lie conformably on the basal conglomerate. The shale is red, and the limestone ranges from reddish brown to yellow. The rocks are dense and even-layered; the limestone beds are more massive near the top of the series. No fossils were found.

The conglomerate shale, and limestone are tentatively classed as Cretaceous and are probably contemporaneous with the sedimentary rocks in southern Yuma County described by McKee[10] and Wilson.[11] Wilson, Cunningham, and

10/ McKee, E. D., Paleozoic seaways in western Arizona: Am. Assoc. Petroleum Geologists Bull., vol. 31, no. 2, pp. 282-292, 1947.

11/ Wilson, E. D., Geology and mineral resources of southern Yuma County, Ariz.: Univ. Arizona, Arizona Bur. Mines Bull. 134, pp. 30, 80, 1933.

Butler,[12] describing mines in the northern part of the Plomosa Mountains,

12/ Wilson, E. D., Cunningham, J. B., and Butler, G. M., Arizona lode gold mines and gold mining: Univ. Arizona, Arizona Bur. Mines Bull. 137, pp. 134-134, 1934.

mention "probable Cretaceous shales and metamorphosed sedimentary rocks of probable Cretaceous age."

The conglomerate, shale, and limestone of Cretaceous (?) age are not regarded as important sources of ground water, as the rocks are relatively impermeable. Wells sunk in fracture zones might yield small quantities of ground water.

Mesozoic and Cenozoic rocks

Cretaceous and Tertiary volcanic rocks

The Cretaceous and Tertiary volcanic rocks include lavas that range from light-colored rhyolite to dark-gray, almost black andesite and basalt and deposits of ash, tuff, and agglomerate.

The oldest rocks in this unit are probably the volcanic sedimentary rocks 2 miles northeast of Bouse. They are mapped with the sedimentary and igneous complex areas. The deposits consist of light-colored tuff and agglomerate interbedded with dark-red arkose. The tuff and agglomerate are thin-bedded, well sorted, very tightly cemented, and water-laid.

Southeast of Ibex Mountain the volcanic rocks are basalt, andesite, and some agglomerate. These rocks dip southwest. Interbedded with this sequence near U. S. Highway 60-70 is approximately 20 feet of yellowish-green and red coarse-grained sandstone.

A reddish sandstone was observed in the western part of the Bouse Hills. The deposit is underlain and overlain by basalt regarded as Cretaceous and Tertiary in age. The fine- to coarse-grained sandstone is well stratified and firmly consolidated and is approximately 3 feet thick. Its presence indicates a brief break in the vulcanism.

Another rock included in the Cretaceous and Tertiary volcanic series is a white thin-bedded compact tuff. Deposits of this material were observed in a small area in the southwestern part of the Bouse Hills and also in the Plomosa Mountains approximately 6 miles north of U. S. Highway 60-70. The tuff is underlain and overlain by light-colored volcanic ash.

South of Hope in Pyramid Peak is a sequence of volcanic rocks capped with basalt. Particularly prominent is a layer approximately 20 feet thick of fine-grained equigranular tuff. (See pl. 3 A.) It is red faintly laminated, and semiconsolidated. The tuff is friable and appears to be held together by compaction and by the weak cementing effect of a ferruginous coating on the grains. The red tuff is overlain by scoriaceous agglomerate which, in turn, is capped by basalt.

The deposits of ash, tuff, and agglomerate found in the Ranegras Plain area indicate explosive activity during Cretaceous and Tertiary time. The only probable source of explosive material recognized is the mountain known as Four Peaks (see pl. 3 B), 6 miles southwest of Bouse. This mountain is probably a volcanic neck. The rock is composed of quartz phenocrysts in a light-red ground mass.

Fine-grained basaltic rocks regarded as Cretaceous and Tertiary in age are the predominant lavas in the sedimentary and igneous complex area in the northern Plomosa Mountains. Associated with these lavas are diabase dikes that cut the older rocks of the complex.

The lavas in the northern Plomosa Mountains and Bouse Hills are, for the most part, highly fractured and faulted and should offer opportunity for the downward percolation of water, but no wells are known that produce from this unit. The lava flows in the remainder of the area are more continuous and are impermeable except where fractured. Most of the water-laid tuffs associated with the lavas are dense, compact, and relatively impermeable. An exception is the porous red tuff found in Pyramid Peak south of Hope. This was the only outcrop observed, but the tuff may exist beneath talus-covered slopes in other volcanic hills in the vicinity and may extend out under the valley. If the areal extent is considerable, the tuff might be important as an aquifer.

Cenozoic (?) rocks

Tertiary (?) conglomerate and alluvium

Included in the sedimentary and igneous complex area west of Bouse, and not separately mapped, is a dark-red semi-consolidated fairly well sorted conglomerate of Tertiary (?) age. The outcrops weather into rounded, elephant-back-like hills. Faint stratification separates coarse- and fine-grained layers. The coarse aggregate is composed predominantly of lava fragments and lesser amounts of fragments of gneiss and intrusive rocks. The pebbles and boulders are subangular to subrounded. The finer aggregate is composed principally of volcanic rocks and quartz and the fragments are not so well rounded as those of the coarse aggregate. The conglomerate is cut by a few small faults. It is tilted very steeply in one place, but elsewhere it dips gently.

The conglomerate probably was formed after the major vulcanism of Cretaceous and Tertiary time and before the deposition of the estuarine or lacustrine beds of late Tertiary time. The conglomerate is lithologically similar to one described by Lasky and Webber[13] in the Artillery Mountains of southern Mohave County, Ariz. They named it the Sandtrap conglomerate and tentatively assigned it to the upper Pliocene.

13/ Lasky, S. G., and Webber, B. N., Manganese resources of the Artillery Mountains region, Mohave County, Ariz.: U. S. Geol. Survey Bull. 961, 1949.

The Tertiary (?) conglomerate is tightly cemented and has not been faulted as much as the other units of the complex. It is regarded as of little value for the storage or transmission of ground water.

In the report, Tertiary (?) alluvium is restricted to the clay and smaller amounts of sand and gravel of estuarine or lacustrine origin. The upper part of these sediments may be of Pleistocene age but no fossils were found in the beds and they are classed as Tertiary (?). The thickness of this material is unknown but logs of wells in the area show that it exceeds 1,100 feet.

The only known exposure of the Tertiary (?) alluvium is at the mouth of a mine tunnel a mile east of Bouse, where beds of ash and clay are in fault contact with lavas tentatively assigned Cretaceous or Tertiary age. The exposure was too small to map. It is possible that the clay is related to similar deposits penetrated in the deep irrigation wells in the valley (see table 4). The logs of the irrigation wells west of Desert Wells show predominantly clay and small amounts of sand from 100 to 800 feet, and coarser material from approximately 800 to 1,242 feet, the maximum depth attained. The log of one well near Utting shows "hard red shale, red clay, etc." from about 850 feet to a total depth of 1,269 feet. Possibly the clay was originally as little as 100 feet below the present surface level in the vicinity of Utting, but subsequent channeling removed much of the clay.

Origin of Tertiary (?) alluvium.—Although the lower part of the valley fill of the Ranegras Plain is Tertiary (?) in age, considerable doubt exists as to the conditions under which the sediments were deposited. Though the few deep wells in the area have penetrated materials similar to those described by Knechtel[14] and Turner[15] near Safford, Ariz., which are considered

[14] Knechtel, M. M., Geology and ground-water resources of the valley of the Gila River and San Simon Creek, Graham County, Ariz.: U. S. Geol. Survey Water-Supply Paper 796-F, pp. 196-200, 1938.

