DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 225

GROUND WATERS OF THE INDIO REGION, CALIFORNIA WITH A SKETCH OF THE COLORADO DESERT

BY

WALTER C. MENDENHALL

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By Walter C. Mendenhall.

INTRODUCTION.

Water is the first requisite to the existence of all life; hence everywhere in the arid West the question of water supply is of paramount importance. Agricultural and industrial activity can not continue without water; mining is seriously handicapped by small supply; and in the more arid districts generally all hope of permanent human occupation depends upon the possibility of developing or introducing water in relatively large quantities.

Those deserts whose watering places are widely separated are dreaded by travelers and, if possible, avoided. The number of desert tragedies has not been reduced by the building of railroads within the last quarter century, because the lessened danger has been balanced by a greater influx of inexperienced travelers.

The Colorado Desert in southern California is one of the most sensationally interesting as it has been one of the most truly arid parts of western North America. Since the first journeys were made across it by the mission fathers to extend the influence of their church from the older settlements in Mexico and New Mexico westward and northward into California, it has been in ill repute among travelers.

For more than a hundred years travel between the settlements east of Yuma and those on the California coast north of San Diego has followed a highway that crosses this desert. By this route the missions of Mexico, New Mexico, and Arizona were connected with those of San Diego, San Luis Rey, Capistrano, San Bernardino, San Gabriel, and San Fernando. After the Mexican cession and before the building of the great railways a transcontinental stage route crossed it, and American traders occasionally drove freight teams from Yuma to San Bernardino along a course which was later followed closely by the Southern Pacific Railroad. This longer road, which traversed the desert from end to end, was less generally used than one which crossed it from east to west and entered the mountains by way of San Felipe Creek and Warners Valley, so reaching

San Jacinto and later Los Angeles with less of desert and more of mountain travel.

EXPLORATION AND DEVELOPMENT OF COLORADO DESERT.

One of the most satisfactory published accounts of the Colorado Desert is that prepared by the first of the American scientific explorers who have visited it. In 1853 a military expedition, led by Lieut. R. S. Williamson, explored the southern part of the San Joaquin Valley, the passes leading from it to the Mohave Desert, those connecting this desert with the valley of southern California, and, finally, those which connected that valley with the Colorado Desert. The primary object of the expedition was to determine feasible routes for railroad construction, but, as was usual at that time, a naturalist was attached to the expedition to report on matters of scientific interest that might be observed along the route of travel. This assignment was held by Prof. William P. Blake, and the report [a] which he published after the expedition had been disbanded presents the most complete and graphic scientific account of the physical features of this section of arid America that is yet available.

The party to which Professor Blake was attached entered the desert from San Bernardino through San Gorgonio Pass. The first stop was made at Palm Springs and the second at Indian Well, in the northwestern end of the desert, now usually called the Coachella Valley. The explorers visited the springs at Toro and Agua Dulce, which have since been included in the Indian reservations and were then centers about which Indian habitations were clustered. Below Figtree John's the expedition encountered difficulties in its attempt to reach the old stage road which followed Carrizo Valley from the desert floor to the base of the Peninsula Range. Along the west side of Salton Sea there is a wide area in which potable water was at that time very scarce, and it was only after several of the animals of their pack train were nearly exhausted that the members of the expedition finally found water in the vicinity of Salt Creek, near what are now known as "McCain Springs."

Professor Blake describes the physical aspect of the desert, the effects of wind erosion upon it near Palm Springs, the old water line along the western border, and such other geological phenomena as were observed; and he mentions the springs which he visited during his journey or about which he could obtain reliable information. It is interesting to note that in the course of his discussion he predicted

[a] Reports of explorations and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, made under the direction of the Secretary of War in 1853-54, according to acts of Congress of March 3, 1853, May 31, 1854, and August 5, 1854: Sen. Ex. Doc. No. 78, 33d Cong., 2d sess., vol. 5, pt. 2; Geological report by Wm. P. Blake, geologist and mineralogist of the expedition.

that artesian water would be found beneath the surface of the desert. Thirty-five years afterwards this prediction was fulfilled, although the waters are found in the Pleistocene alluvium instead of in the consolidated Tertiary rocks, where Professor Blake expected that it would be found.

The desert was made much more accessible in 1879 by the construction through it of the main line of the Southern Pacific Railroad from New Orleans to San Francisco. Extensive travel across it by wagon ceased with the construction of the railway, and at the various stations along the line water may always be procured, so that the danger of death from thirst has been greatly reduced.

In 1888 the Southern Pacific engineers, in searching for water for their locomotives and station houses, obtained small artesian flows at Thermal and Coachella. Six years later a successful well was put down at Walters, now called Mecca, thus proving definitely the existence of water under this portion of the desert basin with sufficient pressure to rise to the surface. Attempts to sink wells with the ordinary well rigs in use in adjacent parts of southern California are not, however, attended with success here, because of thick strata of fine sand, through which it has been found extremely difficult to sink the casing and keep the tube in alignment by the standard methods. Experiment has proved, however, that the hydraulic method, in use for shallow wells in the coastal plain of southern California, is well adapted to this desert region. As a result of this discovery numbers of successful wells have been sunk, and the reclamation of the northwestern arm of the Colorado Desert is under way (Pl. X, *A*, *B*, and *C*) through the utilization of the waters thus developed.

At about the same time that the underground waters began to be used extensively about Indio, the California Development Company, by utilizing an old distributary of Colorado River, carried waters from that stream to a part of the desert that lies in Imperial County, near the Mexican line, and that is now called the Imperial Valley. When this water had been successfully conducted out upon the old desert floor it was found that the soils over much of the area were very fertile. Settlers hastened to the region, successful ranches were established, and now several thousand people are living in the heart of what was once a most dreaded waste. Thus the transformation of the southern, broader end of the Colorado Desert was begun.

GEOGRAPHY.

The Colorado Desert lies in a wide valley, the northwest extension of the great depression whose southern end is occupied by the Gulf of California. (See Pl. I.) This valley extends northward to San Gorgonio Pass, in Riverside County, 200 miles above the present head of the gulf. It is bounded on the west by the Peninsula Range and on the east by a network of desert ranges, known in their various parts as the Cottonwood, the Ironwood, and the Chuckawalla Mountains. The Peninsula Mountains do not present a regular front toward the desert. This eastern face of the range exhibits a series of salients and reentrants, which result in great steplike irregularities in the western wall of the valley. The first and least prominent of the salients seen in passing from San Gorgonio Pass southward is formed by the eastern base of San Jacinto Mountain. Back of it lies the lower valley of Palm Canyon, whose width increases that of the desert to 9 or 10 miles.

The next of the great Peninsula salients is formed by the Santa Rosa ridge, whose southern end lies just west of the Salton Sea. Back of this lies Borego Valley and the canyon of Coyote Creek. At this point the width of the desert increases to 35 miles. Still farther south Carrizo and Black mountains form another salient, and below them the desert attains its maximum width of nearly 50 miles. At the international boundary is Signal Mountain, a northern outlier of the Cocopa Range, which divides the lower portion of the desert into an eastern part, occupied by the Colorado delta, and a western part, lying below sea level at its lowest point and containing the Laguna Salada, a fluctuating body of bitter water.

The barren ranges that form the eastern wall of the desert are the southeastern continuation of the San Bernardino Mountain mass. They are irregular in arrangement and altitude, but there is not the system in their irregularity which is displayed by the Peninsula Range. They are interrupted by high passes, by which they may be traversed to the valley of the Colorado River of the West, which lies east of them; and in a general way they diminish in altitude toward the south until, in the vicinity of Yuma, they disappear, and the desert unites around their southern end with the valley of the Colorado River. These mountains are typical arid ranges, barren of all normal types of vegetation. Here and there characteristic distorted desert growths, like the barrel cactus, the ocatilla, the cholla, the greasewood, the ironwood, and the palo verde are found sparingly distributed over the rocky mountain sides.

The lower slopes of the Peninsula Range west of the desert are as barren as the mountains east of it, but as the crest is approached the more humid conditions which prevail on the Pacific slope and extend for short distances over the crest toward the desert produce more abundant vegetation. Conifers of a few types, palms in some of the lower, better-watered canyons, grasses, the hardier varieties of chaparral, and other common southern California plant forms are found. Needless to say, practically all the perennial streams that flow to the desert rise on the upper slopes of the ranges to the west and north of it.

The floor of the desert itself exhibits various physical aspects. The portion first reached in passing into it from Redlands or San Bernardino is a region of sand dunes. Practically the entire valley bottom here is a waste of shifting sand, in almost constant motion through the action of the strong winds that blow at frequent intervals from San Gorgonio Pass and the high mountains which flank it on the north and south.

Just south of the sand-dune area and below the sea-level contour the valley floor is silt covered, relatively smooth, and sustains a luxuriant growth of desert vegetation. The mesquite bush here attains the dignity of a tree, and forms which are dwarfed in less fertile and drier sections of the desert here grow luxuriantly, because the artesian waters, imperfectly confined beneath the partially pervious clays that underlie the surface, seep toward it and furnish a supply of moisture which for these desert plants is unusually abundant.

Farther southeast, about the borders of the Salton Sea, strongly alkaline areas are found, and here the desert floor, smooth or sharply gullied and gently sloping, is generally devoid of vegetation. At the lowest point in the valley, now occupied by the Salton Sea, the alkalies had accumulated to such an extent as to form a true "salina," and salt was mined there in a commercial way for many years before the inflow of the Colorado.

Still farther south, beyond the Salton Sea, in the region now known as the Imperial Valley, the desert is floored with a fine laminated silt, deposited in past centuries by the Colorado River. This region appears level to the eye, but in reality slopes toward the Salton depression. Before irrigation and settlement only indefinite channels, seldom filled with water, extended from the area of annual summer overflow in the vicinity of the lower Colorado toward the sink; but in the last few years two of these channels—New and Alamo rivers—have been deepened and enlarged, until they are now continuous deep cuts with wall-like banks from a point south of the Mexican line to the shores of the new lake.

As a physical feature the Colorado Desert is continuous from San Jacinto Peak southeastward to the head of the Gulf of California. As a result of settlement and the attendant development, however, different portions of the lowland have been given different names, which have no physiographic significance but are based entirely upon human occupancy. The Imperial Valley, the most important of these subdivisions, has been outlined. It occupies the southernmost part of that portion of the Colorado Desert lying within the United States. The northern, narrow end, lying between the base of San Jacinto Peak and the margin of the Salton Sea, is known as the "Indio region," or the Coachella Valley. The fertile and cultivated portions of this section lie, for the most part, south of Indio and below the sea-level contour, settlement and development being controlled entirely by the occurrence of underground waters, which are most abundant and accessible within the limits outlined above.

East of Imperial Valley and extending from Mammoth station southward to the international boundary is a belt of sand dunes, 6 or 7 miles wide and 40 or 50 miles long, lying east of the well-marked old beach line, while west of the valley is the sandy beach marking the western shore of the old lake, between which and the base of the mountains is a belt of alluvium, such as usually borders desert mountains.

GEOLOGIC SKETCH.

STRUCTURAL FEATURES.

The west wall of the Colorado Desert from the vicinity of Banning to the southeastern point of the Santa Rosa Mountains is made up exclusively of massive plutonic rocks of granitic or acid dioritic type, and of metamorphic rocks which are intruded by the igneous masses. The axis of the San Jacinto Mountains appears to consist of an unaltered dioritic mass, about whose periphery there is a zone of schist and gneisses with occasional bodies of highly altered limestone. These metamorphic rocks are found along the southern border of the desert in the vicinity of White Water and Palm Springs, and are believed to exist some miles east of the latter point, along the southern border of the Conchilla Desert. The projecting points in the neighborhood of Indian Well and at places farther south, toward Toro, are formed of massive granitic rocks, but still farther south, back of Figtree John's, the wall of the Santa Rosa ridge again proves to be geologically more complex. Diorites occur in this vicinity in small masses, but basic schistose rocks and marmorized limestones are found in large bodies.

None of the rocks of this type have any value as water bearers. So far as water in commercial quantities is concerned they are practically impervious. East and west of these metamorphic and intrusive masses much younger rocks of totally different character cover extensive areas. West of the San Jacinto mass blue and buff shales, with occasional traces of vegetal remains and of fresh-water shells, extend along the ridge between San Timoteo Canyon and the San Jacinto Valley nearly to Colton. These impervious shales are overlain unconformably by heavy bodies of alluvium made up of well rounded river cobbles, sands, and clays intermingled or in alternating beds. In this region the attitude of these rocks and their porosity make them valuable water bearers, and in the Yucaipe Valley and San Timoteo Canyon near Redlands deep wells have been drilled in them which yield water in sufficient quantities

RED CANYON, NORTHEAST OF MECCA.

to irrigate near-by lands. The age of these consolidated sediments is not known with certainty, but it is probably Pliocene.

East of the point of the Santa Rosa Mountains rocks that are similar in general character though probably older, but about the details of whose distribution and structure very little is known, extend southward to the Mexican boundary. These areas were traversed by Professor Blake from the Santa Rosa Mountains to Carrizo Creek, and in his report upon that region he describes them as highly folded and exhibiting the usual Tertiary sedimentary succession of sandstone and shale.

More detailed work has been done in the vicinity of Carrizo and Black mountains by the writer, and something has been learned of the stratigraphic sequence and of the structures there. The basal members of the sedimentary series in Carrizo Mountain are usually conglomerates of limited thickness, 100 to 200 feet being about the usual measure. Overlying these are buff and greenish shales which are at least 1,000 feet thick, and may be much more. They are succeeded in turn by a body of soft shales, which in places show a pink tint and are interbedded with thin brown concretionary sandstones. These have a wide distribution over the western margin of the desert between Carrizo Mountain and the Cocopas. A few springs occur along the outcrop of the sandstone members of this series, but water in sufficient quantity and purity to be valuable for irrigation has not been developed in them, although a number of wells drilled in prospecting for oil have penetrated the rocks to depths of a thousand feet or more.

The age of the basal members of this sedimentary series in the Carrizo Valley is Miocene. The higher beds may be somewhat younger. The core of Black and Carrizo mountains which has served as a basement on which the sediments have been deposited, like the main range farther north and west, is a complex of metamorphic rocks and massive intrusives. Small patches of effusive lavas and associated tuffs also occur in this section, overlying the basement complex and interbedded in places with the lower members of the sedimentary series.

North and east of the Colorado Desert the relations are in a general way similar to those on the south and west sides. At the base of the north wall of San Gorgonio Pass is a belt of folded and faulted alluvial sediments, not more than 2 or 3 miles wide, which locally has been cut down by erosion and buried under modern wash. Whereever it remains, however, and is exposed for examination the rocks are seen to be coarse sandstones, gritty clays, and heavy conglomerates which have been thrown into complex attitudes and broken along many lines.

North of the sediments are the schists and massive rocks that make up the main body of the San Gorgonio Mountain mass. The

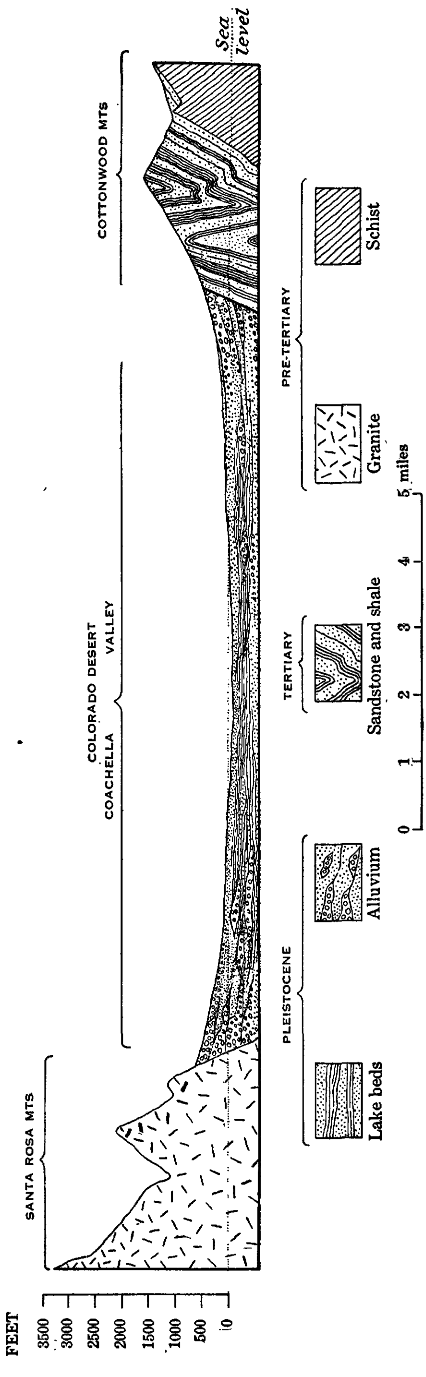


FIG. 1.—Diagrammatic section across Coachella Valley through Mecca.

contact between the metamorphics and the sediments here is a fault contact. North of Indio the normal valley filling of unconsolidated lake sediments and alluvium extends for a distance of approximately 2½ miles; beyond this lies a range of low foothills formed of folded Tertiary sediments, somewhat similar in general aspect to those in San Gorgonio Pass but not so coarse, probably because they lie at a greater distance from the source of the material of which they are composed. They are closely folded here, as elsewhere, and the exposures are so perfect that the succession of synclines and anticlines can be traced with the greatest exactness (fig. 1).

