THE DELTA COUNTRY OF THE COLORADO

By

Fred B. Kniffen

THESIS

Submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Geography

in the

GRADUATE DIVISION

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THESIS

The Delta Country of the Colorado

The Colorado Delta occupies a portion of the Gulf Trough, a great structural depression. The whole area is characterized by a complex tectonic history. It is marked by a number of semi-parallel fault lines which have a general trend south by east, which direction marks the strike of several desert ranges.

The true delta cone is limited in extent; contiguous to it are extensions of the alluvial surface possessing profiles characteristic of deposition under lacustrine and estuarine conditions. Two of these marginal areas, Salton Sink and Pattie Basin, lie partially below sea level, representing former extensions of the gulf cut off by alluvial barriers, induced by uplift.

Delta building is rapid and independent of local climatic conditions, so that climatic forces find little direct expression in the delta landscape. Mechanical weathering, erosion, and denudation have sculptured the desert ranges into forms varying with lithologic composition and joint pattern. The granitic ranges are intricately and regularly carved; the extrusive, volcanic ranges possess a pattern less intricate and regular.

Marginal to the mountains are found extensive accumulations of weathered material. The larger depositional forms are established as relict by the fact that they are not aggrading, but rather are unfailingly dissected. In part they possess a terrace form; the terraces are of the same age, and in fact an extension of the "ancient beach line" which borders Salton Sink.

The historical period of the delta may be divided into three stages of human activity. In the primitive stage a comparatively dense Indian population was supported through the practice of agriculture and gathering of wild foods.

The exploratory stage found the Spaniards unsuccessful in their attempts to establish a permanent footing in the area. With the rush to California in 1849 the importance of the corridor through the delta was established.

In the stage of exploitation stock raising has been succeeded by agriculture. South of the boundary this has taken the form of large-scale cotton ranches, with one organization owning practically all of the arable land. There have arisen special settlement forms out of the Mexican *colonias,* Chinese farmers, and the customs barrier, and utilization is constantly concerned with problems of alkali deposits, floods, and silt disposal.

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PREFACE

This study is based upon field-work carried out in the Colorado Delta region during the years 1927 and 1928, together with an examination of the literature bearing on the area. A preliminary acquaintance with the problem was gained during the months of May and June, 1927, when the writer was engaged in research in another field, in the Imperial Valley. The months of November and December, 1927, and a period from March through June, 1928, were spent in the field.

The paper deals with the genesis of the natural and cultural landscapes of the Colorado Delta and contiguous areas. The major emphasis has been placed on that portion of the delta lying south of the international boundary, in Mexico. The area north of the boundary was eliminated because of the prior claim of another investigator. It is considered only by way of contrast, or as clarifying and supplementing the landscape south of the boundary.

Of the ten chapters, seven deal with the natural landscape. This is perfectly legitimate in view of the fact that the natural landscape is basic, that it is relatively more complex and less ephemeral than the cultural landscape.

The difficulties in doing field-work in the area are many. Roads are poor or non-existent, so that many hours and even days were spent in extricating the automobile from

sand and bog. Even so, the use of a car provided a saving of time, for the scarcity of water holes and the distance between them, over much of the area, eliminated the profitable use of riding animals. For the same reasons, walking was out of the question, excepting for shorter distances near a base camp. Other difficulties for travel were introduced by the overflow and by the accompanying swarms of mosquitoes.

Because of these difficulties it was impossible to visit some sections of the delta, notably the region between the old channel of the Colorado and the Hardy, and certain areas along the western side of the Sierra Cucopas.

So many acknowledgments of assistance and hospitality are due that to mention names would be a slight to others equally worthy. To those who understand it is sufficient to say that here in the delta are maintained the traditions of the old frontier, which unquestioningly give to the stranger whatever he may need.

THE DELTA COUNTRY OF THE COLORADO

By

Fred. B. Kniffen

CHAPTER 1 -- INTRODUCTION

The delta of the Colorado River of the West lies within the area included between the parallels of 31° and 33° 31' N., and between the meridians 114° 30' and 116° W. (fig. 1). It includes that portion of this area in which alluvium derived from the waters of the Colorado forms the dominant surface soil constituent.

Climatically this area is a desert, various portions of it differently named with local usage. It is a part of the great desert area continued in the east as the Sonora Desert and to the north as the Colorado Desert. The well-watered portion of the delta has never been a desert in the popular mind, and quite possibly this distinction is a legitimate one.

Physiographically it falls into the Basin Range Province, a region of isolated diastrophic blocks and intervening valleys, which extends northward to the Columbia Plateaus, and southward far into Mexico. This province is bounded sharply on the west by the Peninsular Range and on the east by the Colorado River and the physiographic pro-

vince for which Powell has suggested the name "Sierra Madre".[1]

The delta is included within the Lower Sonoran division of the Lower Austral life-zone. Even more strongly than with the classification as a desert does the delta disagree with this characterization. Both as to flora and fauna it stands in striking contrast to the truly desert area about it. It is the steaming jungle which breaks abruptly into the sparsely vegetated aridity which surrounds it.[2]

Description of the area --

The delta of the Colorado, as here interpreted, extends from Salton Sea on the north to Punta San Felipe on the south; from the Peninsular Range or its outliers on the west to Santa Clara Mesa on the east. The maximum length of the area is approximately 150 miles, its greatest width about 40 miles.

To the west lies the great crystalline mass of the Peninsular Range. South of the international boundary the eastern front of this range presents a remarkably regular scarp wall. In the area north of the border it forms a series of salients and reentrants which result in great

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[1]See Powell's section on the physiographic regions of the United States, p. 95, in The Physiography of the United States, New York. (1895)

[2]Merriam, C. Hart. Life Zones and Crop Zones of the United States, U. S. Dept. of Agric., Biological Survey, Bull. 10: p. 41. (1898)

step-like irregularities. The Santa Rosa Mountains form one of the salients; accompanying it are the corresponding reentrants: Palm Canyon and Borrego Valley.

To the east the mesa rises sharply above the delta and extends many miles in a great flat-lying plain before encountering the desert ranges. The plain, evidently of marine origin, is composed of recent sands and gravels. The latter frequently exhibit excellent developments of pedregales or desert pavements. Nowhere are there clear evidences of stream dissection or even of stream channels; only along the edge of the mesa where it stands at a height of from thirty to fifty feet above the delta alluvium is there a suggestion of erosion. Striking relief features of this generally smooth plain are the two areas of dunes; the one the Algodones Sand Hills, the other the sand hills lying about twenty-five miles east of the mesa edge in Sonora.

Within the area bounded by the Peninsular Range and the Santa Clara Mesa, and to some extent interrupting the continuity of the alluvial surface, are a number of desert ranges and isolated peaks. Occupying a central position with respect to the long axis of the delta, and closely paralleling the scarp front of the Peninsular Mountains, lies a continuous series of mountain structures to the whole of which the name Sierra de los Cucopas is commonly

applied. This system is separated from the Sierra Juarez, as the Peninsular Range is here called, by the width of the alluvium-filled basin of Laguna Salada. In major part the Cucopa system is composed of granite, but there are areas of extrusives and metamorphics. The two rock types stand in marked contrast in the forms which they reveal in weathering. Several of the constituent parts of this system in their steepness of slope to the east and more gentle slope to the west suggest a structural origin similar to that of the Sierra Juarez where the same slope pattern is repeated on a larger scale.

The great bare alluvial plain which extends south beyond the tip of the Cucopas to Punta San Felipe is bounded on the west by an irregular series of volcanoes and interbedded tuff and lava mountains to which the name Sierra de las Pintas is applied. These mountains are extremely irregular in form as well as in extent, are frequently made up of strikingly colored rocks, and are practically destitute of vegetation.

Between Las Pintas and Sierra Juarez lies another desert range, somewhat more distinctly a single system than the former, which is called Sierra de las Tinajas. Crystalline rocks are present in this area but they are subordinate in significance to a great mass of lavas and tuffs. A portion of the northernmost part of this range is a basalt capped

mesa, the basalt extending with interruptions to the wall of Sierra Juarez.

Another semi-isolated mountain range is Superstition Mountain, which lies on the western side of Imperial Valley. This has a core composed of crystalline rocks which are flanked by Tertiary sandstones interbedded with basalt and tuff. This dry, barren mountain has an extreme outlier in an exposure of sandstone found a few miles west of the town of Imperial. This forms one of the few rock exposures within the delta proper.

Most aptly termed by Sykes the "three corner stones of the delta" are the conspicuous, isolated masses of Cerro Prieto, Pilot Knob, and Punta San Felipe.[1] Pilot Knob stands at the contact of mesa and delta and marks the emergence of the Colorado from its restricted channel on to the broad alluvial plain that is its delta. The mountain is composed of granite intruded by later volcanics.

The extinct volcano, Cerro Prieto or Black Butte, stands conspicuously alone, several miles removed from the eastern flanks of the Cucopas. It also marks the contact of the mesa sands which lie between it and the mountains to the west with the river alluvium.

The rounded granitic dome of Punta San Felipe stands on the western shore of the Gulf of California and marks the

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[1]Sykes, Godfrey. The Delta and Estuary of the Colorado River, Geogr. Review, vol. 16: p. 235. (1926)

southern limit of surface exposures of river alluvium. South of it the beaches are sandy; north of it the alluvial plain widens rapidly as the head of the gulf narrows into the river mouth.

The general configuration and slopes of the delta show an adaptation to the unique conditions under which the structure was formed. Instead of a free open sea the river has debouched into a closely confined gulf. Accompanying this latter feature has been the resulting significant strong tidal action. It is generally true that in areas of strong tidal action great deltas do not form so that, as might be expected, the Colorado Delta exhibits some abnormal characteristics.

What may be termed the delta crest follows roughly a line from Pilot Knob to Cerro Prieto. Its western terminus is marked by the dry bed of Volcano Lake. South of the crest the slope is quite uniform to the gulf with a gradient of less than two feet to the mile. North of the crest the slope to Salton Sea is much greater (fig. 2).

Subordinate and secondary to the above are the slopes of the alluvium-surfaced Pattie Basin in which lies Laguna Salada. This basin is a true bolson in that it has no drainage outlet. To the north it is separated from the Salton area by a rocky ridge which connects the northern tip of the Cucopas-Centinela- with the Sierra Juarez. The channel of ingress for the silt-bearing waters has been

through the opening which lies between the southern point of the Cucopa system-Sierra Mayor- and the desert ranges to the south. The lowest point in this gap has an elevation of about ten feet above the sea. The lowest point in the basin, in the extreme northeastern corner, lies several feet below sea level. The lower margin lies along the eastern side of the basin; to the west there is a long slope up to the sands and gravels derived from the Sierra Juarez.

In very few instances is there any difficulty in delimiting sharply the contact of river alluvium with soils of other origin. In many places it is the easy distinction between fine silt and coarse sand or gravel. Throughout most of the area the lines of contact are relief forms. The term "mesa" as used in this area means flat-topped sand and gravel surfaces which lie marginal to the alluvial plain and present to it a steep-walled ascent of from thirty to fifty feet. Wherever the line of contact lies some distance from the mountains the mesa is clearly distinguishable. Where the river alluvium lies close to the mountains the contact is equally clear but of a somewhat different nature. The eastern face of the Cucopas is in large part bordered by an apron of colluvial material. There are in places notable fans, subordinate to the apron as a whole. This apron presents a by no means continuous front, as it has been somewhat

dissected since its formation. In some areas it resembles nothing so much as a series of parallel mine dumps: narrow, elongated, flat-topped, steep-sided, abruptly terminated. The sand and gravel between the "mine dumps" is of like origin; the river alluvium appears at the base of the "dump". It is a strikingly notable feature that the outer edge of the apron preserves a constant level throughout its extent along the mountains. There are no intersecting slopes as are so frequently found in areas having fan developments.

Naturally the drainage pattern of the area is dominated by the Colorado. There are represented in the area all the features of a stream having great seasonal fluctuation in volume of water carried: natural levees, annual overflows, and alternate scouring and deposition in channels. There are the features of delta areas: delta lakes, anastomosing and distributary channels. Where river current is combined with the tidal action of the sea there are the mud flats, ephemeral islands, and overflow channels which lead away from the main river channel.

Within recent times the area of the river's activity has been largely restricted to the region lying between the delta crest and the gulf. Occasional overflows have carried water into Salton Sink and Pattie Basin but these are mere incidents and the stream patterns developed in these areas are insignificant. The present deep channels of the New and Alamo were culturally induced.

No streams originate within the area. In fact, the mesa plains and large areas of the alluvial plains betray no signs of stream channels. Leading out of the canyons of Sierra Juarez there are dry stream courses which, under the most favorable circumstances, carry water to the edge of the alluvium; but the necessary conditions occur infrequently. To a lesser extent this also holds for the desert ranges. Within the Cucopas there is a well-developed drainage pattern: waterfalls, pools, deep abrasion forms -- all normally dry.

The natural vegetation of the area shows striking contrasts both as to type and as to luxuriance. The abundant water of the Colorado has served to effect a marked dissimilitude in flora as between delta and surrounding desert. In areas of regular overflow or near permanent channels the line of distinction between delta and desert flora approximates the boundary between river silt and mesa sands and gravels. In other areas, the factors of alkali deposits and irregular water supply rob this line of its significance.

That portion of the delta lying south of the crest is covered by a heavy growth of deciduous trees: cottonwood, black willow, mesquite, and sycamore. In the same general association appear the tules, rushes, and arrow-weed. The old permanent stream channels are marked by the cottonwoods which line their banks. The lower lying overflow land is covered with willow, the higher with arrow-weed. These latter

grow in great profusion and frequently form nearly impenetrable thickets. Mesquite is widely distributed and forms solid woodlands on the higher ground. About the sites of springs along the base of Santa Clara Mesa, in swampy sections of the lower delta, are found tules and rushes. These frequently occur in areas where other vegetation is lacking, so that their bright green color is refreshing in an otherwise drab landscape.

On the islands of the river mouth, on the alluvial plains of the lower river, about the brackish springs which border the mountains are patches of salt grass, frequently forming closed stands. About the margins of undrained depressions, the alkali lands, the halophytic saltbushes stand as the vegetational outliers.

The bed of Laguna Salada and the great alluvial plain stretching south from Sierra Mayor are without any cover of vegetation.

Most characteristic of the mesa is the creosote bush. Accompanying it is the ocotillo with garambuyo (Opuntia sp.) and cholla appearing on the little sand hills. In the sandy washes appear palo verde, desert willow, and the smoke tree. The evergreen, parasitic mistletoe appears in drooping clusters on the palo verde, palo fierro, and mesquite.

On the detrital slopes is found the palo fierro, with visnaga appearing from seemingly bare rock surfaces. On the

higher portions of the Sierra Cucopas, and against the base of the Juarez, the maguey is found -- though its restriction to these areas may be partly cultural. Deep in the canyons which lead from the Juarez, in at least one high valley of the Cucopas there grow a few fan palms, indigenous to the area and marking the sites of permanent water.

These are the material elements of which the milieu is composed, but the picture is bare and lifeless without an appreciation of those other elements impossible to grasp and dissect at one's leisure. To make the scene vivid it is necessary to feel the scorching heat of midsummer, to follow the ever retreating mirage, to see the sky smoky with the great dust whirls of the alluvial plain, to hear the cry of the waterfowl as the tide enters the river mouth, to see the sunset over the Juarez with the desert ranges as sharply distinct as a cameo.

The cultural scene is restricted to the area lying north of Cerro Prieto and east of the Cucopas. Here the irrigation canals and the cotton fields of Baja California are a part of, yet distinct from, the agricultural development to the north of the border in Imperial Valley. South of this region the natural landscape remains effectively untouched. Several unfenced cattle ranches occupy the area; the cattle harvest the native vegetation. The flood, which brings to the agricultural district the serious problem of levee building, is of concern to the cattlemen only as it provides feed for their stock.

CHAPTER 2 -- THE TECTONIC FRAME

The Peninsula of Lower California and the Gulf of California are important features of the zone of the mobile crust involved in the "World Ridge" which extends from Cape Horn to Cape Finisterre. The gulf has genetic affinity to the Persian Gulf and the Red Sea. Even more striking in its parallelism to the area under discussion is the position of the Italian Peninsula, separated by the Adriatic from the land mass to the east. The origin of such features is generally explained in terms of the depression of an elongated section of the earth's crust lying between parallel fault lines.[1] For these forms the term graben is to be preferred to the term rift which is also sometimes used.

The significance of tectonic forces in such areas is frequently made impressive by the contemporary activity of faulting. Added proof is given by the impossibility of accounting for these depressions by other processes which create relief. Stream erosion, glaciation, and tidal scour cannot be responsible. The choice is only between a faulted surface and a geosynclinal one. Lawson, in speaking of the area under discussion, said in 1908:

> "The Colorado Desert and its continuation in the Gulf of California are certainly diastrophic

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[1] e.g., Eduard Suess, Das Antlitz der Erde, A. Philippson, Das Mittelmeergebiet.

> depressions, and may with much plausibility be regarded as a great Rift valley of even greater magnitude than the now famous prototype first recognized by Suess. This great depression lies between the Peninsula of Lower California and the Mexican Plateau. All three of these features find their counterpart in southern Mexico. The Sierra Madre del Sur is the analogue of the peninsular ridge; it lies on the line of its prolongation, and is similarly constituted geologically. Inside of this range, and between it and the edge of the Mexican Plateau, is a pronounced valley system which is the analogue of the Gulf of California."[1]

Freudenberg is in agreement with Lawson's views. He considers the whole structure to be a tectonic feature of the first order, and compares it with the Sacramento-San Joaquin Valley of California.[2]

Whatever the gross structure of the feature may be cannot as yet be decided; in detail the whole area in recent geologic periods has been characterized by great changes in level. The most notable of recent episodes in its structural history seems to have been a very general and considerable uplift. The evidence is so plain and convincing so as to have attracted the attention of nearly all, if not of all, trained observers who have seen the area.

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[1]Report, Earthquake Investigation Comm., A. C. Lawson, Chairman: p. 52. (1908)

[2]Freudenberg, W. Geologie von Mexiko, Berlin, 1921: pp. 8-9.

Lawson postulates a post-Pliocene uplift of the California coastal area from San Francisco to San Diego of from 800 to 1,500 feet. He suggests the strong probability of a similar uplift in the area to the south, which he did not examine.[1]

Ellis[2] distinguished a considerably greater recency in the uplift of the coastal area to the south of San Diego. Wittich[3] probably erred in considering the characteristic "wool-sack" granite boulders of the Peninsular Range as evidence of recent uplift above the sea. However, he found numerous deposits of recent shells on the divide between the gulf and the Pacific, and he noted fossil dunes containing shells and standing 1,500 feet above the sea.

Cited last but probably the first to record his observations of recent uplift was the Jesuit, Clavijero.[4] In his history of Baja California are noted several proofs of the emergence of the land from the sea. Argillaceous soils containing shells were found at elevations of several hundred feet. The Jesuits at Loreto had, in a forty year period, noted a marked retreat seaward of the shore line. Along the

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[1] Lawson, A. C. The Post Pliocene Diastrophism of the Coast of Southern California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 1, no. 4: p. 157.

[2] Ellis, A. J. U. S. Geol. Surv., W. S. Paper 446: pp. 26-27. (1919)

[3] Wittich, Ernst. Ueber Meersschwankungenen an der Kueste von Kalifornien, Deut. Geol. Gesell., Zeitschr., Monatsb. vol. 64: pp. 505-512.

[4] Clavijero, Francisco Javier. Historia de la Antigua o California, translated from the Italian, Mexico, 1852, pp. 3-4.

west coast Clavijero found littoral sands on the mesas at considerable elevations above the sea. His inference was that the land mass of the peninsula had emerged from the sea and that ultimately many islands would be joined to the mainland through further elevation.

That the Salton Basin is a continuation of the structural trough of the Gulf of California is so evident as hardly to need mentioning. Suffice it to say that the deepest well drilled into the delta went down to a depth of 400 feet below sea level and revealed only river sands and gravels, while at Coachella a drill hole showed no bedrock 1,000 feet below the sea.

Though the Gulf-Salton trough does not continue as such to the north there is a northward continuation of a number of fault lines which may in part be responsible for its structure.[1] The San Andreas Rift has been traced without a break from the Coachella Valley to the San Francisco Peninsula. The San Jacinto fault has been tentatively extended by Beal to the mud volcanoes near Cerro Prieto, south of the international boundary.[2] Both according to local tradition and in some measure to official report, every major

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[1] The position of the major fault lines of California is shown on the maps accompanying the report of the Calif. Earthquake Invest. Comm., issued as a publication of the Carnegie Inst. of Washington. (1908)

[2] Beal, Carl H. The Earthquake in the Imperial Valley, California, June 22, 1915. Bull. Seis. Soc. Amer., vol. 5, no. 3: pp. 130-149.

earth movement occurring in California has had its counterpart in local quakes and in increased activity of the mud volcanoes.

Viewing broadly the general structure of Southern California and the northern section of Baja California, there appear to be two directions along which the major structures trend. One trends somewhat west of north, the other northwest and southeast. The first marks the strike of the Sierra Nevada of California, terminated by the Tehachapis on the south, and the Juarez-San Pedro Mártir system in Baja California. Between these two ranges is an area in which the north-south lines are intersected by those striking northwest-southeast. Together with a third set of east-west lines these are accountable for the striking and characteristic development of the series of structures previously described as spurs and reentrants, and applied to such features as the Santa Rosas and Borrego Valley.

As suggested above, the Juarez-San Pedro Mártir Range is in its structure -- and it may be added, in its lithologic character -- very similar to the Sierra Nevada and somewhat contrasted to the mountain systems lying between.[1] This range rises to much greater heights than do the ranges

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[1] This descriptive similarity between the Peninsular Range in Baja California and the Sierra Nevada of California is brought out in Emmons' and Merrill's Geological Sketch of Lower California, Geol. Soc. Amer., Bull., vol. 5: p. 491 ff. (1894)

immediately to the north, it possesses a continuous and regular east-facing scarp, and its summit is a plateau.

Within the delta the prevalence of tectonic activity is emphasized by the frequency and number of earth tremors. There occur shocks of major intensity, but more frequent are minor ones felt in closely restricted areas. Of the former class Beal mentions those of 1852, 1892, 1915[1], and that of 1927 should also be included. Of the latter class there are so many as to receive scant attention from the local inhabitants. A noteworthy feature of these minor shocks is that they may be felt at one point while a few miles away they are not detected.

If the tremors represent displacements in the bedrock, lying far below the surface, it is to be expected that the alluvial cover should hardly reveal a distinguishable rupture. Such is generally the case but on occasion there are surface breaks. One such, occurring perhaps forty years ago, was of sufficient magnitude to cause the diversion of the Colorado at a point near its junction with the Hardy. Another was traceable from Cerro Prieto along a line leading southeast through Santa Clara Slough, and its course was marked by mud eruptions.

Though no accurate record has been maintained, there is an impression prevalent among the engineers of the area that

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[1] Op. cit.: p. 138.

the frequency of the minor tremors is greatest at the time of the annual overflows, that is, in the summer months. At this time of year the added weight of the flood waters with their burden of silt is undoubtedly great, but it is hard to believe that this could be accountable for deep-seated movements. Possibly it is effective in causing superficial readjustments in the alluvium.

As representative of volcanic activity in the area there are a number of surface forms ranging in size from the extinct volcano of Cerro Prieto to active mud volcanoes, fumaroles, and hot springs. One group of mud volcanoes is found seven miles west of Niland, and in the same neighborhood are several obsidian buttes. The other group of active forms is found near Cerro Prieto (pl. 1a). Relict forms are to be found north of Cerro Prieto, along Santa Clara Slough, and near Pozo Cenizo at the northern tip of Sierra Tinajas (pl. 1b). Isolated hot springs, in part sulphuretted, are found along the edge of Santa Clara Mesa, south of Mesa Andrade.

The distribution of these forms is by no means haphazard, and taken in conjunction with other types of forms they would seem to lie along certain well defined lines of weakness. The association of increased activity of the mud volcanoes with major earthquakes is one now well established. This was noted by Major Heintzelman at the time of the earth-

quake of 1852 when clouds of steam rising from the volcanoes of Cerro Prieto were clearly observable at Fort Yuma, forty miles away.[1] When particularly active they give off a roaring and booming noise which is said to resemble the sound of heavy guns.

The major relief features of the area owe their position as such to the agencies of diastrophism and volcanism. These endogenous forces have created the framework about which the secondary, exogenous forces produce the complex of forms which constitutes the natural landscape. As the two sets of forces work simultaneously there are few forms which are entirely the work of endogenous forces, unmodified by the forces of weathering. Only some of the minor volcanic forms prove the exception. However, the fact that relief exists proves that the relief-creating forces have at some time acted at a rate faster than that of the relief-destroying ones. The slope relations within the attacked form and between it and the depositional form reveal the history of the relative dominance of one or the other set of forces. The whole interrelationship makes a descriptive classification of "tectonic" or "volcanic" forms quite difficult, so it is here chosen to make a classification of "relief" forms, particularly forms of positive relief having their origin in diastrophism or volcanism. This classification is descriptive,

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[1] Reported to Professor Blake and cited by him in the Pacific Railway Report, vol. 5: p. 115. (1856)

is based largely on the magnitude of the forms, and so disregards the sequence of events which gave them their relief.

Diastrophic and Volcanic Relief Forms

1st Order: In this class, standing alone is the great depression which is the trough of the Gulf and Salton Basin. This also includes the depression of Pattie Basin (Laguna Salada).

2nd Order: Sierra Juarez-San Pedro Martir, particularly the east-facing scarp. Granitic face varying in slope from thirty to ninety degrees from the horizontal. Sufficiently steep to prevent the accumulation of residual or detrital material, therefore largely vegetationless.

3rd Order: Sierra Cucopas. Dominantly a granitic mass, yet containing metamorphics and volcanics. Eastern face somewhat steeper than the western. Slopes varying from perhaps twenty to ninety degrees. In places sufficiently gentle to permit the accumulation of detritus.

Sierra Las Pintas. Very irregular in form. Volcanic in origin, made up of tuffs and lavas, in part bedded. Slopes from zero to ninety degrees.

Sierra Las Tinajas. More regular in form than S. Pintas. Crystalline rocks present but strongly dominated by bedded lavas and tuffs. The northern portion a basalt capped mesa. Slopes of all degrees.

4th Order: Volcanoes such as Cerro Prieto and the isolated forms bordering the Serra de las Pintas. Essentially flows, yet containing some cinder and ash. Slopes not exceeding forty-five degrees, and many sufficiently low to permit of accumulations of detrital material.

5th Order: The minor volcanic forms such as the mud volcanoes, both active and extinct. The mud contains siliceous elements, the relict forms are resistant to the forces of weathering, and tend to retain the steep slopes of the active forms.

In addition to the above classified forms, there are others which, as relief features, may be tectonic in origin. Notable among these are certain areas of high ground in the lower delta which have long been free from inundation by the annual floods. Then there are forms which owe their being indirectly to tectonic activity. Mesa Andrade is quite certainly a former portion of Mesa Santa Clara, which has been cut off by erosion along a fault line. The course of New River follows a fault line in part. The river terraces and the ancient beach line represent indirect tectonic forms.

With this consideration of the tectonic and associated volcanic forms, by fixing them on a map and noting their relative positions, it is possible to detect what appear to be certain well established lines of weakness. If topography is a criterion, one of these lines passes along the eastern front of the Sierra Juarez. Another is certainly distinct in places along the eastern front of Sierra Mayor (pl. 1c). That this extends continuously along the whole front of the Mayor-Cucopa system is by no means so certain. A third, better established line is found in the southward extension of the San Jacinto fault. As previously cited, Beal tentatively extended this to the mud volcanoes near Cerro Prieto. It is proposed to extend this in the same general direction passing it to the east of Mesa Andrade, along the course of Santa Clara Slough, along the base of Santa Clara Mesa. South from here its course is rather uncertain. It

may continue to the southward along the coast or it may pass inland and account for the sudden appearance of the Tertiary sandstone mass which rises above the Quaternary gravel plain of Mesa Santa Clara.

A careful working out of the complex geologic history of this area is beyond the scope and intent of this report; it is not necessary to the treatment of the geomorphology. A brief résumé of the principal geologic events, particularly with regard to their magnitude and sequence, will provide the necessary orientation before proceeding to a consideration of the exogenous forces.

The following is a simple geologic classification of the rocks and unconsolidated materials which form the principal surface exposures in the area. An understanding of their geologic time relations and an examination of the topographic positions which they occupy with respect to each other serves as a key to the working out of the earlier tectonic history of the region:

1. Pre-Tertiary granites. The Peninsular Range and the granitic desert ranges are composed principally of igneous rocks belonging to this group.

2. Tertiary sediments. Both consolidated and unconsolidated sands, clays and gravels. Both marine and terrestrial. Generally highly disturbed and in places slightly metamorphosed. They underlie the Quaternary and Recent deposits which form the surface of Salton Sink. They are found in surface exposures along the base of the Peninsular Mountains, in places along the Cucopas, near Cerro Prieto, and east of the head of the gulf. Near Salton Sea they form a part of the "mesas" and exhibit beveling by wave action.

3. Late Tertiary extrusives. Basalts, tuffs, cinder. Bedded flows and volcanoes. Cerro Prieto and Sierra de las Pintas.

4. Quaternary sands and gravels. The principal constituent material of the mesas. Largely undisturbed and exhibiting marine planation.

5. Recent alluvium. Largely the material derived from the Colorado and forming the surface of the delta.

By middle Tertiary the gulf trough seems to have been fairly well established as a structural feature. The sea stood several hundred feet higher than it does at present and extended far beyond the present head of the gulf. The Peninsular Mountains and probably the Cucopas were islands. From the mountains there was derived the material for heavy marine deposits. Conditions were favorable to the existence of abundant marine life forms.

With late Tertiary there was a decided uplift. Quite possibly this was accompanied by a depression of the gulf trough. At least there was enough differential movement so that the earlier Tertiary sediments along the base of the Peninsular Mountains were highly distorted; some of them were faulted out. During this same period there was very considerable igneous activity, and it probably continued over into early Quaternary. This activity resulted in the formation of the Sierra Pintas and such isolated forms as Cerro Prieto.

By middle Quaternary the sea had advanced again and stood at an elevation of perhaps a hundred feet above present

sea level. It reached to the base of the mountains and it lay over the mesas; to some extent it beveled off the folded and faulted Tertiary deposits.

During the Recent period there has been a general and fairly evenly distributed uplift -- as demonstrated by the old beach line cut into Quaternary and Recent sediments, and by the fact that the Quaternary sediments are little disturbed. The most significant depositional activity has been the continuation of valley filling initiated in the Tertiary, principally through the agency of the Colorado River and its alluvial burden (fig. 3).

These are the raw materials with which the exogenous forces have had to deal. The diastrophic and volcanic forces have created a framework; the river has contributed its alluvium. Out of all this the unique ensemble of exogenous forces characteristic of this particular area has created a set of surface forms.

CHAPTER 3 -- RIVER AND SEA

The River

The Colorado River of the West is the name generally applied to the stream formed by the confluence of the Green and Grand rivers in southeastern Utah. In a geographic sense the Green and Colorado are one continuous river.

The water-shed of the Colorado system includes parts of five western states and comprises a total drainage area of some 265,000 square miles. Most pertinent to a study of the delta region is the fact that climatic conditions within the area of the water-shed vary between wide limits. The course of the river below the Grand Canyon passes through a region of increasing aridity with winter temperatures above freezing. The area of greatest precipitation lies about the headwaters of the Grand in western Colorado. Even here the precipitation does not exceed thirty inches but the effective runoff is great, as this is an area of cold winters, of heavy winter snows, and even in summer the initial loss due to evaporation is not great. Here, as on the headwaters of the Green, there occur small glaciers, snowbanks which do not melt until late summer, little lakes, and springs.

It is these climatic conditions, modified by the nature of the relief, soil cover, and vegetation cover that determine the regimen of the Colorado near its mouth.

Of those tributaries above and including the San Juan it may be said that they are dependable and predictable in the time and volume of water which they will contribute. In the spring comes the flood as the result of the melting snow; throughout the year these streams furnish the bulk of the water.

The lower tributaries are unreliable; during much of the year they contribute nothing; at unexpected times they contribute sudden "flash" floods of large volume whose effectiveness as transporting and erosive agents is very considerable. Of these latter streams may be mentioned the Gila, Bill Williams, Virgin, and Little Colorado. In the anomalous relation which exists between its lower course and the climatic region in which it lies, the Colorado presents a phenomenon similar to that of the Nile. The latter stream also rises in a humid area and has its mouth in an area in which the stream's loss in volume is greater than its increment. That such a relationship should produce unique results in the landscape has already been suggested and will be further developed in a later chapter.

An examination of the twenty-four year average discharge of the Colorado as recorded at the Yuma gauging station reveals a number of points. From September 30th to March 30th the discharge remains fairly constant with an average volume around 13,000 second feet. The average maximum occurs during the last week in June and reaches approximately 81,000

second feet.[1] Of course, this represents "average" conditions. It does not show the occasional "flash" floods such as that of February, 1920, when the Gila brought the Yuma discharge up to 164,000 second feet for a day. Nor does it show the fact that very frequently the annual summer flood occurs not in one peak but perhaps in two, three, or four, which may come as they did in 1926, at monthly intervals, the first on the 12th of April, the fourth on the 19th of July. Still it remains true that the river floods its banks in the summer months and is low during the winter months. As figures[2] for the absolute maximum and minimum discharge there is for the former 186,000 second feet for June 28, 1921, and 1,200 second feet for September 11, 1924 (fig. 4). There is at Yuma a mean annual run-off of 17,000,000 acre-feet.[3] Translated into comparative terms this means one-fourth of the run-off of the Nile at Cairo, and in general this relationship of one-fourth to one-third is maintained between the Colorado and Nile as to run-off, length, and irrigable area.

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[1] These and other figures were kindly furnished by the Yuma office of the U. S. Reclamation Service.

[2] The figures are to be found in U. S. Geol. Surv., W. S. Paper 395: p. 23.

[3] This whole matter is treated so well in other sources as to receive only the briefest reference here. See Cory, H. T., Imperial Valley and Salton Sink, San Francisco (1915), also, Water Supply Papers 395 and 556.

The lower valley of the Colorado above its delta is irregular in form, this irregularity being dependent upon the proximity of the mountain ranges which bound it on both sides. As a result, the width of the valley varies from the width of the river to a distance of perhaps thirty miles, producing in effect a series of subsidiary valleys connected by the course of the stream. As suggested, the minor tributaries are few and insignificant.

But what is most significant about this valley for the purposes of this paper is the fact that the Colorado in its lower course is not a bedrock stream and that its flood plain is bounded on both sides by a continuous terrace. Soundings indicate that in all the canyons of the lower river bedrock is at least 100 feet below the river bed.[1] The terrace is marked by a conspicuous bluff which rises up from 50 to 100 feet above the flood plain and continues far to the north along the valley.[2]

From these conditions the natural inference is that the valley has been subjected to a deep fill and that subsequent to this even the cutting and transporting power of the stream has been markedly increased so as to cause the formation of terraces. Further reference to these events and their implications for the delta area will appear later in the chapter.

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[1] Lee, W. T. Geologic Reconnaissance of a Part of Western Arizona, U. S. Geol. Surv., Bull. 352: p. 66. (1908)

[2] Brown, J. S. The Salton Sea Region, California, Water Supply Paper 497: p. 34. (1923)

The Silt Burden --

Though the river as such is a feature and form of the landscape its tremendous geographical importance lies in its present and past activity as an agent or tool in creating surface forms out of its own soil burden. This alluvial matter, though it varies in size from a very fine sand to colloidal clay, is commonly called silt and will be here so designated. As a carrier of silt the Colorado is probably without a peer among the greater streams of the world. An examination of the river water at Yuma over a period of several months in 1892-93 revealed an average ratio of 1 to 277 for dry material to water. Corresponding ratios for the Nile would be 1 to 1900; for the Mississippi, 1 to 1500; for the Danube, 1 to 3060.[1] In 1904, Forbes[2] of the Arizona Experiment Station made a careful study of the river silt. He found that an acre-foot of Colorado River water contained on an average 9.62 tons of silt, and that for the year the river's burden amounted to over 120,000,000 tons -- this for a year when the total discharge was considerably under normal. The average annual load passing Yuma is probably around 160,000,000 tons, which translated into terms of volume of dry soil would be approximately 80,000 acre-feet.[3]

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[1] Collingwood, C. B., Univ. Ariz. Agr. Exper. Sta., Bull. 6: p. 7. (1892)

[2] Forbes, R. H., ibid, Bull. 44: p. 200. (1902)

[3] La Rue, E. C., U. S. Geol. Surv., W. S. Paper 395: p. 220.

It is to be expected that the silt burden of the stream should vary at different times of the year, and this is true. However, an increasing volume of water does not mean proportional increase in silt content. In part this is to be explained by the fact that a falling stream by bank cutting and caving is a more efficient remover of silt than a rising stream, in part by the fact that the lower, "erratic" tributaries of the Colorado contribute a proportionally greater amount of silt than the upper, "reliable" ones. In this connection it may be added that each tributary contributes silt so unique and characteristic that those familiar with the area claim the ability to recognize the source of the deposited delta alluvium by its color and consistency. The lower tributaries of the Colorado, namely, the Gila, Bill Williams Fork, Little Colorado and San Juan carry more silt during their flowing season than does the upper Colorado.[1] They are largely the effective causes in the "flash" floods of spring and autumn so that the silt burden of these periods is proportionally greater than that of the much larger summer flood.[2]

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[1] Sellew, F. L. In Cory's Imperial Valley and Salton Sink, previously cited, p. 1480.