[15] Turner, S. F., Ground-water resources and problems of the Safford Basin, Ariz.: U. S. Geol. Survey (mimeographed), 1941.

lacustrine, there is no basis for actual correlation of the deposits in the two areas other than physical similarity, as no fossils were found in the area covered by this investigation. However, because lakes were known to have been common in this region during Pleistocene time,[16] it is possible that

[16] Meinzer, O. E., Map of the Pleistocene lakes of the Basin and Range province and its significance: Geol. Soc. America Bull., vol. 33, no. 9, pp. 541-552, 1922.

the lacustrine theory of origin may apply here.

The Tertiary (?) alluvium may contain good aquifers in some places, but the specific capacity of a well may be small because of the great abundance of clay. A well may be expected to produce sufficient water for domestic use, and locally wells may produce sufficient water for irrigation.

Wilson[17] has described outcrops of marine sediments along the Colorado

[17] Wilson, E. D., Geology and mineral deposits of southern Yuma County, Ariz.: Univ. of Arizona, Arizona Bur. Mines Bull. 134, pp. 31-32, 1933.

River near Cibola, approximately 50 miles southwest of Bouse. He found fossils in "approximately 1,000 feet of well-stratified, weakly consolidated marls and sandstone." The fossil types found indicated brackish water from a marine invasion of Miocene or Pliocene age. Wilson also described an outcrop in Osborne Wash approximately 15 miles northwest of Bouse. He states, "The same formation underlies basalt and rests upon tilted, beveled, red beds. At that locality, Blanchard and Ross found it to contain two brackish-water fossil species." With these extensive marine deposits nearby, it is possible that the clays penetrated by the deep wells in the Ranegras Plain represent deposits in an estuary.

Cenozoic rocks

Quaternary (?) volcanic rocks

Dark-gray vesicular olivine basalt of Quaternary (?) age occurs in numerous places in the Ranegras Plain area. Outcrops were found in the southern and southwestern parts of the Bouse Hills. Other outcrops occur on two isolated black hills 3 miles west of Vicksburg. Basalt also occurs on the southwest side of Pyramid Peak. The only basalt of probable Quaternary age observed in the Plomosa Mountains was that in the vicinity of U. S. Highway 60-70.

The Quaternary (?) flows are thin and are small in areal extent. They are not regarded as an important potential source of ground water.

Quaternary sedimentary deposits

Caliche-cemented fanglomerate.--Small areas of caliche-cemented fanglomerat occur at numerous places in the Plomosa Mountains, in the Bouse Hills, in the isolated hills northwest of Bouse, and in one locality in the Granite Wash Mountains. The fanglomerate is unstratified, well consolidated, and cemented by caliche. It weathers to a jagged surface (see pl. 4 A), buff in color. Caliche forms about half the rock, coarse aggregate the rest. There is no soil in the caliche.

The fanglomerate forms vertical cliffs 10 to 20 feet high. The upper surfaces of the outcrops slope more gently than the underlying bedrock. The fanglomerate thickens down slope and is thickest at the vertical cliffs (see pl. 4 B). Wherever observed it was formed on hard rocks. In the Granite Wash Mountains, sec. 36, T. 7 N., R. 15 W., the fanglomerate dips under the alluvium of Butler Valley. This was the only locality where the relation between the fanglomerate and the alluvium could be seen. The fanglomerate was formed on the slopes of the hills of volcanic rocks and limestone, and the coarse aggregat is composed entirely of talus fromthe hills upon which the fanglomerate rests. The absence of soil in the fanglomerate indicates that it was not formed as a normal alluvial deposit. Deposition near the shore of a lake is suggested by the way the fanglomerate occurs at the same elevation around the hills on which it is formed.

The fanglomerate is very tightly cemented and has only a small area of outcrop. It is not an aquifer.

Alluvium.--The Quaternary alluvium beneath the Ranegras Plain generally does not exceed a few hundred feet in thickness. The deposits are sand, gravel, and some clay. The sand and gravel form the best aquifers in the area. The two deep wells near Utting penetrated water-bearing sand and gravel between 125 and 850 feet, and the wells have been successfully used for irrigation. It is probable that the materials found there were deposited in erosion channels cut into the Tertiary (?) alluvium, and similar buried channels may exist elsewhere beneath the Ranegras Plain.

There is no indication that the Ranegras Plain was ever drained by a major stream, and the alluvium probably was deposited by ephemeral streams that flowed only during periods of heavy rainfall. Where these streams emerged from the mountains and spread out upon the plains, the loss of velocity caused the deposition of coarse materials in the form of alluvial fans that were gradually extended for some distance out from the mountains. The finer materials - clay and silt - were carried farther out and deposited nearer the center of the valley. Therefore, wells drilled in the center of the basin wouldtend to be poor producers, owing to the fineness of the materials. The best wells should be those drilled in the coarser materials of the alluvial-fan deposits or in gravel-filled channels. There is no topographic or geologic expression on the present surface of the plain that indicates where buried alluvial-fan deposits or channels might be found.

A clay deposit, probably formed in a Recent playa, was observed approximately a mile southeast of Bouse. The high mineralization of the ground water near the surface at Bouse is probably attributable to this playa deposit.

The youngest Quaternary alluvium, other than the Recent playa clay, is the Recent sand and gravel in Bouse Wash and Cunningham Wash and in the beds of the many washes coming out of the mountains. It is not differentiated from Quaternary alluvium on the map (pl. 1). The material is coarse, unsorted, and unconsolidated. It is through these deposits that the ground-water reservoir receives most of its recharge.

GROUND-WATER RESOURCES

OCCURRENCE AND MOVEMENT OF GROUND WATER

Ground water occurs in both the Quaternary and the Tertiary (?) alluvium that forms the valley fill, but the best aquifers are found in the sand and gravel lenses of the Quaternary alluvium. The water table forms a comparatively uniform sloping surface, indicating that the alluvium is sufficiently permeable to allow horizontal and vertical movement among lenses of sand and gravel. Southeastward, or upstream, along Bouse Wash, the slope of the water table is less than that of the land surface, and the depth to water becomes progressively greater. Also, the slope of the water table is less than the slope of the ground surface from Bouse Wash toward the mountains (see pl. 1).

Ground-water movement is in the direction of the slope of the water table. In the Ranegras Plain the movement of the ground water is predominantly northwest. Some water moves southwest from Butler Valley and then northwest down the Ranegras Plain. There appears to be a ground-water barrier about 2 miles northwest of Bouse. This is shown by the shallow depth to water (about 30 feet) near Bouse and for a mile downstream, then an increase to more than 100 feet in the next mile.

Lines of equal depth to water were drawn on the map (pl. 1) in parts of the area where the wells were most abundant. However, because no elevations were available, ground-water altitude contours could not be drawn.

RECHARGE TO GROUND WATER

Recharge to the aquifers of the Ranegras Plain is derived from the following sources: (1) runoff from rainfall, (2) underflow from Butler Valley, and (3) seepage from irrigation.

There are no perennial streams in the area. Bouse Wash, Cunningham Wash, and tributary washes from the mountains flow only after a heavy rain or cloudburst. It is probable that the largest recharge to the ground-water reservoir occurs from the stream flow resulting from these heavy rains. A study of the recharge to the ground-water reservoir in a typical desert wash was made by Babcock and Cushing,[18] and they state, "about half of the flow of

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

Queen Creek at the mouth of its canyon was recharged to the ground water."