The northern wall of the valley back of Mecca has also been examined. Here a space of perhaps 2½ miles intervenes between the railroad and the first bed-rock exposures. The section of folded Tertiary beds and their relations to the older rocks are plainly shown in the box canyon that opens on the desert almost due north of Mecca (Pl. II). The basement rocks exposed near the head of this canyon are highly altered schists containing acidic dikes and quartz stringers. Directly upon these, with a normal depositional contact, rest from 1,000 to 1,200 feet of dark brownish-red sandstones and conglomerates (Pls. II and III, *B*, and fig. 1). Overlying these, apparently conformably, are from 3,000 to 4,000 feet of yellowish sandstones and sandy shales containing masses of coarse conglomerate and alluvial material (fig. 1).

These sediments are all closely folded. They dip from the base of the beds toward the valley for 1½ miles, but this dip is interrupted just at the valley border by a sharp anticline, which brings to the surface again many of the beds that had passed below it at points farther north. No fossils have been observed in any of these sediments north of the desert, and as they are alluvial in character and probably in large part fresh-water deposits, they are unpromising fields in which to search for organic remains. For the same reason they are not regarded as particularly promising as sources of oil or gas. It is probable, however, that the porous rocks in the synclines contain small quantities of ground water, and that this water would flow to the surface if tapped at favorable points, but its quality is problematic. The waters of the Tertiary rocks generally in this part of the State contain much alkali in solution, and at many places are unfit for drinking or even for irrigating purposes.

This belt of folded sediments extends along the east side of the valley at least as far as Imperial Junction, but is less conspicuous than farther northwest because it has been worn down more completely by erosive action. Usually, however, it forms a zone between the higher desert mountains of metamorphic rock, from which it may be separated by a belt of overlying alluvial fans, and the relatively level lands of the central desert.

Between Imperial Junction and the Salton Sea are isolated outcrops of sandstone, and another outcrop within the valley is but a few miles northwest of the town of Imperial, near the bank of New River. This outcrop is nearly in line with Superstition Mountain, west of the river. This mountain is reputed to have a granitic axis and to be flanked by sediments, and the outcrop near Imperial is considered as the southeastward extension of the same ridge.

Besides these sedimentary rocks it is to be noted that a row of knobs of obsidian, pumice, scoriaceous lava, and tuff extends southwestward for several miles from a point about 6 miles west of Imperial Junction. Originally these masses stood out merely as rock knolls in the desert; now they are islands in the Salton Sea. These rock outcrops near the south end of the Salton Sea suggest that the valley filling may be relatively shallow here—that is, that bed rock may be nearer the surface than either north or south of this locality.

The relations between the sediments and the metamorphic complex that forms the desert ranges east of the valley were observed only in San Gorgonio Pass and at a point a few miles east of Mecca.

In the pass extensive faulting has taken place, and one of the fractures is between the sediments and the older rocks. Back of Mecca, however, a normal depositional contact is found, a true basal conglomerate forming the lowest member of the sedimentary series (Pl. II). The same conditions have been observed about Carrizo and Black Mountains, and are inferred at the southern end of the Santa Rosa group from general relations. Hence if the great Cajon-San Gorgonio fault extends into the desert it probably follows its axis closely, since it is not to be found along its borders. Here it is buried completely beneath the modern lake sediments, and its presence can be inferred only from isolated phenomena like the obsidian cones near Imperial Junction, with their accompanying solfataras, or from general physiographic evidence.

A sketch of the geologic phenomena of the desert would not be complete without further mention of these solfataras (Pl. IX). About 7 miles a little south of west of Imperial Junction, near the row of obsidian knobs already described, an interesting group of mud volcanoes existed before the area was flooded by the rising of the lake. Some of these were quite perfect cones with craterlets at top, others were in various stages of formation or destruction. The usual accompaniments of hot pools, gaseous emanations, sulphur and salt deposits, acidulated waters, and boiling mud pools were to be found here. Near the principal group were smaller groups of extinct or at least quiescent mounds. These mud volcanoes are regarded as representative of the last phase of the volcanic activity that produced the lava knobs in this part of the desert.

A more extensive field of mud craterlets is found about 40 miles south of the international boundary line, along the western shore of Volcano Lake. The forms that result from the activity and the phenomena generally are similar to those near Imperial Junction, but on a larger scale.

ORIGIN OF THE DESERT LOWLAND.

Of the details of the origin of the valley occupied in its southern part by the Gulf of California and at its northern end by the Colorado Desert, but little is known. It may be said, however, as a generalization, that it belongs to a type which physiographers describe as constructional—that is, it represents an area which has been depressed as a result of crustal movement, as contrasted with valleys due to erosion. There are many proofs of this. The fact that its rock floor is below tide, even in those parts north of the gulf where the actual surface is well above sea level, proves that a part at least of its position is due to actual subsidence of a block of the earth's crust, because erosive action can not extend below the ultimate base level, which is usually sea level. Wells drilled near Imperial indicate that

A. CALCAREOUS INCRUSTATION ON GRANITE ALONG OLD WATER LINE.

B. CANYON CUT IN TERTIARY ALLUVIAL SANDSTONES NORTHEAST OF MECCA.

there is no bed rock within a depth of 600 or 700 feet below tide, and others in the Coachella Valley and at Salton prove that at these places bed rock is at least 1,000 feet below sea.

The topographic character of the western margin of the desert within the United States and near the international boundary also indicates very distinctly the presence of fault lines along this margin. The eastern edge of the Peninsula Mountains is a marked fault scarp, throughout at least a portion of its length. The valley occupied by the Laguna Salada, west of Calexico, appears to be a dropped block. Salients like the Santa Rosa Mountains and the group south of San Felipe Creek, projecting toward the desert from the northwest, appear to be limited on one or the other side by faults. The Santa Rosa ridge itself is a particularly suggestive mountain mass. It has a steep, abrupt southwest face, with short drainage lines, and a relatively smooth and sloping northeast face, with long drainage lines. On its northeast face there are many large surfaces, comparatively unscarred by modern arroyos, which at once suggest remnants of an old eroded surface. In short it has the topographic characteristics of a faulted block tilted toward the northeast and plunging into the desert toward the southeast.

Little is known of the eastern desert border, but where it has been visited in the vicinity of Mecca there is no evidence of faulting, the rocks of which it is made up dipping toward the desert away from the old crystalline surface upon which they were deposited.

One of the most extensive faults in California runs southeastward through the coast ranges, north of the San Gabriel Mountains, through Cajon Pass, south of the San Bernardino Range, and through San Gorgonio Pass into the Colorado Desert. Here it is no longer traceable; but since, if projected, it would follow closely the axis of the desert valley, through the Salton Sink and southeastward toward the Gulf, it may well be even here one of the lines of weakness that has helped determine the position of the depression. As the entire basin is occupied by lake silts and alluvium of most recent origin, it is evident that unless movement had taken place along this fault at a very late date there would be no surface indication of it. Phenomena like the obsidian buttes 6 or 8 miles southwest of Imperial Junction and the group of solfataras seen there until submerged by the waters of Salton Sea may well be associated with a profound fracture of this nature. The other group of solfataras, 35 or 40 miles southeast of Calexico, near the base of the Cerro Prieto in Mexico, is distributed for 2 or 3 miles along a northeast-southwest line, parallel to the structures in the mountain ranges to the west.

All of this evidence, taken together, indicates strongly that the desert valley is associated with structures in which faults are prominent, and leads logically to the conclusion that the desert is a constructional depression due to the marked and probably irregular subsidence of a number of faulted strips.

The Tertiary (Miocene?) rocks which border the desert on either side seem, so far as their relations are known, to have been affected by much of the movement in which the desert originated. Carrizo Mountain, on the western margin of the desert, about 12 miles north of the Mexican line, is a knob of crystalline rocks surrounded by Miocene sediments that dip away in all directions at angles greater than the original angle of deposition. About 7 miles south of Carrizo Mountain the crystalline rocks of the main range are not flanked by Tertiaries, but pass directly beneath the alluvial cones of the desert border, as though the sediments had been faulted out there. Signal Mountain is flanked by late sediments on the north and south at least, and they have been folded in varying degrees of intensity. This same observation applies to the sandstones and shales that flank the Santa Rosa Mountains on the southeast, south, and west; and along the eastern border of the desert, wherever the sediments are exposed, from Whitewater River well down toward Yuma, they have been closely folded. One section studied (fig. 1) from Mecca northeastward to the crystallines, shows that the sediments rest directly upon the schists as they were originally deposited and dip from them toward the valley, the regular dip in this direction being interrupted by a single well-marked anticline. As a rule, then, the Tertiary sediments dip from the valley borders toward its axis, and, as a rule, also, along its axis they are well below sea level and are deeply buried under recent alluvium.

Distinctly within the valley, yet not far from its borders, are a few isolated exposures of the Tertiary bed rock that presumably forms its floor almost everywhere. Around some of the obsidian cones southwest of Imperial Junction lie beds of upturned and somewhat altered material that may represent a part of the valley basement, although it is more likely that they are a part of the Pleistocene filling indurated by volcanic action. Between these cones and the railroad are occasional exposures of sandstones that belong clearly to the Tertiary series. Beyond Imperial Junction to the east, north, and northwest are the folded clays and sandstones that make up the valley margins generally. Here, however, they are planed off to an even surface that slopes toward the lake.

A few miles west of Imperial, near the east bank of New River, is a single exposure of sandstone of the type familiar about Superstition Mountain. Indeed, it probably represents merely an extension to the southeast of the Superstition ridge. Elsewhere, so far as known, there are no rock exposures near the axis of the valley.

The conclusions as to the origin of the great depression occupied by the Colorado Desert and the Gulf of California, in so far as they can be drawn from evidence at hand, are, then, that it is due to crustal movement—subsidence along a number of fault lines, or, perhaps, slight subsidence in this area combined with elevation in the areas east and west, leaving the desert not far below its original position; that at least a part of this movement has taken place since the Tertiary rocks were deposited—fossils prove the presence of Miocene beds, and clearly later rocks are probably Pliocene—and as associated solfataric phenomena and the derived land forms are so well preserved, it is likely that much of the movement is late Pliocene or Pleistocene.

LATE DEVELOPMENT OF THE COLORADO DESERT.

At a period that is geologically very recent indeed the long, narrow depression whose origin has been thus briefly indicated was occupied by the Gulf of California to a point far north of the present head of the gulf. It is probable that the gulf waters then swept inland to the base or nearly to the base of San Jacinto Peak, although all evidence which would enable us to fix its exact limits has been obliterated by still more recent geologic events. At that time the mouth of Colorado River was in the vicinity of Yuma, 60 miles in an air line north of where it now is. Presumably then, as now, it was discharging annually enough silt to cover 1 square mile to a depth of 53 feet with dry earth, equivalent to 1 cubic mile each century, cut from the great canyons in the upper Colorado and the Gila Valley and carried to the gulf. Running water will carry in suspension matter that quickly settles in still water, the settling process in this case being aided by the clarifying effect of the salt water.

As a result of these processes the Colorado delta was gradually extended southwestward toward the Cocopa Mountains, and when it reached them it had separated the old gulf into the present gulf and an inland sea. Delta growth, however, did not cease with the separation of the water body into two parts. Silt continued to be brought down the stream and to be deposited in its bed, along its banks, and in the still waters at its mouth. A stream by this process of deposition along its channel eventually builds the channel up until it is higher than the lands adjacent on either side. It is then in a condition of unstable equilibrium, and at some favorable time, as during an exceptional flood, it will break out of its immediate banks, and establish itself in some more favorable course. By this process, often repeated, it comes eventually to flow over all parts of its delta, building up each part in succession. By such a process the Colorado must have discharged alternately into the gulf and into the depression now known as the Salton Sink, meanwhile building up the delta dam that separates them until it reached a height of about 40 feet above sea level. During this process it is highly probable that water filled the Salton depression and evaporated from it many times, for it must have quickly disappeared whenever the erratic river changed its course to the gulf, for the run-off from the mountains that surround the sink is too slight to maintain a permanent water body in this region of intense evaporation. Meanwhile the original body of salt water that occupied the sink had been displaced by the volumes of fresh water poured into it from the river, and in the intermediate stages of the lake's existence, at least, its water was fresh or nearly fresh. A clear and definite indication of the last occupancy of this depression by a lake, presumably just before the river had shifted to the course that it now follows to the gulf, may be seen in the remarkably well-preserved old water line that rims the desert from Indio to the Cerro Prieto at a height of 40 feet above sea level (Pls. III, *A*, IV, and V). On the rocky points that projected into the lake it is marked by a thick deposit of calcium carbonate (Pl. III, *A*), by slightly cut sea cliffs, and by a change in the profile of the rocky spurs at the water line. Where alluvial cones and the sandy floor of the desert formed the shore line, beaches have been developed, and although of soft sand, easily eroded, they are even now well preserved, thus testifying to the recency of the action that produced them. Over the floor of the desert and along the sandy beaches are myriads of shells of fresh or brackish water mollusks[a] that lived in the lake.

There are some reasons for thinking that the lake at this latest stage was not perfectly fresh—that its waters were at least distinctly "hard." Its area, when it stood at 40 feet above sea level, was somewhat in excess of 2,100 square miles. The average flow of the Colorado has been determined as about 11,000,000 acre feet per annum. The evaporation from a surface of the area of the old lake, under the conditions that prevail here, has never been determined, but is undoubtedly high. If it is as high as 8 feet per annum it would nearly equal the average annual inflow from the Colorado; if it is but 7 feet per annum the average inflow would exceed the evaporation by 2,000 second-feet, or somewhat less than 14 per cent of the inflow. In either event the waters of the lake would be markedly more alkaline after a term of years than those of the Colorado. The calcium carbonate incrustations (Pl. III, *A*) on the rocky points about the shores of the old lake are best explained by supposing that the lake waters contained large quantities of this salt, so that wherever they broke in spray and evaporated more rapidly than usual the carbonate was deposited. This necessary excess of inflow

[a] Stearns, Robt. E. C., Remarks on fossil shells from the Colorado Desert: Am. Naturalist, vol. 13, pp. 141-154.

THE "WATER LINE" ABOUT THE BASE OF A GRANITE OUTLIER SOUTHWEST OF COACHELLA.

over outflow at the period of maximum area of the lake, taken in connection with the thick calcium carbonate incrustations on the shores, indicates distinctly hard water. It may be assumed that other salts than calcium carbonate were also present in large amount, for the conditions that would lead to an abundance of the one salt would also lead to an abundance of the others. The shells so thickly distributed over the desert floor, however, are not salt-water forms, but are identical with those now found living in the springs and occasional permanent streams about the desert borders. Many of these springs and streams are somewhat brackish, and the creatures flourish in them. It seems probable, then, that the lake waters also were rather alkaline, perhaps even brackish, at the time when the lake attained its maximum area.

The period at which this lake disappeared can not be precisely fixed. The time units of geology are too large and too indefinite to translate satisfactorily into years, so that when we say that the disappearance of the lake is the most recent of geologic events we still leave the mind groping for a definite human standard of time. The sandy beaches which mark the borders of the ancient lake are cut away, to be sure, where washes cross them from the mountains, but in sheltered places they are still perfect. Where they stretch across an embayment from one rocky point to another they are mere embankments of sand, old barrier beaches, with depressions behind them once occupied by shallow lagoons. In other areas, where they contour the alluvial cones, they are gullied and cut away where streams have flowed across them, but in other places are preserved unscarred. At one locality noted a low sea cliff that had been cut in alluvial-fan material was still preserved, although the loose sand and bowlders would slump in a few heavy storms.

In a region of abundant rainfall such ephemeral forms as these would be more nearly obliterated within fifty years after the lake had disappeared than they now are in the desert. In such a region the precipitation is twenty times that of the desert. It is the crudest of estimates—merely a guess in fact—to state that, reasoning from geologic evidence alone, it may be a thousand years since the lake disappeared, yet it puts in concrete form such a guess as the geologist is able to make, and this guess may be correct within a margin of error of 50 per cent.

When human records are studied some evidence on this point is found, but it is almost as uncertain as to time as that furnished by the physical features. The Indians in the Coachella Valley have distinct legends to the effect that at some time in the past the valley was occupied by a large body of water. Professor Blake records that they told him of a time when a great water body existed in which were many fish, and of the manner in which that water disappeared "poco á poco"—little by little—until the lake became dry.

The Indians now living in the desert put this event as far back as the lives of four or five very old men, say four or five centuries ago at the most. There are, of course, no records and there is no known check on this assertion. Statements by Indians as to time, beyond the limits spanned by their own memories, are notoriously inaccurate. Furthermore, we do not know the means used to procure this statement. The native races are usually very prone to follow the suggestions contained in leading questions, and so to give the answer desired by the questioner. To obtain an entirely independent and unguided answer is one of the most delicate of tasks. Yet their statement has some value, and combining the evidence of the physical conditions and the Indian legends, it may be said that it is probable that the lake disappeared and left the desert as we have known it in historical time, from five hundred to one thousand years ago.

