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Ground-water supplies and irrigation in San Pedro Valley, Arizona

By

Kirk Bryan, G. E. P. Smith, and Gerald A. Waring

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ABSTRACT

The San Pedro Valley in southeastern Arizona extends from the International Boundary northward about 120 miles to the junction of the San Pedro River with the Gila River. The river basin also extends about ~~75~~ 50 miles into Mexico. The valley varies in width from 5 to 20 miles, being widest in its middle portion, in the vicinity of Benson. The area of the portion of the basin within the United States is about 3,770 square miles.

The southern route of the Southern Pacific Railroad from El Paso, Texas, to Los Angeles, California, traverses the southern part of the valley. The northern route of the same railroad crosses the central part of the valley. The principal towns are Winkelman, at the mouth of the valley, Benson in its middle portion, and Tombstone, a silver-mining town on its eastern side. Each had a population of approximately 1,000 in 1934. St. David is an agricultural community a few miles south of Benson. Elgin is a village near the west border of the valley. Fairbank is a small community at the junction with the main line, of branch railroads to Tombstone and to Elgin.

The entire region is arid, the average yearly rainfall ranging from about 10 inches in the lower lands to nearly 20 inches in the upper inhabited portions. The principal rain season is during July, August and September, when nearly one-half

of the total precipitation falls. On the bordering mountains snow falls during the winter months.

The San Pedro River is the main stream of the valley. The Babocomari River is its principal tributary from the west, and joins the San Pedro near Fairbank. Aravaipa Creek drains a considerable area in the northeast and joins the San Pedro a few miles above its mouth. All three streams are perennial and are used for irrigation, nearly the entire low-water discharge of each being diverted for this purpose. No storage reservoirs have been constructed.

There is much arable land for which no surface water is at present available for irrigation. Primarily in order to study the possibilities of developing ground-water supplies for this purpose a joint study was undertaken in 1920 by the United States Geological Survey and the Arizona State Agricultural Experiment Station. Later studies have also been made, to bring down to date the information on the ground water and its development.

Most of the region is devoted to cattle raising, to which industry the growing of forage crops in the bottom lands is an adjunct. The principal agricultural development is in the vicinity of Pomerene and St. David in the middle portion of the valley, in the Hereford and Palominas districts in its upper part, and in the Elgin district in its western portion. Silver mining near Tombstone and at other places in the bordering mountains was not active in 1934, although the recent increase in the price of silver had caused some revival of prospecting.

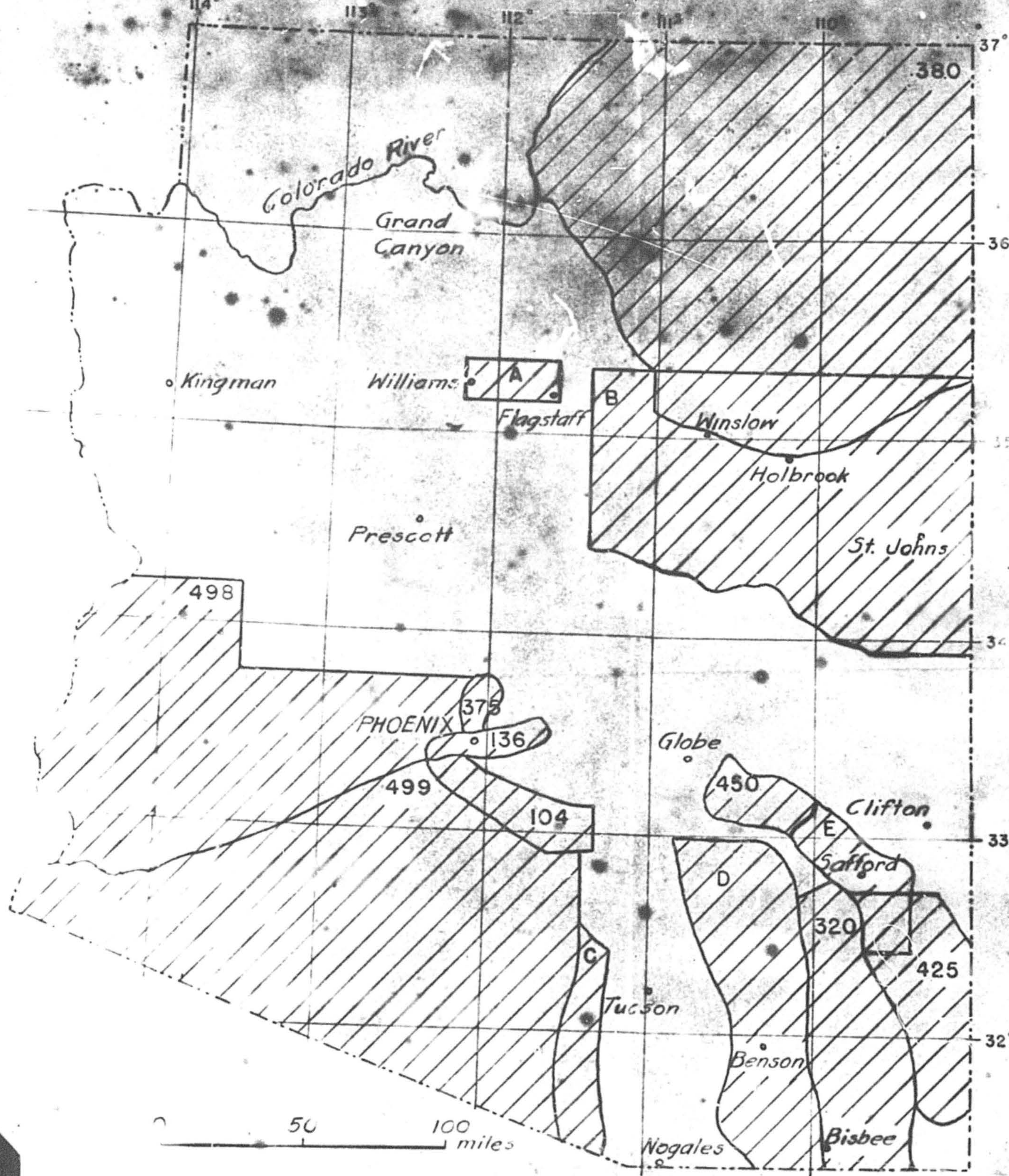
The valley is bordered by several detached mountain masses, whose principal peaks rise to altitudes of 6,000 to more than 9,000 feet. From the base of the mountains wide uniform slopes of the type known as mountain pediments extend down to the lower land and form bluffs which border an inner valley that consists in large part of bottom land. In this inner valley the San Pedro River since ~~about~~ 1883 has entrenched itself below its former flood plain.

Portions of the inner valley are occupied by large ranches composed chiefly of Spanish grant lands and devoted to cattle raising. American agricultural settlement began in 1878 [1877] and irrigation was developed by means of ditches taking water from the river. The project of a storage reservoir near Charleston in the upper part of the valley has been studied. Water for the irrigation of several thousand acres could be stored at this site, but the construction of a dam would involve the rebuilding of nearly 10 miles of main-line railroad which passes through the dam site and reservoir basin.

In several areas within the inner valley flowing artesian wells have been obtained. The largest area is in the St. David-Pomerene district, where more than 200 wells of small diameter have been drilled. These are used for domestic supplies and for watering gardens and small fields. The artesian head is not strong, however, and the water-bearing beds are of comparatively small yield, so that the wells are not of great importance for irrigation.

Non-artesian ground water is present in comparatively small amount in the lavas and ancient crystalline and sedimentary rocks of the mountains which border the valley; but on these higher slopes there are a number of perennial springs which are used for cattle watering, and wells also furnish small supplies for domestic and stock use. The Tertiary deposits of sand and gravel that flank the mountains yield supplies of several gallons a minute to wells dug or drilled to the ground-water level of the inner valley. These deposits supply the artesian wells. The alluvium of the inner valley is in most places 20 to 80 feet thick and contains ground water at slightly above the level of the neighboring river channel. Numerous domestic and cattle-watering wells tap this supply, but little attempt has been made to develop it for irrigation. In some places there are probably shallow layers of gravel from which considerable water for irrigation could be obtained, but the costs of pumping are high, as compared with those of the use of ditch water from the river.

In general the ground water is not highly mineralized, and it has comparatively low hardness. Some of the well waters however, and especially some of the artesian waters, contain an unusually large content of fluoride. Where these waters are used for domestic supply the tooth defect known as mottled enamel is common, and is believed to be caused chiefly by the fluoride.



INDEX MAP OF ARIZONA SHOWING AREAS COVERED BY PRESENT REPORT AND OTHER WATER-SUPPLY PAPERS OF THE U. S. GEOLOGICAL SURVEY (THE NUMBERS ARE THEIR SERIAL NUMBERS)

A. FLAGSTAFF AREA B. HOLBROOK REGION C. AVRA VALLEY D. SAN PEDRO VALLEY E. SAN SIMON VALLEY

FIGURE 1.- INDEX MAP OF ARIZONA SHOWING AREAS COVERED BY PRESENT REPORT AND OTHER WATER-SUPPLY PAPERS OF THE U. S. GEOLOGICAL SURVEY (THE NUMBERS ARE THEIR SERIAL NUMBERS)

A. FLAGSTAFF AREA B. HOLBROOK REGION. C. AVRA VALLEY
D. SAN PEDRO VALLEY E. SAN SIMON VALLEY

INTRODUCTION.

Location and Extent.

The San Pedro Valley, in southeastern Arizona, extends from ~~about 50 miles south of~~ the International Boundary northward ~~nearly 170~~ about 120 miles to the Gila River. The valley also extends about 50 miles south of the Boundary in Mexico. ~~Only that portion~~ ~~of the valley~~ ~~which is in Arizona is treated in the present report.~~ Its position within the state is shown in the index map, Figure 1.

Figure 1. Index map of Arizona showing areas covered by the present report and by other Water-Supply Papers of the U.S. Geological Survey.

The width of the valley varies from about 5 to 20 miles, being widest in its middle portion in the vicinity of the town of Benson. The area of ~~that portion of~~ the entire drainage basin is about 4,720 square miles. The area of the portion within Mexico is about 950 square miles leaving a drainage area of 3,770 square miles for that portion which is in Arizona.

Grover, N.C. and others, Surface Water Supply of the United States, Part 9 Colorado River Basin, 1932, ~~pp. 113 and 116~~ U.S. Geol. Survey Water Supply Paper 734, pp. 113 and 116, 1933. ~~These give~~ The drainage basin above the mouth of the river at Winkelman is given as 4,720 square miles, and the drainage basin above Palominas as 991 square miles, of which about 40 square miles is north of the International Boundary.

This includes the basin of Aravaipa Creek, the main tributary to the San Pedro River, which is the principal stream, as shown on Plate 1.

Plate 1, map of the San Pedro ~~River~~ Valley, Arizona, showing wells and springs.

Although the spelling "Aravaipa" is the local usage and was approved in 1934 by the United States Geographic Board, the earlier ruling of the Board in favor of "Arivaipa" is etymologically correct. The name signifies "clear water", the syllable "ari" meaning water, as in Arizona (from Arizonac, a Papago word meaning "small springs").

N.B. [illegible] map is drawn [illegible] the approved spelling [illegible] the name [illegible] on the 19[illegible] [illegible] uses [illegible] on his [illegible] Geol. map, and also on his [illegible] topographic quadrangle sheet. C.A.W. 3/23/35.

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Purpose and Scope of Investigation.

The San Pedro Valley contains much arable land which could be farmed if water were available for irrigation. Attempts have been made at dry farming but only in years of more than usual rainfall have such efforts been successful. In order to learn the possibilities of developing ground water for irrigation a co-operative study of the valley was begun in 1920 by the United States Geological Survey and the Arizona Agricultural Experiment Station. The investigation of the geology and ground water conditions of the higher portions of the valley was undertaken under the supervision of O.E.Meinzer, Geologist in Charge of the Division of Ground Water of the Federal Survey, the field work being undertaken by Kirk Bryan, Geologist. The investigation of irrigation by surface water and by artesian wells in the lower portions of the valley was undertaken by Professor G.E.P.Smith, Professor of Agricultural Engineering at the University of Arizona, and his assistants.

The introduction and geologic discussion, and part of the ground-water data in the present report have been prepared from information collected by Dr.Bryan, and the discussion of irrigation development and artesian wells has been prepared from the ~~data~~ studies of Professor Smith. ~~Information on~~ The ground-water conditions and development in the non-artesian areas were re-examined in 1934 by G.A.

G.A.Waring, Geologist of the Federal Survey who has prepared the descriptions of ground water conditions in these areas.

During both periods of investigation samples of well water were collected for analysis. Some of the analytical work was done by Mr.Robert A.Green in the laboratory of the University of Arizona. Other samples were analysed by Margaret D.Foster and E.W.Lehr under the direction of W.D.Collins Chemist in Charge of th the Division of Quality of Water of the U.S.Geological Survey. The statements concerning the individual analyses have been verified by Mr.Lehr and the discussion of fluoride content has been reviewed by Miss Foster.

Previous Studies.

In 1903 the portion of the valley near Benson was examined by Willie T.Lee and a short report of his investigation has been published.

Lee, Willie T., ~~San Pedro Valley.~~ Notes on the underground water in the San Pedro Valley Arizona. In U.S.Recl.Service,3d Rept. for 1903-04 pp.165-170, 1905.

Preliminary studies of storage possibilities on the river were made by the United States Reclamation Service in 1903 the same year.

Newell,F.H., San Pedro Project. U.S.Recl. Service 3d Rept. for 1903-04 pp. 61-62 and 157-170, 1905.

A report on ground water in the Sulphur Spring Valley, which adjoins San Pedro Valley on the east has been published as a joint study by the ~~United States~~ Geological Survey and the State Agricultural Experiment Station. Similar studies of portions of the next basin to the east were made by Schwennesen. A more recent study of that portion of the San Simon Valley which is in Graham County has been made by Knechtel. The areas covered by these reports are indicated in figure 1.

Meinzer, O.E. and Kelton, F.C. Geology and Water Resources of Sulphur Spring Valley Ariz., with a section on agriculture by R.H.Forbes, U.S.Geol.Survey Water Supply Paper 320, 1913.

Schwennesen, A.T., Ground Water in San Simon Valley, Arizona and New Mexico U.S.Geol.Survey Water Supply Paper 425, pp.1-35, 1919; Geology and Water Resources of the Gila and San Carlos Valleys in the San Carlos Indian Reservation, Arizona U.S.Geol.Survey Water Supply Paper 450, pp.1-27, 1921.

Knechtel, M.M. Geology and ground-water Resources of the Gila and San Simon Valleys, Graham County, Southeastern Arizona U.S. Geol. Survey Water Supply Paper —, 19—. ~~(in preparation)~~.

An examination of the mineral deposits in an area including a western portion of the San Pedro Basin was made by Schrader and Hill. A comprehensive study of the mining resources in the Aravaipa District has been made by C.P.Ross, and a detailed study of the Tombstone mining district has been made by Ransome.

Schrader, F.C. Mineral Deposits of the Santa Rita and Patagonia Mountains Ariz., with contributions by J.M.Hill U.S.Geol.Survey Bull.582,1915.

Ross, C.P. Geology and ore deposits of the Aravaipa and Stanley mining districts, Graham County, Ariz., U.S.Geol.Survey Bull.763,1925.

Ransome, F.L. The Tombstone Mining District (unpublished Manuscript).

Historical sketch.

Long before the Spanish explorers visited the region the San Pedro Valley and adjacent areas were sparsely inhabited by pueblo-dwelling aborigines, the nearly obliterated ruins of whose villages have been examined and described by Sauer and Brand.

The following notes have been taken largely from a previous report by Dr.Bryan which contains historical information condensed from a manuscript prepared by Dr.F.L.Ransome. (Bryan,Kirk, The Papago Country, U.S.Geol.Survey Water Supply Paper 499,pp.3-23, 1925.)

Sauer, Carl, and Brand, Donald, Pueblo sites in Southeastern Arizona; Univ. Calif. Publications in Geography,vol.3 no.7,pp.415-458,1930.

They indicate(in fig.1 of their report) and mention evidences of Pueblos at Fort Grant, at the Hooker Ranch, about 10 miles north of that ranch, and at three sites about 3 miles southeast of Klondyke and they also mention several small cliff-dwellings overlooking the upper Aravaipa Valley. In the main San Pedro Valley they examined sites at the mouth of Ramsey Canyon in the Huachuca Mountains, on the Miller ranch 3 miles southeast of St.David, on a bench 2 miles north of Pomerene at two localities near Cascabel, and on the mesa north of Redington school. They did not extend their studies as far downstream as the pueblo near the mouth of Kilberg Canyon, and the mounds near Aravaipa school, on Plate 1 of the present report.

These early tribes seem to have been supplanted by other Indians for during the days of early Spanish exploration the valley was occupied by groups of Saipuris Indians closely similar to the present Papagos.

The route of Coronado's expedition from Mexico northward in search of the fabled "Seven Cities of Cibola" in 1539 may have been along part of the San Pedro Valley. Some modern authorities believe that the expedition travelled ~~no-~~ northward down the valley of the San Pedro to about where Benson now stands, then crossed eastward through Dragoon Pass and continued northeastward to the valley of the Gila River and beyond. Bancroft and several other historians however think that the route was down the Santa Cruz Valley past the present sites of Tucson and Florence and thence northeastward over the mountains.

~~Brower, J.V., Memoirs of Exploration in the Basin of the Mississippi~~

Hodge, F.W., Coronado's March to Quivira in Brower, J.V., Memoirs of Exploration in the basin of the Mississippi vol.2, pp.29-73 St.Paul, Minn. 1899.

Coues, Elliott, On the Trail of a Spanish Pioneer, vol.2, pp.481-485 and 517-518, New York, 1900.

Bancroft, H.H., The works of Hubert Howe Bancroft, vol 17; History of Arizona and New Mexico, 1530-1888; pp.39-41, San Francisco 1889.

In 1687 Father Eusebio Francisco Kino, an Austrian priest of the Company of Jesus founded a mission in Mexico about 60 miles south of the present Nogales on the Arizona border. In 1692 he made his first visit to the Indians along the San Pedro River which he named Rio Quiburi from the Indian village of that name near the present Hereford. ~~For 25 years he served as~~

For 25 years Kino served as 20

missionary to the Province of Alta Pimeria, which included the San Pedro Valley. During that period there were 14 villages in the valley, containing about 2000 Indians, and adjacent territory. In 1697 Kino with a small party was joined at Quiburi by a small band of soldiers and they proceeded down the San Pedro Valley to its lower end and thence westward down the Gila River. For a long period the region seems to have been one of peaceful missionary effort. In 1818-19 the Navajo Indians in the north made war against the Spaniards and during the next few years preceding the establishment of the Republic of Mexico in 1823 the missions were abandoned and the local Indians were raided by the more warlike tribed from the north.

~~The~~ first ~~white men~~ Americans entered what is now southeastern Arizona from Texas and other southern states about 1825 and engaged in hunting, trapping and prospecting for minerals. For a number of years the Apaches of the region were in general friendly but in 1836 several of them were killed by Americans and for many years they were a constant menace to settlers. Portions of the San Pedro Valley were deeded as ~~Spanish or~~ Mexican grants on which cattle raising was carried on. ~~San Rafael del Valle and San Juan de las Boquillas y Nogales along the upper San Pedro River, and the Babocomari grant along the river of the same name occupy considerable portions of the lower valley land.~~

The rancho San Rafael del Valle and the rancho San Juan de las Boquillas y Nogales each cover 4 square leagues (17,474.93 acres), along the upper part of the San Pedro River. The rancho San Ignacio del Babocomari covers 8 square leagues along the valley of the Babocomari River. These tracts were sold at auction in the early 1830's by the Treasurer-General of the Sovereign State of Sonora; the Boquillas grant being sold for $60 a square league, and the Babocomari grant at $60 for six of the "sitios" and at $10 for the other two, a total of $380 being paid for the land. Title was confirmed to these grants in 1899-1903 by a United States Court of Claims, long after the discovery of silver in the Tombstone district. Probably on this account and to protect certain mining interests near Charleston, the title to gold, silver, and quicksilver beneath the lands was reserved to the United States, together with the right to work the deposits.

During the Mexican War the region was traversed by two military expeditions. General S.W.Kearny with a band of about 200 dragoons followed down the Gila River and thence to California in 1846. His party was accompanied by Lieutenant W.H.Emory. In December 1846 Lieutenant-Colonel P.St.George Cooke ~~led~~ leading a party of about 500 men for the purpose of opening a wagon route to California

Emory,W.H., Notes of a Military Reconnaissance from Fort Leavenworth in Missouri to San Diego Calif. 30th Cong.1st sess.,S.ex.Doc.7 (H.ex.Doc.41) pp.1-416,1848.

Cooke,P.St.G.,Report of his march from Santa Fe N.Mex.to San Diego, Upper California, 30th Cong. 1st sess.H.Ex.Doc.41,pp.551-563,1848.

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entered the present Arizona near its southeast corner. Thence he proceeded west to the San Pedro Valley, down it to the site of Benson and then westward to Tucson and beyond. His party was called the "Mormon Battalion" because it consisted ~~largely~~ of Mormons who had entered the service for the purpose of reaching California where according to the terms of their enlistments they would be discharged.

Bancroft,op.cit.p.410.

By the treaty of Guadalupe Hidalgo, ~~ratified May 30th~~ signed Feb 2, 1848, lands north of the Gila River were ceded to the United States. By the Gadsden Purchase of December 30 1853 lands south of the Gila including the San Pedro Valley as far south as the International Boundary established at 31 degrees

Emory, W.H., Notes of a military reconnaissance from Fort Leavenworth in Missouri to San Diego in California, including parts of the Arkansas, Del Norte and Gila rivers: 30th Cong., 1st sess., Senate Ex. Doc. 7, 1848., also published as 30th Cong., 1st sess., Ex. Doc. no, 41, 1848.

Cooke, Philip St. George, Official journal of ~~[illegible]~~/ Lieutenant Colonel Philip St. George Cooke from Santa Fe to San Diego (Oct, 13, 1846 -Jan. 29, 1847): 30th Cong., 1st sess., Senate Ex. Doc. 7, 1848., also published as 31st Cong., Special sess., Senate Doc. 2, 1848., and as publication no, 517 in the Congressional series of public documents.

20 minutes north latitude became part of the United States. Surveys for a railway route to California were already in progress and in 1854 Lieutenant J.G.Parke crossed the San Pedro Valley from Tucson eastward ~~and~~ through Dragoon Pass, approximately along the route later followed by the Southern Pacific Railroad In 1855 Lieutenant Parke led a second expedition eastward. He and his assistant, Dr. Thomas Antisell, took a small party up the Gila River to the mouth of the San Pedro, and up the valley of that river to the vicinity of the present Benson, where they joined the main party and continued eastward. Antisell was the first to write a connected geological description of Southern Arizona.

~~U.S.Pacific R.R.Expl. vol.~~

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Fort Breckenridge afterward Camp Grant was established in the lower San Pedro Valley in 1856 as protection against the Apaches. Fort Huachuca was established in the southwest part of the valley for the same purpose in an area where there was good grazing for the cavalry horses. In 1857 the semi-weekly Butterfield stage line began operating from San Antonio Texas to San Diego California over the Cooke route down the valley. In 1858 the route was changed, turning westward near Camp Grant and going up through Camp Grant Wash. By 1860 the route crossed the valley through Dragoon Pass and thence westward to Tucson and beyond. This

Double space

Antisell, Thomas, in, U.S. War Dept., Reports on the exploration and Survey to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean: 33d Cong., 2d sess., Sen. Ex. Doc. 78, 1855-1860., vol. 7, part 2, Geological report by Thomas Antisell, M.D., geologist of the expedition. 206 pp., 2 maps, 14 geological plates and 10 paleontological plates. (Chapter 20, Canyons of the Gila River and Pinaleno Mountains, pp. 139-144).

stage line was operated until the beginning of the Civil War. Up to this time there had been much mining activity in southeastern Arizona but on the outbreak of war the regular stage service was discontinued, the troops were withdrawn ~~and~~ the Apaches again became an active menace, and most of the mining was stopped. Arizona was established as a Territory in 1863 but took little part in the Civil War. In 1872 General O.O.Howard, who was made a special Indian Commissioner, ~~and~~ visited the Apache Chief Cochise in his stronghold on the eastern side of the San Pedro Valley and induced him to abandon hostilities and use his influence with other chiefs to do likewise. For a few years thereafter the Indians were peaceable but in the late ~~70's~~ seventies they carried on raids again and were not finally subjugated until the surrender of Chief Geronimo to General Nelson A. Miles in 1886. About 1872 Fort Grant was moved to the west base of the Pinaleño Mountains, where a good water supply was available from springs.

The first settlement by American farmers in the San Pedro Valley was by a party of ~~four~~ several Mormon families who came from ~~the~~ a colony at Mesa near Phoenix in the southcentral part of the State, and ~~established~~ camped near the present St. David in November ~~1876.~~ 1877. The colony of St. David was established in the following May.

The silver deposits of Tombstone were discovered by Ed. Schiefflin in February, 1878, and during the next year ~~of the same year, and in 1879~~ the principal strikes of ore were made. The town of Tombstone was established in 1881. At its height the town had a population of about 15,000. The principal mines were dry down to a depth of about 500 feet, where ~~the~~ ground-water ~~level~~ was ~~reached~~ encountered, and soon the amount of water reached such great volume that some of the mines shut down. Several of the richest mines combined in pumping, until the flooding of the largest placed the company in legal difficulties. After years of litigation the principal group of mines was sold at auction, and pumping and production were resumed for a time. The cost of pumping at last became prohibitive, however, and the silver mines were shut down. The associated manganese ores were then marketed for several years; but in April, 1921 this work was stopped, and the population soon dwindled to about 900. In 1934 the increased price of silver was causing renewed interest and mining activity. The picturesque events of the early days of Tombstone have been ~~preserved~~ kept in mind by the preservation of such landmarks as the Birdcage Theater, the Opera House, and the scenes of struggles between the town marshal and outlaws, for several of whom the final chapter is written in Boothill Graveyard.

In 1880 the main line of the Southern Pacific Railroad was built through Dragoon Pass and across San Pedro Valley, and the town of Benson was established. Ore was discovered in the Mule Mountains and the mining camp of Bisbee sprang up in 1878. For the first few years it was a lead producer, but later became a great copper-mining district. Benson was for a time the nearest railroad point, and the smelted product was transported from Bisbee to it by teams along the valley. In a few years the El Paso & Southwestern Railroad was built from Benson to Fairbank, and a toll road was built northward from Bisbee through Mule Pass, thus greatly shortening the wagon haul. Branch railroad lines were built from Fairbank eastward to Tombstone and westward up the valley of the Babocomari River, to connect with a railroad between Nogales and Tucson. A branch line was also built to Fort Huachuca; and in the nineties a railroad was built from Dragoon northward to copper mines at Johnson. These produced for about 45 years, until shut down about 1928.

In 1902 the railroad was completed from Fairbank, then a village of several hundred people, to Bisbee. A southern route of the Southern Pacific from El Paso to Tucson was later built, entering the San Pedro Valley at Bisbee Junction and thence continuing down the eastern side of of the valley to Fairbank, where it crossed the river and gradually ascended the western side to the pass at Mescal.

Tungsten deposits in the granite of the southern part of the Little Dragoon mountains have also been worked. Richards, R. W., The Dragoon, Ariz., tungsten deposits: M. Science, vol. 57, pp. 93-94, 1908.

Settlements and industries.