Little or no recharge to ground-water storage results from moderate rainfall on desert areas. The greater part of the rainfall absorbed by the soil is probably lost by evaporation and transpiration.[19]

[19] Turner, S. F., and others, Ground-water resources of the Santa Cruz Basin, Ariz.: U. S. Geol. Survey (mimeographed), p. 42, 1943.

Additional field work would have to be done to determine the amount of underflow from Butler Valley into the Ranegras Plain. The existence of a ground-water barrier or constriction at the mouth of Butler Valley is indicated by the comparatively shallow depth to water in the SE¼SE¼SE¼ sec. 9, T. 7 N., R. 15 W., approximately 2 miles north of the mouth of the valley. There the water is within 95 feet of the surface, although 6 miles farther upstream in Butler Valley the depth to water is approximately 240 feet. The depth to water increases below the constriction or barrier to 173 feet at Utting.

Recharge from irrigation seepage is not important at present because the amount of water applied is small.

DISCHARGE OF GROUND WATER

Discharge of ground water from the Ranegras Plain is by pumping and by the natural processes of underflow and evapo-transpiration.

As of February 1949 the pumping for irrigation exceeded that for domestic and cattle use. The amount of water pumped in the Ranegras Plain is very small compared with pumpage in the more highly developed basins in the State. Two irrigation wells near Utting were in use and about 1,000 acres were under irrigation. A third well was being placed in use near Desert Wells.

An important form of ground-water discharge is the underflow over the assumed ground-water barrier northwest of Bouse. The amount of water discharged by evapo-transpiration within the area is believed to be very small. Only in the vicinity of Bouse is the water table sufficiently near the surface to support phreatophytes, and even there it does not support a luxuriant growth similar to that along many other stream channels in the State.

AGRICULTURAL DEVELOPMENT

Six irrigation wells, each approximately 1,000 feet deep, had been drilled by March 1950. Of these, only two were in use. They are in sections 22 and 26, T. 6 N., R. 16 W., near Utting. The static water levels in these wells were 168 and 173 feet, respectively, below the surface in November 1948. No pumping-test data are available, but it is reported that the wells are good producers.

The other four wells are in the southern part of the area, near Desert Wells. The static water levels of the four wells were between 125 and 132 feet below the surface of the ground when they were drilled. Only the well in sec. 18, T. 4 N., R. 15 W., produced more than 2,000 gallons per minute. This production was accomplished by gravel-packing the well. The pumping lift (reported by the well driller) was approximately 300 feet.

SAFE YIELD OF THE GROUND-WATER RESERVOIR

The quantity of water (safe yield) that can be pumped annually from the ground-water reservoir without depleting the supply available for continued economical pumping is of vital concern to people interested in the agricultural possibilities of the Ranegras Plain. In this case the maximum safe yield of the ground-water reservoir can be approximated by estimating either the average annual recharge to the basin or the average annual discharge from the basin under natural conditions.

The average annual recharge is the amount of rainfall and flood flow that percolates to the ground-water reservoir. To evaluate this amount, it is necessary to know the average annual rainfall, the drainage area of Bouse Wash and its tributaries, the part of the rainfall appearing as surface runoff, and the part of the runoff recharged to the aquifers.

No climatological data are available for the Ranegras Plain. Tables 1 and 2 show that the average annual rainfall at Salome and Quartzite is 8.56 and 6.04 inches respectively. Because the Ranegras Plain is between the two localities, the average annual rainfall is assumed to be 7 inches.

The drainage area of Bouse Wash and its tributaries can be only estimated because existing maps do not show accurately the drainage in the southeastern part of the Ranegras Plain. An approximation of the drainage area is 1,550 square miles. Of this, about 20 percent or 300 square miles is mountainous.

Recharge to the aquifers occurs near the base of the mountains from runoff resulting from normal rainfall in the mountainous areas. Heavy rains result in flood flow and recharge in the lower reaches of Bouse and Cunningham Washes where the washes have definite channels. The determination of the recharge rates would require extensive field work. The only area similar to the Ranegras Plain in which the recharge rate has been determined is the Queen Creek area, Pinal County, Ariz. There, runoff from rainfall in mountainous areas was about 8 percent of the average annual rainfall,[20] and approximately 50 percent of the runoff at the base of the mountains was recharged to the ground-water reservoir.[21] The factor of 50 percent was arbitrarily reduced to 33 percent for the Ranegras Plain area, because the conditions for recharge are not as favorable as in the Queen Creek area. There is additional recharge, of unknown amount, fromflood flows in the lower reaches of Bouse and Cunningham Washes. Though it conceivably could be equal to the recharge near the mountainous areas, it probably is much less.

20/ Turner, S. F., personal communication, 1949.

21/ Babcock, H. M., and Cushing, E. M., op. cit.

Using the estimated figures for rainfall, drainage area, and percentage of runoff reaching the ground-water reservoir as recharge, it is computed that 3,000 acre-feet per year enters the ground-water reservoir from runoff resulting from normal rainfall in the mountainous areas. Another 1,000 to 3,000 acre-feet per year may be recharged by flood flows along Bouse and Cunningham Washes. Thus, according to this method of computation, the total recharge, in round figures, may be about 5,000 acre-feet per year.

Another method of estimating the safe yield is to determine the amount of ground water that is discharged from the basin. In the Ranegras Plain area the principal discharge occurs as underflow over the presumed barrier northwest of Bouse. The amount of underflow could be determined by: (1) Running earth-resistivity probes to determine the width and thickness of the aquifers overlying the barrier; (2) drilling wells to bedrock at the barrier; (3) making pumping and recovery tests on several wells and measuring drawdown and recovery in observation wells in the immediate vicinity, to determine the coefficient of permeability of the aquifers; and (4) leveling between observation wells to permit determining the hydraulic gradient. An estimate of the discharge can be made by assuming; an aquifer 100 feet thick and 2 miles wide, a hydraulic gradient of 70 feet per mile, and an average field coeffici of permeability of 500. The field coefficient of permeability[22] is the rate

[22] Wenzel, L. K., Methods for determining permeability of water-bearing materials: U. S. Geological Survey Water-Supply Paper 596, p. 7, 1942.

of flow, in gallons per day, through a 1-foot thickness of water-bearing materials 1 mile in width (measured at right angles to the direction of flow) and under a hydraulic gradient of 1 foot per mile. Using these values, the average annual discharge is computed as about 7,500 acre-feet.

On the basis of the estimates of recharge and discharge, the safe yield from the ground-water reservoir of the Ranegras Plain area may be less than 5,000 acre-feet per year. It probably does not exceed 10,000 to 15,000 acre-feet. If irrigation development is expanded until the pumpage exceeds the safe annual yield, the result will be a general and continuing lowering of the water level and, as shown below, an increase in the mineral content of the ground water.

QUALITY OF WATER

The analyses of ground water (table 5) are of 5 samples collected in 1946 and of 11 samples collected in the period November 1948 to March 1949. These data indicate that the ground water is extremely varied in quality, ranging in dissolved-solids content from 390 to 3,700 parts per million. Chloride, sulfate, sodium, and calcium are the predominant constituents in the more concentrated waters.