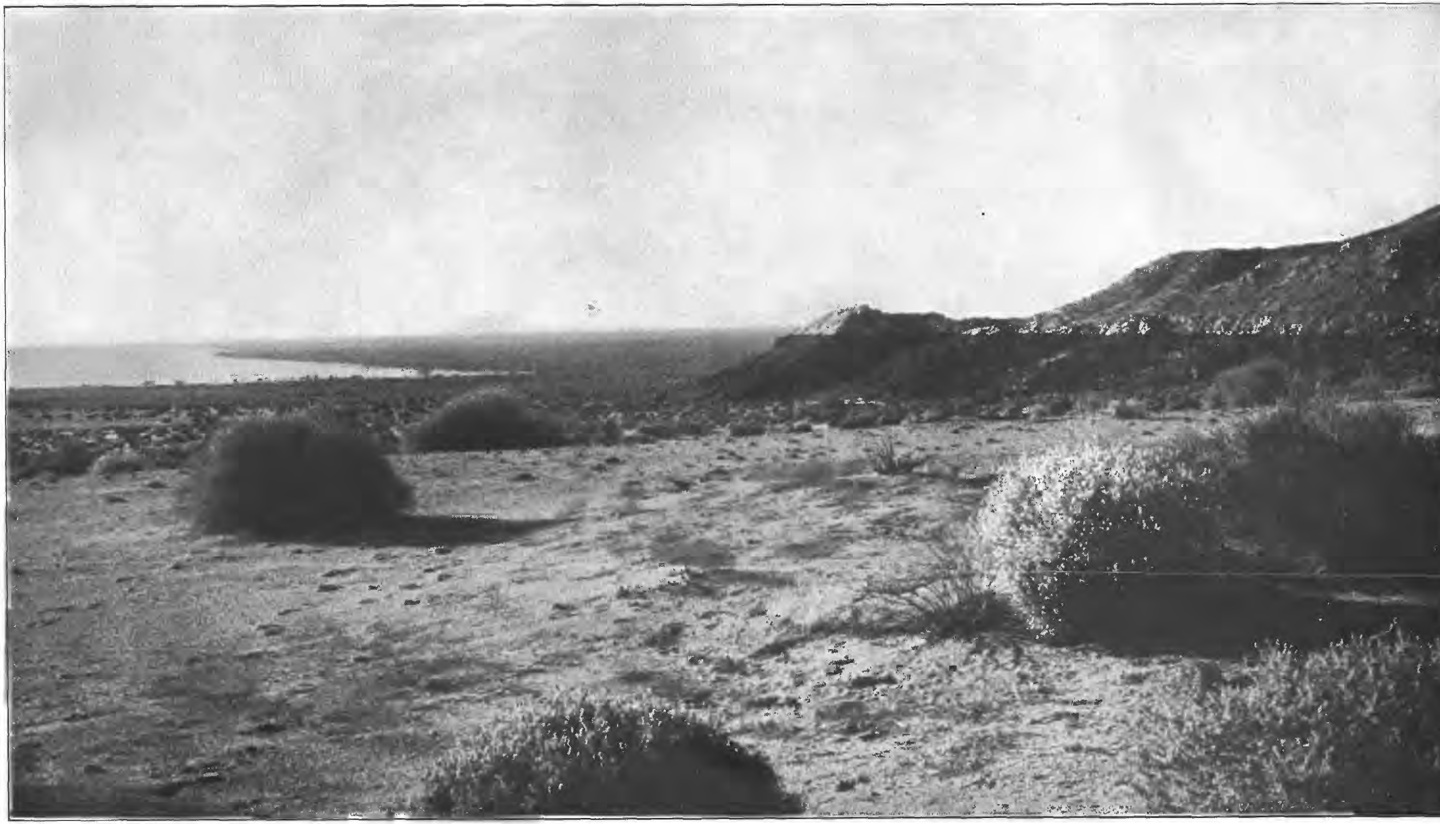
THE DESERT FLOOR.

SLOPE OF FLOOR.

From this sketch of the origin of the desert it will be realized that the floor of the greater part of it for many miles north and south of the international boundary line is Colorado River delta, and that the grades of those portions of it now above the gulf level and originally above the level of Lake Cahuilla[a] are the grades that would be established by a river of the type of the Colorado, carrying the burden of silt which it carries, and are fairly uniform. The peculiar and—from the engineer's point of view—the most significant feature about the desert surface, however, is the steep grade of its northern slope from the old water line in the vicinity of the international boundary to the bottom of the Salton Sink.

From Yuma to the gulf, a distance of about 80 miles, there is a fall of 142 feet, uniformly distributed, while from Yuma to the bottom of the Salton depression is approximately 120 miles and the fall about 416 feet, but this fall is not uniformly distributed (Pl. I). The grade from Yuma to the gulf, therefore, is only about half of the average of that from Yuma to Salton, and throughout a part of the latter distance the difference is even greater; for example, from Sharps heading to the −250-foot contour north of Brawley the distance is

[a] The writer had proposed to call the ancient water body of which the Salton Sea is the successor "Blakes Sea," after Prof. Wm. P. Blake, who, as a result of his exploration of the Colorado Desert in 1853, explained so clearly and so satisfactorily the phenomena that exist there and their origin. The manuscript of this report was prepared in accordance with this intention, but before it was published Professor Blake had himself proposed the name Lake Cahuilla (Nat. Geog. Mag., vol. 18, p. 830). While I regret that the name of this honored pioneer in western geology can not be attached to one of his most striking discoveries, I realize that no other man has an equal right to name the now vanished water body, that the name is especially appropriate, and that it now has priority; therefore it is adopted here.



THE OLD WATER LINE AND THE NEW LAKE ABOVE FISH SPRINGS.

not over 50 miles and the fall is about 280 feet, or more than three times that from Yuma to the gulf.

This steep and irregular character of the northwest slope of the Colorado delta, as compared with its flat and relatively uniform southeast slope toward the gulf, is due entirely to the fact that the latter slope represents a stream grade determined under usual conditions, whereas the former is determined in part by the deposition of the silt in the still water of the lake that once existed there. The two slopes are therefore of entirely different origin and, of course, are of different grade.

This fact bears in two important ways on the problem of conducting Colorado River waters to the Imperial Valley for irrigation. In the first place it makes it easy to lead the waters in this direction, as it would not be were the grade no steeper toward the sink than toward the gulf; and in the second place it introduces an element of danger, because the northwestern course is so much more favorable than that toward the southwest, and it is always possible that during floods the stream may abandon its course to the gulf and adopt a new and more favorable one toward the sink. These possibilities and this danger have been illustrated in a startling way by the spectacular events of the last few years in the Imperial Valley.

DEVELOPMENT OF IMPERIAL CANAL SYSTEM.

In April, 1896, the California Development Company was organized by S. W. Ferguson, J. H. Beatty, H. Heber, and C. R. Rockwood to conduct water from Colorado River, at a point about 1¼ miles above the location since chosen for the site of the cement headgate to a point 14 miles away, on the Mexican side of the international boundary, where the channel of the Alamo was sufficiently well-defined to serve as a canal. It was planned to conduct the water along this channel through Mexican territory to the international boundary again 7 miles east of where Calexico now stands, and there to distribute it by means of a system of canals over lands in the United States.

Actual construction of the canal was begun about 100 yards above the international boundary in 1900, and was carried through to Calexico in June, 1901, when water was first delivered and irrigation begun. C. R. Rockwood, long a high officer in the company, estimates that there may have been 1,500 or 2,000 people in the Imperial Valley at that time, a large proportion of them in the employ of the California Development Company.

For three or four years after the first delivery of water to the lands colonization was rapid, the agricultural areas were extended, and what had been regarded as worthless desert was gradually reclaimed.

The fields of grain and alfalfa and the rows of trees, principally cottonwoods, which were planted completely altered the appearance of the country

INFLOW OF THE COLORADO.

During each low-water period after the completion of the canal some difficulty was encountered in getting water to flow freely through the canal just below the intake because of the silt that accumulated there. As the demand for water became greater with the increasing acreage under irrigation this difficulty was increased, and it was found necessary to cut, first a by-pass around the headgate at the intake, and then new intakes lower down, the dredges at hand being unable to keep the upper end of the original canal free from silt. It was intended that these additional cuts should be kept open only temporarily, in order to keep up the supply of water during the low-water period.

In October, 1904, the lowest intake, known as No. 3, was cut, in order to avoid a shortage of water during the period of low flow then on. Attempts were made to close it early in 1905, but high waters swept away the dams that were built, and the flood period of 1905 approached with this third intake still open. During this flood period the intake and the canal were greatly enlarged by the tremendous volume of Colorado River waters which flowed through the opening, and by the time the summer floods had subsided the entire Colorado had abandoned its normal channel to the gulf and was flowing westward and northward to Salton Sink by way of the channels of its old distributaries, Alamo and New rivers.

During this period the lake in the Salton depression grew rapidly, and the Southern Pacific Company was forced to build a succession of "shoo-fly" tracks, each higher than the last, in order to keep above the advancing waters and prevent interruption to traffic on its main line. The floods, too, had accomplished extensive destruction in the Imperial Valley, drowning many acres of valuable lands and destroying canals and farms near the flood channels (Pl. VI). It was realized, therefore, that the situation was grave, and preparations were made on a more extensive scale to control the river when the summer floods of 1905 should have passed.

A brush mat and piling dam, known as the Edinger dam, was begun in the autumn of 1905, but was swept away by the flood of November 30. An attempt was then made to extend a dam from an island opposite the intake to the west bank of the river, but high water swept this work away too. Constantly recurring floods during the spring of 1906 foiled all efforts to redivert the river, and during that period and the period of the summer floods the channels to the

A. NEW RIVER IN FLOOD NEAR THE FIVE HEADINGS.

B. A CHARACTERISTIC RECENT DRY ARROYO IN THE DESERT.

C. NEW RIVER IN FLOOD, NORTHWEST OF IMPERIAL, SUMMER OF 1905.

Salton Sink were deepened and widened, the destruction within the Imperial Valley was extended, and the lake grew and forced the Southern Pacific to rebuild at higher and higher levels.

When the summer of 1906 had passed with the river still beyond control, the California Development Company had reached the end of its financial resources, and all growth in the valley had ceased because of world-wide recognition of the menace to property interests which the uncontrolled condition of the Colorado meant. It was then felt that the only powers at hand capable of dealing with the situation were the Southern Pacific Railroad and the United States Government. The Southern Pacific made loans to the California Development Company to carry on its fight against the stream, and by means of its transportation facilities rendered additional essential aid. After the passage of the summer floods of 1906, the first attempt to control the river was the completion of the Rockwood gate, work upon which was begun the year before, but suspended in order that the plan realized in the building of the Edinger dam might be tried. With the failure of the Edinger dam and the approach of low water in the fall of 1906, the Rockwood gate was completed, but this, too, was carried out in the flood of October 11, 1906. A spur track was then built from the main Southern Pacific line at Hanlon Junction down the Colorado past the base of Pilot Knob; a trestle was built across the canal, which long since had been enlarged to the size of the original Colorado channel, and an attempt was made to check the stream by dumping into it, from flat cars, broken rock drawn from all the available quarries along the Southern Pacific line within several hundred miles. At the same time earth dikes were built parallel to the river for a number of miles above and below the dam, which came to be known as the Hind dam, in order to prevent the river from cutting around the structure when completed.

This effort was successful in November, 1906. The stream was turned from its course to the Salton Sea and forced into its old channel to the gulf, and it seemed that the end sought had at last been accomplished.

But on December 7, during a moderate flood following the closure, a breach was effected in the levee 2,500 feet below the dam, and in a short time this break had deepened and widened until the whole stream was again turned toward the sink.

The people of the Imperial Valley, the engineers in charge of the work, and the Southern Pacific officials whose immediate and prospective interests were seriously menaced were deeply discouraged by this turn in affairs. Money and effort had been freely expended. The struggle, at times apparently hopeless, had been long continued, and the longer the stream flowed toward the desert the more difficult the problem became of controlling it, because, the grade toward the sink being approximately two and one-half times that toward the gulf, there was a well-marked tendency to scour out the bottom of the channel and thus to cut the new bed below the old one. This tendency was expressed in a most spectacular way by the extension through Calexico in July, 1906, of a fall of 40 feet or more in New River. This fall retreated upstream at an alarming rate, and at one time there was a serious and well-grounded fear that the entire canal system of the Imperial Valley would be left without a water supply by its extension to the Alamo channel above Sharps heading. In a final readjustment of grades by the river it was evident that the channel would be greatly deepened for many miles above Yuma, the Government dam at Laguna rendered impossible, and all agricultural interests along the lower course of the river destroyed, because the grade of the river would be lowered far below the canal intakes.

In the face of the repeated failures, the Southern Pacific seemed ready to abandon its attempt to close the canal, and appeal was made to the Government. The matter soon attracted national attention. An extensive correspondence was carried on between the President and Mr. E. H. Harriman, president of the Southern Pacific Company, and a special message dealing with the problem was sent to Congress. The Government had neither available funds, proper authority (the break was in Mexican territory), nor the equipment at hand for the prompt and vigorous action that was necessary to control the situation, and the railroad company, which had all of these, finally again undertook the work, the Government lending its engineers for consultation. The levee was practically reconstructed, broadened, made higher and extended downstream, and the same method was used to close the actual break that had proved successful when the Hind dam was built. Work was begun on this last project December 20, 1906, and the closure was completed February 11, 1907. Since then the work has withstood two summer seasons of high water, and there seems no reason why it should not prove permanent.

To safeguard the valley finally and completely, however, and to insure for it a regular water supply, further extensions of the levee system are necessary, and a more satisfactory method of dealing with the silt that the river carries must be worked out.

THE VALLEY DEPOSITS.

Classification of materials.—The evolution of the desert having been sketched and some of the events which are directly dependent upon its character as determined by that evolution having been pointed out, the nature of the materials which underlie it and the bearing of their character upon the problem of the occurrence of ground waters may now be considered. The four classes of materials that make the floor of the desert valley in different parts are the delta silts, the consolidated clays and sandstones, the stream-deposited alluvium, and the wind-blown sands. A fifth class of deposit, of very small mass but of some commercial value—the saline deposits of the Salton marsh—should also be mentioned.

Delta silts.—The most important of these in mass is the body of silts and fine sands supplied by the Colorado and making up the whole of the delta lands, the greater part of the southern end of the Salton basin, and an important share of the northern end of the basin. Presumably the larger part of the total volume of these fine silts was deposited in still water, the gulf or the old lake. An important part, however, represents alluvial deposit from the overflow of the river waters. So fine are all of the materials that no important difference exists between those deposited in the gulf or the lake and those representing overflow or flood-plain deposits. They are all so fine grained as to be nearly impervious; that is, the pore spaces are so small that water circulates through them with extreme slowness. Their chief function in ground-water problems, therefore, is to serve as a barrier to percolation. Furthermore, within the delta proper they contain a notable amount of salts, so that the few springs which issue from them along the channels of New and Alamo rivers yield salty water, and the few experimental wells that have been put down in the Imperial Valley are dry or yield only a very small amount of salt water.

In the northern narrower end of the desert about Indio, Coachella, and Mecca, the material that fills the valley does not consist wholly of silts supplied by the Colorado, but of these intermingled with alluvium brought down by the intermittent streams from the surrounding mountains. The lake silts, or Colorado River silts, when thus interbedded with the coarser local material, perform the function of impervious confining strata, beneath which circulating waters accumulate under pressure. They are therefore important in bringing about the artesian conditions that prevail in this vicinity.

Consolidated Tertiary beds.—The floor of the west side of the valley from Signal Mountain northwestward to the base of the Santa Rosa Mountains is made up of Tertiary sandstones and clay beds, usually folded and in some places veneered with a covering of waste—sandy and gravelly alluvium. Near the valley axis, and especially below the old beach line, these beds are generally deeply buried beneath the valley filling, but toward the borders of the valley they stand higher and at many places they have been cut by erosion into fantastic badland forms. About ten years ago there was some excitement about oil in this region and a number of wells were drilled. These did not yield oil, but they served to test underground conditions.

The Yuha well, 6 miles north of the Mexican line and about 25 miles west of Calexico, was bored to a depth of about 1,200 feet. Salt water was found but no oil. Other wells like the Barrett, in Carrizo Creek valley, and the Hanna, at the north base of the Fish Creek Mountains, are dry holes, or obtained only salt water in the Tertiary beds. The Harper well, however, in the San Felipe Wash, at a reported depth of about 300 feet struck potable artesian water in the valley alluvium that overlies the Tertiary rocks.