In addition to the towns that have been already mentioned, Winkelman, near the junction of the San Pedro River with the Gila, was in 1934 a town of about 600 people. It had been more active during copper-mining developments at Kelvin and Ray, several miles to the northwest, and at Christmas to the northeast. Mammoth was formerly an active mining settlement where copper ore from the mine on the valley side to the west was brought down to a mill at the river, where water was available for operations. In 1934 there was only a watchman at the mill. The village was a supply point for ranches along the valley, and contained about 150 people. Some prospecting was being done on the adjacent slopes, and also in the Galiuro Mountains on the east side of the valley, in the vicinity of Copper Creek mining camp. Oracle was a settlement of about 300 people on the upper border of the valley, on the road between Mammoth and Tucson. At Redington there was a post office and a school. At Cascabel there was post office, school and also small store for the convenience of settlers in that part of the valley. ~~A graded road extended from Redington southward along the east side of the valley to Cascabel, and thence to the highway at Benson, a town of nearly 1,000 people.~~ Part of the road northward from Redington to Mammoth was washed out by a flood in ~~1927~~ Sept 1926 and had not been rebuilt, but a passable road extended for several miles, then forded the river and climbed northwest up the slope to Oracle. A graded road extended westward from Redington up the west side of the valley and across the Santa Catalina Mountains to Tucson. A graded road also extended from Redington southward along the east side of the valley, to Cascabel, and thence to the highway at Benson, a town of nearly 1,000 people. At Fort Huachuca on the southwest border of the valley, there was a garrison of about 1,000 cavalry.

There are several ranches along the lower part of Aravaipa Creek, and also in the upper valley of this creek, with settlements of ~~perhaps~~ 100 or 200 people at Aravaipa, Klondyke, and Bonita. The State Industrial School for Boys occupied the buildings at Fort Grant, at the head of the valley.

From Tucson, U.S. Highway 80 passes eastward to Benson and thence southeastward to Tombstone, Bisbee, and on eastward. State Highway 80 extends from Benson eastward through Dragoon Pass to Willcox and beyond. State Highway 82 connects Elgin and Fairbank with the main highways.

GEOGRAPHIC AND GEOLOGIC FEATURES

Mountains

The northern part of the San Pedro basin is formed by Aravaipa Valley which is bordered on the east by the Turnbull, Santa Teresa and Pinaleño Mountains. These rise to altitudes ~~above~~ of about 7,000 feet and culminate in Mount Graham at an altitude of 10,720 feet, the highest peak bordering the basin. Ranges of hills on the west separate the drainage of Aravipa Creek from the main San Pedro Valley. Other hills ~~form a~~ enclose a small upland valley in the vicinity of Hooker Hot Springs. Farther south the Little Dragoon and Dragoon Mountains form the divide between ~~the~~ San Pedro Valley and Sulphur Spring Valley to the east. The pass between these two groups of mountains has an altitude of about ~~4,615~~ 4,600 feet. The mountains themselves rise to 7,512 feet in Mount Glen. South of the Dragoon Mountains there is another wide pass ~~in~~ at the head of Government Draw, beyond which are ~~which forms the drainage divide southward~~ ~~to~~ the Mule Mountains, ~~which form a small group near Bisbee.~~

On the west side of the valley the Tortilla Mountains in the north form a broad divide cut by numerous washes but having comparatively low relief. The Santa Catalina and Rincon Mountains border the western side of San Pedro Valley for about 15 miles their highest peaks rising to altitudes of 8,385 feet in Kellogg Mountain and 8,700 feet in Mica Mountain. Lemmon Mountain, the highest peak of the Santa Catalina Mountains, rises to 9,150 feet, but is somewhat west of the drainage divide. At the south end of the Rincon Mountains there is a broad divide in the vicinity of Mescal which extends to the Whetstone Mountains, separating the San Pedro Valley from the drainage of ~~Pantano Wash~~ Cienaga Creek, a tributary to Santa Cruz ~~River~~ Valley on the west. The highest points in the Whetstone Mountains ~~culminate in~~ are Apache Peak at an altitude of 7,684 feet, and Granite Peak at 7,387 feet. Another broad upland area then forms the drainage divide of the San Pedro river basin southward to the Canelo Hills and Huachuca Mountains. The former constitute a rugged area of ridges trending southeast-northwest on the western side of the Huachucas. The latter form a large mountain mass having a crest extending for several miles and ~~culminating in~~ rising to Miller and Carr Peaks at altitudes of 9,445 and 9,214 feet.

Mountain pediments.

The mountains which border the San Pedro Valley do not extend down to the lowland. Their bases are rather sharply marked in most places by gently sloping plains which extend at nearly uniform slopes down towards the trough of the valley. The upper portions of these plains havebed-rock surfaces or only a very thin layer of gravel and rock waste. Such features were studied by Bryan in the Papago country farther west and were defindd by him as follows:

In general, the mountains of the Papago country rise from plains which are similar in form to the alluvial plains that commonly front mountains of an arid region, but large parts of the plains are without alluvial cover and are composed of solid rock. These plains constitute a land form that is distinct and requires a name. "Mountain pediment" has been chosen as the name of such a plain of combined erosion and transportation at the foot of a desert mountain range.

Bryan, Kirk, The Papago Country: U.S. Geol. Survey Water-Supply Paper 499, p. 93, 1925.

In the study of the San Pedro valley two pediments of different geologic age were recognized which have been described by Bryan thus:

Bryan, Kirk, The San Pedro Valley, Arizona, and the geographic cycle; Geol. Soc. America Bull. vol. 37, p. 170, 1926.

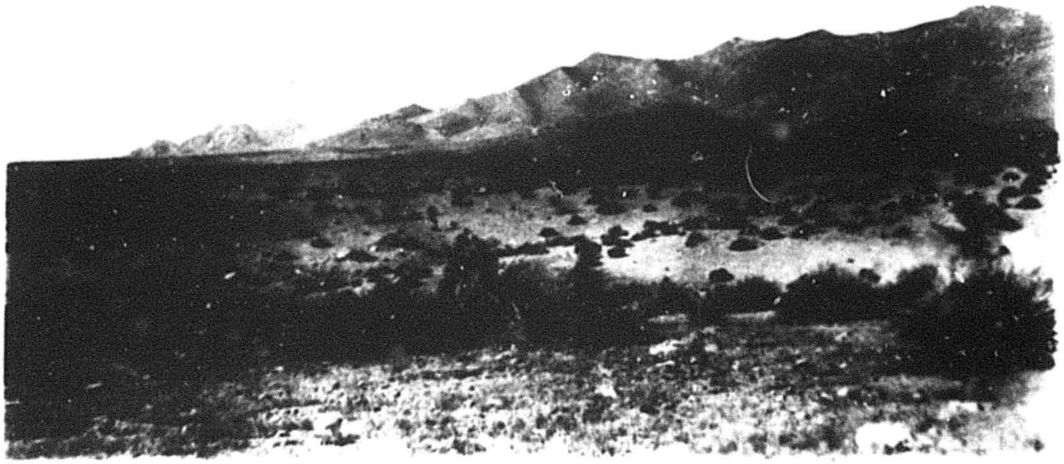
" Following deformation long-continued erosion formed a widespread surface, here termed the Tombstone pediment. The residuals above this surface consist of the harder rocks, or are located at points distant from main drainage lines. They have, therefore, all the characteristics of residuals in the normal cycle of erosion, save only their steep slopes. The slopes of mountains are, however, a function of the type of rock and the climate, when once the initial stage of development is over, and in arid regions the slopes of mountains are steeper than in areas of normal climate. Similarly, the erosion surface conforms to the drainage pattern in all its intricacies; is wide on main drainages; tapers into long, narrow triangles along minor streams; is enlarged on soft rocks, narrowed on hard rocks, and presents all the features of a peneplain in the normal cycle, except for steepness of slope. The slope ranges from 50 to 200 feet per mile, gradients far in excess of those developed by streams in the old-age stage in humid regions. The Tombstone pediment is, therefore, an expression of peneplanation, though perhaps not complete base-leveling in an arid region.

Before the last residuals had been reduced, the Tombstone cycle was interrupted by the incision of the streams. At a lower level a second less complete pediment was developed. In this second, or Whetstone, pediment similar features were produced, but the cycle was again interrupted by the incision of the streams to the still lower level of the Aravaipa terrace. Below this terrace lie the valleys of the streams, once deeper than they now are because of a Recent fill that is now being removed in part by renewed erosion begun in 1885.

As the Tombstone pediment was not brought to completion it affords only partial evidence as to the ultimate land form produced by erosion under arid conditions. "

Plate 3. A. Dissected pediment at southwest end of Dragoon Mountains;

B. Pediment at base of Dragoon Mountains near Sycamore Spring.



The two pediments are shown on the physiographic map, Plate 2

The upper or Tombstone pediment is developed in a wide zone along the base of the Dragoon Mountains north of Tombstone, and is a remarkably uniform surface floored by bed rock of granite and other ancient rocks for much of its extent. Its general character is shown in Plate 3, A and B. It seems to have been formed during a long period of erosion when the region was reduced almost to a peneplain at this high level. An almost equally prominent mountain pediment was (Whetstone pediment) cut in the valley sides at a lower elevation during a later period of erosion. This broad gently sloping plain, which in some places has the features of a terrace rather than a peneplain, constitutes the Whetstone pediment. It is prominently developed along the east face of the Whetstone Mountains and also along the west face beyond the limit of the San Pedro Valley. Over most of the area which it covers this pediment has been cut chiefly in early Tertiary sediments but in several districts it has been cut in the bed rock. A detailed map of the Tombstone district illustrating the way in which the two pediments at different levels have modified the ancient surface of the lower mountain slopes is shown ~~in~~ on Plate 4 .

Plate 4 Map of the Tombstone District showing the Tombstone and Whetstone pediments
folding-page plate

Plate 5.A. Dissected pediments along east side of the Tortilla Mountains, looking north.

B. Tucson Wash, looking upstream, showing remnants of pediments.

The character of the terraces and the way they are swept by washes is shown in Plate 5, A and B.

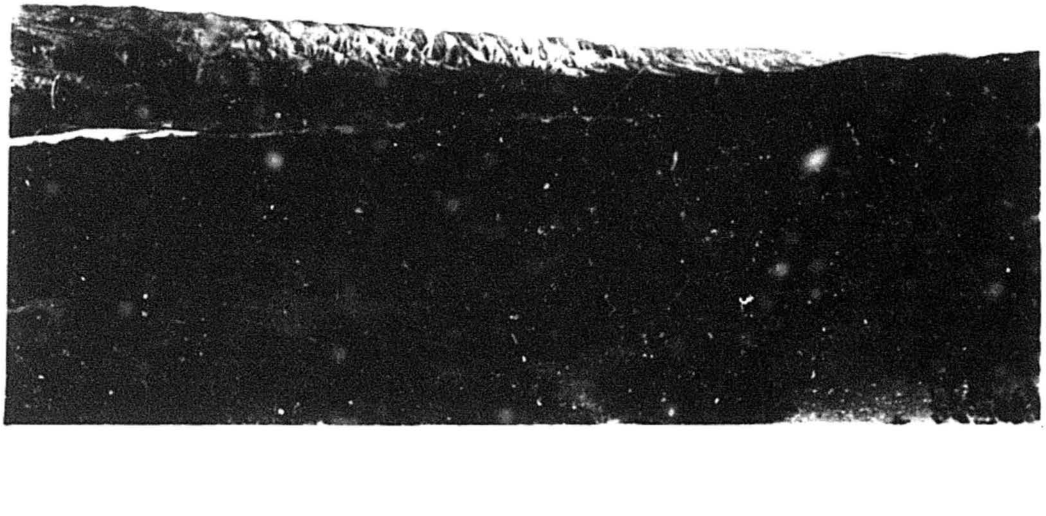
Eastward from Benson the slopes grade upward into the pediment cut in the granite and dissected by Texas Canyon, but undissected at the divide to Sulphur Spring Valley. Eastward however the pediment is overlain by alluvium. The pediment along the west base of the Dragoon Mountains is also dissected but not opposite Stronghold Canyon where there is a remarkable area of granitic pediment.

The mountains are residual elevations resulting from an uplift that may have involved the Gila conglomerate and the overlying Tertiary deposits. In the fine grained deposits are large vertebrate fossils. ~~determined by Gidley as late Pliocene.~~

There are two types of fine-grained deposits, red clay with sand and soft white limestone, and yellow sandy clay with sand, diatomaceous earth and gypsum. The two classes of material are of the same period of deposition and constitute parts of the same formation. Deposition of the Gila conglomerate and associated beds was complete by the end of the Pliocene and the uplift is subsequent. The deformed Gila conglomerate rests unconformably on older rocks including early Tertiary lavas. The post-Gila deformation closed the Pliocene epoch. The mountain uplift is of block-fault type.

Plate 6. A. Aravaipa terrace, lowland along San Pedro River, and pediment slopes on west side of valley;

B. Bluffs of the Whetstone pediment 3 miles southeast of Cascabel, looking downstream.



Terraces.

Along the lower San Pedro valley in the vicinity of the mouth of ~~Aravipa Cre-~~ Aravaipa Creek there are remnants of a wide prominent terrace of gravel sand and silt which is called the Aravaipa Terrace. This lies about 30 feet above the lowland along the river and represents an early stage of erosion and deposition by Aravaipa Creek. The terrace and its relation to the Whetstone pediment and higher slopes is shown in Plate 6, A and B.

Throughout the course of the San Pedro River north of the International Boundary and probably also for some distance in Mexico the stream flows in an "inner valley" This is bordered in part by bluffs 20 to 60 feet in height which mark the lower border of the Whetstone pediment. This inner valley constitutes bench or terrace land along the river which flows in a channel between banks several feet high.

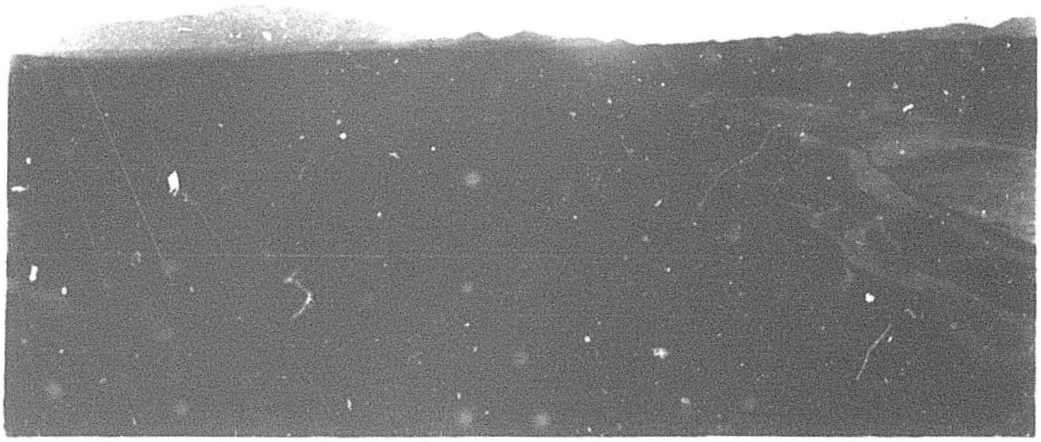
In the valley of the upper portion of Aravaipa Creek there are similar although less prominent bench lands and also along portions of the Babocomari River which is the largest tributary that enters the San Pedro Valley from the west.

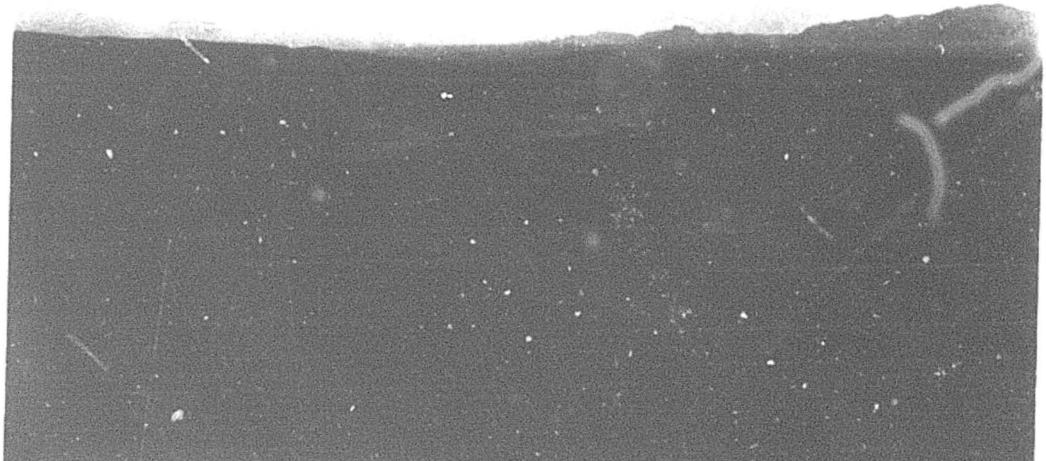
Channel trenching.

Before cultivation of the valley land was undertaken it is recorded that the stream channels were small and there was little destructive erosion. The evidence on this matter in the San Pedro Valley has been summarized by Bryan as follows:

Plate 7. A. San Pedro River 4 miles below Redington, showing lateral cutting and irrigated bottomland, looking upstream;

B. Mesquite-covered bottom land 2 miles north of Redington, looking upstream. Cliffs of volcanic tuff upstream, in the distance.





Bryan, Kirk, Date of channel trenching (arroyo cutting) in the arid southwest; Science, new series, vol. 62, pp. 342, 1925.

The channel on San Pedro River was cut progressively headward between the years 1883, when the arroyo first formed at the mouth of the river, and 1892, when the head water fall cut through the boundaries of the Boquillas Grant, 125 miles upstream. The floor of the valley was originally covered by sacaton grass with groves of cottonwood, ash and willow. Since the arroyo was cut a great forest of mesquite has sprung up.

The character of the trenching along a part of the river channel north of Redington and the development of a wide mesquite flat in the same district are shown in Plate 7, A and B.

Within recent years much cutting has been done by the San Pedro River especially between Charleston and Los Alamos and between Redington and the mouth of the stream. Before 1900 the river near Benson is said to have had a channel only 3 feet deep. In 1934 the river was there entrenched about 15 feet deep with vertical banks which were widening and destroying cultivated fields. Floods in 1920-1927 are said to have deepened the channel as much as 9 feet in some portions below Benson. Much of the recent cutting however has consisted of a widening of the channel rather than its deepening.

Triple space

The altitude of the river channel at the International Boundary is about 4,270 feet;at the Charleston damsite 23 miles downstream it is 3,950 feet. At "The Narrows" 39 miles below Charleston the altitude is close to 3,300 feet. At the damsite near Redington 26 miles farther downstream it is 2,820 feet,and at the junction of the San Pedro with the Gila,44 miles farther downstream,the altitude is 1,910 feet. The gradient of the four portion of the river marked by the three bed-rock gorges are therefore 13.9,16.7, 18.5,and 20.7 feet to the mile. This steepening of the gradient downstream is different from the gradient of most river channels,which are steeper in their upper portions than in the lower portions of their courses. The steepening of the gradient along the San Pedro River has possibly been a factor which aided the headward deepening of the channel after trenching was started.

Plate 8. A. Canyon of Aravaipa Creek at Brandenburg ranch;

B. Valley of Babocomari River, near Horne ranch, 5 miles below Elgin.

Streams.

The drainage basin of the San Pedro River is comparatively narrow and there are few tributary streams of importance. The largest two are Aravaipa Creek and the Babocomari River. Both have perennial flow but they become almost dry in the latter portions of dry seasons. The San Pedro River usually becomes dry along portions of its lower course during the dry season as its water is diverted into irrigation ditches.

The general character of the lower portion of the canyon of Aravaipa Creek is shown in Plate 8,A and the middle portion of Babocomari River is shown in Plate 8,B.

The area of the drainage basin above Palominas which is 3 miles north of the International Boundary is 991 square miles, of which about 40 square miles is in the United States. Gaging stations have also been maintained farther down stream, near Fairbank, in connection with a dam site at Charleston, to which place the gaging station was later moved. A short record is also available of the river discharge near Mammoth in its lower course, and a separate station has been maintained on Aravaipa Creek. The available records are given in the following tables:

U.S.Geol.Survey Water Supply Paper 734, p. 113, 1933.

Yearly run-off of San Pedro River, in acre-feet.

From records of the U.S. Geological Survey (Water-Supply Paper 389 and later published data)

Years ending Sept. 30.

Gaging station:	near Mammoth	near Fairbank	at Charleston	at Palominas
Drainage area, square miles:	3,850	1,500	1,260	991
Year.				
1914		148,000		
1915		60,300 [a]		
1916		34,200		
1917		90,200		
1918		20,300		
1919		93,500		
1920		41,800		
1921		102,000		
1922		36,500		
1923		41,200		
1924		25,300		
1925		36,800		
1926		122,000		
1927		51,700		
1928		20,100		
1929			54,100	
1930			53,500	
1931			64,900	31,800
1932	65,800		45,900	26,100
1933	15,000		28,200	13,800

[a] Record missing for Dec. 19-30 and Jan. 1-21.

Discharge in 1933:	Second-feet. Maximum	Minimum
Near Mammoth	19,400	0
At Charleston	9,600	3
At Palominas	4,700	1

The maximum recorded discharge of the San Pedro River at Charleston was about 98,000 second-feet, on Sept. 28, 1926.

Run-off of Aravaipa Creek 6 miles above its mouth.

From U.S.Geol.Survey Water-Supply Papers 734, p. 117, 1933 and 749, p. —, 1935.

Drainage area,535 square miles.

For years ending Sept.30.

Year.	Acre-feet.
1932	29,100
1933	13,700

Discharge in 1933:	Second-feet	
	Maximum	Minimum
	9,300	2

The maximum recorded ~~measurement of~~ discharge of Aravaipa Creek was 20,000 second-feet, on Aug.2,1919.

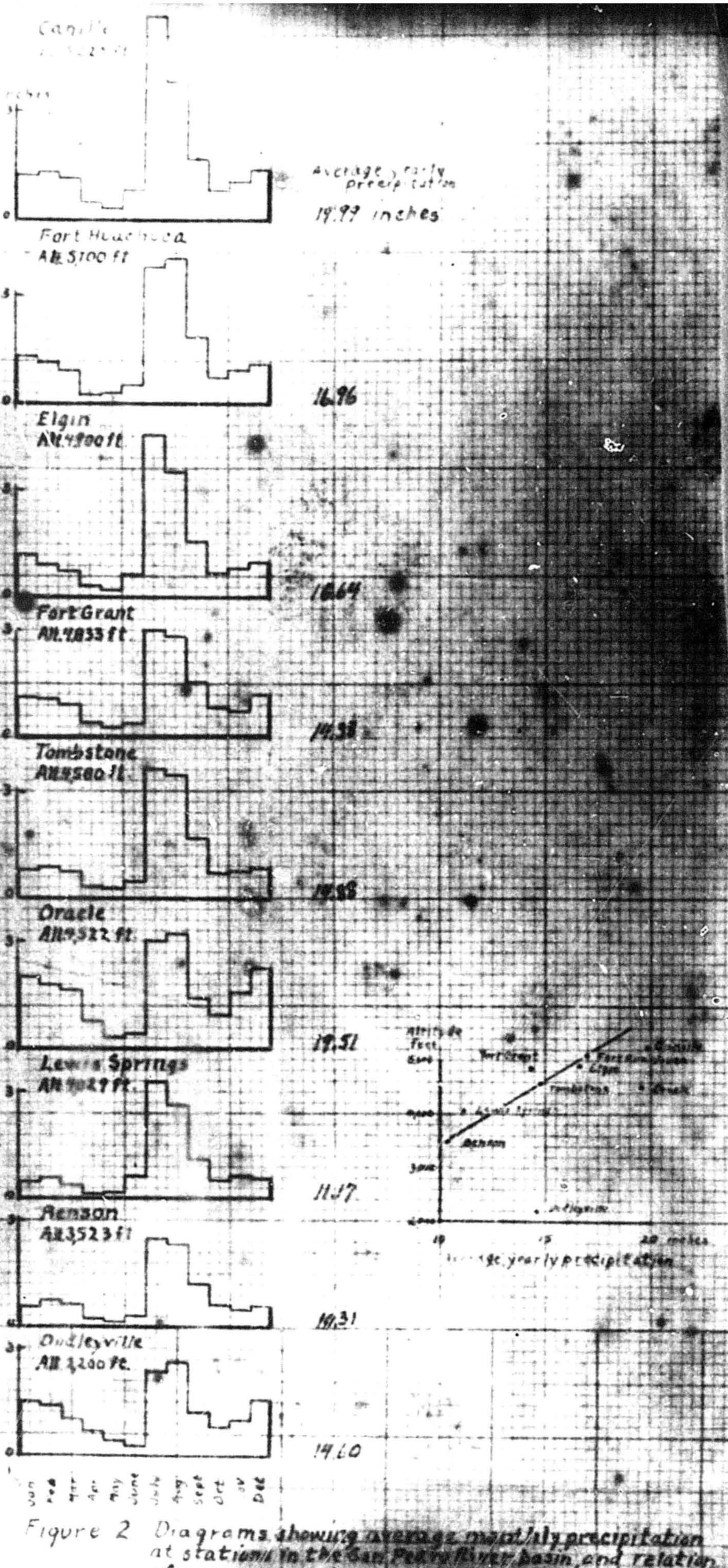


Figure 2 Diagrams showing average monthly precipitation at stations in the San Pedro River basin, and relation of average yearly precipitation to the altitude.

Climate.

The climate of the entire San Pedro River-basin is arid, the average yearly precipitation being about 10 inches in the lower portions increasing to about 20 inches in the higher valley lands. Nearly one-half of the entire rainfall comes in between July 15th and September 15th, with a secondary rainy season from December to March. The average monthly rainfall at several stations, taken from records of the United States Weather Bureau are shown graphically in Figure 2 which clearly shows the rainy seasons. The rainfall increases almost directly with the increase in altitude although local conditions have some effect. If the average yearly precipitation at Benson, Tombstone, and Fort Huachuca be taken as representing the normal increase with altitude, it appears that the precipitation at Lewis Springs and at Fort Grant is somewhat below this normal. This may be due to the fact that they are situated in open areas at the western base of wide uplands. At Canille (near Canelo school) and at Oracle, both of which stations are on the northern slope of uplands, the precipitation is somewhat above that which is normal for equal altitudes in the valley lands. At the former village of Dudleyville near the mouth of the San Pedro River the rainfall is considerably above that in the lower part of the San Pedro Valley because the station is within the area of increased rainfall which extends up the valley of the Gila River.

During December to March snow occasionally falls on the mountains above altitudes of 6,000 feet and may remain for several weeks. The yearly records of precipitation at several stations that have been maintained in the river basin by the United States Weather Bureau are given in the following tables:

Page 44 goes here →

The figures show a great variation in the precipitation from year to year and also a considerable variation in the different portions of the valley. This is due to the fact that most of the summer rains come as local showers which are not uniformly distributed. The winter precipitation comes as more general storms.

The great yearly variation in the rainfall considerably affects the shallow ground water supplies and greatly affects grazing conditions. Springs and other shallow watering places may go dry during prolonged draughts and even domestic supplies from shallow wells may fail. The ample rainfall of 1905-1907 and 1914-1916 induced the settlement of considerable land where attempts were made at dry farming but in each period the succeeding dry years caused the abandonment of many homesteads.

Precipitation at stations in the San Pedro River basin.

The record of snowfall at several stations in the river basin is as follows:

Record of average snowfall at stations in the San Pedro River basin, Ariz.
From records of the U.S. Weather Bureau.

Station.	Length of record Years.	Snowfall Inches.
Camille	29	13.8
Fort Huachuca	18	7.7
Oracle	35	13.1
Tombstone	32	5.4

The following records show the average temperature, and range of temperature at several stations:

Record of temperatures at stations in San Pedro River basin, Ariz.
From records of the United States Weather Bureau.

