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THE TOPOGRAPHIC FEATURES OF THE DESERT BASINS OF THE UNITED STATES WITH REFERENCE TO THE POSSIBLE OCCURRENCE OF POTASH.[1]

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INTRODUCTION.

In essence the "desert basin" or "dry lake" potash theory is very simple and rests upon three propositions:

(1) Rocks and soils give up various salts, including those of potassium, to drainage waters which flow over them.

(2) In areas of inclosed drainage these salts, still including those of potassium, are concentrated wherever the waters evaporate.

(3) In this concentration the salts of potassium *may* have been sufficiently segregated from other salts to form a workable deposit.

It has long been known that a considerable section of the United States is undrained and apparently contains regions satisfying the conditions requisite to potash[2] concentration. The problem set the writer, early in the present Governmental investigation into possible potash resources, was the study of all of these undrained areas, or "desert basins," in the effort to determine which of them, if any, might possibly contain potash deposits, and which could reasonably be considered the more favorable from this point of view. The problem is a complex one and includes at least three distinct and different questions: (1) The question of accumulation; or of source, concentration and retention; (2) the question of segregation of the potash from the other salts; and (3) the question of the accessibility

[1] Manuscript prepared July, 1912.

[2] Throughout this bulletin the word "potash" is used in accordance with common usage, to signify any ordinary soluble compound of the element potassium.

NOTE.—This paper describes a topographical examination which has been made of the desert basins of the United States, with a view to the possible discovery of potash in commercial quantities, and is intended particularly for those interested in the production of fertilizers.

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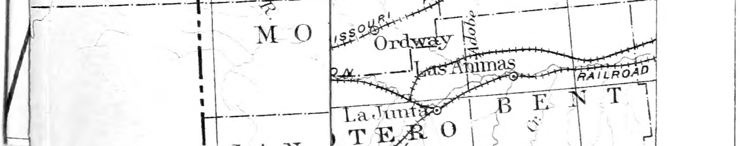
of the deposit if any exists. It can not be said that any one of these questions is more important than the others, since the solution of all will be essential to a full understanding of the greater problem. It is fair to say, however, that the question first named must first be solved. It takes precedence, perhaps, not logically, but chronologically. It is obviously useless to spend time in study of the conditions which may have controlled segregation in a basin to which no potash has been supplied or from which it has escaped.

The problem, then, is first of all that of locating those areas in which potash reasonably may be expected to have accumulated and from which it apparently has not been withdrawn. This is not a matter of simple observation. There are only very few of the basins in which deposits of soluble salts are exposed on the surface and may be examined directly. Nearly everywhere the salt bodies indicated on substantial though theoretical grounds have been more or less deeply buried by later deposits. Their character, even their presence or absence, must be inferred from general geological evidences, apparently somewhat remote from the point at issue.

Direct evidence being thus lacking and not easily obtainable, the first question (that of accumulation) becomes essentially one of topography and of areal geology. It is reasonable to expect that potash will have accumulated in largest quantity in that place where the greatest drainage has been concentrated for the longest time and where the rocks from which that drainage is derived are such as may reasonably be expected to yield potash most largely, easily, and rapidly. The matter may be reduced to three formal criteria: (1) The drainage area of the basin (past as well as present); (2) the existence or possibility of a present or past overflow (which might have removed the potash); (3) the nature of the rocks and soils exposed to the drainage.

Of these criteria the first two are the most important and both are essentially topographic. It is seldom that the rocks of an area are either entirely potash bearing or entirely the reverse. The study of the areal geology is not only seldom conclusive, but is always laborious and is obviously never necessary unless topographic conditions are known to be favorable. The first step of the inquiry is, therefore, the study of the topography of the undrained regions, and it is this step only which is taken in the present report. The writer here sets out to answer the question "In what basins has potash probably accumulated and been retained in significant amount?" With the no less important matters of segregation and position (especially depth) he is not here concerned.

The topographic data upon which the report is based have been gathered from many and various sources. Chief and most important are the topographic sheets of the United States Geological Survey,



Moab
MO
ROWLEY
PACIFIC
MISSOURI
Ordway
Las Animas
RAILROAD
BENT
La Junta
OTERO
SAN

FERTILIZER INVESTIGATIONS
FRANK K. CAMERON, IN CHARGE

DESERT BASINS OF THE UNITED STATES

PLATE I

Mapped by
Edward E. Free
1912

BASE MAP IS A SECTION FROM
U.S. GEOLOGICAL SURVEY MAP
OF THE UNITED STATES

Scale
APPROXIMATELY 40 MILES TO 1 INCH

LEGEND
Pre-Lahontan Divides ———
Post-Lahontan Divides Internal — —
Post-Lahontan Divides From Sea - - - -

and where these were available other data have seldom been sought. For areas as yet unsurveyed by the Geological Survey, use has been made of the maps of the Wheeler and King surveys, of the maps and notes of the General Land Office surveys, of railway surveys and profiles, of various special maps and reports published by the Geological Survey and by the early Government surveys, of the maps and journals of the early explorers, of many private maps, both published and unpublished, of maps and articles in the technical press, etc. These data have been supplemented by about 25,000 miles of personal travel through the regions in question and by conference with official and private surveyors, railway engineers, prospectors, and others familiar with the country. It is impossible to acknowledge all these sources in detail, but the writer wishes to make special acknowledgment of the kindness of Prof. G. E. Bailey, of Los Angeles, in tendering the use of his collection of personal maps and notes of the desert basins of California, as well as in communicating the various conclusions resulting from his extensive travel in these regions.

The topographic data from all the sources mentioned have been collected, carefully compared, and the final conclusions used in platting on base maps the boundaries of the various basins. From these maps have been calculated the areas given in the following pages. Every possible care has been used in the platting of the lines and in the computation of the areas, and it is believed that accidental errors have been almost if not quite eliminated. In nearly all cases the areas as given may be considered accurate within 10 per cent and in most the accuracy is far greater. In a few places, mainly in country of slight relief and where divides are inconspicuous, the position of present and past water partings remains uncertain, and the areas are correspondingly open to doubt. All such cases are noted in detail in the text and, in general, a perusal of the text will indicate the probable accuracy and assurance of the various conclusions better than could be done by any general statement.

THE GREAT BASIN AND ITS DEVELOPMENT.

The most important areas of internal drainage in the United States lie within the so-called "Great Basin" of Utah, Nevada, and California. This is by no means a unit, but an area of somewhat complex topography divided into a number of basins of various ages and characters. In order that this topography may be the better understood it is necessary to discuss briefly the history of its development, and this is perhaps the more useful since its development has been in many ways parallel to that of other undrained areas which lie beyond its borders. There is scarcely a phase of basin topography elsewhere that has not its counterpart in the Great Basin.

In Paleozoic and Pre-Cambrian time the area which is now the Great Basin was alternately above and below the sea, finally attaining in late Carboniferous time an emergence which was to be permanent. Its Triassic and Jurassic history is recorded only in fragments. Apparently it was largely and more or less continuously above the sea and was probably eroded to a low and mature relief. With the end of the Jurassic came the birth of the Sierra Nevada and with it the movements by which the basin was first outlined. The forces and the yielding of which the nascent Sierra were the expression did not spend themselves in this alone, but extended far to the east. At first by folding, later by profound and complex faulting, the former region of inconspicuous relief was broken into a series of troughs and ranges limited on the east by the westward-facing scarp of the Wasatch, as on the west by the Sierra. The more prominent lines of fracture being north and south, and the accompanying crustal displacement mainly by monoclinal tilting, there originated the series of north-and-south trough valleys and of parallel, monoclinal ranges so characteristic of the Great Basin.

Extensive faulting is likely to be pictured as cataclysmic, and one is tempted to think of the Great Basin as breaking in a day, like a dropped platter, from its original unity into the hundreds of structural fragments that now compose it. This is radically wrong. The present structure of the basin has grown very gradually. The movement initiated at the close of the Jurassic has continued ever since and is still in progress. So slow, indeed, has been the development of the relief that many streams have been able to maintain what seem to be their Jurassic channels and have cut the rising ranges as fast as they arose. This did not always happen, and sometimes the streams were turned. It would seem that different displacements were of different ages and have grown with differing rapidities.

Neither must it be imagined that the structure is completely simple and regular. The general parallelism of valleys and ranges is quite unmistakable, but details are much more complex. Ranges sink and bend and merge with other ranges; valleys join to other valleys and are cut by transverse uplifts; all to make a structure of extreme complexity, but through which the original simplicity may still be discerned.

It is impossible to say just when in this slow structural development the region became a "basin;" probably not for a long time after the structure had begun to take form. The whole of the Cretaceous and the early part of the Tertiary seems to have been a period of open seaward drainage and energetic erosion—an erosion which has severely modified many of the ranges. In the early Tertiary this erosional period was closed (though not necessarily with causal relation) by a period of intense and long-continued vulcanism which is only now drawing to a close and which was marked by extensive and repeated flows of rhyolites and basalts, and by the discharge of enormous quantities of fragmental material. This period was characterized by the existence of a number of scattered and successive lakes, often quite extensive but probably shallow, in which the fragmentary volcanic material found a resting place. Apparently the region was then cut off partially or completely from the sea, and while most of these lakes probably overflowed, the occurrence of salt and gypsum among their deposits indicates that some of them were saline.

The division between this Tertiary period and the present is not a sharp one. With the lapse of time vulcanism has decreased, movement has disturbed the Tertiary lake beds, and erosion has doubtless been active; but conditions are essentially the same now as then and the Tertiary lakes find their direct descendants in the present "dry lakes" or playas and in the great lakes of the recent past.

In summary, the history of the Great Basin region begins at the close of the Jurassic with crustal movements which have continued ever since. At first these movements did not interfere with seaward drainage or normal erosion, but early in the Tertiary the separation from the sea began to be effective and the "Great Basin" (perhaps then drained by overflow) was produced. Since that time rising walls and increasing aridity have joined hands to make the imprisonment of the drainage more effective.

So much for the general outline of the history. It is now necessary to examine its most recent section a little more closely. In a time which is usually correlated with the Glacial Epoch many of the inclosed valleys of the Great Basin contained large and persistent lakes. The beginnings, the early history, even the exact chronology of the lakes remain unknown. They were probably preceded by a period of aridity and they probably rose very slowly. All this is yet uncertain and need not be pursued. Starting with these lakes, we find that they were subject to extreme variations of level, probably in response to the climatic fluctuations, now coming to be recognized as both incessant and world-wide.[1] These fluctuations are not yet worked out in detail, but they seem to indicate two main periods of lake expansion separated by a long period of contraction, probably to complete desiccation. The second expansion was followed by a second desiccation and contraction to the present condition. Since the beginning of this double-lake period the structural movements, though continuing, have been slight and have not affected the topography.

The detailed history of this lake period—its precedent conditions, its chronology, its various physiographic and chemical relicta—is

[1] See the books and papers of Ellsworth Huntington, especially the Pulse of Asia (1907) and Palestine and its Transformation (1910).

among the most interesting of present-day geologic problems, but it can not be pursued here. It will suffice to note briefly a few of the effects of it and the preceding history upon the topography, and especially upon the formation of inclosed basins. In the long period during which the Great Basin has been cut off from the sea the erosional waste of its mountains has been accumulating in its valleys until all are now filled very deeply with such alluvial débris. The character of all is the same. Where the mountain reaches the plain it is surrounded by a broad alluvial slope or "apron," which stretches outward with ever-decreasing slope until it merges with the apron of another mountain or into the practically level plain which forms the deepest depression of most of the valleys. This plain may carry a tiny lake, but more commonly it has only a clay flat or "playa," on which waters gather in wet weather or after storms, but which is usually dry. This succession of mountain slope, apron, gradually flattening plain, and playa is typical of all the desert basins. The playa is the place of concentration of all the present drainage and the playa is usually more or less saline, depending upon the amount and character of this drainage and the time during which it has been received.

The alluvial filling of the valleys is not of itself of much importance to this inquiry, but one phase of it is very much so. Where canyons cut back into a mountain range the discharge of detritus is more concentrated and the normal apron grows into an alluvial cone or fan which may extend many miles into the valley. If two mountain ranges face each other across a trough-like valley (as they usually do in this region), and if a canyon in one range chances to discharge opposite a canyon in the other, the fans which they build may ultimately merge in the center of the valley and gradually build a ridge or dam which rises few or many feet above the general valley level. By this process of "alluvial damming" a valley trough may be cut off at one end or both, or split into sections by dams composed entirely of alluvial mountain waste. Obviously this is possible only where the climate is arid. If the rainfall and run-off are sufficient to maintain a vigorous through-flowing stream the fans can not merge. The detritus will be carried entirely out of the valley, or graded to slopes which permit free egress of the waters. But it is probable that the Great Basin and its environs have been essentially arid ever since the early Tertiary and the processes of fan-building and fan-merging have been everywhere at work. Many valleys structurally open to the sea have been dammed in this way and many of the basins whose major limits are structurally defined have been divided by one or many of these alluvial dams.