[2] An excellent digest of the available data concerning the Colorado basin with particular reference to the relation of rainfall, run-off and evaporation with a section devoted to areal distribution of denudation, is contained in a paper by Reichel and Leitr of Berlin, Der Wasserhaushalt des Coloradogebiets, appearing as No. 2, 2nd Series of the Geographische Abhandlungen, edited by Dr. Albrecht Penck. Stuttgart (1928).

It is these lower tributaries that contribute most of the true silt and colloidal material. From the Virgin to the headwaters the Colorado, even in high water, contains a fine, siliceous material commonly called quicksand.[1]

Whatever the origin of the material, the essential point is that the Colorado below Yuma is a stream containing an enormous silt burden, that the silt is not only the passive material from which the delta is formed but that by its presence it introduces important modifications in the mechanics of stream flow.

Mechanics of Stream Flow --

In this study, which aims at a classification of surface forms as an end, a general treatise on the mechanics of stream flow would be superfluous. However, it is pertinent to mention a few peculiarities of a silt-burdened stream such as the Colorado. It is said by an engineer working in the area that the silt tables generally accepted as applying to silt-bearing streams fail of accuracy for the Colorado Delta area. Whether or not this be true the presence of silt in the stream produces some very interesting phenomena.

In its lower course the Colorado is alternately a degrading and an aggrading stream. This is strikingly brought out by the sections taken of the channel at Yuma

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[1] Grunsky, C. E., in Cory's paper: p. 1535.

during periods of high and low water. (See fig. 4) Obviously the stream becomes degrading after its volume has reached a critical point nor is this totally dependent on the increased carrying capacity of the larger amount of water. There may appear the paradox of an increasing discharge and a falling gauge height. An examination of the Yuma gauging records for a period of years showed that the cross-section in a given year increases from minimum to maximum, 39% due to rise in the water level, 61% due to scour. The critical point above which the river scours and below which it deposits seems to be around 47,000 to 50,000 second feet -- though this figure is by no means a fixed one. A part of this scouring goes on at a time when the river water is apparently carrying in suspension its greatest possible burden of silt. The continued scouring beyond this point has been explained as the bodily pushing down stream of the silt resting on the stream bottom by the hydrostatic pressure exerted by the superimposed mass of water and suspended silt.

Within the bed of the stream where the course is straight the lowest point of the cross-section seems to seek first one side and then the other. This feature is reproduced in the irrigation ditches under ideal conditions of a straight channel and a constant head of water. Here the current scours on one side and deposits on the other, then conditions are reversed. In other words, these are incipient meanders which migrate slowly downward with the gradient.

During high water, on the bends of the stream there is to be observed a phenomenon in which with monotonous and periodic regularity the main force of the current swings toward the outside bank, suddenly advances in a wave which may reach two feet in height, then swings back toward the center of the channel to repeat the performance. This is probably to be accounted for by the building of bars from the inside of the bend. These bars increase in size until they act as a dam piling up a head on their upstream side. The head reaches a critical point, then advances, suddenly scouring out the bar. A natural bar, a wier, a sharp bend, the increased volume of a tributary introduce a measurable decrease in the velocity of the stream far above the obstruction. This then is followed by an increased velocity below the obstruction.

Of interest and certainly of importance to levee builders are the "bores" which may develop without warning at the base of the levees. The water suddenly starts a whirl, eats its way through the embankment, without any apparent seepage by which it may start. These are extremely difficult to stop and account for most of the levee breaks. These also occur along the base of levees which have become dry and cracked.

Before the artificial diversion of the Colorado from its old channel in 1905 the annual flooding of the delta area came from comparatively gentle, overbank flow. There

were occasional minor crevasses but these were the exception rather than the rule. This type of overflow is still maintained on the lower delta. By this process, natural levees are built and added to from year to year so that the slope of the land is gently away from the stream. The coarser, sandy material is deposited immediately and marks the presence of old or contemporary channels. The deposited alluvium increases in fineness with distance away from the stream course. Where there are natural depressions, such as ox-bow lakes, which act as settling basins, there is deposited the finest material, forming an adobe. Those familiar with the region think to detect the source of the deposited material with "red silt, Little Colorado; black silt, Grand", etc.

A part of the flood waters is lost by evaporation, certainly very little by seepage. The remainder spreads in a sheet for some distance from the main stream and then is gathered in by small channels which converge into larger ones. Eventually the waters are returned by a tributary to the main river.

The Secondary Deltas --

The two preceding paragraphs give a schematic sketch of the development of the delta, particularly as it was before the diversion of the Colorado from its old channel. Since then the river, by processes not thoroughly understood,

has constructed a new set of unusual forms. These are the secondary deltas with their anastomosing channels. In their formation the whole stream has been deflected from the old course and turned across the country where other channels are not available. On all this overflow land brush grows in the greatest profusion. This immediately serves as a check and the larger portion of the silt burden is dropped. The water, without a channel and with thick brush obstructing the way, is forced to find its way through, here and there at the weakest points. On the other side of the brush it finds its way to one of the old gathering channels and becomes again a united stream.

In January of 1922 the main stream, which was then flowing to the west through the Bee River channel, was diverted toward a branch of the Pescadero, one of the gathering channels of the Hardy. The brush was cleared and a channel dug for a distance of several miles. The slopes away from the channel were at the rate of sixteen feet in five miles. After the first summer flood this had increased to five feet to the mile, The dug channel had been scoured by the flood waters to a depth of twenty feet. The greater part of the silt had been deposited within five miles of the end of the constructed cut; beyond that there was a fall of six feet in 200 feet distance, then an open channel, and beyond that small braided channels with rapids and log jams. In all this course there was only adobe, no sand or sandy loam.

By the fall of 1926 the river had canalized itself for a distance of six miles beyond the end of the constructed channel and was continuing the process at the rate of two miles each year. This it was doing by constructing a delta cone and extending it. For each year silt was deposited to a depth of thirteen feet immediately at the end of the channelized portion of the stream. From this the cone sloped off laterally to no deposit at a distance of 4,000 feet. The stream constructed its channel over the surface of the old delta and after it was established turned about and scoured, to some extent, its own self-constructed bed.[1]

These brief references to some of the more striking processes whereby the river constructs its forms will become more coherent in the description and classification of the forms of the delta which owe their origin to the river and its deposition of its silt burden.

The Forms --

By way of orientation for the sections which follow it may be well to insert here a brief description of the pattern which the stream channels have developed within the delta. Reference is made to the map where the details are expressed graphically.

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[1] The facts for these two paragraphs were taken from two unpublished manuscripts by R. M. Priest, U. S. Reclamation Service engineer at Yuma, and kindly made available by him.

With the exception of the period 1905-1907, the main channel of the Colorado lay along the eastern margin of the delta until the year 1909. Apparently equally stable as a feature of the delta was the channel of the Hardy which occupies a position along the western margin of the delta, and at that time extended northward to Volcano Lake.

South of the crest the general slope of the delta was away from the Colorado and toward the Hardy. The main stream was confined to the old channel by natural levees. During the overflow period water passed over the banks and as it moved slowly westward was gathered into small channels such as the Bee, Pescadero, Paredones, and Alamo. The first three of these were tributary either to Volcano Lake or the Hardy, and most of the water which they carried eventually found its way to the gulf through the Hardy. The Alamo lay north of the crest and carried its water to Salton Sink. A portion of the water entering Volcano Lake found its way through New River to Salton Sink.

From 1905 to 1907 the main stream of the Colorado flowed through the New and Alamo to Salton Sea. In 1907 it was returned to its old channel, and flowed to the gulf until 1909. From 1909 until 1922 the main channel was through the Bee River to Volcano Lake, from where most of the water reached the gulf through the Hardy. By means of a dam, the main channel was diverted from the Bee to a tributary of the Pescadero in 1922. Since that year the Pescadero has remained

the main stream, the water passing into the lower Hardy and so to the gulf.

Properly to be considered first are the normal river channels with their associated features, eliminating for the present those very special types which are particularly ephemeral. The channels immediately fall into two general classes: those which are cut through the clays or adobes and true silts with their resulting narrow stream courses and steep, not easily eroded banks; and those which are cut through the coarser, more easily eroded soils where the banks are less steep and the streams show greater ease in meandering and cutting new channels.[1] This differentiation, which obviously has its basis in difference of soil type, becomes largely one of proximity in location to the old bed of the Colorado. Such streams as the Hardy, Pescadero, New, Alamo, and the mouth of the Colorado fall into the first group of those having steep banks. The upper part of the old channel of the Colorado, and most of the Bee and Paredones, fall into the area of coarser, sandy soils.

What might be termed "channel" forms are the islands, sloughs, bayous, and lakes whose origin has been due to

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[1] This has been previously noted by Godfrey Sykes, an excellent observer, long familiar with the area. Geogr. Rev., vol. 16: p. 250. (1926)

meandering (pl. IIa). These forms are present in greater or less number over all the area, but here again there is a difference, according to the soil through which the channel takes its course. In the areas of sandy soils they are more abundant but also more ephemeral. In the areas of adobe soils they are fewer in number but tend to be comparatively permanent. Certain lagoons and islands of the lower delta have been used by the Indians since time immemorial and are still in existence.

Bounding the upper part of the delta and extending up both Colorado and Gila are the terraces previously alluded to. Though there appears no material coarser than a very fine sand in the delta deposits, these terraces are composed of coarse sand and gravel. They rise abruptly from the flood plain of the river and extend as gravel and sand plains to the mountains. They vary from thirty to fifty feet in height above the flood plain, and their absolute elevation varies with the gradient of the streams which they bound.[1] A section through the terraces reveals alternate layers of sand and gravel with the usual features of cross bedding and lenticular inclusions (pl. IIb).

Of great importance in their implications for surface forms are the underground channels and general sub-surface

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[1] See: Ross, C. P. The Lower Gila Region, Arizona, Water Supply Paper 498: p. 75. (1923)

water conditions. The major source of the underground water is of course the Colorado; only about the desert margins or in extremely deep-seated horizons are other sources significant. Within the delta the conditions which determine the presence or absence of ground water are those of soil texture. The finer colloidal material forms a very effective barrier to the percolation of water. After rains or overflows the water stands in pools until removed by evaporation. In the western part of the delta, composed as it is of silt and colloidal material, the water table is low, except along the banks of permanent channels. In such areas as Yuma Valley, where the underlying soil is a quicksand, the water table is high, having approximately the same elevation as the river. Where the delta borders on the mountains, as along the base of the Cucopas, mountain-derived sands underlie the river alluvium and these are water bearing.

The above observations concern themselves with such surficial conditions as are significant in determining the presence or absence, and abundance of, plant growth. Of the deep-seated waters there are a variety of conditions. Within the Salton Basin there are developed two areas of deep wells, in part artesian. In Coachella Valley the mountain-derived sands and gravels form the water bearing strata, the overlying silt and clay belts the impervious stratum, which together produce artesian conditions. Figtree John Spring and Fish Springs are natural indicators of this condition.

In this area the ground water has its origin in the mountainous region which bounds it.[1]

In the eastern portion of Imperial Valley, about Holtville, there is another artesian area whose waters are derived from the Colorado. This area seems to be strictly limited in extent. Here the wells have been drilled to a distance averaging several hundred feet to a stratum of sand or gravel. A few miles to the west, holes drilled much deeper are dry or yield very little water.[2]

South of the boundary another area of pumped wells along the delta crest suggests an underground condition as yet not thoroughly understood. Well logs reveal a gravel ridge, lying about 200 feet below the surface, which extends in a direction along the delta crest, west by south from Pilot Knob. In shape this appears to conform closely to the delta surface, thinning out on both sides of the crest line. The gravel is fairly well rounded igneous material, said to be derived from the Gila. There seems little possibility that the origin of the water could be any other than the Colorado, though its fluctuation of level follows the fluctuations of the Colorado only in minor degree. It seems possible that this water, as well as that of the Holtville wells, might very well be derived from the

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[1] Brown, J. S. Water Supply Paper 497: pp. 73-75.

[2] Ibid., pp. 78-83.

continual loss of the Colorado between Grand Canyon and Yuma, suffered even during the low water stage of the river.

Overflow Forms --

Another set of forms is introduced by the overflows in which the river leaves its established channel and passes out over the surface of the delta.

First in point of origin are the natural levees. Generally these are distinguishable only by instrumental observation as their slope away from the river is ordinarily gentle, say at the rate of five feet to the mile. At certain stages of the overflow period the levees stand out by virtue of their covering of vegetation.

The overflow plains are a part of the levee slope. On these the flood waters lie in a sheet, not yet gathered into the channels which restore them to the main stream. These forms are characterized by a gentle slope away from the stream channel, are dissected by only minor gathering channels, and vary in material from the fine sand of the main channel to the silt of their outer margins. With these there are also associated small lagoons which represent portions of old channels, ox-bow lakes. The lagoons may be without inlet or outlet channels, and may in time become exterminated through silting up. Volcano Lake, Laguna Maquata, and Salton Sea represent special cases which will be considered later.

Dissecting the outer margin of the overflow plain are the gathering channels -- narrow, steep-walled channels as compared with that of the main stream.

The description of the above forms has had in mind conditions as they were before the Colorado was diverted from its old channel. The present condition of secondary delta building, with its accompanying phenomenon of anastomosing channels probably represents the normal conditions by which that portion of the delta lying south of the crest has been built. These forms, then, have had their counterparts in the past history of the delta. Under conditions whereby the main channel builds itself up to a height above that of the surrounding country, it is inevitable that eventually it should swing out to a more favorable gradient, establish a new channel by gradually extending a secondary delta, then repeat the whole performance.

With the withdrawal of the flood waters there are formed in the deposited silt a number of minor features. Probably the most striking of these are the mud cracks. These reach their greatest development where there has been a thick deposit of the finest alluvium. Here the surface breaks into large, irregular sections which are separated by cracks that may reach a width of several inches and extend downward to a depth of several feet (pl. IIc). If the deposit is thinner or composed in part of coarser

material the sections are smaller, are more superficial, the edges curl up and they readily disappear through crumbling (pl. IIIa).

Associated with the larger mud cracks are small cone-shaped depressions of perhaps twelve inches in diameter by twelve to fourteen inches in depth which apparently represent a point where the covering waters have found an opportunity to escape to a more permeable stratum below (pl. IIIb). These forms were seen only on a high water portion of the channel itself.

In addition there should be mentioned the ripple and current marks which appear in the coarser material within a drying channel.

Influence on Vegetation --

Indirectly, the river as the agent of soil differentiation, by its presence as water, as a bearer of seeds effects within the delta area a characteristic vegetation pattern. Cottonwood, willow, arrow-weed, mesquite, grass and the various reeds are the main constituents of the vegetation formation whose areal variation in make-up is an expression of conditions imposed by the river.

The cottonwood or alamo is largely restricted to a narrow margin along both banks of the old channel of the Colorado. Here it has a continual supply of water without suffering long periods of too abundant water, as is true of

the flood plains on either side. This position also suggests an area of the coarser alluvium.

The optimum conditions for mesquite demand water within reach of the roots without a considerable period when water covers the surface. As a result, the best stands are found on the finer soils occupying areas only occasionally flooded, or about the lagoons, or along such streams as the Hardy.

Arrow-weed occupies areas subject to overflow, but cannot stand long continued submergence. From its distribution it appears certain that its seed is water born. It forms pure stands of great density in the overflow areas (pl. IIIc).

Willow demands and can stand a great deal of water. Its seed is water borne and it occurs in great thickets in such places as the necks of stream bends, where the soil is coarse in texture and is last exposed by the retreating flood waters. On the sloping banks of channels, willow sometimes is found in rows running parallel to the course of the stream. The larger trees are found in the upper row and the other rows grade down to the size of the lower row. Each row evidently signifies a seeding at a certain stage in the river's height (pl. IVa).

The rushes and tules occupy sites which provide permanent surface-water. These conditions are found in the stiller portions of the channels, about lagoons, and in certain swampy areas of the lower river.

Very great changes in the distribution of vegetation have been introduced by the abandoning of its old channel by the Colorado. According to one man, familiar with the area for fifty years, the country as he first knew it was one of extensive grassy plains. Cottonwood and willow were restricted to the main channel while arrow-weed and tule were found only in the area of the extreme upper delta. Mesquite was rather widely distributed over the delta, along the streams, and about the lagoons. This description corresponds quite well with recorded accounts of the last century in so far as they are comparable.[1] It is certain that there were large areas, such as that lying between the New River and Centinella, which were largely vegetationless. The Holmes Map of 1902 contains some notations as to vegetation which bear this out. This is also largely true of the Silsbee[2] Map of 1904, though this latter shows heavy willow timber east of Volcano Lake along the course of the Paredones. This may be significant, since by 1904 the Paredones had become in part an actual diversion of the Colorado to the westward. Old photographs show "savannas" with heavy

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[1] Emery, Major W. H. Report on the United States and Mexican Boundary Survey, 34th Cong., 1st Sess., House Ex. Doc. 135 (1857). Mischler's report, vol. 1, p. 105; vol. 2, p. 80 (Parry's report).

[2] The originals of these two maps are in the possession of the Colorado River Land Co., for whom they were made.

grass stands, stands of quelite, canaigre, and carisso[1] which are mentioned as good cattle feed, all conditions extremely hard to find ~~duplicate~~ at present.

If this represents a true picture, certainly conditions have been greatly altered since thd diversion of the river to the west. There has been a great extension of arrow-weed and willow, the grassy areas have largely disappeared. All this represents a change in natural conditions and does not take into consideration changes effected by man which have been great and will be lasting.

About the channels of the Bee and Paredones there are great thickets of arrow-weed, and willow is extremely widespread. The lower delta remains least altered. Near the mouth there are areas of salt grass, growing under conditions which favor its survival. An exotic note is introduced by the coming of Bermuda grass, which has gained a firm hold on the lower delta within the last few years. Willow is present, as is also arrow-weed, but they fail to dominate as they do farther upstream. The mesquite here holds its own. This whole matter of the alteration of vegetation seems to be, in this area, a question of the greater or less availability of water, and changes in soil conditions. The river has changed its course, with marked results for the vegetation.

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[1] quelite = Amaranthus palmeri.
canaigre = Rumex hymenosepalus.
carisso = Phragmites phragmites. (Cane or tule)

The Sea

The Gulf of California extends from Cabo Falso, the southern tip of Baja California, a distance of 650 miles in a north-northwestern direction. It is narrow, varying in width from 50 to 120 miles. In its southern portion it maintains a fairly constant width but near its head it narrows sharply. From a width of 70 miles at San Felipe, it narrows to the river mouth, only 50 miles north. An examination of the pilot chart shows a sharply bounded trough in the sea floor near the center of the gulf, east of San Felipe.[1] This disappears farther north and near the head of the gulf the floor is comparatively level at a depth of about nine fathoms.

Curious features are the occasional patches of red-colored water which appear in the upper gulf, which have been ascribed to the presence of river alluvium in the sea water. The true explanation lies in the presence of great numbers of flagellate infusoria, which float on the water and give it a milky-red color.[2] Being without significant currents the temperature of the water follows closely that of the land about it, which means that it is fairly warm throughout the year.

Both as to species and numbers the gulf is rich in the life forms that it contains. Edible and non-edible

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[1] Pilot Chart 619, U. S. Navy, Hydrographic Office.

[2] Mexico and Central America Pilot (West Coast) p. 120 (1928)

fish, mollusks, seals, turtles, occur in extraordinary abundance. The area has been of importance as the source of pearls and coral.

During the winter and spring months the prevailing winds are from the northwest, during the summer months from the southeast. This finds a simple explanation in the fact that the gulf, being a water body, preserves a fairly constant temperature throughout the year. The land surface about the head of the gulf varies considerably in temperature from winter to summer. This means that with respect to the land the gulf becomes a low pressure area during the winter and a high pressure area in the summer.

In the upper gulf there are frequent northwest gales, lasting two or three days, during the months of December, January and February. Winds of extreme severity are few though waterspouts are said to be of fairly frequent occurrence about the mouth of the Colorado. There is a decided land-and-sea breeze, about the upper gulf, during the period of warming days in spring. Quite probably this phenomenon extends in lesser measure through other portions of the year. Hardy[1], sailing into the river mouth area in August, mentions storms of chaotic wildness, raised by the cross-seas, due to suddenly shifting winds.

The upper gulf is sufficiently narrow so that under favorable wind conditions the surface of the water may become as calm as that of large lakes; there is no constant surf.

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[1]Hardy, Lieut. R. W. H. Travels in the Interior of Mexico: p. 319. (1829)

During the storm periods the waves strike the shore with sufficient height and force as to be efficient tools for the cutting and carrying of the materials of which the strand is composed.

Tides --

The whole gulf is so proportioned as to be favorable to the development of tides, and with the narrowing of the mouth of the Colorado there is reached a climax of conditions which produce tides of unusual height and rapidity of change. At San Felipe, spring tides rise about twenty feet; at Phillip's Point, in the mouth of the Colorado, there is a spring range of 31.5 feet, or an average range of 21.6 feet.[1] The tides here sometimes run at a speed as high as six knots, and there is no slack water between ebb and flow.

The most striking feature of the incoming tide at the river's mouth is the bore, or, as the Mexicans call it, "el burro". Without the warning of slack water, the ebbing tide is met by a wave extending from bank to bank and sweeping upstream. At spring tides this wave is about four feet high normally, and may rise to ten feet in shallow water. The distance upstream to which the bore, and the tides in general, are effective is dependent upon the stage

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[1] These figures are from p. 180 of the Mexico and Central America Pilot (West Coast), previously cited.

of the water. When the river is very low there is a bore of one and one-half feet at Mayor, 100 miles by river from Phillip's Point in the mouth. When Volcano Lake contained water the tide was felt there, and at present the tidal effect extends up the Hardy to a point near the dry bed of the lake. In the old channel of the Colorado the tides could ordinarily be felt up to Heintzelman's Point.

Again, the freshness or salinity of the water of the lower delta is dependent upon the river's stage. During flood periods the river water is potable even at half tide as far down as Coyote Slough, opposite Montague Island. During periods of low water in the river the Hardy is scarcely potable up to Mayor. At one period of continual low water in the lower river small sharks and other salt water fish ascended nearly to Mayor and the water was unusable even by cattle.

Significant as the tides are as forces which have created characteristic forms in the confined channels lying within the sphere of their influence, they are of even greater importance as the force which meets the flood waters of the river and produces the overflows of the lower delta. The overflows of the upper delta come as a result of normal over-bank flow. In the lower delta the swollen river water meets the resistance of the incoming tides with a resultant building up of a head which finds relief in overflow. It is this flooding that, under favorable conditions, sends its waters to Laguna Salada.

The Forms --

There is a series of surface and sub-surface forms attributable to the sea. This includes those which owe their origin to the action of wave and current, to the deposition of the alluvium contributed by the river, to the combined action of river and tide.

Of beaches there are three types: mud beaches, sand beaches, rock beaches. The latter two are absent within the delta area proper, being found only marginally.

Near the mouth of the river the shore of the gulf is a high, nearly vertical bank of mud. South of this it becomes gently sloping, is irregular in form, and exposes bars and spits at low water. In major part this mud shore is without topographic relief and is unbroken by vegetation. Beginning perhaps nine miles north of Point San Felipe there is a sand dune barrier parallel to the coast. At high water there is a sandy beach; at low water a mud beach. Inland from the dune there is a section of alluvium unmixed with sand, which lies at an elevation possibly a little less than sea level, contains driftwood, and shows signs of recent inundation. The dune strip extends north along the coast nearly to Ometepec Bay, twenty-seven miles north of Punta San Felipe. At a point twelve miles north of San Felipe the sea breaks through the dunes and there is a water-filled channel running parallel to the dune,

extending to and entering Ometepec Bay.[1] For the sand of which the dune is composed there is only one possible origin: it has come from the west. How it should take form as an active dune, lying in part between channel and sea, is not so clear. It could be a matter of uplift and subsequent depression or it might be that the sea had built an off shore bar upon which the sand lodged.

Ometepec or Ometepes Bay, if all the variously timed reports are to be accepted, has had a varied history. The Narragansett Survey of 1873-75 reported this bay to be a circular body of water about three miles in diameter, connected with the gulf by a channel 300 feet wide and one-fourth mile in length. In 1926, Sykes[2] reported the closing of the entrance channel, while a fisherman of the area is responsible for the statement that at present there are three channels and that there is a bay again.

This whole line of the mud beach is hard to examine. It is difficult to approach by sea because of the shallowness and great tidal fluctuation. By land it is equally difficult because the lowness of the terrain and great

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[1]The dune and dry channel were observed in the field. The information concerning the channel extending south from Ometepec is from a German fisherman, long familiar with the area, whose accuracy of statement as based on cross-checking of other information is not to be questioned.

[2]Sykes. Op. cit.: p. 242.

tidal range mean that each high tide covers a large area and on retreating leaves behind it a liquid mud very difficult to traverse.

The only rocky coast in the area is a little stretch above the point of San Felipe. Here at high tide there are rock bluffs against which the waves beat; at low tide there is a beach of large angular blocks of rubble, cobble beaches and sand beaches. The whole of the point is bounded by a terrace lying about thirty feet above sea level. In part this is composed of the sands and gravels at the mouths of the arroyos which separate the several masses which make up the point; in part of well cemented cobbles which lie on a bench cut into the solid rock. In places this conglomerate has been undermined and lies in great sections on the beach.

This area about San Felipe also has sandy beaches, and from this point south sandy beaches dominate the coast. Several minor arroyos enter San Felipe Bay and all these have their mouths closed by sandy barriers. Immediately north of San Felipe there is a sand beach with Colorado alluvium exposed beyond it at low water. This sand beach is backed by a bluff of arkosic material perhaps thirty feet in height. This becomes less marked and passes inland to the north where the expanse of river alluvium becomes wider.

River and Sea --

With the contact of sea and river there is produced another set of forms. About the river mouth the shores stand as high banks of the very finest alluvium. About the edges these banks are dissected and gullied, the result of the occasional overflows which cover them. The plains which run back from the channel are vegetationless but have a considerable amount of driftwood cover.

Gore and Montague Islands are low and flat, and are composed of regular clay strata about one inch in thickness. Their shores rise as steep banks a distance of sixteen to thirty feet, at low water. The edges are dissected, the result of the run-off of occasional floodings. There are a few knobs on Montague which are never covered with water. On the surface of the islands there is a driftwood and salt-grass cover.

At a point somewhere a short distance south of the mouth of the Hardy and the old Colorado channel there passes an east-west line which marks the dividing point between the spheres of river and sea. North of this line the alluvial plain slopes away from the river to the west, still a part of the general delta profile. South of this line the plain slopes gently toward the sea and river, the normal form built by the sea.

Within the zone of influence of both river and sea there are developed forms taking their characteristics from

both. The inside bank of the river bend becomes something of a tide flat at high water (pl. IVa). If this is a sufficiently extensive area there may be developed a beach on the cut side of the bend. This is brought out the more strikingly by the action of waves on the clay in producing little rounded clay balls or pellets.

Well within the area where the delta profile maintains itself there are a number of overflow channels which pass away from the river toward Laguna Salada to the west. These channels contain water when a flood stage of the river coincides with a high tide so as to produce an over bank flow. These channels near the river are broad and shallow, with beds composed of hard cracked clay, strikingly in contrast to the loose, crusted alkali material about them (pl. IVc).

South of the area of overflow channels there are some other channels, which lead back to the stream. These owe their origin in part to the return tidal overflow, in larger part to the return flow of a part of the water which escapes the river by means of the distributaries higher in its course.

In addition, there are the true tidal thoroughfares which dissect lower lying areas subject to the influence of the tide. Where the area has a close grass cover the channels tend to be narrow and deep; with no vegetation cover, broad and shallow.

CHAPTER 4 -- THE SALTON SEA AND LAGUNA SALADA

The problem of the origin of Salton Sink, of the history of the cutting off of a section of the Gulf of California, of its genesis as a desert lying below sea level, is a major one in itself. But this whole question is so closely tied up with history of the delta that a review of the facts bearing on the problem will reveal much concerning the geomorphology of the area with which this paper is primarily concerned.

By a scrutiny of the observable facts bearing on the problem it seems possible to suggest a modification of the long accepted theory. Therefore, before theorizing it seems wise to submit the evidence as it has been noted in the field.

The terraces and other indications of a former higher water level are certainly striking features of the area and of prime importance as evidence. About the Salton Sink these features have been long observed and frequently described. Here they have been traced as an almost continuous line, and mapped as extending from a point on the flank of Cerro Prieto north along the western side of the sink, swinging to the east side near Indio and passing south to a point near the international boundary, east of Calexico. This ancient beach line, as it is called, varies in elevation from twenty-six feet near Centinela to fifty-

eight feet east of Brawley.[1] Where the line passes through alluvial deposits or along the sandy floor of the desert it finds expression as a well preserved beach. Where it abuts rock masses it is indicated by their slight notching, and more strikingly by deposits of calcium carbonate, or tufa. This appears only on the more resistant rocks, which are in this case granitic, lying below the old beach line. Jones[2] ascribes the formation of these deposits to algae.

But what is more important concerning the terraces is the fact that they do not end, as generally indicated on the maps, but extend on to the south, bounding the whole upper gulf. Instead of ending at Cerro Prieto, the terrace extends along the flank of the Cucopas and Sierra Mayor and swings to the westward into the Pattie Basin, encircles this and passes away to the south toward San Felipe. On the east the terrace appears as the Yuma Mesa, the Santa Clara Mesa in Sonora, and so on to the south, along the eastern margin of the gulf. On the whole the ancient beach line to the south of the area, where it is generally recognized, is not so well preserved. However, it does lie at elevations within the range of the line to the north, and it seems difficult to dissociate the two by what appears to be an imaginary dividing line (pl. Va, b, c).

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[1] See U. S. Geol. Surv. Reconnaissance Map of the Salton Sink, Calif. (1906)

[2] Jones, J. Claude. In The Salton Sea, by D. T. MacDougal. Publ. of the Carnegie Institution of Washington. (1914)

To complete the evidence as regards the terraces it is necessary to refer again to the river terraces which bound the Colorado and Gila. As previously mentioned, these terraces bound the streams for a great distance above Yuma; they lie at approximately the same height above the river flood plains as does the ancient beach line above sea level. Moreover, they are continuous with the terraces which form the old beach line, so that it is impossible to say where one ends and the other begins.[1]

Brown[2] suggests the three possible explanations of the origin of the river terraces as being: (1) diversion of the Colorado into the dry Salton Basin; (2) uplift about the head of the gulf; (3) climatic change. The first he eliminates because of the time factor, the time required to fill the sink and so reduce the gradient of the stream below the cutting point being not sufficient to account for all the material removed at the time of the terrace formation. He rejects the idea of uplift by saying that the water body within the old beach line was fresh, and can, therefore, not represent an uplifted portion of the gulf. He is inclined to favor the idea of climatic change as permitting an excess of evaporation over inflow into the fresh-water lake, and so allowing a sufficient period of time for the removal of the river alluvium.

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[1] Cited by John S. Brown, op. cit.: p. 36.
[2] Ibid: pp. 36-40.

The difference in slope of the delta, as between Salton Sink to the north and the gulf to the south, has already been mentioned (fig. 2). The steep northern slope, Mendenhall[1] says, is to be accounted for in part by the fact that it represents deposition in the still waters of the lake which existed there; that the flat and relatively uniform slope toward the gulf represents a stream grade determined under usual conditions.

Apparently somewhat independent of the true delta slopes is an elongated depression which borders the delta on the west and is occupied in part by New River, the old bed of Volcano Lake, and the Hardy.

Volcano Lake, extinct since the diversion of the Colorado to the Pescadero, was long a fluctuating body of water whose volume was dependent upon its annual increment from the overflow of the Colorado. Accounts as to its former depth of basin are conflicting. It was spoken of as being "bottomless". In the latter part of the past century supply boats sailed over it and conveyed provisions to the cow camps on the Pescadero. At the time the Silsbee map was made it was an ephemeral feature depending on the annual overflow for its water. Silsbee[2] himself, in a deposition concerning Volcano Lake, said that it contained water only

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[1] Op. cit.: pp. 20-21.

[2] From the records of the Colorado River Land Co., Los Angeles.

during high floods, and that at low water there was a channel connecting the Paredones and Hardy which passed through the bed of the lake. To the west was Laguna Prieta, about five acres in extent, which always contained water derived from hot springs. He describes the bed of Volcano Lake as being bounded on the north by a bank but as being low and willow girt on the south.

When the water level of the lake reached a sufficient height, part of its waters overflowed through a high channel passing to the west. So nicely was this channel balanced upon the delta crest that part of the diverted waters passed to the south through Salt Slough -- a tributary to the Hardy -- a part to the north in the channel of the New. Whatever the former depth of Volcano Lake may have been, by 1907, after it had been receiving a direct flow from the Colorado via the Paredones, its bed was reported as being some ten to fifteen feet above sea level, this after considerable silting must have taken place.[1] During the period of 1916 to 1920, when the lake was receiving the discharge of the Bee -- then the main Colorado channel -- its maximum gauge was 42.9 feet.[2]

This means that this depression is a feature which cannot be accounted for by the normal processes of delta

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[1] Grunsky, C. E. (Report to the Secretary of the Interior) The Problem of the Lower Colorado River: p. 9. (1907)

[2] From the engineering records of the C. R. Land Co., Mexicali, B. C.

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building, that here is a part of an old channel lying far below the level of the ancient beach line. Grunsky[1] suggests that this may be a remnant of the old overflow channel from the ancient Salton Sea to the gulf. The Hardy has kept the southern portion of this old channel open because it lies in the lowest part of the delta, a natural gathering channel for the flood waters of the main stream. The corresponding depression to the north of the delta crest is now occupied by New River, but previous to 1840 it contained only an irregular series of shallow lakes. The dry bed of Volcano Lake is the connecting link in the depression. Volcano Lake is perched directly on the crest of the delta. A stream would not normally flow from end to end along the delta crest, but rather to one side or the other. By a diversion of the alluvium-bearing waters, first to one side of the crest, then to the other, a section of the depression was closed at both ends by an alluvial barrier, forming the bed of Volcano Lake.

Another important piece of evidence is offered in the forms created by running water. With the exception of portions of the south delta slope, all of the slopes unfailingly reveal that previously created forms are in the process of dissection. This applies not only to the delta slopes, in particular those north of the delta crest, but

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[1] Op. cit.: p. 9.

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also to the fans and terraces, all forms constructed by running water (pl. Vc). Eliminating climatic change, there remains only one possible explanation: the lowering of the base-level of erosion. This might come about by the disappearance of a water body, say through evaporation; it might represent a general uplift of the land with respect to sea-level.

Previous to 1905 there was no great dissection of the north delta slope only because it was not subject to the action of flowing water in sufficient quantities and concentration. The heavy overflows of 1828, 1840, 1849, 1852, 1859, 1862, 1867 and 1891 were sufficient to cause the presence of considerable water bodies in Salton Basin.[1] These overflows most certainly did not represent the whole flow of the Colorado and were carried by the then relatively shallow beds of the New and Alamo rivers.

New River seems to have come into existence as a recognized channel between 1840 and 1849; the Alamo appears to be somewhat older. The little lakes which lay in the New River depression were not part of the river channel, yet received their water from the stream.[2, 3] In 1899 Cameron Lake, through which New River flowed, occupied a basin

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[1] These dates from MacDougal's Salton Sea: p. 173.

[2] Job Dye passed through the area in 1832 and claimed that New River did not then exist; he furthermore claims to have discovered it in 1849. From J. J. Hill's The History of Warner's Ranch and Environs: p. 97. (1927)

[3] Also from Hanks, H. G., Second Report of the State Mineralogist of California, appendix: p. 238. (1882) He states that New River was formed in 1840.

which measured a half-mile in length and was twenty feet deep. The lake was rapidly silting up with the material brought in by the New.[1] During the last decades of the 19th century there was a minor break in the Colorado near Algodones, occurring annually at the time of the summer flood. A portion of the diverted water went down to the Salton Basin in the channel of the Alamo. A greater portion passed through the Paredones to Volcano Lake and was there divided, a larger part passing south through the Hardy, a lesser to the north through the New.

At the time of Ansa's trip across the area in 1774[2] there was at least one deep arroyo along the delta crest (the Paredones?) containing water in places at the time of year he traversed the area (winter). On his return trip he crossed lower down the delta slope and mentions nothing that could be New River.

With the accidental diversion of the whole volume of the Colorado into the Salton Sink in 1905, the situation was radically changed. In a period of nine months the New and Alamo cut their channels to an average depth of fifty

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[1] Barrows, D. P. National Geogr. Mag., vol. 11: p. 343. (1900)

[2] From a manuscript containing the diaries and reports of the two Ansa expeditions, translated and edited by Professor Herbert Bolton of the University of California and kindly made available by him.

feet, with a width of 1,000 feet, and extended them for a distance of forty-three miles -- this by a process of headward erosion[1] (pl. VIa).