Along the eastern border of the valley, as along the western, there is a fringe of Tertiary rocks, somewhat more extensively folded, as a rule, than those on the west, but bearing the same general relation to the valley. No wells have been drilled in these rocks so far as is known, but their character is such that waters of good quality need not be expected from them, although flowing waters might be obtained in some of the synclines. In the vicinity of Durmid, Bertram, Frink, and Imperial Junction these beds have been planed off and form a portion of the smooth, sloping, desert floor below the old beach line. Generally, however, along this eastern margin of the desert they are deeply eroded and form rough foothills along the base of the higher mountains to the east.

Sand dunes.—At certain seasons of the year strong winds blow toward the desert from San Gorgonio Pass and the mountains on either side of it. As these winds sweep down into the upper end of the desert they sift the sands from the alluvial material brought from the basins of the Whitewater, Mission Creek, Palm Canyon, and other streams, and carry them farther out into the desert basin. In this vicinity the effectiveness of the wind as a transporting agent is enormous. Professor Blake observed the effects of wind erosion here and figured examples of dense and resistant rocks deeply etched by the sand blast (Pl. VII, *B*). Since the Southern Pacific Railroad was built many other proofs of this action may be seen (Pl. VII, *A*). For example, the telegraph poles are worn away near the ground and have to be protected there by posts or rock piles. The more resistant knots or growth rings are brought into high relief by the etching of softer parts. The fish plates and bolts of the railway tracks are eroded rapidly, and the tin cans strewn along the track are kept bright and polished by the driving sand and are quickly etched through, as by acid, and worn away.

In the neighborhood of Indian Well there is a belt of sand dunes several miles long, but generally in this north end of the desert the phenomena are those of rapid removal rather than of even temporary accumulation as in dunes. As a result the desert floor is a sandy, rocky waste, with scant vegetation, and the air is full of dust, sand, and fine pebbles whenever the wind blows. But a very extensive sand dune area exists in the southeastern portion of the desert.

A. TELEGRAPH POLE NEAR PALM SPRINGS STATION DEEPLY CUT BY WIND-BLOWN SAND.

B. BOWLDER OF GNEISS NEAR PALM SPRINGS STATION, ETCHED BY WIND-BLOWN SAND.

From the vicinity of Mammoth station to a point a few miles south of the Mexican line, a distance of 40 or 50 miles, there is a continuous belt of dunes (Pl. VIII), from 2 to 6 or 8 miles wide.

An approaching sand storm in this region may always be seen while it is yet a long distance off, because the air is filled with dust to a height of several hundred feet. An estimate of the amount of material moved at such a time would be interesting, and though exact figures can not be obtained suggestive estimates are possible.

Saline deposits.—The bottom of the Salton depression before it was covered with water as a result of the inflow of the Colorado River was a salt-incrusted marsh. Within certain sections the salt crust was 6 inches or 1 foot thick, and sufficiently pure to permit it to be gathered in a commercial way and marketed at a good profit. The New Liverpool Salt Company undertook the commercial development of this marsh in the early eighties, and a profitable industry had been established when the inflow of water in 1904 put a stop to the work. In mining the salt the crust was removed and purified, and after a time was found to have been renewed.

The New Liverpool Salt Company sunk a well to a depth of somewhat more than 700 feet, and obtained flowing water under a pressure of 48 pounds per square inch. This water contained 1 per cent saline matter, thus proving the existence of salts at great depth in this depression. The managers of the salt company report that there is always water at or just below the level of the crust, and this in spite of the rapid evaporation there during the summer. Mr. Durbrow, for a number of years manager of the salt company, has testified to maximum evaporations of as much as $\frac{9}{16}$ inch in twenty-four hours in shallow pans during a period when maximum temperatures of 140° were reached. The water thus constantly carried into the air by evaporation must be replaced from underground sources, because surface inflow normally is slight and comes at very irregular intervals. The artesian pressures proved by the drilling of the salt company's well, by the numerous flowing wells farther north in the desert, and by the springs at Figtree John's, Alamo Bonito, and Agua Dulce, indicate that there is constant seepage toward the surface, The bottom of the sink has been an evaporating pan for a long period. From the time when this depression was first separated from the gulf by the extension of the delta dam from Yuma to the Cocopas, it has probably been filled by inflow from the Colorado and emptied by evaporation many times. During all of this time, also, it has been shoaling slowly because of accumulating wash and silt. Whenever the depression has been occupied by a lake, more or less silt has been deposited from the waters. In dry periods occasional heavy rain storms in the desert result in an inwash of materials from its borders. The muds thus deposited in the bottom of the sink have contained definite though minute quantities of salts, and thus saline matter has accumulated there.

Probably the most abundant source of salts is the underground water that percolates slowly toward the basin from the northwest. This is of exceptional purity, as is shown by analyses of water from wells at Indio and Coachella, but like all natural waters it contains a small percentage of salts, and all of this is left behind as the water evaporates from the surface of the salina.

Since the ground waters rise at other points than in the very bottom of the valley, salts are found at the surface in many areas outside the Salton Sink. Indeed, wherever the ground-water level is so near the surface that the processes of evaporation and capillarity are sufficiently powerful to draw them quite to the surface, alkalies will inevitably accumulate, their amount depending on the rapidity of the process. When salts have accumulated at the surface all storms of sufficient magnitude to give surface streams into the sink carry a portion of these salts with them and assist in their concentration there.

WATER RESOURCES.

RAINFALL AND DRAINAGE.

The region north and east of Indio has not been mapped with sufficient accuracy to enable us to make a close estimate of the drainage area tributary to the Coachella valley; but a rough estimate, based on fairly accurate maps of the south and west limits of the valley and on much less accurate data in other directions leads to the conclusion that the drainage basins whose surplus waters escape to the Salton Sea from the northwest have a combined area of about 2,000 square miles. Probably 20 per cent of this total has a rainfall of from 5 to 25 inches per annum. The following tables comprise records of rainfall at Palm Springs (1889–1905), Indio (1878–1905), and Yuma, Ariz. (1884–1905):

EASTERN BORDER OF SAND DUNE AREA WEST OF MAMMOTH STATION.

Rainfall records.

AT PALM SPRINGS, CAL.

Year.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	Rain-fall for season.
1889	......	......	......	......	......	......	0.30	0.06	1.54	0.00	0.01	0.00	1.91
1889-90	0.00	0.07	0.00	0.53	0.00	4.64	.52	.10	.00	.00	.00	.00	5.86
1890-91	.00	.25	.38	.00	.00	.50	.00	7.44	.00	.00	.00	.00	8.57
1891-92	.03	1.02	.10	.00	.00	.23	2.18	.26	.05	.00	.12	.00	3.99
1892-93	.00	.00	.00	.00	.00	.00	.40	.00	1.18	.00	.10	.00	1.68
1893-94	.35	.40	.10	.00	3.00	.11	.00	.00	.00	.00	.00	.00	3.96
1894-95	.00	.00	.00	.00	.00	4.25	3.50	.00	.00	.00	.00	.00	7.75
1895-96	.00	.00	.00	.00	.00	3.50	.00	.00	.81	.03	.00	.00	4.34
1896-97	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1897-98	.00	.00	.00	.00	.00	1.09	.00	.00	.60	.00	T.	.00	1.69
1898-99	.00	.00	.00	.00	.00	.70	1.21	.12	.00	.00	.00	.00	2.03
1899-1900	.00	.62	T.	.00	.50	2.86	.80	.00	.00	.00	.00	.00	4.78
1900-1901	T.	.00	.00	1.29	T.	.00	T.	3.50	.00	.00	.00	.00	4.79
1901-2	.00	.00	.00	.00	.00	.00	.50	.00	.50	.50	.00	.00	1.50
1902-3	.00	.00	.00	.00	.70	.70	.00	.00	.70	.00	.00	.00	2.10
1903-4	.00	.00	.00	.00	.00	.00	T.	T.	......	.00	.00	.00	T.
1904-5	.00	1.00	.00	.10	T.	.00	2.16	3.95	1.66	T.	.48	.00	9.35

Average for 16 years, 3.90 inches.

AT INDIO, CAL.

Year.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	Rain-fall for season.
1878	......	......	......	......	......	......	0.10	0.00	0.00	0.00	0.00	0.00	0.10
1878-79	0.00	0.00	0.00	0.00	0.00	1.00	.60	.30	.00	.00	.00	.00	1.90
1879-80	.00	.00	.00	.00	.40	.00	.00	.00	.00	.00	.00	.00	.40
1880-81	.00	.00	.00	.00	.00	.70	3.45	.00	.50	.00	.00	.00	4.65
1881-82	.00	.00	.00	.00	.00	.00	1.50	.00	.00	.00	.00	.00	1.50
1882-83	.00	.00	.00	.00	1.00	.00	.80	1.13	.11	.00	.00	.00	2.43
1883-84	.00	.00	.00	.06	.00	.86	.00	3.16	.62	.44	.46	.00	5.60
1884-85	.00	.00	.00	.00	.00	.70	.00	.00	.00	.10	.00	.00	.80
1885-86	.00	.00	.00	.00	.90	.00	.00	.00	.00	.00	.00	.00	.90
1886-87	.00	.00	.00	.00	.12	.00	.00	.93	.00	.30	.00	.00	1.35
1887-88	.00	T.	.05	.15	.00	.00	.75	.00	.00	.00	.00	.00	.95
1888-89	.00	.00	.00	.00	1.10	1.11	.57	.00	1.05	.00	.00	.00	3.83
1889-90	.00	.95	.00	.60	.01	3.29	.65	.06	.00	.00	.00	.00	5.56
1890-91	.00	.10	.20	.00	.00	.22	.00	1.90	.00	.00	.00	.00	2.42
1891-92	.00	1.16	.00	.00	.00	.25	2.00	.43	.22	.04	.14	.00	4.24
1892-93	.00	.00	.00	.00	.00	.00	.03	.00	1.60	.00	.00	.00	1.63
1893-94	.05	.75	.07	.00	.14	T.	.00	.00	.00	.00	.00	.00	1.01
1894-95	T.	.00	.00	.00	.00	.00	6.01	.00	.00	.00	.00	T.	6.01
1895-96	.00	.00	.00	.00	.00	.00	.92	.00	.00	.00	.00	.00	.92
1896-97	.00	.00	.00	.00	.00	.00	1.10	.19	.00	.00	.00	.00	1.29
1897-98	.00	.00	2.10	.00	.00	.00	.10	.00	.30	.00	.00	.00	2.50
1898-99	.00	.30	.00	.00	.00	1.00	.40	.00	.00	.00	.00	.00	1.70
1899-1900	.00	.00	.10	.00	.60	.20	1.00	.00	.30	.15	T.	.00	2.35
1900-1901	.00	.00	.08	1.04	.17	.00	.29	1.46	.00	.00	.00	.00	3.04
1901-2	.00	.00	.00	.00	.00	.40	.20	.00	.00	.00	.00	.00	.60
1902-3 [a]	.10	.00	.00	.00	.50	.80	.00	.00	......	.75	.00	.00	2.15
1903-4 [a]	.00	.10	.12	.00	.00	......	......	......	......	.00	T.	.00	.22
1904-5	.00	.33	.00	.00	......	......	2.16	3.95	1.66	T.	.48	.00	8.58

Average for 25 years, 2.65 inches.

[a] Broken record.

AT YUMA, ARIZ.

Year.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	Rain-fall for season.
1884	......	......	......	......	......	......	T.	1.58	1.48	0.07	0.44	T.	3.57
1884-85	0.01	0.32	T.	T.	T.	1.96	......	.02	......	.07	......	0.00	2.38
1885-86	.05	.86	0.00	0.00	1.71	.01	1.06	.08	.33	.31	.00	.00	4.41
1886-87	T.	2.23	.00	1.11	.23	.00	.00	T.	.00	.20	T.	.01	3.78
1887-88	T.	T.	1.09	.02	2.43	.15	.18	.05	.05	T.	.00	.00	3.97
1888-89	.04	T.	.01	.99	.68	.95	1.12	.06	.24	.00	.00	T.	4.09
1889-90	T.	.25	.00	.59	T.	2.43	.08	.11	.06	.53	T.	.00	4.05
1890-91	.02	T.	......	T.	T.	.00	.00	2.53	T.	.00	T.	.00	2.55
1891-92	.04	.05	T.	.00	.00	.05	1.85	.87	.52	T.	.05	.00	3.43
1892-93	.00	.02	.04	.00	.00	T.	T.	......	1.53	.00	.31	.00	1.90
1893-94	.40	.42	.30	.00	.30	.11	.00	.00	.00	.00	T.	.00	1.53
1894-95	.30	.01	.12	1.25	.00	.29	.78	.02	T.	.00	.00	T.	2.77
1895-96	.01	T.	T.	.15	.37	.00	.14	.00	.43	T.	T.	.00	1.10
1896-97	.41	.32	.31	.10	.06	.78	2.83	.06	.48	T.	T.	.00	5.35
1897-98	T.	.57	.20	T.	.00	.04	.42	.00	.39	.01	.00	T.	1.63
1898-99	.00	.19	......	.00	.21	1.16	......	.01	T.	.00	T.	T.	1.57
1899-1900	T.	.06	.00	.02	.50	......	.08	.11	.06	.53	T.	.00	1.36
1900-1901	.02	T.	......	(?)	T.	.00	.12	3.01	.30	T.	T.	.00	3.45
1901-2	T.	.22	.00	T.	.00	.00	.26	T.	.21	.00	.00	T.	.69
1902-3	.11	T.	T.	.00	.57	.78	T.	.23	T.	T.	.00	.00	1.69
1903-4	.04	T.	.67	.04	.00	T.	.00	T.	.28	T.	.07	.00	1.10
1904-5	.05	.69	.24	T.	......	.10	1.15	3.43	3.33	.16	.00	.00	9.15

Average for 21 years, 2.95 inches.

The more effective portion of the tributary drainage area includes the eastern slope of San Jacinto Peak and the southern and eastern slopes of the San Gorgonio Mountain mass. From these mountains small perennial streams flow into the northern end of the desert. The largest of these is Whitewater River, which rises on the eastern slopes of San Gorgonio Peak. At the foot of San Gorgonio Pass its waters are divided, one portion being utilized for irrigation in the vicinity of Whitewater station, while another portion, at one time used for irrigation at Palm Springs, is allowed to waste into the desert.

From Palm Canyon also a perennial stream flows, and Tahquitz Creek and other minor streams which rise on San Jacinto Peak furnish small amounts of water to the neighboring portions of the desert.

Over the remaining 80 per cent of the desert ranges whose slopes are in the direction of the Coachella Valley, the precipitation is extremely meager. At Indio it averages about 2.65 inches per year, and is probably but little more on the desert ranges to the east. A somewhat larger amount, which increases with the altitude, falls on the northern slopes of the Santa Rosa Mountains, because these are higher and receive some share of the moisture that is borne eastward by the Pacific winds.

Much of the rainfall in the desert comes in heavy storms of short duration, and since the slopes on which it falls are free from vegetation and have but little soil covering, the proportion of run-off is large—much larger than in more humid and better forested areas. But as the desert air is intensely dry, the immediate loss by evaporation must be a large proportion of the total fall.

At the base of each mountain range, where great alluvial fans containing much coarse material are piled up, such flood waters as reach them are promptly absorbed. Hence, in spite of the intense heat of the long summer, and the unfavorable situation of the valley in regard to rainfall, the large tributary drainage area must result in a considerable aggregate annual contribution to the underground supply. It is not possible, however, to make any definite estimate of its amount.

East and west of the southern end of the desert—the Imperial Valley—are arid ranges like those that inclose the Coachella Valley, except that they are not so high and not so effective as rain makers. Furthermore, this south end of the desert is much wider than its northern end, and the very slight and uncertain run-off from its bordering mountains does not reach the heart of the basin. On the other hand, a portion of the overflow from the annual summer floods of the Colorado occasionally extended down into the valley before irrigation began there. Sloughs of fresh water were thus occasionally found along the channels of New and Alamo rivers, and intermittent water basins like Cameron Lake, Blue Lake, and Mesquite Lake were sometimes filled by these flood waters. Farther south, in Mexico, in the vicinity of Volcano Lake, which is near the divide between the Salton Basin and the Gulf of California, flooding during the summer high-water period in the Colorado is usual instead of rare. Indeed, this part of the desert, which for years has been used as a cattle range, owes all of its value for this purpose to the natural irrigation that it receives during the summer floods in the river.

UNDERGROUND WATERS.

LIMITS OF ORIGIN.

The geologic conditions within and about the borders of the desert preclude the possibility of its ground waters originating in drainage basins beyond the surrounding mountains. These ranges are formed of granitic and metamorphic rocks, practically impervious to water, 50 or 100 miles through, and extending indefinitely downward. It is impossible to conceive that water circulates through them in any valuable quantity. It has also been suggested that these waters may be derived from Colorado River, not by percolation through the separating mountain ranges but by subsurface flow around the southern point of these ranges through the sands and silts of the valley. A consideration of the distribution of temperatures and of the character of the waters over the Coachella Valley is sufficient to show that the supply does not come from the southeast. The average temperature of well waters near the northwest end of the area in which developments have taken place is about equal to the mean annual temperature of the region—72°. Nearer the Salton Sink the temperatures of waters are higher. Here the springs or shallower wells have temperatures of 75°, 80°, and 90°.