Some of the alluvial dams are very ancient, some are very recent. The period of lake expansion was, of course, a period of vigorous streams, and it is probable that few new alluvial dams were formed. But with the advancing aridity which has caused the disappearance of the lakes many valleys once freely open have been barred by alluvial dams and converted into areas of inclosed drainage. Obviously this has great importance from the present viewpoint. A valley where inclosed drainage is a condition of recent origin can not reasonably be expected to have retained important quantities of salts. In cases, therefore, where the boundaries of valleys are alluvial dams it is necessary to determine so far as may be possible the age of the dams, and whether they are sufficiently old and permanent to have retained behind them the more plentiful waters of the lake period.

The building of alluvial dams has been accompanied by another basin-creating process—the decay of the drainage systems due to an excess of evaporation over rainfall and the consequent failure of streams to maintain themselves over their whole length. In this way local depressions in the valleys become cut-off lakes, and channels or flood-plains become alkaline flats, even without the formation of important alluvial dams. Very much of the West is not so much an area of inclosed drainage as one of no drainage, but thousands of dry stream beds furrow its surface and scores of greater channels bear witness to a time when rivers were not all of sand. Occasional floods may fill these channels for a day; there may be still some constant drainage through them as underflow, but essentially they are dead and the alkali flats which dot their courses mark the places of their burial.

Alluvial damming and stream decay mean two things; first that many new and recent basins have been produced, and second, that a large part of the drainage and salt supply of the earlier basins has been cut off; for these processes have been just as active in the regions tributary to the greater basins as in regions once tributary to the sea, and the areas from which salt and water now reach those basins are often but a small fraction of what was once their compass. This, however, is not a matter of great importance. The answer to it is the same as to the statement—frequently made as an objection to the general potash theory—that the desert basins are too arid for the occurrence of rock decay and the freeing of potash. The basins were not always so arid. The lake period was one of considerable humidity, and we may be sure that during it plenty of potash was freed and carried to the central sinks. The doubt is not whether there is any potash, but where it is and whether it has been sufficiently segregated.

There remains to notice one more aspect of the history of the region. It has already been noted that extensive salt deposits are very rare on the surfaces of the present basins. In many of the basins no salts at all are visible. There can be no reasonable doubt that large amounts of salts have entered these basins and remained there. Where are they now? To meet this dilemma Gilbert and Russell devised the theory of salt burial and of "freshening by desiccation." Essentially this theory says that when a body of salt is left behind by a desiccated lake on a playa or its topographic equivalent, this salt body may ultimately be covered by inwashed clay and sand without solution, and if a second lake comes later to occupy the basin the buried salt deposit will be protected by its alluvial seal and will remain undissolved. Certain stages of this process have actually been observed, and there is little doubt of the essential correctness of the theory or of its applicability to the present problem. We can assume quite safely that the salt which must have been in the great Quaternary lakes is now buried beneath the floors of their basins.

There arises at once the question of the horizon at which these salts are to be found, and the duplicity of the lake period seems to furnish at least a suggestion along this line. Periods of lake expansion and stream vigor are periods of salt accumulation. It should be concentrated and deposited when the lakes evaporate. There are, therefore, at least two horizons at which salt deposits are to be looked for: (1) That corresponding to the drying of the first great lake (the "interlake arid period") and (2) that corresponding to the drying of the second great lake; that is, the arid period of the present and the recent past. The few surface salt deposits known in the desert basins are believed to belong (with perhaps one exception) to this second period of accumulation. The "interlake" salt—probably far larger in amount—is believed to be everywhere more or less deeply underground.

The various undrained areas outside the Great Basin have had their own structural histories, sometimes analogous to that of the basin but more often not. Where necessary these structural histories will be noted briefly in the detailed chapter which follows. The climatic history, however, has been everywhere the same. In particular the processes of alluvial damming and of stream decay have been as active outside the Great Basin as within it, and indeed most of the undrained areas external thereto have originated in this way. The contraction and mutilation of the great drainage systems have left tremendous areas now without seaward drainage and split into inclosed basins of larger or smaller area. The following chapter will furnish numerous illustrations.

A brief word as to nomenclature is perhaps necessary. The double period of lake expansion has been variously referred to as "Quaternary," "Pleistocene," "Glacial," etc. All of these terms carry suggestions of chronology and correlation, the discussion of which is beyond the scope of the present report, and which it is desired to avoid. It is thought best, therefore, to designate this period simply by the name of the great lake which best illustrates its history, and to refer to it as the Lahontan period. This is meant to include the whole period of deciphered lake history from the initial rise to the end of the second or final desiccation. No implication is intended as to the internal character of this period, and no specific names are applied to its various divisions.

THE UNDRAINED AREAS OF THE UNITED STATES.

It has already been noted that the Great Basin is not a unit. Its parallel mountain ranges cut it into numerous more or less connected valleys, and about halfway across the basin from east to west is one range in particular—the White Pine-Ruby Range—which has formed a major parting of the waters of the basin. East of this range is the Bonneville Basin, whose deepest depression was occupied by the ancient lake of that name and whose valleys now drain to its remnant—the Great Salt Lake of Utah. West of the range the Humboldt River cuts across the northern ends of the north-south ranges and discharges into the Carson Sink, once the home of the ancient Lake Lahontan. The basin of this lake then included not only the drainage of the Humboldt River, but also that of the Carson, Truckee, and Walker Rivers, the two latter of which have since been cut off by desiccation. These, with various smaller basins tributary to the early lake, form the Lahontan Basin.

North of the whole of the Great Basin and south of the eastern or Bonneville section of it the ranges and trough valleys which characterize it merge into wide, dissected plateaus, that of the Columbia and Snake River lavas on the north and that of the Colorado Plateau on the south. The southern limit of Lahontan is very different. The great trough valleys which characterize the core of the Great Basin are diverse in their slope, some draining northward and some southward. Most often, however, they drain both ways from an alluvial divide somewhere near the center. Thus the troughs forming the eastern part of the Lahontan Basin drain into the Humboldt River from their northern portions, while their southern extremities slope and drain either toward smaller basins also inclosed or toward some tributary of the Colorado River. Farther to the west the southern boundary of Lahontan is a transitional area of irregular cross uplift in which are a number of small basins, conveniently grouped with those of the Nevada trough valleys that chance to be inclosed. West and southwest of these is the great trough system of California, containing the Owens, Searles, and Panamint Valleys and their smaller analogues, and the great basin of Death Valley, to which belong the present and former drainage systems of the Amargosa and Mojave Rivers.

The Great Basin contains but one other major division. Northwest of the Lahontan Basin, where the zone of uplift and fracture extended into the great lava plateau of eastern Oregon and northeastern California, a number of small basins were produced. Some of these drain or have drained to Lahontan, some to the sea, and some have been permanently inclosed.

Outside the Great Basin there is but one inclosed area where structure appears to have controlled the restriction of the drainage. This is the great trough between the Sacramento and San Andreas uplifts in central New Mexico, and extending southeastward into western Texas. Even here the structural character of the basin is far from certain, as will appear when the region is discussed. The only other large and well-known basin is the Salton, in southern California. It, too, occupies a structural trough which is, however, open to the sea, the only barrier being an alluvial dam apparently built by the Colorado River.

Though the above statements cover all important structural basins and all which have attracted any considerable attention, there remain numerous and extensive areas where seaward drainage has ceased because of the decay and contraction of the river systems. These areas are of considerable diversity, but fall well into geographical groups and will be so discussed.

In the detailed discussion which follows all undrained basins of the United States will be treated under the following groups:

(1) The Lahontan Basin and its tributaries.
(2) The Bonneville Basin and its tributaries.
(3) The basins of the Lava Plateau.
(4) The trough valleys of Nevada and the basins of the Transition Zone.
(5) The trough valleys of California and the Mojave Desert.
(6) The Salton Basin.
(7) The basins of the New Mexico-Texas trough.
(8) The trough valleys of Arizona and Sonora.
(9) The Lordsburg-Membres region (New Mexico) and the Chihuahua bolsons.
(10) The Rocky Mountain basins.
(11) The Great Valley of California.
(12) The filled lakes of the California ranges.
(13) The basins and ponds of the Colorado Plateau.
(14) The ponds and coulées of Eastern Washington.
(15) The ponds of the Great Plains.
(16) Local basins of unusual origin.

This classification, while setting out to be both genetic and geographic, has ended by being scarcely more than arbitrary, but this seems not to be remedied, and it is hoped that the index and the key map will help to cover the lack of a more logical arrangement. Each basin or group of basins has been given a name by which it is known throughout the report and which is, wherever possible, the name by which it is known to residents of the neighborhood or in former geologic studies. These names are given on the accompanying map, in the index, and in the synoptic list of Table I (p. 60) and will enable the ready location of information concerning any basin or region.

THE LAHONTAN BASIN AND ITS TRIBUTARIES.

At the present time the Lahontan Basin contains internal divisions, structural and alluvial, dividing it into a number of separate basins of which the major are the Black Rock Basin, the Humboldt-Carson Basin, the Truckee or Pyramid Lake Basin, and the Walker Basin. The studies of Russell [1] have shown that the water of Lake Lahontan rose sufficiently to unite all of these basins into one water body. At the highest stages of the lake the present Humboldt-Carson Basin was connected with the Walker through the pass south of old Fort Churchill, with the Truckee through the Ragtown Pass and the pass at Wadsworth, and with the Black Rock through the pass north of Humboldt Station on the Southern Pacific Railway, the latter basin being also connected with the Truckee at the north end of the present Pyramid Lake. Both the Black Rock and the Truckee Basins were connected with the smaller Honey Lake Basin through passes at the northwest corner of the present Pyramid Lake. At this time the drainage area of the Humboldt River was much greater than at present, a large part of it having since been cut off by alluvial damming. The areas tributary to the Truckee and Walker Rivers were also slightly larger than now. The Carson was practically the same.

As the waters of the lake went down the first divide to appear was probably that between the Humboldt-Carson and the Allan Springs Basin, a small tributary to the south. Next the Walker became a separate basin, though perhaps continuing to overflow into the Humboldt-Carson. At about the same stage the direct connection between the Humboldt-Carson and the Black Rock was broken, though there still remained the indirect connection through the Truckee. A hundred feet additional lowering saw the appearance of the divide at Wadsworth between the Humboldt-Carson and the Truckee and the separation of the original lake into three water bodies—the Black Rock, Honey Lake, and Truckee

[1] U. S. Geological Survey, Monog. XI (1885).

body to the north, the Humboldt-Carson in the center, and the Walker to the south. The divide between the Truckee and the Black Rock was the last of the greater divides to appear, and with its emergence the basin assumed its present major divisions. The total area tributary to Lake Lahontan during the period of greatest expansion was 45,730 square miles. The investigations of Russell have shown conclusively that the lake never overflowed, and consequently all the salts received from this tremendous area must be still within it. There follows a brief description of the topography of the present divisions of the basin.

THE BLACK ROCK BASIN.

The present Black Rock Basin occupies an area of 8,550 square miles, mainly in Nevada, but with extensions into Oregon and California. Its sink, the Black Rock Desert, lies in the great filled trough east and southeast of the Black Rock Mountains, and, with its extensions southwestward in the Granite Creek, Smoke Creek, and Mud Lake Deserts, covers an area of over 1,030 square miles. The main present tributary is the Quinn River, which enters the Black Rock Desert at its northern extremity. Though the waters of the Quinn River still reach the sink at high-water periods, the stream now possesses scarcely a tithe of its former vigor, and its channel is much choked with débris and contains many alkali flats caused by local evaporation. Other streams which lead toward the sink are either dry except for occasional floods, or lose themselves immediately on entering the playa. Like other playas, the Black Rock Desert is not exactly level, but in the absence of accurate surveys the position of its lowest sink is not determinable. Probably it contains several local depressions each a few feet below the general surface and each separated from its neighbors by gentle slopes and invisible divides. After seasons of heavy snow and rainfall, shallow bodies of water sometimes stand for several weeks in certain portions of the playa, and these are probably among the areas of greatest depression.

From the mountainous country west of the Black Rock Mountains the basin receives the overflow of High Rock Lake, with a drainage area of 670 square miles, and of Summit Lake, which drains about 40 square miles. Water supply to both these lakes is now so far reduced that their overflow, if any, seldom reaches the desert, but essentially they still drain thereto and their drainage areas are included in the area given above.

During the higher stages of Lahontan the Black Rock section of the lake was connected with or received the drainage from the Kumiva, Granite Springs, Hot Springs, and Jungo Basins. Including these, its Quaternary drainage area (including the area covered by the lake) was 10,500 square miles. The Honey Lake Basin, though long connected with the Black Rock, is discussed as a separate unit and is not included in the area given above.

THE KUMIVA BASIN.

The Kumiva Basin lies in the small trough east of Kumiva Peak and separated by low alluvial divides from both the Black Rock Desert and the Granite Spring Basin, next to be described. The age of these divides is uncertain, but both were covered by the waters of Lake Lahontan. The divide into the Black Rock Desert is a little the lower, and it is probable that when the Lahontan waters were subsiding the drainage out of the Kumiva Basin was in this direction. Indeed, it is quite probable that this divide is recent and was formed by post-Lahontan alluviation. The lowest depression of the Kumiva Basin contains a playa about 10 square miles in area, but because of the recency of outward drainage it is not to be expected that this playa or the basin will contain any considerable amount of salt. The area of the present basin is 445 square miles.

THE GRANITE SPRING BASIN.