Another bit of evidence, possibly connected with the matter of slope dissection, is the fact that there are, in the lower delta, areas which are free of inundation by tide or river overflow. One of these areas is found about the site of La Bomba, another between the old course of the Colorado and the Pescadero, another to the east of the Hardy, south of Volcano Lake. As the agencies which created the forms have undoubtedly been tide and overflow, the fact that they are now above inundation means either that they are higher or that the agencies which created them have decreased in effectiveness.

Historical evidence favors the conclusion that for a period of 400 years the Colorado maintained its course from Yuma to the gulf. As Grunsky[2] suggests: from Diaz and Alarcon in 1540 to Ives in 1857 there is no intimation that the river had any other course than that which it maintained previous to 1905. Something of a point has been made of the map of Rocque, issued about 1762, which shows the Colorado and Gila as uniting and flowing into the northern end of a body of water, detached from the gulf. If this diversion

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[1] Cory, H. T. Op. cit.: p. 1324.

[2] Grunsky, C. E. Op. cit.: p. 6.

took place, it was noted neither by Consag in 1746 nor by Garces in 1771, who found the Colorado very much as it was previous to 1905. If the Colorado were diverted, say in 1755, it would certainly have been flowing into the Salton Sink at the time of Garces' visit and would have continued until such time as the sink contained a volume of water high enough to overflow into the gulf.[1] The source of the map is known and its general character is such that it may be regarded perhaps rather as an inexact copy of other maps than as utilizing the data of some exact, forgotten observer.

From Indian artifacts and legends there is another line of evidence. The Collins Valley Indians have legends of great white "birds" which sailed up the waters of what is now Salton Sink and discharged white men. They tell of the disappearance of water from the sink and of its sudden return. These legends may be good as supporting evidence, but in themselves they are worth very little.

The artifacts are more satisfactory. About the old beach line there have been found circles of stones which have

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[1] In this connection, it is interesting to note an item appearing in the diary of Fray Juan Diaz, kept during the trip of Anza in 1774. From the Indians he learned of a river, twenty leguas (about sixty miles) above the mouth of the Gila, which left the Colorado during the flood period and flowed to the west. After a short distance it entered another large stream of very red water; lower in the course these were joined by a small stream of salt water.

been interpreted as being fish traps.[1] These would at least indicate the presence of man within the area during the period when the basin was filled. Even more positive evidence of human occupation is found in the carvings which appear in the tufa of Travertine Point.[2] These carvings, which are undoubtedly of Indian origin, are not only carved in the tufa but they have been covered over by deposits of the same material. The first inference to be made from this evidence is that the rock upon which the tufa deposits appear has experienced at least several distinct periods of exposure to the carbonate-bearing waters of the lake. Whether or not this means several distinct fillings of an inclosed lake is a moot question. If this body of water were subject to great tidal fluctuations could not these carvings be made at low water?

The presence of the tufa is in itself evidence of fresh or at least brackish water conditions. This is borne out by the great numbers of fresh or brackish water mollusk shells which are found along the old beaches and on the floor of the desert. They are identical in form with living mollusks

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[1] From a conversation with Mr. Percy Palmer, of Brawley.

[2] MacDougal, D. T. A Decade of the Salton Sea, Geographical Review, vol. 3: pp. 459-460. (1917)

now found in the occasional permanent streams and springs about the desert margin,[1] many of which are somewhat brackish.[2]

In summarizing and synthesizing the evidence regarding the recent history of Salton Sink there appear certain well founded premises from which to proceed to a theory:

1. Considerations of the problem must not be restricted to Salton Sink. The extension of the beach line to the south makes it the problem of a larger area. Yet the water occupying the Salton Basin was fresh while the water of the gulf to the south was certainly not.

2. The river terraces are continuous with those of the beach line and represent depth of cutting equivalent to the height of the old terraces above present sea-level.

3. There is only one definite ancient beach line. There are numbers of terraces but these are definitely of a secondary and subsequent nature, and represent merely a receding water surface.

4. The desiccation of the Salton Sink area is an event geologically very recent. This assertion is borne out by the freshness of the old beach line, and by the Indian carvings in the tufa. The ancient lake represents a brief incident, for nowhere along the old beach line did the waves

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[1] Mendenhall, W. C. Op. cit.: pp. 18-19.

[2] These mollusks are described and identified by Stearns, R. E. C., in the Amer. Naturalist, vol. 13: pp. 141-154. (1879) Some of the specimens were taken from a depth of 50 feet below the surface. Stearns describes them as being fossilized and semi-fossilized and suggests that they might have lived in minor lagoons and ponds as well as in a large lake.

cut deeply into the solid rock. The undissected nature of the north delta slope offers proof of the recency with which water stood in the basin.

5. There is abundant evidence that there has been, in the area about the head of the gulf, recent and considerable uplift. As proof of this there is the unfailing dissection of fans and terraces, the existence of areas above inundation within the delta, the difference of over thirty feet in elevation as between different sections of the ancient beach line within Salton Sink.

6. Finally, the delta is inadequate as a dam behind which there could be impounded a lake with a level of even forty feet above the sea. It is not high enough and in addition there was some sort of channel which cut it to depth near sea-level along the line of the Hardy, Volcano Lake, New River Depression.

Hypotheses --

As an explanation of the sequence of events leading to the formation of the Colorado Desert, Blake's hypothesis has been accepted almost without question. This hypothesis he first postulated in 1853. At that time he was not aware that the old beach line stood above sea-level. He suggested the building of a delta barrier by the deposition of the silt of the Colorado, which, perhaps with the assistance of slight uplift, became effective in closing or nearly closing off the area within Salton Sink. The latter was maintained

as a fresh-water body by the northward diversion of the Colorado. Possibly there remained a connecting channel between lake and gulf, to the west of the delta.[1] At a later date, after more careful work had determined the elevation of the terraces about the Salton Sink, Blake postulated the existence of a lake which stood above sea-level and discharged its waters into the gulf.[2] He still admitted the possible assistance of uplift in making of the delta an effective barrier.

Subsequent workers in the area have accepted this view, largely without modification. Barrows[3] suggested crustal elevation of the earth beneath the central region covered by the delta; Free[4] ventures the hypothesis that the Salton Sink has very recently become a part of the gulf trough, lying below sea-level.

A consideration of all the evidence here noted leaves the impression that a modification of Blake's hypothesis is in keeping with the facts:

For a brief time during the period of maximum depression of the trough, the gulf stood at the level represented by the old beach line; it occupied the Pattie Basin, it stood along

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[1] Report of Exploration and Surveys from the Mississippi River to the Pacific Ocean, vol. 5, part 2: pp. 235-240. (1856)

[2] In MacDougal's Salton Sea, op. cit.: pp. 3-5.

[3] Barrows, D. P. National Geogr. Mag., vol. 11: p. 340. (1900)

[4] Free, E. E., in MacDougal's Salton Sea: pp. 25-29.

the Santa Clara Mesa. The Colorado entered the gulf at a point near Yuma and extended its delta across the gulf toward Cerro Prieto. As the delta advanced westward and became higher (assisted perhaps by general uplift) the deflection of the Colorado to the northward caused the water enclosed by the extreme head of the gulf to become fresh, or at least brackish. Along the western margin of the delta the tide maintained an opening along the line marked by the Hardy, Volcano Lake, and New River Depression. The embayment to the north was subject to tidal fluctuations and through the opening the excess waters passed to the gulf.

Then came a general uplift of the area and with it the delta became an effective barrier, cutting off the Salton basin from the gulf. As the river had been flowing toward the north the steeper gradient now lay toward the gulf, and the river was deflected to the south. With the uplift its cutting power was increased and it formed the terraces which now border it. Without increment the waters of the sink gradually disappeared through evaporation, leaving successive minor terraces.

During the subsequent period, up until 1905, the Colorado maintained its course to the gulf, grading and building up the southern delta slope to a gradient normal to stream deposition. During all this later period the Salton Basin has received only small amounts of water, which have resulted in nothing more than ephemeral lakes.

Laguna Salada

As previously noted, Pattie Basin is the name applied to the area lying between the Cucopa-Mayor and Juarez ranges. It includes an area of perhaps fifty miles long by twenty wide. It is definitely a part of the delta and continues the general delta slopes, having an elevation of some ten feet above sea-level at its entrance south of Mayor and sloping down to the northward to a minimum elevation of some five feet below sea-level.

In the varied history of the water body which has occupied it, in its aspects as a delta feature, there is a strong similarity between this basin and the larger Salton Basin to the north. Both are basins lying below sea-level, both are subject to occasional flooding, and both are cut off from permanent occupation by the sea by means of alluvial barriers.

The occasional floodings come as a result of the conjunction of high water in the river and high tides in the gulf. This interaction of forces means a backing up of the river waters and a breaking over the banks at a point near the mouth of the Hardy. From this point, several broad, shallow channels run to the westward, passing south of the point of Mayor (pl. IV<u>c</u>). Here the channels become less definite and the water spreads out in a shallow lake. To the northward and close in to the flank of Mayor, there is a series of gathering channels, deeply cut into the silt.

These are finally joined into one channel which debouches onto the plain about twenty miles northwest of Mayor. North of this is the area occupied by the lake, Laguna Salada or Maquata, during its intermediate and lower stages. If there be sufficient water, the lake extends much farther south.

In addition to the historical records, which show the basin to have been occupied by lakes in 1884, 1893, 1906, 1914, 1923, and 1928,[1] there is evidence in the form of strand lines. The highest of these is probably a continuation of the ancient beach line, the others are less well marked, frequently being indicated by a line of vegetation.

As the lake derives its water from the overflow of the river, it is, of course, fresh at its higher stages. With the loss of volume the water becomes more saline, and finally the lake is reduced to the brine and salt deposits which occupy the northeastern part of the basin. According to one visitor, who camped at the northern end of the lake in 1923, the water was potable there. What is more striking is his account of the tidal effect, which he says amounted to a movement of six inches, occurring twice a day. This, of course, does not infer a direct connection with the sea, but means rather an alternate increase and decrease in the head of water forcing its way into the basin.

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[1] A part of this information as to dates from D. T. MacDougal, The Desert Basins of the Colorado Delta, Amer. Geogr. Soc., Bull., vol. 39: p. 719. (1907)

Positive proof of the freshness, or at least brackish qualities, of the water of the former lakes, is found in the presence of the great numbers of mollusks which are found about the floor of the basin. Orcutt[1] stated that these are of the same species as those found in the Salton Sink area.

Older accounts of the Pattie Basin reveal very much the same conditions as at present. Garces,[2] in the account of his first trip into the area, mentions a "Rio Amarillo", which is unquestionably to be identified as a channel leading from the river toward the Pattie Basin. While a member of the first Ansa expedition, he correctly stated the origin of the ephemeral lakes of the basin. Ansa's first expedition crossed the upper end of the basin at a time when the lake had nearly -- if not entirely -- disappeared. About the old shores they found windrows of fish, stranded by the retreating water, or unable to withstand the increasing salinity. A similar experience was encountered by the MacDougal[3] party of 1907, and by Orcutt[4] in 1890.

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[1] Orcutt, C. R. West Amer. Scientist, vol. 7, no. 59: p. 159. (1891)

[2] From the previously cited manuscript of Professor Bolton.

[3] Bull, Am. Geogr. Soc., vol. 39: p. 720. (1907)

[4] Orcutt, C. R. The Colorado Desert, 10th Rep. State Mineralogist of Calif.: p. 914. (1890)

As to the origin of this area as an enclosed basin cut off from the sea, there seems to be no necessity in going beyond the explanation offered for the origin of the Salton Basin:

Until a very recent time, geologically, Pattie Basin was part of the gulf. The area was included in the region of general uplift about the head of the gulf. With increased elevation the delta slopes were extended southward, closing the space between Mayor and the coastal range to the south. The arm of the gulf became an enclosed basin, and was desiccated through evaporation. Its subsequent history has been largely concerned with ephemeral lakes, depending for their existence upon overflow water from the river.

CHAPTER 5 -- THE MODIFYING FACTORS

The preceding chapters have considered the nature and origin of the grosser forms of the landscape in the area of the Colorado Delta. It now remains to consider the modifying effects of another group of forces, largely climatic, which, though of less magnitude in momentary comparison, are persistent and thus effective in the landscape. Ordinarily the work of the river would appear in this latter group of forces, but in the area under consideration the Colorado is an exotic element which derives its power from another region. In addition to its exterior origin, its importance as a sculpturing agent is such as to class it with the other forces of the first order of magnitude.

Climatic Elements --

It is essential to know something about the qualitative and quantitative nature of the climatic elements for an understanding of the workings of the climatic forces. For the lower delta region there are meteorologic stations only at Calexico and Yuma.[1] These stations serve very well for an understanding of the lowland area of the delta crest but they fail to indicate the modified conditions about the head of the gulf or in the highlands of the desert ranges.

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[1] A meteorologic station has been recently established at Mexicali, in Mexico, but as yet the observations do not cover a sufficient period to be of any value.

For Yuma, a record of the years from 1876 to 1926 reveals for January, the coldest month, a mean temperature of 54.4 F., with a mean minimum and maximum of 42.2 F. and 66.7 F., respectively. For the warmest summer month, July, the corresponding figures are : mean, 91.0 F.; mean minimum, 76.6 F.; mean maximum, 105.4 F.[1,2] A sixteen year record for Calexico differs appreciably from this only in that there appears for July a mean maximum some 12 degrees higher. The absolute maximuma and minima are: for Calexico,[3] 117 F. and 21 F.; for Yuma, 120 F. and 22 F.

These figures mean a hot summer and a mild winter. It is not a frost-free region, however, for the forty-seven year record at Yuma reveals only eight years in which the minimum did not drop to 32 degrees. The average possible frost period comes between December 19 and January 21[4]. For agriculture this is significant; as an aid to mechanical weathering it is insignificant.

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[1] In a modified Koeppen climatic classification, Russell has designated the Colorado Desert by the symbol "BWhh". This means that in addition to falling into the class of driest, or desert regions, the mean January temperature is above 32 F., and that there are three months or more with mean maximum temperatures averaging 100 F., or over. Climates of California, Univ. Calif. Publ. Geog., vol. 2, no. 4: pp. 77-78. (1926) (See fig. 5.)

[2] Annual Meteorological Summary, Yuma, Arizona. (1926)

[3] Summary of the Climatological Data for the United States, Sec. 13. Weather Bureau. (1921)

[4] Op. cit.: p. 3.

For the latter consideration it is of importance that the contrast in temperature as between day and night is great. This is a phenomenon generally true of desert areas and particularly is true in the Colorado Desert in spring and fall. On one occasion, in the lower delta, a field thermometer registered a minimum of 22 F. during the night. By 10:30 a. m. it registered 88 F. in the sun, this in early December!

By common repute it is always 10 degrees cooler than Yuma at points about the head of the gulf; San Felipe is said to be ever muy fresca. It is certain that the modifying influence of the gulf is felt far up toward the delta crest. The low elevation of Centinela (2,262 feet) is sufficient for an occasional snow cover. In spite of these seeming exceptions, the actual temperatures as given for Yuma and Calexico serve very well for the whole delta region. The apparent temperature contrasts are frequently sensible rather than actual, and this is a matter of comparative relative humidities.

As an average condition, the Colorado Delta is an area of low relative humidity. In substantiation of this there may be submitted the much quoted figures giving the results of an experiment conducted in Calexico by the California Development Company.[1] The measurements covered a three-year

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[1] Soil Survey of the El Centro Region, California, U. S. D. A., Bureau of Soils: p. 11. (1922)

period and showed the average annual loss through evaporation from a free water surface to be 80.66 inches, or 6.72 feet.

For Yuma the figures of relative humidity are given for three hours of the day: 6 a. m., noon, and 6 p. m.[1] The mean annual figures for these hours are: 60, 27, and 27, respectively. In general there is a close correlation between the hottest period of the year and lowest relative humidity. But what is most striking is that the highest mean 6 a. m. figures are for August and September, two of the hot months. The figures for this hour may be supposed to reflect conditions as they are during the night, and so there is probably no exaggeration in the stories of dripping eaves during the nights of these months. Certain it is that the camper frequently finds himself in need of waterproof covering. Of course, such conditions raise the sensible temperature and make late summer the most dreaded part of the year.

The presence of the river is of material effect in raising the relative humidity of the lowland area, immediately adjacent to its channel. It has no effect upon the mesa, though the latter may be washed by the stream.[2] In such

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[1] Op. cit.: p. 5.

[2] Figures bearing this out are to be found in MacDougal's article in the Bulletin of the Amer. Geogr. Soc., vol. 38: p. 4. (1906)

cases the proximity of hydrophyte and xerophyte is the usual thing.

Such conditions of increased relative humidity find their origin in moisture-bearing winds from the gulf. Throughout the whole area of the lower delta it is in general true that southwest winds dominate during late summer, north winds during fall and winter, west winds in the spring and early summer. For certain localities this generalization is subject to modification because of topography or because of such phenomena as the land-and-sea breeze.

In this region the wind is certainly significant as a molder of surface form. Its importance in this respect is not to be measured in such terms as "total windy days" but rather in terms of number and duration of winds of high velocity.

Brown[1] made a detailed study of the wind records for Yuma covering a four-year period, having in mind the dominant direction of the high winds. As a resultant he obtained a northwest wind, and from field observation this appears to apply to the whole lower delta. The dunes show, certainly, the dominance of a wind acting from this direction.

Precipitation --

For Calexico[2] the average annual precipitation is 3.10 inches; for Yuma,[3] 3.42 inches. For both places the rainy

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[1]Brown, J. S. W. S. Paper 497, previously cited, pp. 14-16, 28.

[2]Op. cit.: p. 4.

[3]Op. cit.: p. 5.

season falls in the winter months, with a strong secondary maximum in late summer. The first is cyclonic in nature, the latter likely to be of the thunderstorm type. The region, then, lies in the transition area between the typical cyclonic winter rainfall of California, and the summer convectional rainfall of Arizona.

As regards its importance as an agency in moulding the landscape, the case of precipitation is analogous to that of the wind. The heavy, cloudburst type of rain storm is proportionally of far greater importance than the gentle rain. The summer rains are more likely to fall in the former class than are the winter rains. In August of 1909 there fell in Yuma, in 24 hours, 4.01 inches of rain.[1] Such rains, of course, are rare, but they are definitely to be considered in an analysis of the landscape.

Truly a desert characteristic is the great variation in amount of precipitation from year to year. As an extreme example there may be cited the Yuma figures for 1904 and 1905. In the former year there fell but 1.43 inches, while in 1905 the total reached the unprecedented figure of 11.41 inches.[2] It may be mentioned in this connection that there is a wide variance in the same years for Yuma and Calexico, though their average is practically the same and they lie only some sixty miles apart.

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[1] Ibid.: p. 4.
[2] Ibid.: p. 3.

Forms of condensation other than rain are unimportant. Snow does occur occasionally, and dew is quite frequent in late summer. Fog occurs about the head of the gulf and infrequently is carried as far north as Yuma.

Preparation of the Material --

Within the area of the delta proper, the surface configuration, the land forms, are primarily an expression of the work of the river. The homogeneous, fine alluvial material has been but little affected by the climatic forces of the area within which it lies. Only the wind and the vegetation serve to some extent as modifying factors.

On the other hand, the desert ranges which lie about the margins of the delta are, in their origin and subsequent forms, expressions of conditions indigenous to the area. In the degradation of these rock masses into their characteristic profiles and forms there is recognizable the dominance of forces particularly significant in a dry climate: mechanical weathering, the movement of dry, weathered material down slope, cloudburst rainfall, and wind.

Great aridity, abrupt temperature contrasts as between night and day make for a dominance of mechanical weathering. This condition particularly favors weathering through exfoliation and granular disintegration. Chemical activity is certainly not entirely wanting, as is evidenced by the presence of caliche-cemented deposits, colored concentric bands in boulders, and solution along joint planes.

Granites --

In broad outline the sculpture of the granitic masses shows an intricate, regular carving. The slopes are steep, the divides symmetrical. In the desert ranges the skyline is likely to be somewhat serrate. The pattern of dissection resembles nothing so much as a series of intersecting and overlapping inverted "V's" (pl. VIb). In detailed examination there is revealed the very great importance of jointing. The latter not only exerts a major influence in details of weathering, but also plays a large part in determining the direction and steepness of slope of the denuded rock surface.

It is a rule that in general the most intricately jointed granites produce the smallest boulders. The first disintegration takes place along the joint planes, and this continues so that finally the areas between the joints become protuberances. These may eventually be severed from the parent mass and become boulders. These latter show a rounding, but as they are exposed to the sun they show a crumbly exterior as opposed to the smooth beach or stream cobbles. With the production of one cobble there is necessarily the production of much finer material as waste. This latter is much more readily removed by wind and water, leaving an accumulation of the larger fragments.

Accompanying the joint-controlled weathing-out of boulders there sometimes appear examples of what may be termed "socket" weathering, forms which resemble the sockets

of ball-and-socket joints (pl. VIc). These are not large, reaching a maximum size of perhaps eighteen inches in diameter. They may appear as concave depressions in boulders or as depressions in protuberances of the bedrock. Forms somewhat similar to these are explained by Bryan as being the work of insolation and solution. Solution gets a start at a point on the surface poorly protected by the iron stained crust, common to desert boulders.[1] Examples of this type of weathering forms were noted only in sites of maximum exposure to the sun, though this may be only a coincidence.

Another striking weathering form developed in granite is that of the "boulder piles". They appear as fantastically shaped accumulations of boulders weathered and rounded out in situ, that reach the size of small hills. These forms are perhaps best exemplified in the area near Mountain Springs on the road from San Diego to Imperial Valley. It may be indicative of the significance of chemical weathering that they appear only on the desert margin at elevations not less than 2,000 feet. Bryan[2] suggests that insolation is effective to distances of at least twenty-five feet from the surface, so that the boulder piles may represent the combined action of chemical and mechanical weathering.

Occasionally, in the desert ranges, the granites and associated pegmatites, when in contact with finely jointed

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[1]Bryan, Kirk. Erosion and Sedimentation in Papago County, Arizona. U. S. Geol. Sur., Bull. 730: p. 49. (1923)

[2]Ibid.: pp. 39-40.

volcanics or schists, act as ridge builders, the other material falling away in detrital slopes. In no case are these major forms.

An examination of a typical, desert granitic range, such as Sierra Mayor, reveals in the characteristic inverted "V" dissection pattern what appears to be a well developed drainage system. There are channels filled with well rounded boulders, tanks, cascades and waterfalls -- all generally dry. If the area were to become suddenly humid the disposal of rainwater would be adequately handled. This might be used as an argument for recent and considerable climatic change, but in view of the fact that the volcanic ranges of the area offer no such evidence this conclusion is hardly tenable. What suggests itself is that this pattern represents the normal one developed in such a homogeneous mass by the movement down slope of the dry, weathered material, that this has served as a means of concentrating the occasional desert rains, with the superficial development of normal stream dissection channels.

The Volcanics --

In broad outline the volcanic lavas and tuffs show a much less symmetrical and homogeneous pattern. In form they range from the basalt capped mesas to an extremely irregular mass of plugs, cones, cores, and dikes (pl. VII<u>a</u>). As opposed to the granitic masses the volcanics tend to preserve the individuality of the several constituent elements. In

detail the material varies from highly resistant, massive lavas to the easily disintegrated tuffs.

The more massive thick flows develop widely spaced joints and maintain steep slope angles. The ordinary bedded lava flows, in weathering maintain intermediate slopes, talus mantled, whereas the tuffs have gentler slopes. In places the tuffs have almost entirely disappeared, leaving the old volcanic cores rising in cliffy slopes.

The volcanic areas as a whole show nothing of the development of the dry stream pattern characteristic of the granite. About some of the more considerable-volcanic masses the talus pediments show an extensive dissection by steep-walled, dry water courses. The materials are generally angular, showing little rounding effect along the channels. Perhaps the channels are due to the evident lowering of base-level, possibly, as Bryan[1] suggests for similar conditions, to the effect of occasional cloudbursts.

The Sediments --

The major exposure of sediments is found in the Tertiary deposits located about the eastern side of the head of the gulf. They are composed of intermittent, thin, sharply dipping, sandstone strata, which appear as low ridges in a mass of gritty clay. The latter is highly weathered with a crumby structure, but for want of a disturbing force frequently retains fairly steep slopes. On contact with a

disturbing force it crumbles, and in so doing exposes numerous gypsum inclusions.

From its front along the gulf and for a distance of about five miles to the eastward, this Tertiary formation shows an excellent development of badland topography (pl. VIIb). It probably represents an exposure of the same age and topographic development as that described by Mendenhall,[1] lying on the western side of Imperial Valley.

Conglomerates appear as prominent exposures but rarely in this area. Where they do appear, subject to the normal process of weathering, their resultant forms simulate those of the granitic rocks.

Work of the Wind --

That the frequent strong winds of the desert are important agents in the transportation of the weathered material cannot be questioned. The numerous sand and dust storms are proof of this. They are sufficiently characteristic of the area about the head of the gulf so that Hardy speaks of it as the "Smoky Coast".[2]

As a positive factor in the building of forms, the wind is represented by areas of dunes of varying types, and by other sand accumulations. The source of the wind-transported material is very largely found in the weathered

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[1] Op. cit.: p. 25.

[2] Op. cit.: p. 324.

debris about the base of the mountains. The Colorado alluvium, through its vegetation cover, or because of its alkali encrusted surface, is ordinarily resistant to removal by the wind. Its surface may be broken by the burrowing of animals, by the action of growing plants, by such cultural forces as wheeled vehicles, perhaps in a measure by weathering. Accumulations of such materials are developed by the wind, but these are secondary in importance to the forms composed of sand.

There may be witnessed, across the crusted surface of Pattie Basin, the movement of wind driven sand, very much after the fashion of drifting snow passing over ice. The sand accumulations are found abutting the mountains or in sheltered spots where the wind eddies. Upon the hard surface exposed to the sweep of the wind, accumulations are found only where some protuberance provides shelter. This function may be fulfilled by a piece of wood, wheel ruts, only occasionally on this alkali ground by a clump of vegetation.

The whirlwinds so common to the hot summer days are very effective carriers of material. Quite frequently these winds are of sufficient violence to transport not only dust but sand and even small pebbles. Such winds, though in the aggregate they move considerable amounts of material, are so irregular in their nature as to contribute little to the building of discernible forms of either negative or positive relief.

In the area examined there was encountered no positive example of the abrasion of rock by wind driven material. On the other hand, there were found numerous examples of wind abrasion in mounds of sand and silt.

Fixed, rather than active, dunes exhibit abrasion, for active dunes move before the wind through the migration of each individual particle. Perhaps with the death of the vegetation cover the wind initiates a cutting of the fixed dune. Through the larger mounds the blast cuts a vertical section which lies in a plane parallel to the direction of the prevailing wind.

For the area to the north, Mendenhall[1] cites examples of the abrasive action of wind-blown sand in etching gneiss boulders, the eroding of fish plates and bolts of the railway track, and the cutting of telegraph poles. The enormous importance of the wind as a transporting agent is admitted but it is here held that the abrasive power of the wind is restricted to a height of a few feet above the surface and so is of relative unimportance as a builder of relief forms.

The Forms --

In the foregoing discussion of weathering processes there has been some reference to relief forms, largely those attributable to one set of forces. In the disposal of the

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[1] Op. cit.: p. 26.

weathered material, and in its integration into land forms, there operate a number of forces: gravity, wind, running water, vegetation, and, to some extent, zoogene forces. Though these are the principal forces their effect is modified by such extraneous factors as uplift and depression, and the influence of the Colorado. The resulting forms, then, are frequently complex in origin.

Fans, Aprons, Pediments --

In the building of these forms three forces are dominant: denudation, running water, wind. The first two vary in importance with the nature of the mountain mass from which the materials are derived. The detrital material about the base of the lower lying volcanic mountains is composed, in general, of coarse, angular fragments possessing little stratification, their position largely due to the slow movement down slope of dry, weathered material. The higher lying granitic masses, such as Sierra Mayor, are flanked by deposits of well rounded, stratified gravels. About the higher volcanic masses there is evidence of some water transport of the weathering débris in the characteristic "mine dump" deposits, previously referred to.

Alluvial deposits of sufficient convexity to be called cones are lacking. Alluvial fans are well developed along the eastern flank of the Juarez, less so along the Cucopas. As previously suggested, the alluvial deposits along the Cucopas are covered better by the term "apron" than by "fan".

True fan slopes are recognizable as emerging from the re-entrants of this range but they coalesce, without appreciable break, into the uniform slope maintained by the flanking apron. On the western side of the Cucopas there are developed a number of prominent fans which retain their characteristic profiles out over the river alluvium of Pattie Basin. Along the base of the Peninsular Range the fan development is much greater with great boulders, gravel, and sand. But even here there is preserved a general uniformity of slope that appears to be due to something more than merely coalescing fans.

The alluvial deposits flanking the Peninsular Mountains are deep-seated and extensive; those flanking the desert ranges are more superficial. This is a natural condition of affairs in view of the greater height and more westerly position of the former range. The deep-seated, alluvial sands and gravels of the Salton Sink were cited when speaking of the artesian wells of that area. The general configuration of the floor of Pattie Basin suggests the same condition there, with its maximum depression along the eastern side and its silt-mantled slope rising to the west (fig. 3). Well logs are lacking for the area along the base of the Cucopas, but depths of twenty-eight feet below the surface reveal the gravels dipping so sharply as to preclude the possibility of their great extent.

The most striking feature of these fan and apron forms is the fact that they unfailingly show dissection as the most

recent incident in their evolution. About the flanks of the Cucopas the alluvial deposits are vegetation-mantled with a cover of palo fierro, palo verde, creosote bush, mesquite, ocotillo, and visnaga. This plant covering speaks for a stability of these surfaces, in fact reduces them to the category of relict forms. The courses of the ephemeral streams issuing from the mountains are steep-walled arroyos cut into the alluvial sands and gravels (pl. V<u>c</u>). The easiest way of accounting for these forms is to posulate a recent uplift, and this is in keeping with other evidence. Proof of the recency of the uplift is rendered by the absence of any discernible secondary fan building.

The most extensive feature of the mountain derived material is the great alluvial plain which extends from the base of the mountains east to the edge of the river silt, and from San Felipe north to the point of Las Pintas. The plain is composed of granite derivatives: sands, gravels, and arkosic conglomerates. Through its gently sloping surface the volcanic masses rise as islands. There is no question that it is water-transported material derived from the distant mountains to the west. In its make-up it resembles closely the mesa which bounds the delta to the east. The origin of both plain and mesa must involve similar events. Quite possibly the alluvium forms only a superficial deposit, for there is exposed by arroyo cutting a very different material, a few feet below the surface. It

is of about the texture of silt, contains irregular pebble inclusions, and maintains vertical walls on erosion. This all strongly suggests residual material.

North of Punta San Felipe the road crosses a series of arroyos, for a distance of perhaps ten miles. They are steep walled, with flat, sandy bottoms. Toward the sea they increase rapidly in depth to a maximum of perhaps 30 feet, with a width of 200 yards. They are not long, having a maximum length of perhaps five miles. Toward the mountains they become shallower and split into little, sandy washes. Here, again, lowering of base-level through elevation of the land explains the origin of such forms.

Desert Pavements --

The term desert pavement or pedregal is applied to a bare, level surface composed of gravel or small cobbles, embedded in a finer matrix. Such surfaces may be divided into two general types: those composed of alluvial gravels, and those composed of detrital material. In the latter case, if the material is transported at all, it is by the slow movement down slope of dry material, on the face of the retreating mountain slope.

The first type may be found as an elevated form. More frequently, as on the mesas, it is an area of negative relief. Its surface is composed of gravels of uniform size darkened by "desert varnish" (pl. VIIc). Below the surface is found a hard, clay-like material. The origin of such a

form is to be found in the work of the wind, which removes the finer material and causes a gradual lowering of the general surface with a resulting concentration of gravels. The terrace surfaces and the fan slopes, as along the eastern base of the Cucopas, exhibit a similar development.

The second type is found particularly well developed about the little volcanic hills north of San Felipe. A detailed examination of one of these forms revealed it as maintaining a slope inclination of ten degrees away from the mountain. There is a perceptible though not angular break between pavement and mountain slope -- the latter averaging about twenty-five degrees (pl. VIIIa). The pavement-surface is composed of angular cobbles showing some desert varnish (pl. VIIIb). It is only one block deep, and is imbedded in a thin stratum of fine material of like origin. Below the fine material is a stiff sand, sufficiently deep and free of rocks as to be in some measure undermined by animal burrowings. The factors significant in the formation of this land form appear to be: (1) the retreat of the mountain slope through denudation; (2) the movement of the weathered material down slope; (3) the removal of the finer material by the wind.

The Dunes --

Of the forms of wind accumulated material there may be distinguished two general types: active dunes, and fixed

dunes. The former have little, if any, vegetation cover, and are continually changing form and position through a wind impelled movement of the sand grains of which they are composed. Should they become stationary for any reason they then fall into the second class of fixed dunes. This latter class also includes the accretion dunes which may be composed not only of sand but also of silt and clay. These forms grow about a nucleus initially fixed, the material being held in place by the roots of vegetation.

There are two major sets of active dunes, though both are marginal to the lower delta region. The first is the Algodones Sand Hills, lying in the eastern part of Imperial County; the second, the belt of dunes lying parallel to and east of the edge of the Santa Clara Mesa, in Sonora. These latter are not easily accessible and are little known, though they may be easily seen from the edge of the mesa, twenty-five miles away. From this distance it appears that they are at least in part of barchan form and that the dominant wind is southerly.

The Algodones Sand Hills have a northwest-southeast orientation, forming what is in reality a continuous range some forty miles long with a maximum width of about five miles. The hills lie upon the smooth plain of the mesa which bounds the delta at the north and east, spilling over a bit at its southern end onto the alluvium of the delta. The irregular forms of the dunes suggest that they are not under

the domination of any particular wind. The range is surrounded by extensive areas of desert pavements and it seems possible that in part the dunes owe their origin to the concentration of the material removed by the wind in the formation of the pavements. On the basis of comparison of present form and position with that represented on old maps, Brown[1] comes to the conclusion that the Sand Hills in their larger features have changed very little, at least in the last seventy years. He suggests a slight movement to the southeast; this is borne out by the presence of extensive areas of fixed dunes, south of the major range, on the delta. Here the conditions of abundant moisture and plant growth are much less favorable to the existence of live dunes.

Barchan dunes were observed on the Sonora mesa near the head of the gulf, where conditions are such as are considered ideal for their development -- a hard floor, and a strong wind blowing in a constant direction (pl. VIIIc). The dunes observed along the coast north of Punta San Felipe are apparently subject to the effects of winds blowing from different directions (pl. IXa).

Evidence of the very considerable height to which wind-driven sand may be forced up steep slopes is offered by several examples. The northern tip of Las Pintas, which

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[1] Water Supply Paper 497: p. 29.

rises to a height of at least 500 feet above the alluvial plain, stands directly in the path of the strong winds which sweep south out of the Pattie Basin. At one point, where the slope of the range measures about thirty-five degrees, the sand has been driven completely over the crest and lies as a white band down both sides. Though this is the extreme case, many other examples of less magnitude are observable.

In no case was there observed an active dune in which the constituent material was finer than sand. On the other hand, fixed dunes may be composed in part or in whole of materials of the texture of silt or clay. These latter are of the type termed "accretion" dunes. The distinction between active dunes which have become fixed by vegetation and accretion dunes composed of sand is rather difficult. In time both come to approach the same form. The action of roots in destroying the structure, the accretion of finer materials, and the decay of vegetation tend to make the origin obscure (pl. IXb).

Good examples of accretion dunes are the mounds which collect around springs due to the retentive powers of the vegetation which the presence of water induces. One such is the Kane Spring mound in Imperial Valley.[1] There are traditions in the lower delta of an "Agua Hechicera" (witch water) in which the spring emerged from the top of a dune.

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[1]Cited by J. S. Brown, op. cit.: p. 31.

Another type of accretion dune is that previously mentioned, where the sand, in sweeping over a bare surface, is lodged in a depression or behind some obstruction. Examples of this are seen on the bare, alkali surface of Pattie Basin, where wheel ruts catch the drifting sand. Vegetation takes root in the sandy spot, particularly sea-purslane. A series of mounds is built up; they in turn offer further obstruction to the sand; other species of vegetation are introduced (such as creosote bush), and the accumulation continues (pl. IXc).

An examination of a number of forms thought to be of this origin revealed a series of dunes, irregular in form, some with a crater-like top covered with mesquite. On the flanks of some were small active dunes. An examination of the structure revealed a rough bedding with alternate layers of fine sand, magnetite, coarse sand, fine sand, with inclusions of small, irregular rock fragments.

Mounds composed of silt or clay material are found in all sizes, from those of a height of ten feet or more to those of no more than a foot. These forms are generally quite smooth as to outline, though they vary in form from those having steep sides to those which are low lying and have gentle slopes. There seems little doubt that these are wind accumulations, held together by vegetation. Even where these have become denuded of vegetation, examination reveals numerous remains of roots. Such forms generally

occur in groups and are highly restricted in distribution. An examination of one of these revealed a surface very much hardened with carbonate concentrations. Below appeared the alluvium, soft, moist, cool, and containing plant remains, small black seeds, and small bones. As this particular form lay in the entrance from the Colorado to Laguna Salada it is possible that some factors other than the wind and vegetation have been significant.