Analyses of ground water from wells in the flat lands near the center of the basin indicate that most of the water may be rated "permissible to doubtful" or "doubtful to unsuitable" for irrigation use, as classified by Wilcox[23] with respect to specific conductance and percent sodium. The

[23] Wilcox, L. V., The quality of water for irrigation use: U. S. Dept. Agr. Tech. Bull. 962, p. 26, 1948.

percentages of sodium usually exceed 60, and the application of such waters to the land may cause the soil to become relatively impermeable to the downward movement of water. The shallow ground water in the vicinity of Bouse which has a dissolved solids concentration similar to that from well 36 may be classified as unsuitable for irrigation.

Most of the ground water in the basin contains enough dissolved mineral matter to have a noticeably unpleasant taste. Near Bouse the water is high in chloride, sulfate, and dissolved solids. Excluding the two wells in sec. T. 4 N., R. 16 W., all other samples showed the ground water to be very high in fluoride, the range being from 3.8 to 8.9 parts per million. According tc the U. S. Public Health Service[24] a satisfactory drinking water should contain

[24] Public Health Service drinking water standards, 1946: Public Health Repts., vol. 61, no. 11, Reprint 2697, pp. 371-384, Mar. 15, 1946.

no more than 1.5 parts per million of fluoride. Excessive amounts of fluoride may cause mottling of the tooth enamel of children who drink such waters during the time their permanent teeth are forming.

The most dilute waters in the Ranegras Plain basin occur in the recharge areas. These areas are along the mountain bases and gravel-filled channels of washes. For example, the well in sec. 15, T. 4 N., R. 16 W., is near the mountain front and the water is relatively low in dissolved solids. Likewise, the wells in the SW¼ sec. 15, T. 7 N., R. 17 W., are near Bouse Wash, and their waters are relatively low in dissolved solids, even though the water in some of the nearby wells at Bouse is highly mineralized. The occurrence of a less concentrated water in this vicinity is possibly due to recharge from fresher water flowing through the wash. The highly mineralized shallow water at Bouse is believed to reflect the influence of nearby deposits.

All the dissolved solids that leave the basin are carried out by the surface flow and underflow of Bouse Wash. The accumulation of soluble salts in the basin will gradually increase as discharge from the basin is decreased by pumping for irrigation. However, the effects can be minimized by providing adequate drainage structures to keep the water table from rising too near the surface in the irrigated tracts, and by providing the proper amount of excess irrigation to keep the soil flushed out.

SUMMARY AND CONCLUSIONS

The area included in this investigation is the northern part of the Ranegras Plain, known locally as the "Bouse country." It is in northern Yuma County, Ariz.

Ground water occurs in the Quaternary and Tertiary (?) alluvium that forms the valley fill. The best aquifers are the sand and gravel lenses of the Quaternary alluvium. The Tertiary (?) alluvium appears to be "tight" because of the great abundance of clay, silt, and fine-grained sand. The movement of ground water is predominantly northwest, although some water moves southwest from Butler Valley and then northwest down the Ranegras Plain.

Recharge to the aquifers of the Ranegras Plain is principally by runoff from rainfall. Discharge of ground water is principally by underflow out of the basin and by pumping.

The safe yield of the ground-water reservoir may be less than 5,000 acre-feet and it probably does not exceed 10,000 to 15,000 acre-feet per year. As of March 1950 the safe yield had not been exceeded because only two wells were in use.

The waters from wells in the flat lands near the center of the basin may be considered "permissible to doubtful" or "doubtful to unsuitable" for irrigation use, and some of the shallow waters near Bouse are "unsuitable" for irrigation use. The ground waters generally contain enough dissolved mineral matter to have a noticeable taste. Most of the samples showed amounts of fluoride sufficient to cause mottling of tooth enamel in small children.

Table 1.—Summary of climatological data, 1909-40, Salome, Yuma County, Ariz.
(From records of U. S. Weather Bureau)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Mean max. temp., °F	63.4	67.0	73.7	81.9	90.7	100.9	104.1	102.0	96.9	86.2	74.8	64.8	83.9
Mean min. temp., °F.	33.1	36.3	40.7	45.7	52.2	61.9	72.1	71.3	63.1	49.7	39.5	34.4	50.0
Mean temp., °F.	48.2	51.7	57.2	63.8	71.4	81.4	88.0	86.6	80.0	68.0	57.0	49.4	66.9
Extreme max. temp., °F.	85	91	96	103	111	118	117	117	111	106	94	85	118
Extreme min. temp., °F.	15	18	24	26	34	42	50	50	42	28	16	16	15
Mean precipitation, in.	.93	1.07	.63	.29	.06	.16	1.11	1.47	.69	.48	.53	1.14	8.56
Greatest monthly precip., in.	3.81	5.06	2.23	2.27	.37	2.25	4.20	9.27	6.16	2.09	2.97	3.74	-
Least monthly precip., in.	0	0	0	0	0	0	.08	T	T	0	0	0	-

Table 2.—Summary of climatological data, 1918–40, Quartzite, Yuma County, Ariz.
(From records of U. S. Weather Bureau)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Mean max. temp., °F.	65.8	71.1	78.9	87.7	97.0	105.5	109.4	107.4	102.3	89.7	76.0	65.7	88.0
Mean min. temp., °F.	33.9	38.6	44.2	52.2	60.4	70.1	78.7	77.4	68.6	53.4	41.0	35.3	54.5
Mean temp., °F.	50.0	54.7	61.5	69.9	78.5	87.7	94.0	92.4	85.3	71.4	58.5	50.4	71.2
Extreme max. temp., °F.	84	88	100	111	121	122	124	124	116	108	97	84	124
Extreme min. temp., °F.	9	17	25	27	40	43	52	62	42	30	17	16	9
Mean precipitation, in.	.43	.84	.35	.23	.06	.15	.67	1.06	.71	.37	.40	.77	6.04
Greatest monthly precip., in.	2.72	5.85	1.51	1.28	.43	1.40	2.09	5.53	6.16	1.93	3.31	3.30	–
Least monthly precip., in.	0	0	0	0	0	0	0	0	0	0	0	0	–

Table 3.--Records of wells in northern part of Ranegras Plain area, Yuma County, Ariz.

Measuring point: Usually top of casing, top of pump base, or top of well curb.
Type of pump and power: T, turbine; C, cylinder; E, electric motor; G, gasoline; W, wind; H, hand; O, diesel.

Well no.	Location	Owner	Driller	Date completed	Depth of well (feet)	Diameter of well (inches)
	T. 4 N., R. 15 W.					
a/ 1	NE¼NE¼SE¼ sec. 2	E. J. Relf	G. Relf	1944	r/ 300	8
2	NW¼NW¼SW¼ sec. 7	J. Fred Ash et al.	Robinson & Mason	1948	528	20
a/ 3	NW¼NE¼ sec. 8	J. S. Riley	-	1935	r/ 420	6
4	NW¼NE¼ sec. 8	do.	-	-	-	6
5	SE¼NE¼ sec. 8	do.	Riley and Franks	1926	r/ 206	8
6	NW¼SW¼ sec. 9	Ora C. Jordan	-	1938	r/ 250	8
7	NE¼NW¼ sec. 9	R. B. Reed	-	-	r/ 250	6
a/ 8	NW¼NW¼NW¼ sec. 18	Perry Bros.	Robinson & Mason	1948	1,005	20
9	NW¼NW¼SW¼ sec. 18	Perry, Settan, and Granville	Thompson Bros.	1949	1,242	12
10	SE¼SE¼SE¼ sec. 23	-	-	-	-	6
11	SE¼NW¼NW¼ sec. 28	Crowder Cattle Co.	-	-	-	-
	T. 4 N., R. 16 W.					
a/ 12	NW¼NE¼ sec. 15	Frank Williams	Rex Roberts	1948	r/ 303	-
a/ 13	NW¼NE¼ sec. 19	Mrs. Callie Battles	-	-	r/ 285	6
a/ 14	SW¼NW¼ sec. 19	E. M. Rathburn	Rex Roberts	1946	r/ 530	8
	T. 5 N., R. 14 W.					
15	NW¼ sec. 16	-	-	-	-	60

a/ See table 5 for analysis of water from this well

Use of water: I, irrigation; S, stock; D, domestic; P, public supply; N, none; RR, railroad.