The Granite Spring Basin is essentially similar to the Kumiva, and is similarly barred from the Black Rock Desert by a low alluvial divide which was overtopped by Lake Lahontan. This divide is higher than that which limits the Kumiva Basin, and probably it is more ancient, but the previous connection with Lahontan destroys any possibility of important salt concentration. The area of the present basin is 890 square miles. Its lowest depression is occupied by a playa of usual character, covering about 30 square miles.

THE JUNGO BASIN.

The Jungo Basin is a small depression in the strait which once connected the Black Rock and Humboldt-Carson water bodies north of Humboldt Station. At present the basin is separated from the Humboldt Valley by an alluvial divide west of the Eugene Mountains and from the Black Rock Basin by a similar and inconspicuous divide on an approximately east-west line passing through the Dunisher Hills. This second divide is the lower and the Jungo Basin probably retained connection with the Black Rock Basin some time after its connection with the Humboldt-Carson was broken. Indeed, this northern divide, though now about 125 feet above the bottom of the basin, has probably been considerably raised by recent alluviation and perhaps also by dune movement, and it is by no means certain that the divide existed in Lahontan time. At any rate, there was connection with the larger lake body over the divide and any great retention of salt in the Jungo is not to be expected. The present basin area is 340 square miles, and the typical playa which occupies its lowest depression covers about 5 square miles.

THE HOT SPRINGS BASIN.

West of the Granite Creek Desert and just north of Granite Peak there is a small pocket in the mountains into which extends an arm of the Black Rock playa. This arm is now cut off from the main desert by a low and recent divide and contains an "alkali" flat which owes its salinity mainly to the evaporation of the waters of several hot springs rising within and around it. Its saline accumulations are probably very superficial and of no importance. The drainage area is 270 square miles and the area of the alkali flat about 10 square miles.

THE HONEY LAKE BASIN.

The depression which forms the Honey Lake Basin has perhaps closer topographic affiliations with the basins of the lava plateau region than with the Lahontan group, but, chancing to have a low pass opening eastward, it was filled by an arm of the great lake during most of the lake's existence. The direction of water movement between the two bodies is not fully certain, but that matter is beyond the scope of the present report. The present basin has an area of 2,660 square miles, in which is included the tributary basin of Eagle Lake. The waters of this lake do not now reach the central basin, but they did so very recently. The main present tributaries are the Susan River from the west and Long Valley Creek from the south. The bottom of the basin is an extensive playa diversified by some vegetation and a number of old dune areas. In the deepest depression of this playa is the present Honey Lake, a shallow body of slightly brackish water and very variable in size. East of the lake the playa stretches out in a broad area known as Flannigan Flat, nearly level and with few visible drainage lines. Many portions of this flat are now alkaline from local drainage concentration, but the salinity has been recently acquired and is unimportant. Little salt is now visible in the Honey Lake Basin.

On the northwest slope of Peavine Peak there is a small basin about 30 square miles in area which contains a small marsh separated from the headwaters of Long Valley Creek only by a low alluvial divide near the station of Purdy, on the Nevada, California & Oregon Railway. During Quaternary time this small basin undoubtedly drained into Long Valley Creek, and it has therefore no importance to the present inquiry. Its area is included in the above figures for the Honey Lake Basin.

THE TRUCKEE BASIN.

The Truckee Basin consisted in Quaternary time, as it does now, of the drainage basin of the Truckee River heading in the Sierras, notably in Lake Tahoe, and emptying into the twin lakes Pyramid and Winnemucca. The approach of the river to these lakes is over somewhat dissected alluvium, and the river has flowed at times into the one lake and at times into the other. At the present time it flows into the Pyramid. During the existence of Lake Lahontan the valley of Winnemucca Lake contained a long, narrow arm of water connected with the Pyramid Lake body at its southern extremity, while the northern end of the latter lake joined the water body of the Black Rock Desert. This latter connection was one of the last to be broken when Lahontan disappeared, and it is probable that the Truckee Basin continued to overflow into the Black Rock long after the rest of the Lahontan water bodies had fully separated. The Truckee River, being headed in a region of higher rainfall in the Sierras has suffered less truncation than the other rivers of the Great Basin and has been able to keep its channel fairly clear. Several tributary valleys have lost their free outward drainage and have become somewhat saline, but they are few and insignificant. In the Lahontan period, however, Pyramid Lake received another considerable tributary which entered it from the west through a gap in the Virginia Range, bringing the drainage of the so-called Winnemucca Valley (which has no relation to Lake Winnemucca).

This drainage line has entirely decayed, and a large area once tributary to it—the Lemmon Valley, north of Reno—has been cut off by an alluvial divide and become an inclosed basin whose flat bottom carries a group of playas. This basin has an area of 90 square miles. Just north of this there is the smaller Warm Springs Basin, with an area of less than 20 square miles and separated from the Hungry Valley and the Pyramid Lake drainage by an alluvial divide over 300 feet in height. It is impossible to read clearly the history of this basin from data now at hand. It may be that the divide between it and the Truckee is quite ancient and that the Lahontan period saw it, as now, completely landlocked. However, this question is unimportant, since the basin is too small to have accumulated any considerable salt body. Including the Lemmon Valley, but not the Warm Springs Basin, the total area of the Truckee Basin is 2,975 square miles.

THE HUMBOLDT-CARSON BASIN.

The Humboldt-Carson Basin is the core of the Lahontan area. Its present bottom is a great playa covering over 500 square miles and containing in its lowest portion the Carson Sink, a shallow and variable lake of brackish water. South Carson Lake, also on the main playa, is a shallow lake produced by the meanders of the Carson River. A slough connects it with the North Carson Lake, or Carson Sink. The Humboldt River enters the playa from the north through a narrow gap near the station of Parran, on the Southern Pacific Railway. During high water of Lake Lahontan a sand bar was built across this gap, behind which Humboldt Lake has been formed. However, overflow has partially cut this bar, and at high-water stages the water of the Humboldt Lake now flows through it and into the Carson Sink.

In its upper courses the Carson River, like the Truckee, has kept some measure of its vigor and retains essentially its Lahontan drainage. Farther down, where it flows over what was once its flood plain at the margin of the retreating lake, it has left many local playas which are now without escape for their waters. All these were either covered by Lake Lahontan or were tributary to it, and have no importance in the present connection.

The history of the Humboldt River is very different. More than any other river of the Great Basin, perhaps excepting the Mojave, it has suffered by alluvial damming and by the decay of its tributaries. Its present drainage area is scarcely a half of that which it once possessed. The description of the Humboldt in detail is unnecessary. In general it may be said that it cuts across the northern extremities of the trough valleys in the eastern half of the Lahontan area, draining these valleys north as far as the limits of the Great Basin and south to the alluvial divides which separate the Lahontan drainage from that of the Colorado River and of the smaller basins to the south. Several of these trough valleys, once tributary to the Humboldt, have been cut off behind alluvial dams, creating the Buena Vista, Buffalo Springs, Crescent Valley, Gibson, and Clover Basins. Even where the valleys have not been cut off entirely, the decay of the streams has left them with innumerable local playas and alkali flats but since these are still essentially tributary to the Humboldt they do not require individual discussion.

The Humboldt and the Carson are the only important rivers tributary to the basin. A few small valleys tributary to, or filled by, the Great Lake are discussed below as the Fernley, Allen Springs, and Sand Springs Basins. The present drainage area of the Humboldt-Carson, including all local playas and other areas not cut off by actual divides, is 19,300 square miles. Its Quaternary area was 27,575 square miles.

Mention should perhaps be made of the Ragtown Soda Lakes, situated on the Carson Playa, about 6 miles northwest of Fallon. These are small depressions, probably of volcanic origin, in the bottoms of which are lakes of brine from which carbonate of soda was once made commercially. From his studies of the lakes Russell concluded that their soda content was probably derived from waters which had percolated through the saline clays of the surrounding playas and acquired salinity therefrom. They are not believed to have any important significance to the present inquiry.

The Wabuska topographic sheet of the United States Geological Survey shows another small local depression in the eastern extension of the Pine Nut Mountains about 4 miles east of Lyon Peak. Its nature is unknown to the writer, but it is too small to have any practical importance.

THE FERNLEY BASIN.

The Fernley Basin is a small depression lying between the Humboldt-Carson and the Truckee Basins, as does the Jungo Basin, between the former and the Black Rock. When Lahontan was high this basin was a strait connecting these two water bodies. On the fall of the waters the connection with the Truckee was broken first, the connection with the Humboldt-Carson, by way of Ragtown Pass, remaining much longer intact. At the present time the bottom of the Fernley Basin is about 100 feet below this pass, but it is not certain that this has always been so. Recent alluvial deposition must be taken into account and is difficult to estimate. The present bottom of the basin carries three playas, the two extreme of which drain toward the central one. All the playas are somewhat saline, but no segregated salt deposits are known. The area of the present basin is 215 square miles.

THE ALLEN SPRINGS BASIN.

South of the Carson Playa there is a deep, narrow mountain valley which was filled by the Lahontan waters and connected with them through a narrow strait at Allen Springs. The bottom of this valley is about of the same level as the Carson Playa, but a divide over 200 feet high intervenes. This divide is probably pre-Lahontan and the Allen Springs Basin has probably always been landlocked, except when Lake Lahontan was high enough to overflow the divide. Previous connection with the larger lake is sufficient to destroy the probability of a large amount of salt having been accumulated or retained. The present area of the basin is 235 square miles and that of the pl ya which occupies its present depressions is 4 square miles.

THE SAND SPRINGS BASIN.

From its southeast side an arm of the Carson playa stretches into the Sand Springs Valley and is cut off from the main playa by a low and inconspicuous divide which, according to Russell, is due to a small recent fault which cuts across the mouth of the valley. East of this the surface drainage of the valley has collected in a central depression and deposited there a considerable quantity of common salt derived from the more or less saline clays which floor this part of the playa. This deposit is entirely recent and secondary, and there is no reason to suspect salt accumulations of importance to the present inquiry. In earlier times the Sand Springs Valley was filled by Lake Lahontan, and even the fault-formed divide which now exists is apparently quite recent. The drainage area cut off by this divide aggregates 200 square miles.

Just south of the Sand Springs Valley there is another arm of the main playa, also containing an alkali flat and a salt deposit, and probably possessing a similar topography and structure. These are not known in detail to the writer and the valley has been included with the Humboldt-Carson in all computations.

THE BUENA VISTA BASIN.

Turning now from those cut-off valleys previously tributary to the main Carson water body to those tributary to the Humboldt River, the first basin to engage attention is the Buena Vista. This occupies the trough extending northeastward and lying between the Humboldt and East Ranges. Toward the south the basin is barred from the Carson playa only by a low divide, and a similar low divide separates it from the Humboldt River to the north. The latter divide is apparently the lower and is alluvial, whereas King maps the southern divide as of basalt. Both divides were overtopped by the waters of Lahontan, but the southern was probably the earlier exposed and in the latest Lahontan stages the Buena Vista Valley was probably a tributary of the Humboldt River. The present bottom of the valley is occupied by a playa of the usual character and with an area of about 50 square miles. The total area of the present basin is about 4,000 square miles, but this area is somewhat uncertain, because the position of the alluvial divide at the northern end is not exactly known.

THE BUFFALO SPRINGS BASIN.

The Buffalo Springs Basin is a small valley lying north of the Battle Mountain range and separated from the Reese River only by a low divide composed partly of alluvium and partly of blown sand. This divide appears to be very recent and there can be little question that the time is short since the drainage of the basin found free egress to the Reese River and thence to the Humboldt. The area of the basin is about 500 square miles, there being again some uncertainty as to the exact position of the recent divide. It contains a playa approximately 25 square miles in area.

THE CRESCENT VALLEY REGION.

East of the north-south trough occupied and drained by the Reese River and extending eastward as far as the Sulphur Springs Range is an area of rather complicated topography in which the north-south trend of valleys and ranges, while still traceable, becomes less obvious. This area has been very inadequately mapped, and the information at hand is not sufficient to permit a detailed statement of its past and present drainage conditions. However, a brief personal visit indicates that it is divided by the east-west uplift of the Simpson Park and Roberts Mountains into two divisions of different affiliations. South of this uplift lie the Monitor, Kobeh, and Dry Valleys, which drain or drained to the Diamond Valley. North of the divide the country was once tributary to the Humboldt River and comprised two northward-flowing stream systems—that of Horse and Pine Creeks to the east and that of the Grass and Crescent Valleys to the west, the two being separated by the Cortez Mountains. Both of these drainage lines have suffered severely by stream decay and have been broken into numerous shallow basins and local playas, the exact limits of which can not be determined from existing information. So far as known there are no areas of considerable or long-continued drainage concentration, and all playas and marshes are believed to be not only local but very recent.

The total area of the region believed to have been tributary to the Humboldt is 2,430 square miles.

THE GIBSON BASIN.