Caliche --

Caliche[1] is a calcareous deposit characteristic of arid lands which may appear in nearly pure deposits or may act as a cement in sands or gravels. Caliche is widespread in these arid areas and is frequently known locally as hardpan or cement. It is thought to be derived from ascending ground water, or to be a deposit from rain water, which characteristically effect a solution and concentration of soluble salts in desert areas.

In the delta area caliche is found in the pure form exposed along cuts, but it is more significant as a cementer of sands. Along the edge of the Santa Clara Mesa there appear exposures of caliche-cemented sandstone, fallen and broken into slabs. The sand appears to have been cemented a short distance below the surface, to have been exposed by denudation, then caved and broken by undermining (pl. Xa).

[1] A discussion of the origin and function of caliche appears in Lee's Underground Waters of Arizona, U. S. Geol. Surv., Water Supply and Irrigation Paper 136: pp. 107-111. (1905)

It seems quite possible that many of the conglomerates present along the stream channels of this region represent the effect of caliche. Most of the conglomerates are not basal and their cementation is effected -- if not by caliche -- by some other process quite common to arid areas.

CHAPTER 6 -- SUMMARY OF GEOMORPHOLOGY

Diastrophism and the Colorado River are the two agencies of major importance in the genesis of the delta landscape. Diastrophism is significant in that it has produced the framework about which the alluvial materials are deposited. It sets certain areal limits within which the river may work. By this restriction it has effected the gross configuration of the alluvial surface.

The river is significant primarily as a transporting force which has carried into the area a great burden of silty alluvium. In the Delta Cone area the river has effected the detailed surface relief, almost to the total exclusion of other forces.

In a manner, diastrophism and the river are forces which work against each other in the net result on the landscape. Diastrophism has produced relief; the river has tended to destroy it. In detail the river does produce relief forms. Still, the four major areas of the delta surface mark depressions in the diastrophic framework.

Volcanism and recent faulting have produced modifications in the frame. The sea and the climatic forces work with the river to produce a general reduction of relief.

In a consideration of the genesis of the delta landscape, as of any other, it is necessary to think of a mutual interaction of forces, going on constantly. Genetically "pure"

forms are rare. The nearest approach to such forms is to be found in areas of recent and contemporary volcanic action.

The Diastrophic Frame --

It has not been proved that the depression occupied by the Gulf of California is a simple graben. It is impossible to point out two continuous fault planes between which there is a dropped block of the earth's crust. So far as definite evidence goes the form may as well be a geosynclinal one.

The trough does, however, form a zone in which faulting, and to a lesser extent, volcanism, are highly significant in their morphologic implications. At least three phases of diastrophic activity can be recognized in the delta landscape:

1. The forming of the gulf trough. This may represent folding or faulting on a large scale. The trough is a structural form which extends from Coachella Valley to Cape San Lucas, and has been traced onto the Mexican mainland.

2. Changes in elevation over a broad area. Characteristic of Post Pliocene period, along the coast of Southern and Baja California. In the delta area the ancient beach line marks a uniform degree of uplift over a large area.

3. Faulting of orogenic and lesser magnitude. It has produced as relief features such forms as the Cucopas, Sierra Juarez, and Pattie Basin. Tertiary sediments have been exposed to the effects of erosion and denudation. To some extent faulting has exerted a control over erosion in the development of surface forms.

Volcanism is significant in the delta landscape principally as a producer of relief forms. It has been active in periods so recent geologically (late Tertiary and

early Quaternary) that the volcanic forms have been but little reduced by the attack of denudation and erosion. In the case of the Sierra Pintas, volcanism has affected the areal configuration of the delta surface in nearly making of Pattie Basin a mountain-encircled topographic depression.

The Covering --

In the process of covering the diastrophic frame the function of the Colorado has been to deposit its alluvial burden in the depressions; denudation and erosion have been of major effectiveness in attacking and leveling the eminences. Of the two sets of forces the river makes by far the most impressive showing in the present landscape. Choked by a burden or river silt the sea has ceased to be an active erosive force and has become the agent which, by wave and tide, disposes of the alluvium in characteristic forms.

The building of the delta represents only the most recent development in a long continued filling of the gulf trough. As a surface form the delta is no older geologically than late Pleistocene. Alluvium of the same textural character as that now being deposited, has a depth on the delta crest of no more than 200 feet. At the present rate of increment all of this silty alluvium might have been carried into the area within a period measured in hundreds, or at most a few thousands, of years.

Probably the whole delta surface is underlain by Tertiary and Quaternary sediments. At least a part of the Quaternary deposits represent a contribution by the Colorado River of that time. A Quaternary sea stood over the mesas and gave the alluvial sands and gravels their present character as flat-lying, undissected plains.

A late Quaternary uplift resulted in the withdrawal of the sea from the mesas. The Colorado was rejuvenated; it deepened its bed, and deposited gravel in the gulf trough. Succeeding this period came a depression in which the Colorado silted-up its previously deepened channel. The sea advanced to a point near Yuma, forming what is now recognized as the ancient beach line.

With carrying power reduced, the lower river transported only the finest alluvium. From this time, somewhere in late Pleistocene, the development of the present delta has taken place. At a time, perhaps 500 to 1,000 years ago, the delta emerged as a surface form and became the barrier which separated Salton Sink from the sea. In effecting the closure between the two water bodies the normal delta building processes were assisted by a gradual and extensive uplift.

In the subsequent extension of the river deposits there have been formed three types of surface, each characteristic of the manner of deposition of the material. These three types of surface are exemplified in the four natural areas into which the delta may be divided: the Delta Cone, Pattie Basin and Salton Sink, and the Gulf Plain.

The Delta Cone possesses a gently convex surface, formed by the pendulum-like swing of the main river channel. The river channel becomes relatively high ground through deposition, forcing the stream to seek a more favorable gradient. Since the cutting off of Salton Sea from the gulf, the activity of the river has been mainly restricted to the area lying south of the delta crest. The area north of the crest has been served by overflows from the main channel; occasionally the overflows have caused the diversion of considerable amounts of water.

Laguna Salada and Salton Sink have the concave profiles characteristic of deposition in still water. In their previous condition as estuaries of the gulf these areas undoubtedly received alluvium derived from the Colorado. At present they are dependent for any additional deposition of silt upon the occasional flood waters from the river. At such times as they are flooded, both are the sites of lakes in which the silt is precipitated.

In cross-section, the Gulf Plain resembles a very flat "V". This configuration has been effected by the tide in the manner characteristic of estuarine deposition. The tide advances with considerable force over the flat, carrying the silt with it. The ebb is marked by a less concerted retreat of the water, which remains in shallow pools, or trickles back slowly; the silt is deposited.

The climatic factors have been of almost no significance in the development of the delta surface. With the exception

of the dunes and occasional patches of alkali, they find little direct expression. The alluvium remains essentially in the same state and position as it was when deposited. The soil horizons -- if they may be called such -- are horizons of deposition rather than of alteration.

The climatic forces find their major activity in an incessant attack on the mountain masses. In the never ending contest between relief-creating and relief-destroying forces, certain forms reveal the relative dominance of one or the other set of forces. At the southern end of Pattie Basin there are several little granitic hills, nearly submerged in a plain of sand and gravel (pl. XIIb). These forms reveal the near victory of the climatic forces; the steep escarpment of the Sierra Juarez reveals the opposite case.

Mechanical weathering is more significant than chemical weathering because of the nature of the climatic factors: scanty precipitation, and sudden and considerable temperature contrasts. Denudation is more significant than erosion, partially for the same reasons -- though the occasional occurrence of cloudburst rainfall makes erosion a factor to be considered.

The residual surface of the granitic masses possess a pattern which is regularly and quite intricately developed, since the rock is regularly jointed and of homogeneous composition. The volcanic masses are irregularly jointed

and heterogeneous in lithologic composition. As a result their residual surfaces are highly irregular in form.

Along the base of the Cucopas there are considerable colluvial deposits, unfailingly dissected, which give the impression of being relict. As these deposits exhibit beveling by the sea at elevations approximating those of the ancient beach line, they can be referred in age to the time when Salton Sink was a part of the gulf (perhaps a thousand years ago). It would be venturesome to say that alluvial fans are not forming at present, but certainly their building has not proceeded far enough to make them readily discernible.

Somewhat the same case holds for the volcanic ranges. Here there are sandy washes which appear to occasionally contain water. There are forms, constructed of colluvial materials, certainly relict. One such form, particularly striking, is found at the base of the Sierra Pintas. It is flat topped, perhaps 300 feet long, and rises to an elevation of twenty feet above the tide flat by which it is surrounded. The form is composed of sand and gravel, with enough finer material to retain fairly steep sides. It is separated from the apron of colluvial materials which fronts the mountain, by a distance of about a hundred feet. Such a form is a marker of uplift, but it also indicates a former activity in transportation and deposition of weathered materials that is certainly not apparent at present.

For the-whole delta area probably the most troublesome problem is concerned with the matter of colluvial deposits. Briefly summarized, the significant points are as follows:

1. Along the base both of the Cucopas and of the Sierra Pintas, the colluvial deposits possess forms which are characteristically flat-topped, terminating outwardly in an abrupt face. In both cases the forms appear to be relict, are mantled by slow-growing trees, and are unfailingly dissected. The Cucopas deposits are composed of well rounded and partially stratified materials; the Sierra Pintas deposits are composed of irregular fragments, not appreciably stratified.

2. The only fans possessing a normal profile are found along the western side of the Cucopas. Even they are heavily mantled with vegetation.

3. The building of secondary, or new fans, is not discernible.

In an explanation of the forms -- or lack of forms -- uplift is a factor admitted without question. For the rest there appear to be two possibilities: simply, climatic change or no climatic change. Climatic change of such a nature that fans are no longer formed, solves the problem immediately. With stability of climatic conditions it is necessary to introduce a time factor in which uplift is involved: the process of building the forms is such a slow one that sufficient time has not elapsed since the uplift to permit of the formation of subsequent deposits.

Particularly about the margins of the Delta Cone the contact of river alluvium and colluvial materials is sharp. The line of distinction is least clear along the base of the Sierra Juarez, where the occasional mountain torrents have carried sand out onto the surface of Laguna Salada.

The wind has also contributed to a mixing of sand with the silt. Its activities have been least significant in that portion of the Delta Cone possessing a heavy plant cover.

The distribution of dunes bears a relationship both to the source of the sand and to the direction of the strong winds. The two major dune areas (Algodones Sand Hills and Sonora Hills) are both located on the mesas, at least twenty-five miles from their western margins. The large areas of desert pavements on both mesas suggest a source of the sand. At least for the Algodones area the dominant, strong winds blow from the west and northwest. In Pattie Basin the dunes show the dominance of the north wind. The source of the material is to be found in the colluvial deposits. So strongly does the wind sweep through the basin that the dunes are not found out on the alluvial surface, but only in places where irregularities in the mountain front offer protection. In the sheltered spots the dunes rapidly take on a growth of vegetation and becomes fixed.

Problems --

There are a number of problems concerned with the geomorphology of the delta area which are well worthy of attention and study:

1. A solution of the gulf trough problem. Whether there is involved a geosynclinal structure or a simple graben.

2. The problem of the colluvial forms. If these forms owe their present character to climatic change or if it is simply a matter of a complication

of time introduced by uplift. In this connection an investigation of the well developed "drainage" pattern found in the granitic ranges and not in the volcanic ranges.

3. The mechanics of a delta-building stream. Particularly with reference to the secondary deltas with their anastomosing channels. If these forms originate simply through the presence of an almost impenetrable growth of vegetation, or if other factors, such as soil or relief, are of significance.

4. Another problem might include investigation of the local earthquakes. Are they at all connected with the annual overflow? Why are they so localized in effect?

5. The problem of the tide. The mouth of the Colorado has a tide of unusual range and rapidity of change. Just what are its effects on the river? What is its method of disposal of the river silt?

CHAPTER 7 -- THE NATURAL AREAS

On the basis of a systematic combination of morphologic features there are distinguishable in the Colorado Delta, five natural areas: the Salton Sink, the Delta Cone, Pattie Basin, the Gulf Plain, and the desert mountain areas, the Cucopa and Las Pintas ranges. For reasons already stated, the first of these, the Salton Sink, is eliminated in the discussion which follows.

The Delta Cone --

This area is so named and so distinguished because it is only this area of the five which possesses the profile and surface configuration generally associated with the term "delta". The other areas are included in the delta region only by virtue of their alluvial surfaces, or because they occupy contiguous positions. The Delta Cone is the heart of the delta, and in it are presented most vividly the striking contrast between the well watered channel of the Colorado and the arid surroundings through which it flows.

The surface of this area forms a broad, flat cone, with gentle slopes averaging less than two feet to the mile. The northern boundary of the area is placed at the line where the degree of slope increases sharply toward Salton Sea. To the south the edge of the cone meets the Gulf Plain

at a point where the river gives way to the sea as the dominant force in the landscape.

The area is really a great plain, broken by no forms possessing considerable relief but with a surface minutely broken by all those characteristically deltaic features: meandering channels, lakes, natural levees, and the somewhat specialized forms of the secondary deltas with their anastomosing channels.

In its historical development the delta has advanced from a stage when the river debouched into the gulf at a point near Yuma. The alluvial burden of the river was rapidly dropped on contact with salt water, and a large part of it was removed by the strong tide and widely distributed. The alluvium gradually formed a barrier, and, aided by uplift, it effected a closure, cutting off Salton Sink. The river had previously been deflected to the north of the alluvial barrier, but with the uplift it was turned toward the gulf. The main channel swept back and forth across the gulf slope; occasionally it overflowed its banks sufficiently above the delta crest to form a temporary lake in Salton Sink.

This area, then, in its surface features, represents primarily the work of the river. Even the Hardy, Volcano Lake, and New River Depression, which are remnant portions of the old tidal thoroughfare connecting the gulf and Salton Basin, have been greatly modified by the activities of the Colorado.

In addition to these remnant forms there are a few others whose origin cannot be traced to the river: Mesa Andrade, the mud volcanoes, and the dunes.

The dunes are found extensively only in that part of the region which was formerly poorly covered with vegetation. This includes most of the area lying north of Volcano Lake, and this is the area most infrequently flooded by the Colorado. The area was freely open to the northwest winds, which formed dunes with sand derived from the mesas bounding the Delta Cone on the west. In the present cultural landscape, a portion of these dunes have been leveled, and the others have become fixed by vegetation. That the dunes were formerly numerous and extensive is ably borne out by the accounts of early travellers, who found great difficulty in forcing a passage through the area east of Centinela.[1]

The climatic factors have been of little significance in the development of the morphology of the Delta Cone. The river alluvium is already in a state of such fine subdivision as to defy further disintegration through mechanical weathering. In spite of high temperatures and abundant water, even chemical weathering is not highly significant, possibly because of the scarcity of humic acids in the soil. Chemical activity is represented by alkali concentrations, and by slight inclusions of organic material in the upper soil horizon.

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[1] From accounts of members of the Ansa expedition. Bolton's manuscript, previously cited.

The soils of the Delta Cone, and in fact of the whole alluvial surface, represent deposition rather than residual development. Their case is analogous to that of fresh glacial or loess soils. In texture they vary between narrow limits, from an adobe to a very fine sand. In their areal distribution over the surface of the delta they are indicative of the conditions under which they are deposited. The sandy soils are found close to the stream channels; the adobes are found in the beds of lakes and lagoons.

An excellent statement of these soil conditions is found in the report of the soil survey of the El Centra area:

"The soils of the El Centro area are all so young that they do not differ greatly from the geological formations which make up the surface deposits of the region. Very little progress has been made in soil development. On account of the extreme desert conditions which existed in the region until a very few years ago there was so slight a covering of native vegetation that the accumulation of organic material in the surface soil was very slight. The surface soils and the subsoils are, in this respect, very much alike. In some cases the surface soil is slightly darker than the subsoil, but this is not universal, so that as a whole it can be said that very little progress in the development of a surface soil with an important constituent of organic matter has been made.

As will be brought out in the description of the soils, the horizons found in them are horizons of deposition rather than those of soil development. They are geological horizons, strictly speaking, rather than soil horizons, although it should be borne in mind in this connection that soils and geological formations are identical at the period of time when deposition of material in a given area has stopped or become slow enough to permit the growth of plants. The stage of development of the soils of the El Centro area has passed but little beyond this most primitive stage.

The presence in the soil of a small, often very small, percentage of soluble salts seems to cause the development of well-defined soil horizons at an early stage in their

development. An amount of salts sufficient for such development is unquestionably present in a large part of this area, but on account of the extremely recent deposition of the soil material it is rather difficult to determine in many cases whether the presence of a heavy subsurface horizon is due to deposition or to soil development. It is clear, however, that the development has not gone far enough to warrant the separation of the soils on this basis. They have been differentiated, therefore, on the basis of features that have been inherited from the geological character of the material itself or from conditions of deposition."[1]

The agriculturist of this area makes soil distinctions based largely on texture. He recognizes the soil horizons as being depositional forms, and frequently can name the area from which the alluvium was derived. One advanced the following classification of soils:

1. Gray alluvium which cracks and remains coarse. (Probably a silt.)

2. Gray alluvium which breaks up into rather fine particles. (Silt mixed with small amount of sand.)

3. A reddish, adobe-like alluvium, as in the bed of Volcano Lake. (Colloidal material.)

4. A more broken, reddish alluvium. (Silt?)

5. A fine sand or quicksand.

6. A mixture of all.

Another advanced the following:

1. Hard, with something resembling hardpan. (Probably a silt or adobe with a subsurface concentration of soluble salts.)

2. A "buckshot" soil. Is the best agricultural soil and retains water well. (Mixture of silt and sand.)

3. Sand. Does not retain water.

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[1] Field Operations of the Bureau of Soils, 1919: p. 18.

These practical classifications have seized very well upon the distinguishing characteristics of these soils. It is notable that they make no place for alkali soils, and that is quite fitting, for on the well washed and well drained slopes of the Delta Cone there are no considerable alkali concentrations.

An areal classification of these soils becomes a matter of tracing out the recent morphologic history; with a knowledge of the peregrinations of the river it is possible to predict the type of soil to be found in any particular area. The alluvial burden of the river is so great and the deposits so thick that it is possible that there should be a complete change in soils with the flood of one summer.

A parallel case is that of the vegetation, which also shifts and changes with the course of the stream, and, to some extent, is associated with changes in the upper soil horizon. Within the mesophytic formation of the delta there is a nice adaptation to conditions of soil and water. As these conditions are changed by shifts in the course of the stream, so is the balance disturbed. MacDougal has depicted this very well for the lower portion of the Delta Cone:

> "The soil, climate, moisture, and temperature of the entire delta are fairly uniform, and also differ but little in elevation and exposure -- a condition which tends to promote the multiplication of the number of individuals of a few species of plants, and these species are also able to maintain themselves in pure culture to some extent. An analysis of the vegetation of the delta confirms this view. Canes (Phragmites), cattails (Typha),

willows (Salix), poplars (Populus), arrow-weed (Pluchea sericea), quelite (Amaranthus palmeri), wild hemp (Sesbania), each occupy extensive areas, to the almost total exclusion of other seed-plants, although there are many places in which several of these will be found contending for the mastery. In all such areas of unstable equilibrium some change of drainage, or of the action of the river, will be found as a disturbing cause."[1]

Where conditions are long stable, as they were about the old channel of the Colorado, and as they are about the head of the gulf, there is a corresponding adaptation and stabilization in the plant world. The screwbean (Prosopis pubescens) and mesquite (Prosopis velutinea) are rather widely distributed, and are found in areas of stable soil and water conditions. The cottonwood (Populus macdougalii) is most dominant in strips which border the old channel of the Colorado (pl. Xb).

Saline soils introduce special conditions which reduce the number of possible plant occupants. Characteristic of the saline soils about Volcano Lake are Achronychia cooperi and Atriplex fasciculata. In the areas subject to occasional tidal overflow are found salt-grass (Distichlis) and Cressa (pl. XIIIc).

The mesophytic plant formation of the Delta Cone is striking evidence of the modifications introduced into the desert by the presence of a large stream. Nor is this entirely a matter of increased water supply. Edaphic modifications wrought by the river are of decided importance, so that the line of contact between the river alluvium and the

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[1] MacDougal, D. T. The Delta of the Rio Colorado, Amer. Geogr. Soc., Bull., vol. 38: pp. 10-11. (1906)

sands and gravels of the colluvial aprons becomes a significant one. There are, about the margins of the delta, alluvial areas that are unwatered or alkaline. In such cases the vegetation is wanting or effects specialized forms to meet the conditions. But frequently the marginal contrast is a startling one, with an abrupt transition from mesophytic to xerophytic plant formations. On the silty floor there may be a dense growth of mesquite and arrow-weed, with a short rise to the mesa a formation dominated by ocotillo, creosote bush, and cactaceae.

If the Delta Cone has a unique and vigorous vegetation cover, so is it the home of a varied and abundant animal life. In the streams are found the beaver, muskrat, and a variety of fish. Land animals range in size from the mule deer and "lion" through the coyote to raccoons, rabbits, and lizards. Game birds include both aquatic and upland forms, while the non-game birds are represented by the crow, blackbird, turkey buzzard, and numerous other species.

The Delta Cone is, then, of all the natural areas of the delta region the only one which possesses the true deltaic form. It is also the area which offers the most striking contrasts to the desert within which it lies. In its morphologic development it has been nearly independent of the climatic factors. It represents truly the work of the Colorado River.

Pattie Basin --

It is quite possible that Pattie Basin represents a tectonic feature comparable to Borrego Valley, north of the international boundary. It is bounded on east and west by granitic ranges; along the base of both there runs a fault line. Definite evidence is lacking, but from the surface configuration of the basin it seems probable that it contains a deep fill. Colorado alluvium forms a surface veneer which slopes gently from the base of the Cucopas upward to the base of the Sierra Juarez. Underlying most of the surface is a substratum of sand and gravel derived from the Sierra Juarez.

The alluvium is a lacustrine deposit, undissected by stream channels, and bounded by a series of strand lines. The highest of these is the most marked and probably represents a continuation of the ancient beach line (pl. Va). The others are less well marked and represent stages of the ephemeral lakes that have occupied the basin from time to time. In part they are distinguishable only by virtue of the line of vegetation which marks them.

Within the basin there are distinguishable several surface types. The alluvium is composed of colloidal material, but around the edges there has been something of a mixture with wind blown sand. The basin is without drainage so that there has been extensive concentration of soluble salts. The vegetation cover is in no case abundant, but on the saline

surfaces it is entirely lacking. On a basis of soil texture, salinity, and vegetation cover, the types of surface may be distinguished as follows:

1. The salt beds. These lie in the lowest part of the depression when it is not occupied by a lake. Extensive deposits of crystallized salt of commerical importance.

2. The black-alkali surface. A smooth surface, without covering of vegetation cover. Moist and soft, beneath the surface, the moisture being held by the calcium and magnesium chlorides in the soil (pl. Xc).

3. The baked, crusty surface splotched with small hummocks which break under foot. Nearly barren of vegetation. The hummocks are characteristic developments on a drying surface (pl. XIa).

4. Shallow pans or troughs with a surface of hard, cracked alluvium. Little or no vegetation cover.

5. Flat surface of mixed sand and alluvium. Small accretion mounds of the same material capped with Sesuvium.

6. The sand hills. Fixed by vegetation. With flat tops which preserve something of a general level.

7. Colluvial sands and gravels. The apron which lies at the base of the Sierra Juarez. Composed of sand, gravel, and boulders. Cut by sandy washes. Abundant vegetation cover dominated by palo fierro and mesquite.

In the main the alluvium forms a great barren plain, with extensive areas perfectly destitute of vegetation, marked only by the white salt deposits or by patches of moist alkali soil. About the margin of the alluvium there are a number of water holes. With these there is introduced a comparative abundance of life forms.

Pozo Cenizo lies near the edge of the gravel terrace north of the tip of Las Tinajas Range, and marks the site where wells are dug down to a depth of eight to ten feet to water. The presence of water here probably represents nothing more than a subsurface sand or gravel stringer which reaches out from the terrace. About this site there are several mesquite trees. Fairly dense patches of arrow-weed are bordered by salt-grass. Animal life ranges from the occasional burro and coyote to the desert mouse.

Pozo Coyote, at the southern tip of Sierra Mayor, is another well of the same type as Pozo Cenizo. Its site gives something of a park-like appearance, with mesquites rising out of a mat of salt-grass. In common with the other wells of this area Pozo Coyote must be dug out and bailed before the water is usable (pl. XVIIIb).

North along the base of the Cucopas there is a hot spring whose waters register a temperature of from 112 to 128 degrees F. This lies along the fault line which bounds Pattie Basin on the east.

Coming into the area after the recent desiccation of one of the ephemeral lakes, MacDougal recognized a number of strand lines in terms of a banding of vegetation. For the highest strand he noted a zone of mesquite, below it a narrower zone occupied by salt-bush and mallows, while the lowest bore only clumps of sea-purslane.[1] At the present

[1] MacDougal, D. T. The Desert Basins of the Colorado Delta, Amer. Geogr. Soc., Bull., vol. 39: p. 722. (1907)

time the surface has been uncovered for a sufficient period so that the purslane extends far out over the plain, growing in scattered sandy hillocks.

Pattie Basin, then, is a structural depression which has been filled by sand and gravel derived from the adjacent mountains. Over these has been deposited a surface layer of river alluvium, laid down under lacustrine conditions. The alluvial surface is impregnated with soluble salts in varying degree. A large part of the area is without any vegetation cover; only near the margins where the water table is high and the soil less alkaline is it at all abundant.

The Gulf Plain --

This is the term applied to the area about the head of the gulf, where the littoral deposits are formed of alluvium derived from the Colorado. This is the realm of the sea, in which tide and wave have constructed a characteristic set of forms.

This area occupies a portion of the diastrophic depression, the gulf trough. It is bounded on the east by the San Jacinto fault and the Santa Clara Mesa, on the west by the Sierra de las Pintas. The alluvial fill in this depression must be a considerable one, for the water shoals rapidly from a depth of eighty fathoms east of San Felipe to a depth of eight fathoms east of Ometepec Bay. There is no reason for believing that this represents a rise in the rock floor which underlies

the alluvium. An interesting, but at present unexplainable, feature is the granitic island, Consag Rock. It has a pillar-like form and is surrounded by deep water. The natural inference is that it represents a fault sliver, but what its structural affiliations are is uncertain.

In profile the Gulf Plain resembles a flat "V", with the shores sloping gently up from the waters of the gulf which occupy the apex. This is the normal surface configuration to be expected of a sea-built shore; it stands in striking contrast to the gently convex surface of the Delta Cone.

Where the energy of the tide is concentrated, as near the mouth of the river, the shore line of the Gulf Plain is a nearly vertical bluff. Further south, where the tide is of less influence as an erosive agency, the shore line is gently shelving. Instead of a bluff it exhibits such features as bars, spits, and lagoons.

The surface of the Gulf Plain is generally barren and without relief. When wet this surface is composed of a very sticky mud. When dry it is salt encrusted. A portion of it, about the outer margins, is not subject to inundation even by the highest spring tides. This condition has probably come about due to uplift.

Along the shore there is a considerable cover of driftwood, brought down by the Colorado. In great part the plain is without vegetation but there are occasional clumps of alkali weed (Cressa) to which the mirage gives wierd properties.

Near the mouth of the river the plain is broken by the little channels which are tributary to the gulf. Their course across the plain is frequently marked by a border of vegetation, mesquite and Atriplex. The association of vegetation with these channels is not so much a matter of the occasional presence of fresh water as it is of reduced salinity of the soil.

The boundary between Delta Cone and Gulf Plain is one which has shifted southward with the progressive extension of the river channel. It is a slow process which has been carried out by innumerable floods and meandering of channels, with the superimposing of the convex surface of the Delta Cone over the Gulf Plain. It has meant an extension of all the forms which characterize the Cone surface: natural levees, lagoons, and dense vegetation.

Since the slopes of the two surfaces are gentle it is difficult to distinguish their line of contact by reference to profile alone. Much better as a marker is the contrast in vegetation introduced by differences in salinity of soil and water. Cottonwood and willow form a characteristic border along the old channel of the Colorado, but they do not grow on ground moistened with brackish water. In 1907 MacDougal found that the tide ascended to a point near Mesa Andrade and that the cottonwood-willow association did not descend beyond that point. Yet within the memories of old

Indians then living the limit of those trees had advanced a distance of eight or ten miles southward.[1]

In advance of the cottonwood-willow association, on land newly claimed by the Delta Cone, are found the mesquite and Atriplex. These forms are somewhat more tolerant of saline conditions. Tules grow even along the banks of streams affected by the tide, and sloughs of "wild rice" (Uniola palmeri) are found. On the saline soils are found the halophytes: iodine bush (Spirostachys occidentalis); on the mud flats, sedge (Scirpus fluviatilis); on the land subject to tidal overflow, salt-grass and alkali weed (pl. XIIIc).

To compensate for this loss at the north, the Gulf Plain has experienced steady growth at the south. Sykes' map of 1907 shows the plain as reaching to a point about ten miles south of Ometepec Bay. At the present time (1928) it extends in an ever narrowing wedge to the rocky mass of Punta San Felipe. Through a combination of tide, wave, and current, there is first effected a shallowing of the water along the shore. In the next stage the alluvium appears as an exposure at low tide (pl. IXa). In the final stage it appears as a wide plain, inundated only by the highest tides.

Were the old regimen of the Colorado continued, the Gulf Plain and the Delta Cone would advance to the south in

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[1] Carnegie Inst., Publ. 99: p. 34.

the gulf trough. Upstream from the Delta Cone there would be developed the normal valley profile of the river having great seasonal fluctuation in volume: natural levees, with the flood plain sloping gently down to the valley walls. As it is, with the diversion of much of the river's volume, and the loss of much of its alluvial burden, it is quite probable that there has been reached something of a condition of stability, and that further shifts will be slight.

The contact between the alluvium of the Gulf Plain and the bordering sands and gravels is a distinct one. Since the effect of the ephemeral streams is slight, the only mixture of silty alluvium with sand is through the medium of the wind, and this is not considerable.

Equally abrupt is the transition in vegetation cover, from the nearly vegetationless Gulf Plain to the sands and gravels, with their highly specialized xerophytic flora. For the area north of Punta San Felipe, MacDougal has described this contact so well that his account may be quoted at some length:

"The lower coastal slopes are sandy and gravelly, the depressions and dunes near the shore furnishing suitable conditions for Lycium torreyi [squaw thorn] and Parosela spinosa [smoke tree] , which latter becomes a tree 25 feet in height. Ascelepias subulata was abundant in clumps, and Ditaxis serrata grew on level areas. Other species which were characteristic of the lower levels were Ibervillea sp., Croton californicum, Lupinus mexicanus, and the curious Frankenia palmeri [yerba reuma] . The low alkaline pockets reached by the spring tides furnished conditions suitable for Spirotachys occidentalis [iodine bush] . Covillea [creosote bush] , with its enormous capacity of adjustment,

extended from near the shore across the entire slope and up the granite mountains through a range of over 2,000 feet in elevation. The various portions of the slope between the sea and the first range of coastal mountains supported ocotillo (Fouquieria splendens), which attained its maximum height of 30 feet, palo verde (Parkinsonia microphylla), palo fierro (Olneya tesota), and Gaertneria ilicifolia. .... in 1904 a new copal tree was found, Terebinthus macdougali, which also is now known to occur on the eastern shore of the Gulf, and which secretes a resin so copiously as to make a distinct deposit on the ground underneath the low-spreading branches.

The streamways leading down from the mountains were inhabited by a number of eriogonums and euphorbiaceous herbs. A few opuntias of the cylindrical arboreous type, an Echinocactus [garambuyo?], a Cactus, and a small Cereus were also seen. Pilocereus sargentianus, which is found on the mainland far southward, here reaches the greatest density yet observed, forming forests many acres in extent. Perhaps the most notable feature from a geographical point of view was shown by the presence of a great tree-cactus having the appearance of Cereus pectenaboriginum. Cereus pringlei is known to be abundant, under the name of "cardon" farther south, but this plant appears to agree with the former and makes a splendid picture in the arid landscape, finding here its extreme northern limit of known occurrence."[1] (Pls. XIb, XIIIb).

The Desert Ranges --

The Cucopas

This natural area includes the mountain chain extending from Centinela on the north to Sierra Mayor on the south, and in addition the flanking deposits of sand and gravel. It escapes being an island in a sea of silt only by virtue of the low rocky ridge which connects it on the north with the Peninsular Range.

Though it forms a topographic unit and may properly be considered a natural area, the range is not at all homogeneous

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[1] Carnegie Inst. of Wash., Publ. 99: pp. 42-43. (1908)

in make-up nor is it a simple and unit structural feature. From north to south along the range there are recognizable four distinct structures: (1) the semi-isolated Cerro Centinela; (2) the granitic massif of which Cerro Borrego is the culminating peak; (3) the metamorphic and volcanic hills, locally known as the "Cucopas"; (4) the granitic Sierra Mayor.

With the exception of the "Cucopas" the whole range is essentially granitic, but there appear patches and exposures of other rocks which are suggestive concerning the geologic history of the area. A dark diorite flanks Sierra Mayor in places along its eastern side and appears in patches on some of its higher peaks (pls. Ic, IIc). The contact between the two is sharp, the diorite being somewhat metamorphosed. Farther north along the base of Mayor the diorite is succeeded by a highly distorted schist, and at one site there is an exposure of a bedded quartzite, recently faulted. The presence of these distorted, metamorphosed rocks may be indicative of the laccolithic nature of Sierra Mayor.

The low-lying hills north of Mayor possess a granitic core, intrusive in a mass of highly distorted and broken metamorphics. Near the contact of these hills with Sierra Mayor there is found a deposit of sulphur, probably derived from recent solfataric activity.

Flanking Centinela on north and west is a massive sandstone, probably Tertiary in age. High on the side of the mountain this same formation appears as a true quartzite.

It seems probable that this indicates metamorphism which has taken place long subsequent to the formation of the mountain as a laccolith or batholith.

Minor faults are abundant and distinct, and the evidence is sufficient to postulate a more extensive one which extends the length of the range. It lies along the western sides of Centinela and of the Cerro Borrego massif. Here its course is marked by an escarpment and hot springs. It passes through the Cucopa Hills and along the eastern side of Sierra Mayor. In the Cucopa Hills the course of the fault is at least suggested by the sulphur deposits, and along Mayor it is abundantly indicated topographically (pl. Ic).

Sierra Mayor and Cerro Borrego meet Bryan's definition of a typical sierra as being a mountain which is "longer than it is broad and presents to the observer, when viewed from the side, a jagged crest, which decreases in altitude from a point near the middle toward each end."[1] (pl. IIc). They further qualify by possessing slopes scored by narrow gorges or canyons, between which are projecting ridges.

The residual surfaces of the granitic masses are scored in the characteristic inverted "V" pattern, with systematically distributed cliffy slopes indicative of faulting. In this they stand in striking contrast to the Cucopa Hills, where

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[1] Contributions to the Geography of the United States, 1922, U. S. Geol. Surv., Bull. 730: p. 90. (1923)

the heterogeniety of rock and structure has resulted in the development of a very irregular pattern.

Along the base of the whole range there are detrital sands and gravels which display gently convex depositional profiles about the mouths of the larger reentrants, and then merge into the general level of the piedmont apron. Along the eastern front of the range the apron terminates abruptly in a scarp face, and unfailingly shows dissection. Along the western side of the range there are a number of well developed alluvial fans whose slopes merge naturally with the floor of Laguna Salada. But even these are densely covered with mesquite and give the impression of being quiescent, or only occasionally active.

The Cucopas are not of sufficient height to induce an appreciably greater precipitation so that they share the general aridity of the desert within which they lie. Their altitude is sufficient, however, to bring something of a temperature reduction, as is indicated by an occasional snow cover on the higher peaks. This certainly means a reduced evaporation rate, with its possible significance for plant life.

But few springs are known for the area. There are several along the western base of the range, one of which is hot. High up on Borrego Peak there is a small valley which contains a permanent spring, the water from which supports a grove of native palms (Neowashingtonia). This is the only known occurrence of palms in the range.

A portion of the precipitation is retained by rock tanks or tinajas. The most significant ones are those formed by irregularities in the beds of the ephemeral streams. The larger ones are found at the foot of falls where the dropping water erodes a basin in the solid rock. Others are formed through the erosion of a section of bedrock less resistant to abrasion than the rocks which surround it. Still others are found in coarsely jointed rock where the joint plane dips upstream. Through the removal of a portion of the rock between two joint planes there is formed a rock tank. Very few of these tanks retain water throughout the year. Several days spent about Sierra Mayor in midsummer failed to reveal one that contained water. The fact that wild sheep were seen on the mountain may mean that the tanks containing water were simply not encountered.

The vegetation cover of the Cucopas is of a character most nearly related to that of the arid areas of Arizona and Sonora. Due to its isolated position and to its geologically recent island or peninsular form, the area contains a number of endemic plant species.[1] In general it is characterized by the creosote bush-ocotillo-cactaceae association common to the rocky areas of the whole delta region.