An experimental well has been sunk in the very bottom of the Salton basin by the company that mined salt there before the inundation, and a flow of water with 1 per cent saline matter and a temperature of 92° was obtained at a depth of 500 feet.

Other saline and sulphuretted waters were found in wells, now submerged, in the vicinity of Mortmere, and the springs southeast of Figtree John's are saline, sulphuretted, or carbonated.

Below the Salton Basin, 5 or 6 miles south of Lano station, in an area now submerged, there was a group of boiling mud springs. The waters that rose here were not potable; some were acidulated and some had temperatures of 212°. Furthermore, in the vicinity there are the remnants of old volcanoes. It is wholly unlikely that Colorado River waters percolate eastward through areas in which highly mineralized and highly heated waters of the types just mentioned exist. This is particularly true because the normal waters of Indio and vicinity are of great purity. That they contain but 15 to 25 parts of solid matter per 100,000 parts of water is shown by the following analyses:

Analyses of Colorado desert waters.

[Analysts, G. E. Colby and M. E. Jaffa, University of California.]

[Parts per 100,000.]

	1. From surface-water well 20 feet deep, one-half mile northeast of Indio station.	2. From water strata 120 feet deep, one-half mile northeast of Indio.	3. From reservoir at Coachella.	4. From artesian strata 500 feet deep at Coachella.	5. From surface well 25 feet deep, one-half mile north of Coachella.
Sodium and potassium sulphates, etc	4.3	4.3	4.92	6.3	3.80
Sodium chloride (common salt)	1.12	.20	.18	.20	.10
Sodium carbonate (sal soda)	2.1	2.10	6.40	4.30	5.30
Calcium and magnesium carbonates, etc; Calcium sulphate (gypsum)	7.0	6.8	1.10	3.00	7.80
Silica	4.0	4.0	1.00	1.00	2.00
Organic matter and chemically combined water	.40	.40	1.40	1.12	6.60
	18.00	17.8	15.00	16.00	25.60

All the water clear, colorless, odorless, and tasteless.

An additional proof of the dependence of the Indio underground supply upon local rainfall was furnished by the prompt response of the wells to the exceptional rainfall in the winter of 1904–5. Wells whose yield had been noticeably affected by the developments of the preceding four years were restored to approximately their original flow by that seasons's rains. Such a response could not occur if the Colorado River were the source of the waters.

These arguments add strength to the inherent improbability, amounting practically to a certainty, that waters in any valuable quantity percolate through the 100 miles or more of close-textured Colorado River silts that lie between Yuma and Indio. It must therefore be concluded that these waters enter through the alluvial material that occupies the borders of the valley, especially near its northern end, where the water supply is greatest, and move thence slowly toward the center of the basin. It is these waters in slow motion toward the Salton Sink that are intercepted by the 400 wells of the Coachella Valley.

The physical conditions which control the movements of the underground waters may be readily inferred from the character of the deposits that fill the valley. Except about the borders these deposits are fine. This follows directly from the fact that they are in part lake sediments and in part the outer edges of alluvial fans. Well drillers in the valley are able to sink wells to depths of 600 or 800 feet by the hydraulic method, which can be used only where no coarse material is encountered (fig. 2). The strata which they pierce are alternating layers of clay and sand with occasional streaks of very fine gravel. This alternation of fine and coarse material (fig. 3), which is essential to artesian conditions, exists presumably only in the northern end of the desert. Few bowlders are encountered (fig. 4), and these are about the borders of the

A. GROUP OF ACTIVE MUD VOLCANOES WEST OF IMPERIAL JUNCTION.

B. GENERAL VIEW OF QUIESCENT MUD VOLCANOES NEAR IMPERIAL JUNCTION.

basin, where their source may usually be recognized in a near-by canyon. South of Salton Sink, where the original lake was larger and the material with which it was filled was supplied more directly

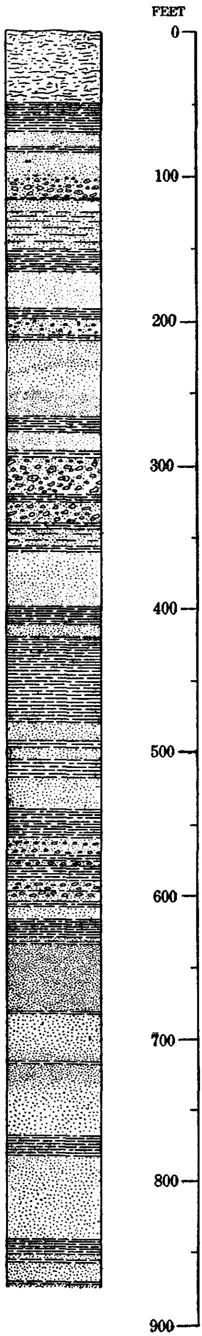


FIG. 2.—Section of Southern Pacific well at Indio, Cal.

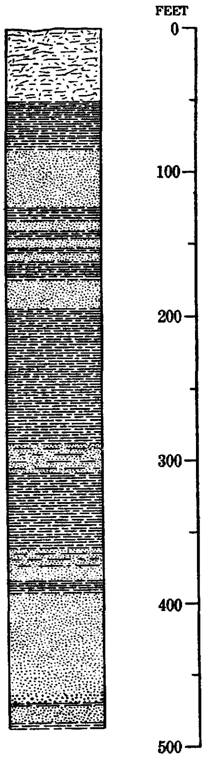


FIG. 3.—Section of Southern Pacific well at Mecca, Cal.

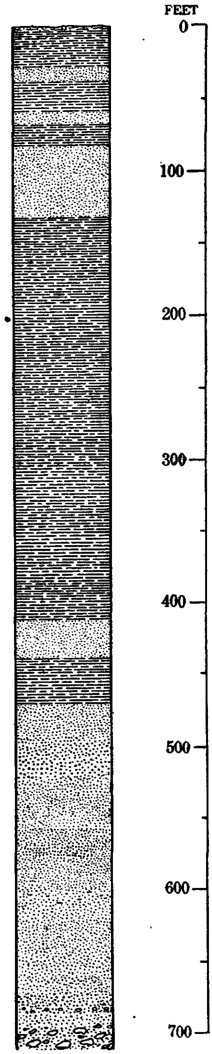


FIG. 4.—Section of Southern Pacific well at Mortmere, Cal.

by the distant Colorado River, the coarser strata are much more rare. Drill records here reveal a comparatively uniform series of fine sediments through which the circulation of waters in sufficient amounts to give artesian pressures is scarcely possible. Two or three deep wells have been drilled near Imperial, but no flow was obtained, and the water found in limited quantity was too saline to be usable. The northern limit of these nonartesian conditions can not be predicted closely. North of the southern end of the old Salton marsh, however, flowing waters will be found, although for a number of miles they will not be suitable either for drinking purposes or for irrigation; but south of this limit artesian waters of any quality need not be expected, except perhaps in small areas near the mouths of the larger canyons where local conditions may be favorable. The Harper well, near the San Felipe wash, drilled for oil but yielding flowing water, is a case in point.

A matter of more importance to the irrigator than the theoretical limits of the artesian basin is the limit of the usable waters. This can not be determined theoretically; but the waters developed by wells drilled near the old Mortmere switch, and the position and character of some of the natural springs, indicate that ground waters sufficiently pure and in sufficient quantity to be used for irrigation may be found northwest of a line crossing the valley from the southern end of the Santa Rosa Mountains to the vicinity of Salton Station; southeast of this line the waters are distinctly saline. The heavy incrustations of surface alkalies which occupy the center of the valley for a number of miles northwest of this limit of usable waters, and preclude the use of the land for agricultural purposes, will probably be more potent than the character of the waters in checking development toward the southeast.

SOURCE AND CHARACTER OF THE UNDERGROUND SUPPLY.

The only source of the underground waters of this region is the rainfall on the desert and the surrounding mountains. It has frequently been suggested that distant and less obvious sources might supply the waters that seem to irrigators within the Coachella Valley too abundant to be due entirely to run-off from the desert ranges about them. A similar opinion is commonly held in artesian areas, because proper value is not given to the importance of the time element in the accumulation of underground waters. The waters that are being developed in the Coachella Valley have slowly accumulated there throughout a long period. The amount annually added to them is but a small percentage of the total supply. Before irrigation was begun this annual increment served simply to balance the amount annually reaching the surface by capillarity and artesian pressure and there evaporating; for with the land surface in the Salton Sink 273 feet below sea level, and a great body of nearly impervious silts intervening, there can be little if any escape of desert waters toward the gulf by percolation. Irrigation, through the boring of artesian wells, probably somewhat reduces this natural loss in the lowest parts of the area, because it reduces artesian pressure; but it substitutes a greater loss from the irrigated surface and from locally raised water tables.

PRESENT DEVELOPMENT AND CONTROLLING CONDITIONS.

In April, 1905, the amount of water developed by the artesian and pumped wells in the Indio basin during the irrigating season was about 100 second-feet, an amount equivalent to a continuous flow of about 20 or 25 second-feet maintained throughout the year. Impressive estimates of the total amount of water stored in the desert might be made, since it has an area of at least 400 square miles above Salton Sink and the depth of the saturated sands over this area probably averages more than 1,000 feet. Such an estimate, however, can have little value, not only because it is based upon many unknown factors, but also because the amount of water which may be taken from a basin depends not on the total amount stored there but on the amount annually added. This amount is necessarily much smaller for the desert than in the more humid area to the north, known as the valley of southern California, and even there, where the amount of water annually available for a recharge of the underground reservoirs is many times what it is in the Indio region, the artesian areas have shrunk 35 per cent in the past ten or twelve years as a result of intense development.

The effect of the development for irrigation upon the flow of the wells in the Indio region, particularly about the upper part of the basin, had been marked previous to the winter of 1904–5. The exceptional rainfall during that winter, however, amounting to 8.58 inches at Indio, where the average is but 2.65 inches, is reported by the well owners to have practically restored the yield of the wells to its original amount. A repetition of such exceptional weather conditions, however, is not to be expected often, so it is desirable to consider the usual effect of the present development.

The accompanying table has been prepared to show the actual condition of a few of the wells at two periods separated by an interval of two years. The first measurements were made in April, 1905, and the second in April, 1907. This list includes 36 wells distributed from Agua Dulce to Indio and represents therefore all parts of the basin. In nearly every well the water plane has lowered or the yield has lessened. In a few wells the change has been very slight; in others it has been marked. In some of the wells that two years ago were flowing freely the water now stands several feet below the surface.

Comparative records of wells.

Number.	Owner	April, 1905.		April, 1907.	
		Flow.	Distance to water.	Flow.	Distance to water.
		Inches.	*Feet.*	*Inches.*	*Feet.*
6	A. L. Gordon & Bro.	[a] 12			1½
7	J. W. Newman	[a] 5			10
9	S. B. Twomey	[a] 15		7	
10	J. T. King	[a] 15		7	
11	C. B. Bisbee	[a] 8		2	
13	W. H. Mather	[a] 15		[a] 10	
15	E. D. Morrill	[a] 25		[a] 15	
16	.....do	[a] 25		[a] 15	
17	J. K. Ross		6		11
18	.....do		8		12
41	N. O. Nelson		[b] 16 12		
42	.....do		[b] 15 14		21
43	.....do		[b] 16 18		20
44	.....do		[b] 16 18		20
45	.....do		[b] 17 18		20
46	C. A. Hayott		[b] 13 18		
50	Will Everett		12		16
51	.....do		9		13
52	.....do		9		14
74 75	Toro Indian Reserve	[a] 25		20	
78	D. Bond	[a] 14		13	
92	Mrs. S. A. Williams	[a] 10		8	
128	F. A. Leap	23		4	
132	R. B. Thayer	26		7	
133	E. N. Stanley	33		11	
144	Town of Coachella	[a] 4		1	
160	Mr. Teagle		22		23½
171	A. W. Haight	5			4
182	W. I. Hobbs	21		7	
183	.....do	[a] 8		4	
222	O. C. Eberhardt	7		2	
223	.....do	11		2	
244	Stanley and Payne	[a] 7		5	
255	Martin and Moore	11		2	
261	G. L. Keith	20		10	
279	Peters, Evans & Gage	8		5	

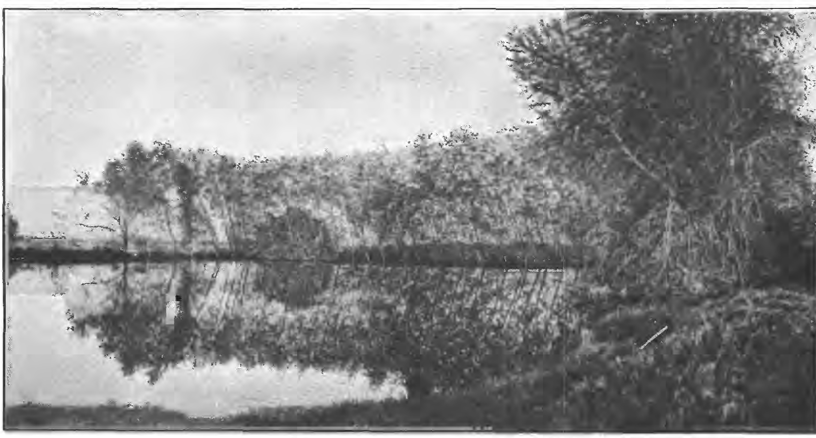
[a] Estimated flow. [b] January 3, 1905.

NEED OF CONSERVATION.

The continued drilling and use of wells in an artesian region diminish the area in which the wells will flow, and those about its borders that are least favorably located decrease in yield or cease to flow, so that to maintain the water supply it becomes necessary to install pumping plants. This stage has already begun in the Coachella Valley, and it will undoubtedly extend over larger areas about the northern end of the artesian belt. The gravity of the condition will depend largely on the extent of future developments and on the care with which wells that are now flowing are managed. The unlimited drilling of wells in the lower, most favorably situated portions of the valley will hasten the depletion of the supplies in the higher, less favorably situated areas, and the use of pumping plants will quickly influence the yield of adjacent flowing wells.

The practice of leaving strong wells uncapped when the water is not needed can not be too strongly condemned. This waste of the water not only depletes the underground reservoirs but injures the

A. A DESERT HOMESTEAD SOUTH OF INDIO.



B. EARTHEN RESERVOIR NEAR INDIO.

C. COTTONWOODS, 2 TO 4 YEARS OLD, NEAR COACHELLA, CAL.

soil over which it flows, because when the flow of water is not controlled and properly distributed the greater portion of it is evaporated from the surface, bringing about the concentration of alkali there. The greatest damage, however, results from the needless tax on the deep basins. The supply in this region will necessarily be sensitive, because the amount annually added to it by rainfall is small. A strong public sentiment, therefore, should be created, which will under all circumstances oppose the careless use of artesian wells. It should be insisted that the man who wastes or uses needlessly a product on whose abundance the prosperity of the section depends is his own and his neighbor's worst enemy. Although ranch owners generally in this section realize the need of care in this respect, there are a few important exceptions, on whom the pressure of public opinion should be brought to bear.

In addition to this obvious and useless waste there is other waste through poorly developed irrigation methods and poorly constructed reservoirs and ditches. This is a condition that is almost inevitable in new communities. Better irrigation practice comes only at a later stage, when the value of lands has been thoroughly established and agricultural habits have become fixed. It is probable that the amount of water now developed, if it could be utilized without waste, could be made to irrigate 50 to 100 per cent more land than at present.

FUTURE OF THE WATER SUPPLY.

Now, while it is obvious that additional development or even the maintenance of the present development will cause a gradual shrinkage in the artesian zone and a gradual expansion of the pumping zone—because additional development means increased drainage of the underground reservoirs by artificial means—it is nevertheless probable that the highest possible use of the underground waters will not have been reached until further developments have been carried out. There is a continuous slow movement of these subterranean waters beneath the Indio region toward the southeast, but the water does not escape to the gulf. Much the greater part of the subsurface percolation probably reaches the surface eventually in the vicinity of the Salton Sea, and before the inflow of the Colorado it escaped into the air by evaporation. A loss takes place in this manner wherever the water table stands so near the land surface that capillarity becomes effective. This condition originally prevailed over the entire area of the Salton Sink and now exists over many square miles about the lower part of the Coachella Valley above the borders of the Salton Sea. Whatever reduces artesian pressure reduces the leakage of the ground waters in this way and so decreases loss. Hence the development of artesian waters has some slight effect in lessening the proportion that is lost under natural conditions, and correspondingly increases the proportion available for man's use.

It is believed that while slow decline of artesian pressure will necessarily take place in the Indio basin, this decline need not be especially harmful to the agricultural interests of the valley for many years to come, even although twice the amount of water now developed is procured, and it is also believed that by a proper utilization of the waters now developed and those to be developed in the future several times the acreage at present under cultivation in the valley may become productive without too great drafts on the supply.