East of the Sulphur Spring Range, which forms the eastern border of the Crescent area, the parallel troughs and ranges again become the distinctive features of the topography. The first of the troughs is mainly occupied by Diamond Valley, which has probably always been landlocked, and will be discussed among the trough valleys of Nevada. East of this, between the Diamond and Ruby Ranges, lies the great trough of the Huntington and Gibson Valleys, which, bending a little to the west, extends southward through the Little Smoky, Hot Creek, and Reveille Valleys, well below the thirty-eighth parallel. The northern part of this trough, containing the Huntington and South Fork Valleys, now drains to the Humboldt. Just south of this is the Gibson Valley, the northward drainage of which is cut off by a low and poorly defined divide southwest of Hastings Pass. This divide is probably largely alluvial, but may be due in part to minor and local cross-uplift. At any rate, it is believed to be recent, and the Gibson Valley is believed to belong to the former drainage of the Humboldt. Another alluvial divide cuts the Little Smoky Valley just north of the thirty-ninth parallel into two divisions, one of which drains northward into the Gibson, the other southward into Hot Creek and Railroad Valley. This divide marks the southern limit of the Lahontan Basin in this trough. The area of the Gibson Basin, including the tributary part of the Little Smoky Valley, is 1,150 square miles. It contains a long, narrow playa (Newark Lake) having an area of over 30 square miles. This playa is somewhat saline, but the salinity is believed to be recently acquired and the conclusion of recent outward drainage removes any expectation of extensive salt deposits.

THE CLOVER GROUP OF BASINS.

The north-south mountain line represented by the Ruby Range is almost everywhere the line of the Bonneville-Lahontan divide, but beyond the northeast corner of this range and perched on the very crest of the divide lies the Clover group of three closely connected basins which are believed to have belonged to the Lahontan division. This group consists of two parallel north-south valleys, the Clover to the west and the Independence to the east, separated in their northern parts by the Independence Mountains. To the south these mountains vanish and the valleys merge. Independence Valley contains two local depressions due to recent alluviation and containing playas of the usual type. Clover Valley has a single depression, which is the deepest in the group and contains the shallow water body of Clover or Snow Water Lake. Independence Valley is completely landlocked except for its connection with Clover Valley. The latter has two low passes, one north into the Humboldt River, about 200 feet above the valley bottom and the other south into the Ruby Basin and a little higher. The former is alluvial and is believed to be recent. The latter is mapped by King as basalt. It is very probable that the early drainage of this group was northward into the Humboldt, and their interest to the present inquiry, accordingly, disappears. The total area of the group is 1,075 square miles.

THE WALKER BASIN.

There remains for discussion only this one division of the great Lahontan water body. It lies south of the Lahontan body proper, and consists essentially of two north and south troughs lying on either side of the Walker Range. Rising in the Sierras, the Walker River flows northward through the western trough, around the north end of the Walker Range, and into the deeper eastern trough, the deepest depressions of which contain the present Walker Lake. Structurally, the affiliations of the Walker trough are much more with the isolated trough valleys to the east and south than with the valleys of the main Lahontan area. Only the accident of a low pass to the north enabled the early Walker Lake to overflow and establish a connection with Lake Lahontan. This connection was never a deep one, and the Walker body was the first of the main Lahontan water bodies to become separated when the lake began to fall. It is probable that it continued for a time to overflow into Lahontan, but advancing desiccation must have put an early end to this, and the independent history of the Walker Basin is probably a fairly long one.

Like the Truckee and the Carson, the Walker River has been able to keep its stream fairly vigorous and its main channel fairly clear, but numerous local playas and "alkali" flats have been formed in the tributary valleys. Most of these are too local and recent to deserve especial notice. The most important is the chain of two basins north of the Gillis Range and now separated from the Walker Valley and from each other by low alluvial divides. Several similar basins border the Walker River in its northward course through the western trough.

Along the west Walker River (a branch of the main river) are several basins which are interesting because of their less usual origin, though no more important to the present inquiry. It seems that the upper course of this river was once a series of lake basins apparently of structural origin. In the course of time the river cut narrow canyons through the walls of these basins and drained the lakes. But, this done, the river has sometimes deserted the axis of the basins for a channel along a traversing delta of its own building, leaving to one side or the other depressions still below the river or its outlet. With complete desiccation these depressions have become undrained basins with central playas of usual type. This appears to be the history of the playa in the north end of Smith Valley. The playas and alkali lakes of the Antelope Valley probably owe their origin in part to similar processes, though these processes have been much complicated by fan-building and alluvial deposition.

The area of the Walker Basin at the present time is approximately 3,200 square miles. Including all the areas once tributary to it but now cut off by damming or stream decay, it covers 3,850 square miles. Walker Lake has a present area of 104 square miles, but this has varied greatly in the recent past, as is attested by the extensive and complete system of old-shore lines which surrounds it.

THE BONNEVILLE BASIN AND ITS TRIBUTARIES.

Though somewhat larger than the Lahontan Basin, the Bonneville Basin is much more nearly a unit. In Lahontan time it received the drainage of all the inclosed region east of the Bonneville-Lahontan divide, its deepest portion being occupied by the Great Lake Bonneville, with an area at its highest stage of nearly 20,000 square miles.

This early lake and its history have been fully studied by Gilbert,[1] and the reader is referred to his report for all details. From the present viewpoint the most important feature of Gilbert's work is the conclusion that the lake acquired and long retained an outlet into Snake River and thence to the sea. During the greater part of the existence and fluctuations of Lake Lahontan, Lake Bonneville was an overflowing lake of normal character and was undoubtedly fresh. This fact alone is sufficient to remove most of the importance of the basin to the present inquiry. The salt contained in the Great Salt Lake, which is the present remnant of Lake Bonneville, is simply that present in the waters of the early lake at the time when overflow finally ceased plus that added in the drainage since that time. However large, it is probably not comparable with that which accumulated in Lake Lahontan.

The present Bonneville Basin is divided by a low and recent parting into the basin of the Great Salt Lake to the north and the Sevier Basin to the south. Local divides, for the most part recent as well, have cut off a few small basins from the two main divisions. The total drainage area of the Bonneville Basin during the Lahontan period was 57,960 square miles.

THE GREAT SALT LAKE BASIN.

This basin is the central remnant of the original Bonneville Basin and includes the valley of the Great Salt Lake and all valleys now tributary thereto. The north-south trend of ranges and valleys, though here less marked than in the Lahontan Basin, is still quite distinct and the long parallel ranges form islands in the present lake or divide the trough valleys which drain into it. As in the Lahontan region, desiccation and stream decay have reduced the vigor of the rivers which once occupied these valleys and many local playas and marshes have been produced. The chief present tributaries of the Great Salt Lake are the Bear River from the north, the Weber River from the east, and the Jordan River and Utah Lake drainage from the south. Having their sources in well-watered highlands, these streams have retained a considerable measure of their former vigor and are, indeed, largely responsible for the persistence of the Great Salt Lake itself. There was once another considerable tributary entering the lake from the southwest through the Snake Valley. This has entirely decayed and the Snake Valley and some of its tributaries have acquired small local playas and brackish marshes of very recent origin. The obstructions to drainage out of the valleys are not considerable even now, and would be overcome and removed by a very moderate increase in average rainfall.

The Great Salt Lake has a present area of about 2,200 square miles and a maximum depth of approximately 50 feet, being somewhat variable in both dimensions. It is extremely saline. West and southwest of the present lake is the Great Salt Lake Desert, a broad playa-like flood plain but recently abandoned by the lake and covering an area of over 3,000 square miles. Innumerable local depressions in this plain have become small and shallow areas of inclosed drainage and salt concentration and have come to contain greater or lesser deposits of common salt formed essentially like the Sand Springs salt deposit described on page 16. The divides between these

[1] U. S. Geol. Sur., Monog. I (1891).

little basins are indistinguishable and never more than a few feet in height. A very slight increase in rainfall would be sufficient to flood and drain them and wash their salt back into the Great Salt Lake.

The present area of the Great Salt Lake Basin is perhaps 25,000 square miles. Including the Great Salt Lake Desert and the other similar areas of local playas and marshes, but excluding the basins cut off by real though recent divides, the area is 33,760 square miles. Including former tributaries, now the Steptoe and Ruby groups, and the White Valley, Rush, and Cedar Basins, the area is 42,300 square miles.

THE STEPTOE BASIN.

During the Lahontan period one of the main tributaries of Lake Bonneville headed between the Egan and Schell Creek Ranges, well south of the thirty-ninth parallel, flowed northward through the great trough of the Steptoe and Goshute Valleys, crossed the Toano Range and entered Lake Bonneville east of the present railroad station of Cobre. Since that time alluvial deposition, probably assisted by local uplift, has barred the pass in the Toano Range and cut off the Goshute Valley from discharge. At the same time alluvial damming and stream decay have broken the former through-flowing stream into a score of separate basins, each with its local playa and each separated from the other by low and indistinguishable divides. The whole valley has become an area of practically no drainage and no point or points of considerable concentration can be distinguished. This early drainage line still receives the insignificant discharge of what was once a considerable stream from the Antelope Valley, and it once received also the drainage of the Ruby group about to be described. The area of the Steptoe, Goshute, and Antelope Valleys with their tributaries is 3,930 square miles. Adding the Ruby group, the total becomes 6,590 square miles.

THE RUBY GROUP OF BASINS.

The Ruby group lies on the crest of the Bonneville-Lahontan divide, south of the Clover group already discussed and between the Ruby and Egan Ranges. It consists of the Ruby Valley to the north, with two parallel north-south valleys, the Butte and the Murray [1] lying south from it and formerly tributary to it. The deepest depression of the Ruby Valley proper lies at its western edge under the steep slope of the Ruby Range and contains Ruby and Franklin Lakes. Eastward from this depression the valley rises very gradually toward the low gap of the Goshute Pass between the Egan and Pequop Mountains. It is reasonably certain that the Ruby Valley previously discharged through this gap into the Goshute Valley and thence to Bonneville. The topography of the pass is complicated by alluvial deposition and apparently by recent and local movement, and it is not possible to determine with assurance whether the Ruby Valley of the Lahontan period had an unresisted drainage into the Goshute Valley or contained a lake which overflowed thereto over a permanent dam. The writer has not found conclusive signs of lake occupation in the Ruby Valley and hence inclines to the former opinion. In either case the valley lacks interest from the present viewpoint.

Of the southern tributaries of the Ruby Valley, the Butte Valley is confined only by a low and inconspicuous divide across its northern end. This divide is alluvial and probably very recent, and there can be little question of the previous free drainage of the valley toward the north. It contains a rather poorly developed playa with an area of approximately 12 square miles. The Murray Valley is separated from the Ruby Valley by divides of similar character, but higher and better defined. They too are believed to be post-Lahontan, and the earlier outward drainage is be-

[1] This valley is known locally as Long Valley, but there being numerous other Long Valleys in the Great Basin, and this name being in general use for another basin (see p. 29), it is impossible to retain it here.

lieved to have been unrestricted. The valley now contains a number of local playas, but no area of considerable drainage concentration is known.

The Ruby Valley proper has a present drainage area of 1,200 square miles, Butte Valley has 740 square miles, and Murray Valley 720 square miles, making a total area of 2,660 square miles for the group.

THE WHITE VALLEY BASIN.

The White Valley Basin is a north-south trough lying between the Confusion and the House (or Antelope) Ranges and directly south of the Great Salt Lake Desert. It is essentially structural in origin and is entirely surrounded by mountains or hills. However, the lower hills to the north were overtopped by the waters of Lake Bonneville, and even on the recession of these waters it is probable that the White Valley maintained for a time an outflow to the Great Salt Lake Basin, either through the low hills west of the Fish Spring Range or through Sand Pass Canyon between this range and the House Range and leading into the Fish Spring Valley. Both of these passes are now over 300 feet above the floor of the valley, but may have been raised by recent alluvial deposition. In any event, the separate existence of the White Valley Basin can not antedate the final recession of the waters of Bonneville. The area of the present basin is 920 square miles, and it contains two playas separated by a low alluvial divide crossing the valley from east to west somewhat south of its middle. The northern playa is the larger and probably slightly the lower.

THE RUSH VALLEY BASIN.

The Rush Valley is essentially similar to that last discussed, but lies north and east from it between the Onaqui and Stansbury Mountains on the west and the Oquirr Range to the east. The surrounding divides are entirely structural, but the valley originally drained into that of the Great Salt Lake through a gap in the northern divide just north of the present town of Stockton. This gap was below the waters of Bonneville and the waves of that lake built a sand bar across it. When the waters receded this bar became a dam essentially similar to the one formed by Lahontan, at the southern end of Humboldt Lake, as described on page 14. In this case, however, the dam has never been breached and the drainage of the valley is still retained behind it, forming a small brackish lake in a portion of the pre-Lahontan river channel. The area now tributary to this lake is 700 square miles.

THE CEDAR VALLEY BASIN.

This is a third basin essentially like those of the White and Rush Valleys. It lies just east of the latter and between the Oquirr and Lake Ranges. The latter range is low and poorly defined and the waters of Lake Bonneville transgressed it in several places, forming of the Cedar Valley a partially inclosed sound separated from the water body of Utah Lake Valley on the east by a chain of islands. There is also a fairly low pass leading westward from the Cedar Valley into the Rush Valley described above, and it is possible that this also was below the highest stage of Lake Bonneville. To the east the connection with the Utah Lake Valley was probably retained until quite late in the recession of the great lake and the inclosed character of the Cedar Valley appears therefore to be quite recent. Its present area is 300 square miles. It contains two playas of usual character.