Well no.	Water level: Depth below measuring point (feet)	Water level: Date of measurement	Pump and power	Use of Water	Temp. (°F)	Remarks
1	262.0	Nov. 17, 1948	C,E	D	-	-
2	124.50	Nov. 8, 1948	-	N	-	See log
3	r/116	Nov. 17, 1948	C,E	D	-	-
4	127.70	Nov. 17, 1948	None	D	-	Casing being withdrawn, Nov. 17, 1948
5	128.25	Jan. 8, 1945	C,G	D	-	Observation well
6	r/135	Nov. 18, 1948	C	D	-	-
7	-	-	T,E	D	-	-
8	130.66	Nov. 8, 1948	None	N	82	Discharge, approximately 900 gallons a minute. Well abandon See log.
9	131.94	May 10, 1949	T,E	I	-	Discharge, reported by driller, 2,000 gallons a minute with drawdown of 170 feet. See log.
10	158.42	Nov. 22, 1948	None	N	-	-
11	-	-	C,G	S	—	-
12	211	Nov. 17, 1948	C,G	D	-	-
13	243.4	Nov. 18, 1948	C,E	D	-	-
14	r/200	Nov. 18, 1948	C,E	D	-	-
15	37.43	May 25, 1948	H	D	-	Taps perched water body. Known a Desert Prospect about 1910.

r/ Reported.

Table 3.—Records of wells in northern part of Ranegras Plain area, Yuma County, Ariz.—Continued

Well no.	Location	Owner	Driller	Date completed	Depth of well (feet)	Diameter of well (inches)
	T 5 N., R. 15 W.					
16	NE¼ sec. 5	A. T. and S. F. R. R.	Ariz. and Cal. Ry. Co.	1911	r/ 343	10
17	SE¼SW¼ sec. 7	-	-	-	-	8
a/ 18	NE¼NW¼ sec. 21	Crowder Cattle Co.	-	-	r/ 250	6
19	NE¼NE¼ sec. 30	-	-	-	-	8
20	SE¼SW¼SW¼ sec. 32	P. Higgins	Robinson and Mason	1948	r/ 600	20
	T. 5 N., R. 16 W.					
a/ 21	SW¼NW¼ sec. 9	Crowder Cattle Co.	-	-	r/ 145	6
22	SE¼SE¼SE¼ sec. 9	-	-	-	146	7
23	SE¼SE¼ sec. 10	-	-	-	-	16
	T. 6 N., R. 15 W.					
24	SE¼NE¼NE¼ sec. 32	-	-	-	-	8
	T. 6 N., R. 16 W.					
25	NE¼NE¼ sec. 22	Chester Johns	Thompson Bros.	1948	878	20
a/ 26	NE¼NE¼ sec. 26	do.	do.	do.	1,269	20
27	NW¼ sec. 32	-	-	-	r/ 900	16
	T. 6 N., R. 17 W.					
28	NE¼ sec. 12	-	-	-	-	12
	T. 7 N., R. 15 W.					
29	SE¼SE¼SE¼ sec. 9	R. H. Thompson	Rex Roberts	Feb. 1950	-	6
	T. 7 N., R. 17 W.					
a/ 30	NW¼ sec. 6	do.	do.	1946	r/ 134	6
31	NE¼SW¼ sec. 9	-	-	-	112.8	6

Well no.	Water level: Depth below measuring point (feet)	Water level: Date of measurement	Pump and Power	Use of Water	Temp. (°F)	Remarks
16	r/253	Feb. 1, 1911	-	-	-	See log
17	146.40	Nov. 15, 1948	None	N	-	-
18	202.17	Nov. 16, 1948	C,W	S	-	-
19	154.40	Nov. 16, 1948	None	N	-	-
20	119.09	Nov. 8, 1948	None	N	-	Well was test-pumped. Small production
21	122.23	Nov. 15, 1948	C,W	S	-	-
22	120.54	Nov. 12, 1948	None	N	-	-
23	114.00	Feb. 21, 1946	None	N	-	-
24	269	Feb. 17, 1949	None	N	-	-
25	169.33	June 8, 1948	T,E	I	-	See log
26	173.14	Nov. 16, 1948	T,E	I	82	Discharge, approximately 2,300 gallons a minute with drawdown of 25 feet
27	98.46	Nov. 12, 1948	None	N	-	Probably drilled for irrigation but used only for stock
28	64.12	Jan. 9, 1945	C,W	S	-	-
29	95	Feb. 26, 1950	C,W	S	-	-
30	110.56	Feb. 20, 1946	C,G	S	78	-
31	110.00	Nov. 22, 1948	None	N	-	-

Table 3.—Records of wells in northern part of Ranegras Plain area, Yuma County, Ariz.—Continued

	Well no.	Location	Owner	Driller	Date completed	Depth of well (feet)	Diameter of well (inches)
		T. 7 N., R. 17 W.					
	32	Sec. 10	-	-	-	-	48
a/	33	SW¼NE¼SW¼ sec. 15	-	-	1905	47.7	6
a/	34	SE¼NW¼SW¼ sec. 15	-	-	-	55.5	6
	35	SE¼SW¼SE¼ sec. 15	C. A. Martin	G. Williams	Mar. 1949	125	8
a/	36	SE¼NE¼NE¼ sec. 22	C. Whiteley	-	-	44	48
	37	SE¼NE¼NE¼ sec. 22	do.	-	1946	r/ 90	6
	38	NW¼NE¼ sec. 22	Bellows	-	-	r/ 38	72
	39	SE¼NE¼NW¼ sec. 22	C. Whiteley	-	-	r/ 90	6
	40	SE¼NW¼SE¼ sec. 22	Mrs. Bouse	-	-	33.5	6
	41	NE¼SW¼ sec. 23	A. T. and S. F. R. R.	Ariz. and Cal. Ry. Co.	1911	r/ 690	13
	42	NE¼SW¼ sec. 23	C. Milton	-	1916	r/ 73	6
	43	NE¼NE¼SW¼ sec. 23	M. Lopez	-	-	r/ 45	6
	44	NW¼NE¼SW¼ sec. 23	-	-	-	-	48
a/	45	SW¼NE¼SW¼ sec. 23	J. C. Townsend	Sutton	1946	r/ 92	6
	46	NE¼NW¼SW¼ sec. 23	R. Montijo	R. Montijo	1946	r/ 42	48
a/	47	NE¼NW¼SW¼ sec. 23	T. G. Bolieu	-	-	r/ 60	48
	48	NE¼NW¼SW¼ sec. 23	do.	-	-	r/ 77	6
	49	NW¼NW¼SW¼ sec. 23	H. N. Peterson	Robison	1948	r/ 90	6
	50	NW¼NW¼SW¼ sec. 23	A. G. Lingle	Rex Roberts	1948	82.5	6
	51	SW¼NW¼SW¼ sec. 23	-	-	-	37.5	-
	52	SE¼NW¼SW¼ sec. 23	State Highway Department	-	-	-	6