Station	Length of record, years.	Temperatures, °F. Average yearly °F.	Average maximum (July)	Average minimum. Dec.	Jan.	Highest recorded.	Lowest recorded.
Benson	47	64.3	96.5	28.8	29.1	110	5
Camille	40	60.1	89.4	25.6	25.4	109	7
Fort Grant	24	61.8	88.9	33.3	33.8	111	10
Fort Huachuca	32	61.4	90.9	33.6	33.3	105	0
Oracle	35	62.2	91.4	38.2	38.9	106	8
Tombstone	35	62.7	93.6	34.0	34.8	110	9

As in all arid regions the range of temperature between day and night is great, and although the summer days are hot the nights are usually cool. The average annual temperature and the monthly maximum and minimum temperatures, also the highest and lowest recorded temperatures for several stations in the valley are tabulated on page

Vegetation and animal life.

Along the main stream channels where ground water is at a shallow depth there are scattering cottonwoods and willows, but perhaps the most characteristic trees of the lower lands are the mesquite, palo verde and palo fierro. All three are legumes and bear pods containing seeds that were used by the Indians for food and are still eaten by cattle. The mesquite grows most thickly on the former flood plain of the San Pedro River and forms low forests of trees 15 to 30 feet high, with trunks from several inches to a foot in diameter. Some of these forests have developed within the past 50 years on lands that were formerly covered by sacaton grass and willows. But these growths have been replaced by the mesquite since the river channel has deepened and the ground water level has consequently been lowered.

Bryan, Kirk, Change in plant associations by change in ground-water level: Ecology, vol. 9 no. 4 pp. 474-478, 1928.

In some places along with the mesquite there are a few palo verde trees, which are easily recognized by their green trunk and branches. On higher slopes these trees are much smaller and in some places are hardly more than shrubs. The palo fierro (ironwood) is usually found along dry washes on the higher alluvial slopes and near the bases of mountain slopes. Where it is well developed it forms a large tree with a bushy crown of blue-green leaves.

The upper alluvial slopes are in places partly covered by catclaw (Uña de gato) a term used for several bushy species of acacia whose branches carry many curved thorns. The ocotillo is one of the most striking of the desert plants and is found on some of the higher pediment slopes in the northern part of the valley. The plant consists of a number of stems about an inch in diameter and 5 to 10 feet long rising and spreading from a low base. The stems have numerous short thorns, and in the springtime are covered with clusters of small bright-red flowers. On the upper parts of the slopes in the northern part of the valley there are occasional individuals of the sahuaro cactus. This great candelabra-like cactus is not so common in the San Pedro Valley as it is farther west in the vicinity of Tucson. Smaller species of cactus are found on some portions of the pediment slopes in the northern part of the valley. The creosote bush also covers portions of the lower alluvial outwash slopes; and sacaton grass, a coarser variety of some value for forage, grows on some of the bottom land where ground water is present within a few feet. On open slopes in the Elgin district in the southwest part of the river basin the yucca or Spanish bayonet, and the sotol, a species of agave or century plant, are common. In this area bear grass, a coarse harsh variety which grows in large clumps is also found in some portions. Above an altitude of about 5,000 feet these desert plants give way to live oaks, beneath whose shade there are several varieties of gramma and other forest grasses. On the higher mountain slopes there are junipers and pinon trees, and above 6,000 feet a thin forest of yellow pine. These upper mountain areas have been included in the Crook National Forest and Coronado National Forest in order to conserve the timber and efficiently use the grazing.

The region has so long been settled and used for cattle raising that there is not a great amount of native wild life. Among the larger animals the coyote, wild cat and fox are occasionally seen. They probably increase and diminish in numbers in accordance with the supply of jack rabbits and cottontail. A few small rodents chiefly the pack rat and a species of kangaroo rat are fairly common. The early explorers trapped beaver along the San Pedro River but these animals were long ago killed off. It was locally reported that a few deer still are to be found in parts of the mountains.

Turkey buzzards, ravens, a few owls and small hawks are the most notable birds in the region. An occasional road runner may be seen, and in the higher lands there are a few bands of quail and doves. During the dry seasons there are few snakes or poisonous insects in evidence, but these are to be seen more commonly in the rainy season.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES.

The rocks which compose the mountains that border the San Pedro Valley consist chiefly of granite, diabase, and porphyry, which are mostly of pre-Cambrian age; schist of probable Archaean age; quartzite, limestone, and shale of Cambrian age; limestone of Devonian age; small areas of sedimentary rocks of Carboniferous age; sandstone and shale of Lower Cretaceous age; and less consolidated deposits of Tertiary and Quaternary ages.

The more ancient rocks are for the most part compact and contain only small amounts of ground water. In some places where the rock is deeply disintegrated, as it is in the Oracle district, water may be found in the dense rock at depths of less than 50 feet. In other places, as exemplified by the mines of Tombstone, the dense rocks may be dry down to depths of several hundred feet. The several classes of rock and their approximate thicknesses and water-bearing properties, in the San Pedro Valley and adjacent mountains, are listed in the following table.

Principal rock formations in the San Pedro River basin, southeastern Arizona, and their water-bearing properties.

System, series, and formation	Character of material.	Approximate thickness feet.	Water-bearing properties.
Quaternary	Alluvium; silt and sand of the inner valley; and sand and gravel of washes.	10-~~100~~ 80	Saturated with ground water at comparatively shallow depth and supply moderate amounts to wells.
Unconformity			
Tertiary Pliocene	Stream and lake deposits of sandy clay, sand, gypsiferous clay, gravel, and conglomerate (Gila conglomerate), of the upper valley sides.	1,000+	Partly consolidated porous beds containing considerable water which is under artesian pressure in some beds In general the deposits are too fine grained to yield abundant supplies.
Unconformity			
Cretaceous Lower Cretaceous	Red shale and sandstone, with thin beds of gray limestone; chiefly on the west side of Whetstone and Huachuca Mountains.	1,000+	Comparatively porous rocks which store considerable ground water and supply small amounts to springs and wells.
Unconformity			
Carboniferous Pennsylvanian Tornado limestone	Dense limestone	200+	These are dense rocks containing little water except that which is stored in fractures and seams; and supplies small springs.
Devonian Martin limestone	Dense, thick-bedded white limestone, forms parts of several of the mountain masses.	200-400	

Cambrian			
Upper Cambrian			
Abrigo limestone	Dense,gray,crystalline limestone.	500-700	
Bolsa quartzite	Thick ledges of white quartzite		
	(These two formations make a narrow zone underlying the Martin limestone in the mountains on both sides of the southern part of the valley.	150-450	
Cambrian or Algonkian			
Apache group	Quartzite,limestone,and shale;small areas on the flanks of mountains on northwest side of the valley.	200+	
Archaean ?			
Pinal schist	Dark mica schist;constitutes a large part of the Santa Catalina Mts.,most of the Rincon Mts.,and small portions of the Little Dragoon,Dragoon,Mule,and Whetstone Mts.	1,000+	
Igneous rocks:			
Tertiary and Cretaceous	Volcanic rocks consisting of rhyolite, basalt,tuff,ash,and agglomerate.	500+	The fragmental materials are porous and afford storage for considerable ground water.
Cretaceous	Intrusive rocks,of granite,diorite,and porphyry.	1,000	These are dense rocks which in most places contain little water;but where greatly frac - tured they may afford storage for considerable suppl[illegible]
Mostly pre-Cambrian	Granite,diabase and other crystalline rocks.	1,000+	

Pre-Tertiary rocks.

On the east side of the valley the Santa Teresa and Pinaleno Mountains consist chiefly of granite and schist, although there are some later e rocks in the southern portion of the latter mountains. In the lower part of the canyon of Aravaipa Creek there are areas of ancient diabase. The northern part of the Little Dragoon Mountains consist of schist overlain by Carboniferous and Devonian limestones. The southern part of these mountains is of granite, which extends southward and forms a large part of the Dragoon Mountains, together with Devonian limestone and intruded granite porphyry. In the central part of the mountains these older formations are in part overlain by Lower Cretaceous sandstone and shale. The Tombstone Hills are of Carboniferous and Devonian rocks, intruded by Cretaceous granite and overlain by remnants of Cretaceous strata. According to Ransome as quoted by Darton, the rocks in the Tombstone district consist of

Darton, N.H., Guidebook of the western United States, Part F, The Southern Pacific lines New Orleans to Los Angeles: U.S. Geol. Survey Bull. 845, p. 177, 1933.

~~Basl~~ basal strata of 440 feet of Bolsa quartzite and 700 feet of Abrigo limestone. Next above are 340 feet of Martin limestone, 500 feet of Escabrosa limestone (Mississippian), and 2,000 tp 3,000 feet of Naco limestone (Pennsylvanian and Permian). There is much faulting.

At Lewis Sprin s and at intervals northward porphyry is exposed along the valley bottom,probably along the crest of a buried ridge that extends from the Tombstone area.

The Mule Mountains consist of a core of granite and schist,with Carboniferous and older limestones and quartzites on the western side.

On the western side of the valley the Tortilla Mountains in the north are of granite,with a band of Cambrian and Algonkian rocks along their east border and some Cretaceous volcanic rocks in the southern end of the mountains, The

Black Hills are an extension of the same rock formations southeastward into the lower portion of the valley. In the Oracle district ancient granite is the principal rock but a large part of the northern portion of the Santa Catalina Mountains is of intrusive granite with minor areas of diabase and of ancient limestone and quartzite. The Rincon Mountains consist almost wholly of schist. Farther south the Whetstone Mountains consist of granite in the northern portion and of ancient sedimentary rocks in the southern portion. Cretaceous sandstone and shale overlie the older sedimentary rocks in the southwest part of these mountains. In the Mustang Mountains the Martin limestone, of Devonian age, forms prominent cliffs and is intruded in some places by Cretaceous granite. The north flank of the Canelo Hills is formed of Carboniferous and Devonian rocks. The core of granite is exposed however in a pass near the east end of the hills. In the Huachuca Mountains the granite core is extensively exposed but is overlain in part by the ancient sedimentary rocks, and sandstone and shale of Lower Cretaceous age form the western side of the mountains.

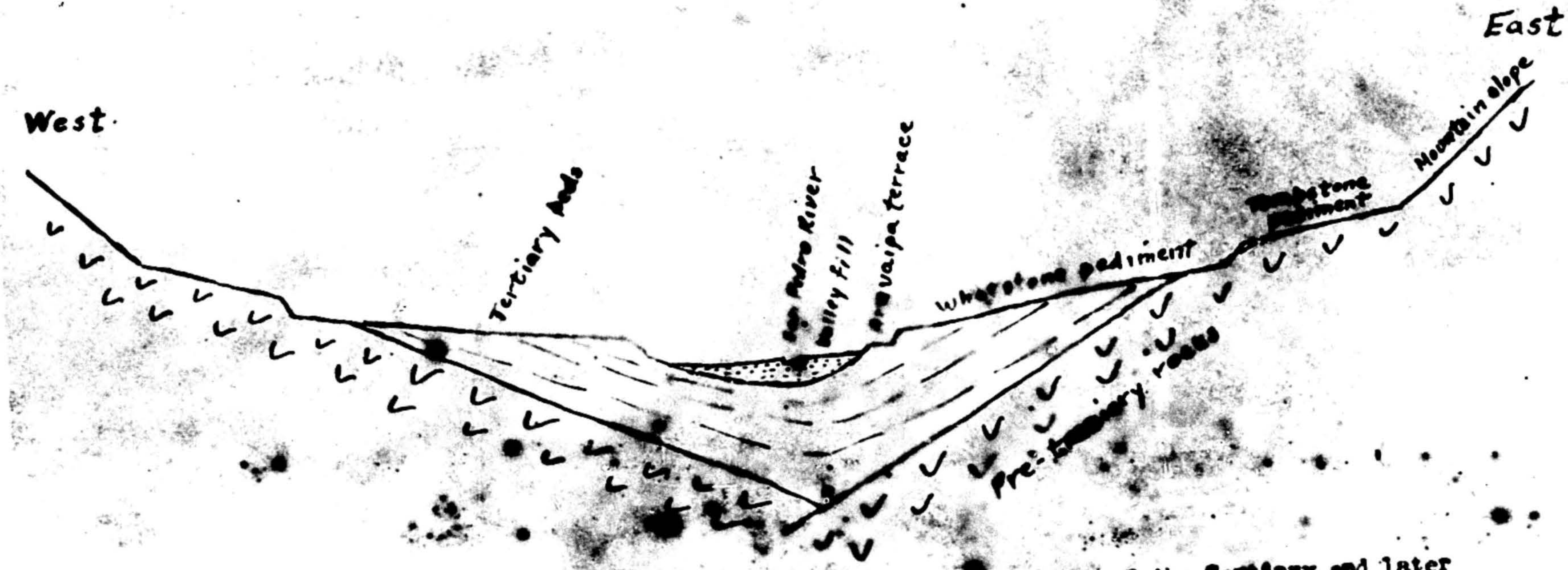


Figure 3. Sketch section showing general relation of the bed rock and the Tertiary and later deposits in San Pedro Valley. (After note-book sketches by Willis T. Lee and Kirk Bryan).

Tertiary sedimentary deposits.

The greater part of the lower slopes of San Pedro Valley is underlain by deposits of clay, sand and gravel. Some of these beds were laid down in fairly uniform layers in a lake or lakes that once occupied the valley during ~~a part of~~ Tertiary time. The coarser deposits probably were laid down by streams which entered the lakes. The approximate extent of these deposits is shown by the extent of the Whetstone pediment, indicated on the physiographic map Plate 2. The geologic boundaries of these Tertiary deposits were not mapped in detail during the course of field examination. The relation of these sedimentary beds to the older bed rock is indicated approximately in the ~~sketch~~ cross section, Figure 3. The earliest Tertiary deposits seem to consist of beds and lenses

Figure 3, Cross section showing general relation of the bed rock and the Tertiary and later deposits in San Pedro Valley.

of coarse conglomerate which were named by Gilbert the Gila conglomerate from their prominent exposures in the Gila River Valley.

Powell, J.W. U.S.Geog.Surveys W.100th Mer.Rept.vol.3 Geology 1875 Part 5 Geology of portions of New Mexico and Arizona explored in 1873 by G.K.Gilbert, pp.503-542 (Description of Gila conglomerate on pp.540-541).

The character of this conglomerate in the vicinity of the lower part of the San Pedro Valley has been described by Ransome who considered it tentatively to be of Pleistocene age. Schwennesen considered the Gila conglomerate to be a distinct formation underlying finer-grained lacustrine deposits but Knechtel after making more detailed studies in the same region considered that the beds of Gila conglomerate interfinger with and are an integral part of a thick series of stream and lake deposits that are, at least in part, of upper Pliocene age. Knechtel believes however that in some places there may be present a series of Tertiary deposits earlier than the Gila conglomerate and its associated beds.

- Ransome, F.L., The copper deposits of Ray and Miami, Ariz.; U.S. Geol. Survey Prof. Paper 115, pp. 71-74, 1919. U.S.Geol.Survey, Geol.Atlas, Ray folio (No.217) pp.13 and 14, 1923.
- Schwennesen, A.T., Geology and Water Resources of the Gila and San Carlos Valleys in the San Carlos Indian Reservation, Arizona, U.S.Geol.Survey Water Supply Paper 450, Fig.2 and pp.7, 8, 1921.
- Knechtel, M.M., Contribution to the late Tertiary and Quaternary history of southeastern Arizona, Geology and Water Resources of the Gila and San Simon Valleys, Graham County, southeastern Arizona: U.S.Geol.Water Supply Paper (in preparation). —, p. , 19—

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Fossil bones of mastodons and other large mammals and also of smaller animals have been found in the deposits in the San Pedro Valley and identified as being of upper Pliocene age. At five places in the San Pedro Valley such fossils were found by Bryan and Gidley and the material has been described in two publications by the latter.

- Gidley, J.W. Preliminary report on fossil vertebrates of the San Pedro Valley, Ariz. U.S.Geol.Survey Prof.Paper 131 pp.119-131, 1925;
- Fossil proboscidea and Edentata of San Pedro Valley Ariz. U.S.Geol. Survey Prof.Paper 140 pp.83-95, 1926.

In the fine-grained deposits there are in some places beds of gypsum and

Ross observed in the Aravaipa district tilted sedimentary

Ross, C.P., Geology and ore deposits of the Aravaipa and Stanley mining districts, Graham County, Ariz., U.S. Geol. Survey Bull. 763, pp. 29-30, 1925

deposits, interbedded with lavas and tuffs, which he considered to be of Miocene (?) age. There is an angular unconformity between them and the overlying nearly horizontal beds of the Gila conglomerate. Moore has mapped tilted sedimentary beds

Moore, Bernard N., ~~U.S. Geol. Survey, Geol. Atlas, Tucson folio (in preparation).~~ Oral communication

along the Pantano Wash, west of the San Pedro Valley, which he considers to be of Miocene age. It is possible that the tilted beds along the Babocomari River, that have been considered to be a part of the Gila conglomerate formation, may also be of earlier geologic age than the Gila conglomerate.

diatomaceous earth. Gypsum beds 2 or 3 feet are exposed near the mouth of Aravaipa Creek. Beds of diatomaceous earth 3 feet thick are exposed about 8 miles southeast of Benson and have been worked commercially, some of the material being used at the plant of the Apache Powder Company nearby. In the same locality there are also beds of gypsum which have been worked by the Arizona Gypsum Plaster Company.

These Tertiary beds of comparatively soft and porous materials contain much ground water and constitute the most extensive water-bearing formation in the valley. On the higher slopes water is found in them at depths dependent on the thickness of the deposits and the depth to the more compact bed rock. Beneath the lower valley they contain at depths of a few hundred feet water that is under artesian pressure, and in a few areas this pressure is great enough to produce flowing artesian wells.

Tertiary volcanic rocks.

During Tertiary time there was considerable volcanic action in this region. In addition to flows of lava thick deposits of volcanic breccia were formed in the lakes of the valley and there were extensive showers of volcanic ash. On the east side of the valley the Galiuro and Winchester Mountains which separate the upper valley of Aravaipa Creek from the main San Pedro Valley are composed almost entirely of Tertiary volcanic rocks. Farther south the southwestern part of the Dragoon Mountains is composed largely of Tertiary lava. Near Tombstone there are small areas of basalt which seem to be of Tertiary age.

In the lower part of the San Pedro Valley there are a few small hills composed of lava, tuff and agglomerate of probable Tertiary age. The harder rocks are of little importance as water bearers but the layers of tuff and agglomerate are quite porous and are capable of storing much water. Where they are exposed on the surface however they are too thin to have much value as reservoirs for shallow ground water. Probably within the series of Tertiary beds in the northern part of the valley near Malpais Hill there may be some tuff and agglomerate interbedded with the finer grained more truly sedimentary materials. Such buried layers of volcanic material if present may contain much ground water.

A small lava hill on the east side of the San Pedro River 3 miles southeast of Winkelman is composed of tuffaceous beds which dip ~~about 35°~~ 27° northeastward. Malpais Hill consists of ~~steeply dipping~~ gray andesite and breccia, dipping about 40° to the northeast.

Post-Tertiary deposits.

The post-Tertiary deposits are limited chiefly to the alluvium along the principal stream channels. The area of chief importance for its ground water possibilities is the inner valley along the San Pedro River. The alluvium or valley fill is believed to have a maximum thickness of about 80 feet as judged from available well records.

The alluvium is saturated with water at approximately the level of the river channel and supplies water on many small ranches by means of shallow wells dug in the bottom land. These wells yield ample supplies for domestic use but at the time of examination the shallow ground-water supply had hardly been tested for irrigation purposes. In most of the inner valley where the bottom land is wide enough to afford considerable areas of cultivable land nearly all wells that have been sunk have been drilled to the deeper horizons of artesian water, and the shallow waters have been cased off.

IRRIGATION.

Surface water.

Early use.

After the establishment of the Mexican Republic in 1823, the settlement of valley lands that now form part of southern Arizona took place. Along the upper San Pedro River two grants of land were made by the Mexican government, the San Rafael del Valle grant extending from the present Hereford to Lewis Springs ~~and about~~ ~~[illegible]~~; and the San Juan de Las Boquillas y Nogales grant embracing the land of the inner valley from Charleston downstream for about 14 miles. The San Ignacio del Babocomari Another grant in the valley of the Babocomari River includes most of the valley land~~s~~ along that stream.

These lands were used by the Mexican proprietors for the grazing of cattle in connection with which industry much of the bottom land was devoted to the growing of wild hay. Irrigation of these meadows was accomplished by ditches taking water from the river. Such use has been continued to the present time.although ownership has passed from the Spanish-American to American owners the land grants have not been subdivided as they have been in other parts of Southern Arizona and in Southern California; but they have been continued as cattle ranches and have been added to by the acquisition of adjacent lands chiefly through the purchase of homesteads.

In 1934 the two grants along the San Pedro River ~~had~~ and considerable land on the adjacent slopes were operated by the Boquillas Land ~~and~~ & Cattle Company. The Babocomari ranch was operated by the Babocomari Cattle Company.

Hereford ditch.

One of the earliest irrigation ditches to be constructed was that which supplies water to lands in the upper part of the San Rafael del Valle grant. This has its intake about 2 miles above Hereford and covers bottom lands on the east side of the river for about 2 miles below that place. After the summer floods have ceased the custom has been to construct a brush and sand wing dam diverting water into the ditch. The deepening of the river channel in in recent years has however rendered difficult the diversion of water by this simple means. During some seasons of low water little irrigation has been accomplished.

Boquillas ditch.

In the northern part of the Boquillas ranch a considerable area of bottom land has been irrigated by a ditch taking water from the river about 3 miles above ~~Fort~~ Fairbank. For several years prior to 1934 however the limited supply of water available and the cutting and shifting of the river channel had greatly reduced the acreage that could be thus watered.

St.David ditch.

In ~~19~~ the nineties a community ditch was built by the colony of St.David taking water from the river about 9 miles upstream and supplying land on the east side of the valley in the vicinity of St.David. In 1934 there was under irrigation from this ditch about ~~1,000~~ 2,000 acres most of which consisted of alfalfa fields. Difficulty has been experienced in keeping the ditch in operation because the diversion dam which is partly of plank construction has been repeatedly washed out by minor floods. The deepening and widening of the channel has also necessitated much work in directing the river water into the ditch. By lining part of the ditch with concrete the seepage losses have been considerably reduced.

Curtis ditch.

A minor ditch at a lower level than the St.David ditch was early constructed ~~about 1910~~ to irrigate land on the farm of Mr.J.N. Curtis and adjacent landowners. Much difficulty was experienced in keeping the intake of the ditch in operating condition and in some seasons of low water ~~little~~ water was available for this ditch. In ~~1927~~ 1926 the diversion works were destroyed by flood. In 1934 this ditch had not yet been repaired and the orchards and alfalfa fields formerly irrigated by it were not productive.

Benson ditches.

The main Benson ditch, operated as a community enterprise by farmers in the valley between St.David and Pomerene, takes water from the river about 1 mile below St.David by means of a concrete diversion dam. The main ditch has a length of about 7 miles along the east side of the inner valley and is lined with concrete in some portions. It supplies water to nearly 1,000 acres of alfalfa, wheat and corn. The character of the irrigated lands near Pomerene is shown in Plate 9 A. Early in 1934 another concrete diversion dam was constructed about 2 miles below the headworks of the main ditch to irrigate land on the west side of the river.

Minor ditches:

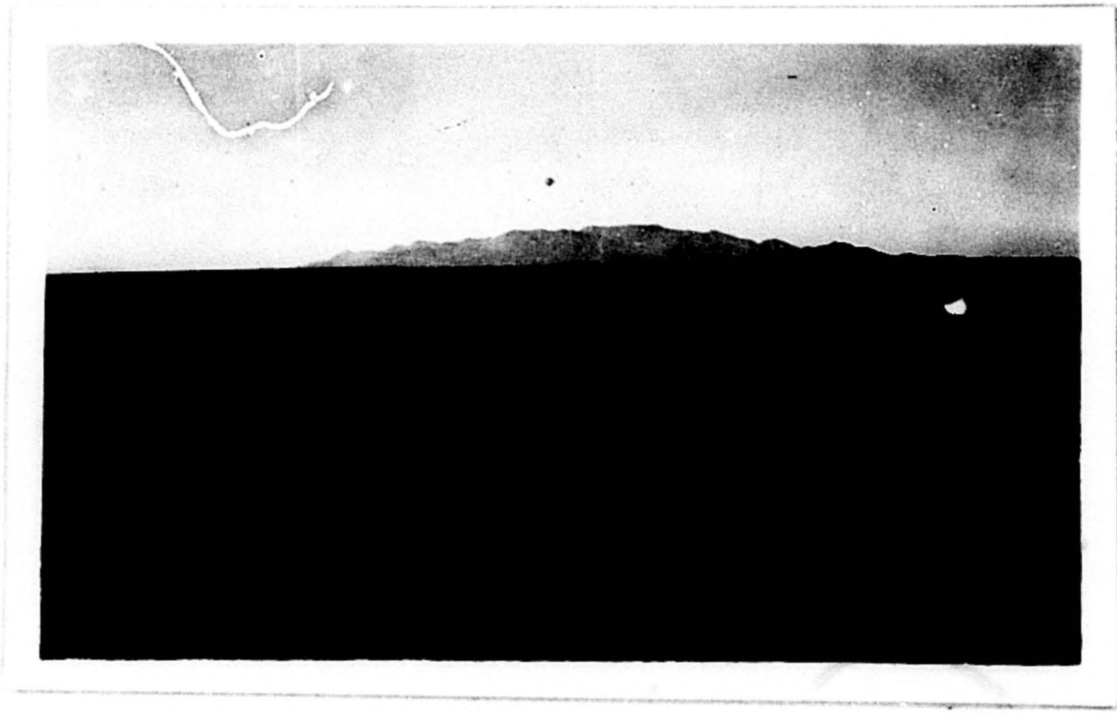
During the early years of settlement of the valley below Benson numerous ditches were constructed on both sides of the river to water small fields, but the deepening of the river channel rendered ~~Minor ditches.~~ most of them inoperative. In 1934 only a few were in use.

On the west side of the valley about 2 miles below Tres Alamos fields of meadow land on the White House ranch have been irrigated by a short ditch taking water from the river. The deepening of ~~the river channel in this portion~~ this portion of the river channel since 1920 has reduced the efficiency of this ditch however, and made it difficult to maintain diversion works.

On the Arandoles ranch above Apodaca school a small ditch in 1934 supplied water to about 60 acres of alfalfa. Near the school another ditch took out water and irrigated a similar area 1 to 1½ miles below, on the Hernandez ranch. A third ditch watered fields on the next ranch below and a fourth ditch irrigated about 80 acres on the Poole or Bedegain ranch. All the bottom land along this portion of the river is on its eastern side, for the stream cuts against the bluffs on the west side of its channel, (See Pl.6 B.)

Plate 9. A. Fields near Pomerene, irrigated in part from flowing artesian wells. Benson and the Whetstone Mts. in the distance;

B. San Pedro Valley near Redington, showing irrigated land. Galiuro Mountains in the distance.



Bench land 1 to 2 miles north of Cascabel has been brought under irrigation from a small ditch heading near the postoffice. This portion of the river channel was deepened several feet by floods in 1927 and reconstruction of the ditch was necessitated. Even in times of low water there is a supply available to it however from spring water or river underflow which comes to the surface in the channel about 100 yards above the head of the ditch.

From the Baylies ranch at Redington about 60 acres of alfalfa is watered from the river, and 2 miles downstream another field of bottom land, which is shown in Plate 9, B is similarly irrigated.

On the west side of the river the bottom land on the Sacaton ranch was formerly irrigated with ditch water but the cutting of the river banks in 1927 rendered the ditch unusable. On the Wills ranch on the east side of the valley about 5 miles farther downstream river water has been used for irrigating alfalfa and on the Clark ranch near Mammoth about 20 acres was under irrigation by ditch in 1934.