THE SEVIER BASIN.

Structurally the present Sevier Basin consists of three parallel troughs trending approximately north and south. The middle of these, though the largest and probably the deepest, is less well defined than the others. In its northern portion it expands to form the great filled valley of the Sevier Desert. In its middle portion it is comparatively narrow and is further narrowed by the north-south range of the Mineral Mountains, almost equidistant between its sides. Farther to the south it bends westward and again expands into another filled valley, the Escalante Desert.

The easternmost of these three troughs is much more regular and stretches almost unbroken from the fortieth parallel to the Arizona line, being bordered on the west by the continuous uplift of the Parowan, Tushar, Pavant, and Canyon Ranges and on the east by the western scarp of the high plateau country. Essentially this valley is but a southward extension of the Jordan and Utah Lake Valleys, the depression which lies just beneath the great west scarp of the Wasatch Range. But only the southern part of this trough belongs to the Sevier drainage, the parting being the local uplift of the Tintic Mountains, and a low divide, probably alluvial, in the Juab Valley at the same latitude. This southern half of the trough is occupied by the northward-flowing Sevier River, which, paralleling the behavior of the Humboldt, turns westward across the north end of the Canyon Mountains through the deep Sevier Canyon and enters the middle or main trough of the basin.

The westernmost trough is well defined but less than half the length of the others. It consists of the Sevier Lake and Preuss Valleys and merges to the north into the Sevier Desert. It is interesting mainly because it contains the present deepest depression in the basin, the sink of Sevier Lake.

At the higher stages of Bonneville the middle and western troughs were largely filled with the waters of the lake. The eastermost trough is higher and was not filled, except for a small embayment at the northern end. It contained a northward-flowing river, the predecessor of the present Sevier, which emptied into this embayment. When the waters of Bonneville fell low enough to expose the comparatively low divide separating the Sevier Basin from that of the Great Salt Lake, the former continued for a time to overflow into the latter through a well-marked channel which may still be seen east of McDowell Mountain and which has been described by Gilbert.[1] With increasing desiccation the outflow of the Sevier Valley ceased and its basin attained the inclosed character which it now exhibits.

At the present time the central and western troughs have become areas of practically no drainage. The northern end of the former—the Preuss Valley— has been cut off from Sevier Lake by a low alluvial divide, while the Escalante Desert has been similarly separated from the central trough. The eastern trough has more nearly retained its original character. The Sevier River is still a fairly vigorous stream until it begins to cross the Sevier Desert. Here it loses itself in a succession of meanders and local marshes, reaching the lake only in time of flood. It is probable, however, that this failure to reach the lake continuously is very recent and due to the large use of the waters for irrigation. The Sevier Desert itself is a succession of local playas much like the Great Salt Lake Desert, but less saline and more often having free but unused drainage channels to the sink. Rush Lake and Parowan Valleys east of the Escalante Desert were once freely drained to the main lake body, but have been cut off by stream decay and now contain small saline lakes. Round Valley, east of the town of Manti, is a small structural basin of the type of the White Rush and Cedar Valleys above described. How long it has been a separate drainage unit is not fully certain—probably not very long and in any case its area of 170 square miles is too little to give it any importance to this inquiry. At the present time the area from which Sevier Lake receives even occasional drainage is probably not over 10,000 square miles. During Lahontan time the Sevier Basin, including Parowan, Rush Lake, Round, and Preuss Valleys, the Escalante Desert, etc., had a total area of 16,375 square miles.

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[1] U. S. Geol. Sur., Monog. I, p. 181 (1890).

THE BASINS OF THE LAVA PLATEAU.

The eastern two-thirds of Oregon and the southeastern quarter of Idaho, with contiguous portions of Nevada and California, are covered by great sheets of Tertiary lavas. In its northerly portions the plateau thus formed, though considerably dissected, is substantially level, but its southern portion has been invaded by the area of uplift and faulting which created the valleys of the Great Basin, and has been split into a number of valleys and ranges of purely structural origin. In the main there has been little flexure and the faulting is usually of a simple monoclinal type. As before, the main lines of displacement run north and south, but there has been a significant degree of irregular movement along lines otherwise directed, and the valleys of the region possess only in lesser degree the simplicity and regularity of structure characteristic of the trough valleys of central Nevada. The topography being dependent on the monoclinal structure, is everywhere much the same. The valleys are long and relatively narrow, with a gentle, somewhat dissected slope on one side and a steep fault scarp on the other.

Many of the valleys of this region possessed from the beginning an open drainage to the sea or soon attained it through the breaching of the surrounding divides. (Pl. II, fig. 1.) Many of these still retain this open drainage or have lost it only recently. However, the portion of the area contiguous to the Great Basin proper has been, like it, a region of low and topographically insufficient rainfall and many of its valleys have never had a seaward drainage. All of the valleys which are now areas of inclosed or restricted drainage are briefly described below. The Honey Lake Basin, described among the Lahontan group, is not essentially dissimilar to the basins of the lava plateau, and owes its connection with the larger group to the chance occurrence of a low pass leading thereto.

THE CHRISTMAS LAKE VALLEY.

The Christmas Lake Valley is the extreme northwest basin of the group and is perhaps the least typical of all. It lies about at the extremity of the region of profound monoclinal faulting and is characterized more by gentle folding and by minor and irregular displacement than by the well-defined fault lines so prominent to the south. The basin is bordered on all sides by rolling plateaus formed by gentle folding of the lava and modified by a comparatively slight subsequent erosion. Undoubtedly these rolling plateaus once possessed more or less well-defined drainage systems, but increased desiccation has entirely destroyed them or reduced them to mere vestiges. The whole region is now one of no determined drainage. This makes it nearly impossible to fix accurately the boundaries of the basin. On all sides the plateau is dotted with innumerable small pans or playas each of which receives and retains the drainage of a greater or lesser surrounding area. (Pl. II, fig. 2.) Most of these small basins represent irregularities in the folding of the plateau and are therefore structural and original, but there can be little doubt that nearly if not quite all of them once overflowed either inward toward the Christmas Lake Valley or outward into the surrounding basins or into the Columbia River. In many cases it is now impossible to determine the original direction of drainage of these pans and both for this reason and because of the inadequacy of the available maps, the divides have been only very roughly determinable and the calculated area is very approximate indeed. This applies particularly to the Great Sandy Desert, across which passes the northern boundary of the Christmas Lake Basin. This is a region of very low relief. The slopes are usually not determinable except by precise leveling and most of the drainage channels which once existed have been wholly or partly obscured by dune sand and alluvium.

The present floor of the Christmas Lake Valley is a broad plain, apparently flat and diversified by several dune areas, especially in its eastern part. It rises more or less gently to the surrounding rolling plateau and shows none of the usual features of lake or playa topography. It is quite possible that it had once an outlet reaching from its northwest corner through the Fort Rock Valley and the Deschutes River to the Columbia. This region has never been mapped and was not carefully examined by the writer. The question must be left open, though the assumption of recent and reasonably free outlet would explain the absence of playa or lake traces and the general topographic resemblance to a tributary rather than a receiving valley, matters which are difficult to understand on the assumption of continuously inclosed conditions.

Christmas and Fossil Lakes, with several other small playas or marshes now present on the valley floor, are mere local depressions formed by wind erosion or dune movement, or both, and fed by springs or local drainage. Christmas and Fossil Lakes owe their comparative permanence to supply from springs. Neither has any relation to the earlier topography of the valley. Thorne Lake, in the southwestern corner, is a small enlargement and local depression in the channel through which the overflow of Silver Lake once passed into the Christmas Lake Valley.

At the present time there is no area of considerable drainage concentration in the valley. Peter Creek, rising in the southern slopes of the Pauline Mountains, maintains a well-defined channel for some distance southward, but finally loses its water to the underflow without forming a lake or playa. Christmas and Fossil Lakes receive the drainage of their immediate surroundings only. During the Lahontan period the drainage area was about 2,000 square miles, exclusive of the Silver Lake Basin, next described. Including this, the area was about 2,750 square miles. Because of the difficulty of determining the actual position of the limiting divide, the figure for the Christmas Lake Valley proper is scarcely more than a rough approximation.

THE SILVER LAKE BASIN.

Silver Lake lies southeast of the Christmas Lake Valley, in a basin of structural origin and bounded by lava scarps and slopes in the manner typical of the region. To the west and southwest its drainage reaches to the crest of the lava plateau and a somewhat indefinite parting from the headwaters of the Klamath River drainage. Between it and the Christmas Lake Valley is the small but steep local uplift of the Conley Hills and Table Rock. There are several low gaps in this uplift, and one of them, south of Table Rock, is only a few feet above the present Silver Lake and contains a dry channel through which Silver Lake discharged into the Christmas Lake Valley very recently indeed. The present Silver Lake occupies the southern portion of its valley, the northern portion being occupied by the Pauline Marsh, which empties southward through the Pauline Slough. The lake is very shallow but practically fresh, a fact which is accounted for by the recency of overflow. The lake is somewhat variable in size and is reported to have entirely evaporated in 1886–87. The present drainage area is essentially the same as that of the Lahontan period, and is about 750 square miles. There is some uncertainty in the position of the divides in this area, but the uncertainty is far less than in the case of Christmas Lake Valley.

FIG. 1.—KAMAS PRAIRIE, NEAR LAKEVIEW, OREG.

[A typical filled lake. The outlet is through the gap visible in the opposite rim.]

FIG. 2.—SMALL INCLOSED PAN ON THE LAVA PLATEAU NORTH OF THE CHRISTMAS LAKE VALLEY, OREG.

FIG. 1.—SOUTHEAST CORNER OF ABERT LAKE, OREG.

[The high-water line of the ancient lake is visible about one-fourth way up the mountain slope on the right.]

FIG. 2.—PLAYA OF ALKALI LAKE, OREG.

[Showing the Lahontan period lake terraces at the foot of the mountains in the distance.]

THE CHEWAUCAN BASIN AND ABERT LAKE.

The Chewaucan Basin lies between the north-south fault scarps of two outward dipping monoclines. On the west is the Winter Ridge, bounded by the 2,500-foot scarp west of Summer Lake and dipping westward to the valleys of the Klamath and the Deschutes. On the east is the similar scarp east of Abert Lake, and beyond that the gentle eastward slope of the monocline down to the Warner Valley. The two fault lines which determine these scarps come together south of Abert Lake and are lost in a region of general uplift which forms the divide between the Chewaucan Basin and the Goose Lake Basin to the south. Toward the north the fault lines diverge, and the basin is bordered by the rolling lava plateau already described in connection with the Christmas Lake Valley. The drainage of this is scarcely at all determinate and the divides between the Chewaucan and the Alkali and Christmas Lake basins are correspondingly uncertain.

The deepest depressions of the basin lie just beneath the greatest heights of the scarps and are occupied respectively by Summer Lake on the west and Abert Lake on the east. Both of these lakes are very shallow. Summer Lake is bordered by a playa area on the north and east and Abert Lake on the north only. Summer Lake is about 200 feet higher than Abert and was once connected with it through the Chewaucan Marsh. This connection is now broken just south of Summer Lake by a low alluvial dam probably due in part to delta and fan formation by the Chewaucan River, which enters the valley just at this point. The divides surrounding the basin as a whole are high and structural and there is no indication of any previous overflow. Abert Lake is surrounded by terraces indicating that the water body has been much larger and deeper than now. (Pl. III, fig. 1.) The heights of these terraces have not been measured accurately, but hand-level and aneroid measurements place the highest of them at about 200 feet above the lake. The terraces can be traced about the Chewaucan Marsh, but not into Summer Lake, the present elevation of this lake being very nearly that of the highest terrace. It is probable that the present Summer Lake was once a shallow bay or filled estuary of the early water body, and that it was then cut off from the main body by wave accumulation and delta building, the details of which have been obscured by subsequent rainwash. It is impossible to determine the date of this separation or whether or not Summer Lake continued for a while to overflow into the Abert body. The present inclosed character of the lake may have originated during the maximum of the lake expansion or it may have been initiated only very much later. The writer inclines to the latter opinion, but, in any case, Summer Lake was once a tributary to Abert, and any extensive salt accumulations should be looked for in or under the latter rather than in the former.

The drainage of both Summer and Abert Lakes is now slightly less than formerly, because of the decay of the drainage from the pans of the plateau region to the north, as already described in connection with the Christmas Lake Valley. The Antelope Valley south of Abert Lake was apparently once a small mountain lake which has been drained by the cutting of the gorge of Crooked Creek and at the same time filled by alluvium. At present it has unrestricted though meager drainage to Abert Lake. Except as water is used for irrigation, the Chewaucan River and Marsh drain freely into Abert. The area now tributary to Abert, including everything except Summer Lake, is about 930 square miles. The Summer Lake drainage totals about 560 square miles, making nearly 1,500 square miles for the two. These figures are open to slight uncertainty because of the indefinite character of the northern divide. The present area of Summer Lake is 75 square miles and that of Abert Lake 60 square miles.

THE ALKALI LAKE BASIN.