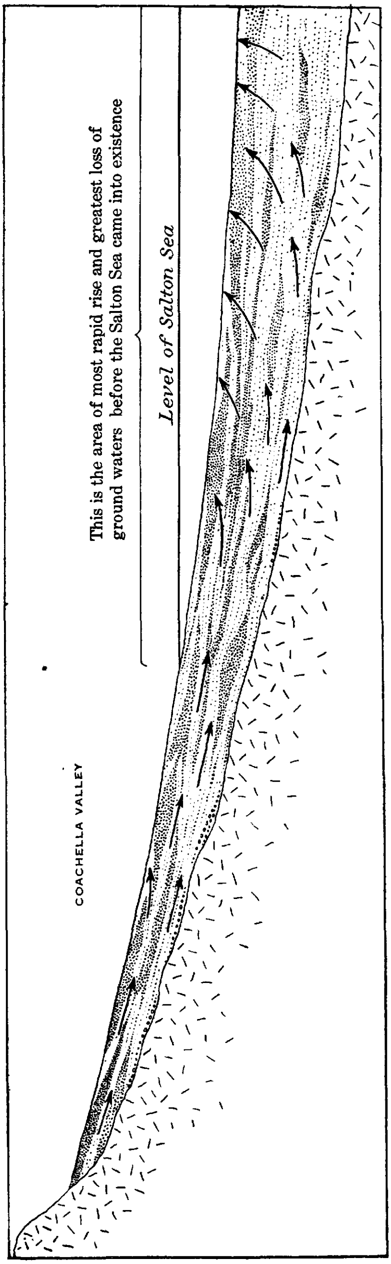


FIG. 5.—Diagrammatic section illustrating course of ground waters through Coachella Valley.

Pumped waters will become increasingly important and will be relied upon more and more as time passes. Abundant water for pumping may be obtained at depths of 100 to 200 or 300 feet, while much deeper wells must be bored over the greater part of the area to obtain an artesian supply. Furthermore, pumped waters are used more carefully than artesian waters. Human nature can not be trusted to value or to manage well that which costs little. Therefore, artesian waters will be wasted and pumped waters will be used with care in the same area. The cheapness of gasoline and crude oil and the efficiency of engines that utilize these fuels will make their application in irrigation more and more feasible as development continues.

EFFECT OF THE FILLING OF THE SALTON BASIN.

When development began in the Coachella Valley the bottom of the Salton Sink was a salt marsh—a huge evaporating pan from whose surface many thousands of tons of water must have passed into the air annually from underground sources. In the spring of 1907 this basin was partially filled by a sheet of water covering an area of nearly 500 square miles and having a maximum depth of about 75 feet. A little consideration makes it evident that the existence of this water body must have a marked effect on the natural waste into the air of the subterranean supplies.

It is to be remembered, in the first place, that a certain analogy may be drawn between the underground flow of the Indio basin and the flow of a surface stream, although the analogy is not close at some points. Just as a surface stream has its source, its mid course, and its mouth or point of discharge, so has this body of ground waters a source, a mid course, and a point of discharge. Its source is in the alluvial fans, particularly their upper portions, where the surface waters sink and join the underflow. Its mid course is the Coachella Valley, through which the ground waters percolate slowly southeastward, in the direction of the general slope of the surface and presumably of the valley bottom, although its attitude must remain conjectural. The point of discharge of the ground waters is the Salton Sink, and indeed all the moist and practically all the alkaline areas about its borders.

Instead of discharging into a larger water body, as do surface streams generally, the ground waters discharge into the air by evaporation from the moist lands (fig. 5), a very minor part, of course, escaping through the springs that are found in the lower parts of the desert.

This escape is effected as a result of the hydraulic head of the ground waters and their constant tendency to rise as a consequence of this head, and, when they are near enough to the surface for it to act, as a consequence of capillarity also. The waters are removed by evaporation as quickly as they approach the surface. With this condition in mind, the effect of the water body in the Salton depression at once becomes apparent. It acts on the underground waters much as a dam across its mouth would act upon a river. A great part of the field from which the ground waters evaporated is covered by the lake and evaporation therefrom is prevented; and a part of the hydraulic head under whose influence the ground waters rose to the surface is balanced by the pressure of the lake waters, and this rise of ground waters is thereby interfered with (fig. 5). Very much less of the water of the Coachella Valley must be wasting now through evaporation than before the creation of the Salton Sea. No quantitative estimate can be made of this effect. It can only be said that it must be sufficiently powerful to be beneficial to the users of ground water in the Indio region.

This beneficial condition is necessarily temporary, as the Salton Sea is temporary. If the engineering work done and to be done about the intake of the Imperial Canal accomplishes its purpose of preventing further inflow of the Colorado, the Salton Sea will probably have nearly disappeared by 1925; and as it gradually shrinks a larger and larger area will be exposed, through which ground waters will escape by capillarity and evaporation, until, with the disappearance of the sea, the conditions that prevailed before it came into existence will have been restored. From the point of view of the users of ground waters in the Coachella Valley, it is to be regretted that the sea can not be maintained at its present level.

HISTORY OF DEVELOPMENT OF THE INDIO REGION.

In the Colorado Desert railroad building was encouraged by the Government in the same way as in other parts of the West—that is, every odd section of public lands for a number of miles on either side of its right of way was deeded to the railroad on condition that it should construct its line. Thus one-half of the lands in the Coachella Valley belong to the Southern Pacific. The railroad has disposed of a few sections near its track, but it still holds the greater part of the original grant, and agricultural development is therefore confined chiefly to the even sections.

The larger portion of these public lands were filed upon under the desert land act in 1885 and 1886. After the completion of the successful deep well at Walters in 1894, proving finally the presence of abundant artesian waters beneath this part of the desert, interest in the possibility of its reclamation was greatly stimulated, but the great cost of drilling wells by the ordinary method prevented further extensive development until 1900. In April of that year the first successful hydraulic well was put down at Indio. It reached a depth of 500 feet in seventeen hours, and the cost was comparatively nominal. From the date of its completion until the present development has been continuous, and now from 350 to 400 deep wells are scattered about over those parts of the desert which are accessible from the stations between Indio and Salton Sea. Of this number, from 250 to 300 are artesian. About 90 pumping plants have been installed, two or three wells frequently being coupled together and pumped from one station.

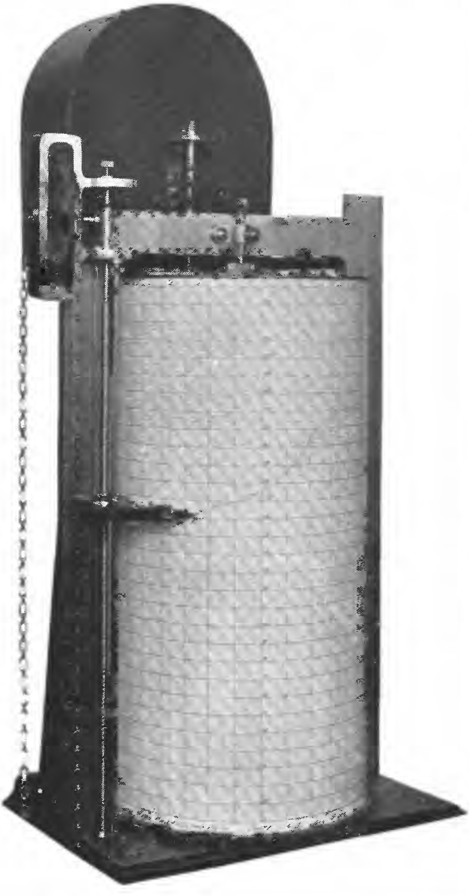
It is estimated that more than $100,000 is invested in the artesian wells that have been bored in the valley, and that the pumping plants with the wells on which they are installed represent an additional expenditure of $75,000. If the cost of reservoirs and of such pipe lines as have been put in are added, it will easily bring the total investment in works for the development and distribution of water to $200,000.

By the use of the waters which have been developed in this way, 4,000 or 5,000 acres of land have been reclaimed and are successfully irrigated. The area in which flowing waters may be pro-

THE

Hydrographic Chronograph

PATENT APPLIED FOR



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BARRETT & LAWRENCE

INCORPORATED

Bullitt Building Philadelphia, Pa.

THE HYDROGRAPHIC CHRONOGRAPH

THIS instrument gives a complete graphic record of the varying head of streams, reservoirs, or other bodies of water. It is invaluable for use wherever it is desired to secure a record showing the water head at all times, particularly reservoirs and power streams. It is indispensable for river and harbor improvement work, and, when used in conjunction with sounding apparatus in a varying tide, will give an accurate record which, when compared with the sounded depths at the corresponding hours, will allow same to be reduced to a mean depth and tabulated correctly.

Advantages

The **Hydrographic Chronograph** has many points of superiority over any other instrument on the market, chief of which are the following:

1. The record chart is oblong in shape, making the divisions regular for all heights of water and for all periods of time.
2. The chart is larger than that of any other instrument, giving a record more distinct, more accurate and more easily read.
3. The number of working parts is reduced to a minimum, eliminating all unnecessary friction and making the instrument so sensitive that the slightest fluctuation in water head is accurately recorded.
4. There are no springs, diaphragms nor other delicate parts to get out of order. The instrument is entirely positive in action; the only part exposed to the action of the water is a glass float, which cannot rust nor corrode, nor otherwise become affected by temperature nor chemical action.

Principle

The instrument is operated by a glass float attached to a brass link chain which passes over the sprocket wheel on the left-hand side of the upper frame (see cut), the other end of this chain being connected to an iron counterweight balancing the dead weight of the float when same is partially immersed in water. As the float rises or falls with the water, the sprocket wheel revolves, thus raising or lowering the recording pen by means of small bevel gears acting on a vertical worm and nut.

The drum is revolved by clockwork, the pen tracing a curve on the chart, each point of the curve corresponding to the time as laid off on the chart.

Installation

The instrument in its case is set on a shelf or platform at a point above the surface of the water. A 3-inch iron pipe is set vertically beneath it in which the glass float travels. This pipe must extend from a point below the lowest water line to a point above the highest. Holes are drilled in it below the water line for free admission of water. The base of the instrument can be set at the same level as the top of the 3-inch pipe; if higher, the float pipe should be capped and the cap tapped for a ¾-inch pipe, which must extend up to the case to enclose the chain. A ¾-inch iron counterweight pipe, of the same length as the float pipe, extends down from the instrument to enclose counterweight and chain.

In setting the instrument, a quart of kerosene oı should be poured into the float pipe; this will lubricate the float and cause it to work easily, and will also prevent the possibility of ice forming in the float pipe in winter.

Types

The **Hydrographic Chronograph** is manufactured in the following standard types and sizes:

Type "A"—31-Day Record

No. 1, 10 ft. maximum variation of water head.
No. 2, 20 ft. maximum variation of water head.
No. 3, 30 ft. maximum variation of water head.

Type "B"—7-Day Record

No. 1, 10 ft. maximum variation of water head.
No. 2, 20 ft. maximum variation of water head.
No. 3, 30 ft. maximum variation of water head.

The Type "A" instrument makes a complete 31-day record, having a chart space of ¾ inch for each day, subdivided into twelve (12) divisions of two (2) hours each. The drum is driven by a 34-day clock movement of the best make.

The Type "B" instrument makes a complete 7-day record, having a chart space of $3\frac{5}{16}$ inches for each day, subdivided into hours and half hours. The drum is driven by an 8-day clock movement of the best make.

The 10-ft. and 20-ft. instruments have a chart space of ¾ inch for each foot of water, subdivided into tenths of a foot.

The 30-ft. instrument has a chart space of ½ inch for each foot of water, subdivided into fifths of a foot.

We shall be pleased to submit estimates for furnishing instruments of any special design or to meet any particular requirements.

Description

The instrument is made entirely of brass, all exposed parts being burnished and the remainder black-lacquered. Each instrument is furnished complete in a handsome weather-proof teakwood case, with glass float, counterweight, fifty (50) feet of brass link chain and bottle of self-recording ink. With each Type "A" instrument is furnished one year's supply of record charts, and with each Type "B" instrument, six months' supply. No piping will be furnished except as an extra, as this can usually be purchased locally to better advantage.

Each instrument is carefully tested and adjusted before shipping, and is guaranteed for one year, and any parts found defective within that time will be replaced free of charge.

We shall be pleased to furnish prices and discounts, and sketch of installation upon application.

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VIEW OF THE SALTON BASIN FROM THE WEST SIDE AFTER THE INFLOW OF THE COLORADO.

cured—it has been roughly outlined by the developments to date—covers approximately 140 square miles. This area extends from a point a short distance above Indio to a point below the present border of the Salton Sea. The greater part of it lies on the south side of the Southern Pacific Railway, but there is a strip from 1 to 2 miles wide on the north side of the line.

Much the stronger artesian flows are obtained at the lower elevations near the southern end of the belt. Wells at the upper or northwestern extremity of the valley give inferior yields, so that it has been found necessary to pump from many of them in order to obtain sufficient water for successful irrigation. This condition is due in part to the originally inferior yield of these higher wells and in part to a decrease in their flow which has followed the increased development. All of the flowing wells lie below the sea-level contour. A few of the northernmost are very near sea level, but the most of them are from 20 to 150 feet below.

COST OF RECLAMATION AND DEVELOPMENT.

The value of lands within the desert depends on their situation relative to the railroad, their fertility, their freedom from alkalies, the improvements which have been made upon them, and the water supply. Those on which successful wells have been bored are, of course, more valuable than those whose water supply has not yet been proved. The unimproved lands have been sold at prices ranging from $10 to $100 an acre. Cultivated land with a proved water supply sells at from $25 to $200 an acre, or even higher in places where the improvements are extensive. Such land occasionally rents for as much as $25 an acre. The majority of the active landowners are residents, have small holdings of 10 to 80 acres, cultivate intensively, and do a great part of their own work. Absentee ownership and large holdings are comparatively rare. A great proportion of the work of clearing new land and preparing it for cultivation is performed by Indians from the reservations along the western side of the valley. They are paid $2.50 an acre for clearing sagebrush and the smaller desert growths and 50 cents each for removing the mesquite trees. The wood obtained from these trees generally pays for the cost of their removal, as it is worth $4.50 per cord at Thermal and Coachella. Some of the lands are covered with hummocks and require grading. The cost of this varies with the amount of work involved, and no accurate estimate can be given.

The drilling of wells by the hydraulic method now in vogue costs about a dollar a foot for both labor and casing for wells of the usual diameters—2 to 4½ inches. Those of larger size are somewhat more expensive. Artesian flows are procured at depths of 275 to 1,000 feet, the shallower waters being found in the southern and western portions of the basin and the deeper ones in the northern and eastern sections. Wells alone, therefore, range in cost from $200 to as much as $3,000 each—the latter amount being given as the cost of the first successful deep well put down by the Southern Pacific Railroad by the old method, at Mecca.

The average flow is rarely great enough to enable ranchers to irrigate successfully direct from the well. It is customary, therefore, to build small earthen reservoirs (Pl. X, *B*) into which the water flows and from which it is conducted in comparatively large volume for purposes of irrigation. These reservoirs are of simple construction, the walls usually being thrown up by a team and scrapers. Some of them are lined with fine clay; others are unlined. Those that are unlined lose much water by seepage. The reservoirs are not covered, and the loss from them by evaporation during the summer must be considerable. Engineers of the Reclamation Service report that the annual evaporation at Yuma is from 80 to 85 inches, or about 7 feet. It is probably not less from small water surfaces in the vicinity of Indio.

SOILS AND CROPS.

The soils of the Indio area have been carefully studied by J. Garnett Holmes, of the Bureau of Soils, U. S. Department of Agriculture.[a] He divides them into five types, but of these the two most widely distributed and most important agriculturally are sandy loams that differ but slightly in coarseness of grain. Together they cover an area of 135 square miles. This area includes practically all of the valuable lands that are water bearing and yet lie above the extremely alkaline areas, which are extensive in the vicinity of the Salton Sea and along a line that follows approximately the lowest part of the valley from the sink to the vicinity of Indio. Mr. Holmes says of the finer of these loams: "It is well adapted to any crop that is suited to the climate of the area. A better soil for general purposes would be difficult to find, since it is easily cultivated, very productive, and retains moisture well." It is worthy of note that these soils contain a very large percentage of calcium carbonate, ranging from a little less than 2 per cent to nearly 37 per cent in the various samples collected. It is not at all unusual to find soils containing 5, 6, and 7 per cent of this mineral. This high percentage is no doubt due to the very great number of small fossil shells that are scattered over the surface of this portion of the desert and through the soils which underlie it.

The agricultural development of the area is still in its infancy. The ranchers are experimenting on various crops and with various

[a] Holmes, J. Garnett, and party, Soil survey of the Indio area, California; Field operations of the Bureau of Soils, U. S. Dept. Agr., 1903, pp. 1249-1262.

degrees of success. Those most extensively raised at present are melons, barley, and alfalfa. Small tracts, however, have been planted, chiefly for experimental purposes, in grapes, sweet potatoes, oranges, and sugar beets; and at the agricultural experiment station near Mecca rather extensive experiments are being conducted in date culture, a number of the finer, rarer, and more delicate varieties having been introduced from northern Africa and Arabia. Some of the date palms are in bearing, and those in charge of the experiment are sanguine as to its success.