The diversion of water by these small ditches renders the river channel dry or nearly so for several miles below Mammoth during the periods of greatest irrigation. Below the mouth of Aravipa Creek however considerable underflow reappears in the river channel. Irrigation on the ranch of Smith Brothers at formér Feldman post office, is accomplished by accumulating the river discharge in Cook's Pond, a shallow reservoir formed by low earthen embankments. This reservoir also stores the water from several springs, possibly of artesian character, which issue for about one quarter of a mile along the border of the river lowland, with a total discharge of perhaps 100 gallons a minute. At periods of about two weeks, when a sufficient amount of water has accumulated to give the necessary head and volume in the irrigation ditches, the water is distributed on 225 acres of bottom land, on which wheat has been grown.

About 6 miles below Smith Brothers' ranch a ditch irrigates 150 acres of alfalfa and orchard on the ranch of Mr. Miles Ray, near the mouth of the valley. The narrow areas of bottom land on the west side of the river near its mouth have been so extensively cut away since 1920 that little cultivated land remained in 1934.

Along Aravaipa Creek and the Babocomari River, which are the two principal tributaries of the San Pedro River, the dry-season discharge of each stream is fully used for irrigation. On the lower course of the former stream (see Pl. 8, A), small orchards and gardens on 13 ranches are irrigated, and the entire discharge at the mouth of the canyon is diverted onto alfalfa fields, so that the stream channel is normally dry where it joins the San Pedro River.

On the Babocomari ranch the river discharge is used chiefly on meadows of wild hay (see Pl. 8 B). The lower portion of the river course is through a canyon in which there is no cultivable land.

Flood water from Government Wash was for a few years stored in an earthen dam beside its lower course for irrigation of fields of maize and Johnson grass; but the uncertainty of the supply rendered the project unsuccessful.

Plate 10. A. Damsite on San Pedro River near Charleston, looking upstream. Bronco Hill in the distance;

B. San Pedro Valley near Palominas, showing long artesian slope of the valley sides. Huachuca Mountains in the distance.

Charleston reservoir project.

Irrigation in the San Pedro Valley by means of the natural flow of the river, with no provision for storage, has proven unsatisfactory because of the great seasonal and yearly variation in the discharge. The irrigation of lands at present cultivated would be rendered much more certain if storage were provided, and it would also be possible to irrigate a much larger acreage if the flood water could be conserved. About one quarter of a mile north of Charleston railroad station the river enters a gorge, and for half a mile passes between steep slopes of granitic porphyry which offer a good dam site, as shown in Plate 10 A. The project was examined in 1903 by the United States Reclamation Service.

U.S.Recl.Service 3d Ann.Rept. for 1903-04; San Pedro Project, pp.61-62 and 157-170, 1905.

A dam constructed to a height of 100 feet above the river bed at a site 1,500 feet north of Charleston would provide 60,235 acre-feet of storage. The tentative plans provided that irrigation water would be discharged into the river channel and taken out 9 miles below the dam by an overfall masonry diversion weir and carried in canal 6½ miles before distribution began. The construction would necessitate the rebuilding of about 9½ miles of the Southern Pacific Railroad which passes through the gorge and reservoir site at a cost estimated at nearly $125,000.

A preliminary estimate of the cost of the project was as follows:

Preliminary estimate of cost of San Pedro project, Ariz.

Total cost of storage dam, moving railroad, and other reservoir costs	$556,152
Total cost of canal and headworks	179,135
Total	$ 735,287

If a yearly supply of 80,000 acre-feet were available by storage and natural flow, it was estimated that with a canal of 250 second-feet capacity, 20,000 acres could be irrigated. The cost of the project would therefore be about $36.77 for each acre brought under irrigation.

Some preliminary measurements of the stream discharge were made and in 1914 a gaging station was established at Fairbank, 11 miles below the damsite. In 1921 several test holes were drilled in the river channel at the damsite, and the depth to bed rock was found to be more than 30 feet. In 1928 the gaging station was moved to the damsite and measurements were continued under a cooperative agreement between the United States Geological Survey and the Arizona State Engineering Department. In 1934 the project was under consideration by the State authorities with a view to obtaining Federal aid in its construction.

Other reservoir sites.

At The Narrows 14 miles below Benson the river channel is bordered on each side by steep slopes of porphyritic granite. Reconnaissance examination of the site by Mr. Bryan indicated that a dam about 300 feet long at the river level and providing for storage 100 feet deep would form a reservoir about 6 miles long with an average width of 1 mile. This would not submerge much land that has been brought under cultivation, for most of the meadow near the White House ranch would be above the water line. The amount of arable land in San Pedro Valley below the dam site is probably too small to justify a reservoir at this place; but it would have considerable value for irrigation and also for flood control if the Charleston reservoir does not prove to be a feasible project.

A damsite 1 mile north of Redington is formed by bluffs of Devonian limestone and shale and the reservoir basin above it would extend up the lower portions of Buehman Canyon and Redfield Canyon. However the cultivated land of the Redington ranch and of several other ranches for several miles upstream would be submerged by the formation of a reservoir at this site. Although the drainage area is somewhat greater than that which is tributary to the reservoir site at The Narrows, the storage basin is probably not so suitable because a considerable acreage of cultivated land would be submerged.

The Coolidge Dam, of the United States Indian Service forms ~~at the lower end of~~ the San Carlos Reservoir, ~~is~~ on the Gila River about 25 miles above Winkelman. During seasons when the water is not needed for irrigation on lands in the ~~Gila Valley~~ Florence district of the Gila Valley, such water is sent through the powerhouse at the dam to generate electricity to meet the needs of consumers. Studies have been made for a storage reservoir to impound this water below the powerhouse so that it may be conserved until needed for irrigation. For this purpose examinations of the lower San Pedro Valley has been made, but no feasible site for the storage of such water has been found.

Artesian water.

Palominas-Hereford district.

Within a narrow zone along the upper part of the inner valley in the Palominas-Hereford district several flowing artesian wells have been developed and used for irrigation. The artesian head is light however and the discharge is so small that extensive development of the artesian water has not been possible. The artesian head is apparently due to hydrostatic pressure that is developed in lensing bodies of sand and gravel beneath the slopes which extend down to the river from the Mule Mountains on the east and the Huachuca Mountains on the west as shown in Plate 10 B.

Near the river upstream from Palominas several drilled wells have struck small flows of artesian water at 150 to 180 feet and furnish supplies for domestic and stock use. Wells that have been drilled at Palominas, which is about 50 feet above the river channel strike water that is under considerable artesian head but not sufficient to produce flowing wells. On the west side of the river about 1 mile north of Palominas the well of Mr. Robert Orhara obtained a small artesian flow at 125 feet, and nearer the river ~~the well of~~ ~~Mr.~~ another well also obtained a small artesian flow.

One of the principal artesian wells drilled in this district is that of Mr. J. B. Pelley ~~Palley~~ in the river lowland about halfway between Palominas and Hereford.

The general character of the materials encountered in ~~the~~ this artesian area ~~of the upper portion of the valley,~~ is shown ~~in~~ by the following log of the well of Mr. J. B. Polley, ~~near the river about 3 miles north of Palomino.~~

Log of artesian well of J. B. Polley near Palomino, Ariz.

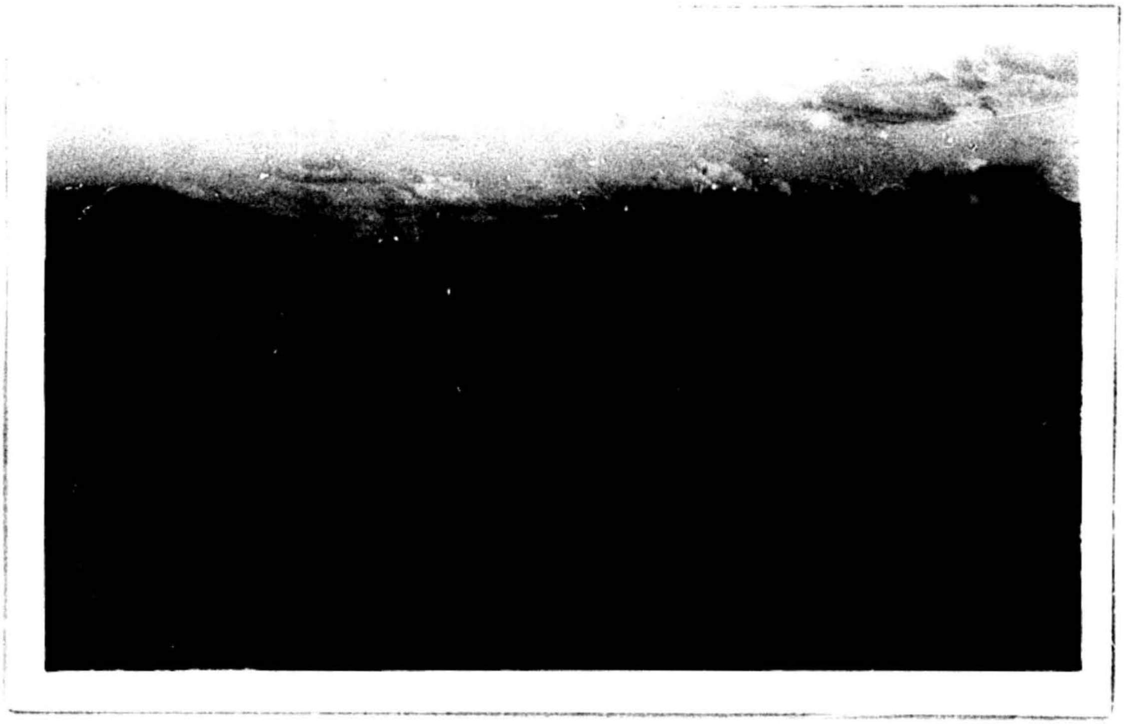
NW¼ sec. 22, T. 25 N., R. 22 E.

Material	Thickness feet.	Depth feet.
Gravel	20	20
Clay	30	50
Sand	55	105
Coarse sand (flowing artesian water)	170	275
Fine sand	33	308

This well was cased only to 100 feet, as the lower materials were partly consolidated and did not cave. The well discharged about 12 gallons a minute ~~[illegible]~~ for several years after it was drilled. A gradual decrease in the yield was probably due to partial clogging, ~~due to~~ caused by the caving of material above the main water-bearing sand.

Plate 11. A. San Pedro Valley near Fairban,. Tombstone Hills in the distance;

B. Artesian spring 5 miles south of St. David.



An artesian well of small flow was drilled near Hereford railroad station about 1900, but its discharge was too small to be of value for irrigation and an engine and pump were installed. As the drawdown when pumping is only a few feet and the pumping cost is therefore comparatively small this well has been successfully used to irrigate adjacent fields of vegetables.

At Lewis Springs station, about 10 miles down the valley from Hereford a well that was drilled by the railroad has a slight artesian flow, but it is pumped for locomotive use. The well that was drilled for railroad supply at Fairbank struck water at about 300 feet which rises to within 6 feet of the surface but does not flow. The character of the valley in this locality and the bordering slopes of gently dipping sand and sandy clay are shown in Plate 11 A.

St.David-~~Benson~~ Pomerene district.

The largest artesian basin in the San Pedro Valley is that of the St.David-~~Benson~~ Pomerene district. The first flowing artesian wells to be obtained in Arizona were drilled near St.David in 1885? A prize of had been offered by the Territorial Government for the first successful artesian well but there is no record that the St.David colonists received this prize.

History of the Mormons in Arizona.

The tests for artesian water were probably stimulated by the presence of several springs in the lowland near the river like that shown in Plate 11 B, which suggested

St.David-Pomerene district.

The largest artesian basin in the San Pedro Valley is that of the St.David-Pomerene district, in which the first flowing wells in Arizona were obtained. Lee wrote of the district in 1903 as follows:

Lee, Willis T., Notes on the underground water of the San Pedro Valley, Arizona; in U.S.Recl.Service, 3d Ann.Rept.for 1903-04, p.169, 1905.

> The first indication of artesian water in San Pedro Valley is said to have been noted at the time of a severe earthquake which occurred in 1887 (May 3). A long fissure is said to have formed, from which water flowed for several hours. This led to the supposition that water existed under pressure beneath the surface of the valley, and boring soon afterward resulted in flowing wells.

In 1885 A prize of $1,500 had been offered by the Territorial Government for the first successful artesian well, ~~but there is no record that the St.David colonists received this prize.~~ and was claimed by McRae brothers who developed a flow of 30 gallons a minute but failed to receive any award. The tests for artesian

McClintock, J.H., Mormon settlement in Arizona; Phoenix, p.238, 1921.

water were also probably stimulated by the presence of several springs in the lowland near the river, like that shown in Plate 11, B, which suggested the presence of artesian water.

At the time of Lee's examination in 1905 there were more than 200 flowing

~~Lee, Willis T.~~

~~U.S.Geol.Survey [illegible] 1905.~~

wells in the district. All except two which had been drilled by the railroad at Benson had been put down with augers 1½ to 4 inches in diameter. These wells were cased only part way. The artesian head is evidently produced by the interbedding of coarse and fine materials, the coarser materials from the mountains pinching out toward the river. The water-bearing beds are irregular in thickness. Some water sands are only 2 feet thick but in other places water gravel more than 20 feet thick has been encountered. The greatest discharge developed from a well was about 80 gallons a minute, but the average discharge for newly-completed wells is only about 10 gallons a minute. For irrigation use several wells are drilled within a few hundred feet of each other and discharge into an earthen reservoir and when sufficient water has accumulated it is used for irrigation. The clay soil holds water readily and a continuous discharge of 5 gallons a minute is considered to be enough to irrigate 1 acre. The limited discharge of the wells is probably due in part to small penetration of the water sands by the drill and to the lack of casing to the water-bearing horizons, which allows leakage into upper strata. The compactness of some of the water-bearing sands also is an important factor in causing their small yield. The discharge of most of the wells has diminished after a short time. This is probably due to the partial filling of the wells by caving material because of the lack of casing. However some wells have flowed for 10 years or more with little decrease in discharge.

The temperatures of the water discharged by different flowing wells vary more than they should if the variations are due only to coming from different water-bearing horizons. It is probable that the cooler waters are cooled by the being mixed with water from the upper water-bearing strata. Temperatures ranging from 67° to 81° were noted in different wells. The warmest water noted comes from a well of Mr. J.E. Parker, 2 miles west of St. David. This well was flowing 15 gallons a minute from sand encountered at 612-616 feet. The well was drilled to 670 feet without increasing the discharge, which was originally 22 gallons a minute, but had been reduced by the partial clogging of the well by drilling tools that were lost in it.

At Benson High School, in the southern and highest part of town, a well drilled 1,505 feet deep encountered artesian water at 902-938 and 1,337-1,371 feet. The water rises to within 13 feet of the surface, and has a pumping capacity of 50 gallons a minute, with drawdown of 30 or 40 feet.

The following logs, from the early report of Lee, show the varying character

Lee, Willis T., ~~San Pedro Valley, in~~ op. cit. pp 167-168 ~~U.S. Recl. Service 3d Ann. Rept. for 1903-04, pp.~~ 1905.

of materials encountered in ~~several of the wells~~ three wells drilled in

the St. David district.

flowing artesian
Log of well drilled on farm of H.O. Carr, 2 miles west of St. David.
(Farm of J.E. Parker in 1934)

NW¼ sec.1, T.18 S., R.20 E.

Material	Thickness feet.	Depth feet.
Sandy silt	70	70
Red clay	290	360
Blind sand	40	400
Sand, gravel, and soft sandstone (flowing artesian water)	200	600

Log of flowing artesian well on farm of W.A. Riggs, 5 miles south-southeast of St. David.

SW¼ sec.27, T.18 S., R.21 E.

Material	Thickness feet.	Depth feet.
Soil and gravel	80	80
Clay	300	380
Fine sand, water	40	420
Clay	80	500
Gravel and stones, flowing artesian water	90	590

Log of flowing artesian well on farm of J.N.Curtis,
6 miles south of St.David.

SW¼ sec.33,T.18 S.,R.21 E.

Material	Thickness feet.	Depth feet.
Sandy clay	150	150
Limy sandstone	1	151
Fine sand,water	10	161
Sandstone,sand and clay	140	301
Clay	50	351
Gravel,flowing artesian water	5	356
Sand and clay,alternating	110	466
Limy sandstone	1	467
Gravel,main flow of artesian water	3	470

Well 2 inches in diameter, cased to 250 feet.

In 1900 the Southern Pacific Railroad drilled two 10-inch wells at Benson, to depths of 707 and 808 feet. Each encountered flowing artesian water at about 500 feet, from which the principal supply was obtained, no horizons of larger yield being found at greater depth. Each well originally flowed 42 gallons a minute, and a supply more than twice as great was obtained by pumping, but the drawdown was about 80 feet. In later years several other wells were drilled by the Railroad, for locomotive supply. All penetrated approximately the same sequence of materials, the log of Well No.3 being as follows: kindly furnished by the Railroad,

Log of Well No.3 of the Southern Pacific Railroad, at Benson, Ariz.

SW¼ sec.10, T.17 S., R.20 E.

Material	Thickness feet.	Depth feet.
Red clay	40	40
Blue clay	20	60
Sand	25	85
Sand and gravel	32	117
Blue clay	383	500
Sand (flowing artesian water)	200	700
Gravel	10	710
Stiff clay	14	724
"Limestone" (hard shale?)	82	806

In the lower portion of the inner valley near Pomerene a number of wells have been drilled which yield small artesian flows, and the water is stored in earthen reservoirs and used to augment the supply of ditch water for irrigation. In the upper portion of the inner valley some of the wells do not quite flow, but are pumped by windmills and small engines, for irrigation use. The general character of the materials in this part of the valley is shown by the following log of a well at the Pomerene school.

Log of well at Pomerene school, 2½ miles north of Benson, Ariz.

SE¼ sec. 34, T. 16 S., R. 20 E.

Material	Thickness feet.	Depth feet.
Soil	20	20
Gravel	70	90
Sand and sandstone	60	150
Pink clay	300	450
Gravel (artesian water rises within 16 feet of the surface).	300	750

Mammoth district

In the Mammoth district a test well for artesian water was drilled on the T.N. Wills ranch 6 miles southeast of Mammoth about 1905. ~~Wills ranch about 1918~~. This test was abandoned at about 700 feet without encountering water under appreciable artesian head; but a second test drilled to 925 ~~nearly 900~~ feet struck an artesian flow in red sandy material that is probably a part of the Gila conglomerate formation. The water has been used for domestic purposes and irrigation. ~~At about the same time another~~ a test for artesian water was drilled on the Smith ranch 2 miles southeast of Mammoth, and ~~This well~~ encountered flowing ~~artesian~~ water at 690-710 ~~about 700~~ feet. The discharge was only a few gallons a minute however, and pumping equipment was installed for irrigation, but used only a few years. ~~This was used for a short time but abandoned several years prior to 1934~~. In 1930 a test well for oil was started a few hundred yards southeast of this artesian well. It was carried to a total depth of 1,485 feet and a strong flow of artesian water was developed in sandstone at 1,275-1,370 feet. This has been used in a small way for irrigation. The log of this well, showing the character of materials penetrated, is here given through the courtesy of Mr. Edwin I. Tant, of Tucson.

Log of well drilled on Smith ranch

2 miles southeast of Mammoth, Ariz. Drilled Feb-Dec.1930

(NE.¼ sec. 33, T. 8 S., R. 17 E.)

Material	Thickness (feet)	Depth (feet)
Sand and gravel	80	80
Sand	5	85
Sand and boulders	55	140
Sand	20	160
Gravel	45	205
Hard sand	15	220
Gravel	65	285
Sand	30	315
Sand and boulders	136	451
Sand	144	595
Sand and gravel	10	605
Gravel	20	625
Sand and gravel	35	660
Running sand	5	665
Sand	80	745
Clay and gravel	10	755
Sand and clay	10	765
Red clay and gravel	240	1005
Brown shale with sand	10	1015
Red clay and gravel	15	1030
Sticky black clay (show oil)	5	1035
Sticky brown shale (show oil)	5	1040
Red clay and gravel	65	1105
Gypsum	5	1110
Red clay and gravel	25	1135
Brown lime	9	1144
Red clay and gravel	16	1160
Hard sand (small amount of water)	35	1195
Red clay	2	1197
Hard brown sand	8	1205
Hard gray lime	15	1220
Conglomerate with lime	37	1257
Red clay	8	1265
Hard conglomerate	2	1267
Red clay	8	1275
Sandstone (artesian water flowing 20 gallons a minute)	95	1370
Hard sandstone	70	1440
Red beds	45	1485

Shallow ground water of inner valley.

Supply and depth.

Nearly all the land of the upper slopes of the valley is too stony or gravelly to be suitable for farming and the depth to ground water is so great that the costs of pumping it for irrigation would be prohibitive. In considering the development of ground water in the inner valley for irrigation the two prinäipal factors to be considered are those of the available supply and the depth to water. The wells that have been drilled in the bottom lands passed through the upper ground water horizon and cased it off in order to maintain the artesian head of the deeper horizons. These wells therefore do not furnish much information as to shallow water conditions. Dug wells are sunk only a few feet beloe the ground water level and since nearly all of them are drawn upon only for domestic and stock supplies they also have afforded little information as to the capacity of the upper water-bearing strata.

It is probable that during the course of many centuries the San Pedro River has shifted its channel back and forth across the bottom lands and that channels of gravel and coarse sand are present buried beneath the later deposits of silty alluvium. Such buried channels and also layers of sand and gravel that have been washed in by side streams probably contain comparatively large quantities of ground
Just where such channels are,
water [illegible] ~~the valley alluvium is in most~~

As the valley allutium is in most places only 20 to 50 feet thick the pumping lift of water from such beds would not be heavy. It is also probable that in some places the uppermost layers of the Tertiary deposits f sand and gravel which underlie the river alluvium carry much water which would be readily yielded to wells.

Pumping plants.

On the dug and drilled wells throughout the valley that are used for domest and stock water supplies windmills are the nearly universal pumping power. At several railroad stations locomotive supplies are pumped by gasoline engines from deep wells. At Benson, Fairbank, Lewis Springs, and Hereford, along the trough of the valley, these supplies are from artesian wells. On the upper slopes ~~wells~~ at Bisbee Junction, Sibyl, and Whetstone there are deep wells which draw from ~~to the non-artesian~~ ground-water, ~~level~~.

The largest pumping plant for water supply is that near Naco, equipped with powerful pumps which furnish a municipal water supply to Bisbee, 7 miles distant and nearly 1,000 feet above the wells. The largest pumping plant in the valley whose water is used for irrigation is that of the Calumet and Arizona mine on the southeast border of the drainage basin. Deep mine pumps were installed about 1908 to keep this mine unwatered and about 2,400 gallons a ~~day~~ minute have been pumped nearly continuously. The water is collected in an earthen reservoir 2 miles south of the mine and since shortly after the beginning of pumping it has been used for irrigating alfalfa and corn on the Warren ranch. In 1934 about 650 acres were under irrigation. ~~a ditch carrying a stream of about ______ gallons a minute from the reservoir being used.~~

At Hereford several acres of garden ~~were~~ have been watered by a small gasoline engine and centrifugal pump. This was installed over a drilled well in which artesian water rose to within 10 feet of the surface. The drawdown when pumping ~~was~~ is only a few feet and probably an equally large supply could be obtained at only a little greater pumping lift from the uppermost ground water.

In the bottom land on the west side of the river near Fairbank about 20 acres of vegetables was under irrigation in 1934 in part with water pumped from a shallow well. To the west near Campstone in the valley of the Babocomari river Mr. Al Turner has irrigated a few acres of garden with a small ~~egt~~ engine auxiliary to windmill power. In the wider part of the inner valley in the St. David–Pomerene district no pumping plants for irrigation were observed in 1934. A few miles downstream on the west border of the Tres Alamos district a small gasoline engine and pump were used to water about 5 acres of corn and maize, the pumping lift being about 50 feet from a well dug near the channel of ~~the~~ Ash Creek.

On the east side of the San Pedro River about 2 miles above Mammoth a pumping plant consisting of ~~10~~ 25 horse power Fairbanks-Morse gasoline engine and 3-inch centrifugal pump were installed ~~about 1920~~ and used for several years to pump water from a drilled well of small artesian flow. The cost of pumping was found to be excessive, however, as compared with the use of ditch water from the river.

The following discussion of wells and pumping equipment for irrigation is based chiefly on studies and observations of irrigation practice in other parts of Arizona which have conditions similar to the San Pedro Valley, and on which several papers have been published.

Author ? ;Oil engines for pump irrigation, and the cost of pumping; Univ.Ariz.Agr.Exp.Sta.Bull.74,

author ? ;The supply, the ~~quality~~ price, and the ~~price~~ quality of fuel oils for pump irrigation; Univ.Ariz.Agr.Exp.Sta.Bull.92,

Smith, G.E.P., Motor driven irrigation pumping plants and the electrical district; Univ.Ariz.Agr.Exp.Sta.Bull.99, 1924 : Use and waste of irrigation water; Univ.Ariz.Agr.Exp.Sta.Bull.101, 1925.

The following statements are taken from the Bulletin by Professor Smith on irrigation pumping plants:

Univ.Ariz.Agr.Sta.Bull.99, pp.85-113,

Dug wells are the most common.For domestic supplies they are simple and cheap,but for irrigation supplies requiring large yields, their use is restricted to localities where the water table is at shallow depths and excellent gravels exist just below the water table,Examples of these conditions are found in the Rillito and Santa Cruz valleys,Well digging is easy above the water table only. The best method of extending a dug well to a considerable depth below the water level is by means of a heavy reinforced-concrete caisson curb,built between forms,and sunk by excavating within it and undermining it.The curb should be thick and heavy,with smooth exterior.It should have a beveled cutting edge,and in most instances it is desirable that the cutting edge be shod with an angle-iron shoe.A centrifugal pump,installed in or over the well,is used to keep the water level down so that workmen can excavate in the bottom,and care is exercised to keep the curb in a vertical position as it settles downward. . . . A combination dug and drilled well permits of placing a direct-connected horizontal centrifugal pump and motor close to the water table,while at the same time the water supply can be drawn from deep strata.In this case the dug well should be excavated first.It should be circular,with a concrete curb.Eight or ten feet in depth should be excavated and curbed,then another similar section,and so on to the water level. . . .

It is highly desirable to install some sort of a pump and make a real pumping test of a well,before purchasing a pump and motor for permanent installation.For the purpose of the test,the pump need not be efficient nor of the size desired.The test consists in determining the yield of the well in gallons per minute and the corresponding downdraw of the water level after several hours pumping.The yield is proportional to the drawdown, provided the water-bearing strata are not uncovered by the drawdown. Thus, if the test shows a yield of 600 gallons a minute with 10 feet of drawdown, the well will yield approximately 1200 gallons a minute with 20 feet of drawdown. . . .

The attainment of high efficiencies in the operation of centrifugal and vertical turbine pumps depends upon whether the pumps are operated under the conditions for which they are designed, that is, with the proper discharge and lift. The discharge is of greater importance but the proper discharge of a centrifugal pump varies somewhat with the lift. If a pump is speeded so that it delivers more or less water than that for which it is designed, the efficiency will be lower, oftentimes much lower, than that named in the guarantee. The proper speed for a given set of conditions should be obtained from the manufacturers. . . .

The lack of symmetry of many pumping plants now in use is so great that it would be real economy to re-design them and make the necessary changes. The most common misfit is a large underspeeded pump operating at low efficiency. Sometimes the pump is set too high, or is set on insecure foundations which permit of much vibration. Belts are often subjected to the weather, and in too many case the whole plant is out-of-doors. Frequently piping is too small; sometimes it terminates several feet above the ground, creating an unnecessary lift. . . In some cases motors or engines are too large. A purchaser should obtain the best advice available to him and should have his detailed plans thoroughly matured before placing an order for a pumping plant. . . .