The Alkali Lake Basin is essentially a northward extension of the Abert Lake trough and is separated therefrom by the region of local cross uplift in the vicinity of Euchre Butte. On the east the basin is bordered, like Abert, by the scarp of an eastward dipping monocline which merges toward the north into the less simple uplifts of Little Juniper and Wagontire Mountains. To the west the basin is separated from the Christmas Lake and Summer Lake Valleys by the usual inconspicuous divide across the lava plateau. It appears that the lake once received from this direction a main tributary which drained the pans and valleys of the lava plateau north of Sheep Rock. This drainage line has now been cut off almost entirely, and the lava plateau has been divided into numerous local basins.

The deepest depression of the valley is Alkali Lake, a playa lake of very variable size. In the dry season it is usually reduced to three or four saline ponds occupying wind-eroded depressions in the playa. (Pl. III, fig. 2.) The northern extension of the Alkali Lake Valley, called "North Alkali," is now cut off from the main valley by a dam of wave and dune sand and has become somewhat saline. However, this separation is quite recent and does not affect the unity of the valley. A series of terraces about both North and South Alkali Valleys indicates previous occupation by a considerable lake, and, as all divides are far above these terraces, the lake must always have been inclosed. The drainage area of the lake was about 400 square miles, which has been reduced to perhaps a third of this value by the cutting off of North Alkali and of the pans of the plateau.

THE WARNER BASIN.

Mention has already been made of the eastward-dipping monocline the limiting scarp of which forms the eastern boundary of the Abert Lake Basin. This monocline is limited on the east by the scarp of a second monocline of precisely similar nature, and between the two scarps lies the Warner Valley. As usual, the deepest depression lies immediately under the scarp, being accentuated in this case by a minor parallel faulting to the west of the axis of the depression. The depression is a long narrow valley between a high steep scarp to the east, and to the west a much lower scarp from the crest of which rises the gentle monoclinal slope before mentioned. To the north and northwest the valley rises into a rolling plateau like those already described, and across which passes the inconspicuous divide between it and the Harney Basin. At the south the basin is limited by a zone of cross uplift and irregular faulting, beyond which lies the Surprise Valley.

The Warner Valley is entirely surrounded by high divides and seems to have been always so inclosed. The surrounding mountains are furrowed by a series of lake terraces of usual character, the highest of which is (by aneroid) a little over 200 feet above the present lake. Several streams descend the gentle slope of the westward monocline and reach the valley proper through narrow canyons cut in the basalt of the low western scarp. During the lake period nearly all of these streams built typical deltas, the remnants of which may still be seen. (Pl. IV, fig. 1.)

The present floor of the valley is a flat clay plain, probably once a playa, but now diversified by considerable vegetation and by occasional dune areas or wind-scoured hollows. Shallow depressions hold two main lakes and several smaller ones, the whole being known as the Warner Lakes. All of the lakes are either fresh or merely brackish, but at the southeast corner of the northern or Upper Lake is a small pond containing a nearly saturated solution of sodium chloride. Its salt is believed to be derived from seepage. The separation of the Warner Lakes is very recent. They are still variable in size and are reported to have been considerably larger about forty years ago.

The only part of the basin which has suffered severely by stream decay is the long western slope. Here many once vigorous streams have dwindled to little or nothing and have ceased to overflow a few local depressions. In nearly every case, however, a very slight increase of rainfall would be sufficient to clear and restore the drainage, and it can not be believed that the present cut-off condition is of any considerable antiquity. This can not be so surely said of Juniper Lake, east of Adel. The basin of this lake, though small, is relatively deep, and Waring [1] reports two old strands on its walls. It may have been inclosed for a considerable time, but the small size of the basin destroys any present interest which it might have.

At present the area tributary to the Warner Lakes as a whole is perhaps not over 1,500 square miles but during the Lahontan period the drainage area was probably slightly over 2,000 square miles, there being some uncertainty as to the exact position of the northern boundary.

THE HARNEY BASIN.

East of the Christmas Lake Basin is another of very similar character—the Harney Basin. As before, the divides are inconspicuous and run over plains and rolling plateaus of little relief. In the case of the Harney, however, there is no question of the recency of overflow. Russell [2] explored and described the channel through which the basin discharged into the Malheur River, and which is now stopped by a dam of recent lava. Behind this dam the valley is broad and flat and the impounded waters, instead of overflowing the dam, have spread out to form Malheur and Harney Lakes.

THE CATLOW VALLEY AND GUANO LAKE.

It will be recalled that the eastern side of the Warner Valley was mentioned as bordered by the west scarp of an eastward-dipping monocline, the crest of which forms the Warner Mountains. Still farther east the Steens Mountains form a similar range, but higher and of opposite inclination. In this case the scarp faces eastward, while the gentle slope is toward the west. Essentially the area between these mountains is a gentle syncline with its trough running approximately north and south and its flanks cut off by the Warner and Steens Mountain scarps. In detail this simple structure is far from apparent. The region is one of gently rolling lava plains, much like those already described and with its topography modified by local and irregular folding and faulting and possibly by erosion. It is little known and very inadequately mapped, and desiccation has destroyed or obscured most of its drainage lines. Its division into specific "basins" is therefore nearly impossible and is not attempted. It is possible to point out only that there are at least two areas of considerable concentration of drainage, the northern in Catlow Valley and the southern in Guano Lake. The Catlow Valley is of the usual flat-floor type with a shallow intermittent lake. It receives the drainage of Rock Creek from the west and of a part of the Steens Mountains slope from the east. Concerning Guano Lake, scarcely anything is known beyond the fact that it receives the flow of Warner Creek coming from the crest of the Warner Mountains to the west.

At its northeast corner a narrow pass opens from the Catlow Valley into the valley of the Donner and Blitzen River, one of the tributaries of Malheur Lake. The present divide in this pass is less than 300 feet above the level of the Catlow Valley, and it is natural to assume that this pass was previously a discharge channel, the present divide having been created or raised by subsequent alluvial deposition. However, Waring [3] reports that the Catlow Valley is surrounded by old strand lines and that these are below the divide. It may be, however, that the strands belong to a recent

[1] U. S. Geol. Sur., Water Supply Paper **231**, 29 (1909).
[2] U. S. Geol Sur., Bul. **217**, 22 (1903).
[3] U. S. Geol. Sur., Water Supply Paper **231**, 65 (1909).

and transient lake and that the basin was freely drained during the main Lahontan period. This could be determined only by extensive detailed study. Nothing at all is known concerning the Quaternary history of Guano Lake. The writer inclines to the opinion that it previously drained into the Catlow Valley, but the evidence favoring such a conclusion is too insignificant to warrant its acceptance.

The present drainage of the Catlow Valley aggregates perhaps 1,000 square miles. During the Lahontan period about as much again is believed to have been tributary to it, making a total of about 2,000 square miles. The remainder of the syncline, including the Guano Lake Basin, has an area of approximately 1,000 square miles, which may or may not have been tributary to the latter.

THE SURPRISE BASIN.

The Surprise Valley is a north-and-south trough lying immediately south of the Warner trough and appearing at first sight to be a continuation of it. Closer examination, however, casts considerable doubt upon this conclusion. The structure of the Surprise trough is much more complex and has never been studied in detail. The deepest depression and highest range are here on the western side of the valley, and if the structure is monoclinal the inclination is reversed from that exhibited in the Warner. From a cursory examination of the valley and the range which borders it on the west, the writer is inclined to the opinion that folding has had almost as much to do with the structure as has faulting and that the appearance of analogy to the Warner Valley is appearance only. To the north the valley rises rather suddenly to the highlands running east from Mount Bidwell and which separate it from the Warner Valley. The structure of these highlands is also unknown. Southward and eastward the valley rises more gradually to a relatively undisturbed lava plateau, the features of which are due to folding and erosion much more than to faulting. The low and featureless range which separates the Surprise Valley from Long Valley on the east suggests a gentle anticline of north-south axis, but this is by no means certain.

The present floor of the valley is very similar to that of the Warner Valley, being essentially a great playa, in shallow depressions of which stand the Upper, Middle, and Lower Surprise Lakes. This plain is somewhat less diversified than that of the Warner and its playa character is more apparent. The lakes are very variable and it is reported that the northern or Upper Lake sometimes evaporates entirely to dryness. The Lower or southernmost lake is connected with the Middle Lake by a narrow slough, the latter being separated from the Upper Lake by a low alluvial divide. A series of old strands of usual character surround the whole valley and indicate previous occupation by a single great lake which stood about 350 feet above the present floor and was permanently without outlet. This lake has left wave bars, terraces, etc., which rival in completeness those of Lahontan and Bonneville. Lake Annie, north of Fort Bidwell, lies behind a wave bar of this kind built across the mouth of a narrow canyon which was an estuary of the ancient lake.

On the crest of the northern divide, east of Mount Bidwell, lies the small basin of Cowhead Lake, once a tributary of the Surprise, but now cut off by desiccation. New Year Lake, near the crest of the eastern divide, is of similar character. South of the valley the large basin of Duck Flat, also at one time a tributary and later filled by an arm of the ancient lake, has been cut off by a low and recent alluvial divide to form an inclosed basin.

The present tributaries of the valley include only a number of short mountain streams, mostly intermittent in character. The area now tributary to the valley is about 900 square miles. With Duck Flat and the basin of Cowhead and New Year Lakes the area is 1,580 square miles. It is possible that Long Valley, to the east, was also once tributary to the Surprise. If the area of this be included the total becomes 2,350 square miles.

THE LONG VALLEY BASIN.

Long Valley lies just east of the Surprise Valley, beyond the crest of the gentle anticline (?) already mentioned. It is a poorly defined valley the detailed structure of which is very complex. On all sides it merges with the folded and dissected lava plateau already mentioned. Its floor is an irregularly shaped playa dotted with shallow and variable lakes, between which are very low and inconspicuous divides. Several low passes lead out of the valley at about the same elevation, one to the Coleman Valley (a tributary of the Warner Basin) and the others either to Duck Flat or directly to the Surprise Valley. Without detailed examination it is not possible to determine which of these, if any, was a channel of ancient discharge. The writer inclines to the opinion that during the Lahontan period there was free or overflow discharge into Duck Flat and thence to the Surprise Valley, but this conclusion can not be considered certain. The present lakes are fresh or brackish only. It is not possible to determine the present drainage of each. The area of the whole valley is about 775 square miles.

THE ALVORD VALLEY.

It will be recalled that the shallow syncline of the Catlow and Guano Valleys was bordered on the east by the uplift of the Steens Mountains. The eastern face of this range is a high fault scarp, directly below which lies the Alvord Valley. Like the Warner and Abert Valleys it is essentially monoclinal in structure, though an anticlinical structure previous and parallel to the faulting has been detected by both Russell and Waring. In the Steens Mountains this anticlinal structure seems to be entirely overshadowed by the much more profound monoclinal movement, but eastward from the Alvord Valley faulting and tilting have not been so profound and the eastward divide of the basin seems to be determined by the crest of one of the original anticlines. To the south the basin reaches the less regular uplifts of the Pine Forest Mountains and Trident Peak. It is separated from the Black Rock Desert only by an alluvial divide across the Pueblo Valley, but this divide is nearly a thousand feet above the valley and is almost certainly pre-Lahontan. The northern extremity of the Alvord Valley is little known and it is possible that there may have been an outlet to the Malheur River, though the considerable salinity of the valley and the presence of old strand lines around it would indicate the contrary.

The present bottom of the valley is cut by alluvial divides into the subsidiary basins of Ten Cent, Juniper, Mann, Alvord, and Tum Tum Lakes and that of the Alvord Desert. All of these were covered and connected by the early lake and it is possible that most of the others drained into that of the Alvord Desert for some time after desiccation had begun. The White Horse Basin was also a former tributary and has been cut off by the accumulation of alluvium and dune sand in Sand Gap, through which it formerly discharged.

The Thousand Creek and Virgin Creek Valley lying on the lava plateau east of Long Valley, Nevada, seems to have been also a tributary of the Alvord and is now separated therefrom only by a low alluvial divide in the gap north of the Pine Forest Mountains. This valley has suffered greatly by stream decay and now contains numerous local playas of small area and very recent origin.

The areas of the various small basins into which the Alvord Valley is now divided have not been computed in detail. Their total area, exclusive of the White Horse Basin and the Thousand Creek Valley is about 1,600 square miles. The area of the White Horse Basin is about 300 square miles, and that of the Thousand Creek Valley 1,300 square miles, making a total of 3,200 square miles for the drainage area of the Alvord Basin during the Lahontan period.

THE GOOSE LAKE BASIN.

South of the Abert Basin, but without any certain structural relation thereto, is another north-south trough in which lies Goose Lake, between the Warner Mountains on the east and the Modoc lava plateau on the west. The southern portion of this valley is occupied and drained by the Pitt River, the northern, or Goose Lake portion, being separated therefrom only by an alluvial divide just south of the lake. This divide is apparently recent and is now only a few feet above the lake. It is probable that the lake has frequently overflowed it, and indeed it is reported that this has occasionally happened within the memory of present inhabitants. Undoubtedly the freshness of Goose Lake is to be thus explained.

THE MADELINE BASIN.