On the rocky aprons at the foot of the slopes are found the members of this association, together with the palo fierro,

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[1]Carnegie Inst. of Wash., Publ. 90: p. 41.

and occasionally mesquite in the sandy washes. Terebinthus, Gaertneria, the prickly pears (Opuntia bigelovi and O. prolifera), Cactus, and Echinocactus, according to MacDougal, find suitable habitats to within a few feet of the summit at 3,500 feet.[1]

Near the summit elevations there appears a bunch grass and a maguey, possibly Agave consociata. Just why this maguey is so restricted in distribution is not clear. It is highly valued by the natives, both as being edible and as furnishing the base for a distilled liquor. Possibly its absence on the lower slopes represents a removal by man of the individuals growing there. On the other hand, it does not appear on the Peninsular Range until elevations of around 2,500 feet have been reached, so possibly its habitat is restricted by climatic conditions. The small but distinct temperature range existing between the base and summit of the Cucopas might then be sufficient as a determining factor in its range.

The range is sufficiently mineralized to induce occasional mining attempts. Some twenty-five years ago there was fairly successful exploitation of the gold placers near El Mayor. The sulphur deposits of the Cucopa Hills were worked for a number of years, and the sulphur was shipped out by river boat. At present there is under way at least one attempt at the exploitation of vein gold.

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[1] Ibid.: p. 41.

The Sierra de las Pintas

This natural area includes the irregular mass of volcanic forms bounding the Gulf Plain on the west, and is really marginal to the delta region. A few of the volcanic outliers are surrounded by the silt of the Gulf Plain. Others are isolated in the great plain of arkosic sands and gravels derived from the granitic ranges to the west.

With the exception of the more ephemeral delta forms these late Tertiary extrusives are the youngest features of the landscape. It is possible that the area is still active volcanically. On the night of June 9, 1928, there was visible from El Doctor, on Santa Clara Mesa, a phenomenon hard to explain on any basis other than that of volcanic eruption. In the sky, slightly to the west of south, there appeared a red glow which became successively weaker and stronger. Through night glasses there was visible a pall of smoke, and on one occasion there appeared what resembled a lava stream breaking over a crater rim. A rough bearing placed the site in line with the volcanic area west of the gulf. The horizon in that direction appeared to be somewhat smoky on the following day. The general region, the strong improbability of human agency, the appearance of the phenomenon itself, all favor an explanation based on volcanic activity.

Without doubt, the great mass of these extrusives is much older, but they are sufficiently young that denudation

and erosion have not yet destroyed the individual character of the component parts. The surface of this whole area is marked by a wierd assembly of diverse forms: cones, stocks, lava-capped mesas, and flat-lying and tilted flows (pls. VIIa, XIIa).

About the base of these mountains there are great accumulations of detritus whose profiles are adjusted to various angles of repose, suited to the nature of the constituent materials. As a whole this material is poorly rounded, though it is occasionally cut by steep-walled erosion channels, and to some extent has been carried out onto the plain to lie in attenuated rows, beveled by an ancient sea.

Water resources are meager. There are reputed to be a few springs of poor water; even the tinajas are few. The water sheds are small in area and extremely irregular in form. About some of the washes which lead out from the larger mountains there are quite convincing appearances of the proximity of water. The growth of palo fierro, palo verde, and mesquite is heavy; bird and mammal life is well represented. Yet an ascent of several of these washes in midsummer failed to reveal a single spring or tank, and attempts at digging were fruitless. Possibly the animals get their water from a distance; the flora must depend upon the very occasional rains.

The aridity and lack of soil of the residual surfaces is reflected in the scanty vegetation cover. About the lower,

detrital slopes there may be a few shrubs; the higher slopes are frequently barren.

Precious minerals are present in these mountains. At least one silver-gold mine was operated on a rather extensive scale for some time, during the early part of the century. An occasional prospector traverses the area; otherwise it is deserted by man.

CHAPTER 8 -- THE PRIMITIVE STAGE

Introduction to Chapters on the Cultural Landscape --

The development of the cultural landscape in the Colorado Delta area may be divided into three stages: the primitive and exploratory stages, and the stage of exploitation. These three stages are more than time intervals. They involve the employment of different sets of cultural tools in effecting alterations in the landscape. To some extent they mark the dominance of different racial stocks.

The primitive stage is the stage of the Indian. He had at his command a certain set of tools, a scope of activities limited by his cultural heritage. He was primarily concerned with providing food and shelter for himself and family.

The exploratory stage involves the delta both as objective and as passageway. Those travelling through the area were interested in roads and trails, feed for their animals, water, perhaps in supplies of food for themselves. The explorers were occupied with surveys, estimates of natural resources, and studies of the Indians. They determined, among other things, the culturally significant international boundary line.

The stage of exploitation has carried with it the idea of taking commercial products from the land. The scope of activities has ranged from the trapping of beaver to the

planting of cotton. It is during this period that man has effected the greatest alterations in the landscape.

If there is any one feature of the natural landscape which has retained its importance in the successive cultural landscapes, and has given them a degree of unity, it is the Colorado River. As the source of water in a climatic desert, as a potentially destructive force, the river has maintained its significance throughout the period of man's occupation of the area.

The Primitive Stage --

The reconstruction of the primitive landscape proceeds through several lines of evidence: the interpretation of artifacts, documentary evidence, by inference from surviving vestiges, by word of mouth from living Indians. The task is not to reconstruct the first stage of an evolving culture, for the newer culture has inherited very little from the old. What may be recovered of the ancient scene and compared with the modern condition of the local Indians does afford a measure of the site value of the Colorado Delta for primitive culture.

Prehistory --

The evidence is scant for postulating a prehistoric culture apparently not ancestral to the later primitive culture. It rests principally on reported adobe ruins, and reported finds of polychrome pottery. There is some other

evidence in the extensive shell mounds, wide scattering of pottery fragments, old sites about water holes, roof-smoked caves, mortars in granite boulders, and well worn trails, but these might all well be expressions of historic cultures.

About the existence of adobe ruins there can be little question. The first report of them encountered is from Ansa in 1775.[1] In a report written to his superior officer from Sta. Olalla[2] he speaks of an ancient Indian edifice examined, three leagues (about nine miles) from "here". He explains it as part of an attempt to establish a Mexican empire. The direction from Sta. Olalla is not clear and it is possible that "here" refers to some other point. At best this is no more than supporting evidence.

Another reference appears in Hardy's account of 1827. He says:

> "Near our present situation [half a league above the mouth of the "Gila"[3]] is one of those old ruins which are supposed to mark out the progressive march of the Aztecs from the north to Mexico. It is called by the natives "Casas Grandas", but the Indians have no tradition respecting its former occupiers, -- none, at least, that I could learn."[4]

There was an Axua (Kamia) settlement about the ruins, which were evidently somewhere east of the river. Hardy

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[1] From Professor Bolton's mms., previously cited.

[2] Professor Bolton fixes the site of Sta. Olalla as near the present Pescadero Dam.

[3] This is Hardy's own statement and, of course, is an error. He thought that he was near the mouth of the Gila, when in fact he was near the junction of the Hardy and Colorado.

[4] Travels in the Interior of Mexico: p. 333.

speaks of the ruins without any suggestion of question as to their existence, but does not state clearly whether or not he or any of his men saw them.

In 1928 an old cowboy, long familiar with the area, said that in 1904 he had seen old adobe ruins south of the junction of the Hardy and Colorado, that they had walls which were eight feet thick and ten feet high, and that no one knew of their origin. His site agrees very well with that of Hardy.

Still, this is not conclusive evidence of the antiquity of those ruins. Hardy's Kamia may not have informed him correctly. The idea still persists among the delta people that there was established for the Cocopa and Papago, a submission, Sta. Clara. The historical accounts show that the early missionaries were on the lookout for building sites along the lower river. Only a thorough examination of the site and the finding of artifacts can establish its genuine prehistoric character.

The pottery evidence is even more ephemeral. When questioned concerning pottery found about the sandstone mesa of the Sonora side, the finders asserted that it was polychrome. No specimens were seen. It is an interesting aside that with respect to the present Indian pottery of the area Kroeber sees it as rather closely paralleling the prehistoric ware from the Papago and Gila country. He sees among the possibilities a direct stimulus or importation from Sonora.[1]

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[1]Kroeber, A. L., Handbook of the Indians of California, Bur. of Am. Eth., Bull. 78: p. 823. (1925)

There are numerous and extensive shell mounds about the head of the gulf, but in every site observed they were made up of forms still to be found living in close proximity (pl. XVIa). In at least one instance there was a suggestion of mounds of varying age associated with different levels of the sea, but even this is not particularly significant, in this area of rapid changes of elevation.

About Pozo Cenizo and Pozo Coyote (on the margins of Pattie Basin) there are numerous potsherds and bits of charred wood. This merely demonstrates that these sites have been for a long time significant ones. The same holds true for Agua Palmita at the base of the Juarez, where the granite rocks are pitted with mortars, and caves in the conglomerate have smoke-blackened roofs.

This leaves the evidence for a prehistoric culture pretty much with the adobe ruins and possibly with the pottery. It is clearly evident that these need further investigation before they are of any value as evidence.

Historic Cultures --

The Indian tribes of the Colorado Delta were all of the Yuman stock. This linguistic group extended its territory to include the Mohave on the north and the Diegueño on the west. To the south the Yuman Kiliwa controlled the area about San Felipe. The Papago, a non-Yuman tribe, claimed the gulf coast, south from Santa Clara slough.

In addition to linguistic unity the tribes about the lower Colorado possessed a cultural unity with a typical culture that partakes of the qualities both of the Southwestern and Californian cultures. However, it has sufficient distinguishing characteristics so that it is not to be regarded as merely transitional between the cultures to east and west.[1]

This culture possesses agriculture and pottery, but poor basketry. It possesses a tribal sense and recognizes hereditary chieftanship. There obtains a well developed military spirit, with use of the shield and club, as well as the bow and arrow, as implements of warfare. There is a sense of communal ownership of property and lack of regard for wealth. This culture lacks the loom and has very simple clothing. Cremation is prescribed for the dead, and also for the personal belongings of the deceased.

Among the material expressions of this culture is the semi-subterranean house, used in winter. A pit was dug and about this logs were up-ended. These were covered with wood and brush and the whole plastered over with dirt. In summer there were simple brush shelters or flat roofs of brush raised aloft on four poles.

A crude tule balsa was occasionally used for ferrying, but the Indians were excellent swimmers and that was the general method used in crossing streams.

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[1] From Kroeber's Handbook, previously cited.

These people possessed no harpoon for use in fishing but they did have a net, woven from wild hemp or willow, which was mounted at the ends of two long poles. They also used a basketry fish trap woven from willow.

As has been suggested, basketry was simple in technique and small in amount. They made trays, fish traps and a large storage basket for corn.

Pottery, on the other hand, was well developed. They used a clay tempered with ground rock which burned red. The pots were decorated with designs in yellow ochre. They possessed a variety of forms and sizes and sometimes were formed from thin spiral coils and smoothed with a paddle and rock.

Clothing was very simple. The women occasionally wore a skirt made of shredded willow bark, but more often a simple breech clout. The men used only a gee-string. No foot covering was the ordinary thing, but at least in later times rawhide sandals were used.

They used only the simple bow which was ordinarily made of willow and strung with a cord of wild hemp. The arrows were of cane and arrow-weed, were feathered, and at least in part tipped with mesquite.

The Delta Tribes --

Of the numbers and tribal distinctions of the Indians living in the delta during the historic period there exist

a number of accounts. These range in time from the account of Alarcón for 1540 to those of the latest visitors to the area. It is difficult to reconcile all these accounts with respect to the areal division among the several tribes. All the tribal names are not to be identified in terms of those now known, nor, in fact, with those of other visitors to the area. Either the recorders gave different names to the same groups, or confused the groups, or else there was a real shift of tribes. But for the geographer this is not particularly important, for shifting groups did not mean shifting cultures. Unity of culture characterized all these Yuman tribes inhabiting the delta. As Kroeber says:

> "Alarcón and Melchior Díaz in 1540, Oñate in 1605, Kino in 1702, Garcés in 1776, accordingly found conditions on the river much as they were when the Americans came. The tribes battled, shifted, and now and then disappeared. The uppermost and lowest were the same for three hundred years: Mohave and Cucopa. Among the conflicts, customs remained stable. If civilization developed, it was inwardly; the basis and manner of life were conservative."[1]

But what to the geographer is significant in the old accounts is the general idea that he gets of the wealth of agricultural products raised by primitive methods, and of the enormous number of people dwelling in villages along the river. Oñate's[2] estimate of the number of people living along the left bank of the river, from the mouth of

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[1] Kroeber, A. L. Yuman Tribes of the Lower Colorado, Univ. Calif. Publ. Am. Arch. Ethn., vol. 16, no. 8: p. 485. (1920)

[2] Zárate-Salmerón, Relación, Translation in Bolton, Spanish Exploration in the Southwest: p. 276. (1916)

the Gila down to the gulf, is around 22,000. This is for 1605. Later reports are not so detailed as Oñate's but they convey the impression that there was no decrease in population. Even in 1827 some 5,000 Indians gathered about Hardy's[1] ship near the confluence of the Hardy and Colorado.

Though Oñate travelled down the east bank of the river, that is, the Arizona- Sonora side, possibly his estimate of the number of Indians fairly well covers the lower river area. From the list of tribes that he enumerates, only two, the Yuma and Kamia, are conspicuously missing. There are reasons for believing that the Kamia came late into the area. Since the river annually overflowed its banks the villages were not permanent ones. It is quite possible that in the year of Oñate's visit the bulk of the Indians was concentrated on the east bank of the river. If such was the case, 22,000 may be accepted as an estimate of the total number of Indians living in the delta area. If the region west of the river was equally densely populated, the first estimate must be at least doubled.

The total arable area for 1605 may be roughly estimated at 300,000 acres. This figure represents the area anually inundated from the old channel of the Colorado, minus certain non-tillable sections. These include the swampy lands and areas of saline soils. The estimate does not allow for native vegetation. Most of the area was covered with annuals, readily removable by a process which the Indians understood -- burning.

[1] Op. cit.: p. 355.

Using the population figure, 22,000, there was available for each person nearly fourteen acres of arable land. If 44,000 is used, the result is seven acres per person. The evidence seems to favor the first figure as being more nearly correct.

There is undoubtedly a great discrepancy between the area available and the area utilized. The Indians did not burn off the vegetation extensively; they practiced no regular field system. There did not exist the inter-tribal friendship and agreement necessary to a full utilization of the available land.

Coming down to modern times, within the memory and tradition of those still living, there remain but three groups of all the Yuman tribes once occupying the delta area: the Yuma, the Diegueño, and the Cocopa. The Yuma are found extending down to the vicinity of Pilot Knob and along the Sonora mesa, the Diegueño (Kamia) in a large village near the present site of Dieguinos on the Inter-California Railroad, and the Cocopa in the region between the Hardy and the Colorado.

Of these three, the Cocopa are the dwellers most abundant in that part of the delta with which this paper is most concerned. With the Cocopa as typical of the Indian groups who have occupied this area it may not be amiss to attempt to reconstruct in some detail their way of living previous to the intrusion of European influence.

The Cocopa say that they were created and have always lived about the Hardy. It was to the west of the river, along the base of the Cucopas, that they moved when the bottom land was inundated during the summer months. On the gravel terraces they erected their summer houses, flat roofs raised on four poles, thatching with willow and arrow-weed, sometimes tule. These simple structures provided protection from the burning summer sun. As they were largely without walls and stood alone on the terraces they were exposed to all the winds. This exposure was of decided advantage in that it tended to hold down the sensible temperature and to reduce the number of mosquitoes.

As the flood waters retreated, the Cocopa moved out onto the delta and planted their crops. About the banks of streams and near the lagoons they planted beans, pumpkins, watermelons, squashes, and gourds. Particularly favored sites for corn and melons were the dried and cracked depressions. The hardened crust was removed and the seeds planted in the moist soil below.

In late summer there was a movement down stream to a large island near the mouth of the Hardy. Here were gathered the seeds of the water grass and wild rice. A portion of this was stored away in earthen jars. At the same time others were gathering the seed of the quelite, which was found on the open high ground subject to annual overflow. Others were gathering the beans of the mesquite and screwbean. Along the

gravelly slopes of the mountains the other leguminous trees -- the palo fierro and palo verde -- yielded their fruit.[1]

The seeds were pounded, or parched and pounded and the meal made into mush or pinole. The quelite seeds were first leached. The mesquite pods were dried and stored. In their preparation pods and beans were pounded in a large mortar, using a mesquite club as a pestle. This pounded mass was placed in a jar with water and permitted to ferment. The result was an agreeable food, evidently with some power to intoxicate.

Annually the Cocopa made trips to the mountains of the Juarez. The Paipai who dwelled there, another Yuman group, were generally friends of the Cocopa, and occasionally allies in warfare waged against the Yuma. The purpose of the trips was for the gathering of pinon nuts and acorns, and for obtaining wild sheep skins from the Paipai.

The trip to the mountains, across the dry and desolate Pattie Basin, was a difficult one, and the routes followed had to be so chosen as to take full advantage of the available water. As a result certain trails became established, with dire results for the one who wandered from them. Accord-

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[1] water grass ..... Echinochloa crusgalli
wild rice ..... Uniola palmeri
quelite ..... Amaranthus palmeri
mesquite ..... Prosopis velutinea
screwbean ..... Prosopis odovata
palo verde ..... Cercidium torreyanum
palo fierro ..... Olneya tesota

ing to MacDougal[1] one of these trails led westward through the palm valley on the flank of Borrego peak, descended the western side, coming out near the perennial spring, Agua de las Mujeres, and then struck across the plain to the mouth of Palomar Canyon, at the base of the Sierra Juarez.

Another trail led across the low range north of Sierra Mayor and passed directly across to the Sierra Juarez. Still another passed around the southern point of Mayor to Pozo Coyote. From Pozo Coyote the trail split, one branch going to Pozo Cenizo (pl. XIIb), another to the tanks at the north end of the Tinaja Range, another to the south through Tres Pozos and Arroyo Grande to the mountains. The water holes which lie on these old trails reveal their former importance in the great mass of potsherds, charred wood, and other artifacts which lie scattered about them. The Cocopa say that they carried no water on these trips but did carry fire. For people without horses these trips were sufficiently risky that when a small party was leaving, friends accompanied it to Pozo Coyote and remained there until signal smokes informed them of the party's safe arrival at the next water.

Another trail which still runs along the base of the mountains far down into the Sierra Pintas, was followed annually to the clam beds near the head of the gulf. According to reports there was water there and an abundance of driftwood.

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[1]Amer. Geogr. Soc., Bull., vol. 39: p. 729. (1907)

When it was time for harvesting the crops, the melons and pumpkins were brought together in a big pile on the ground and covered with brush. Here they were left until used. The seeds were not wasted; those in excess of the ones needed for the following year's planting were preserved as food. The corn and beans were stored in round willow baskets, as large as five feet in diameter. The baskets were covered with a cone-shaped cap and placed in trees or on platforms.

The winter dwelling sites were down in the bottoms, near the fields and stored food. The houses were variously constructed from posts, driftwood, and brush. They generally had their base in an excavation over which there was constructed a framework of posts. The framework was covered with wood or brush and finally with mud. The structure had only an entrance -- no window or smoke hole. On cold winter nights the interior was heated by a preparatory fire which was raked out when the Indians wished to retire. Then they literally piled in thickly on top of a ground cover of skins, closed the entrance tightly, and were snug for the night.

Particularly in spring were the green sprouts of the tule edible, as were the bulbs of the same plants. From April on, the agave was gathered and the core baked. If the present distribution of this plant be indicative, the

agave was gathered only at the expense of climbing far up the precipitous Cucopas.[1]

Fishing, and particularly hunting, seem to have been decidedly secondary to agriculture and gathering as a source of food supply. The area still abounds in game and fish but the Cocopa seem to have been poor hunters and fishers.

For fishing the Cocopa did not have the harpoon but they did have a net mounted on the ends of long poles with which they dipped fish out. They also had a basketry trap made of willow.

They hunted with the bow and arrow and took upland deer, birds, water fowl, and rabbits. In hunting the latter they burned the inflammable tule and shot the rabbits as they rushed out. They took young ducks around the edges of ponds, and are said to have used the corral in hunting deer. Meat was never refused because of its age, but was roasted to a crisp, eaten and enjoyed.

The delta area was a country of abundant food supplies, and even for a non-agricultural people would have supported a large population. There is no indication that it was ever visited by famine.

Modifications in the Native Culture --

Strictly speaking the primitive culture stage ceased to be when it came in contact with elements of culture derived from the European. But the change was slow and it may be

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[1] tule ..... Typha latifolia?
agave..... Agave consociata?

said that these Indians preserved their own culture up until 1850 in quite unadulterated form.

Garcés[1] found the horse among the Yuma and mentions fields of wheat and millet, in 1774. The grain was grown in the open spaces subject to overflow. Hardy[2] says that he was presented with baskets of raw cotton by the Axua, in 1827. Emory[3] found sugar cane growing in the area in 1850. Cattle were brought into the region at the time of the Ansa expedition but seem not to have survivied to extend the breed. At some comparatively modern date a number of swine were turned loose in the area. The fierceness of the "wild tuskers" became proverbial.

It is impossible to accurately date the introduction of European plants among the delta Indians, nor is the manner of introduction known. Possibly it was by a process of inter-tribal transfer from the east: from the Maricopa to the Yuma, and from the Yuma to the Cocopa.

The Cocopa never became horse people, even to the extent that the Yuma did. They seem always to have regarded a horse principally with an eye to his edibility. When herds of cattle and horses were being taken to California in the fifties of the last century the Indians frequently claimed

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1. Diaries and reports of the Ansa expedition, previously cited.

2. Op. cit.: p. 339.

3. Boundary Survey, previously cited, vol. 1: p. 49.

their share. They had arranged a system of smoke signals whereby they might know of the approach of the herds. With a nice discrimination they knew that the cattle and horses on the long trail from Texas were hardly worth taking. Those beasts captured were run to the lower river, fattened and eaten.

The cargoes of the first steamboats on the Colorado the Indians considered as legitimate prey. They stole when they could and as these boats carried mostly supplies for the post at Yuma and surrounding country, the Indians gradually acquired a taste for white man's food. This point is nicely illustrated in a story told by an old Cocopa, still living. When he was a grown man he and some friends managed to secure a sack of bean-coffee from a steamer. Thinking that these rounded pellets were beans they tried to prepare them in the customary manner and were considerably enlightened in the attempt.

During the heyday of navigation on the Colorado the Indians formed a part of the boat crews. With these associations they learned many things which they inculcated into the culture of their tribe. They began to wear clothes; coffee, sugar, and white man's tobacco became necessities; the bow and arrow became secondary to the rifle. With this there came a corresponding neglect of their own culture.

With the closing years of the 19th century came the great cattle period of the delta. Apparently the Indians had

learned by this time that all was not communal property for there are few accounts of difficulties between them and the cowboys.

In the beginning of the Imperial Valley development the Indians furnished a significant part of the labor used in constructing the irrigation system and in leveling the ground for agriculture. They continued to be important as laborers until they were excluded by an immigration ruling.

Present Status of Cocopa Culture --

In spite of all these contacts the Cocopa is still an Indian; he has not made the easy transition and become a Mexican. He is easily distinguishable by his long hair which he wears piled around his head, wrapped with a rag. Occasionally, he works about the ranches or on the railroad; more often he is to be found living off the travelled way, around some little lagoon. The Cocopa still move with the overflow and practice some agriculture. They may be seen walking across Pattie Basin on the long trek to the mountains, or be found camping at some desert water hole. The women still gather seeds and prepare them in the old manner. They all remain good pagans, have their "doctors", and cremate their dead.

But what they have retained is nothing to what they have lost. Their agriculture has decreased in proportion to their taking over of white man's food, which comes in boxes, bags, and tin cans. Sugar and coffee are indispensable. To some

extent they have absorbed the cattle tradition from the ranch days. Their house types have been modified almost beyond recognition.

But what is most striking is the decrease in number. Even discounting the early estimates of the population, and Hardy's thousands in 1827, it is startling that they should be reduced in number to MacDougal's estimate of three hundred for 1906,[1] and for the present certainly no more. There probably remained considerable numbers of Cocopa until the middle of the last century. Since then increasing contact with the Europeans has taken its toll.

The link between the old and new cultures is not strong. Some of the old sites, such as the mouth of the Gila and desert water holes, maintain their same significance. But the old culture pattern is obliterated by the new.

As a final estimate of the site value of the lower Colorado for a primitive culture it may be said that while it did not produce any great historic cultures, it did produce a distinct culture group, and it provided an abundant living for a dense population.

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[1] Amer. Geogr. Soc., Bull., vol. 38: p. 14. (1906)

CHAPTER 9 -- THE EXPLORATORY STAGE

The exploratory stage has involved an interpretation and description of the natural landscape of the Colorado Delta. Somewhat incidentally there has been an examination of the primitive landscape. The work of this stage has been carried on by priest, explorer, surveyor, prospector, trader, trapper, and ordinary traveller. In part the delta area has been the one of principal concern to these individuals; in part it has been the corridor through which they were forced on the road to California.

Aside from the determination of the nature and resources of the country, this stage has left certain material contributions to the cultural landscape, some of which still retain their significance. Roads and political boundaries were laid out; boat, stage, and railroad lines constructed; certain sites, such as that at the mouth of the Gila, were given impetus through early settlement by Europeans.

Preliminary Expeditions --

Ulloa appears to have been the first European to visit the delta area. Sent out on a trip of exploration by Cortés in 1539, he sailed to the head of the gulf, turned south, rounded Cape San Lucas, and passed northward along the west coast.[1] By this trip he demonstrated the peninsular nature of what was then called California.

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[1]Bolton, H. E. Spanish Exploration in the Southwest, 1542-1706: p. 5. (1916)

As a part of the Coronado expedition, dispatched by Mendoza in 1540, Alarcón sailed up the gulf and ascended the Colorado for a distance.[1] He made excellent and extensive observations of the native culture. The pilot, Castillo, made a map of the gulf showing California as a peninsula.[2]

Later in the same year (1540) Melchior Díaz reached the delta at a point below the mouth of the Gila. Thus he was the first European who made a recorded trip to the area overland.

Oñate visited the delta in 1604, making the overland journey from New Mexico. He descended the Colorado to its mouth, making pertinent observations concerning the distribution and number of the Indians. Oñate was impressed by what he considered to be a large, excellent harbor at the mouth of the Colorado. Among the Ozara, who occupied the site about the mouth of the Gila, were seen mantas of cotton,

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[1] Alarcón, Fernando de. Relación, English translation in Hakluyt, Voyages, 3. (1600)

[2] A reproduction of Castillo's map appears as plate 3 in Sykes' article in MacDougal's Salton Sea, op. cit. Sykes is responsible for the statement that the map was first published in 1770, and ably discusses its influence upon currently made European maps, covering the Western Hemisphere.

acorns, and large sea shells. The Indians said that the acorns and shells were brought from the west. This report should have suggested a direct land connection with the Pacific, but influenced by the accounts of the Indians, Oñate believed that an arm of the gulf extended to the northward, beyond the first ranges of mountains. Quite possibly the Indians were attempting only to describe Pattie Basin and its ephemeral lakes.

These three expeditions should have settled once and for all any question as to the peninsular nature of California, but most certainly they did not. Ortelius' map of 1564 represents California correctly, as does the Typus Orbis Terrarum, from the Ortelius Atlas of 1570, Forlani's map of 1574, and Wytfliet's[1] map of 1597.[2] But Henry Briggs' map of 1622 shows California as an island, and represents for this time the ideas not only of European cartographers, but also those of the Spaniards in Mexico.

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[1] The Wytfliet map, together with a number of others, appears in Sykes' article in the Salton Sea. Sykes is particularly interested in these maps as they reveal conditions about the head of the gulf: hydrography, coast line, etc.

[2] All of these, with the exception of the Wytfliet map, together with a number of others, are reproduced in Henry R. Wagner's Some Imaginary California Geography, appearing in the Proceedings of the American Antiquarian Society, April, 1926. Mr. Wagner treats exhaustively and in an able manner the cartographic and written history of three fables: the Mythical City of Quivira, the Strait of Anian, and California as an Island.

Twice, then, California was, in the popular mind, an island. The first time, when only the southern tip of the peninsula was shown, the concept was natural; after several voyages of exploration it was inexcusable. But it remains a fact that by the early part of the 17th century California was again cartographically an island. This is probably to be explained by a tendency on the part of the cartographers to extend the gulf north to the Strait of Anian. Quite possibly Oñate's report of a western arm of the gulf was of some influence.

This matter of the insular or non-insular nature of California became a significant one for the Spaniards. When Kino, a hundred years later (about 1701) re-demonstrated its peninsular character, his was a recognized accomplishment. The discovery that through the delta lay the land passage to California was an event of far reaching importance for the lower Colorado area.

The Jesuits --

The Jesuits approached the delta from two directions: from their missions in what is now Baja California, and from their missions in Pimería Alta. In part the journeys were reconnaissances, the preliminary steps in a well defined plan for combined spiritual and temporal conquest. In this, church combined with state. The explorers were interested

in number and distribution of native populations, water, vegetation, harbors, and sites for missions, presidios, and pueblos.

In increasing measure the journeys had the objective to find a land passage between Pimería Alta and California. The two principal areas of Jesuit endeavor lay in Pimería Alta and in what is now the Southern District of Baja California. The two fields were separated by the turbulent Gulf of California; it was desirable that any land connection be discovered. The delta, of course, lay too far to the north to serve the Jesuits' purpose, as their missions were then situated.

Coming from the east, from the Pimería Alta missions, Father Kino made a series of trips into the area during the period 1699 to 1706. On his trip of 1699 he reached the Yuma. Finding them in possession of large, blue sea shells he saw the strong possibility of a land connection with California. In the year 1700 Kino actually reached the Colorado, noted the rich soil, extensive cultivation, and dense population. He was evidently impressed with the strategic position of the site at the mouth of the Gila; to it he gave the name Rancho Dionisio.

The Gila enters the Colorado a short distance above the point where the latter flows in a channel confined between high conglomerate walls. This is the lowest point in the course of the stream where it is so confined. For a primitive

people the site offered among other things: proximity to water, with dwelling sites above flood level; an abundance of agricultural land in the river valley, both above and below the constriction; something of a stronghold with an elevated area surrounded by plains.

A portion of Kino's journeys took him across the Sonora Desert to points near the head of the gulf; he travelled down to the mouth of the Colorado. He was well versed in the surfaceconfiguration and make-up of the area between the Gila and the gulf. He left a map which one may judge to be a very fair representation of conditions in 1700, in the lower Colorado area.[1] On this map California appears once more as a part of the mainland.

In his final estimate, Kino decided that the best approach to the delta area from the east lay through the site at the mouth of the Gila. Thus to him goes the honor of discovering the eastern gateway which has proved itself to be the only practical one in the passage across delta and desert to the mountains. That succeeding explorers had to re-do Kino's work detracts not at all from the credit due him.

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[1] Kino's Historical Memoirs of Pimería Alta, H. E. Bolton, Editor, Cleveland, 1919. As frontispiece is Kino's map. Bolton makes a point of a note in the memoirs which definitely dates the map 1705. There had been some dispute on this point.

In Kino's case it was largely a matter of selecting the best site for crossing the Colorado. He had no accurate knowledge concerning the terrain which lay between the Colorado and the Peninsular Range. There was a good ford near the junction of Colorado and Gila. Below this point the river was difficult to ford because of the muddy banks; the delta surface was marked with channels and covered with a dense growth of vegetation. To the north of this point lay the gravelly mesa with its ranges of shifting dunes. To one who knew the area there was really little choice of route.

Ugarte, a Jesuit from Loreto, sailed to the mouth of the Colorado in 1721,[1] and returned to the south satisfied that California was not an island.

In 1746 the Jesuit Consag led a canoe party along the west coast of the gulf to the mouth of the Colorado. He made a survey as he went, and later embodied his observations in a map. To the site of the modern San Felipe he gave the name San Felipe de Jesus. Between there and the Colorado he found a shore line without bay or watering place.

In 1748 and again in 1750 another Jesuit, Sedelmair, visited the delta, coming from the east.[3] His visit marks

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[1] Bancroft, H. H. History of the Northern Mexican States, 1531-1800: pp. 443-444.

[2] Life and Works of the Rev. Ferdinand Konščak, S. J. 1703-1759. Translated by Msgr. M. D. Krmpotic, Boston. (1923) A reproduction of Consag's map is contained in this volume, pp. 8-9.

[3] Bancroft, H. H. History of Arizona and New Mexico, 1530-1888: pp. 367-368.

the last Jesuit contact with the delta during the exploratory period. Link made the attempt in 1766, travelling overland from the mission of San Borja, in California. At a point which was estimated to be some twenty or thirty leagues short of the mouth of the river the attempt to reach it was abandoned.[1]

Jesuit activities were formally concluded with their expulsion from the area in 1767. During the sixty-seven years in which they had conducted reconnaisances, their contributions to the geographical knowledge of the lower Colorado were important. They discovered the Gila route to the Colorado; they saw the significance of the site at the junction of the Gila and Colorado. Knowledge of the peninsular nature of California was re-established. The bay at San Felipe was discovered and pointed out as significant in a coast largely devoid of good harbors.

The Franciscans --

With the expulsion of the Jesuits the Franciscans took over the field. But it was not until 1771 that one of them, Garcés, descended the Gila and went down the Colorado nearly to the mouth. He was not aware that he had reached the Colorado but thought that it lay still further to the west. However, he did get the idea that here lay the way to California.

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[1]Bancroft, H. H. History of the Northern Mexican States, 1531-1800: p. 473.

[2]Coues, Elliott. On the Trail of a Spanish Pioneer.

The Way to California

Spanish occupation of Alta California involved the transfer of troops and supplies from Mexico; for this a land route from the outposts in Sonora was almost a necessity. The missions of Baja California were poor, and could do little for the assistance of travellers. In addition, the route through Baja California involved the crossing of the San Borja Desert. The alternative to this route, a trip by sea, was equally difficult.

The difficult part of the overland journey between Sonora and California lay in the area east of the Peninsular Range. The driest and hottest desert region in North America extends from the Mojave south along both shores of the Gulf of California; it extends from the Peninsular Mountains to the highlands of eastern Arizona. To those travelling by primitive means the region offered difficulties in the way of scant water supply, poor feed for animals, and intense summer heat.

The well-watered delta was an oasis between two difficult desert jornadas. Here travellers were assured of water, feed for their beasts, and possibly provisions for themselves.

Inspired by Garcés' diary of his 1771 trip, Don Juan de Ansa, captain of the presidio at Tubac, in Sonora, attempted and succeeded in making the round trip from Sonora to Cali-

fornia in 1774 and again in 1775. He characterized the route as an easy one, passing through regions inhabited by friendly Indians.[1]

West of the mouth of the Gila, Ansa entered a region previously unvisited by Europeans. The area lying north of the delta crest, and between it and the mesa, formed the most favorable passageway. Here the surface was without the dense vegetation cover of the lower delta, and without the great dunes of the mesa. East of Centinela (Signal Mt.) lay an area of dunes, and to the northward the hard floor of Salton Sink marked the most desolate and waterless stretch of the whole jornada.

There was some choice of route in leaving the sink for the Peninsular Mountains. The Cucopa Range and the steep wall of Sierra Juarez were apparently sufficiently forbidding to prevent considerable use of any routes south of Centinela. There were opportunities to leave Salton Sink through the Mountain Springs route to Jacuma Valley, up Carrizo Creek through Vallecito to Valle San Felipe, and directly up San Felipe Creek to Valle San Felipe. From the crest of the mountains on, the route offered few difficulties as compared with the course over the desert. Routes further north than these three were hardly to be considered, for they would involve the preliminary crossing of an even greater stretch of desert.

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[1] From Bolton's manuscript, previously cited.

There was no dependable water hole after leaving the Colorado until the base of the mountains was reached. There were a few springs about the margins of the sink; later, wells were dug; in late summer and early fall there might be pools of water in overflow channels. But all these sources of water failed at times, and then the trip from the Colorado to the mountains was waterless.

Ansa, influenced in his choice of route by an Indian guide, made his way to the swampy area which marks the junction of San Felipe and Carriso creeks. From there the way was not difficult up San Felipe Creek to the mountains. On his second trip he corrected the errors of the first, but the two portals of the desert way were the same.[1]

The Mission --

Convinced that the new route from Sonora to California was a practical one, the Spanish authorities determined to establish a way station at the crossing of the Colorado. It was proposed to found a new type of combined presidio, mission, and pueblo.

In 1780 the proposal became an accomplished fact. Two sites were utilized: the one called Puerto de la Purísima Concepción, on the California side of the Colorado, below the mouth of the Gila; the other, San Pedro y San Pablo de Bicuñer, also on the California side of the river, near Pilot

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[1] Bolton, op. cit., traces Ansa's route in detail.

Knob. As these were to be not only missions but also presidios and pueblos, the four priests brought with them from Sonora fifty-three families: twenty of settlers, twelve of laborers, twenty-one of soldiers, "all with wives and plenty of children".[1]

For a while things seem to have gone smoothly with the new settlement, and considerable was accomplished. Until a few years ago there remained portions of the stone walls of small buildings and the church, at the upper site. Traces of acequias were long to be seen near Pilot Knob; perhaps they still remain.

In 1781, a short year after its founding, the settlement was wiped out, in consequence of a well planned coup de grâce on the part of the Indians.[2] For nearly seventy years, or until the establishment of a military post by the Americans, this significant site was to know no permanent settlement.

The Interim --

Ansa's route still knew some usage, but the Colorado, instead of being a pleasant oasis between desert marches, became a difficult passage through which travellers might have to fight their way. Small, well armed parties not in-

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[1] Coues, op. cit.: pp. 18-19.