Of the various types of pumps, the centrifugal pump has been most used for irrigation pumping. Centrifugal pumps are adapted to large heads of water, they cost the least and are subject to the fewest troubles and interruptions to service. If the bearings are lubricated properly and the water is free from sticks and grit, they last almost indefinitely.

Centrifugal pumps are built either with a short horizontal shaft or with a long vertical shaft reaching to the ground surface. These two kinds are recognized as two distinct types, though the action of the rotating impeller is the same in both cases. . . .

The pump should be set as close to the water level as possible, so as to reduce the suction lift. The possible suction lift depends upon the atmospheric pressure, which decreases as the altitude increases. The practical suction lift for altitudes less than 4000 feet is limited to from 17 to 24 feet, though one plant, in Pima County, was found to be operating with 38 feet of suction lift. High suction lifts require especially well made pipe joints and tight gland packing. Tests of the pumping plant in the East well on the University Campus showed a sharp decrease in discharge and in efficiency when the suction lift exceeded 23 feet, though a searching investigation did not reveal any air leak. If, when a new well is tested, the suction lift is found to exceed 17 feet, and if it is desired to use a horizontal centrifugal pump, then it is advisable to try to develop the well to a better yielding capacity...

Horizontal centrifugal pumps are the freest from troubles; there is practically nothing to get out of order. They have the highest efficiencies, they are adapted to direct-connection with electric motors and they cost much less than vertical pumps. Their disadvantages are that they must be primed, and, in case the water table fluctuates widely either from natural causes or due to pumping, it may fall below the limit of suction. . . .

Vertical centrifugal pit pumps, with long vertical shafts held in crossbraced frames,were much used a few years ago,but have given way to vertical turbine pumps . . .

Vertical turbine pumps have been highly developed during the past decade,and are well adapted to irrigation pumping.Strictly speaking, they are vertical centrifugal pumps,but they are built with the vertical shaft enclosed within the discharge pipe so that they can be lowered into wells drilled from the ground surface,and they are built with such high mechanical perfection,at least by a few manufacturers,that they stand in a class by themselves.

The distinction between a turbine pump and other centrifugal pumps is that the turbine has,in addition to the rotating vanes,scientifically designed fixed vanes.The water issues from the impeller with very high velocity,and the fixed vanes aid in the conversion of the high velocity into pressure without excessive losses in eddies and shock.Horizontal turbine pumps are obtainable also,but few of them are found in irrigation service. . . .

Small single-acting reciprocating,or plunger,pumps are common, being in use with windmills or gasoline engines at thousands of house wells in Arizona.Plunger pumps of large capacity are impractical, because of the slow speed.Forty strokes per minute are about the limit for low lift,and 30 strokes per minute for lifts of 80 to 90 feet.At 30 strokes,about fifty gallons per minute can be obtained from a 6-inch cylinder with a single-acting pump,that is,with a single piston and one line of pump rods.Such pumps can be used,in conjunction with small,low,earth reservoirs,for the irrigation of home gardens.

The stroke of a plunger pump,for irrigation,should be about twice the diameter of the cylinder,for lifts up to 50 feet,and the ratio should increase as the lift increases.The cylinder should be of brass or brass-lined. The discharge pipe should be a trifle larger than the cylinder. Hard-wood pump rods are preferable to pipe rods, and the rod couplings should be heavy forged straps with copper rivets, with threaded joints. At each joint there are a pin and a socket with a square shoulder on each. In putting the rods together, they are screwed up until the shoulders butt tightly.

NON-ARTESIAN GROUND-WATER CONDITIONS

~~Ground Water~~

General Features

The valley of San Pedro River, as a whole, constitutes a long narrow trough, whose sides slope fairly uniformly to the river channel. There is comparatively little flat valley land, the widest area of such character being in the vicinity of Benson, near the middle course of the valley. There for about 3 miles north and 10 miles south of Benson, the lowland area widens to an inner valley, 2 to 4 miles ~~in width~~ bordered by bluffs 20 to 60 feet high. In this area there has been the greatest development and use of both the surface and the ground-water supply. In the southern part of the valley, in the vicinity of Palominas, there is a smaller area, where considerable irrigating is done from flowing wells. Northward from Benson small areas are irrigated by ditches from the river, but the ground water has been developed only for domestic and cattle-watering supplies. Along the trough of the valley, water is obtained in most places in shallow wells at a few feet above the river level. On the higher slopes ground water conditions vary greatly from place to place according to the rock formation and depth of loose materials.

Alluvial ~~Water in loose materials~~

Although the lowland zone along San Pedro River is for most of its length quite narrow, as shown by the limits of the inner valley, on the physiographic ~~geologic~~ map (Pl. 2) there is a strip of alluvium along nearly its entire course. Much of the settlement, especially in the valley north of Benson, is along this alluvial band, and water is commonly obtained from dug wells, most of which are equipped with pumps and windmills. On the upper slopes water is obtained along many of the washes but the depth varies greatly according to local conditions, and is surprisingly deep in some places. In general, ground water is found nearly at the bottom of the loose materials, into which the rain water, circulating downward, collects where held up by the nearly impervious bedrock.

~~Water in~~ Tertiary deposits

The greater part of the lower slopes of San Pedro Valley is underlaid by deposits of gravel, sand and clay, laid down in fairly uniform beds that were formed in a lake which once occupied the valley during a part of Tertiary time. ~~The extent of these deposits is shown on Mr. Bryan's geologic map, Pl.____ and are described by him.~~ Within these bedded deposits water is obtained in some places on the upper slopes at relatively shallow depths, where perched water tables have been formed by impervious beds which prevent the ground water from sinking to greater depths. In other places wells have been sunk through the surficial wash and into these bedded deposits for considerable depths, before encountering water. Along the trough of the valley, all the wells which yield artesian flow obtain their supplies from sandy beds in these lake deposits. ~~The principal artesian areas near Benson, near St. David and near Hereford, are described by Professor Smith in his discussion of irrigation in the valley.~~

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~~Water in~~ Pre-Tertiary sedimentary rocks

In the Whetstone and Mustang Mountains, on the west side of the valley, and in several of the ranges on the east side, there are considerable areas underlain by compact sandstone, shale and limestone, of Cretaceous and earlier geologic ages. In general these rocks are too compact to be good water carriers, but in a few places small supplies are obtained from them. Such supplies are found chiefly where the rocks are much fractured, and it is the fractures and crevices which contain water, rather than the pore spaces in the rocks. Within the areas of these older sedimentary rocks, there are a number

Tertiary volcanic rocks

On the northeast side of the valley the Galiuro and Winchester Mountains are composed almost entirely of lavas, chiefly of basalt, rhyolite, and tuffs of Tertiary age. These rocks store considerable rain water which feeds numerous small perennial springs, but the mountains are not high enough to receive much snow to supply springs of notable size. In some of the ravines along the lower slopes of the mountains, dug wells obtain water at shallow depths, but this water is found in the wash material and there is little supply from the upper portion of the lava bed rock. In the other mountains that border the San Pedro Valley, Tertiary lavas are not extensive enough to be of importance as reservoirs for ground water.

a number of springs, of small but perennial flow, which are fed by water that is stored in the fractured rocks and faults where local conditions are favorable.

Water in crystalline rocks

Large portions of the mountains on each side of San Pedro Valley are composed of granite and other crystalline rocks, which are relatively impervious to water, and large supplies cannot be obtained from them. In some localities, however, these rocks are deeply weathered and disintegrated. In this broken material, small amounts of water are obtained from dug wells sunk only to about the bottom of the weathered rock, which serves as a porous material to collect and store rain and melted snow-water. At many places on the mountain slopes small springs are fed by such ground water, and many of them have been increased in yield and developed as watering places for cattle by excavating and by piping the water to troughs.

Descriptions of ground-water conditions

Winkelman district.—The San Pedro River joins the Gila near the town of Winkelman. This was a community of about 600 population in 1934, dependent in part on mining activities near Ray, to the northwest, and in part on the grazing interests of the surrounding region. The municipal water supply is furnished by the Arizona Edison Co. from wells about 1 mile east of town.

Settlers in the neighboring valley lands get water ~~chiefly~~ from shallow wells in the loose materials of the river lowland. Along the valley southward, bordering the San Pedro River, there are a number of ranches where alfalfa and other forage crops are grown as feed for cattle during dry periods. Domestic and cattle-watering supplies are obtained from shallow dug wells at depths a little above the river level. Prior to ~~1927~~ 1926 there was a village, Dudleyville, on the west side of the river, 2 miles south of Winkelman; but a flood in September of that year washed out the highway bridge and greatly widened the river channel. In succeeding years the channel has continued to widen, until very little cultivable land remains on the west side. The channel is also said to have cut several feet deep, so that it is no longer feasible to take out ditches to lands formerly irrigated along the river. The slopes on each side rise at grades of 300 or 400 feet to the mile, ~~as shown by the contours on the Winkelman topographic sheet, Pl.~~ but the ground-water level also rises nearly as fast, although the depth to water is controlled chiefly by local features of washes and alluvial material. At the Young ranch, about 3 miles east of the river, and 1,300 feet above it, water was reported at about 40 feet in the wash on which the ranch is situated. On the west side of the valley, water is also obtained at fairly shallow depth along the larger washes, being at about 30 feet at the Munere ranch, and 30 to 35 feet in gravel and sand near the head of Antelope Wash.

The shaft of the old Antelope Copper Mine, sunk prior to 1913 to a depth of 450 feet did not encounter water until it reached 140 feet, the compact granitic rock of this locality being dry in the upper portion; But from the shaft 60,000 gallons a day was pumped to a reservoir for mine use. Along the drainage divide west and south from the Antelope mine, the depth to water varies somewhat with the depth to which the granite is disintegrated, but is less than 100 feet in all wells observed. On the higher slopes this weathered bedrock supplies a few small springs, of which Cottonwood Spring, yielding about 1 gallon a minute during ordinary dry seasons, is one of the best known. Wells in the area find water at fairly shallow depths but not in all places of good quality. The Dennis well, 3 miles south of Cottonwood Spring, is sunk into granitic rock containing considerable pyrite, which renders the water distinctly mineralized.

Lower Anaheim Wash--In that portion of its course where Arastra Creek swings farthest north, the stream passes through a narrow canyon, having cliffs of volcanic tuff and ash. It is locally called a box canyon, although it is not too steep to traverse on foot. The principal trail into the upper part of the valley, however, climbs out of the canyon near Brandenburg Mountain,

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and follows the higher slopes along the north side of the drainage basin to the upper valley. Aravaipa Creek is perennial in the lower part of its canyon, and in 1934 a few acres were irrigated on each of the 13 ranches along this stretch. This portion of the valley is noted for its oranges and grapefruit, being the only locality in the San Pedro Valley where citrus fruits have been successfully grown. Domestic water supplies are obtained both from the creek and from wells 10 or 15 feet deep in the stream wash. In the last 3 or 4 miles of its course, the stream is usually dry except during rainy periods, as the surplus water from upstream irrigation is diverted onto alfalfa in this lower portion. About 2 miles below its junction with the San Pedro River, springs issue along the edge of the lowland. These are of nearly constant flow, yielding a total of perhaps 100 gallons a minute, of water at a temperature of 66°F. As this is 3° or 4° degrees above the normal for surface waters of the region, the springs seem to be artesian in character. An engineering study of the discharge of Aravaipa Creek and of the springs, made for private interests a number of years ago, is said to have indicated that the springs are formed by the reappearance of the creek water. Such a condition seems plausible, in view of the relative positions of the creek and the springs. The spring water is collected within earthen embankments, which form Cook's Pond, and is used together with river water in the irrigation of ~~about 200~~ 225 acres of wheat on Smith Brothers' ranch, near former Feldman post office. ~~Analyses of samples of the river water near Cook's Pond, and from the northernmost spring, nos. and of Table show the latter to be much less mineralized; though both are fairly low in mineral matter, and are quite suitable for irrigation and domestic uses.~~ On the steep slopes which rise southeastward from lower Aravaipa Creek ~~and culminate in~~ to Table Mountain, there are a number of springs, of which Oak Spring and Holy Joe Spring are the largest. Although perennial, each spring yields only 2 or 3 gallons ~~per~~ a minute during most of the year, but they have been improved as watering places for goats. Since the first introduction of goats about 1915, the rugged slopes of this area have been given over as range for them. During normal years, the returns from the ~~Angora~~ angora fleece are said to have compared favorably with the returns from equal areas grazed by cattle.

Aravaipa Valley. The valley portions of upper Aravaipa Creek were settled in the ~~70's~~ seventies and early ~~80's~~ eighties, for grazing. There is about 3,000 acres of bottom land, bordered by bluffs ~~which~~ from terraced upland. Later there was much prospecting in the adjacent mountains, and ~~about 1911 this activity culminated in the shipment~~ in 1910-1912 of some gold and copper ore was shifted. Since that time, however, only a few thousand dollars in gold have been taken out, and the area has reverted almost entirely to grazing. The upper end of the valley is separated by a broad low divide from the open slopes southeastward to Sulphur Spring Valley. Into this the headwaters of Aravaipa Creek are cutting, and are surely though very slowly extending the valley southward. In the broad alluvial portions of this upper area, ground-water level is practically at the surface along Hooker's Wash. At the Sierra Bonita ranch, established in 1872, water is obtained from dug wells at 10 to 20 feet, and part of the lower land forms a natural marsh or cienaga.

About 1872 Camp Grant was moved from its first location on a bench near the mouth of Aravaipa Creek, to the west base of the Pinaleno Mountains, where water is available from springs. This site is on a great outwash slope overlooking the upper end of Aravaipa Valley. During recent years the property has been used as a State industrial school for boys. In addition to water piped down 7 miles from springs in the mountains, a well has been dug 60 feet deep through gravel to bedrock. This well furnishes only a limited supply of water, however, and in dry seasons becomes low.

A well at Bonita post office normally has water at about 20 feet, but in wet seasons the level may be within 10 feet of the surface. During prolonged dry seasons the well, 30 feet deep, goes nearly dry. At Sunset, 10 miles to the west and near the drainage divide a well 60 feet deep usually has water at about 40 feet.

Marcia Spring on the western side of upper Aravaipa Valley, yields several gallons per minute, and is a local watering place. At ranches farther down the valley, dug wells near the stream channel obtain water at less than 40 feet. Dug wells at Klondike also furnish shallow supplies, and a few drilled wells in this locality obtain somewhat better supplies. On some of the higher slopes water from old mine shafts furnishes local supply, where seepage from the fractured rocks collects in the old workings. Lawrence Spring and Tule Spring, in the northern part of the drainage basin, near the mining settlement of Aravaipa, yield small but perennial supplies. About 2½ miles north of this place there is a small warm spring, locally used for bathing and cattle watering. Here apparently water which may come from a considerable depth reaches the surface through a fault in the crystalline rocks.

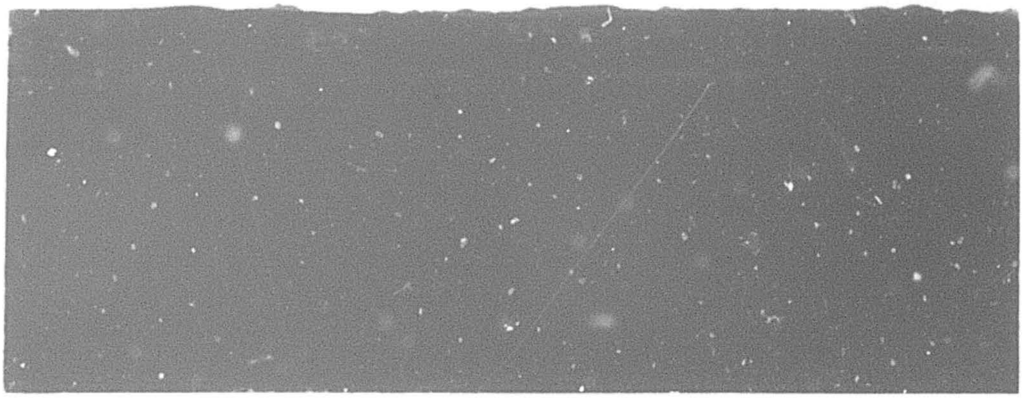
Oracle District.-- The principal settlement in the northwest part of the San Pedro Valley is at Oracle, a town of about ~~200~~ 300 people, nearly on the drainage divide, and at the north base of the Santa Catalina Mountains. Its ~~elevation~~ altitude of about 4,500 feet, near the higher mountain slopes, and its convenient access from Tucson, 30 miles away, have caused the development of the locality as a mountain resort. The geologic formation is of coarse-grained granite, weathered to prominent boulders over the higher surface, but deeply disintegrated ~~deeply~~ along the ravines. Water is obtained in this disintegrated rock at depths of ~~less than 50~~ about 10 to 60 feet, in dug or drilled wells. Since the water supply is from the snow and rain which falls on ~~of~~ the higher slopes, and ~~which~~ percolates down the ravines and saturate the decayed rock, the most successful wells are those which are located where disintegration is deepest. In the bottoms of several wells horizontal galleries have been dug, and these have greatly increased the water supply. Several unsuccessful wells have been dug in and near Oracle because they were put down where unweathered rock is exposed at the surface. Several deep drilled wells have also been failures, one unsuccessful test being drilled to 600 feet, about 2 miles southwest of town.

The old Texas well, at the head of Camp Grant Wash, was dug to 206 feet in gravel and disintegrated granite. After a number of years it caved in, and was not reopened.

Along the main washes extending down to San Pedro River, water for cattle has been developed at shallow depths in the gravel. Willow Springs are on the slope east of the divide, where Tertiary lava agglomerate overlies decomposed granite. The water issues at the contact of the two formations. Putnam's Spring, near the mouth of the wash, issues where the underground flow in the channel is brought to the surface by harder beds, probably by lime-cemented layers in the lake deposits of the area. Northeastward from Oracle, down the slopes and washes to the old mining settlement of Mammoth, a few wells have been sunk, chiefly at the several cattle ranches. On the upper slopes the disintegrated granite and the gravel of the stream washes yield fair supplies, though in period of prolonged drought they may fail. Camp Grant Wash, one of the largest tributaries from the west to the lower San Pedro, is forced by Black Hills to take a northerly course instead of flowing directly down to the river. In the southern portion of these hills there has been considerable mining on lodes which carry copper and vanadium, and in early days on stringers of quartz carrying gold and silver. Domestic water supplies for the mining camps were obtained partly from shallow wells in the washes, and partly from small springs. ~~which issue from the gravels.~~ Dripping Springs and Schultz Springs have long been used; ~~are of this type, in recent years used chiefly~~ as cattle supplies. The former issues from seams in lava bedrock, a few yards upstream from dense conglomerate which forces the water to the surface. The latter issues from coarse conglomerate, probably Gila conglomerate, in which a collecting basin has been dug and the water piped to a cattle trough. The ores were taken down to Mammoth, where more ample water for their treatment was available from the river. Along the mountain slopes southeastward from Oracle one of the most important water supplies is at the 3 C Ranch, where springs furnish a stream of about 5 gallons per minute. The water is also piped northward 1½ miles to the American Flag ranch. The springs issue where a minor fault causes the water to collect, and they afford a perennial supply. A smaller flow issues on lower slopes to the east in Pepper Sauce Wash, which is deeply entrenched in the Tertiary deposits of the higher valley slopes and also in several scattered springs farther south, in an area where the Gila conglomerate and lakebed deposits extend far up the slopes and are deeply cut by washes. At the Interocean ranch ~~there are~~ several small springs issue for one quarter of a mile along a wash, from joints in the granitic rocks in the stream bed, their flow being developed and collected for the ranch uses.

Plate 12. A. San Pedro Valley about 3 miles north of Mammoth, looking west, showing bottom land and broad, sandy wash;

B. Pliocene lake beds overlain by conglomerate at mouth of Kilberg Canyon.



Mammoth district.-- The San Pedro River, for most of its lower course, has been crowded against the western side of its valley by the greater supply of outwash materials brought down from the mountains to the east. Evidence that the former trough of the valley was farther east is shown by the gypsum deposits on the east side, which were probably formed in ancient playas. However there are lenses of selenite, a variety of gypsum, in a gulch on the east side of the Black Hill, nearly a foot thick. Most of the cultivable land is therefore along its eastern side. For several miles above and below Mammoth the bench lands are narrow and there are few ranches. These depend on shallow wells for water supply in the bottom land, as shown in Plate 12, A. About 1905, a deep well was drilled 2 miles above Mammoth, and flowing water was struck at 680 ft. Drilling was continued to 720 feet, the last 30 feet being in grey sandstone, whereas the upper portion of the hole penetrated relatively unconsolidated materials, including a layer of gypsum at 300 feet. Water was found at several horizons below 200 feet, under sufficient artesian pressure to rise within a few feet of the surface. In 1907, a deep well was drilled for water on the Amado ranch, later the Wills ranch, about 8 miles above Mammoth. Flowing water was struck at 804 ft. in soft sandy shale and the hole was carried 25 ft. deeper. A previous attempt in the vicinity was abandoned at 700 feet without getting a flow. In 1930, a well was drilled as a test for oil, near the first artesian well. Small shows of oils were

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The slopes east of Mammoth rise steeply from the narrow lowland to the Galiuro Mountains, in which there has been considerable prospecting for copper. Water in these upper slopes has been obtained in part from springs, several of which are of considerable size. Mulberry Spring has served for prospecting activities in its vicinity, and a small spring near the Bunker Hill mine afforded a supply for the workers in that area. A few miles farther south the Rhodes ranch in upper Schoenhauser Wash, obtains water from springs and also from shallow wells, in the gravel wash.

Redington district.— The portion of San Pedro Valley that is near Redington may be reached fairly directly from Tucson by a road which climbs eastward to a pass in the Santa Catalina Mountains, and thence descends northward to the river. In 1934 the mountain grades of this road were being improved, but the better-used route was down the valley from Benson. Redington post office was the north limit of mail service, as part of the road thence to Mammoth had been washed out by floods several years previously. On the upper slopes a limited water supply is obtained at the Yankey ranch in dug wells at about 30 ft. These penetrate the few feet of gravel in the wash and have been sunk into the disintegrated granite.

About 2½ miles down the wash a perennial supply comes to the surface at Las Mimitas Spring. The walls of the wash are bare of granitic rock, cut by a dyke of porphyry, and the gravel fill is apparently shallow. The place seems to offer favorable conditions where a submerged dam would develop a much larger and more dependable supply. Other ranches in these mountain slopes depend on supplies from the washes, but nearly all are of limited yield, and in prolonged droughts go nearly dry. Along the trough of the valley of Redington and for several miles both upstream and downstream, ample supplies of water for domestic and cattle needs are obtained from shallow wells in the valley alluvium. At the Bayless Ranch at Redington, a well was drilled to 183 feet, only unconsolidated sand and gravel being penetrated. Water was struck at 45 feet, which is a few feet above the river level. A similar well was drilled 7 miles to the north, to about the same depth, for cattle use. During the dry season, when the river water is taken out by several irrigation ditches farther up stream, the channel is dry for considerable distances below Redington. A mile below Redington the river channel passes between granitic hills that form a good damsite, of which some study has been made. On lower Alder Wash, about 7 miles north of Redington, there is a small damsite, known as Carlink reservoir site. It is formed by a gorge cut in a thick bed of volcanic agglomerate, which might prove to be too porous to form a good dam, but should furnish shallow ground water. At the Sheaton ranch, 10 miles north of Redington, a fair supply of water is obtained in the lowlands on the west side of the river. Across the river from this ranch Burro Springs issue at the base of bluffs which border the narrow lowland. Their supply has been improved by pipes and cattle troughs. Their water is essentially of surface origin, stored in the Tertiary sediments, and issues where these beds are cut down to the ground-water table by ravines. The lower part of Kilberg Canyon, 2 miles to the south, forms a deep gorge cut in these sediments, as shown on Plate 12 B, and would be expected to contain similar springs. None were found, however, and an ancient Indian village on the bluffs above the canyon and overlooking the river probably obtained its water supply from the river 200 feet below.

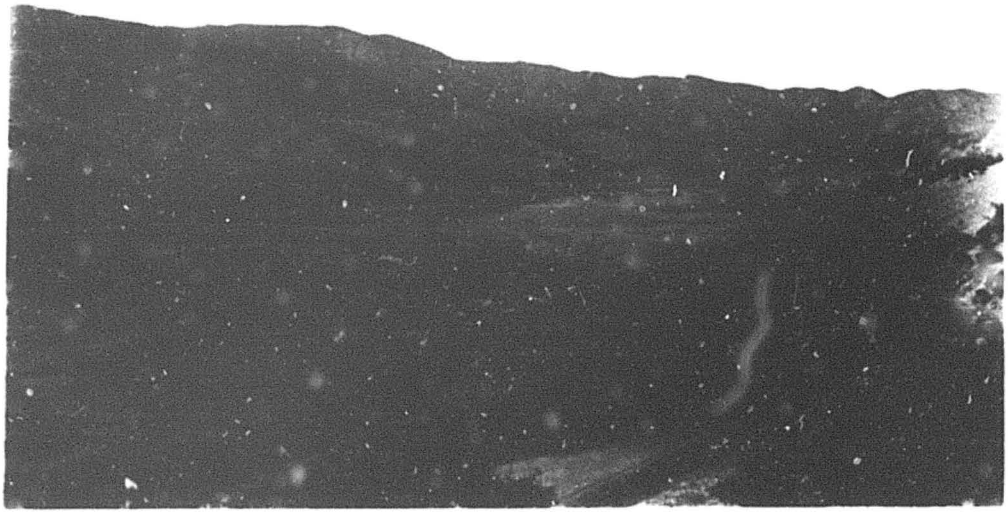
On the east side of the valley for several miles below Redington there are wide alluvial flats, covered with a thick growth of large mesquite trees. In one of these areas extensive observations on the effect of the daily transpiration of these trees on the ground-water level were made by Professor Smith~~, who described them elsewhere in this report~~.