The most highly specialized product of the region is the cantaloupe. The first experiment in its cultivation was made in the summer of 1900. A crate of melons raised during that season was shipped to Chicago, where, because of their high flavor, they found a ready market. Upon the basis of this first venture about 60 acres were planted during the following season, producing 13 carloads and netting to the growers $10,000. The cultivation of this fruit has been successfully continued since, with a constantly increasing acreage. In 1904 the Melon Association of Coachella distributed $67,000 to its members, and in addition the independent operators shipped 11 cars from Indio. The success of the crop is due to the excellent quality of the fruit produced and to the fact that the climatic conditions of the desert permit its early marketing.

Alfalfa and barley are raised with unqualified success, but are less extensively cultivated than melons as a ready money crop. The grapes it is proposed to produce are the fancy table varieties, which the growers expect to place on the market early, as they do the cantaloupes. The vines that have been planted are thrifty, and the experiment promises to be successful. The sweet potatoes that have been produced thus far are excellent in quality; and although they mature early and may be marketed early if there is a demand for them, the growers have found that they are preserved in excellent condition in the dry soil of this climate for months, so that it is not necessary to dig them until market conditions are at their best. Some Indian and Kaffir corn is raised. Sugar beets have been tried as an experiment and have proved successful, but are not extensively cultivated because it is believed that larger returns may be obtained from other crops. Sugar beets have some alkali-resisting qualities and may therefore be raised in lands not suited to the cultivation of more sensitive crops. The date palm is even more capable of resisting alkali. This is especially true after it has become established and deeply rooted. Hence it may prove to be adapted to many soils in the valley where other crops can not be grown.

MAPS AND TABLES.

A map (Pl. XII) has been prepared on which the location of most of the producing wells that had been bored by April, 1907, is shown, the character of each well being indicated by an appropriate symbol. Ordinary domestic wells are represented by a single red dot, artesian wells by a red circle, and pumping plants by a red dot within a circle. Each well is numbered, and the essential facts concerning it—name of owner, location by land lines, diameter, depth, yield, temperature of waters, and cost—are given in the tables that follow. The map shows also approximately the outline of the artesian area, as determined by development, and the areas irrigated.

The data on which this map is based were collected in the field by A. J. Fisk, jr., and W. N. White, who have also rendered great assistance in the office in the preparation of the matter for publication.

Wells in Indio special quadrangle (Map, Pl. XII).

[*Symbols used in tables:* H=hydraulic; B=bored; Dr.=drilled; ? is used after all uncertain data.]

No.	Owner.	Location. Township.	Range.	Section.	Year completed.	Well. Class.	Diameter.	Depth.	Distance to water.	Temperature of water.	Method of lift.	Quantity of water.	Cost.
		S.	E.					Feet.	Feet.	° F.		Miner's in.	
1	W. H. Harris	6	8	23	1904	H.	4½ inches	499		74	Artesian	a 12	$600
2	do	6	8	23	1905	H.	do	509		74	do	a 23	600
3	H. J. Churchman	6	8	23	1904	H.	do	497		74	do	a 20	600
4	A. L. Gordon & Bro	6	8	23	1904	H.	do (2)	512		76	Gas, artesian	a b 15 a c 40	1,000
5	do	6	8	23		H.	do	512		76	Artesian	a 15	500
6	do	6	8	23	1904	H.	do	512			do	a 12	500
7	J. W. Newman	6	8	23	1905	H.	5⅝ inches	526		74	do	a 5	600
8	G. J. Armstrong	6	8	25	1903	H.	4½ inches	538		74	Gas, artesian		d 1,100
9	S. B. Twomey	6	8	26	1903	H.	do	487		74	Artesian	a 15	
10	J. T. King	6	8	26	1903	H.	do	514		74	do	a 15	514
11	C. B. Bisbee	6	8	26	1900	H.	3 inches	601		74	do	a 8	
12	Mr. Holman	6	8	23		H.	4½ inches			74	do		
13	W. H. Mather	6	8	23	1904	H.	do	519		74	do	a 15	500
14	Geo. Stepenet	6	8	14		H.	do	506		74	do		
15	E. D. Morrill	6	8	22	1902	H.	4 inches	498		74	do	a 25	450
16	do	6	8	22	1904	H.	4½ inches	496			do	a 25	512
17	J. K. Ross	5	7	14	1900	B.	8 inches	86	6		Wind		d 136
18	do	5	7	14	1904	B.	do	238	8		Not raised		400
19	U. S. Department of Agriculture	7	9	16	1901	H.	4 inches	484		76	Artesian	a 20	
20	B. G. Johnson	7	9	16	1904	H.	4½ inches	482			do	a 30	500
21	Southern Pacific R. R. Co	5	7	24	1895	Dr.	10 inches	859			do	½	
22	do	5	7	24	1890	Dr.	do	660			Steam, artesian	15	
23	do	5	7	24	1900	Dr.	12 inches	665					
24	C. B. Smith	7	9	22	1903	H.	4½ inches	510			Artesian	a 30	
25	R. H. Myers	7	9	22	1903	H.	4 inches	440			do	1	
26	do	7	9	22	1903	H.	4½ inches	503			do	a 25	
27	M. H. Flint	7	9	26	1902	H.	3 inches	530			do	a 14	
28	H. J. Rogers	7	9	26	1904	H.	4½ inches	530			do		
29	W. V. Covington	7	9	18	1904	H.	do	525		76	do		500
30	do	7	9	8	1900	H.	2 inches	525			do	a 10	202

[a] Estimated, or owner's statement used in column "Quantity of water."
[b] Flows.
[c] Pumps.
[d] Cost of well and pumping equipment used in column "Cost of well."

Wells in Indio special quadrangle (Map, Pl. XII)—Continued.

No.	Owner.	Location.			Year completed.	Well.		Depth.	Distance to water.	Temperature of water.	Method of lift.	Quantity of water.	Cost.
		Township.	Range.	Section.		Class.	Diameter.						
		S.	*E.*					*Feet.*	*Feet.*	*°F.*		*Miner's in.*	
31	Walters school district	7	9	8	1903	H.	2 inches	500			Artesian	8	
32	Mecca Land Co	7	9	8	1901 ?	H.	3 inches	547		77	do	*a* 11	
33	do	7	9	8	1903	H.	4½ inches	531		77	do	13	$530
34	J. R. Robertson	5	7	12	1904	B.	7 inches	186	12		Not raised		200
35	do	5	7	12	1904	B.	do	165	17	74	Hand		200
36	Mrs. V. I. Norsden	5	7	23	1898	H.	2 inches	465		73	Artesian	2	
37	do	5	7	23	1901	H.	4½ inches	500			Gas, artesian	*a* 38	*b* 1,400
38	do	5	7	23	1904	B.	8 inches	218	11		Gas		
39	H. Smith	5	7	23	1899	B.	do	100	20		Wind		*b* 155
40	A. H. Moore	5	7	18	1903	B.	7 inches	165	24		Gas	18	*b* 800
41	N. O. Nelson	5	7	23	1905	H.	3 inches	218	12		Compressed air		
42	do	5	7	23	1903	B.	8 inches	197	14		do		
43	do	5	7	23	1903	B.	do	150	18		do		
44	do	5	7	23	1902	B.	do	370	18		do		
						H.	3 inches	248					
45	do	5	7	23	1903	B.	8 inches	150	18		do		
46	C. A. Hayott	5	7	23	1903	B.	do	155	18		do		
47	P. B. Weir	5	7	13		H.	2 inches	600+		78	Artesian		
48	do	5	7	13		B.	8 inches	480		78	do		
49	Ross estate	5	7	14		H.	2 inches			74	do	4	
50	Will Everett	5	7	14		B.	7 inches	160	12		Wind		
51	do	5	7	14	1903	B.	do	210	9		Gas	5	
52	do	5	7	14	1902	B.	do	150	9		do		
53	D. W. Durbrow	5	7	23	1900	B.	6 inches	652		74	Gas, artesian	*c* 4 *d* 40	
54	do	5	7	23	1894	B.	do	536			Artesian	6	
55	do	5	7	23	1901	H.	4½ in. (2)	600	0		Compressed air		
56	do	5	7	23		B.	6 inches (2)	150	16		do		
57	Fred N. Johnson	5	7	22	1901	B.	7 inches	106	27		Wind		*b* 306
58	do	5	7	22	1903	B.	do	170	27		do		*b* 450
59	do	5	7	22	1904	B.	do	198	22		do		*b* 500
60	Mr. Lewis	5	7	10	1904	B.	7 inches (2)	190	17		Not raised		
61	W. B. Peck Co	5	7	22	1904	B.	8 inches	135	22		Compressed air		
62	do	5	7	22	1904	B.	do	178	22		do		
63	do	5	7	22	1904	B.	do	210	22		do		
64	do	5	7	22	1903	H.	4 inches	534	7		do		
65	do	5	7	22	1897	B.	7 inches	78	22		Wind		

66	....do	5	7	22	1897	B.	...do	61	22		....do		
67	W. S. England	5	7	10	1904	B.	...do	168	16		Not raised		
68	....do	5	7	10	1904	B.	...do	210	15		....do		
69	Berry & Baldwin	6	8	34	1902	H.	4½ inches	510		73	Artesian	37	
70	A. H. Sandford	6	8	34	1904	H.	4 inches	486			....do	12	
71	....do	6	8	34	1902	H.	...do	484			....do	a 25	
72	A. D. Nichols	6	8	34	1904	H.	4½ inches	487		73	....do	a 34	
73	Toro Indian Reserve	7	8	16	1900 ?	B.	10 inches	600			....do	(e)	
74	....do	7	8	16	1903	H.	4 inches				....do	a 25	
75	....do	7	8	16	1903	H.	4 inches (2)	400		81	....do		
76	Moravian Mission	7	8	16	1900	H.	2 inches	300+			....do		
77	W. L. Claberg	7	9	18	1901	H.	3 inches	380		74	....do	a 6	
78	D. Bond	7	8	12	1900	H.	...do	408		76	....do	a 14	
79	E. Brauckman	7	8	12	1901	H.	3½ inches	480		74	....do	25	
80	....do	7	8	12	1901	H.	4½ inches	480			....do	30	
81	Henry Huskins	6	8	17		H.	4 inches			72	....do	a 10	
82	....do	6	8	17	1904	H.	...do			72	....do	a 10	
83	Mr. McArthur	6	8	17		H.	4½ inches			73	....do	a 10	
84	H. R. Hitchcock	6	8	17		H.	4 inches			73	....do	a 6	
85	H. P. Dilworth	6	8	17	1902	H.	4½ inches	558		74	....do	a 7	
86	....do	6	8	17	1903	H.	...do	525			....do	18	535
87	Meek Bros	6	8	17	1902	H.	4½ in. (2)	500		72	....do	a 30	
88	F. Colby	6	8	20	1900	H.	4 inches	518		73	....do	a 10	
89	....do	6	8	20	1903	H.	4½ inches	500		73	....do	a 6	500
90	G. B. Evans	6	8	20	1902	H.	...do			74	....do	a 16	
91	Mrs. F. Colby	6	8	20	1903	H.	...do	520		74	....do	a 16	
92	Mrs. S. A. Williams	6	8	20		H.	4 inches			74	....do	a 10	
93	G. B. Evans	6	8	20		H.	...do			74	....do		
94	....do	6	8	20		H.	...do			74	....do		
95	A. O. Hayward	6	8	30	1901	H.	...do	407		74	....do	7	375
96	....do	6	8	30	1902	H.	...do	437		74	....do	8	390
97	G. M. Beach	6	8	30	1904	H.	4½ inches	474		74	....do	23	
98	....do	6	8	30	1904	H.	...do	485			....do	18	
99	H. E. Sheldon	6	8	30	1903	H.	4 inches	430		74	....do		400
100	....do	6	8	30	1901	H.	2 inches	446		74	....do	2	252
101	....do	6	8	30	1902	H.	3 inches	410		74	....do	11	307
102	S. A. Mann	6	7	24	1901	H.	2 inches	320		74	....do		
103	....do	6	7	24	1902	H.	4½ inches	480		74	....do	4	630
104	Albert Sarbaugh	6	7	24		H.	...do				....do		
105	....do	6	7	24		H.	3 inches			74	....do		
106	....do	6	7	24		H.	...do			74	....do		
107	G. M. Frazey	6	7	24	1901	H.	...do	500+		74	....do	4	
108	....do	6	7	24		H.	4 inches	500 ?		74	....do	5	
109	E. L. Lambie	6	7	14	1901	H.	3 inches	577	4	72	Gas		
110	....do	6	7	14	1901	H.	...do	430	4		....do	6	480
111	....do	6	7	14	1901	H.	...do	418	4		....do		
112	Silas Trickey	7	9	20	1905	H.	4½ inches	480		76	Artesian	37	
113	....do	7	9	20	1903	H.	6½ inches	640		76	....do	33	
114	....do	7	9	20	1904	H.	4½ inches	565		75	....do	30	

a Estimated, or owner's statement used in column "Quantity of water."
b Cost of well and pumping equipment used in column "Cost of well."
c Flows.
d Pumps.
e Small.

Wells in Indio special quadrangle (Map, Pl. XII)—Continued.

No.	Owner.	Location.			Year completed.	Well.		Depth.	Distance to water.	Temperature of water.	Method of lift.	Quantity of water.	Cost.
		Township.	Range.	Section.		Class.	Diameter.						
		S.	*E.*					*Feet.*	*Feet.*	*°F.*		*Miner's in.*	
115	Silas Trickey	7	9	20	1901 ?	H.	3½ inches	500+		76	Artesian	26	
116	do	7	9	20	1901	H.	4 inches	500+			do	26	
117	E. A. Francis	7	9	8	1903	H.	do	550		76	do	31	$400
118	do	7	9	8	1902	H.	2 inches	563		77	do	3	350
119	L. A. Teagle	7	8	12	1902	H.	4 inches	464		74	do	*a* 35	
120	do	7	8	12	1903	H.	4½ inches	434			do	*a* 60	
121	H. J. Sternberg	7	8	2	1901	H.	3 inches				do		
122	do	7	8	2	1903	H.	4 inches	496		74	do		
123	do	7	8	2	1903	H.	do	495		74	do		
124	do	7	8	2	1905	H.	4½ inches	499		74	do	47	
125	C. D. Miller	7	8	2	1905	H.	do	477		74	do	26	
126	D. F. Baxter	7	8	2	1902	H.	do	550		74	do		
127	F. A. Leap	6	8	35	1901	H.	4 inches	585		74	do	13	565
128	do	6	8	35	1903	H.	do	513			do	23	500
129	R. B. Thayer	6	8	35	1902	H.	do	497		74	do	30	
130	do	6	8	35	1902	H.	do	495		74	do	26	
131	do	6	8	35	1905	H.	4½ inches	504		74	do	*a* 56	
132	do	6	8	35	1904	H.	do	514			do	26	
133	E. N. Stanley	6	8	35	1904	H.	do	515		75	do	33	
134	H. W. Cottle	6	8	35	1901	H.	2½ inches	560			do		
135	do	6	8	35	1905	H.	4½ inches	524			do	*a* 20	525
136	do	6	8	22	1903	H.	3 inches	490			do		
137	Toro Indian Reserve	7	8	26	1902	H.	4½ inches			79	do	*a* 35	
138	do	7	8	26	1902	H.	4 inches			79	do	*a* 25	
139	do	7	8	26	1902	H.	4½ inches				do	*a* 20	
140	Mr. Selig	7	8	34	1902 ?	H.	4 inches	780		90	do		
141	Southern Pacific R. R. Co	6	8	5	1888	B.	7 inches; inside, 10 inches.	812	4		Not raised		
142	Rector Bros	6	8	5	1904	H.	4½ inches	549		73	Gas, artesian	*b* 15	}
143	do	6	8	5	1902	H.	4 inches	638			do	*a b* 9	}
144	Town of Coachella	6	8	5	1899 ?	H.	do	548		73	Artesian	*a* 4	
145	R. D. Smith	6	8	6	1899	H.	2 inches	557		73	Hand, artesian	2	
146	do	6	8	6	1902	H.	4 inches	540			Gas, artesian	{ *b* 7 *c* 45 }	} *d* 2,550
147	do	6	8	6	1902	H.	do	542			do		