Well no.	Water level: Depth below measuring point (feet)	Water level: Date of measurement	Pump and power	Use of water	Temp. (°F)	Remarks
32	85.70	Nov. 5, 1948	None	N	-	-
33	32.97	Nov. 2, 1948	C,H	N	-	-
34	47.96	Nov. 2, 1948	C,H	S	-	-
35	38.17	Mar. 31 1949	E	D	-	-
36	41.10	Nov. 3, 1948	C,W	S	72.5	-
37	-	-	C,H	D	-	-
38	28.62	Jan. 1945	G	I	-	Irrigates approximately 10 acres.
39	36.00	Nov. 2, 1948	T,E	D,S	-	-
40	31.68	Nov. 3, 1948	C,G	N	-	-
41	±/ 55	1911	C,G	RR	-	-
42	-	-	C,G	D	-	-
43	41.20	Nov. 3, 1948	C,G	D	-	-
44	56.85	Jan. 9, 1944	-	-	-	-
45	35.49	Nov. 15, 1948	C,E	D	77	-
46	39.00	Nov. 3, 1948	None	N	-	-
47	42.19	Jan. 9, 1944	C,W	D	-	-
48	40.64	Nov. 3, 1948	T,E	D	-	-
49	43.25	Nov. 2, 1948	None	D	-	Not yet in use.
50	40.84	Nov. 2, 1948	None	N	-	do.
51	35.58	Nov. 2, 1948	None	N	-	-
52	37.50	Nov. 3, 1948	G	P	-	-

Table 3.—Records of wells in northern part of Ranegras Plain area, Yuma County, Ariz.—Continued

Well no.	Location	Owner	Driller	Date completed	Depth of well (feet)	Diameter of well (inches)
	T. 7 N., R. 17 W.					
53	SW¼SE¼SW¼ sec. 23	W. Brodie	G. Williams	1949	r/ 84	6
a/ 54	SW¼NW¼NE¼ sec. 26	R. Berkeley	-	1933	52	48
55	NE¼SW¼NE¼ sec. 26	F. Simpson	-	1947	r/ 55	6
56	NW¼SW¼NW¼ sec. 26	J. C. Townsend	-	-	r/ 37	-
57	SW¼SW¼NW¼ sec. 26	do.	-	1947	r/ 92	8
58	SE¼SE¼SE¼ sec. 26	J. M. Jones	-	-	r/ 70	6
59	NE¼ sec. 34	-	-	-	-	-
60	NW¼NW¼NE¼ sec. 35	J. M. Jones	-	1924	-	48
61	NW¼SW¼NE¼ sec. 35	J. L. Zello	Sutton	-	r/ 110	6
	T. 8 N., R. 17 W.					
62	NE¼ sec. 34	-	-	-	-	6

a/ See table 5 for analysis of water from this well.

Well no.	Water level: Depth below measuring point (feet)	Water level: Date of measurement	Pump and power	Use of Water	Temp. (°F)	Remarks
53	35.55	Apr. 21, 1949	None	N	-	Not yet in use.
54	38.18	Nov. 15, 1948	H	D	74	-
55	r/ 35	Nov. 15, 1948	C,H	D	-	-
56	34.02	Nov. 4, 1948	C	D,S	-	-
57	34.28	Nov. 4, 1948	None	N	-	Not yet in use.
58	-	Nov. 4, 1948	C,H	D	-	-
59	59.90	Nov. 4, 1948	C,W	S	-	-
60	31.60	Jan. 9, 1945	C,W	D,S	-	-
61	r/ 32	Nov. 4, 1948	T,E	D,I	-	Small plot under cultivation
62	56.30	Nov. 5, 1948	None	N	-	-

r/ Reported

Table 4.—Logs of wells in northern part of Ranegras Plain area, Yuma County, Ari

	Thickness (feet)	Depth (feet)
Driller's log of well 2		
J. Fred Ash, et al, owner		
NW$\frac{1}{4}$NW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 7, T. 4 N., R. 15 W.		
Soil - - - - - - - - - -	4	4
Caliche - - - - - - - -	3	7
Gravel - - - - - - - - -	3	10
Sand and clay - - - -	180	190
Clay - - - - - - - - - -	225	415
Clay, cemented sand and gravel - - - - - - -	113	528
TOTAL DEPTH - - - - - -		528
Driller's log of well 8		
Perry Bros., owners		
NW$\frac{1}{4}$NW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 18, T. 4 N., R. 15 W.		
Gravel - - - - - - - - -	170	170
Clay and gravel - - -	30	200
Clay - - - - - - - - - -	590	790
Shale and clay - - - -	40	830
Rock and gravel - - -	15	845
Gravel and shale - - -	30	875
Gravel and rock - - -	107	982
No sample - - - - - - -	7	989
Rock and gravel - - -	16	1,005
TOTAL DEPTH - - - - - -		1,005
Driller's log of well 9		
Perry, Setton, and Granville, owners		
NW$\frac{1}{4}$NW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 18, T. 4 N., R. 15 W.		
Sand, clay, and boulders	83	83
Clay, caliche, and shells - - - - - - -	149	232
Clay, streaks of sand	63	295
Sand, gravel, streaks of clay - - - - - - - -	40	335
Clay, streaks of sand	230	565
Clay, streaks of cemented gravel - - -	66	631
Clay with sand and gravel streaks - - -	68	699
Clay - - - - - - - - - -	23	722
Black sticky shale - -	6	728
Red shale and gravel -	70	798
Sand, streaks red shale	45	843
Hard shale - - - - - - -	36	879
Cemented gravel, sand and shells - - - - -	18	897
Conglomerated sand and pea-rock gravel - - -	54	951
Sand and gravel - - -	200	1,151
Driller's log of well 9 -Con.		
Perry, Setton, and Granville, owners		
NW$\frac{1}{4}$NW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 18, T. 4 N., R. 15 W.		
Black swamp mud - - - - -	10	1,161
Conglomerate - - - - - - -	19	1,180
Gravel and sand, lime shells	20	1,200
Conglomerate and bentonite chalk - - - - - - - - -	22	1,222
TOTAL DEPTH - - - - - - - -		1,222
Driller's log of well 16		
A. T. & S. F. R. R., owner		
NE$\frac{1}{4}$ sec. 5, T. 5 N., R. 15 W.		
Cement, gravel, some clay streaks - - - - - - - - -	265	265
Coarse gravel - - - - - - -	65	330
Cement gravel - - - - - - -	13	343
TOTAL DEPTH - - - - - - - -		343
Driller's log of well 25		
Chester Johns, owner		
NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 22, T. 6 N., R. 16 W.		
Sand, silt, and caliche	50	50
Silt and clay - - - - - - -	60	110
Sand and gravel with streaks of clay - - - -	316	426
Sand and gravel - - - - - -	114	550
Sand and clay - - - - - - -	25	575
Sand - - - - - - - - - - - -	55	630
Clay, some with sand streaks	50	680
Sand - - - - - - - - - - - -	30	710
Clay - - - - - - - - - - - -	10	720
Sand - - - - - - - - - - - -	23	743
Sand and gravel - - - - - -	22	765
Sand and gravel, streaks of hard red shale - - -	46	811
Sand and gravel, thin streaks of clay - - - -	43	854
Clay with streaks of sand - - - - - - - - - - - -	24	878
TOTAL DEPTH - - - - - - - -		878
Driller's log of well 26		
Chester Johns, owner		
NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 26, T. 6 N., R. 16 W.		
Sand and caliche - - - -	67	67
Clay and silt - - - - - - -	60	127
Streaks of clay with sand and gravel - - - -	229	356
Sand and gravel - - - - - -	131	487