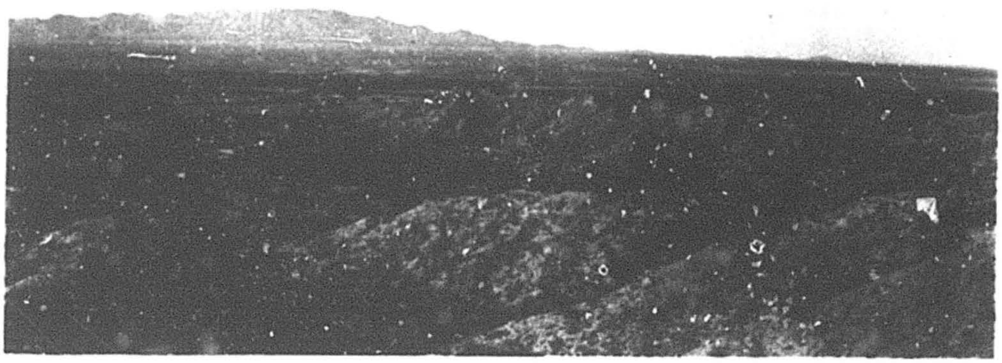
Cascabel District--The narrow valley lowland in the vicinity of Cascabel has long been occupied by a number of small ranches, whose chief income is from grazing a few cattle. Some alfalfa and other forage crops are raised, under irrigation from the river. Domestic water supplies are easily obtained from shallow wells, which obtain water in sand and gravel slightly above the river level. At Cascabel school, half a mile north of the store and post office, the water level stood 26 feet below the surface in Feb. 1934, or about 2½ feet above the river channel. A well sunk in a gravel wash half a mile further north had water at 43 feet, which was 3 feet above the river channel a quarter of a mile distant. In this vicinity, the gradient across the valley of the ground-water table was therefore about 12 feet to the mile. Although the river channel is sometimes dry above Cascabel, there is always water in it about a quarter of a mile below that place. The water issues as seeping springs, in the east part of the river channel, and may be merely the underflow brought to the surface by cemented beds. As the springs are perennial and flow, even when the river above is dry, they may be of ground water from the gravel slopes to the east. The fact that the water issues in the channel as seepage and not in pools at the base of the bluff, indicates that it is not artesian water. Along bluffs near the road, a few miles downstream, small seepages produce alkaline patches of soil. To the west of Cascabel there are limited water supplies in the larger ravines. At the Bar L Y ranch (Denkman ranch) and also further down the same wash, water is obtained at shallow depths from the gravel. On the higher slopes the washes contain seepage water in a few places, Pelon Spring being one of the best known of these small water supplies. Hot Springs Canyon joins the San Pedro River about 1 mile above Cascabel. Along the lower part of the canyon, several families have taken homesteads where there is a little grazing land. Domestic water supplies are obtained in the gravel of the wash. Beneath the mesquite-covered bench land, near the mouth of Hot Spring Canyon water is found in fine sand at about the river level, at 35 feet. One well drilled found a larger supply of water in gravel at 70-80 feet. In the earlier settled valley of upper Hot Springs Wash, water is found at about 30 feet at the Double R ranch. At the Phillips ranch, springs afford domestic and cattle supply. Springs in Bass Canyon, about 2 miles above the ranch, render the stream perennial to its junction with Hot Spring Canyon and Hooker Hot Springs, from which the canyon is named, are the only hot springs in San Pedro Valley. The water issues from several springs, the largest of which yields about 30 gallons a minute, for a mile or more down the stream, at a temperature of 120°. It is only moderately mineralized

~~as shown by the analysis in Table~~ and is used for irrigation as well as bathing. About a mile farther down stream, another warm spring is locally used for bathing. The thermal waters probably issue along a fault~~, which~~ traverses this upland area. The only other thermal spring in the region is a small one about 2 miles north of Aravaipa. This spring also seems to be closely associated with faulting. It is of small ~~flow~~ discharge, used for cattle-watering. At the home ranch of the Muleshoe Cattle Co., 3 miles south of Hooker Hot Springs, a well was drilled to a depth of ~~285~~ 187 feet. The materials penetrated were broken volcanic rock to a depth of 50 feet, dry sandstone to 170 feet, water-bearing sandstone to 185 feet, and red sandstone with clay ~~seams~~ to thebottom of the hole. The water stood at the depth at which it was struck, not being under any artesian pressure. The Antelope well of the same company near the head of Kelsey Canyon, 4 miles south of the home ranch, was drilled to 575 feet, in order to obtain a satisfactory supply of water, which stood at about 475 feet. This well penetrated clay and gravel to 130 feet, cemented sand and gravel to ~~about 440~~ feet, clay and gravel to 475 feet, coarse water-bearing sand, ~~carrying water~~, to 485 feet and clay and gravel to 575 feet. It is at the corner of four pastures, and supplies them with water for range cattle.

Plate 13. A. Upper Paige Canyon in Happy Valley, looking upstream;

B. Bluffs of sandy clay bordering the inner valley east of Benson.





At the Cross X ranch, 4 miles south of the Antelope well, drilling was carried to 280 feet, before water was struck, an additional 40 feet being drilled to assure a supply. In the lower portions of the washes, water is at shallower depths, however. At the V F ranch, in the middle course of Kelsey Canyon, Cottonwood Springs furnish an ample supply for the ranch use.

Happy Valley.—Happy Valley comprises small open areas along upper Paige Canyon and its tributaries. One of the largest areas of open land is shown in Plate 13, A. The district is best reached by road northward from Mescal, up Ash Creek nearly to its headwaters, and thence down the drainage of Paige Canyon. In this mountain area there were about 8 settlers in 1934, all of whom depended on springs for water supplies. Some have been developed from mere seeps into flows of 2 or 3 gallons a minute by blasting and excavating in the creviced granitic rock of ravines. Several springs have been thus developed by the U. S. Forest Service to improve conditions on the adjacent range. All these small springs yield water of good quality, but are of very limited supply. During periods of prolonged drought they are liable to fail.

Tres Alamos district.—Old Tres Alamos was on the east side of the San Pedro, near the mouth of Tres Alamos Arroyo, a wide channel which drains a considerable area to the northeast. Cultivation on the east side of the river has been nearly abandoned, following the deepening of the river channel by floods in 1920-1927, and the present Tres Alamos district consists of the cultivable land on the west side of the valley, along lower Ash Creek and its tributaries. In most of the open land, domestic wells obtain water at 40 or 50 feet, but in limited amounts. The irrigation of small gardens is accomplished by windmills and small pumping plants. The flat valley land is of small extent, and only about 200 acres in the district is cultivated. Along the middle portion of Ash Creek, where it reaches the base of the mountains and turns eastward to the river, there are several dug wells only 20 to 40 feet to water. Farther upstream, where it is confined in a narrow course in the foothills, Ash Creek is perennial for the distance of a mile, though the dry-season flow is hardly more than a seep. Along the river valley downstream from Tres Alamos there are wide alluvial flats covered with mesquite. In a few places, notably at the White House ranch, these bench lands have been cleared and brought under irrigation as hay lands. About 2½ miles below the White House the valley is constricted by granite hills at The Narrows, which form a dam site having storage possibilities. ~~were examined a number of years ago. A dam 100 feet high would form a reservoir nearly 6 miles long with an average width of nearly 1 mile.~~

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~~Benson-St. David district~~ Pomerene--The largest area of irrigated land in San Pedro Valley extends from about 3 miles north of Benson southward to that town (of about 1,000 population in 1934), and about 6 miles farther upstream, including the area around St. David, a settlement of about 400 population. The width of the inner valley between the bluffs on each side is ~~from~~ 2 to 4 miles, as shown on the physiographic map (Pl. 2). The character of these bluffs is shown in Plate 13,B. Throughout all but the upper margins of this inner valley, flowing artesian water may be obtained at several horizons in the underlying sands and gravels, at depths of about 300 to 900 feet. Some irrigation has been carried on from these wells, but nearly all are of small flow, and have been used chiefly for domestic and garden supplies. The well of largest flow was drilled 1 mile south of St. David by Merrill Brothers to a depth of 1,200 feet in an effort to get a supply large enough for irrigation, a discharge of 80 gallons a minute being obtained.

At Benson the Southern Pacific Railroad has drilled 10 wells, 700 to 900 feet deepth, the principal artesian water being found at about 500 feet. The following log of one of the wells shows the character of materials penetrated.

Log of well No. 3 of the Southern Pacific Railroad at Benson, Ariz.

	Thickness (feet)	Depth (feet)
Clay	40	40
Blue clay	20	60
Sand	25	85
Sand and gravel	32	117
Clay	383	500
Sand (artesian water)	200	700
Gravel	10	710
Stiff clay	14	724
"Limestone"	82	806

is now little or no evidence of the ~~buried~~ former channels. The ground-water table varies from about the level of the adjacent river bed to several feet higher along the upper borders of the lowland. The average depth to water is from 10 to 20 feet near the river, and 50 to 70 feet along the upper border of the inner valley. Southwestward from Benson the slopes rise rapidly to the Whetstone Mountains. Most of this upper land is covered by a thin layer of outwash gravel, but ~~in bluffs~~ the Tertiary sediments are ~~well~~ exposed in bluffs that border the lower lands. The upper valley lands are devoted almost entirely to grazing, no cultivation being attempted beyond small garden tracts. ~~About 8 miles south of Benson they contain diatomaceous beds, which have been prospected commercially.~~ On the east slope of the mountains, McGrew or Coyote Springs has long been used for cattle watering. A pipe conducts the water from a rock-walled basin which supplies water to the troughs. The water issues at the lower side of a thick quartzite bed, probably the Bolsa quartzite, which overlies granite, as described by Darton,[1] and illustrated by him (Fig. 4).

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[1] Darton, N. H. Guidebook of the western United States, Part F, Southern Pacific Lines: U. S. Geological Survey Bull 845, p. [illegible] (footnote) and fig. 38, 1933.

Fig. 4. Sketch section across the northwest end of the Whetstone Mountains. (after Darton).

At the Pomerene school, on the east side of the valley north of Benson, water was struck which rose within 16 feet of the surface, but an artesian flow was not obtained. Field irrigation has been carried on chiefly from a canal taking water from the river, but some land is irrigated from flowing wells.

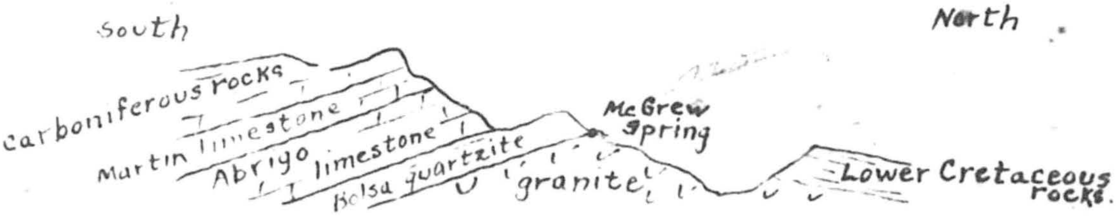

Figure 4. Sketch section across the northwest end of the Whetstone Mountains(after Darton),showing position of McGrew Spring.

About 3 miles southwest of McGrew Spring there are other small springs in the upper part of French Joe Canyon which furnish perennial water supplies. Below the springs a series of about 30 small rock tanks in the schist of the canyon bed serve as storage for much of the spring water.

(Hess, F. L., Notes on a wolframite deposit in the Whetstone mountains, Ariz. U.S. Geol. Survey Bull 380, pp 164-165, 1909)

On the upper slopes of the north end of the mountains, ~~small~~ springs or shallow dug wells in the gravel of ravines furnish small supplies, but these are so dependent on the seasonal rain and snowfall on the higher slopes as to be unreliable water supplies. They have served the needs of prospectors, however, who have examined this area for deposits of ~~scheelite~~ wolframite, a tungsten-bearing ~~mineral~~ found in the granite as described by Hess[1]. Several wells drilled in the thick gravel north of the mountains have obtained fair supplies but at considerable depths. Near the mountains water has been found at 100 to 275 feet, which probably is almost the depth to bedrock in the several wells.

The Hunt well in sec. 26, T. 17 S., R. 19 E., penetrated sand and gravel to 214 feet, then white, jointed rock (quartzite) to 240 feet, water being struck at 218 feet. Yellow clay and fine sand (probably shale) was then penetrated, to the bottom at 266 feet. Although the water was reported to have been struck in jointed rock below the unconsolidated deposits, the ground-water level was probably reached in the lower part of the gravel.

Further north, ~~although~~ down the slope, the depth to water increases somewhat and since the water table is probably not much above the bedrock surface. The area is near the divide between the basins of the San Pedro and Santa Cruz rivers and there is little contributory supply to the ground water. Near the highway about 8 miles west of Benson, and practically on the drainage divide, a test well for oil was drilled in 1928 to a depth of 1,420 feet. Small shows of oil and gas were reported at 1,225 and 1,270 feet, probably in lake bed deposits; but near the bottom very hard rock was encountered, possibly quartzite. Ground water was reached at 322 feet, and some additional water at lower horizons in the sand and gravel deposits. The following log of the well is presented through the courtesy of Mr. Edgar Colglazier of Tucson.

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Log of test well for oil on Mr. Edgar Colglazier's ranch, 8 miles west of Benson, Ariz.; NW.¼ NE.¼ sec. 17, T 17 S., R. 18 E. Drilled in 1928.

	Thickness (feet)	Depth (feet)
Surface soil	20	20
Lime and gravel	40	60
Red bed	18	78
Clay and gravel	42	120
Gray lime	20	140
Sandy white lime	10	150
Red bed	75	225
Lime	10	235
Red bed	10	245
Hard conglomerate	10	255
Red bed	50	305
Blue lime	3	308
Red bed	7	315
Lime and shells	7	322
Gray lime (water)(30 ~~bbls. per hr.~~ barrels an hour)	13	335
Red bed	5	340
Gray lime	45	~~405~~ 385
Lime and shells	20	405
Red bed	35	420
Blue lime (water) 200 ~~bbls. per hr.~~ barrels an hour)	19	449
Red bed	33	482
White shale	13	495
Gray lime	15	510
Shale	10	520
Brown lime	10	530
Brown sand (dry)	12	542
Sandy shale	12	554
Gray lime	11	565
Gray shale	15	580
Hard gray lime	115	695
Soft blue shale	100	795
Blue lime	5	800
Sandy shale	10	810
Blue lime (water)	30	840
Gray-green shale	5	845
Lime	10	855
Gray shale	10	865
Hard blue to black shale	5	870
Lime	15	885

	Thickness (feet)	Depth (feet)
Blue shale	30	905
Light gray lime	55	960
Blue shale	30	990
Lime	25	1,015
Blue shale (show of gas)	25	1,040
Lime	30	1,070
Blue Shale	50	1,120
Lime	25	1,145
Blue shale	80	1,225
Sandy shale (show of oil and gas)	30	1,255
Blue shale (show of oil and gas; 70-1300)	165	1,420

In 1934 the well was unused, though the casing had not been removed and the well was in condition to equip with pump. About 1½ miles east of the oil test the water stood at 320 feet in a cattle-watering well. About half a mile to the west it was at 240 feet, in 2 wells used respectively for domestic and for cattle supplies. The elevation of the water table in the 3 wells indicated that it sloped to the east about 200 feet in the 2 miles. Northward to the saddle of the divide at Mescal railroad station, the ground-water table slopes about parallel with the ground surface, at 100 feet to the mile.

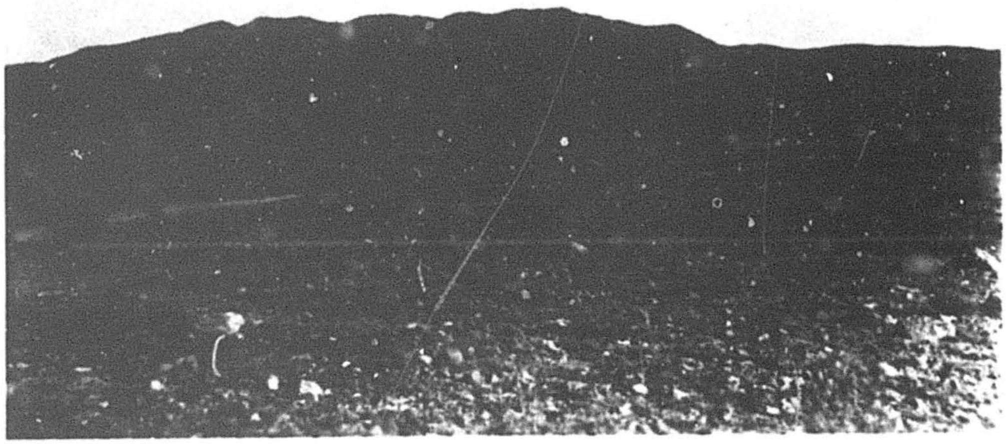
Texas Canyon.-- Texas Canyon is one of the largest tributaries to the valley near Benson. In its lower course it is deeply trenched in the alluvial lake deposits, but in its upper portion it drains the southern part of Little Dragoon Mountains, which are of coarse-grained granite that has weathered into great boulders and fantastic forms. The narrow sandy channel through the granite of the upper part of the canyon forms a natural reservoir for the runoff from the higher slopes, and along it water is obtained at depths of only a few feet. Near the mouth of the canyon, Dave Adams has lived for many years, ample supplies of water for domestic and cattle needs being obtained at about 15 feet in the gravel wash. Even in the dry season the channel is perennial for short stretches where the underflow is brought to the surface by bedrock. One small spring near Texas Canyon school has been protected by cement curbing and supplies several nearby families. The Triangle T guest ranch has obtained water at shallow depths in a small wash near the main canyon, but the supply is limited and in prolonged droughts has become low. A mile to the east several dug wells obtain water at a few feet in a little valley which is evidently underlain by bedrock at a shallow depth. About 5 miles to the north, near Johnson, an old copper camp, water is obtained from decomposed granite at about 1,000 feet; though some of the mine shafts were dry to 300 feet. Just in the saddle of the drainage divide separating the San Pedro Valley from Sulphur Spring Valley to the east, water normally stands at about 15 feet in a prospect shaft sunk in bedrock. Thence eastward to Sulphur Spring Valley the overlying gravel rapidly thickens. About half a mile east of the divide a well being drilled in 1936 had not yet found water at 120 feet. Another example of the great variation in ground-water level, due to the thickness of the gravel and lake-bed deposits, is presented by the canyon 3 miles west of Texas Canyon, in which the ranch of J. M. Oetzwiller is situated. The main water supply is obtained from a spring which issues from the bedrock 2 miles up the canyon. At the ranch a well was drilled 215 feet and yields only a small supply from water-bearing gravel struck at 211 feet, probably at near the base of the sedimentary deposits. Westward down this canyon and others parallel to it, dry cliffs of partly consolidated gravel and sand are exposed in cliffs fully 100 feet high. There are no seeps or springs of water at their bases, even during wet weather; for the base of the deposits is far deeper than the ravines have cut.

On the east side of the valley the bluffs rise so steeply that the railroad winds to gain distance and reduce the grade, until the upper slope is reached near Ochoa siding. The railroad crosses the wash of Texas Canyon three times in this climb, and passes through several deep cuts in the lake sediments and overlying gravels. Near the summit at Dragoon a well that was drilled by the railroad penetrated sand and gravel to 185 feet, and solid rock to 214 feet without obtaining water. About three-quarters of a mile farther east another test went through sand and cemented gravel to 420 feet, solid rock to 478 feet, and broken rock to 554 feet. Water of poor quality for locomotive use was obtained in the last 100 feet of the hole, which withstood a pumping test of 6,000 gallons an hour. About 1½ miles farther east, down the slope towards Sulphur Spring Valley, the railroad drilled another well to 750 feet, water being struck at 350 feet but in small amount, and the well was abandoned. In further search for a water supply on these upper slopes, a well several feet in diameter was dug in the wash 3½ miles southwest of Dragoon. Granite bedrock was encountered at 25 feet, and the small amount of water obtained in the overlying disintegrated rock did not give a satisfactory supply. A well drilled near the wash penetrated gravel and disintegrated rock to 90 feet and granite to 362 feet. Water was struck at 216 feet but of too small yield to be of value for locomotive supply. Farther down the slope a good well was drilled near Sibyl, the principal water-bearing gravel being struck at 800 feet, and drilling continued to 1,100 feet.

Here most westbound freight trains take water, and thus avoid the stop at Benson at the beginning of the climb westward out of the valley. Likewise most eastbound trains take water at Benson, to avoid stopping on the upgrade for water at Sibyl. The log of the well near Sibyl shows that the gravels and lake beds were penetrated the entire depth of the well, which stopped in shale at ~~a depth of 1,200 feet, or~~ about 600 feet below the level of the valley near

Plate 14. A. Dragoon Mountains near the Bar O ranch, showing conditions favorable for small springs and shallow ground water;

B. Dragoon Mountains, near the Horse ranch, at west side of Cochise Stronghold, showing conditions favorable for groundwater in the dry wash.



Benson. The water-bearing horizon therefore seems to be about that of the beds which yield flowing artesian water in the valley.

Dragoon Mountains:

Along the west face of the Dragoon Mountains there are several ranches whose chief water supply is from small springs. At the Fourr ranch, 6 miles south of Dragoon, water is piped from a spring in the neighboring ravine. The water issues from a bed of crystalline limestone, which crosses the ravine and apparently acts as a subsurface dam to collect the small underflow. In the next large ravine to the south two springs have been developed by small excavations in schist. The upper spring is piped to cattle-watering troughs, and the lower was developed in 1934 for domestic supply of a homesteader. At the Horse ranch two dug wells supply water from a depth of 65 feet, in gravel at the mouth of a large canyon which leads back into the mountains, in the area of granitic cliffs and boulders known as Cochise Stronghold, shown in Plate 10, A ~~(Pl.)~~. ~~It was here that a band of Apaches under Chief Cochise made a long stand against soldiers under the command of General O. O. Howard, finally surrendering in 1872, after a conference between the two leaders.~~ On the slopes to the south water, breaks out in a small cienaga, in gravel outwash from the granitic slopes. It has been ponded in a small earthen reservoir, which serves for stock watering, and farther downstream the subsurface leaking from this reservoir again comes to the surface at Ziegler Springs where held up by a layer of cemented gravel and is ponded and used for cattle. Where Slavin Gulch leaves the mountains it crosses granite bedrock in a constricted notch where the underflow appears as a small spring. This is within the ~~Colorado~~ Coronado National Forest, and has been improved by a concrete wall and designated a public water supply. About 3 miles to the southeast the water from two springs in a reentrant of the mountains is piped to the Escapule Ranch for domestic and cattle supply. In the gravel of the ravine itself a small supply has been developed in a dug well, the underflow being found at about 4 feet.

<u>Tombstone district</u>.--Along the southern portion of the Dragoon Mountains, in the district tributary to Tombstone, there are several ranches dependent for water supply on wells~~, as springs are scarce~~. In several ravines dug wells find water at less than 40 feet, though the water level varies much with the season, and in prolonged dry periods the wells may fail. At the Bar O cattle and guest ranch a well drilled 80 feet deep through the gravel outwash into solid bedrock at the base of the mountains, as shown in Plate 14, B, yields a fair supply of water. In dry seasons, however, this bedrock supply also gets low. On lower slopes to the west a well drilled for cattle supply was carried to 400 feet, to assure water, but only small additional amounts

were found below the ground-water level, reached at 300 feet. On the east side of the mountains, on slopes tributary to Sulphur Spring Valley, the towns of Gleeson and Courtland obtain shallow supplies from dug wells.

Although Ed Schiefflin made his discovery of silver ore in February 1878, the main strike was early in the following year, with the first big influx of prospectors.

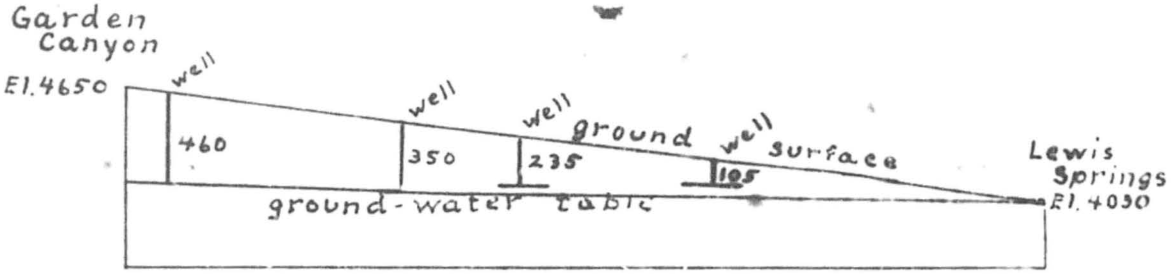
The first mining camp was at Watervale in Walnut Gulch, where water was obtained from shallow wells. The present town of Tombstone was organized in 1881 near the mines, 3 miles southeast of Watervale, and two wells about 30 feet in diameter were dug at Watervale to supply the new town's needs. One of these large wells has continued in use for local water supply. When the amount needed for the rapidly growing town became greater than these shallow wells could supply, a 4-inch pipeline was laid from Sycamore Spring, 7½ miles to the north, and a gravity flow of about 15,000 gallons a day was obtained. This spring issues where a layer of lime-cemented gravel 20 to 30 feet thick brings the water to the surface. This supply soon became inadequate for the needs of the growing town, and the Huachuca Water Company was organized, and laid a line from springs in the Huachuca Mountains 28 miles to the southwest. This line of 6-inch wrought iron pipe was still in use in 1934, and during its 52 years of service had caused very little trouble from corrosion. The dry and limy character of the soil in which the pipe was laid, and the low content of dissolved solids in the water transported have evidently been favorable to the long life of the pipe.

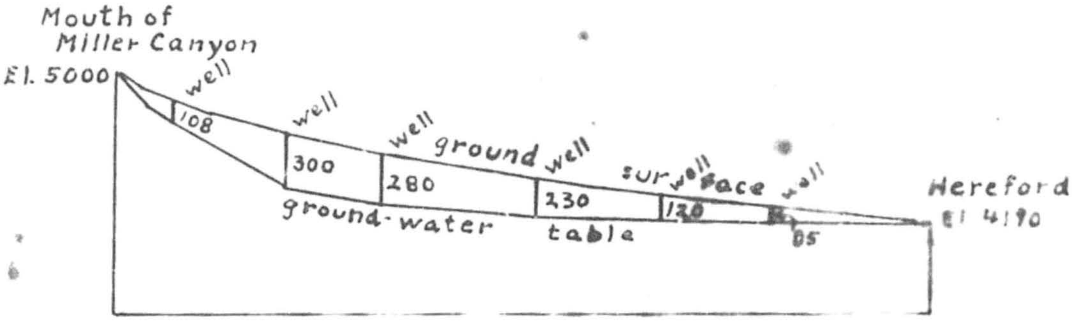
In the vicinity of Tombstone, wells have been dug or drilled along several of the gulches and have found very different water conditions in different localities. In a few places where the bedrock is compact and the gravel of the stream channel is thick enough to serve as a storage reservoir for run-off water, small supplies are obtained at depths of 5 to 30 feet. In places where there is fractured rock exposed near the stream washes, wells or prospect shafts have encountered small water supplies at shallow depths. In other localities the depth to water is unexpectedly great. Beside the highway 7 miles northwest of Tombstone a cattle well found first water at 200 feet. This is on the slopes of thick gravel and lake beds high above the inner valley, and is a good example of the great depth to water in these upper slopes. About 3 miles north of Tombstone another well obtained only a small supply at 340 feet, on the edge of a wide wash, although in a smaller wash in the vicinity water was struck at 75 feet. This great variation in water level probably is due to the thickness of unconsolidated deposits overlying bed rock, water being found near the base of the gravel fill.

Southwest of town the Tombstone Hills are pitted with scores of prospect shafts, nearly all of which are dry. On the lower slopes, toward Charleston, however, a few shafts show the depth to water, which as it does in the area northwest of town, varies greatly according to local conditions. One of the deepest of these western properties is the Old Manila mine, in whose abandoned shaft, 510 feet deep, water stood at about 400 feet in February, 1934. To the east and west of this, however, along a small draw, water stood at such discordant depths in other shafts that a definite ground-water table was not indicated. A short distance east of the Old Manila shaft there was one seepage in the wash, and water stood at 20 feet in a well near the adobe cabin built in 1858 by Frederick Brunckow, mining engineer and prospector, who was killed by Apaches 20 years before the discovery of silver in the district by Ed Schiefflin. This cabin figured in the early history of Tombstone, serving successively as store, saloon and residence; and the name of its original owner, though distorted in spelling and pronunciation was perpetuated by the later miners in Bronco Spring, Bronco Mine, and Bronco Hill.