148	....do	6	8	6	1902	H.	...do	557			....do	b 4	
149	Seth J. Hardison	6	8	7		H.	3⅝ in. (2)	500 ?			Artesian	7	
150	Ed Goth	6	8	6	1901	H.	4½ in. (2)	535				a 50	d 2,000
150a	....do	6	8	6	1901	H.	3 inches	131	13		Gas, artesian		
151	Geo. C. Huntington	6	8	6	1903	H.	4 inches	586		70	Artesian, gas	a 18	
152	A. Golch	6	8	6	1904	H.	4 inches (2)	500+					
						B.	8 inches (2)	115	9		Artesian, gas	b 8 e 40	
153	....do	6	8	6	1902	H.	4½ inches	500			....do		
					1905	B.	8 inches	140			Gas	20	
154	....do	6	8	6		B.	10 inches	590			Artesian, gas	b 1	
						B.	8 inches	115	11		Gas		
						B.	10 inches	150	11		....do		
155	F. R. Strong	6	8	6	1902	H.	2 inches (2)	540 ?			Compr. air, artesian	b 10	d 3,800
						H.	4 inches (3)					c 140	
156	....do	6	8	6	1904	B.	8 inches (4)	135	20		Gas	40	d 1,800
157	Coachella Land and Water Co	5	8	25	1902	B.		550			Artesian		
						B.		250	30		Not raised		
158	C. C. Robertson	5	8	31	1901	H.	2 inches	600			Artesian	3	
159	....do	5	8	31	1902	H.	4 inches	550			Artesian, gas		
					1904	B.	6 inches	197	16		Gas	a 40	d 2,000
					1904	B.	8 inches	85	16		....do		
160	Mr. Teagle	5	8	31		H.	4½ inches	627			Artesian, gas		
						B.	...do	298	22		Gas	59	d 2,200
						B.	5⅝ inches	216	22		....do		
161	M. J. Murray	5	8	31		H.	8 inches (2) 4½ inches	545			Gas, artesian	40	d 1,750
					1901	H.	4 inches	580		72?	....do		
162	F. E. Halloway	5	8	31	1904	H.	4½ inches	540		72?	....do	a 28	d 2,300
					1904	B.	7⅝ inches	116	16	72?	Gas		
163	Rector Bros	6	8	5	1901	H.	3½ inches	556		73?	Artesian	(f)	
164	Coachella Bank	6	8	5		H.	...do	550		73	....do		
165	Coachella Land and Water Co	6	8	5		H.	4½ inches	553		73	....do		
166	....do	6	8	5		H.	...do	540		73	....do	16	500
167	....do	6	8	5		H.	4 inches	548		73	....do		
168	Ruddock & Trench	6	8	5	1900	H.	4½ inches	558		73	Artesian, gas	a 30	1,150
					1901	H.	...do	547		73	....do		
169	Rector Bros	6	8	8		H.	...do	545		73	Artesian	a 40	
						H.	...do. (2)	563		73	....do		
170	H. Woods	6	8	8		H.	4 inches (2)	500?		73	....do	5	
171	A. W. Haight	6	8	8		H.	3 inches			73	....do	5	
172	Coachella Valley Refrigerating Co	6	8	5	1905	H.	4½ inches			73	....do		
173	C. E. Mawby	6	8	5	1902	H.	4 inches	541		73	....do	4	
174	....do	6	8	5		H.	4½ inches	500?	15		Not raised		
175	C. Banta	6	8	8	1904	H.	...do	528			Artesian, gas	a 40	
						B.	5⅝ inches	160	12		Gas		
176	I. H. Fay	6	8	8	1902	H.	4⅝ inches (2)	510		73	Artesian, gas	20	d 1,650
177	C. O. Carlson	6	8	8	1902	H.	4 inches (2)	510		73	Artesian	19	1,000
178	....do	6	8	8		H.	4 inches	542			....do	9	

a Estimated, or owner's statement used in column "Quantity of water."
b Flows.
c 3 pumps.
d Cost of well and pumping equipment used in column "Cost of well."
e Pumps.
f Small.

Wells in Indio special quadrangle (Map, Pl. XII)—Continued.

No.	Owner.	Location.			Year completed.	Well.		Depth.	Distance to water.	Temperature of water.	Method of lift.	Quantity of water.	Cost.
		Township.	Range.	Section.		Class.	Diameter.						
		S.	*E.*					*Feet.*	*Feet.*	*°F.*		*Miner's in.*	
179	C. O. Carlson	6	8	8		H.	4 inches	527			Artesian	12	
180	Hummel Bros	6	8	8	1904	H.	(2 wells)	500?			do	*a* 15	
181	G. M. Beach	6	8	8	1903	H.	4½ inches	500			do	23	
					1905	H.	do	495			do	26	
182	W. I. Hobbs	6	8	8	1904	H.	4 inches	500			do	21	$500
183	do	6	8	8	1902	H.	4½ inches	500			do	*a* 8	
184	Seth Hardison	6	8	7		H.	4½ inches (2)				do		
185	do	6	8	7		H.	4½ inches				do		
186	Frank R. Strong	6	8	7		H.	4⅝ inches				do	16	
187	A. J. Hoskin & Son	6	8	7	1904	H.	4½ inches	508			Artesian, gas	*a* 40	*b* 1,712
						B.	5⅝ inches	120	8		Gas		
188	N. C. Hanson	6	8	8	1903	H.	4 inches (2)	522			Artesian	*a* 12	1,500
					1900	H.	2 inches	540			do		
189	Mrs. N. C. Hanson	6	8	8	1904	H.	4½ inches	522			do		525
190	J. P. Baker	6	8	8	1904	H.	do	550			do	12	550
191	Mr. White	6	8	9	1904	H.	do	540			do	*a* 27	540
192	Coachella Land and Water Co	6	8	9	1902	H.		543			do		
193	Dillman & Baldwin	6	8	7		B.	8 inches				do		
						H.	2⅝ inches				Artesian and gas		
						B.	7 inches				Gas		
194	do	6	8	7		H.	4½ inches	535			Artesian	5	535
195	Hugh Montgomery	6	8	7		H.	3½ inches	540			do	*a* 3	600
196	S. C. Grindley	6	8	7	1902	H.	(3 wells)	500			do	25	
						B.		200			Gas		
197	W. J. McMillan	6	7	12	1900	B.	7 inches	200	18	72	do		
					1904	H.	3 inches	500		72	Artesian, gas		
198	C. R. Cawthon	6	7	12		B.	5⅝ inches	86			Artesian		
						B.	8 inches	110			do		
						H.	3½ inches	500?			do	4	
						H.	4 inches	500?			do	4	
199	do	6	7	12	1902	H.	do	500		72	Artesian, gas	*a* 25	
					1904	B.	4½ inches	177	20		Gas		
200	Mr. Bauer	6	7	12		H.	4 inches			72	Artesian	9	
201	J. Holliday	6	7	12		H.	do	500			Artesian, gas	*c* 2	
202	Mr. Bauer	6	7	22		B.			30		Gas		
203	F. Holley	6	7	16	1905	B.	8 inches	177	42		do	*a* 40	*b* 1,426

204	Mrs. Kearny	6	7	16	1905	B.	...do	215	43	....	Not raised	....	....
205	E. Holley	6	7	8	1903	B.	7 inches	124	40	....	...do	....	....
206	Taitt & Hall	6	7	16	1904	B.	8 inches	123	48	....	Gas	....	....
207	Marshall & Green	6	7	6	1902	B.	7 inches (2)	100	45	....	...do	a 60	....
208	A. P. Green	6	7	6	....	B.	7 inches	190	45	....	Not raised	....	....
210	J. R. Thurmond	6	7	34	1903	H.	4 inches	....	....	74	Artesian	(d)	....
211	Mr. Bauer	6	7	26	1903	H.	3 inches	300?	....	74	...do	(a)	....
212	Mrs. O'Flanagan	6	7	26	....	H.	4 inches	....	....	....	...do	(d)	....
213	Mr. Cohagen	....	....	....	....	H.	...do	....	....	....	...do	1	....
215	J. R. Thurmond	6	7	26	1901 1903	H. H.	...do 3 inches	329 320	....	74 74	...do ...do	13 10	....
216	J. B. Alvord	6	7	35	....	B.	10 inches	....	....	74	...do	8	....
217	...do	6	7	35	....	H.	4 inches	....	....	....	...do	7	....
218	...do	6	7	35	....	B.	8 inches	....	....	74	...do	(d)	....
219	J. S. Glenn	6	7	25	1903	H.	4½ inches	385	....	74	...do	a 9	....
220	...do	6	7	25	1903	H.	...do	337	....	....	...do	3	....
221	O. C. Eberhardt	6	7	36	1901	H.	4 inches	340	....	74	...do	4	....
222	...do	6	7	36	1900	H.	2½ inches	340	....	74	...do	7	....
223	...do	6	7	36	1901	H.	3½ inches	340	....	74	...do	11	....
224	...do	6	7	36	1901	H.	4 inches	340	....	74	...do	14	....
225	A. T. Mann	6	7	36	1905	H.	4½ inches	327	....	74	...do	....	327
226	J. Ainsley	6	7	36	1901	H.	3 inches	340	....	74	...do	6	....
227	G. L. Bugbee	7	7	1	1905	H.	4½ inches	370	....	74	...do	26	375
228	Dozier Lewis	7	8	6	1902	H.	4 inches (2)	340	....	74	...do	a 30	....
229	G. L. Bugbee	7	7	1	1902	H.	5⅝ in. (2)	385	....	74	...do	15	....
230	J. A. Barton	7	7	1	1904 1903	H. H.	4½ inches 4 inches	372 282	....	....	...do ...do	17	625
231	Toro Indian Reserve	7	7	2	....	H.	4½ in. (2)	....	....	75	...do	....	....
232	...do	7	7	2	....	H.	...do	....	....	74	...do	....	....
233	...do	7	7	2	....	H.	...do	....	....	75	...do	....	....
234	...do	7	7	2	....	H.	4½ inches	....	....	76	...do	....	....
235	Seth Hardison	6	8	18	....	H.	4½ in. (2)	....	....	73	...do	a 14	....
237	Fred O. Todd	6	8	32	1901 1902	H. H.	4½ inches 3¾ inches	397 400	....	73 73	...do ...do	15 21	....
238	...do	6	8	32	1903 1904	H. H.	4¼ inches 4½ inches	540 484	....	74 74	...do ...do	17 32	....
239	W. A. Snyder	6	8	32	1903	H.	4 inches	456	....	....	...do	....	....
240	F. H. Hunt	6	8	32	1901	H.	3½ inches	336	....	....	...do	a 1	....
241	W. R. Prouty	6	8	32	1903	H.	4½ inches	448	....	74	...do	a 23	....
242	...do	6	8	32	1901	H.	4 inches	438	....	74	...do	a 6	....
243	Mr. Vogt	6	8	32	....	H.	...do	....	....	74	...do	15	....
244	Stanley & Payne	7	8	4	....	H.	4½ inches	474	....	74	...do	a 7	....
245	Glenn Bros.	7	8	4	....	H.	3¾ inches	....	....	74	...do	....	....
246	...do	7	8	4	....	H.	6 inches	....	....	73	...do	a 8	....
247	Mrs. T. F. Thompson	7	8	4	1904	H.	4½ inches	440	....	74	...do	a 23	....
248	Thermal School District	6	8	22	1903	H.	4½ inches	498	....	74	...do	a 8	....
249	A. P. Green	6	8	22	1900	H.	4 inches	375	....	74	...do	14	....
250	Thermal Land Co.	6	8	22	1902	H.	5⅝ inches	520	....	74	...do	a 25	....
251	...do	6	8	22	1902	H.	...do	520	....	74	...do	a 10	....

[a] Estimated, or owner's statement used in column "Quantity of water."
[b] Cost of well and pumping equipment used in column "Cost of well."
[c] Flows.
[d] Small.

Wells in Indio special quadrangle (*Map, Pl. XII*)—Continued.

No.	Owner.	Location.			Year completed.	Well.		Depth.	Distance to water.	Temperature of water.	Method of lift.	Quantity of water.	Cost.
		Township.	Range.	Section.		Class.	Diameter.						
		S.	*E.*					*Feet.*	*Feet.*	°*F.*		*Miner's in.*	
252	Mr. Martin	6	8	22		H.	4½ inches	520		74	Artesian	21	
253	J. L. F. McLain	6	8	26	1901	H.	4 inches	572		74	do	[a]16	
254	do	6	8	26	1904	H.	4½ inches	510		74	do	[a]19	$570
255	Martin & Moore	6	8	26	1902	H.	3½ inches	500		74	do	11	
256	do	6	8	26	1900	H.	4 inches	511		74	do	9	
257	do	6	8	26	1900	H.	do	517			do	[a]16	
258	Magaw Bros	6	8	35	1904	H.	4½ inches	509		74	do	26	
259	J. A. Potter	6	8	35	1904	H.	4 inches	500		74	do	19	
260	Mr. Hutchings	6	8	35	1904	H.	4½ inches			74	do	38	
261	G. L. Keith	6	8	22	1905	H.	4 inches	577		74	do	20	
262	Toro Indian Reserve	5	8	32		Dug.	4 by 4 feet.	18	16		Hand		
263	do	5	8	32		H.	4½ inches	500			Artesian		
264	Rector Bros	6	8	4	1901	H.	do	542		75	do	12	
265	Mr. West	6	8	4		H.	5⅝ inches	500?		75	do	[a]4	
266	do	6	8	4		H.	4 inches	500?		75	do	8	
267	Ruddock & Trench	6	8	4		H.	do	500?		75	do		
268	Rector Bros	6	8	4	1902	H.	do	500?		74	do	16	
269	do	6	8	5	1904	H.	do	574		74	dc	12	
270	Thermal Land Co	6	8	10	1903	H.	4½ inches	526		75	do	[a]8	
271	do	6	8	10		H.	do	532		75	do	[a]10	
272	do	6	8	10		H.	do	517		75	do	[a]8	
273	B. F. Boome	7	8	34	1902	H.	4 inches	200	0		Not raised		
274	do	7	8	34	1901	B.	8 inches	220	30	91	Gas	35	[b]1,500
275	do	7	8	34	1901	H.	4 inches	250	25	91	do		
276	Mr. Yhost	8	8	14		H.	3 inches	300		92	Artesian	3	
277	Peters, Evans & Gage	8	8	24	1902	B.	10 inches	315		94	do	35	
278	do	8	8	24	1902	B.	do	315		90	do	66	
279	do	8	8	24		H.	4 inches			88	do	8	
280	F. S. Everett	5	7	14	1899	B.	7 inches	170	16		Wind		[b]350
281	do	5	7	14	1903	B.	7 inches (2)	175	16		Gas	25	1,150
282	Southern Pacific R. R. Co	8	9	2		H.	2 inches	502			Artesian		
283	do	8	9	2		H.	do	708			do		
284	do	8	9	2		H.	do	555			do		
285	do	8	9	2		H.	do	589			do		
286	do	7	9	17		Dr.	(2 wells)	480			do		
287	Peters, Evans & Gage	8	8	24	1902	B.	10 inches	601	5		Not raised		

288	Mr. Yhost	8	8	14	1905	H.	8 inches				Artesian	12	
289	J. P. Kiler	7	9	8	1906	H.	4½ inches	582			Gas, artesian		3,000
290	C. R. Harris	7	8	12	1906	H.	do	432			Artesian	16	432
291	do	7	8	12	1904?	H.	4 inches	464		70	do		510
292	C. L. Edmunds	7	8	2	1906	H.	4½ inches	413			do	22	375
293	do	7	8	2	1906	H.	do	417			do	24	375
294	D. K. Baxter	7	8	2	1906	H.	do				do	33	
295	J. P. Read	7	8	2	1905?	H.	do	497			do	a25	
296	J. S. Leach	6	8	35	1906	H.	do	517			do	13	
297	A. W. McGill	6	8	26		H.	do	530			do	15	540
298	Martin & Moore	6	8	26		H.	do				do	3	
299	J. H. Bell	6	8	26	1905	H.	do	503			do	a10	500
300	do	6	8	26	1906	H.	do	513?			do	a10	515
301	C. B. Bisbee	6	8	26	1906	H.	do	590			do	5	
302	Butler Bros	6	8	23		H.	do	499			do	3	
303	Mrs. Brook	6	8	23	1905	H.	do	495			Gas, artesian	a c5 d 20	1,700
304	Adams & Butman	6	8	22	1907	H.	do	575			Artesian	18	
305	do	6	8	22	1900?	H.	do 3½ inches	497			do	a15	
306	Oakley Wood	6	8	34	1907	H.	4½ inches	436			do	a40	
307	Payne Bros	6	8	17	1905	H.	do	522			do	3	
308	Holland Bros	6	8	33	1907	H.	do	493			do	34	
309	do	6	8	33	1907	H.	do	496			do	a20	
310	J. H. Thurston	5	8	31	1905	B.	6 inches (2)	240	15		Gas	a55–60	
311	D. C. Huntington	5	8	31	1905	B.	6 inches	160	9		do	a30	
312	S. Starett	6	8	6	1906	H.	4 inches	1,052			Artesian	9	
313	C. W. Hyde	5	8	31	1906	B.	8 inches	221	16		Gas	30	1,025
314	W. A. Caldwell C. B. Estle Geo. Gillons	5	7	25	1906	B.	do	100	22		do	65	
315	Mr. Baeyertz							150					
316	J. A. Semple	5	7	24	1907	H.	4½ inches	156	20		Gas		435
317	G. W. Durbrow	5	7	23	1906	H.	5⅝ inches 3 inches	1,000+			Artesian	2	
318	C. E. Cooper	5	7	14	1900?	B.?	6 inches(?)	80	15½		Not used		
319	Fred N. Johnson	5	7	22	1907	B.	7⅝ inches	119	16?		Wind		

a Estimated, or owner's statement used in column "Quantity of water."
b Cost of well and pumping equipment used in column "Cost of well."
c Flows.
d Pumps.

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