[2] An account of this uprising may be found in Priestley, H. I. The Colorado River Campaign, 1781-1782, Diary of Pedro Fages. Acad. Pac. Coast Hist., Publ., 3: pp. 135-233. (1913)

frequently made the trip across the delta. There were numerous plans and suggestions for re-opening the route, for it undoubtedly held advantages in distance and directness above all other routes between Sonora and California. But nothing was done either by the Spaniards or by their Mexican successors. The relentless hostility of the delta Indians, particularly the Yuma, forced the main line of travel north to the Mojave.

The advance of American trappers reached the Colorado about 1824.[1] In the succeeding years a number of parties came down the Gila to the mouth. Some descended to tidewater; some made the trip across the desert.

Probably the most famous of these is the Pattie party of 1827. The members of this party descended the Colorado to tidewater, and then struck out overland to the west. Guided by Indians they crossed the Cucopas, north of Sierra Mayor, and walked across Pattie Basin to the base of the Sierra Juarez. They entered a canyon where there were palms, live oaks, and water. In a two-and-a-half day trip they reached the mission of Santa Catarina.[2]

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[1] Hill, J. J. Ewing Young in the Fur Trade of the Far Southwest, 1822-1834: p. 4. (1923) Reprint from Oregon Hist. Quart., vol. 24: no. 1.

[2] The Personal Narrative of James O. Pattie of Kentucky, 1824-1830. In Thwaites' Early Western Travels. (1905)

Kearney's Route --

Few of the trappers left accounts of their travels so that so far as written record goes their contribution to the geographic knowledge of the area was small. But they acquired a knowledge of the lay of the land, of trails, and watering places. They became the guides and scouts of succeeding travellers, and so, in a measure, their knowledge was not lost.

In 1847 Kearney's "Army of the West" passed through the delta and across the desert to California. As a part of Kearney's army was Cooke's "Mormon Battalion", the wagon train of the expedition. This was the first passage of wheeled vehicles through the area; as such it marked the way for others to follow.

Cooke's report is not sufficiently detailed to fix his route exactly, but its general course is clear. He forded the Colorado at the island dotted shallows near Pilot Knob. From there he moved westward, skirting the base of the mesa, and crossed Salton Sink to Carriso Creek. Passing up Carriso Creek the trail led through Vallecito, crossed over the divide to Valle de San Felipe, finally reaching Warner's ranch in San Jose del Valle.[1]

Yuma --

With the great rush to California, beginning in 1848, the Gila route was traversed by thousands; Bancroft estimates

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[1] Notes on a Military Reconnaisaance from Ft. Leavenworth to San Diego, Cooke's Report: pp. 558-559. (1848)

sixty thousand before 1851. With their wagons and stock they followed the trail which Cooke had broken from the mouth of the Gila to Warner's ranch.

The Yuma were still hostile. To a large degree they had abandoned agriculture in favor of stealing from passing parties and running off their stock. In addition to the Indian menace the road was long and hard, and many of the travellers were poorly prepared. A way station at the Colorado oasis was much to be desired.

A party of American soldiers was temporarily encamped at the site in 1849, and in the same year a ferry over the Colorado was put in operation. In 1850 Camp Yuma was established on the south side of the river. In 1851 it was moved to the old mission site on the north bank, and became Fort Yuma. The soldiers pressed the Yuma hard at every opportunity, forcing them to beg for a treaty in 1852. The Yuma remained a nuisance, however, until a war party which they sent against the Pima, in 1857, was virtually annihilated.[1, 2]

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[1] Bancroft, H. H. History of Arizona and New Mexico, pp. 487-488, 544.

[2] Bartlett, J. R. Personal Narrative, etc.: pp. 147, 175-181. (1854) Bartlett, U. S. commissioner on the boundary survey, passed through the area in 1852 and has left a very interesting account of the troubles which the emigrants experienced, both with the Indians and with the natural difficulties of the way.

A settlement grew up about Fort Yuma, first as the appendage to a military establishment, later as a distributing point for the newly developing mining area to the east. Steamboats were placed in operation on the lower Colorado; a line was established between San Francisco and the mouth of the river. From Fort Yuma wagon trains distributed the supplies to the mining camps. The real growth of the town began with the renewed interest in mining after the Civil War; in 1870 there was a Yuma of 1,150 people.[1] But still it retained its character as a corridor site, an oasis, and a supply-distributing point. It remained essentially this until 1910, when the building of Laguna Dam opened the adjacent territory to agriculture.

Lines of Transportation and Communication --

River transportation was initiated primarily as a means of eliminating the long haul from the Colorado to Los Angeles. Transfer depots were established at the mouth of the river and at San Felipe. At these points the river steamers were met by ocean-going vessels. Army contractors built the first river steamer in 1852, and put it into service carrying supplies to Fort Yuma. With the development of Yuma as a distributing point, nearly all the bulky supplies were brought in by steamer.

The navigation of the lower Colorado was no sinecure. High water and low water, currents and bars, all made progress

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[1] Ibid.: pp. 489-490.

difficult. With high water it was frequently necessary to "line" the vessels upstream -- so swift was the current. Even with the attendant difficulties, the river route possessed advantages over the one across the desert. With the completion of the Southern Pacific, however, river navigation virtually ceased. Since 1877 the lower river has become a stretch about which little is actually known. With the diversion of the Colorado it is generally impossible to go entirely by water from Yuma to the gulf -- even in a skiff; even legally the Colorado is no longer a navigable stream.

In 1857 the Butterfield stage line began its service between St. Louis and San Francisco. Between Fort Yuma and Warner's ranch the stages followed what was essentially the old route of Cocke. The ford at Pilot Knob was abandoned in favor of the ferry at Yuma; a station was established near the site of modern Mexicali, marking the crossing of New River. The channel of this stream had been formed subsequent to Cooke's journey; through a portion of the year it could be depended upon to yield water.

With the coming of the railroad the stage line between Yuma and Los Angeles was abandoned. There was still maintained a line between Yuma and San Diego. The two lines had a common route to a point a few miles west of the modern town of Silsbee, in Imperial Valley. From this point the

San Diego route lay through Coyote Wells, Mountain Springs, and Jacumba -- practically the line of the modern highway.

In the building of the railroad across the Colorado the only possible bridge site for many miles was found to be at Yuma, at the old Puerto de la Purísima Concepción. Here a solid base of well-cemented conglomerate permitted the construction of a single-span bridge, with both abutments resting on rock.[1]

West of the river the route follows across the mesa, skirts the sandhills to the east, and crosses the mountains through San Gorgonio Pass. The great stretch of desert involved in this route is of no consequence in view of its directness and favorable grades.

With automobiles and concrete construction, modern highways largely disregard the old routes. The highway west from Yuma passes directly through the sandhills. The highway from Imperial Valley to Los Angeles runs the length of Salton Sink. The modern road to San Diego follows closely the old stage route, while trains make the torturous ascent of the Peninsular Range, somewhat farther to the north.

On the Mexican side of the boundary, the main east-west road follows the old route along the base of the mesa. A

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[1]The first bridge had a middle pier. This type of construction was found to be unsatisfactory because of the propensity of the river for alternately scouring and depositing.

branch of the Southern Pacific runs through Mexican territory from Mexicali to Pilot Knob. This line is used considerably by freight trains, for it involves gentler grades than the line across the mesa.

The Surveys --

Boundary surveys, river surveys, and railway surveys subjected parts of the delta region to rigid scrutiny during the period from 1850 to 1858. They all contributed to a knowledge of the country: the nature and genesis of the natural forms, the culture of the native peoples, and the possibilities for commercial exploitation of the area. By pointing out the qualities of the natural landscape they tended to limit and suggest the lines along which the cultural landscape might develop.

Derby's river survey.....	1850
Sitgreaves' river survey.....	1851
Railway surveys.....	1854-55
Boundary surveys.....	1849-55
Land surveys.....	1856
Ives-Beale, river survey.....	1857-58

Probably most significant in their implications for the development of the cultural landscape were the boundary surveys. The lines were drawn with scant recognition of the features of the local landscape.

The treaty of Guadalupe Hidalgo in 1848 fixed the boundary as extending from the mouth of the Gila to a point on the coast

of the Pacific, south of San Diego. In the delta region the line cut across the mesa, leaving Salton Sink cut off from gravity flow of water from the Colorado, through American territory. A portion of the natural highway from east of the Colorado to southern California lay in Mexican territory.

The Gadsen Purchase in 1853 effected further changes in the delta area. The United States gained complete control of the approaches to the bridge site of the Colorado. Mexico was deprived even of a good ford across the river. To this day there is no bridge connecting Baja California and Sonora -- but only an unsatisfactory scow-ferry.

With the stage of exploration the country was made known. Roads, boundary lines, and railroads were laid out. The resources were examined, the potentialities appraised. The Indians were subdued. But still the landscape remained effectively unaltered. The way was opened, in a measure the course planned, for the succeeding stage of exploitation.

CHAPTER 10 -- THE STAGE OF EXPLOITATION

The stage of exploitation is easily the dominant one in the cultural landscape of today. It had its small beginnings in the trappers of a hundred years ago. Cattle grazing claimed the area in the 80's of the last century. Agriculture as a major expression of this stage dates back a matter of only some fifteen years. Agriculture has effected changes in the cultural landscape that are unique and quite unrelated to any others.

Transient Exploitation --

The real opening of this stage came with the American beaver trappers, and is associated with such names as Pattie, Young, Carson, and Weaver. This represents a phase of the westward movement of the American trappers which reached the Colorado Basin somewhere between 1824 and 1827. The delta was somewhat marginal to the main beaver area, yet a number of parties trapped there. It was not trapped out, as was true of the more accessible waters farther to the north and east, for on the lower Pescadero beaver still remain in considerable numbers. From 1832 to 1837 marked a period of general decline of beaver trapping in the southwest; never again did it assume proportions as a major activity of the frontiersmen.[1]

[1] Hill, J. J. Ewing Young in the Fur Trade of the Far Southwest, 1822-1834: p. 4. (1923) Reprint from Oregon Hist. Quart., vol. 24, no. 1.

How many trips to the head of the gulf were induced by the hope of discovering rich treasures of minerals or precious stones is not known, but there are ample indications that trips were made. Consag's report contains advice for prospective pearl fishers, working the waters of the upper gulf.[1] Hardy's voyage to the head of the gulf was in part induced by the rumored trip of a priest to the Colorado and his return with $200,000 in gold and pearls -- the gold obtained from the banks of the river.[2]

Probably some of the early Arizona and California prospectors wandered down into the area, and there are dated prospect holes which go back to the 70's. But there were discovered no bonanzas to bring large numbers of people and suddenly transform the landscape. Prospectors are still to be seen, and a few mines are worked, but these figure slightly in the present economic system.

The Cattle Period --

The first cattle in the area were probably those introduced at the time of the missions. Fagés says that they were not recovered by the Spaniards;[3] it is sure that they did not long survive among the Indians. Numbers of cattle were stolen from the herds heading for California -- but stolen to be eaten.

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[1] Op. cit.: p. 79.

[2] Op. cit.: pp. 97, 311.

[3] Priestley, op. cit.: p. 45.

The utilization of the area by ranchers seems to have started sometime in the seventies. Certain Mexicans secured title to the Algodones ranch in 1859. In 1874 Andrade appeared on the scene. He seems, at least in part, to have been the Mexican partner of American capitalists. At once he began to acquire land on a large scale. By purchase of pre-existing claims, and with a concession (which was really a purchase) from the Mexican government, he consolidated his great ranch in 1878. It had the enormous extent of 358,235 hectares, and included the major part of the delta, south of the international boundary.[1]

By 1880 cattle grazing on a large scale was established on the delta lands. In 1890 Allison and Silsbee drove herds down from the mountains and established several camps in the river bottoms. Aikins, Babcock, Gaskill, and other American and Mexican ranchers leased land from Andrade -- though the leases were never fenced.[2]

When New River was in flood the cattlemen constructed wiers in its channels so that it might flood a larger area and so produce more feed. As soon as the overflow came, thousands of head were driven into the region from the mountains for summer and fall feeding. Some herds were left throughout the year; at certain seasons their lot and that of the cowboys watching them was not altogether a happy one. Feed and even water became scant in late winter and spring.

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[1] From Mr. C. L. Gómez, Secretary of the Colorado River Land Company.

[2] Also from Mr. Gómez.

In the sticky mud of the overflowed land the weakened cattle were frequently bogged, so that the cowboy had of necessity to be working night and day. He made his camp under a mesquite near some lagoon. He lived on a diet of baking-powder bread, roasted carne seca, and coffee. The mosquitoes permitted him to sleep only when he lay enveloped in a cloud of smoke from his cow dung fire.[1]

It was the beginning of the end of the old cattle period when the Colorado River Land Company entered the field in 1902. This concern took over Andrade's holdings on the Baja California side of the river and bought out the smaller ranchers -- cattle as well as land. The company ranchmen reformed the methods in vogue by planting sections to alfalfa and fattening their stock for the market. In 1908 their Packard ranch contained 10,000 acres of alfalfa.[2] This was a sign whose significance was realized in 1912 when this company turned from cattle to cotton growing as the major utilization of the vast area which it controlled.

The cattle industry still remains -- but on a much reduced scale. South of the Rodriguez levee something of the old conditions survives. The southern part of the Company's[3] holdings is divided into two ranches which are

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[1] Barrows, D. P. National Geogr. Mag., vol. 11: pp. 347-351. (1900)

[2] Figures from Mr. Gómez.

[3] Here and hereafter "Company" refers to the Colorado River Land Company.

leased to cattlemen, and in addition there are a number of private operators (pl. XVIIIc). There is a considerable acreage of alfalfa where cattle are fattened, north of the levee (pl. XVb). The physical conditions are favorable, but the principal market lies in the United States, and the duty is high. As a business proposition cattle raising loses its picturesque qualities, and the glamour which in retrospect attaches itself to the old days is largely gone.

As a modifier of the landscape the cattle industry was significant in its day, but with its passing it left few traces. Some falling corrals, some fenced water holes, and the old Company headquarters are about all that remain in the landscape now dominated by agriculture (pl. XIXa).

Agriculture --

Nearly every early traveller, who has left a record of his visit, has had something to say about the agricultural possibilities of the delta. Each had before him the prospect of the richly productive fields of the Indians, and it did not take much imagination to see this scene changed to a thickly settle European community. There were even suggested schemes for irrigating sections along the river -- of course, this was actually carried out at the time of the mission.

There were several who, at an early date, saw the possibility of utilizing the channel of the Alamo for conveying water from the Colorado to the Salton Sink, and there using

it for irrigation. These men were Americans who were interested in irrigating land, but they saw the necessity of using the natural grade which led through Mexico. Dr. O. M. Wozencraft actually had a bill before congress in 1869 which provided for the reclamation of the area, along some such lines.[1]

Construction was actually commenced by the California Development Company in the late 90's; late in the year 1901 water from the Colorado was delivered to the delta lands lying north of the border. The canal system involved a very simple utilization of the natural gradient of the delta surface. Water was taken from the Colorado near Pilot Knob, merely by making a cut through the natural levee. For a canal the old channel of the Alamo was utilized to a point near the boundary, east of Mexicali. From this point the water was diverted into three mains, all flowing north: one along the eastern side of the sink, one along the western side, and one through the middle.

The development of the Imperial Valley in the United States was rapid. In January of 1901, aside from the surveyors, it contained not a single white man. Two years later there were 2,000 settlers; in 1904, 7,000; in 1905, 12,000 to 15,000. By the latter year there were seven towns, with 120,000 acres under irrigation.[2] In 1904 the area was

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[1] A discussion of these early schemes is to be found on pages 15-16 of Professor Blake's article in Cory's book, previously cited.

[2] Cory: op. cit.: pp. 1268-1269.

connected with the outside world by a railroad, the Southern Pacific running a branch south through the valley. Later this branch was connected through Mexican territory with the line passing through Yuma.

But south of the border, on the Delta Cone, the situation was somewhat different. Here the Company owned practically the whole area. It had behind it the traditions of the cattle industry -- though from the time of its formation it probably had in mind the ultimate shift to agriculture. If it were to engage in agriculture it would have to practice something different from the system of individual farms in vogue to the north of the border. The matter of water for irrigation was solved, for the American company had of necessity to run its main canal through Mexican territory. Here to the south there were jungles to clear and levees to build.

The Changing Landscape --

In 1910 the Company disposed of some 32,000 acres to private companies; the latter began the practice of agriculture on a large scale. In 1912 it gave up stock raising as a major activity and first leased land to individuals for the planting of cotton.[1] But still the combined acreage in use in the Mexican area must have been small, for in one week of January, 1912, there were used only 37 second feet of water south of the line (1200 acres) to 895, north of the

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[1] Mr. Gómez.

line.[1] The growth, once it started, was rapid, until at present nearly all the land, from the mesa to several miles south of Cerro Prieto, is being planted to cotton.

By 1916 the cotton acreage on the Mexican side was equal to that in the American Imperial Valley and amounted to 70,000 acres. Since the great collapse of cotton in 1920 the Imperial Valley has gone more and more into other crops until cotton is relegated to the poorer land. South of the boundary, on the contrary, cotton acreage has grown by leaps and bounds. As a crop cotton is so dominant that others are of very little concern. The per acre production is less than in any cotton producing section of California, but this is made up for by the lower wage level and by the fact that most of the production is absorbed by Mexican mills, thus avoiding the export duty.

Preparatory to the southward expansion of the area devoted to cotton there has been necessary the enlargement of the levee and irrigation system, and the clearing of the heavy vegetation cover. As has been previously mentioned, the Colorado has for the last twenty years been showing a tendency to swing its course westward. The engineering problem has dealt with the prevention of this change of course and with the progressive reduction of the area of land subject to overflow. Its plan has involved the southern extension of a levee along the western bank of the river, and the

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[1] Cory, op. cit.: p. 1259.

building of a series of lateral levees toward the west (pl. XIIIb). In this manner the river is gradually restored to its old channel and prevented from inundating the agricultural lands.

Originally this Mexican area derived its supply of water for irrigation from the Imperial Valley canals. With the increase in acreage this source has been augmented by others. For the area along the delta crest (perhaps 20,000 acres) , too high for gravity canals , there is the series of pumped wells, deriving their water from the subsurface gravel ridge, before referred to. South of the crest a large part of the land (about 50,000 acres) is irrigated with water taken directly from the Colorado through the siphons at Pescadero Dam. In part this latter system utilizes the old channel of Bee River for a main canal.

The difficulty in clearing the land is, of course, dependent upon the nature of the original plant covering. For areas covered with willow and arrow-weed the common method is to drag an anchor chain or railroad rail between two tractors. For the mesquite lands the job is more difficult and involves considerable hand labor (pl. XIXc).

Not the least significant phase of the work involved in preparing the land for cultivation is the leveling necessary in the dune areas. There has been much less of this than in the Imperial Valley but even here it has blotted out several

old dune systems. Where the dunes are too large to handle, as is occasionally the case, they are left and fields are laid out around them (pl. XVa).

The Rural Pattern --

The most striking feature of the rural landscape is found in the network of irrigation canals. These vary in size from the mains which may be forty to fifty feet wide to the field laterals which are a foot wide. The main canals frequently look like hills with their high banks composed of the silt which has been dredged from them.

For the whole area the leased ranches average about 800 acres in size, though several are well over 2,000 acres. For each ranch there is a headquarters camp, the buildings located in a grove of trees -- generally cottonwood or willow. A pond fed by a canal furnishes the water for domestic use. The buildings are simple: quite typically an extensive ramada (a roof composed of a pole-framework covered with brush), under which smaller structures are placed. These latter may be canvas tents or houses of arrow-weed. For each ranch there is a blacksmith shop, corral, perhaps some kind of shelter for the mules. There is always a flag pole from which signals can be displayed to the men in the field; there may be a cellar in which the night-workers sleep during the day. This camp is for the Chinese lessee and his countrymen, who probably constitute at least half of the crew (pl. XXa).

For the Mexican hands there is a row of arrow-weed huts some distance away; there they dwell with their wives and many children.

Along the roads, on the ditch banks, about isolated lagoons may be found the homes of squatters. These people may practice a little agriculture, have a few cattle, or work for the ranchers. Their establishments are particularly interesting for the types of buildings which they contain (pl. XVIIa). There are wattle huts, huts with white plastered walls, huts well built of bundles of arrow-weed. Almost invariably they are neat and home-like and certainly much more attractive than the wooden houses, or even adobes, in which the town dweller is likely to live.

An effort is made by the large companies to keep the squatters off their land. Once established they are hard to evict. As American proprietors in a foreign country it is not a good policy to create too much disturbance over a few acres of land.

Acala cotton, a medium staple variety, is the one principally grown in this area. Because of its uniformity and cleanliness, in this land of little rain, it brings a premium price. The procedure followed in its growing is the same as for other varieties. It is planted in March and April in ground which is as wet as can be traversed with the seeder.

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After the plants have come up perhaps five inches the field is "chopped" to give the proper spacing in the rows. Then the rows are furrowed with the Georgia stock (a small one-horse cultivator), and the plants cultivated with disc harrows. The field is irrigated again after a period of from two to four months; perhaps there may be three irrigations after the planting. Picking comes in September and continues until January. Then the ground is plowed for a new crop.

Destructuve Economy --

With the leasing system, with the abundance of virgin land, it is no wonder that it is with the spirit of the miner rather than that of the agriculturist that the soil is being exploited. There is no well defined system of crop rotation, but it is one crop of cotton after another until the yield falls below the critical point. Factors other than depletion of soil fertility contribute to the decreased yield, it is true, but it must be this unbroken succession of cotton crops which is mainly responsible for the low average production.

The presence of Bermuda grass contributes to the decreased yield. It is reputed to have been introduced originally to prevent the erosion of ditch banks, but this is also denied. Whatever its origin it frequently occurs in amounts sufficient to cause the temporary abandonment of fields. It can be eradicated only by turning the land over with a plow and allowing it to bake under the hot summer sun.

The presence of alkali in amounts sufficient to deter agricultural utilization is still rare. There are areas, however, of poor natural drainage containing fields once utilized, now abandoned. There can be no doubt that ultimately the problem of artificial drainage will have to be solved.

Before the area can be put on a permanently productive basis the problem of silt disposal will have to be taken care of. It is a problem both of the disposal of the silt itself, and of the exorbitant cost which its removal entails. On one of the main canals a forty days run of water was accompanied by a deposit of silt three feet deep. The banks of the canal were already built up with dredged silt to a height of fifteen feet, and were so broad that roadways ran along their tops (pl. XXb).

Agricultural Colonies --

The establishment of agricultural colonies is part of the general government policy in Mexico, initiated in 1910. It has for its purpose the founding of a class of peasant landowners and the doing away with anything suggesting peonage. In the delta area it has the avowed function of forming a strong outpost of Mexican culture against the further extension of the American cultural sphere. Also in this area it is to serve as a subsidy for the Mexican agriculturists in their difficult competition with the Chinese.

In 1927 the area involved amounted to 10,000 hectares, and there were about 135 heads of families whose crops were being financed in part or in whole by the Mexican bank. A large part of the colonists were repatriated Mexicans from the United States.[1]

The colonists are of two types: the one in which the government owns the land and leases it to the colonists, the other in which the colonists are buying the land on terms from the government. In the former the colonist is given the use of as much land as it is judged he can handle well. The government finances the crop and purchase of necessary machinery. It encourages and assists co-operative buying and marketing. At Colonia Progreso there is a government financed flour mill and a central administration building. In addition, this colony has its own hydro-electric plant (pls. XVIIIa, XXc).

The second type of colony is in part the outgrowth of an attempt to settle the problem of squatters who have occupied lands owned by private companies. Rather than evict them the government purchased the property and is selling it to the colonists on very liberal terms.

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[1] A large part of the factual material is taken from the Memoria Administrativa, 1924-1927, of the Gobierno del Distrito Norte de la Baja California: pp. 67-96. (1928)

The difficulties are great and it is no wonder that the colonies have not been wholly successful. Many of the colonists knew nothing about agriculture. There has been the problem of financing by a government none too rich. The land has had to be obtained from foreign concerns. The government administrators have been well aware of the difficulties of the task; it reflects highly to their credit that they have shown a spirit of patient experimentation when they might well have thrown up the job in despair.

Population --

In 1901, when the American Imperial Valley was without permanent inhabitants, it is probable that there were at least a hundred people living on the Mexican side. But with the unprecedented growth of the Imperial Valley and the slow shift to agriculture south of the border, the balance in number of inhabitants went very much the other way. By 1916, cotton production was utilizing 15,000[1] hectares; for this year the population of the municipality of Mexicali had reached 6,400.[2] By 1921 it was 14,599 and by 1927, 18,099.[3] This growth was not entirely a matter of a population attracted by the opportunity for work in a growing agricultural area, but in some measure was due to the direct importation of Mexicans and Chinese by the large growers.

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[1] Memoria Administrativa, previously cited: p. 236.

[2] Taylor, P. S. Mexican Labor in the United States, Univ. Calif. Publ. Econ., vol. 6, no. 1: p. 13. (1928)

[3] Memoria Administrativa: p. 236.

In the period 1921 to 1924, 13,000 Mexicans were brought from the west coast states to take care of the growing cotton production. As late as 1926, 120 families were imported from Torreon.[1] Within recent years the population has been augmented by those returning after a period in the United States. The southern district of Baja California, Sinaloa, and Sonora lead as the areas contributing to the Mexican population.[2] Curiously enough, Guanajuato is fourth; this is probably an expression of the importations of the Company, for it was considered that the people from central Mexico would do best under the climatic conditions prevailing in the delta area.

The Chinese apparently came into the area with the first cotton, for they appeared in 1912; in 1913 there were said to be 1,600 of them. It is estimated that some 7,000 Chinese were brought in by the cotton growers, and in 1927 there still remained 4,500.[3] They came from Mazatlan, Ensenada, China and the United States. They were desired at first because they were good cheap labor. In 1913 it was advertised that they would work eleven hours for a dollar, and board

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[1]Taylor, op. cit.: p. 13.

[2]Taylor's figures, op. cit.; table 3, of Mexicans crossing the border at Calexico, are taken as representing a fair cross-section of the population on the Mexican side. Mexicans have said that it does so.

[3]Taylor: p. 13.

themselves; at the same time laborers on the American side were receiving two dollars-and-a-half for nine hours.[1]

But soon the Chinese began to be more than mere laborers. Originally the lessees from the Company were Americans, but they were gradually replaced by the Chinese until the latter became easily the dominant group, both as lessees and laborers, in the field production of cotton. The introduction of an alien group brought with it few modifications of the landscape other than the presence of the people itself. Under the prevailing system the Company has closely supervised the growing of cotton according to the American method. It is no rarity to see a Chinaman driving a four-mule team, swearing at it in Chinese. In the towns the Chinese became the merchants, almost without competition; they almost equally dominate the restaurant business.

With serious misgivings the Mexicans watched the growth of Chinese population and economic superiority. In 1916 an official ruling was passed which demanded that for each Oriental imported there should also be brought a Mexican.[2] Later a ruling was made which demands that the distribution of labor on the ranches shall be at least one Mexican for each Oriental. This ruling seems to be observed quite well, though it is said that the Chinese sometimes evade it by forming a "company" of a considerable number of men who are also the laborers.

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[1] Ibid.: p. 14.

[2] Ibid.: p. 15.

The animosity of the Mexicans for the Chinese has on several occasions taken violent form, and it is a very real thing. As yet the Mexicans are not prepared to take over the work of the Chinese and until they are, or until another group is introduced, the Chinaman will probably remain.

Urban Development --

Out of the agricultural development there has grown one real town -- Mexicali. Near the site of the old stage crossing on New River, Mexicali became a town with the development of the American Imperial Valley, first as the seat of the Mexican customs office opposite the American town of Calexico. With the expansion of agriculture on the Mexican side, Mexicali grew until in 1918 it was credited with having a population of 5,000. With the American prohibition law Mexicali assumed a place as a border resort town where alcoholic drinks might be obtained and where gambling was legalized. Without over-emphasizing its importance this latter circumstance has contributed materially to Mexicali's growth. The revenue derived from the taxing of liquor and from the gambling concessions has swelled the fund available for public works. In addition, the town has two breweries which employ a number of local people.

Mexicali is the distributing center for the agricultural area; it has the offices of the operating companies; it is the gathering point for the harvested crops. Among the

industrial establishments are gins, cotton compresses, and a soap factory. Here is located the capital of the northern district of Baja California.

The main streets of Mexicali are wide and paved (pl. XVa). The public buildings are substantial affairs. There are residential areas that are not dissimilar to those of the American towns in Imperial Valley. The contrasts are all there, too: dirt streets, adobe houses, arrow-weed ramadas, a Chinatown (pls. XVIc, XXIa).

Along the line of the Inter-California railroad there is a series of minor settlements reaching from Mexicali to Algodones. These villages contain at most a hundred or so people each and are in no case regularly plotted towns (pl. XXIb). They consist of a row of adobe or brush houses which form a single line along the track. A new series of such towns will probably spring up along the line of the railway which is now being extended to the head of the gulf.

South of the railroad the rural pattern dominates the landscape and here clusters of population are found about the ranch headquarters. The ranches are extensive and far from town; the roads are bad. It is impossible for the agricultural laborer to live in town and go each day to his work, as is so often done to the north of the boundary.

There is no permanent port at the head of the gulf. The landing place of the Guaymas steamer varies with the stage of the river (pl. XVc). An official or two remain at Mayor but otherwise there is no permanent population connected with the port.

At San Felipe and at the site called Sta. Clara Beach, on the Sonora shore, there are semi-permanent fish camps. The fishermen and their families come each fall from Guaymas for the winter fishing. At the height of the season, which extends from October until April, there are several hundred people in each camp, living mostly in tents which extend in lines along the beach (pl. XXIc).

The Contrast --

North of the boundary the cultural scene bears a different aspect. The contrast is due in part to the divergent cultural background of the people inhabiting the area; in part it is fortuitous.

Instead of a succession of cotton fields, a thousand acres in extent, there is a varied rural pattern. Groves of citrus trees and date palms lie next to fields of grain, alfalfa, or cantaloupes.

The camps of the cotton ranches are really small villages from which the laborers go forth to the thousand acres of fields. North of the boundary the farms average less than a hundred acres in size. At least in part there is preserved the farmstead pattern: small individual holdings, each with its cluster of buildings. The buildings themselves are characteristically of wood, with a style of architecture that is distinctly American -- be they one-story cottages, or two-

story, square houses (pl. XVIIb). There are frequently flower gardens, even lawns, and no farm is withouts its grove of trees.

With ramadas and huts of arrow-weed, the ditch-bank camps of the cantaloupe and lettuce ranches offer some similarities to the scene on the cotton ranches. But the ditch-bank camps are more ephemeral features than the semi-permanent Chinese headquarters camps. North of the border there is practiced a definite schedule of crop rotation; a field planted to melons one year may contain alfalfa the next.

North of the boundary the Mexican is regarded as being "colored". Hence there are "across-the-track" sections of the towns. These "foreign quarters" present a mixture of American architecture and wooden houses, with the dearth of lawn and trees that is certainly in part Mexican. The American sections find their counterpart in any southern California town.

The highways are paved and tree-lined. The irrigation canals are less conspicuous, with their borders of trees, lying in a landscape dotted with buildings and small fields.

Such things as difference in style of architecture, and the presence or absence of lawns and trees, are possibly expressions of divergent cultures (pls. XVIIb, XVIIc). The contrasted rural pattern is in part fortuitous. It is complicated by a difference in scale of land holdings: the

Company with its nearly a million acres; the hundred acre holdings north of the border. As a customs barrier the boundary itself has been a factor in the differentiation.

CONCLUSION

The Colorado Delta owes its being to the deposition of river alluvium in a structural depression. In plan the delta has adjusted itself to meet the configuration of the depression. In section it has adjusted itself in accordance with the laws governing stream flow and deposition. In its detailed sculpture the delta reflects the activities of a stream subject to great seasonal fluctuations in volume; climatic factors have been of relative insignificance. The true delta cone is limited in area, but beyond it are extensions of the alluvial surface, possessing profiles characteristic of the modeof deposition: estuarine and lacustrine.

The climatic forces find expression in the landscape principally through their incessant attack on the mountain masses. Along the base of the mountains are to be found accumulations of weathered material; dunes on the surface of the delta represent the work of a climatic force.

With its homogeniety of soil, abundance of water, and luxuriant vegetation, the delta stands in striking contrast to the intensely arid country which surrounds it. Were the climate more humid the contrast would be less, for in addition to the modifying effects on the desert, the delta itself would be modified, through the activity of streams originating within the area, possibly through increased

chemical activity. As it is the contrast is sharp; in major part the delta is an expression of forces which find their origin in other regions.

The normal and natural evolution of the delta landscape has been interrupted by man. The tendency of the river to swing toward Salton Sink is suppressed by the building of levees. The progressive march southward of the Delta Cone and Gulf Plain has probably been stopped by the diversion of much of the volume and silt burden of the Colorado. Quite possibly Laguna Salada and Salton Sea will no longer receive flood water; the whole delta area, between the intake of the irrigation canal and the head of the gulf, may become streamless.

If such conditions come to be, the changes effected in the alluvial surface will be great. The mesophytic vegetation may be succeeded by xerophytic. Climatic forces will play a more important part in the landscape; the delta will be invaded by dunes. The silty texture of the soil will be lost through mixture with the sand of the dunes, and through mixture with the steadily encroaching colluvial materials.

As the scene for human activity the delta offers particular advantages in the field of agriculture. By this pursuit, a primitive culture supported a relatively dense population. With modern agricultural methods the area might support a great population -- if there be an

intensive production of food by those who consume it. If the area is devoted to the production of raw materials for export, it need never be heavily populated.

Thus the area is not at all restrictive as to the manner in which its soil shall be exploited. The manner of its modern utilization has been influenced by considerations of labor supply, markets, duties, and mode of land tenure. To a great extent the international boundary has served to introduce sharp contrast in these conditions.

To the south of the boundary the area is dominated by cotton and the Colorado River Land Company. The method of utilization in vogue has involved a leasing system; increasingly the lessees have become Chinese. This is a system which has evolved, certainly for no reason inherent in the landscape; even cotton's introduction into the area was fortuitous. The area possesses conditions extremely favorable for agriculture, in the fertility of its soil, and in the warm, dry climate. Still, the area is devoted to a crop -- cotton -- which here has a productivity less than that of nearly any section in California where it is grown.

With such conditions prevailing it is certain that the cultural landscape has not yet reached a climax form. The pioneer period is still dominant. Great changes will occur until there is reached a better balanced relationship between the land and the people who inhabit it.

PLATE I

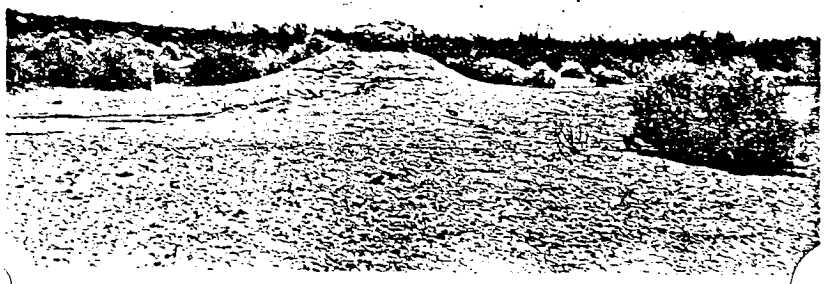
a. Two of the group of active mud volcanoes in the vicinity of Cerro Prieto. In the distance, to the west, can be seen the outline of the Sierra de los Cucopas.

b. A weathered remnant of a mud volcano, long extinct. Along the edge of Sta. Clara Mesa not far from Mesa Andrade. It will be noted how in weathering this material tends to preserve a steepness of slope. Such forms as this, together with hot springs and sulphur springs, mark the extension of the San Jacinto fault, south along the mesa edge.

c. The steep east-facing escarpment of a section of Sierra Mayor. In the foreground appear patches of schist which probably represent the remnants of a mass intruded by the Mayor granite at the time of its formation as a laccolith.

PLATE 1

a



b

c

PLATE II

a. A lagoon about five miles south and west of San Luis, Sonora. It covers several acres and has a maximum depth of perhaps six feet. It represents an old course of the meandering Colorado, but at present it is connected with the main river only by high water channels.

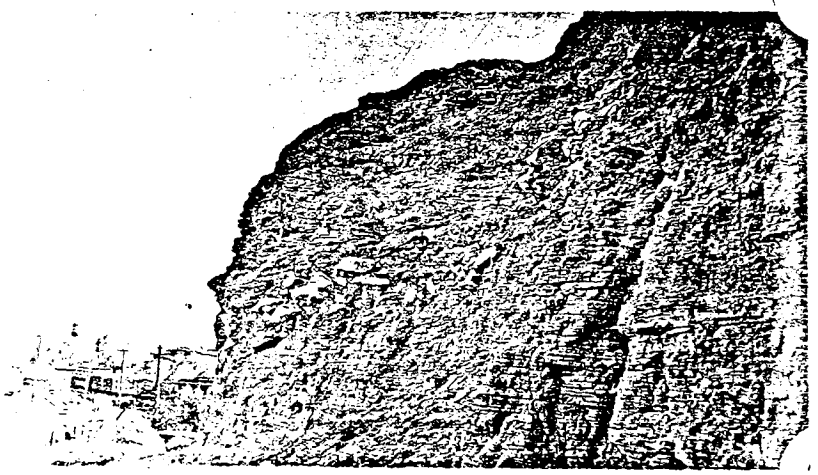
About it are cottonwoods and willows. A corral marks its usage as a watering place for cattle.

b. A section through the river terrace near Pilot Knob. It is irregularly stratified, heterogeneous in composition, and shows such features of structure as cross bedding and lenticular inclusions. Without a distinguishable break this terrace merges with the so-called mesa which marks the "ancient beach line" surrounding the Salton Sink.

c. A development of mud cracks in a small depression which permits a settling out of the finest constituents of the river alluvium. At the time this picture was taken the ground was still damp and the surface "rubbery".