Page 127a goes here

~~The lower lands along the river west of Tombstone below the damsite near Charleston, are sharply set off from the uplands by bluffs and are discussed by Professor Smith in the chapter on Irrigation.~~ To the south of Tombstone, Government Draw is one of the largest drainage channels. In its upper portion


Garden Canyon
El. 4650
well
460
well
350
well
235
ground
well
surface
105
Lewis Springs
El. 4030
ground-water table


Mouth of Miller Canyon
El. 5000
well
108
well
300
well
280
ground
well
230
surface
well
120
well
05
Hereford
El 4190
ground-water table

5

142

to this pipe line, the total dry-season discharge being about 100 gallons a minute. On the hillside 200 feet above Mr. James E. Tomblinson's homestead a small spring has been developed and the water has been piped to the house. Farther down the canyon the underflow appears at Clarkson Spring and furnishes the supply at the Broken Arrow guest ranch. Early in 1934 the amount available at this spring, after an unusually prolonged dry season, was about 15 gallons a minute. The rapidity with which the underflow sinks after leaving the mountains is strikingly shown near here; for in a dug well in the canyon at the ranch water stood at 15 feet, while 1 mile downstream the depth was 108 feet. ~~The~~ The water table noted in wells along the road from Miller Canyon to Hereford, and its relation to the ground surface, is shown in figure 5, b. The seeming change in the slope of the water table is probably due to perched water tables in the intermediate wells. (Page 143 goes here) To the south of Miller Canyon a spring in lower Hunter Canyon has been improved and the water piped to cattle troughs on the upper border of the outwash slopes. Boquillas Spring, near the mouth of Stump Canyon, has long been developed ~~for~~ the use of the neighboring ranch house, and has also been piped to several cattle-watering troughs farther down the slope. In 1934 it was also the supply for the Ash Canyon Camp of the Civilian Conservation Corps. The yield of the spring was fully 20 gallons a minute. Other but smaller springs in Ash Canyon and in the

The name is spelled Bronkow Hill on the General Land Office plat of T.21 S.,R.21 E.,approved by the Surveyor-General Feb. 5, 1902.

a broad divide separates the slopes, tributary to the draw, from those which extend down to Sulphur Spring Valley. This broad divide area is deeply covered with disintegrated outwash materials. Along Government Draw a number of wells have been drilled to obtain cattle water. Several were abandoned at 200 feet or deeper without reaching water; others have obtained small supplies at 175 feet to a maximum of 550 feet. The two western wells in the Trappman pasture found water at 175 and 215 feet and have galleries at the bottoms 30 or 40 feet long to increase the supply. On the east side of the divide the overburden of loose materials is thinner, and small supplies of water are obtained at less than 50 feet. Antelope Spring, about 2 miles east of the divide, has been a watering place since the earliest settlement of the region, and has been the scene of several encounters between conflicting cattle interests. Near the lower course of Government Draw, Charles La Brosse dug a well 235 feet to water, through the alternate layers of caliche and lime-cemented gravel that form the deep desert outwash. Water was struck in red sandstone, probably a member of the lake-bed deposits. About 1 mile to the southwest, the drilled well of R. L. Johnson obtained water at nearly the same elevation as the La Brosse well, although due to the slope the depth at the surface was only about 190 feet. Farther south, toward the

Mule Mountains, the water table is considerably shallower in upper Sacaton Draw. In Tombstone Canyon within the mountains a number of settlers have shallow wells supplied by the underflow in this mountain canyon.

Naco district.— The town of Naco is near the east side of the San Pedro Valley, and is on the Mexican border, the population of the American portion being about 400 and the Mexican portion about 1100. Part of its water supply is from individual wells, the depth being 90 to 110 feet on the American side of the line. In the Mexican part of town, on gentle slopes rising southward to high hills, the wells are somewhat deeper. Near the course of Greenbush Creek, north of town, the depth to water is shallower, but only in amount about equal to the lower elevation. Beside the creek 1 mile northwest of Naco there is a large pumping plant which supplies water to the town of Bisbee, 7 miles to the north, and also furnishes the main supply of Naco. This pumping site was chosen after springs and wells near Bisbee had failed to keep pace with the growing needs of that town, which started as a lead-producing camp in 1878. It is across the drainage divide, in a canyon tributary to Sulphur Spring Valley, but is too high in the mountains to render a water supply from wells in that valley easily available. The plant was constructed in the late ~~90's~~ nineties, and in 1934 consisted of a shaft 168 feet deep, with infiltration tunnels near its bottom driven 100 feet north and 200 feet south, across the direction of underflow. All the material penetrated was stream wash, grading into partially consolidated gravel which may belong to the Gila conglomerate formation. Early in 1934 the amount pumped was 8,000,000 to 10,000,000 gallons ~~per~~ a month, pumped during 8 or 9 hours a day, at a rate of about 500 ~~and equivalent to 170 to 200~~ gallons ~~per~~ a minute ~~continual flow~~. The water level when not pumping stood about 80 feet below the surface.

From Naco eastward to the broad drainage divide near Bisbee Junction the depth to water increases at a rate considerably less than the surface rise in elevation. The surface gradient from the waterworks to the Junction is 40 feet ~~per~~ to the mile, whereas that of the groundwater table is only ~~about~~ 14 feet ~~per~~ to the mile, the depth to water in 2 wells drilled at the Junction by the railroad being 175 feet. On the slope northward from Naco, up toward Don Luis, the ground-water table ~~also~~ seems, from measurements on the few wells that have been drilled, to rise at ~~a comparable gradient~~ about 15 feet to the mile.

In the ~~90's~~ nineties large quantities of mineralized water were encountered in the deeper mines, and extensive pumping was undertaken. Water pumped from the Calumet and Arizona mine has for many years been discharged into an earthen reservoir at a rate of about 2,400 gallons per minute, and thence has been used in irrigating alfalfa on the Warren ranch. The water has been so distributed over the surface that probably little, if any, returns to the ground-water table; for in 1934 no appreciable change in level had been noticed during recent years in the drilled well at the ranch.

West and northwest from Naco, the depth to water in the few wells that have been drilled varies almost directly with the elevation of the wells above the valley of Greenbush Creek. Along this drainage channel, which is dry during most of the year, wells find water at 70 ~~and~~ to 150 feet. ~~On the slopes toward the mountains,~~ especially On the outwash slopes rising to the Mule Mountains, 3 wells had been drilled prior to 1934, being sunk nearly 400 feet to reach water.

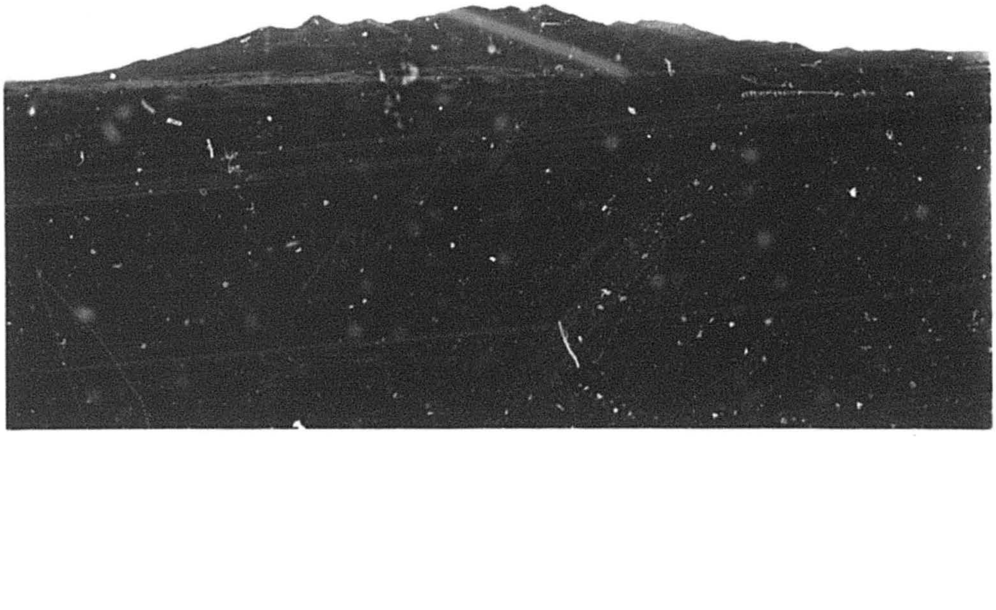
<u>Elgin district</u>— The largest tributary to the San Pedro River from the west is a Babocomari River, in whose basin Elgin, a town of about ~~50~~ 100 people in 1934, is the principal settlement. Although sometimes spelled Barbacomari, and a Spanish derivation attempted, the name is believed to be of Indian origin,

and to be derived from words meaning "rock" and "hackberry tree". In its lower course the Babocomari flows in a canyon, cut near its mouth in granite porphyry. In its middle portion it opens to form the valley included in the Babocomari ranch. In this portion it affords a considerable area of lowland, in part irrigated by ditches and in part consisting of natural meadows and cienegas. Before 1845 this valley was the headquarters for large Mexican cattle interests, the site of the principal buildings and corrals still being indicated by almost obliterated ruins near the present home ranch. Water is obtained along the valley at 30 to 50 feet in wells, most of which have been drilled; and equipped with windmills to supply cattle troughs. For several miles farther up stream the trough of the valley affords shallow water. Several wells at Elgin obtain supplies at 10 to 20 feet. On the slopes on each side of the main channel, wells penetrate nearly to the level of the stream in order to reach water.

The ground-water table in the area west and north of Elgin has a flat gradient; for the limited amount of water that reaches the underground supply sinks deep into the outwash and probably is aided in its downward course by the attitude of the beds. The late Tertiary sandstones and other lake-bed deposits have been locally faulted and tilted. Good exposures of these disturbed beds

Plate 15. A. Looking northwestward up Rain Valley, showing conditions of deep ground water in the valley fill, below cliffs of Martin limestone;

B. Dissected pediment northwest ofthe Huachuca Mountains, showing conditions favorable for shallow ground water along the washes.



are to be seen near the highway bridge at Elgin, where they dip 40° or 50° to the southwest. A few miles to the north, near the Starr King ranch of L. W. Klene, the beds are exposed dipping 30° westward.

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The narrow valley between the Mustang and the Whetstone mountains ~~is~~ as shown in Plate 15, A, is locally known as Rain Valley. A few wells in its central portion obtain shallow water near the stream channel, but most of the wells have been drilled to depths of more than 150 feet to obtain supplies. The alluvium apparently does not contain much water, and better supplies are obtained from the underlying Cretaceous sandstone. The well of Mr. E. W. Harkey, in the open land beyond the lower end of the valley proper, penetrated boulders and gravel to 200 feet, red sandstone to 220 feet and black sandy shale to 310 feet, finding a small amount of water near the bottom. ¶ About 1930 a test well for oil was drilled 3 miles southwest of Elgin to a total depth of 1,154 feet. A small amount of oil was reported to have been struck near the bottom, probably in the lower part of the lake-bed series. No great amounts of water were encountered below the ground-water level, which in 1934 was at about 50 feet in the oil test and also in a cattle-watering well nearby. This was reported to be the depth at which water was struck in these two wells, and in another well 2 miles farther down

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the same wash. No appreciable artesian pressure was found in any of the wells. Near the headwaters of this wash and of Vaughn Canyon, a number of settlers obtain water from dug or drilled wells at depths of 20 to 80 feet. In a few localities where the gravel and lake sediments are unusually thick, the ground-water table is at somewhat greater depth. In a few other places wells have been drilled through this thin cover of wash gravel into the bedrock to depths of 100 to 200 feet, and obtain only small supplies. Close to the trough of the valley several wells reach water at about 30 feet, and find another water-bearing layer at about 150 feet. The southern side of the valley rises rapidly to Mustang Mountains (Pl.). In 1934, water supplies had not been developed on these slopes. On the north side of the valley several wells had water at 100 to 150 feet and on the higher slopes 2 or 3 unsuccessful wells had been drilled deeper than 200 feet.

In the upland plains a few miles east of Rain Valley, a few wells have been drilled for domestic and cattle supplies. Most of these were drilled by Mr. Louis A. Boelecker, who kindly furnished information concerning them. All were drilled some distance below the ground-water level in order to assure non-failing supplies. None reached hard bedrock, water being found either in unconsolidated gravel or in the underlying soft lake deposits. Little difficulty was experienced in drilling, for the materials are sufficiently cemented by lime to stand up without casing. Water was found at about 150 to 300 feet, depending on the surface elevation and local presence of porous water-bearing beds overlying relatively impervious ones. There seems to be no uniform water table within these extensive outwash caliche and lakebed deposits.

The Mustang Mountains form too small an area to be favorable for the collection of snow and rain to feed springs, and no perennial springs were reported within them. In the Whetstone Mountains, however, there are several springs of local importance. Mescal Spring~~s~~ is one of the largest of these. Its discharge of about 5 gallons ~~per~~ a minute ~~in dry seasons~~ has been piped down to the Manistee Ranch, 3 miles below. The water issues at the base of alluvium overlying Cretaceous sandstone which dips 60°N. A well that was drilled at the ranch yields only a small amount, insufficient for cattle needs. On the south and west sides of the mountains Cottonwood Spring and Bear Spring form small watering places, and just west of the drainage divide at the head of Rain Valley, are two or more other small springs. These issue from red Cretaceous sandstone. Cottonwood Spring figures in local history as the "Iron Springs" at which Curly Bill was camped in March, 1882, when overtaken and shot by Wyatt Earp near the south end of the mountains.

The water issues at the base of alluvium overlying sandstone that dips 60°N. The discharge of 5 gallons a minute has been piped down to the Manistee ranch, 3 miles below. A well that was drilled at the ranch yields only a small amount, insufficient for cattle needs.

Cottonwood Spring, farther west, issues at the base of about 30 feet of gravel overlying sandstone. It ~~At the south end of the mountains~~ Cottonwood Spring forms a small watering place in a wide wash, and figures in local history as the spring at which Curly Bill was camped in March, 1882, when overtaken and shot by Wyatt Earp, ex-marshal of Tombstone.

Burns, Walter Noble; Tombstone; p.248, 1927.

Just west of the drainage divide at the head of Rain Valley, Mud Spring, Speed Spring, and probably several other small springs, issue from red, Cretaceous sandstone, and form watering places for range cattle. Farther north and higher on the mountain slopes, Bear Spring issues on the ~~slope~~ flank of Granite Peak; on the northwest slope of the mountains, Apache Spring and Nogales Spring also afford small but perennial watering places.

where a local east-west fault crosses a ravine and probably acts as a dam to collect water in the upstream block.

ex-marshall of Tombstone.

Burns, Walter Noble; Tombstone; p. 248, 1937.

Canelo district.-- The Canelo Hills[1] form part of the southwest border

[1] From the Spanish "canelo" (cinnamon-colored), referring to their prevailing color. The word has been locally mis-spelled Canille.

of the San Pedro basin. The area between the main range of hills and the Huachuca Mountains is divided into the narrow valleys of Cocho Valley, Lyle Canyon and Sycamore Gulch, known collectively as the Canelo district. The rocks of the hills are mainly of Devonian and Carboniferous limestones, dipping to the southwest, which is an exception to the general easterly dip in the region. Granite is exposed in the crest of the hills for a short distance west of the road pass at the head of Cocho Valley. The district is at a considerable elevation above that of the valley of the Babocomari River. In passing southward one therefore rises above the area of cactus and other desert shrubs, through a zone of juniper and piñon trees, into an area of live oaks and scattered pines. Along the valley lands there are a number of settlers, each with a few cattle and with small areas of hay land, irrigated with flood water. Shallow wells supply the domestic needs. Along Cocho

Valley ground water is found at 10 or 15 feet in the bottom land and somewhat deeper along the narrow valley sides. In the upper part of Sycamore Gulch ample water at the Diamond C cattle and guest ranch is obtained from the gravelly stream wash. Farther down stream ~~the~~ a small supply from fissured bed-rock has been developed by Mr. R. L. Parsons into a flowing spring. Near the base of the Huachuca Mountains but high above Sycamore Gulch, on the pediment slopes shown in Plate 15, B ~~there~~ are several small perennial springs, of which those at the Pyatt ranch are perhaps the largest. Their flow of about 10 gallons ~~per~~ a minute is ponded and used for garden as well as domestic purposes. Near the central course of Lyle Canyon the water comes to the surface in a small meadow, and thence flows as a perennial stream for 2 or 3 miles.

Huachuca Mountains--The northern and eastern portions of Huachuca Mountains are included in the Fort Huachuca military reservation, which was established ~~in the 70's~~ as one of the military posts ~~near the Mexican border~~ to control the Apaches. The main water supply comes from 2 springs in the canyon above the fort. The supply is usually sufficient for the needs of the encampment of about 1,000 men and 200 horses ordinarily stationed there. The springs issue at elevations about ?,000 feet lower than the crest of the mountains. The upper spring is near the contact of Cambrian rocks resting on granite. The lower spring, a mile farther down the canyon, issues from Carboniferous limestone, where a small dike of porphyry forms a natural dam. Both springs are evidently fed by the snow and rainfall of the higher slopes. During long dry periods the supply notably diminishes, and in some years it has been necessary to transfer part of the horses elsewhere until rain or snow has replenished the springs. Attempt has been made to obtain additional supply by drilling wells; a well was drilled to nearly 1,000 in bedrock on the east side of the ravine half a mile south of the office buildings, but only a small amount of water was encountered in seams in the upper rock. In 1932 a well was drilled 95 feet deep near where Tanner Canyon opens from the mountains. Water was found at a few feet in the gravel, which was 68 feet thick at the well site. The remaining depth was drilled in disintegrated to fresh granite in which very little water was found. In February, 1934, after months of prolonged drought, water stood at 11 feet in this well, which was capped and not yet used as a supply. The deep gravel of this canyon mouth offers a good place for the development of considerable underflow water by wells dug or drilled in the gravel.

Infiltration galleries in the constricted part of the canyon, about 2 miles above the test well, might also succeed in developing a supply of water that could be piped by gravity to the storage reservoir at the fort. There is a drainage area of nearly 9 square miles in the higher part of the mountains, which is tributary to this gorge. At and near the town of Garden Canyon, just east of the military reservation, several dug wells obtain small water supplies in the beds of washes. In 1934 there was 1 drilled well in town; that of Oliver Frye. This had a total depth of 500 feet, the water level being at about 460 feet. This well supplied a number of houses in the vicinity. Farther eastward, down the wide sloping plain, in part covered with a surface of caliche, the depth to water is progressively shallower as the river is approached. The ground-water table was observed in several wells, and its relation to the water surface is shown in Fig.____. The eastward slope of the water table in this area is only about 10 feet per mile, whereas the gradient of the surface is about 70 feet per mile. Ramsay Canyon is south of Tanner Canyon, and extends back to the crest of the mountains. In its upper portion, settlements at Ramsay and Kimburg, which consist chiefly of summer cottages, owned by residents of Bisbee and Tombstone, are supplied with water from shallow wells.

Palominas District-- In the vicinity of Palominas school, at the crossroads 3 miles north of the Mexican border, there are a number of families having grazing interests supplemented by irrigation along the river lowland. San Pedro River is trenched only 3 or 4 feet deep at the highway crossing, and flows of artesian water are obtained along this bottom land. Typical of the artesian wells is that of J. B. Polley, about 3 miles north of Palominas. This well penetrated about 20 feet of gravel, 30 feet of clay, and 55 feet of sand, to 105 feet, at which depth an artesian flow was obtained. Drilling was continued to 308 feet, the strongest flow being encountered at 275 feet. The well was cased only to 100 feet, as the lower materials were partially consolidated ~~consolidated~~ and did not cave. The irrigation in this district is described by Professor Smith in the discussion of artesian wells.

On the east side the inner valley is bordered by bluffs of outwash and lake deposits. To the west, the slope rises more gradually to the upper lands, ~~as shown in~~ see Pl. 10, B. The boundary between inner and outer valleys is thus not so definitely marked by bluffs or terraces on the west side of the river. During ~~the~~ seasons of more than average rainfall, in 1905-1909, much of the unpatented land for several miles north and west of Palominas, was filed upon as grazing homesteads of 640 acres. The National Forests lands afforded good range, and some dry farming of beans and other quick-growing crops, was attempted. A few settlers proved up on their holdings and remained; but with succeeding dry years, many abandoned their lands or sold them to the larger cattle interests. In 1934 the area had largely reverted to cattle range, with drilled wells and windmills supplying scattered watering places. One of the largest developed water supplies on the west side of the valley was at the Y-Lightning cattle and guest ranch. Here 2 wells respectively 348 and 277 feet deep supplied ample water for the home ranch and cattle needs, the ground-water table being at about 100 feet. As is true from near Fort Huachuca down to the river, the ground-water table in the Palominas district is at shallow depths near the base of the mountains, deepening to a maximum in the middle portion of the outwash slope, and thence getting shallower toward the river until the water table nearly coincides with the level of the river channel. In upper Miller Canyon, there are springs which furnish the supply to the Huachuca Water Company's pipe line to Tombstone. The intake is at a basin 30 feet deep and 20 feet square, excavated in the granite of the ravine. Clark Spring, farther down the canyon, also is appropriated

A similar rapid drop in the water table at a locality in the Santa Crus Valley has been reported by Professor Smith, who found that at the point of the mountains near Rillito station,*

> As the river valley opens put after passing the basaltic mountain, the water table drops from a depth of 18 feet below the surface to a depth of 120 feet in a distance of less than a mile.

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*Smith, G.E.P., Ground-Water supply and irrigation in the Rillito Valley: Arizona Univ.Agr.Exp.Sta., Bull.64, p.179 (footnote) 1910.

ravines farther south have also been developed and used since the early days of settlement.

QUALITY OF GROUND WATER

~~Quality of water~~ Character of the water.

During the course of the field examinations, samples of water for analysis were collected from a number of wells and springs throughout the valley, selectd so far as possible to show the different character of water in different areas.

Outline for discussion of analysis

Beginning in the north, the waters from several wells on the upper slopes west of Winkelman show (discuss samples 1,2,3 and 4).

In the lowland near the mouth of San P edro River (discuss samples 5,6, and 7).

Farther south, the spring near Cook's Pond (discuss samples 8 and 9).

A shallow dug well in the lowland near the springs, as compared with the river water (discuss samples 10 and 11).

On the granite uplands southeast of Oracle the 3 C Spring (American Flag Spring) and the spring at the 3 C ranch (discuss samples 12 and 13).

Waters from the two deepest artesian wells southeast of Mammoth (discuss samples 14 and 15).

On the east side of the valley, Mulberry Spring and the spring at the Bunker Hill Mine (discuss samples 16 and 17).

Farther south, Burro Springs issue from the Tertiary sediments and show (discuss sample 18).

The samples of water collected in 1920-21 were analysed for silica and iron. Silica is an unimportant constituent and was found to be present in comparatively small amounts in all the samples. The amount of iron present in most of the samples was insignificant. These two substances were not determined in the samples collected in 1934. In most of the samples analysed the content of nitrate was low. The presence of more than 10 parts per million in several samples indicates that the water may have been contaminated by the oxidised products of organic matter. On the whole the waters are lower in dissolved mineral matter than are the ground waters in many other arid regions and some of the waters are quite soft.

Fluoride content.

The later samples collected were examined for fluoride, which was found to be present in some of the waters in amounts of several parts per million. In those portions of the valley where such amounts are present in water that is regularly used for domestic supply there are numerous cases of mottled enamel, a disease of the teeth which is believed to be due chiefly to fluoride in the drinking water.

The mottling is primarily a defect of the second or permanent teeth. They become dull chalky white and may or may not become stained from pale brown to nearly black. In severe cases the enamel becomes defective and the teeth chip off.

The character of the well waters with relation to mottled enamel in the San Pedro Valley has been studied by Smith and Smith, who have published the preliminary results of their studies.

Smith, M.C., Lantz, E.M. and Smith, H.B. The cause of mottled enamel, a defect of human teeth; Univ. Ariz. Agr. Exp. Sta., Tech. Bull. 32, 1931.

Smith, H.V. and Smith, Margaret C. Mottled enamel in Arizona and its correlation with the concentration of fluorides in the water supplies; Univ. Ariz. Agr. Exp. Sta. Tech. Bull. 43, 1932.

The following analyses by them show the varying concentration of fluoride in the drinking water supplies of several communities in the valley.

Analyses of ground waters from San Pedro Valley, Ariz.

Made by H.V.Smith and Margaret C.Smith, Univ.Arizona, Agr.Exp.Station,

with special regard to the fluoride content

Parts per million.

	Calcium (Ca)	Magnesium (Mg)	Fluoride (F)	Chloride (Cl)	Sulphate (SO_4)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Residue
1.	82	15	[a] 1.1	272	130	7	276	856
2.	[illegible]	8	[a] 3.9	44	110	7	198	408
3.	105	26	[a] 1.3	58	60	22	368	524
4.	30	4	[a] .6	16	tr	17	195	292
5.	30	8	[a] .5	18	15	7	212	252
6.	30	7	[a] .3	12	tr	0	237	264
7.	25	8	1.4	16	tr	17	207	252
8.	8	0	1.3	10	tr	5	171	264
9.	23	11	.3	12	tr	14	217	268
10.	30	11	.7	10	33	10	173	272
11.	45	4	.2	8	tr	10	142	228
12.	30	8	.8	14	0	29	217	264
13.	23	8	.4	16	tr	0	220	232
14.	60	4	.7	24	tr	10	198	254

1. Winkelman, city supply, from shallow dug well 1 mile east of town.
2. Mammoth, shallow dug well at C.C.Clark store.
3. Oracle, 40-foot dug well at Roy Gonzales filling station.
4. Pomerene school, 610-foot drilled well.
5. Pomerene, well of Mr. Coon.
6. Benson, city supply, from 800-foot artesian well, cased to bottom.
7. Benson, 450-foot artesian well of C.L.Rucker.
8. Fairbank, railroad well, 280 feet deep, cased to bottom.

10. L.Trappman, shallow dug well 2 miles northwest of Tombstone.

9. Boquillas ranch, 90-foot well, 1½ miles south of Fairbank.

11. Tombstone, city supply from springs in Huachuca Mountains.
12. [illegible] school, 20-foot dug well. ← Cavelo
13. Hereford, 420-foot artesian well of J.L.Williams.
14. Bisbee, city water supply from dug wells 1 mile northwest of Naco.

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[a] Smith, H.V., and Smith, Margaret C., Mottled enamel in Arizona and its correlation with the concentration of fluorides in the water supplies: Univ. Arizona Agr. Exp. Sta. Technical Bull. 43, 1932. pp. 223-275, 1932.

[a] These are the revised figures given by H.V.Smith in "Determination of fluorine in drinking water": Industrial and Engineering Chemistry, vol.7, no.1, p. 24, Jan.15, 1935.

In addition to these analyses tabulated, Smith and Smith made analyses of six artesian well waters from the St.David district, which ranged from 1.9 parts of fluoride per million, to 12.6 parts.

In commenting on the results of the analyses the authors state that op.cit. pp.225-280.

~~the nativefborn residents of Benson~~

the native-born inhabitants of Benson are free from mottled enamel while at St.David some of the most severe cases were found. No mottled enamel occurs in the native born at Bisbee, Lowell and Warren who use the city water. No cases were reported from the Canelo district, nor from Fairbank or Hereford; but at Mammoth every native born child was found to have moderately severe mottling of the permanent teeth. At Oracle only a few children were found who had always lived there, but all had moderately severe mottled enamel of the permanent teeth. Considerable variation was noted in the condition of the teeth of children at Pomerene, where some families use the school well water and others have private wells. An intensive study at St.David showed that every child native to the community had mottled enamel of the moderately severe or severe type. The defect was not found in the teeth of the school children at Tombstone, where the water supply is from springs in the Huachuca Mountains. At Winkelman practically every child native to the town had a mild case of mottled enamel.

"The differences in fluoride concentration found in the waters tested could not be correlated with differences in depth of water supply nor in type of well. The belief that artesian or deep-well water is more likely to contain high concentrations of fluorides and to be more frequently associated with mottled enamel was not borne out in this State. In many cases the deeper wellsin use by the municipalities show a lower fluoride content than do the shallower private wells in the surrounding country. Artesian water from great depth, deepwell water, shallow-dug-well water, surface waters, and spring waters have all been found to have abnormally high concentration of fluorides in certain regions. . . . . Prediction from location as to what to expect in the way of fluoride content of water supply in a given region seems impossible."

~~Smith and Smith, op.cit., pp.282-283.~~

Smith, *.'.

Smith, H.V., and Smith, Margaret C., op.cit., pp.282-283.

The distribution of the samples on which determination of fluoride was made, including the samples analyzed by Smith and Smith, is shown on Plate 16, together with the geologic formations in which the waters are found. The areas of highest fluoride concentration are

Plate 16. Map of San Pedro Valley, Arizona, showing fluoride content in ground waters, and principal geologic formations (folding-page plate)

seen to be in the inner valley, in artesian waters from the Tertiary sedimentary deposits. The three waters from the granitic area of the Dragoon Mountains that were analyzed contain appreciable amounts of fluoride; but the ground water along the eastern side of the Huachuca Mountains seem to be nearly free from fluoride.