On the lava plateau north of the Honey Lake Basin is the very similar basin of the Madeline Plains. The structure of its walls is very irregular and in many places the divides are not exactly determinable. A number of low passes lead both to the Pitt River drainage and to the Honey Lake Basin, and some one of these may formerly have served as a channel of overflow. However, old strand lines are visible at several points about the basin and serve to indicate the existence and fluctuations of an inclosed lake. Until passes and strands have been studied more exactly and compared with each other it is impossible to read with any assurance the history of this ancient lake or to determine whether it overflowed or how long the overflow continued. Still less is it possible to decide whether the overflow, if any, was into the Pitt River or into Honey Lake.

The present floor of the valley is flat and featureless, except for occasional dune areas. There are many small local playas, but no area of general concentration is noted on the available maps or was observed by the writer. The plain is nowhere saline. At its southwestern corner an outlying tongue of the plain has been cut off by a low alluvial divide and forms the Grasshopper Valley. This valley was evidently once a part of the Madeline water body, but its subsequent relations thereto are uncertain. It now contains a small march. The total area of the Madeline Basin, including Grasshopper Valley, is about 900 square miles.

THE MODOC LAVA BEDS.

West and northwest of the Goose Lake Valley a series of great basalt flows stretches westward to the volcanic uplift which culminates in Mount Shasta. Diversified only by minor faults and folds and by a few deep and narrow canyons of erosion, the region has not developed any extensive drainage system and advancing desiccation has destroyed what little drainage there once was. The streams are dry and the occasional shallow depressions are areas of inclosed drainage floored by local playas. The region is not unlike that surrounding the Christmas Lake Valley as described on page 23, and, like it, has no importance to this inquiry. The small basins of the lava beds are so tiny and their inclosed condition is so recent that salt accumulation in them is practically out of the question. This applies also to the basin of Medicine Lake on the western edge of the area near Mount Hoffman, though it is not so fully desiccated as its analogues to the east.

THE KLAMATH LAKES.

On the northeastern border of the lava bed region are a series of shallow basins holding the Klamath Lakes. The geologic history of this region has not been studied in detail, but a brief examination of the major features has suggested to the writer that the present lakes probably occupy local depressions in the bed of a much larger lake, perhaps of late Tertiary age, which lake has been drained by the cutting of the gorge of the Klamath River. A similar history, on a smaller scale, is to be ascribed to two tributaries of the Klamath group—the Klamath and Sycan Marshes. During the Lahontan period the whole of this region doubtless drained freely to the sea, but subsequent desiccation has so weakened its streams and increased fan-building that much of the area is now cut up into small basins and local saline playas. Even the large Tule Lake overflows only intermittently and several of the smaller lakes do not do so at all. All this, however, is quite recent and essentially the region has been and is one of seaward drainage.

THE TROUGH VALLEYS OF NEVADA AND THE BASINS OF THE TRANSITION ZONE.

The general character of these basins and their relations to the other divisions of the Great Basin were noted briefly on page 9. There is really no essential structural difference between them and those similar trough valleys which have chanced to drain to Lake Lahontan or to the Amargosa River, but this difference of drainage is quite important from the present viewpoint and makes desirable a separate treatment. The valleys of this division, though much alike in essentials of structure and topography, present an almost infinite variety of detail. It is obviously impossible to discuss them thoroughly, and the following statements are confined to a brief note of location and to those facts essential to the present inquiry.

THE DIXIE BASIN.

The Dixie or Osobb Valley occupies the first inclosed trough east of the Carson Sink. It now receives the drainage of the Pleasant Valley from the north and the Middle Gate and East Gate Valleys from the southeast. Neither of these drainage lines is now active, but both are freely open and are still traversed by the flood waters of heavy storms. The Fairview Valley to the south was probably once a tributary of the Dixie, but is now cut off by a low ridge the nature of which is not fully certain. The writer regards it as probably due to recent minor faulting, but possesses no conclusive evidence to this effect. Behind this barrier has been formed a small nonsaline playa known as Labou Flat.

The northern end of the Pleasant Valley is separated from the Humboldt Valley by a divide the present surface of which is alluvial, but this divide is high above the bottom of the Dixie Valley and the valley is believed never to have discharged in this direction or in any other. The greatest depression of the valley contains a mud flat nearly 60 square miles in area, in the center of which is a body of loosely crystallized common salt about 10 square miles in area and from 2 to 10 feet thick. This salt deposit is known as the Humboldt Salt Marsh and was once the source of commercial salt for metallurgical purposes. Old strand lines 150 feet and 40 feet above the present surface of the salt bed indicate the existence and fluctuations of the lake from which it was probably derived.

The area now permanently or occasionally tributary to the Dixie Valley is 2,000 square miles. The Fairview Valley has an area of 290 square miles, making a total of 2,290 square miles for the probable Dixie Valley of Lahontan time.

THE GABBS VALLEY.

Gabbs Valley lies southeast of that last described and is the northernmost of the small basins which constitute the transition zone. It is entirely surrounded by mountains of considerable height and has almost certainly never overflowed. It contains a saline flat with a sandy instead of a mud surface and about 25 square miles in area. There are no traces of an early lake. The total area of the basin is 1,280 square miles.

THE SODA SPRINGS TROUGH.

South of the Gabbs Valley and west of the Pilot Mountain Range is a short trough, now separated by alluvial divides into four small basins—the Acme, Luning, Mina, and Rhodes. Each basin contains a small playa, that of Rhodes being very saline, though the others are not especially so. The present areas are: Acme 130 square miles, Luning 175 square miles, Mina 65 square miles, and Rhodes 210 square miles, making a total of 580 square miles.

It is very difficult to guess the topography of this trough during the Lahontan period. Both divides and playas have been raised by post-Lahontan alluvial deposition and it may be either that the whole trough once drained into Rhodes or that it all, including Rhodes, drained northward into Walker Lake. The writer inclines to the opinion that the trough drained partly one way and partly the other, the Acme Basin being tributary to Walker Lake and the Luning and Mina Basins to Rhodes. If so, this may account for the greater salinity of the Rhodes playa, though the writer has been unable to discover any conclusive evidence of the existence of a Quaternary lake in this basin. On the assumption stated the Lahontan period drainage area of the Rhodes Basin would be 450 square miles. There is also a bare possibility that the Garfield Flat, next to be described, once drained into the Mina Basin and thence to the Rhodes. Including this and the Acme Basin, the Rhodes drainage area would be 670 square miles, which is a maximum value.

THE GARFIELD BASIN.

Just west of the Mina Basin and north of the main ridge of the Excelsior Mountains lies a small inclosed valley, the deepest depression of which is the Garfield Flat playa. The divide between this basin and the Mina Basin is in one place scarcely 150 feet above the playa and it is barely possible that there may once have been an outlet over or through this divide. The drainage area of the basin is but 90 square miles and this is believed far too small to have attained discharge over a divide of the present height, but the divide may formerly have been lower and subsequently raised by the deposition of alluvium. The question could probably be settled by careful study of the basin, but is unimportant, since the area is too small to give the basin any interest.

THE TEELS BASIN.

The Teels Basin lies directly south of the Garfield Basin. The lowest pass opens into the Rhodes Basin, but is over 800 feet above the floor and apparently never could have been a channel of overflow. Neither has the basin ever had any tributaries. The only chance of former inflow would be from the Huntoon Basin (described below) and the dividing pass is so high as to render this extremely improbable. The area of the basin is 320 square miles. In its deepest depression is the well-known Teels Salt Marsh, a playa of high salinity and which has unusual interest for the present inquiry because of the reported occurrence of hanksite and other saline minerals associated with the potash deposits at Searles Lake, California.

THE HUNTOON BASIN.

The Huntoon Basin is another basin quite similar to the Garfield and the Teels and lying west of the latter. The lowest pass leads into Teels, but since it is over 300 feet above the bottom, it is not considered probable that it was ever a line of discharge. The deepest depression contains a playa of the usual type, and not especially saline. The area of the basin is 115 square miles.

FIG. 1.—OLD DELTA OF HONEY CREEK, IN THE WARNER BASIN, OREG.

[A delta built into the Warner Lake during the Lahontan period and since much dissected by stream erosion.]

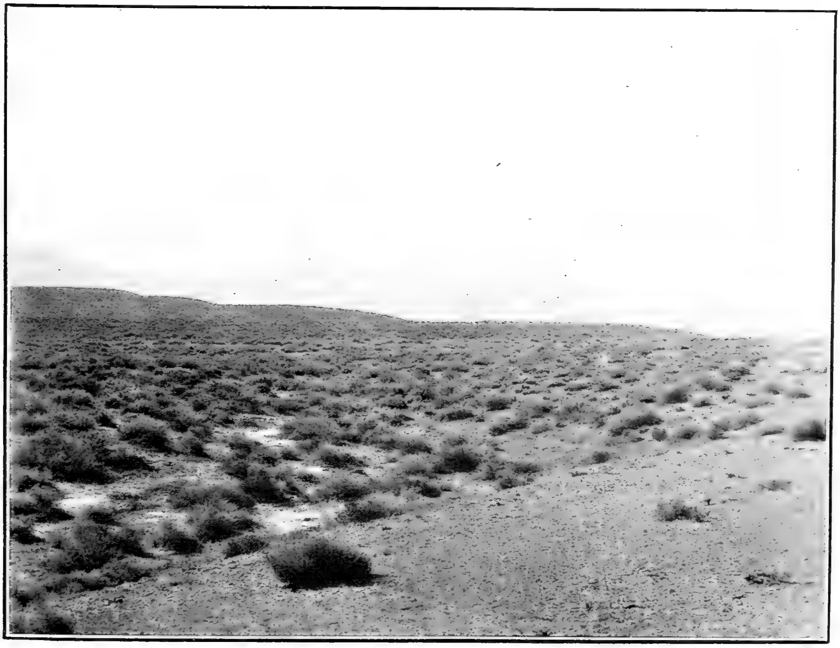

FIG. 2.—ANCIENT LAKE TERRACES ON THE EAST SIDE OF THE RAILROAD VALLEY, NEV.

FIG. 1.—SURFACE OF THE SALT BODY AT SEARLES LAKE, CAL.

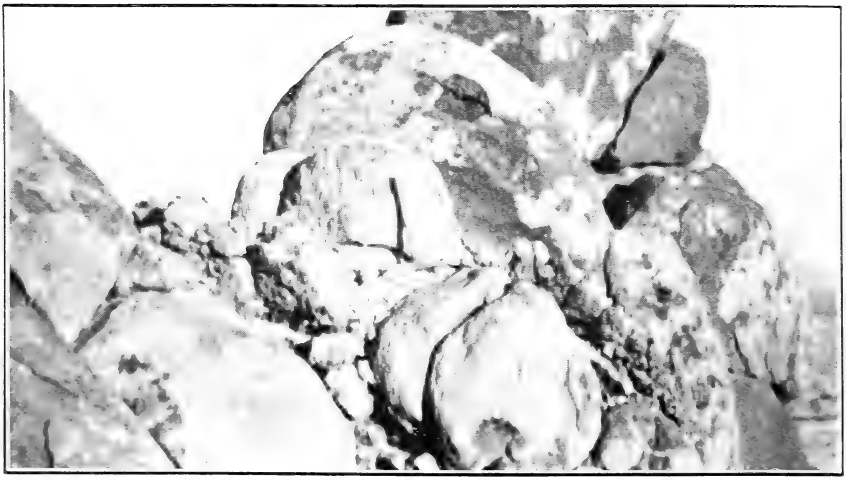

FIG. 2.—CALCAREOUS TUFA COATING ON ROCKS 300 FEET ABOVE THE BOTTOM OF SEARLES LAKE BASIN, CAL., AND DEPOSITED BY THE WATERS OF THE ANCIENT LAKE.

THE MONTE CRISTO BASIN.

East of the Soda Springs Trough and surrounded by the Monte Cristo, Pilot, and Cedar Mountains, lies the Monte Cristo Basin. Its lowest divide is in the gap between the Cedar and Monte Cristo Mountains and is but little over 300 feet above the bottom of the valley. This divide is not alluvial, but there are some indications of recent movement and it is not impossible that this pass was once lower and the locus of an outflow into the Big Smoky Valley. The area of the basin is but 300 square miles, and, whether it overflowed or not, it is too small to be of great importance. Its deepest depression is now covered by loose blown sand.

THE COLUMBUS BASIN.

South of the Soda Springs Trough is the north-south trough of the Fish Lake Valley, all of which drains freely northward to the playa called the Columbus Salt Marsh and occupying the extreme northern end of the trough. The stream which occupied Fish Lake Valley has lost much of its vigor and a number of more or less saline marshes and playas have been left along its course. All of these are recent and unimportant. The lowest pass through which a discharge from the Columbus playa would be possible leads into Rhodes and the Soda Springs Trough, but the divide is nearly 500 feet above the playa, and there is little probability that discharge actually took place over it. The basin has almost certainly been an inclosed one during and since the Lahontan period. There is a system of strand lines of usual character, the highest about 150 feet above the flat. The present drainage area of the Columbus is quite small, but including the part of the Fish Lake Valley recently tributary to it, though now cut off, it equals 1,350 square miles. The Columbus playa is about 50 square miles in area.

THE CLAYTON OR SILVER PEAK BASIN.