Table 4.—Logs of wells in northern part of Ranegras Plain area--Continued

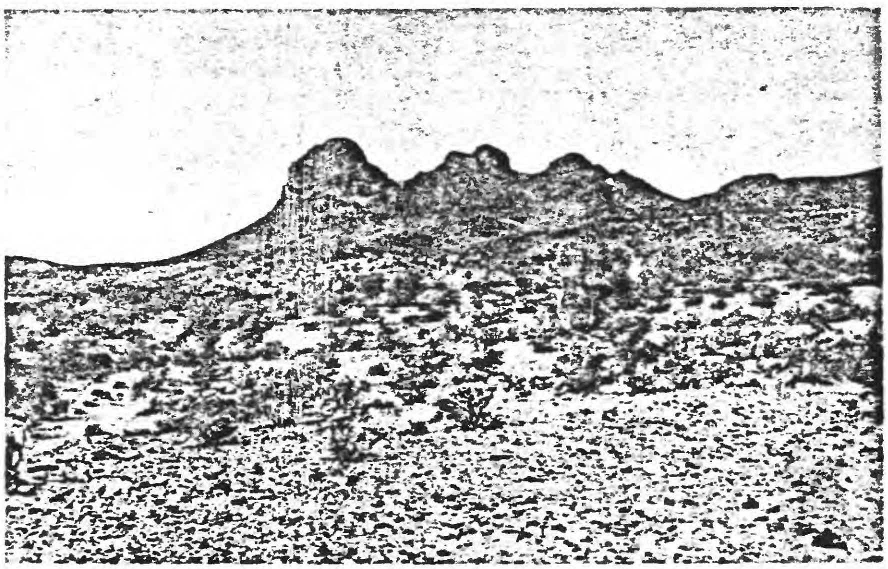
	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Driller's log of well 26 - Con.			Driller's log of well 41		
Chester Johns, owner			A. T. & S. F. R. R., owner		
NE¼NE¼ sec. 26, T. 6 N., R. 16 W.			NE¼SW¼ sec. 23, T. 7 N., R. 17 W.		
Sand and clay - - - - - -	146	633	Sand, clay, and gravel - -	178	178
Sand - - - - - - - - - -	79	712	Cemented gravel with streaks of clay - - - - -	152	330
Clay streaks with sand	73	785	Clay and shale - - - - - - -	20	350
Sand - - - - - - - - - -	94	879	Reddish conglomerate - - -	100	450
Hard red shale - - - -	121	1,000	Grayish traprock with streaks of clay - - - - -	240	690
Red clay and sand streaks	269	1,269	TOTAL DEPTH - - - - - - - -		690
TOTAL DEPTH - - - - - -		1,269			

Table 5.—Analyses of water samples from typical wells in northern part of the Ranegras Plain area, Yuma County, Ariz.
Analyzed by Quality of Water Branch, Geological Survey
(Parts per million except specific conductance and percent sodium)

Well no.	Date of collection	Specific conductance ($K \times 10^6$ at 25° C.) (micromhos sq. cm.)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness as $CaCO_3$	Percent sodium
1	Nov. 17,1948	1,560	26	13	281	146	198	265	5.5	19	929	118	84
3	Nov. 17	2,290	203	1.3	333	26	900	175	6.5	16	1,660	512	58
8	Mar. 8,1949	1,680	181	6.3	191	121	553	138	4.1	16	1,190	478	47
12	Nov. 17,1948	774	12	1.4	150	55	123	108	8.9	16	462	36	91
13	Nov. 18,	845	127	6.3	62	278	226	7	.5	3.3	601	343	29
14	Nov. 18,	616	15	14	109	327	27	17	.4	14	390	95	71
18	Feb. 22,1946	1,400	-	-	-	164	-	208	-	-	-	-	-
21	Feb. 23,	1,390	45	8.6	216	87	224	206	4.7	11	758	148	76
26	Mar. 31,1949	1,730	50	9.2	304	192	284	240	5.4	22	1,050	163	80
30	Feb. 20,1946	1,020	52	6.8	164	176	189	118	-	9.4	626	158	70
33	Nov. 15,1948	724	88	9.9	70	459	13	6	5.6	.5	470	260	37
34	Nov. 15,	1,420	-	-	-	75	-	85	-	-	-	-	-
36	Feb. 22,1946	5,630	344	68	888	126	886	1,430	4.4	20	3,700	1,140	63
45	Nov. 15,1948	1,460	52	17	181	193	287	86	4.2	5.6	762	200	66
47	Feb. 22,1946	1,920	116	23	279	172	360	325	3.8	8.4	1,200	384	61
54	Nov. 15,1948	2,560	24	8.3	543	358	603	235	7.7	.7	1,630	94	93

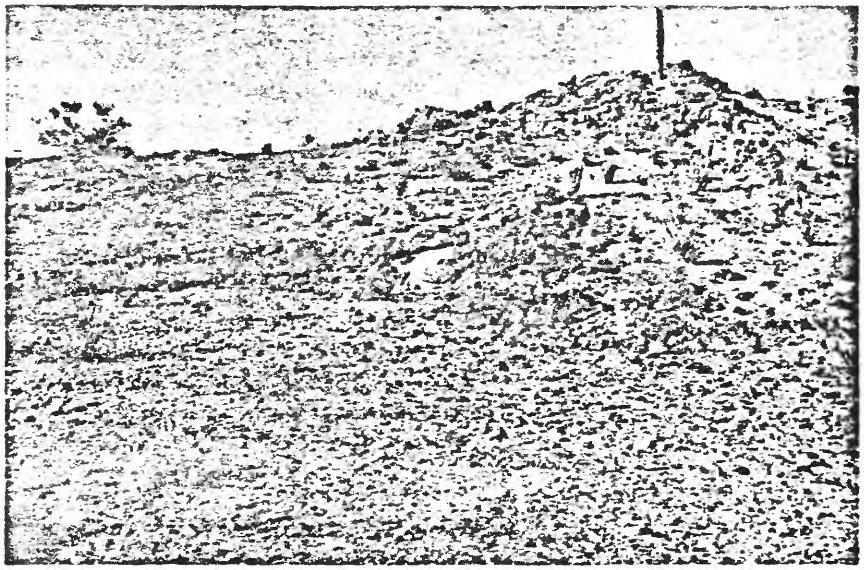
PLATE 3

A. Tuff exposed on the east slope of Pyramid Peak. The dark stratum is red fine-grained, equigranular tuff of Cretaceous and Tertiary age.