PLATE 11

a



b

c

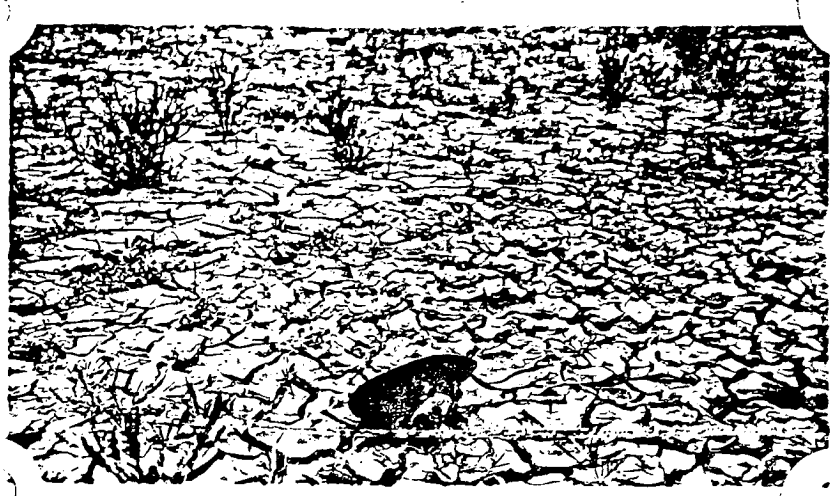
PLATE III

a. Shallow mud cracks which indicate that the soil in which they are formed contains some of the coarser alluvial constituents. The sections are readily crushed into dust and may then be removed by the wind.

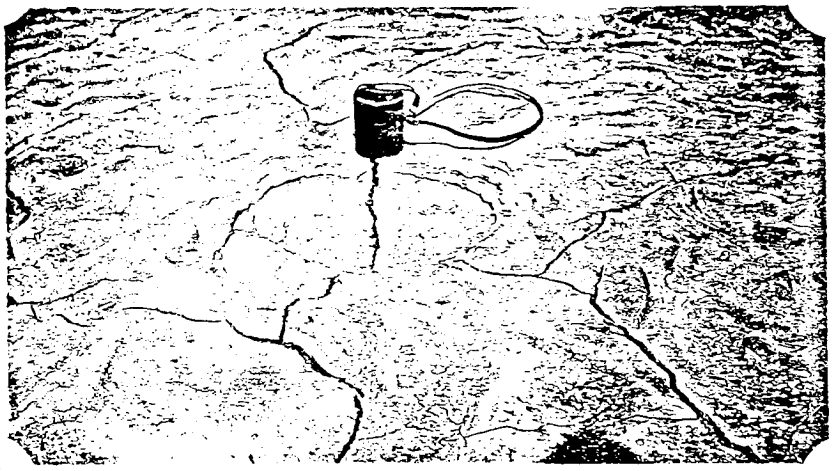
b. A funnel-shaped depression in a surface recently flooded. It probably indicates an escape of the impounded waters to a more permeable stratum below.

c. A dense growth of arrow-weed in a solid stand, on land subject to annual inundation. There are many stands much heavier than this.

PLATE 111



a



b

c

PLATE IV

a. Rows of willows along the west bank of the Hardy, near its junction with the Pescadero. The trees increase in size ascending the bank. This site is on the inside of a bend of the river; quite possibly the rows of willows mark a progressive march toward the cut bank by the river channel.

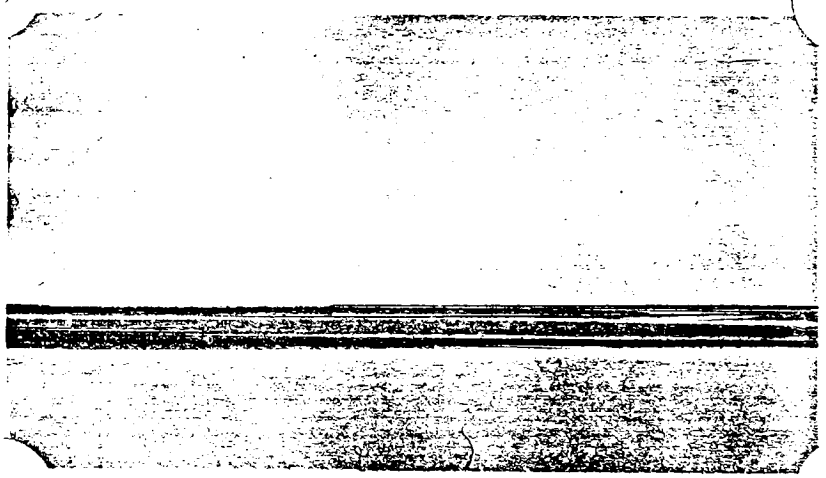
b. Looking toward La Bolsa from the west bank of the Colorado, a few miles south of the mouth of the Hardy. This area is well within range of the tide. The low-lying ground marks a movement of the channel westward. It is alternately the inside bank of the river bend, and a tide flat, as the flood sets up the river.

c. One of the overflow channels by which water is conducted from the Hardy into Laguna Salada. Its surface is hard and cracked, in contrast to the alkali-encrusted soil about it. The car is standing on the road which follows the channel.

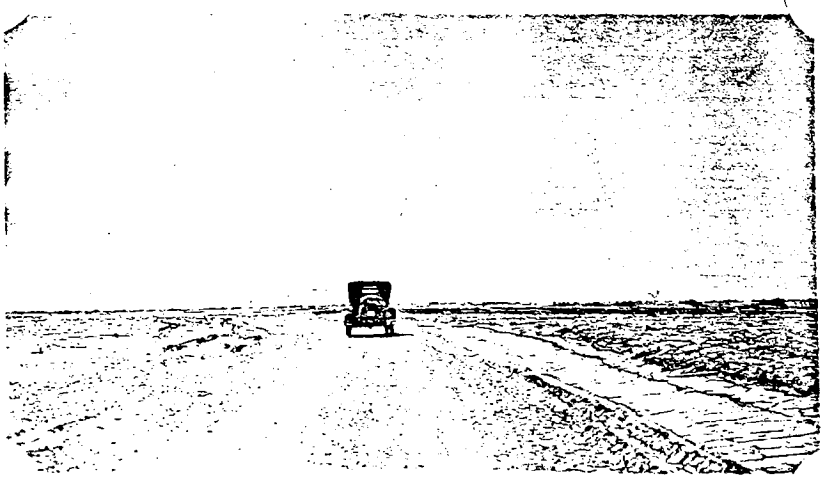
In the distance can be seen the outline of the northern extension of the Las Pintas Range.

PLATE 1V

a



b



c

PLATE V

a. An old beach line along the eastern side of Pattie Basin, which probably connects with the terraces on the eastern side of the Cucopas. The feature is more evident than the picture would indicate.

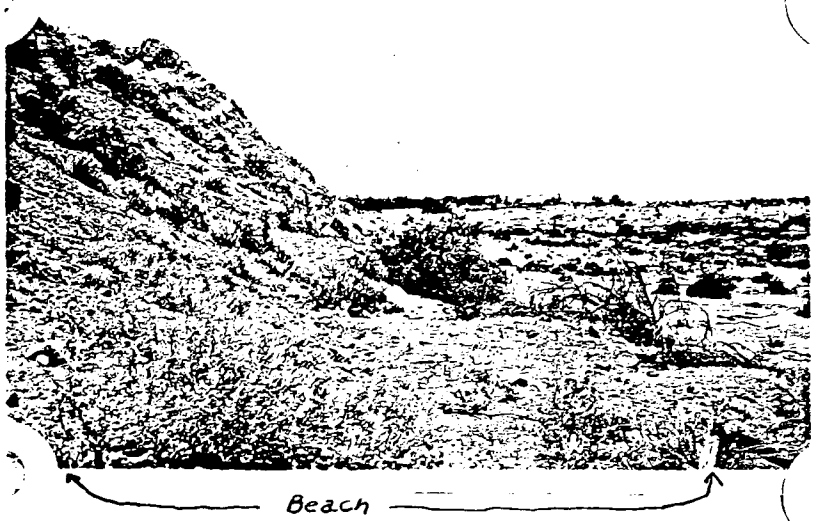
In the far background can be seen the dark mass which marks a mesquite-covered fan, extending out over the surface of the basin.

b. A section through one of the terraces extending to the eastward from Sierra Mayor. The material is well stratified, is coarse in its upper layers and at least fine enough below to permit it to stand in vertical cliffs. The terrace here reaches an elevation of about forty feet above the delta surface.

Not all the terraces are of precisely the same composition

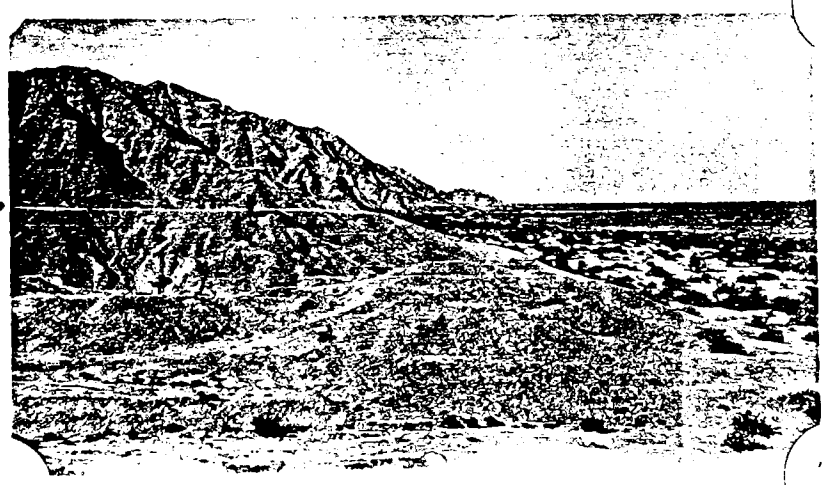
c. The terrace level which is preserved in the distance as far as the view carried. This view exhibits several characteristic qualities which the terraces possess: a flat top preserving a general level, an abrupt outward termination, and unfailing dissection where exposed to the occasional cloudburst torrent.

PLATE V



a

b



c

PLATE VI

a. A part of the great channel excavated by New River, 1905-1907.

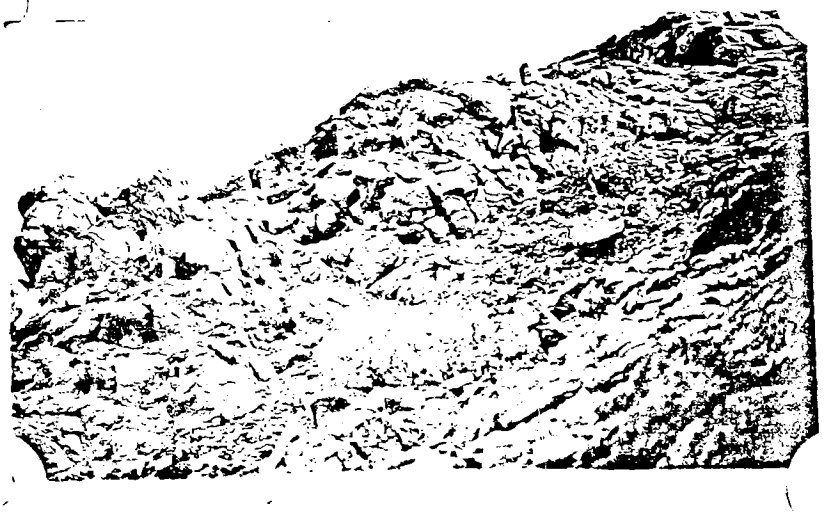
b. Typical pattern developed in the granite masses, Sierra Mayor. The pattern exhibits regularity in its development, due to the homogeneity of the material and to the influence of jointing.

c. A detail of weathering in granite as exhibited on a southeast slope of Sierra Mayor, at low elevation. The term "socket" weathering has been suggested to apply to the process by which these forms are created.

PLATE V1

a

b



c

PLATE VII

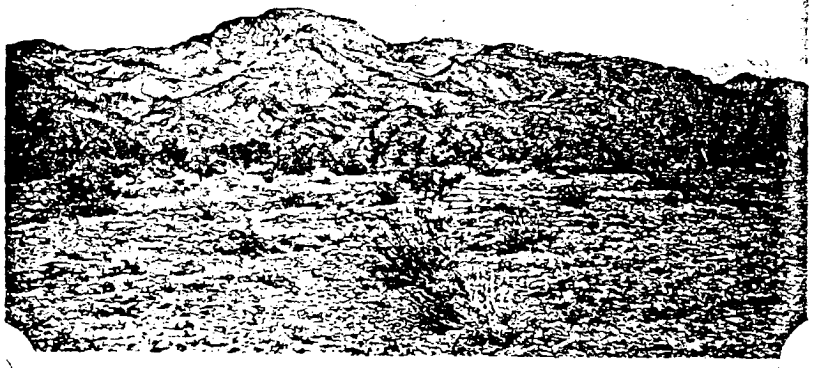
a. A part of the Sierra Pintas Range, which illustrates the irregular sculpture of the volcanic mountains. They are made up of a number of constituent elements, each of which tends to preserve its individual form.

b. Incipient badland topography developed in the Tertiary sediments lying to the east of the head of the gulf. This type of topography extends inland only a few miles and then is succeeded by a high mesa, developed apparently in the same material.

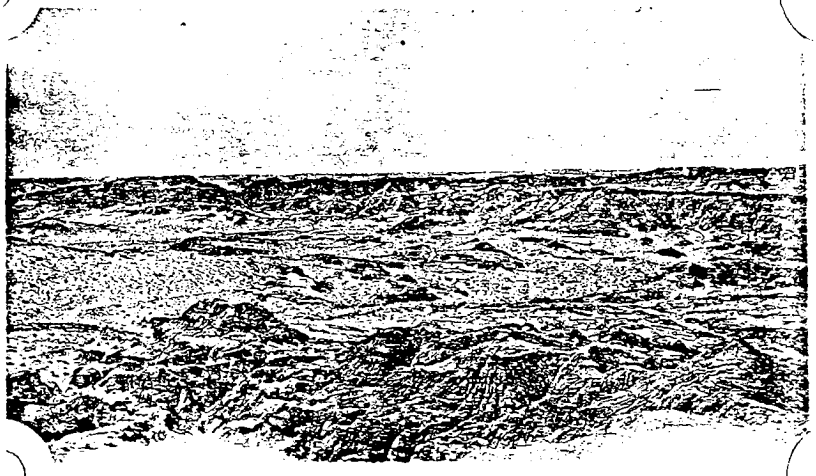
c. A "desert pavement" developed in fine, well rounded pebbles, derived largely from granite, and lying many miles from any rocky eminence. Many of these pavements are formed of much coarser material. Santa Clara Mesa,

A few creosote bushes with little sand accumulations about them interrupt the rocky surface.

PLATE V11



a



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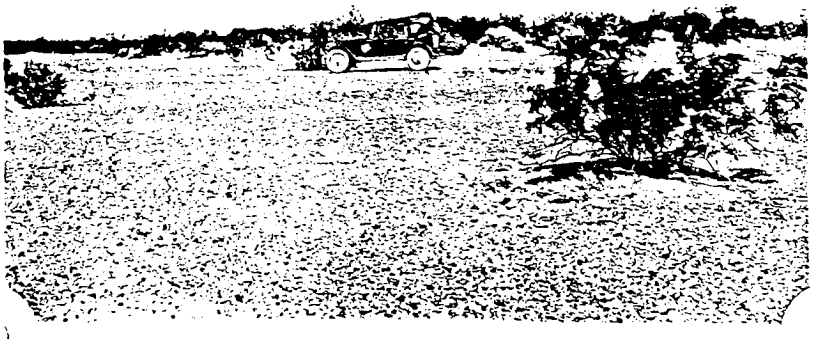


c

PLATE VIII

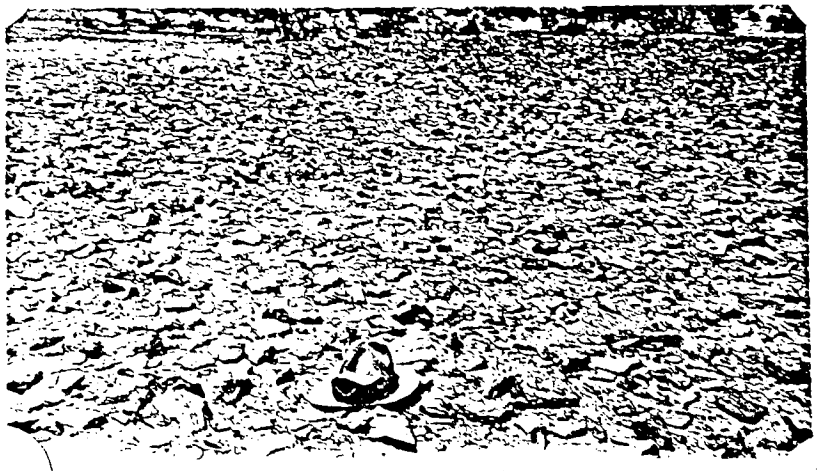
a. Another type of desert pavement, which derives its rock material from the slow movement down slope of the dry debris of weathering. In this case it is formed in the lee of a little basalt hill, an outlier of the Sierra Las Pintas.

b. A close-up of one of the same type of pavement. In this particular instance the rock was underlain by a material so fine that it had been burrowed by animals.

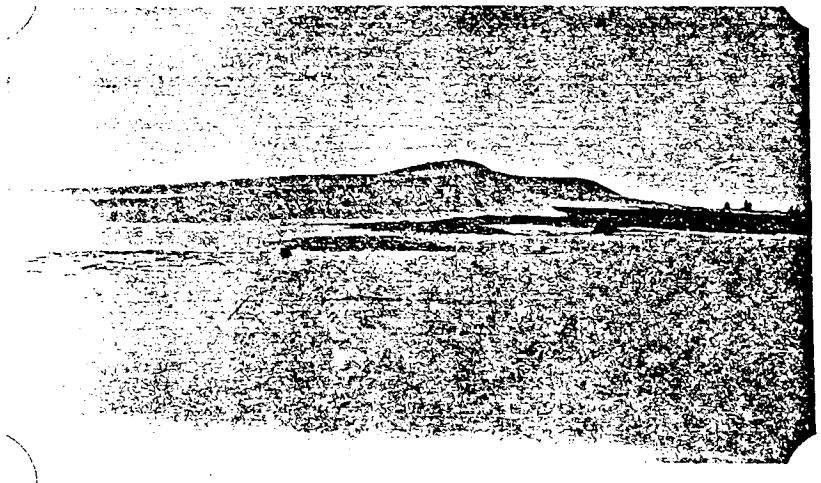
c. A north-facing barchan dune resting on a desert pavement surface, east of the head of the gulf, on the Tertiary mesa.

PLATE V111

a



b



c

c. Accretion dunes rising out of the barren alluvium surface lying at the entrance to Pattie Basin. These forms afford a foot-hold for vegetation which cannot grow on the alkaline soil about them.

PLATE IX

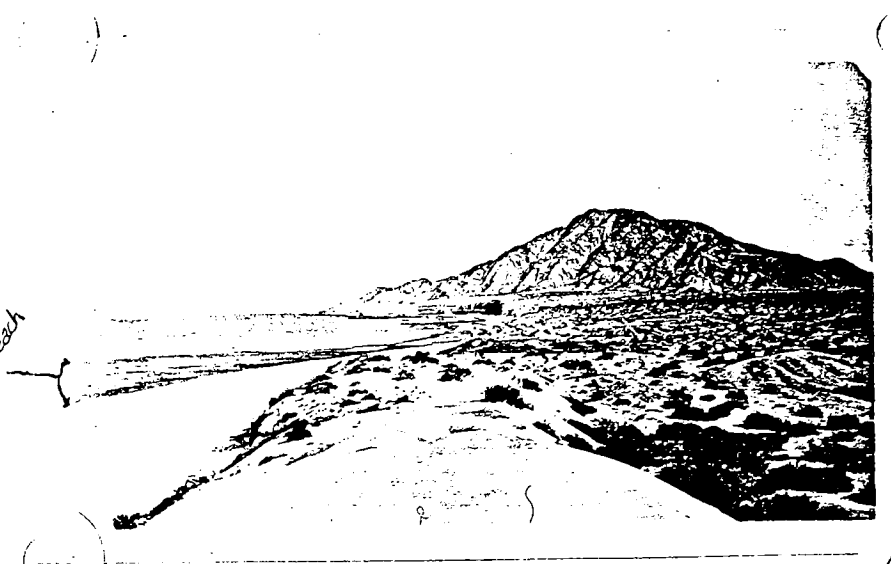
a. Looking ~~south~~ north from the end of the dune belt, which extends along the western side of the head of the gulf. The sand of which the dune is composed has come from the west, but as revealed by its profile it is subject to winds from different directions.

A part of the sand has fallen over the bank which separates the dune from the water, and forms a sandy beach at high tide. A part of the low tide mud beach can be distinguished in the picture. This forms the southernmost appearance of Colorado alluvium in surface exposure. ~~In the distance lies Punta San Felipe, one of the three "corner stones" of the delta.~~

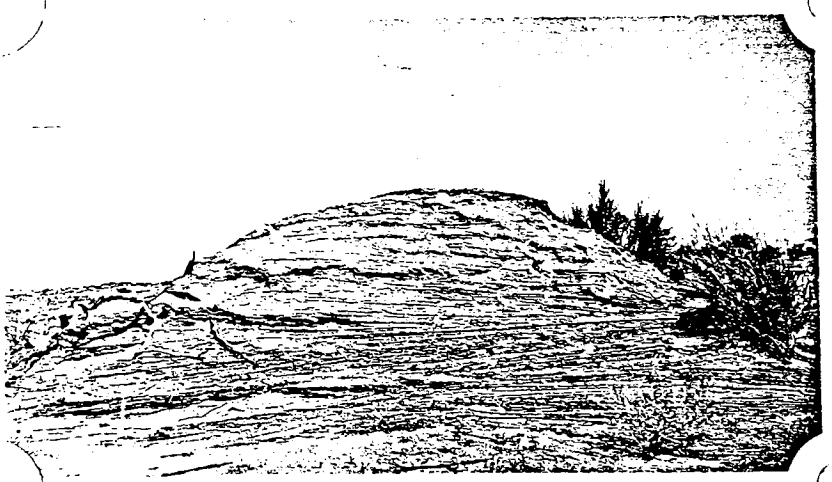
b. A fixed dune, showing the effects of the abrasive action of wind-transported material. This dune is located at the southern end of the Pattie Basin, where it is exposed to the sweep of the dominant northwest wind. To the left can be seen the dead roots of the vegetation which held the dune together, and which possibly contributed to its formation.

The material is not pure sand, as can be seen by the fact that it maintains a vertical face.

PLATE IX



a



b

PLATE X

a. Santa Clara Mesa, near the head of the gulf.

A sandstone, poorly cemented with caliche, which has bee exposed by denudation. It has acted to some extent as a more resistant layer, has been undermined, and so has reached its present position.

b. The channels of the Colorado, from the east, a short distance south of the boundary. In the far background is the heavy forest of cottonwood trees characteristic as a bordering strip on both banks of the old channel of the Colorado. This was noted by nearly every visitor to leave a record of his visit.

Near this point is a very primitive ferry which serves as the sole land connection between Sonora and Baja California lying in Mexico.

c. The black-alkali surface which borders the salt beds of Laguna Salada. Under the surface the material is moist, but it dries readily on exposure to the sun.

In the distance can be seen a part of the northern range of the Cucopas.

PLATE X

a

b

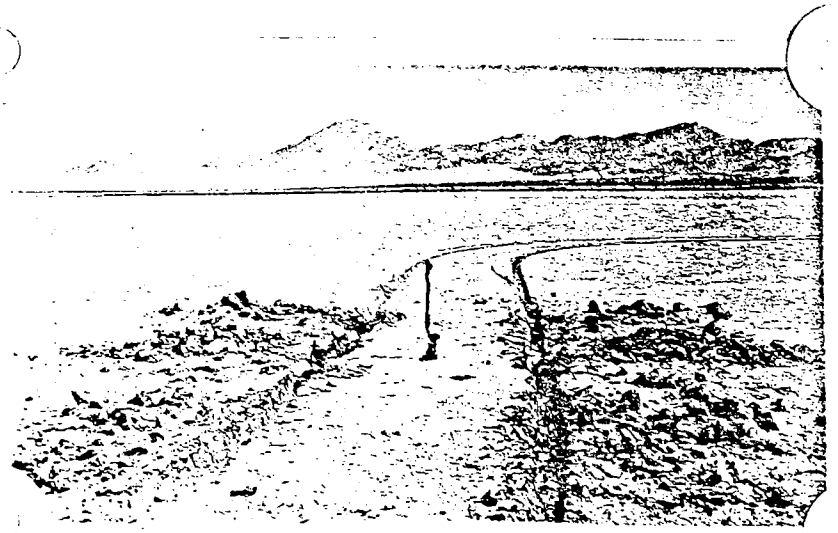


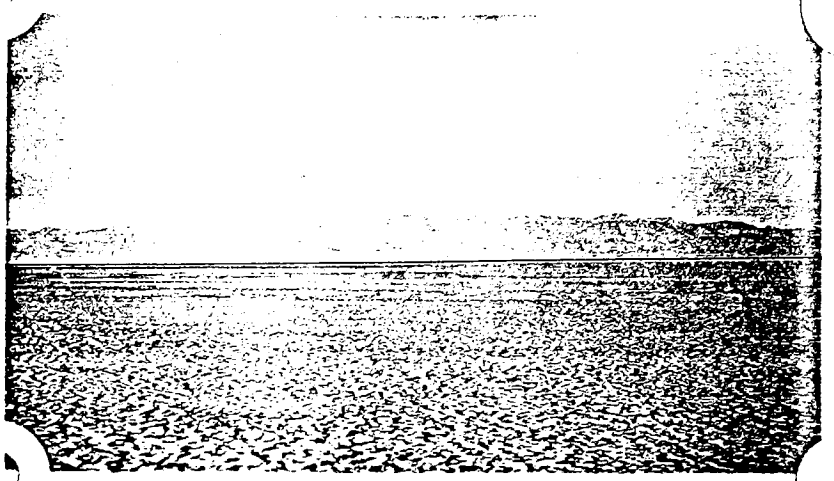
PLATE XI

a. The barren, alkali-encrusted surface which occupies much of the floor of Pattie Basin. An important alteration is going on in this surface as revealed by the wind-blown sand which is lodged in the little depressions. The Cucopas in the distance, looking east.

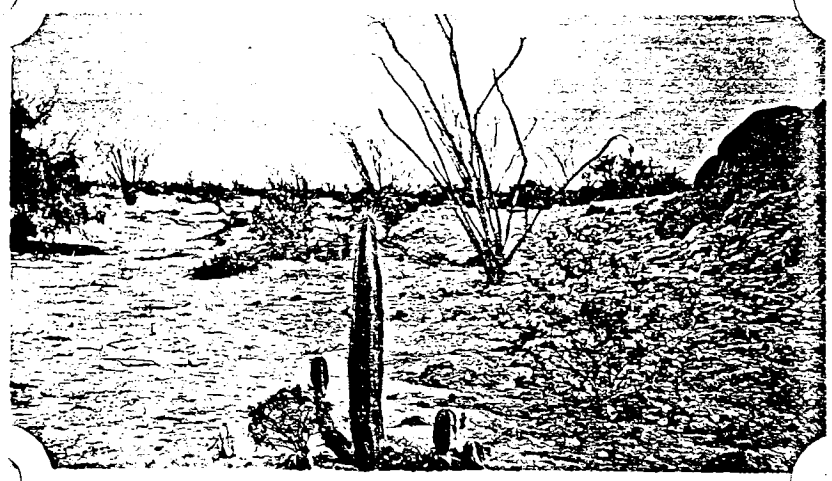
b. Vegetation along a little sandy wash which joins with others of the same nature to form the San Felipe Arroyo. In the middle foreground appears garambuyo (cactus), to the right creosote bush, and in the background ocotillo. To the left can be seen a drooping mass of mistletoe, entwined about the dead branches of the tree to which it clings.

c. Sierra Mayor viewed from the south. ~~Patches of~~ schist are indicated by darkening.

PLATE XI



a



b

c

PLATE XII

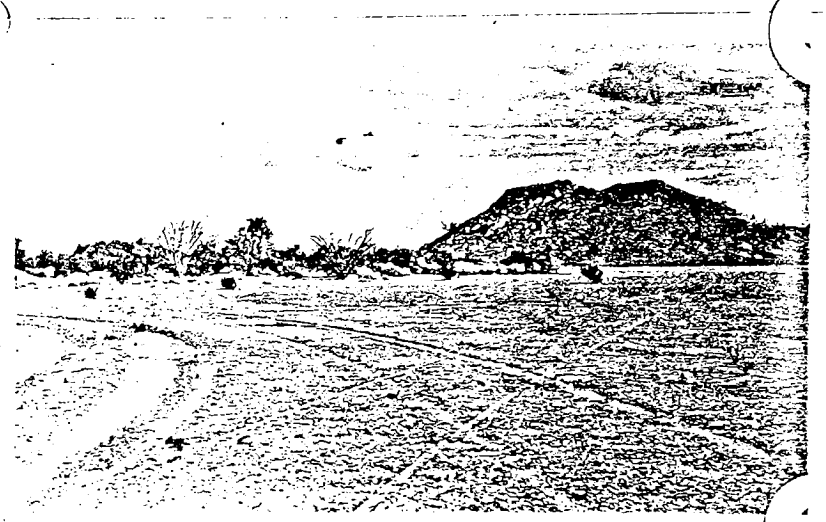
a. The basalt-capped mesa which constitutes the northern portion of the Sierra de las Tinajas.

b. At the southern end of Pattie Basin. Little granitic hills, nearly submerged in a plain composed of alluvial sand and gravel, and beveled by a Pleistocene sea.

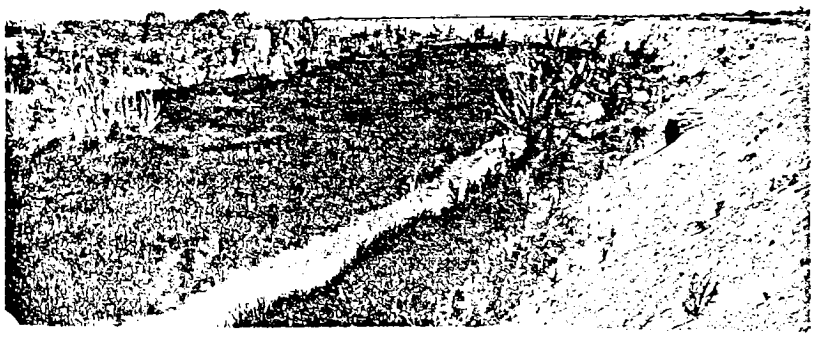
c. Along the edge of the Santa Clara Mesa near the head of the gulf. The tule swamp and the bordering cottonwoods are indicative of the presence of fresh water, which issues from springs along the base of the mesa.

PLATE X11

a



b



c

PLATE XIII

a. One of the little sandy washes tributary to San Felipe Arroyo. The sand on the floor of the wash is coarse grained and derived from granite.

b. The strange copal tree (Terebinthus macdougali), on the mesa north of San Felipe. Sometimes called "turpentine tree" and parrote. In this area it finds the northern limit of its habitat.

c. Extensive salt-grass plain near the mouth of the Colorado, subject to annual inundation. Grazing cattle can be distinguished in the distance.

PLATE X111

a

b

c

PLATE XIV

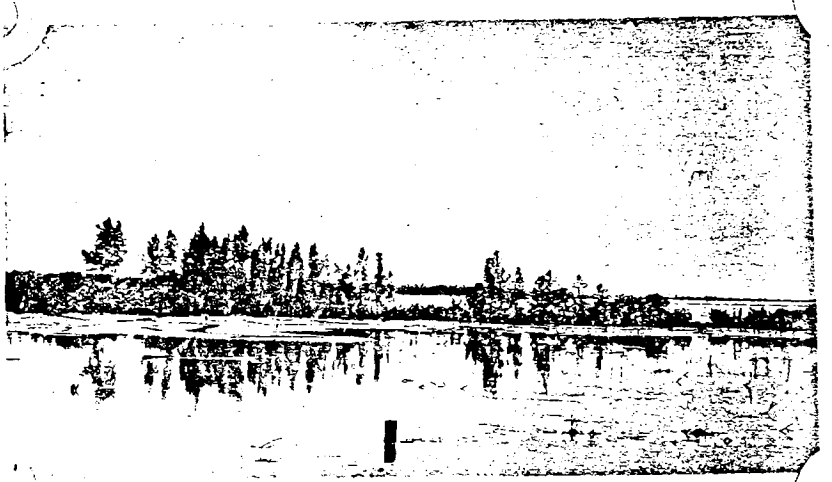
a. The lower Hardy River, several miles below the mouth of the Pescadero. The river has a width of about 200 yards, and is in the normal stage preceding the summer flood. Sierra Mayor appears in the distance to the west.

b. Looking south from the Rodriguez Levee. The inundated area lying between levee and the main river channel here measures some four miles.

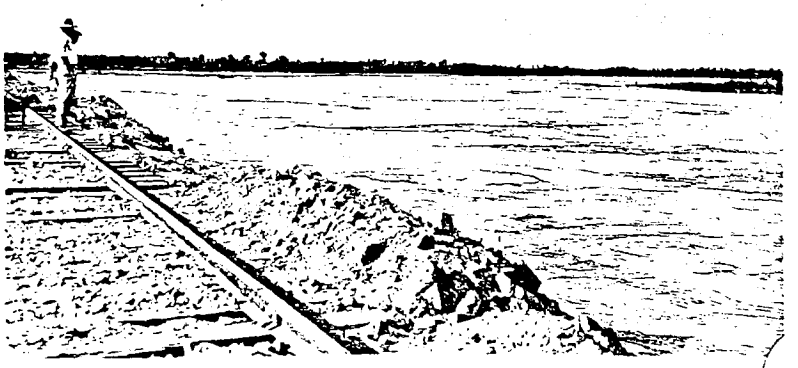
c. Pescadero Dam. Part of the main levee which borders the Colorado on the west. A railroad track runs along the top of the levee and is used principally to haul rock from Pilot Knob. The rock is used for "rip-rapping" the levee.

PLATE XlV

a



b



c

PLATE XV

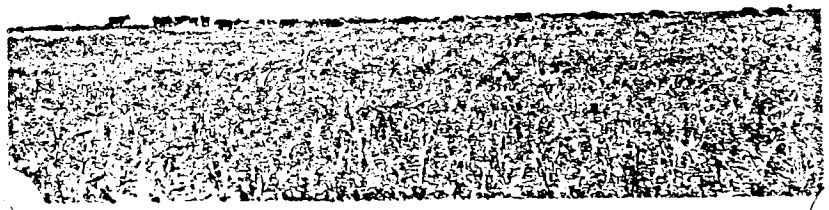
a. Fixed dune on the delta near Cocopah, on the Inter-California Railroad. The dune proved to be too large for the scrapers, when the land was leveled, so the field was laid out about it.

b. Cattle being fattened on alfalfa, about fifteen miles south of Mexicali.

c. The S. S. Rio Colorado, tied up at El Mayor. This landing is used during the high water period. The vessel serves to connect the delta region by water with Guaymas and Mazatlan.

PLATE XV

a



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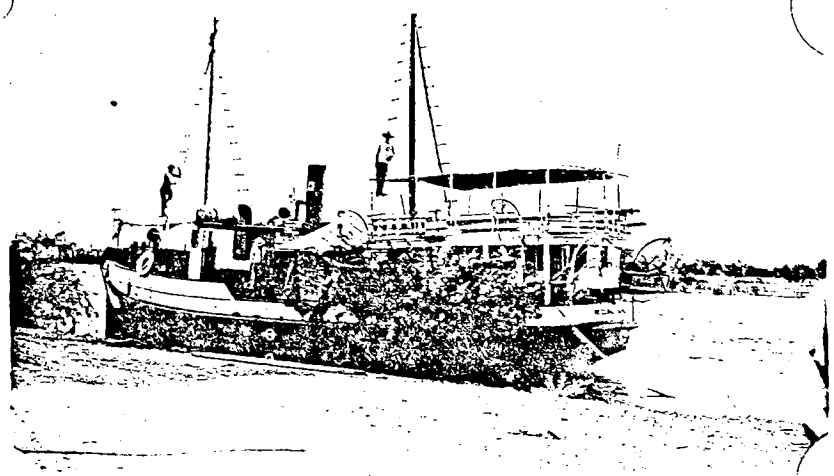


c

PLATE XVI

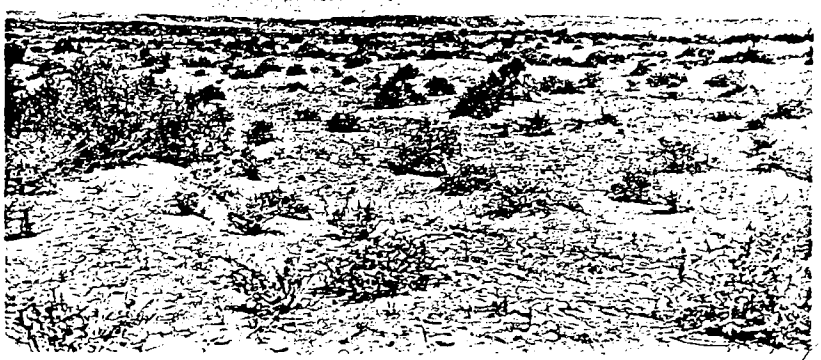
a. Shell mounds near the head of the gulf, on the Sonora shore. The mounds had an area of about 200 acres, with an average depth of about five feet. Living forms of the same type are to be found on the shore which is only a half-mile distant. No spring or well is known for a distance of several miles.