~~Discussion of analyses.~~

On the slopes of the west side of the San Pedro Valley the well of Mr. T.H. Dennis near its north end was sunk through 30 feet of gravel to a depth of 81 feet in monzonite, a variety of granitic rock, which in this locality contains considerable pyrite. The water is strongly charged with dissolved mineral matter. Analysis 1 of the table (~~page~~ p. 169), shows a content of 3,612 parts per million of dissolved mineral matter, most of which consists of gypsum (calcium sulphate) in solution. There is also considerable magnesium present, with lesser amounts of sodium and bicarbonate. It is probable that if other tests were mad in the vicinity a location would be found where the ground water is of much better quality.

About 3 miles southwest of the Dennis well and farther up the valley side the dug well at the Lopez Brothers ranch contains water of fair quality. Analysis 2 shows tht the principal dissolved substances ~~are~~ in solution are calcium, sodium and bicarbonate. ~~At t~~

At the Finch ranch about 4 miles farther south of the Lopez ranch water of similar character is obtained in a dug well though it is somewhat more strongly mineralized as shown by analysis 3.

At the Hayden ranch on the upper slope of the valley analysis 4 shows that the well water contains considerable calcium in solution and is comparatively hard. The contents of sodium and bicarbonate are comparatively low. These four waters from wells dug on the higher slopes in the northwest part of the valley are believed to be representative of the shallow ground water of that district.

In the lowland near the mouth of the San Pedro River two shallow wells of Mr.M.W.Ray contain water that is rather highly mineralized. Analyses 5 and 6 show that both are gypsum waters, calcium and sulphate being the dominant constituents. These waters also contain considerable amounts of sodium, bicarbonate and chloride. The water of the north well is nearly three times as strongly mineralized as that of the south well but is similar in composition to the latter except that it contains ~~proportionably~~ proportionately more sulphate and less bicarbonate.

About 7 miles up the valley the springs near Cook's Pond discharge water that has a comparatively low content of mineral matter in solution. Analysis 7 shows it to be a bicarbonate water with a minor content of sulphate. However since calcium and magnesium are present in greater amounts than sodium and potassium, it is a comparatively hard water.

The springs which issue near the bases of mountain slopes ~~west of Mammoth~~ on the ~~30~~ 50 ranch west of Mammoth issue from granitic rock or from conglomerate immediately overlying the bed rock, and are waters of comparatively low mineral content. Analyses 8 and 9 of the two principal springs show that they are very similar in character, being calcium carbonate waters of moderate concentration.

The two artesian wells in the valley southeast of Mammoth are shown by analyses 10 and 11 to be sodium bicarbonate waters which also contain considerable amounts of sulphate. They are however very low in calcium and magnesium and hence are very soft waters. It is of interest to find such soft waters coming from the deep formations in an area where beds of gypsum are exposed on the neighboring hillsides.

On the eastern side of the valley Mulberry Spring and the spring near the Bunker Hill Mine discharge waters which are shown by analyses 12 and 13 to have calcium and bicarbonate as the principal dissolved mineral substances. Although they are much harder than the artesian well waters because of the large amounts of lime carbonate in solution they contain approximately the same amount of total dissolved mineral matter as does the water from the deep well on the Wills ranch. The amounts of silica in the two spring waters are somewhat higher than is present in most waters of the region.

Burro Springs issue on the east border of the inner valley at the base of bluffs of Tertiary sediments. Analysis 14 shows that the water is rather highly mineralized and it contains 1,086 parts per million of dissolved mineral matter. The principal substances are the bicarbonates, sulphate and chloride of sodium. There are comparatively small amounts of calcium and magnesium present, so the hardness is low.

In the Redington district the waters from the two drilled wells on the Bayliss ranch differ considerably in character. Analysis 15 of a sample from the well 6 miles north of Redington contained only 134 parts per million of dissolved mineral matter, sodium and bicarbonate being the chief constituents. The well water at Redington contains 510 parts per million of dissolved mineral matter and is a hard water containing calcium and sulphate in considerable amounts.

The samples from four wells in the vicinity of Cascabel vary considerably in chemical character. Analysis 21 of the water from the dug well at Cascabel school shows 310 parts per million of dissolved mineral matter of which bicarbonate is the chief constituent, with calcium and magnesium approximately equal to sodium and potassium. The shallow well of Mr. Thomas Hewitt at Cascabel, analysis 22, contains water having 768 parts per million of dissolved mineral matter. It is therefore nearly 2½ times as concentrated as that of the school well. There are larger proportionate amounts of sodium and potassium and also of chloride. A dug well half a mile south of Cascabel supplies water which is shown by analysis 23 to be similar to that of the school well. Its somewhat greater total content of mineral matter, 362 parts per million, is due to a larger content of sodium and potassium and to the recorded presence of 40 parts of silica which substance was not determined in the sample from the school well.

On the Poole ranch (Bodegain ranch) a dug well supplies water which is shown by analysis 24 to contain 522 parts of mineral matter in solution. It is a sodium bicarbonate water which also contains considerable sulpha[illegible] All four waters from near Cascabel which were analysed are of good quality for domestic and other uses in so far as their mineral content is concerned, and the low nitrate content in the samples indicates that at the time of collection the waters were not contaminated by the oxidized products of organic matter.

High on the valley side east of Cascabel in the valley of Hot Springs Canyon which joins the San Pedro River near Cascabel, there is a dug well on the Double R ranch. Analysis 51 of water from this well shows that it contains only about 200 parts per million of dissolved mineral matter, one-quarter of which consists of silica. It is a soft sodium bicarbonate water. In the same valley Hooker's Hot Springs, analysis 53, discharged a moderately mineralized water in which sodium and bicarbonate are the principal constituents. The amount of silica in solution is about twice as high as in most of the waters of the region, however. A warm spring on the Muleshoe ranch farther down stream, analysis 32, yields water that is very similartot that of the hot springs. A cool spring on the Phillips ranch, analysis 52, yields water that contains more calcium and sodium carbonates in solution than do the thermal springs, but it contains a smaller total content of dissolved mineral matter.

The Antelope well in the south part of Hot Springs Valley was drilled through unconsolidated deposits in which ground water was reached at 475 feet. Analysis 54 shows it to be a soft sodium bicarbonate water. Calcium, magnesium, sulphate and chloride are present in very small amounts.

In the Tres Alamos district on the west side of the San Pedro Valley one of the principal water supplies is Pacheco Spring. The water issues from a low bluff of Pliocene sediments. Analysis 25 shows it to be a calcium carbonate water containing only 176 parts per million of total dissolved mineral matter. The content of sodium and of chloride is quite small.

Samples were collected from three wells in the pediment area west of Benson. Analyses 26 and 27 of the western two wells show that both are calcium carbonate waters of moderate concentration. The Jespersen well, analysis 26, is beside the highway and near the drainage divide between San Pedro and Santa Cruz Valleys.

The water contains only 173 parts per million of dissolved mineral matter, of which 47 parts are of calcium and magnesium and only 10 parts are of sodium and potassium. The Hunt well farther south and nearer the base of the Whetstone Mountains contains 276 parts of dissolved miner l matter and is somewhat more concentrated than the other water in both calcium and sodium.

The drilled well of Mr. James Harmon is partly down the slope toward Benson. It apparently obtains water from gypsum-bearing lake beds; for analysis 39 shows that in addition to sodium and bicarbonate the water contains considerable amounts of calcium and sulphate. Its total mineral content of 424 parts per million is considerably higher than that of waters from wells situated farther up the slope.

At the northeast base of the Whetstone Mountains, McGrew Spring issues from a quartzite ledge and has been developed for cattle use. Analysis 28 shows that its water is quite similar to that from the Hunt well afew miles to the north, calcium and bicarbonate being the principal constituents. The presence of nearly 2 parts per million of fluoride in this water is of interest; especially so because the water issues from the dense rocks of the mountain and has not come in contact with the Tertiary deposits which cover the lower lands.

Samples for analysis were collected from six wells in the valley near Pomerene. All the wells were drillee to the deeper water horizons and four of them are flowing artesian wells. The water in the well at Pomerene school did not rise quite to the surface and in the northernmost well, analysis 33, the casing apparently was broken and water stood at the ground water level, about 50 feet below the surface. This well contains water which has a rather high content of calcium, bicarbonate and sulphate. This is probably the shallow groun ground water. The other five wells, analyses 34,-38 a , yield waters which are similar in their content of mineral matter, which ranges from 211 to 287 parts per million. All are sodium bicarbonate waters containing small amounts of calcium sulphate (gypsum) in solution.

Samples were collected in 1934 from two of the wells that had been sampled in 1921, in order to check a possible change in the composition of the artesian water, and to examine it for fluoride. No appreciable change in composition is indicated by analyses 36, 36 a, 38 and 38 a, but the last analysis shows an unusually high content of 4.2 parts of fluoride.

During examination of the area in 1921, samples of water were collected from five wells in Benson. All were drilled to the main artesian horizon at about 500 feet, but two of them situated in the higher part of town did not flow. Analyses 40,-44 show that they are all bicarbonate waters containing approximately equal amounts of calcium and sodium. The contents of sulphate and chloride are low, and the total amounts of mineral matter in solution in the five samples range only from 257 to 276 parts per million. The waters are of good quality so far as their mineral contents are concerned for all domestic and other uses. These samples were not examined for fluoride.

Analyses 45 and 45 a of water samples collected in 1921 and 1934 from a small drilled well 3 miles south of Benson which has been used for cattle watering show that it is a bicarbonate water containing nearly equal amounts of sodium and calcium. Minor changes in its mineral content had taken place between the dates of collection of the two samples, the total solids having decreased, chiefly due to the presence of less calcium and bicarbonate, but there had apparently been a small increase in the contents of sodium and sulphate. Its content of 2.6 parts per million of fluoride is also noteworthy.

About 3 miles southeast of the small drilled well just described the artesian well of greatest discharge on the ranch of Mr. J. E. Parker was sampled in 1921 and again in 1934. Analyses 46 and 46a show it to be a bicarbonate water of low concentration with calcium and magnesium present in considerable excess over sodium and potassium. Like the cattle watering wells to the northwest, the water of the Parker well has become less mineralized in the interval between the collection of the two samples. The water carries a content of 3 parts per million of fluoride.

Water samples were collected from seven flowing artesian wells at and near St.David in 1920-21, and samples were again collected from six of these wells in 1934 to examine them for fluoride and for possible changes in the dissolved mineral content. Samples 55-58 a from wells within a mile of each other show them to be similar in composition. All are sodium bicarbonate waters and are quite soft. The apparent decrease in mineral content in all of them is chiefly due to the determination of silica in the early analyses but not in the later ones. All four waters contain amounts of fluoride great enough to be a contributing cause to mottled enamel of the teeth if they are used continually as a drinking water supply. Analyses 59-61a of three artesian wells in the lowland south of St.David show them to be ~~are~~ soft sodium bicarbonate waters like those closer to the village. One characteristic worthy of note is their lower content of fluoride.

In Texas Canyon east of the valley lands of Benson and St.David small water supplies are furnished by several springs. Analysis 67 of water from a spring near Texas Canyon school shows it to contain an unusually low content of dissolved mineral matter. This might be expected since the water is essentially underflow in the upper part of a wash in the granitic hills. Calcium and bicarbonate are the principal constituents, with secondary amounts of sodium and sulphate. The amount of fluoride present although it is only .6 part per million, is greater than in some of the artesian waters of the inner valley. It may be of significance in indicating that the fluoride is derived from minerals in the granitic rocks.

Samples of water were collected from two springs and three dug wells along the base of the Dragoon Mountains. Analysis 74, from Fourr Spring, shows that it is a calcium carbonate water as would be expected because it issues at the base of a limestone ledge. The source of the comparatively large content of sulphate in the water is not so evident however. Although it is a hard water the content of dissolved mineral matter is only moderate and so far as the mineral character is concerned the water is suitable for domestic and other purposes.

The water of a dug well at the Horse ranch comes from granitic wash and is similar in mineral content to the spring water in Texas Canyon. Analysis 75 shows that the well water has as its principal mineral constituents calcium carbonate in solution. Its content of fluoride is nearly the same as that of the spring in Texas Canyon.

Sycamore Spring, analysis 76, discharges a rather hard water whose principal dissolved mineral matter consists of calcium carbonate; but in so far as its mineral content is concerned it is a good water for all ordinary uses.

The shallow dug well on the J O Bar ranch, analysis 77, and the dug well of Mr. L. Trappman, analysis 78, yield calcium carbonate waters similar in character to others near the Dragoon Mountains which were examined. The water of the Trappman well on the broad drainage divide at the head of Government Draw contains only about one-half as much mineral matter in solution as does the water of the shallower well.

On the pediment slope south of Tombstone the well of Mr. C.H.Myers reaches water in red beds which are probably a basal part of the lake beds or the Gila conglomerate. Analysis 68 shows that the water is of fair quality for domestic use with calcium carbonate in solution as the principal constituent and sodium and sulphate as minor substances present.

About 10 miles south of the Myers well and farther down the pediment slope the dug well of Mr.Roy Rambo reached water at 110 feet. Analysis 70 shows the wa water to be similar in mineral constituents and in total amount of dissolved mineral matter to that of the Miles well. The high nitrate content in the samples collected from each well is of interest in these comparatively deep ground waters.

In the valley lowland west of Tombstone a shallow dug well on the Boquillas ranch, analysis 62, furnishes water of comparatively low mineral content. It resembles the ground water of the higher slopes in having calcium carbonate as the principal mineral in solution. The presence of only .1 part per million of fluoride is noteworthy.

Hasselgren Spring near Lewis Springs railroad station issues from sandstone of the Pliocene deposits. Analysis 69 shows that it is a calcium carbonate water of moderate concentration.

Samples were collected from two non-flowing artesian wells at Hereford. Analysis 71 of water from the school well and analysis 72 of water from a well near the railroad station show that both are waters of moderate mineral content having calcium and bicarbonate as the chief substances in solution. Sodium is present in minor amounts, and the contents of chloride and sulphate are low.

On the west side of San Pedro Valley samples of water were collected from six wells in the Elgin district. Analyses 17 and 18 from two drilled wells on the Starr King ranch of Mr. L. W. Klemm show them to be calcium carbonate waters of moderate concentration containing minor amounts of sodium and chloride and unusually low content of sulphate. The wells obtain water from red sandy beds probably of the Gila conglomerate. The shallow dug well at Elgin school, analysis 19, also furnishes a calcium carbonate water of moderate mineral content.

To the south of Elgin the shallow well of Mrs. Mattie Johnson in Coche Valley yields water which is shown by analysis 20 to contain calcium and bicarbonate as the principal dissolved substances. The absence of fluoride from this water is noteworthy. The well is in a narrow valley bordered by hills of ancient sedimentary rocks.

In Rain Valley a few miles northeast of Elgin the drilled well of Mr. A.H. Harkey probably obtains water from the basal part of Tertiary sandstone and conglomerate resting on ancient sedimentary rocks. Analysis 29 shows that the water has a comparatively low mineral content. By far the greater part of the dissolved material is calcium carbonate, presumably derived from the limestone of the neighboring hillsides. The low contents of sodium and sulphate and the absence of fluoride are noteworthy.

At the Babocomari home ranch east of Elgin the water from a well drilled to ground water level in the stream valley is of fair quality. Analysis 30 shows that calcium and bicarbonate are the chief mineral constituents as they are in most other waters of the district. Farther east down the valley of the Babocomari River the drilled well of Mr. Al Turner near Campstone railroad station supplies water of moderate concentration. Analysis 48 shows calcium and bicarbonate to be the principal substances in solution. No fluoride was found in this water, ~~whose temperature of ______ degrees indicates that it~~ which is not the uppermost ground water but comes from ~~a depth of perhaps ______ feet.~~ about 140 feet, to which depth the wells was drilled and cased.

On the pediment slope north of Campstone a well that was drilled by the County Highway Department obtained water that is comparatively highly mineralized

Analysis 47 shows that the principal dissolved mineral constituents are calcium, bicarbonate and sulphate. It probably obtains water from gypsum-bearing beds in the Tertiary sediments.

At Garden Canyon on the upper part of the pediment near Huachuca Mountains a deep drilled well of Mr. Oliver Frye reached water at a depth of 460 feet. Analysis 49 of this water shows that it has a low content of mineral matter in solution calcium carbonate being the principal dissolved mineral. It contains very minor amounts of sodium and sulphate and no fluoride.

A test well drilled a few miles east of Fort Huachuca in outwash at the mouth of Tanner Canyon struck water of unusually low mineral content as shown by analysis 50. As the contents of calcium and magnesium are quite small, it is a soft water. In this respect it would be preferable to the water supply for Fort Huachuca which is obtained from springs. Analysis 51 shows that this spring water is comparatively hard with a rather high content of calcium and bicarbonate, which is very probably derived from limestone of the upper mountain slopes.

On the western side of the valley along the pediment slopes at the base of the Huachuca Mountains samples for analysis were collected from three wells and one spring. The dug well of Mr. L. B. Jordan reached water at 105 feet on the wide gravel covered plain. Analysis 63 shows that the water is of fairly low mineral content, calcium carbonate being the principal mineral in solution. The low contents of sodium and sulphate are of interest. About 10 miles farther south the well of Mr. John Dinwoodie drilled on the same pediment plain struck water at 300 feet. Analysis 64 shows that the water contains only 127 parts ~~to a~~ per million of total solids, calcium and bicarbonate being the chief mineral constituents with unusually low sodium and sulphate contents.

Bequillas Spring issues at the base of the mountains with a constant discharge of about ~~twentyfive~~ 25 gallons a minute. Analysis 65 shows that it is a calcium bicarbonate water as would be expected from the presence of much limestone in the nearby slopes.

The ~~Add~~ drilled well of Mr. Stanley Stoneis reached water in the gravels of the pediment at 315 feet. Analysis 66 of water from this well shows it to be less mineralized than that of Bequillas Spring although similar in composition with calcium and magnesium and bicarbonate as the principal substances in solution. The absence of fluoride from the four samples of groundwater collected along the east side of the Huachuca Mountains indicates that the rocks of this district do not contain appreciable amounts of fluoride-bearing minerals.

Table of analyses

The following table presents the analyses of the samples of water that were collected in 1920-21 and 1934. The 78 wells and springs from which samples of water were analysed may be grouped and classed ~~in following~~ thus:

	Number of samples.	
	Calcium carbonate Calcium bicarbonate waters.	Sodium carbonate Sodium bicarbonate waters.
Uppermost ground water, from springs, dug wells, and wells drilled only to the ground-water table.	46	5
Deeper ground water, from drilled wells, cased to the lower water-bearing layers.	5	22

It appears that in general the uppermost ground water is of calcium bicarbonate type, whereas most of the deeper waters, which are limited to the inner valley, are of sodium bicarbonate type.

The principal characteristics of each water analysed have been mentioned in the discussion of the quality of the waters.

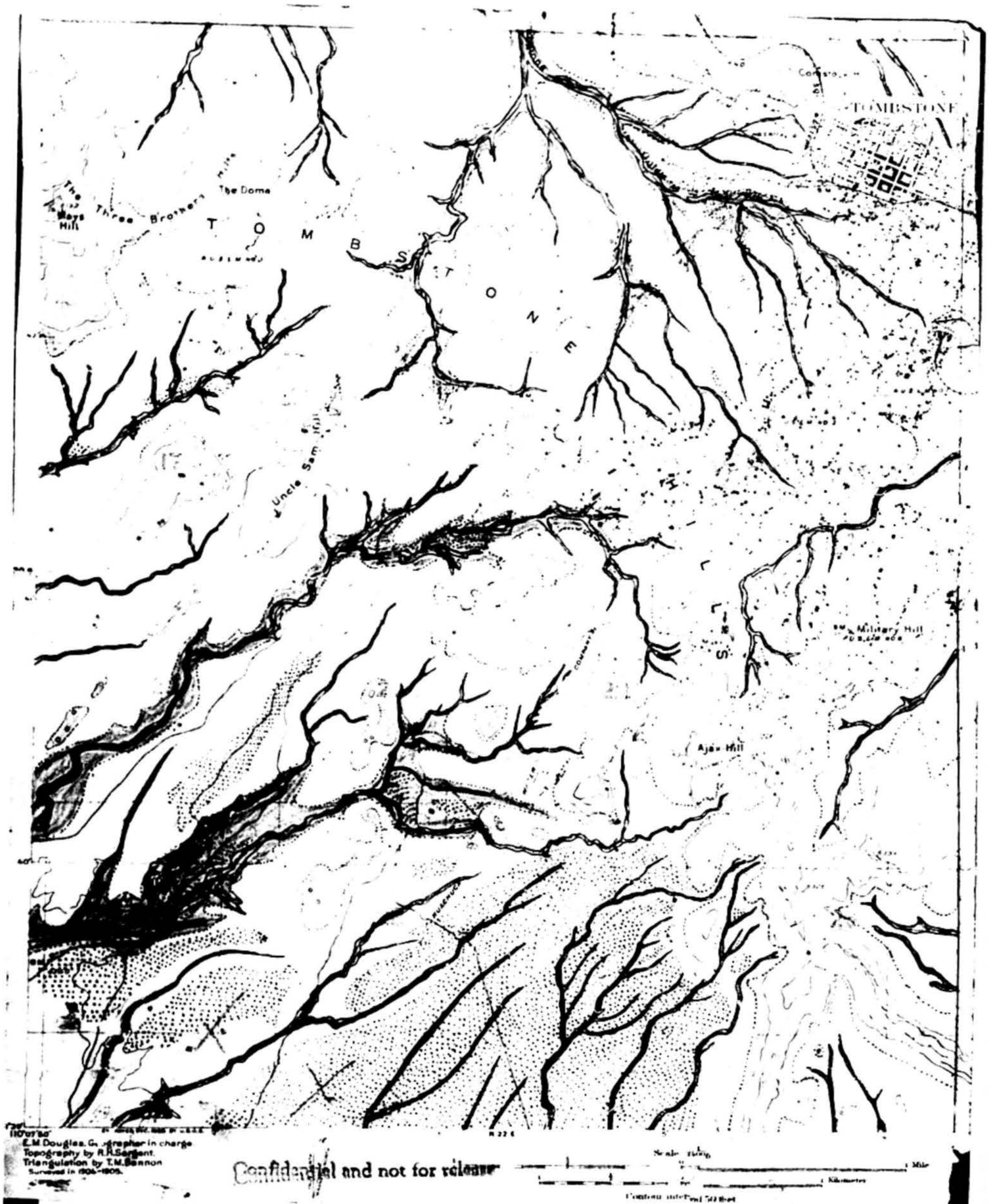


Plate 4. Map of the Tombstone district, Ariz., showing the Tombstone and Whetstone pediments.

Residual mountains. Tombstone pediment. Whetstone pediment.

Areas covered by alluvial gravel. By Kirk Bryan, 1921.

Negatives of Waring's San Pedro Valley illustrations are in Big Map Cabinet.

C5 Figures 1,3,4,5, and Plates 4 and 16 are in roll C5. (Photostat negatives)

C6 Small copies of well location map. (Photostat) Original in R C 8.

C7 Topo sheets with well locations by Waring

RC8 Large ~~gxk~~ geologic maps and well location maps.

Checked by S.F.T., Feb. 13, 1942.

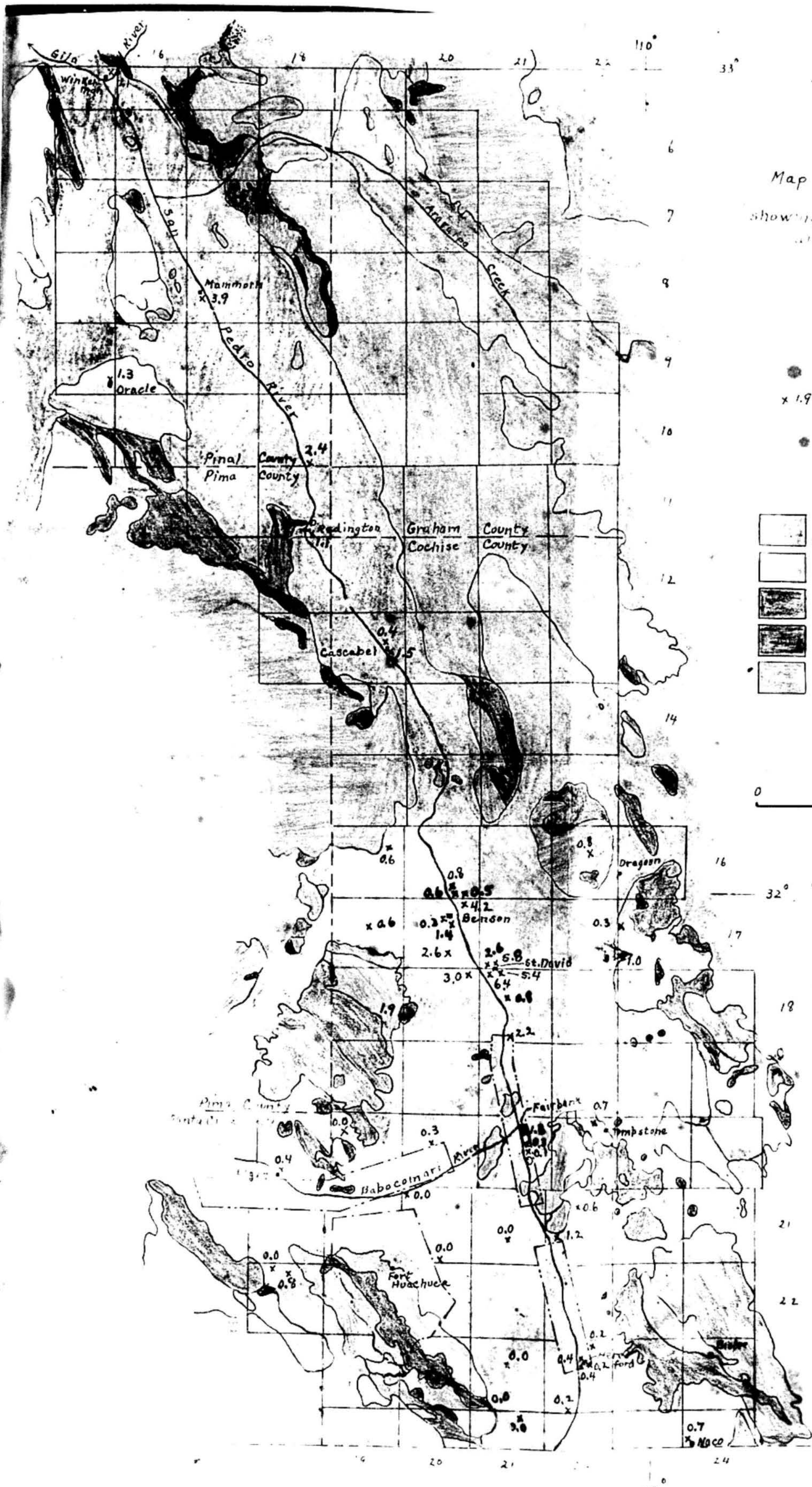
The above were checked July 25, 1949 by L.A.H. and found as listed with the following additions:

A second roll labeled C6 with additional copies of the well location map

A second roll labeled C7 with topo sheets and soil conservation map copies which have been partialled traced unto tracing paper.

Plate 16.

Map of … Valley, Arizona
showing fluoride content in … water, and principal … formations



Explanation

x 1.9 Fluoride content, in parts per … in waters analysed

Quaternary and …
Tertiary and … lava…
Cretaceous … rocks
Pre-…etaceous sedimentary rocks
Cretaceous … older … other crysta… rocks, …

0 10 2…