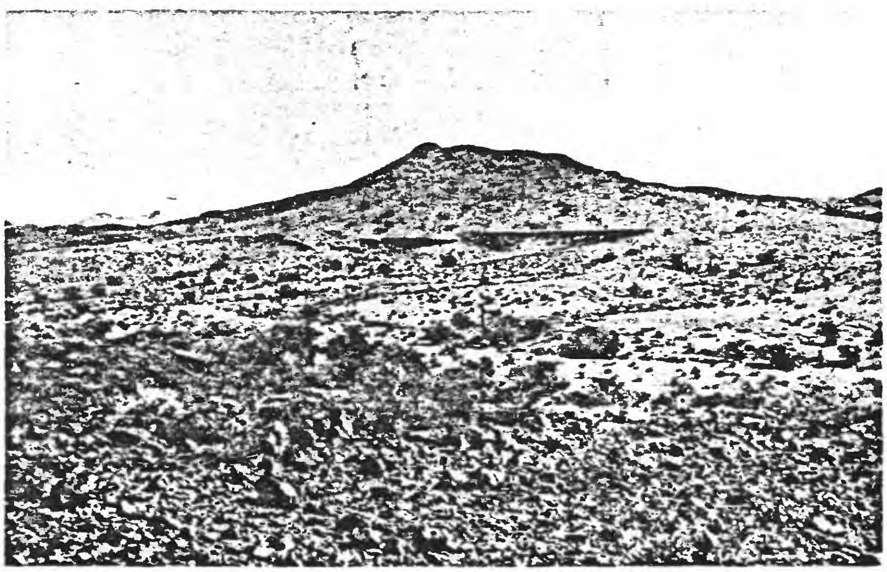


B. Looking west at Four Peaks. The mountain is probably a volcanic neck of Cretaceous and Tertiary age.

PLATE 4



A. Caliche-cemented fanglomerate formed on a hill of Cretaceous and Tertiary volcanic rocks. The outcrop is 2 miles northeast of Bouse, on the west side of the Bouse Hills.



B. Looking northeast at an outcrop of caliche-cemented fanglomerate on the slope of a hill composed of Cretaceous and Tertiary volcanic rocks, about 4 miles east of Bouse.

51-28

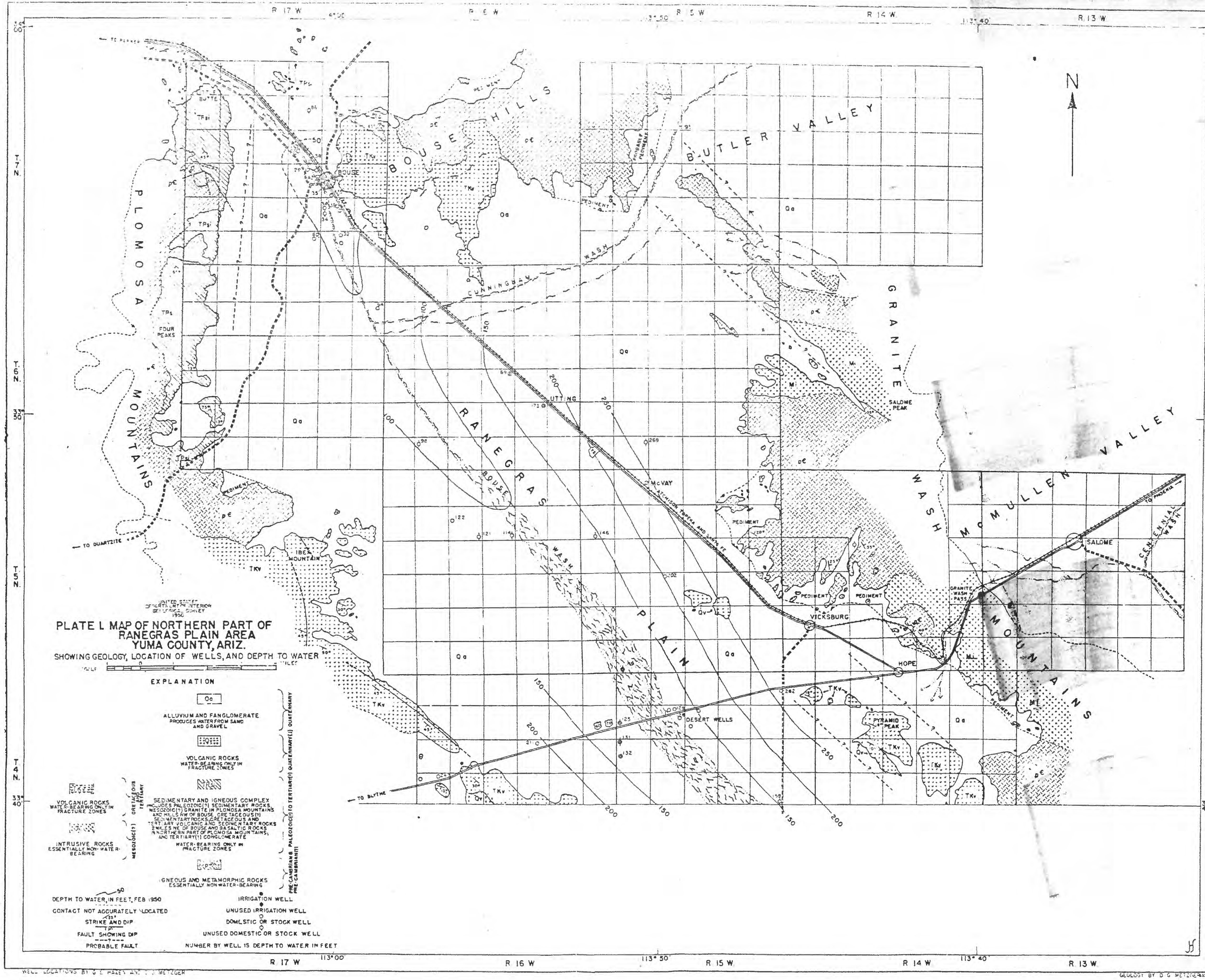


PLATE I. MAP OF NORTHERN PART OF RANEGRAS PLAIN AREA YUMA COUNTY, ARIZ.
SHOWING GEOLOGY, LOCATION OF WELLS, AND DEPTH TO WATER
EXPLANATION
Qa
ALLUVIUM AND FANGLOMERATE PRODUCES WATER FROM SAND AND GRAVEL
VOLCANIC ROCKS WATER-BEARING ONLY IN FRACTURE ZONES
SEDIMENTARY AND IGNEOUS COMPLEX
WATER-BEARING ONLY IN FRACTURE ZONES
IGNEOUS AND METAMORPHIC ROCKS ESSENTIALLY NON-WATER-BEARING
VOLCANIC ROCKS WATER-BEARING ONLY IN FRACTURE ZONES
INTRUSIVE ROCKS ESSENTIALLY NON-WATER-BEARING
DEPTH TO WATER, IN FEET, FEB 1950
CONTACT NOT ACCURATELY LOCATED
STRIKE AND DIP
FAULT SHOWING DIP
PROBABLE FAULT
IRRIGATION WELL
UNUSED IRRIGATION WELL
DOMESTIC OR STOCK WELL
UNUSED DOMESTIC OR STOCK WELL
NUMBER BY WELL IS DEPTH TO WATER IN FEET
PLOMOSA MOUNTAINS
BOUSE HILLS
BUTLER VALLEY
GRANITE WASH
McMULLEN VALLEY
MOUNTAINS
RANEGRAS PLAIN
BOUSE WASH
CUNNINGHAM WASH
CENTENNIAL WASH
BOUSE
UTTING
McVAY
VICKSBURG
HOPE
SALOME
SALOME PEAK
GRANITE WASH PASS
PYRAMID PEAK
DESERT WELLS
IBEX MOUNTAIN
FOUR PEAKS
PEDIMENT
TO QUARTZITE
TO BLYTHE
TO PHOENIX
R 17 W
R 16 W
R 15 W
R 14 W
R 13 W
T 7 N.
T 6 N.
T 5 N.
T 4 N.
113°50'
113°40'
33°30'
N
GEOLOGY BY D. G. METZGER