These mounds lie in an area which probably belonged to the Papago.

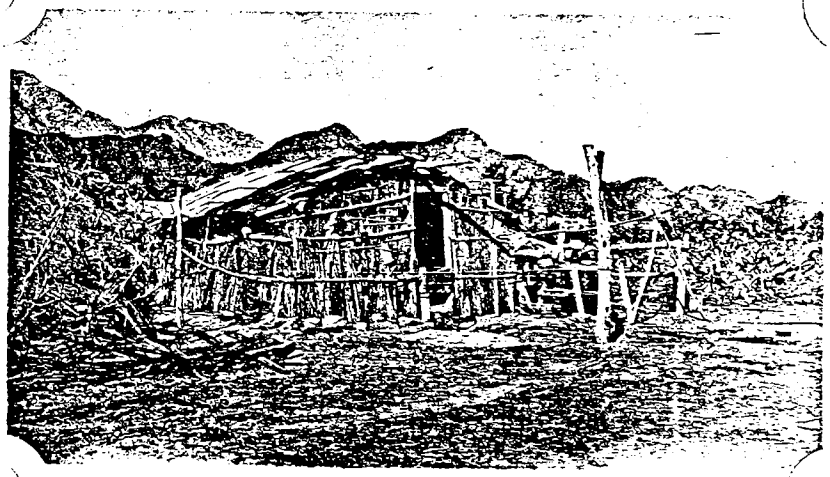
b. The house of a Mexican small farmer, near El Mayor. The walls are composed of arrow-weed thatching, the roof of tin from gasoline cans.

c. The fine edifice which houses the offices of the territorial administration -- Mexicali.

PLATE XVl



a



b

c

PLATE XVII

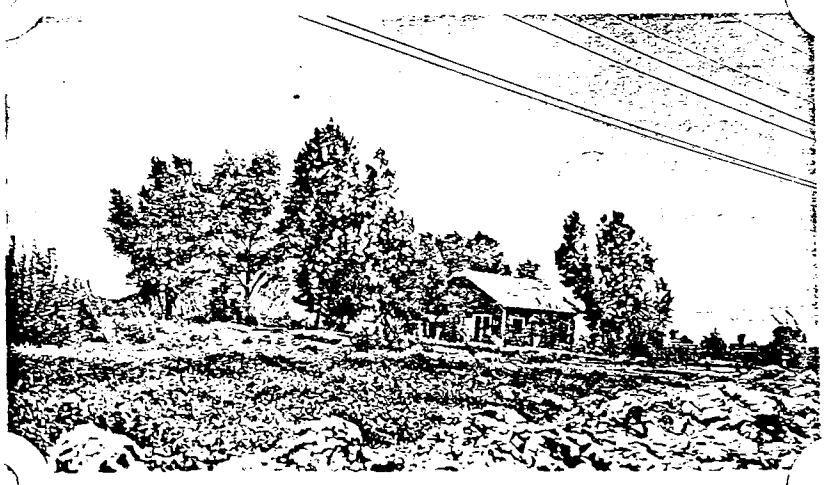
a. A squatter's establishment about four miles east of Mexicali. The main house has a thatched roof and adobe-plastered walls.

b. The dwelling of a Mexican rancher near San Luis, Sonora.

c. The residence of an American cotton grower in Yuma Valley.

PLATE XV11

a



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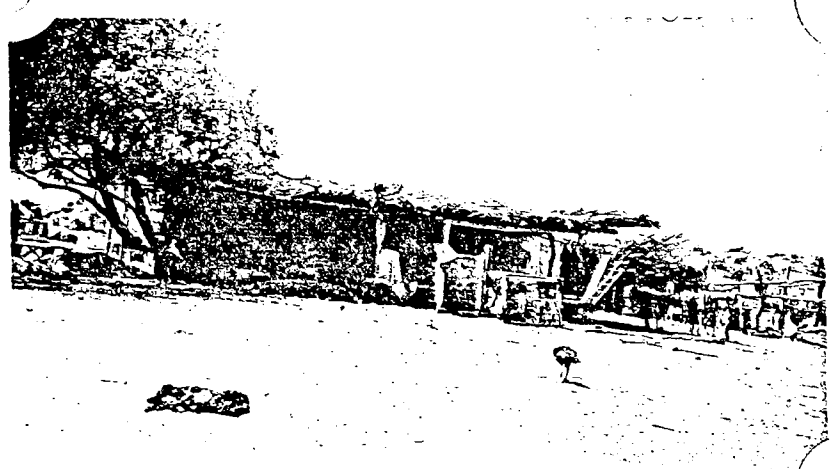


c

PLATE XVIII

a. One of the farmsteads of Colonia Progreso.

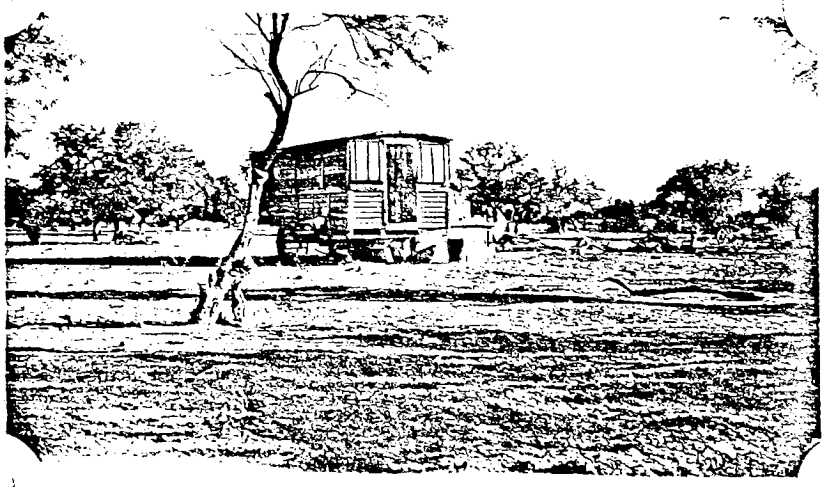
b. Part of the mesquite grove which marks the site of Pozo Cenizo. The principal well is to be found in the right foreground, near the small mesquite.

c. Cattle camp on the Hardy a few miles below the mouth of the Pescadero. Still known as "Los Texanos", this site marks a place occupied since the days when it served as the headquarters of the Texan cowboys working for the Colorado River Land Company.

PLATE XVIII

a

b



c

PLATE XIX

a. The old brick headquarters camp, a hangover from the cattle days of the Colorado River Land Company, located a short distance southeast of Mexicali. Now occupied by one of the Oriental lessees of the Company's land.

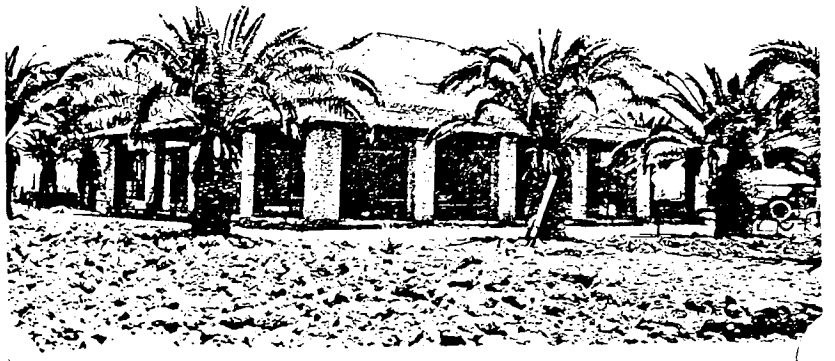
The trees are date palms.

b. The Rodriguez levee, which forms the first line of defenses against the inundation of the agricultural land by the Colorado. This picture was taken in June when flood water was high on the levee, as shown on the right.

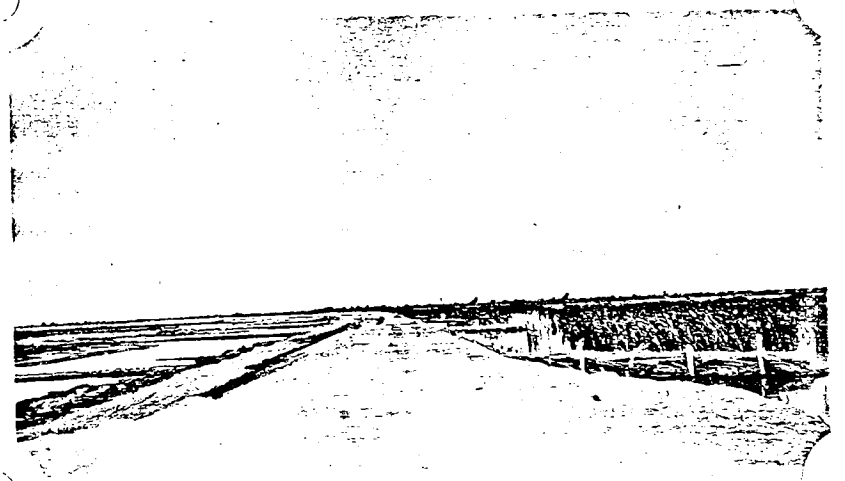
This levee has a general east and west direction and is one of several which are transverse to a main levee which runs along the west bank of the Colorado.

c. Cotton field, and in the background a dense forest, largely of willow, similar to that cleared from this field three years before. A short distance west of Pescadero Dam.

PLATE XIX



a



b

c

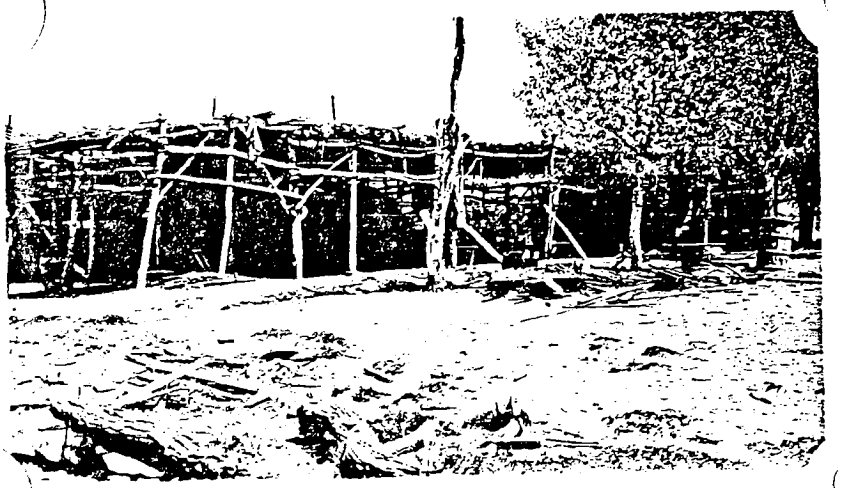
PLATE XX

a. Headquarters camp of a Chinese lessee who is growing cotton on the surrounding ranch. In the shadows beneath the ramada are several screened structures which serve as dining room, sleeping quarters, etc. In the center of the picture is the characteristic flag pole, and to the right part of a grove of cottonwoods.

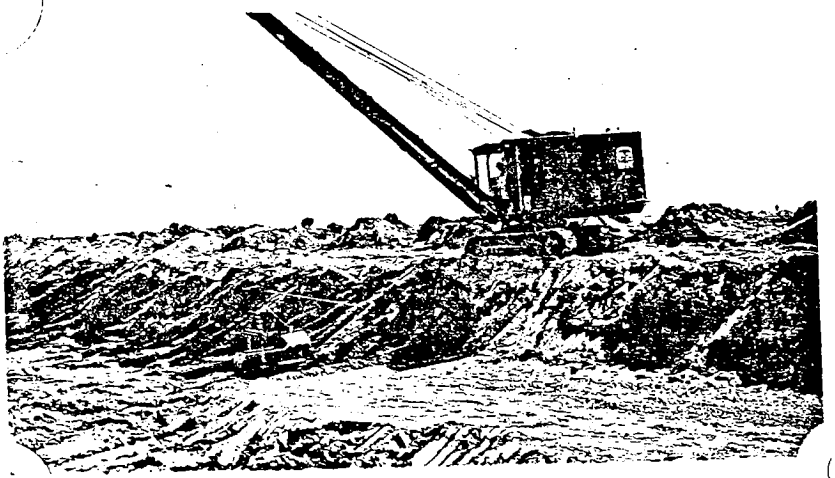
b. One of the serious problems of the present system of utilization is epitomized in this picture, which shows a clam in the process of removing the silt accumulation from a main irrigation canal. The three feet accumulated came as a result of a forty days run of water through the canal.

c. To the right the flour mill, and to the left the headquarters building of Colonia Progreso.

PLATE XX



a



b

c

PLATE XXI

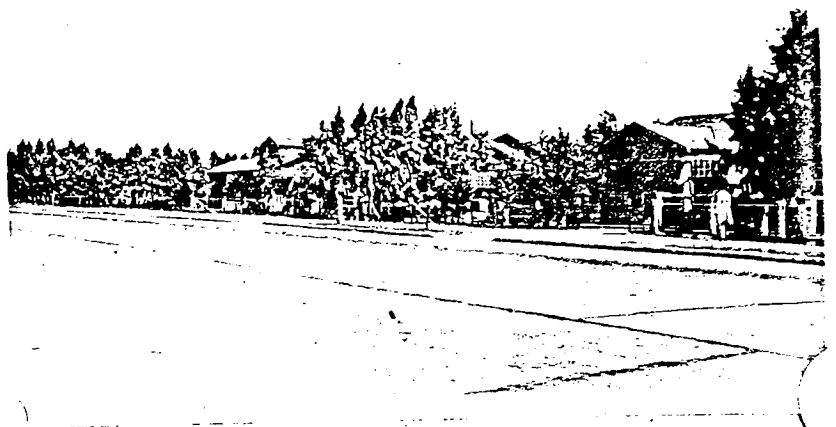
a. A wide, well-paved street in Mexicali. The residences will compare very favorably with those of towns on the American side of the boundary.

b. Paredones, one of a number of little settlements at stations along the Inter-California Railroad. These little towns have sprung up without any particular urge of site, and serve no particular function. They consist typically of a single row of dwellings, with perhaps a store and filling station or so. They are being replaced by regularly plotted and subdivided town sites. The main advantage of the latter lies in the facilities for sanitation which they will provide.

c. One of two camps on the bay at San Felipe. The fishermen come largely from Guaymas for the winter fishing; in summer the camp is nearly deserted.

To the west lies the great sand and gravel plain out of which there rises an old volcanic form. In the background is a granitic range which comes down nearly to the coast; beyond it lies the Sierra San Pedro Mártir.

PLATE XXI



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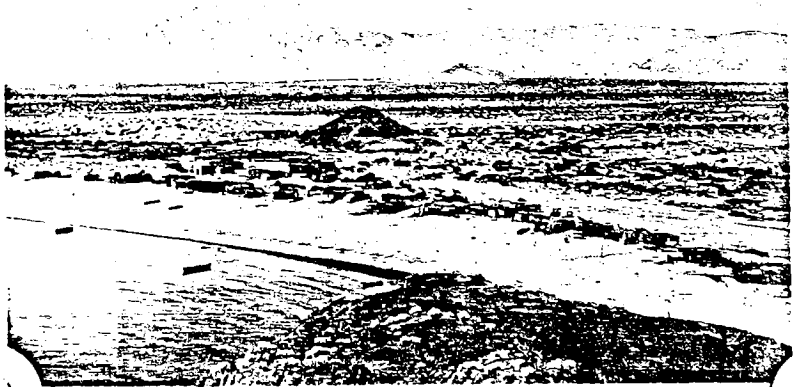
b



c

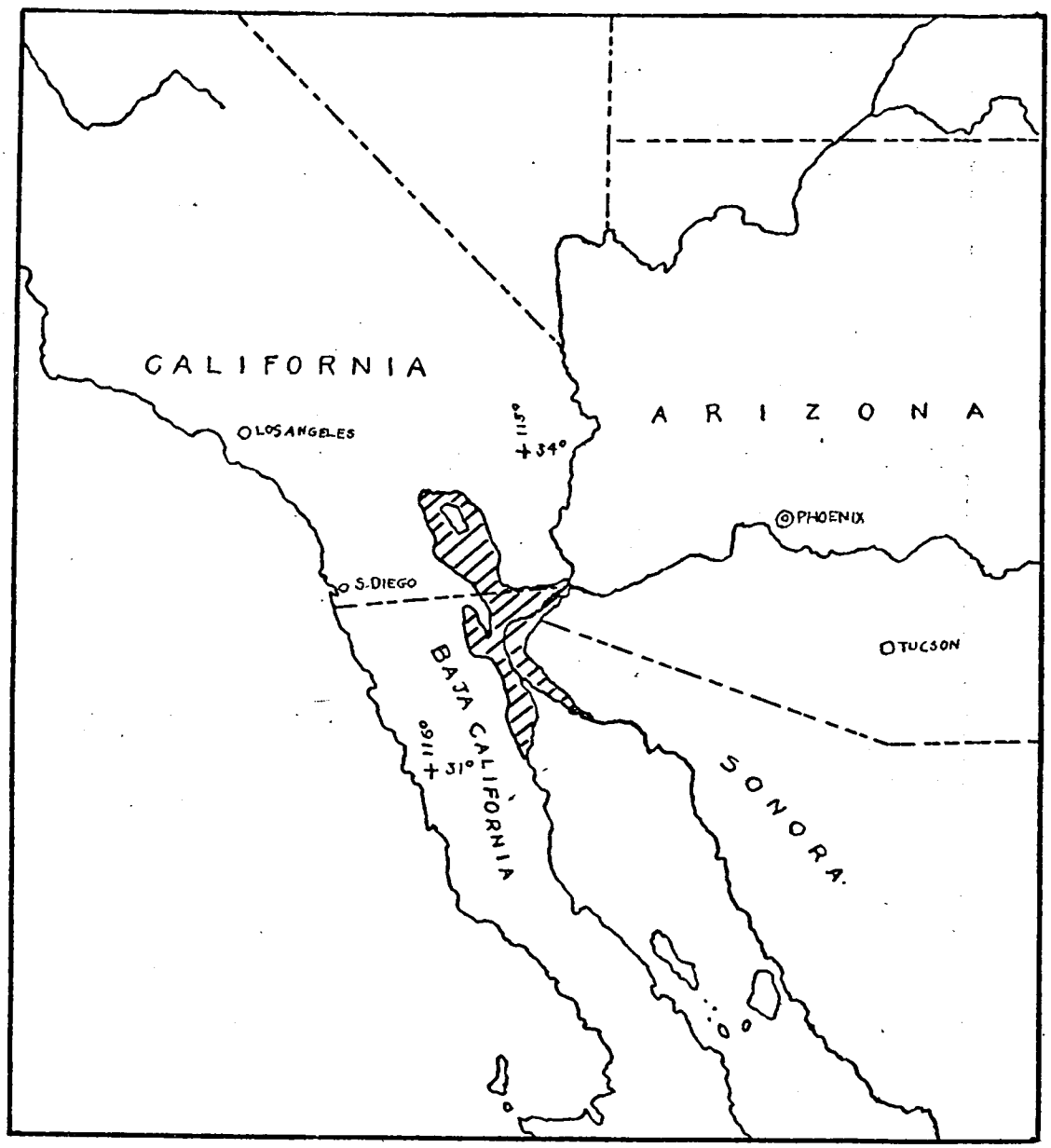

CALIFORNIA
ARIZONA
LOS ANGELES
S. DIEGO
PHOENIX
TUCSON
BAJA CALIFORNIA
SONORA
o911 + 34°
o911 + 31°

Fig. 1

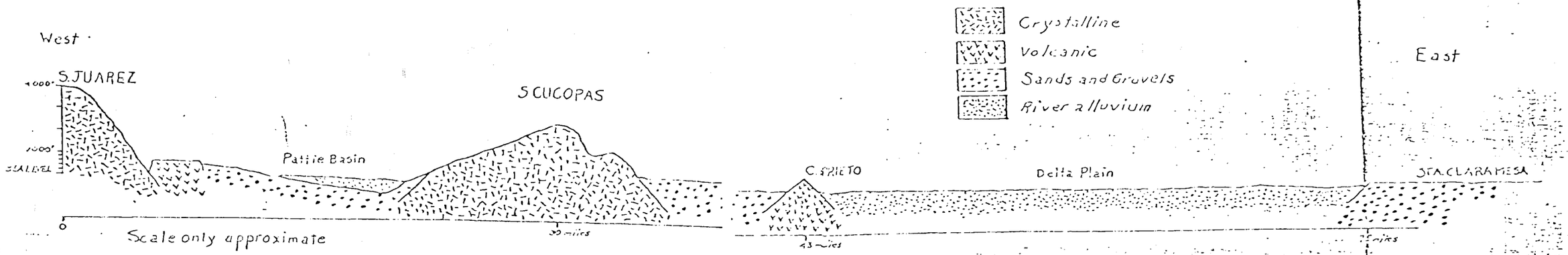

West
S. JUAREZ
1000'
500'
SEA LEVEL
Pattie Basin
S CUCOPAS
0
Scale only approximate
30 miles
Crystalline
Volcanic
Sands and Gravels
River alluvium
East
C. PRIETO
Delta Plain
STA CLARA MESA
43 miles
75 miles

Fig. 3

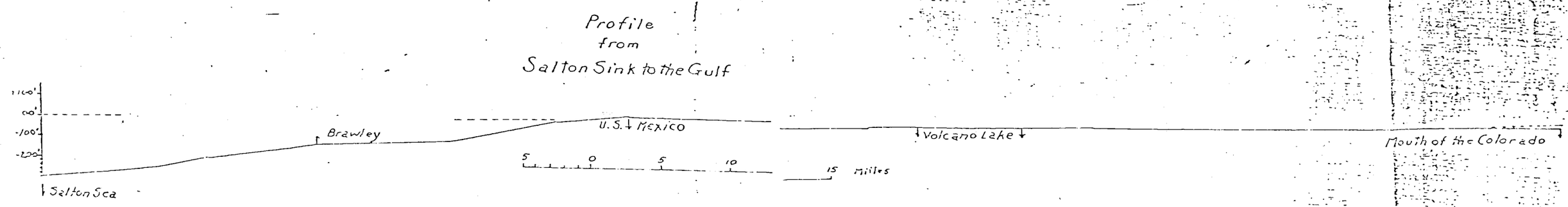
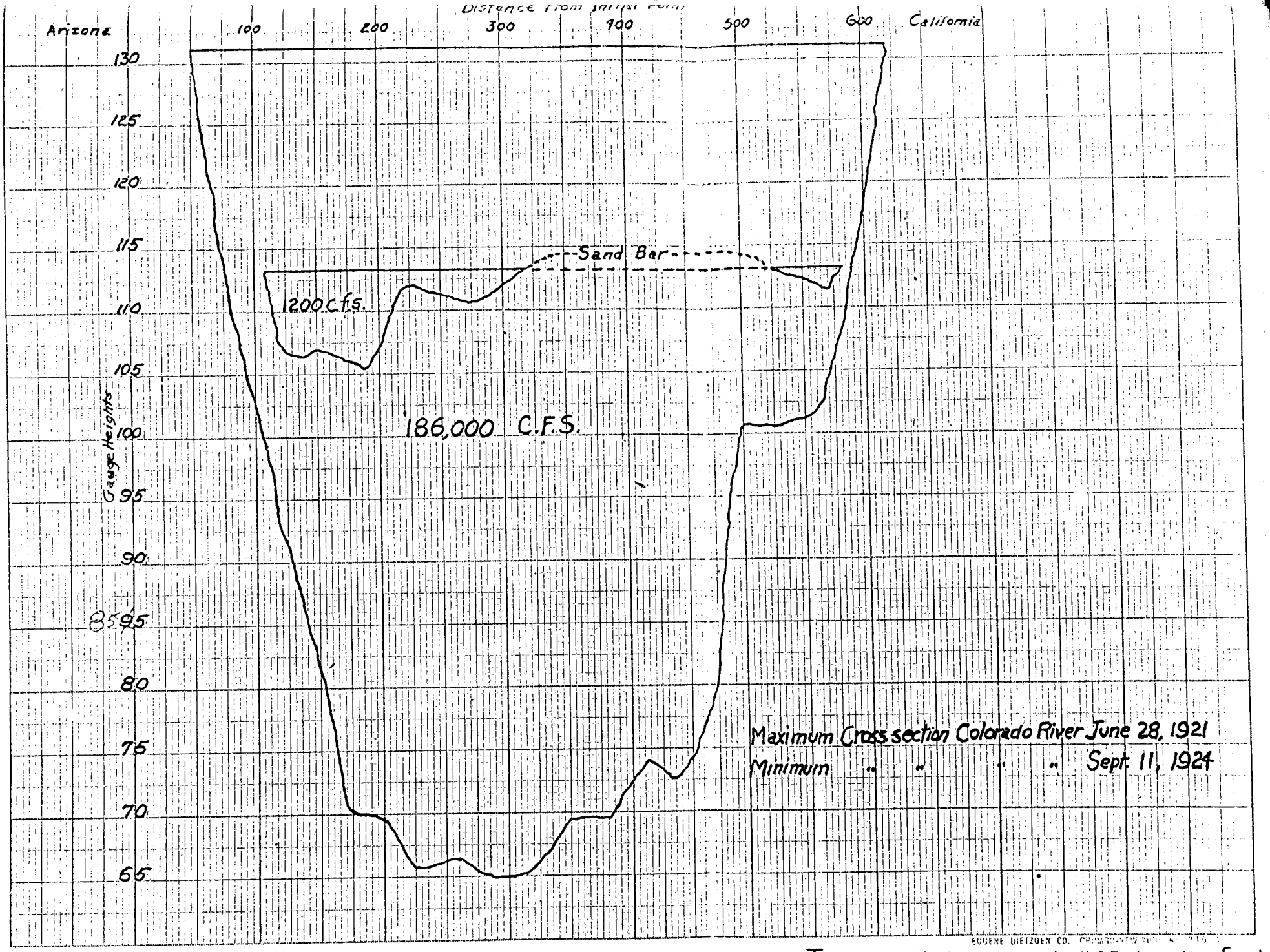

Profile
from
Salton Sink to the Gulf
+100'
0'
-100'
-200'
Salton Sea
Brawley
U.S. ↓ Mexico
5 0 5 10
15 Miles
↓ Volcano Lake ↓
Mouth of the Colorado

Fig. 2



Taken directly from the records, U.S. Reclamation Servic

Fig. 4

POLAR TYPE CLIMATIC CHART BASE

NO. 2

STATION: Calexico, Calif.

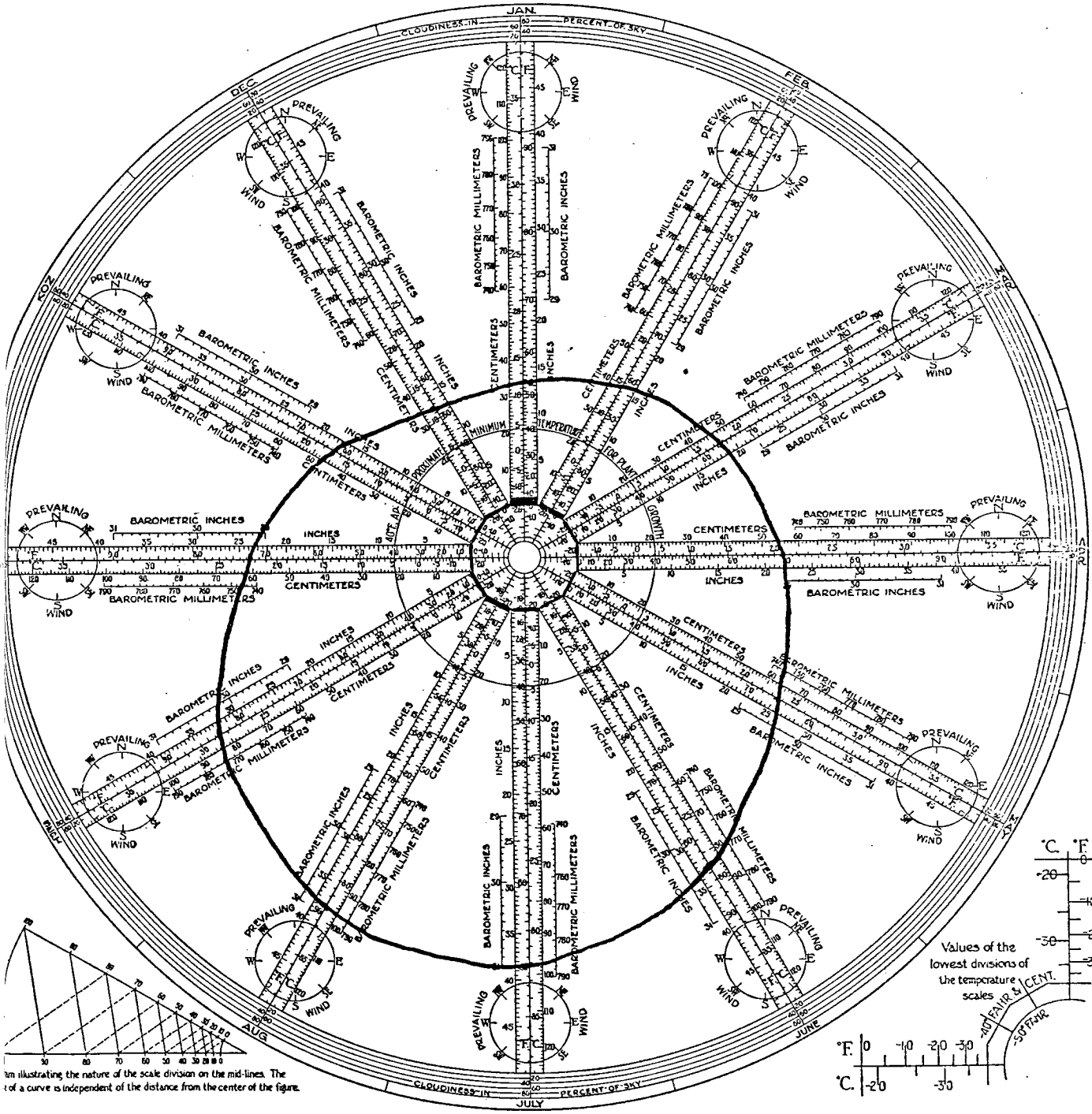
ATITUDE: 32°45'N

LONGITUDE: 115° 30' W.

LEVATION: Sea level

RELATION TO SEA: 80 miles from the Gulf of Calif.

THER FACTORS:



Illustrating the nature of the scale division on the mid-lines. The of a curve is independent of the distance from the center of the figure.

SUMMARY:

MEAN ANNUAL TEMPERATURE: 71.0°F.

MEAN ANNUAL RANGE OF TEMPERATURE: 36.7°F

MEAN ANNUAL PRECIPITATION: 3.10 inches

LENGTH OF RECORD: 15 years.

SOURCE OF DATA:

CHART PREPARED BY: U.S. Weather Bureau

EXPLANATION AND REMARKS:

■ precipitation

⌒ temperature

TYPE: Hot desert BWh of Köppen

JBL del

Fig. 5

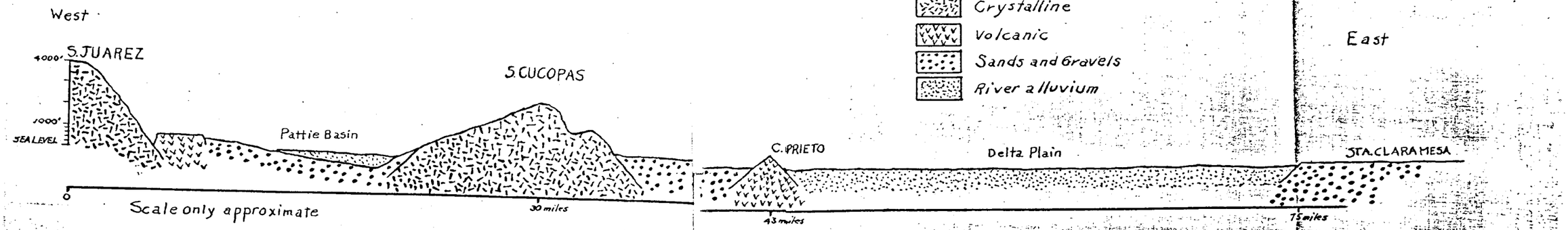

West
East
S. JUAREZ
4000'
1000'
SEA LEVEL
Pattie Basin
S. CUCOPAS
Scale only approximate
0
30 miles
Crystalline
Volcanic
Sands and Gravels
River alluvium
C. PRIETO
Delta Plain
STA. CLARA MESA
43 miles
75 miles

Fig. 3

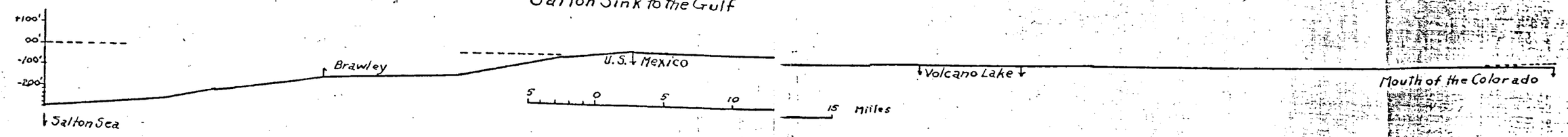

Profile
from
Salton Sink to the Gulf
+100'
00'
-100'
-200'
Brawley
U.S. ↓ Mexico
Salton Sea
5
0
5
10
15 Miles
Volcano Lake
Mouth of the Colorado

Fig. 2

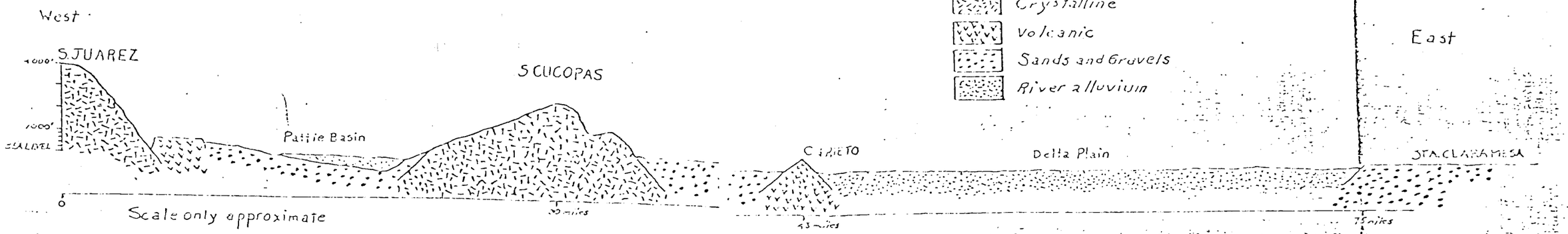
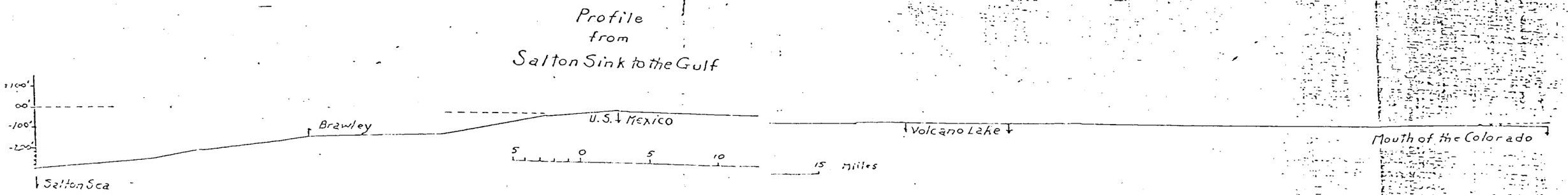

West
S. JUAREZ
4000'
1000'
SEA LEVEL
Pattie Basin
S CUCOPAS
0
Scale only approximate
30 miles
CERRITO
Delta Plain
STA. CLARA MESA
43 miles
75 miles
Crystalline
Volcanic
Sands and Gravels
River alluvium
East

Fig. 3


Profile
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Salton Sink to the Gulf
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00'
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-200'
Brawley
U.S. ↓ Mexico
Volcano Lake ↓
Mouth of the Colorado
5 0 5 10
15 Miles
Salton Sea

Fig. 2