The Clayton or Silver Peak Basin occupies a rather irregular structural depression just east of the Fish Lake Valley. Its lowest pass being 650 feet above its bottom, there is reasonable certainty that it never overflowed, though there is no satisfactory direct evidence that it formerly contained a lake. Its bottom is a very saline playa with many crusts and layers of common salt, both on the surface and in the clays below. The area of the playa is about 30 square miles and that of the basin about 550 square miles.

THE BIG SMOKY BASIN.

Eastward of Gabbs Valley and the southern end of the Dixie Valley lie three parallel north-and-south troughs, of which the outer two slope and drain southward, while the middle carries the northward-flowing stream of the Reese River. Toward the south the central trough and its limiting ranges pinch out and the two outer troughs merge into a much broader valley which continues to slope southward. These two outer troughs and their southward extension form the Big Smoky Basin. The whole has suffered greatly by stream decay, with the formation of many local playas and the cutting off by alluvial dams of the extremities of both of the northern troughs. The deepest depression of the basin is in the extreme southwest corner and is a playa of small salinity and somewhat diversified by small dune areas.

Just west of this playa between the Silver Peak and Monte Cristo Ranges is a pass scarcely 200 feet above the playa and leading into the Columbus Basin. The drainage area of the Big Smoky seems great enough to have filled the depression during the Lahontan period to a depth greater than 200 feet, but there is no evidence of discharge over this pass, and the highest of a system of lake terraces which surrounds the present playa is below the level of the pass. It is probable, therefore, that the Big Smoky did not overflow.

The area now tributary to the Big Smoky playa is probably not over 1,000 square miles, but the addition of the area to the north cut off by stream decay makes a total of 2,140 square mile. With the Kingston Basin, which was formerly tributary to it and is described below, the total area is 3,325 square miles, which was probably the drainage area of the valley during the Lahontan period.

THE KINGSTON BASIN.

The Kingston Basin occupies the northern tip of the eastern trough of the Big Smoky Basin, as above described. The separation from the Big Smoky is by an alluvial divide of uncertain age, but which the writer regards as recent. The floor of the basin carries a chain of local playas of greater or lesser size, lying along what was probably the old drainage line. These playas are separated from one another by alluvial divides mostly very low and inconspicuous. Their basins have not been individually traced or computed. The total area of the Kingston Basin, including all the local playas north of the main alluvial divide, is 1,190 square miles, all of which seems to have been formerly tributary to the Big Smoky Basin.

THE EDWARDS CREEK BASIN.

The Edwards Creek Basin lies east of the Dixie Basin above described and between the Clan Alpine Mountains on the west and the Desatoya-New Pass Range on the east. The surrounding divides are all well defined and mountainous, except at the south end. This southern divide, while superficially alluvial, seems to be fundamentally structural, and the writer regards it also as pre-Lahontan. The Edwards Creek Basin has probably long been landlocked.

The basin now receives the drainage of the northern end of the Smiths Creek Valley and it seems probable that it once received the entire drainage of this valley, as described below. The lowest depression is a playa about 15 square miles in area and not known to be especially saline. There are a few suggestions of old lake strands about the walls of the valley, but these are by no means unmistakable. The present drainage area of the basin is about 490 square miles. With the Smiths Creek basin the total is 990 square miles.

THE SMITHS CREEK BASIN.

The Smiths Creek Basin occupies the northern tip of the western trough of the Big Smoky Basin as described on page 33. Its past and even its present drainage relations are not certainly known. It seems that it is limited at both ends by alluvial divides. The southern of these is between 300 and 400 feet above the valley floor and forms the separation from the Ione Valley, a present tributary of the Big Smoky Basin. To the north the end of the valley is structurally defined, but the extreme north end of the structural trough drains westward through the narrow gap of New Pass Canyon and does not belong hydrographically to the Smiths Creek Basin. This northern end is separated from the main body of the Smiths Creek Valley by a low divide which the writer has not examined and concerning which no information is available. It is probable that it is low and alluvial and that the Smiths Creek Basin discharged over it and through New Pass Canyon into the Edwards Creek Basin above described. If this be true the playa, which now occupies about 23 square miles in the Smiths Creek Valley, must be of quite recent origin. The total present drainage area of the Smiths Creek Basin is about 500 square miles.

THE GOLDFIELD BASIN.

The Goldfield Basin lies west of the town of Goldfield and occupies what is structurally a southward extension of the eastern trough of the Big Smoky. It is cut off from the latter basin by an alluvial divide about 500 feet above the bottom of the

Goldfield Basin and about 600 feet above that of the Big Smoky. There is another divide at about the same elevation in a gap leading into the Clayton Basin. Both of these divides are believed to be pre-Lahontan and the Basin is thought to have been always inclosed. It has an area of 330 square miles and contains a small playa of usual character.

THE DIAMOND BASIN.

The Diamond Valley proper is a narrow north-south trough stretching north from Eureka, Nev., between the Sulphur Springs and Diamond Ranges. In itself it has an area of less than 1,000 square miles, but into its southwest corner discharges the remnant of a former great drainage system which drained the southern portion of the topographically poorly-defined region mentioned on page 16. The area of this drainage system aggregated 1,870 square miles and included the present Kobeh, Dry, and Monitor Valleys, the latter extending south to the north end of the Ralston Valley (Armagosa drainage system) near the old town of Belmont. Most of this drainage system is still essentially open, though never fully occupied by water. Storm waters occasionally fill part of it, but seem never to reach the Diamond Valley itself. In many places, especially in the southern end of the Monitor Valley, low and recent alluvial dams have been built and have caused the formation of local playas and marshes. None of these have any present importance.

The deepest depression of the Diamond Valley contains a very saline marsh or playa carrying a body of common salt of unknown extent and character. The lowest outward pass is Railroad Canyon at the northeast corner and leads into the Huntington River and thence to the Humboldt. This pass is now about 275 feet above the Diamond Valley salt marsh and it is uncertain whether it ever served as a channel of discharge. The writer inclines to the opinion that it did, but that the discharge was by overflow and occurred only during the maximum of the lake expansion. A long subsequent history as an independent valley seems very probable and is directly indicated by traces of old strand lines on the walls of the valley. In this report the valley is classed as landlocked and its area is not included in that of the Humboldt-Carson Basin.

The present drainage area tributary to the Diamond Valley playa is perhaps 900 square miles. The Lahontan period area was 2,800 square miles.

THE RAILROAD VALLEY.

The Railroad Valley is the largest of the inclosed troughs of Nevada and lies just southeast of the geographical center of the State, between the White Pine Range to the east and the Pancake Mountains to the west. The former range is one of the best defined of the Great Basin and, being high and continuous, it has formed a permanent divide between the Railroad Valley and the drainage of the Colorado River. The Pancake Mountains are much lower and less well defined and are crossed by several fairly low passes, through one of which (Twin Springs Pass) the Hot Creek Valley still drains into the Railroad Valley. West of the Hot Creek Valley is the Hot Creek Range, for the most part high and continuous, but cut about its middle by the canyon of the Hot Creek, through which comes the drainage of the southern portion of Fish Spring Valley, lying still farther west. The northern portion of this valley is now cut off by a low alluvial divide, but this is almost certainly very recent. Hot Creek Valley has also two other tributaries—part of the Little Smoky Valley from the north and part of the Reveille Valley from the south. The former is cut by an alluvial divide, north of which the drainage goes to the Gibson Valley, as discussed on page 17. This divide is believed to be pre-Lahontan and to have been a permanent parting between the Lahontan and Railroad Valley drainages. Reveille Valley is cut into three portions by two alluvial divides, the northern portion draining into the Hot Creek Valley, the southern portion into the Kawich (see p. 36), and the middle portion eastward into the Railroad Valley proper. At its northern extremity the Railroad Valley proper is limited by an alluvial divide across the narrow Newark Valley; but this divide, though superficially alluvial, is really due to the general uplift of this region and is unquestionably pre-Lahontan. The southern extremity of the Railroad Valley is determined by the eastward bend of the Quinn Canyon Mountains (White Pine Range) to join the Reveille Range, which is the southward extension of the Pancakes. It is probable that the Penoyer Valley, lying south of this divide, was once a tributary of the Railroad Valley, but this will be discussed below.

The present deepest depression of the Railroad Valley lies rather north of its center and is a typical playa about 80 square miles in area and not unusually saline. South of this are a large number of smaller playas determined by recent alluvial divides and receiving the drainage of their immediate surroundings only. One of these, lying south of the Twin Springs Pass, is of considerable size and is separated from the main valley by a fairly high divide due mainly to the fan built eastward by the Hot Creek Valley discharge as it leaves the Twin Springs Pass. This divide may be of considerable antiquity and the basin behind it may have had a significant independent history. It is, however, the writer's opinion that both divide and basin are post-Lahontan. Some of these southern playas are of considerable salinity and about the north end of the main playa are a number of small pans apparently caused by previous dune accumulations and which are also quite saline. The salts of some of these pans contain significant proportions of potassium and the Railroad Valley Company of Tonopah is now (1912) drilling at the north end of the main playa in the hope of finding buried deposits of potassium salts.

Hot Creek Valley and its tributaries have suffered less from alluvial damming than has Railroad Valley proper. The channel which traverses it is still open, though seldom occupied, and no significant areas of local concentration are known. A small stream apparently derived from the Hot Creek Valley underflow traverses the Twin Springs Pass, but does not reach the main Railroad Valley playa.

There can be no doubt of the permanently inclosed character of the Railroad Valley, and a series of old strand lines and wave bars witnesses its former occupation by a persistent lake. (Pl. IV, fig. 2.) The highest of these strands is 155 feet by aneroid above the main playa.

The area now tributary to the main playa is perhaps 2,000 square miles. Including Hot Creek Valley and its present tributaries and all the playas of the Railroad Valley proper, the area is 4,555 square miles. Fish Spring Valley adds 415 square miles, making a total of 4,970 square miles which is reasonably certain to have been tributary to the valley during the Lahontan period. With the Kawich and Penoyer Valleys, which were probably though not certainly once tributary, the total drainage area would be 6,340 square miles. This is a maximum value.

THE KAWICH BASIN.

The Kawich Valley has already been noted as lying south of the Reveille Valley and separated therefrom only by an alluvial divide. This divide is now about 400 feet above the bottom of the valley, but has probably been considerably raised by recently added alluvium. The writer is of the opinion that it is post-Lahontan and that the Lahontan period drainage of the Kawich was north, through the middle portion of the Reveille Valley, and thence northeast into the Railroad Valley. The present floor of the Kawich Valley is a flat on which are a number of playas of the usual character. The area of the basin is 370 square miles.

THE PENOYER BASIN.

The Penoyer Valley lies south of the Railroad Valley proper and is believed to be separated therefrom only by an alluvial divide of recent origin. However, the maps of the region are very inadequate and the writer's personal examinations have not been sufficiently thorough to warrant a decided opinion. The bottom of the valley is known to carry a playa, but its nature is unknown. The basin area is about 1,000 square miles.

THE GOLD FLAT BASIN.

Gold Flat lies west of the Kawich Basin and below the northern slope of the Pahute Mesa. Its lowest side is toward the north and is never less than 600 feet above the flat. The topography is such that it can not be considered entirely impossible for this north boundary to be due to recent alluvial accumulation, but it does not seem probable. The writer is of the opinion that the inclosed character of the basin is pre-Lahontan. The flat carries one playa about 3 square miles in area and several smaller ones. The basin area is 640 square miles.

THE EMIGRANT BASIN.

The Emigrant or Timpahute Valley lies south and southeast of the Penoyer Basin. No satisfactory maps of it are available, and it has not been visited by the writer. Nearly everything concerning it is uncertain, but it is believed to be inclosed by permanent divides and to have a drainage area of about 800 square miles, concentrating in a playa about 10 square miles in area. There is, however, great uncertainty as to the position of the divide between it and the Pintwater Basin (see below), and the actual drainage area may be as large as 1,000 square miles or as small as 400 square miles. It is more likely to be smaller than larger than the figure of 800 square miles given above.

THE YUCCA BASIN.

The Yucca Basin lies directly southwest of the Emigrant Valley. Little is known concerning it, but it is separated from the Frenchman Flat Basin to the south by an alluvial divide less than 100 feet high and is believed to have been tributary thereto. It now contains a small playa. The basin area is slightly less than 300 square miles.

THE FRENCHMAN FLAT BASIN.

Frenchman Flat lies south of the Yucca Basin in the depression within the crescent of the Spotted Range. There is a pass about 500 feet high opening into the Amargosa Valley, but this divide, though partly alluvial, is believed to be pre-Lahontan. The basin has probably been permanently inclosed. It contains a typical playa. Alone, the area of the basin is about 450 square miles, but including the Yucca Basin (see above), which was probably once a tributary, the area is about 740 square miles.

THE INDIAN SPRING BASIN.

The Indian Spring Valley is a north-south trough lying east of the Frenchman Flat Basin and between the Spotted and Pintwater Ranges. It is separated from the Lee Canyon Basin by a divide only 130 feet high. This divide is alluvial and almost certainly recent and there is little doubt that the basin once drained into the Lee Canyon Basin and thence to the Las Vegas Valley and the Colorado River. The area of the present basin is 650 square miles.

THE PINTWATER BASIN.

The Pintwater or Desert Valley is a trough similar to that of the Indian Spring Valley and lying east of it. At its south end it is separated from the Lee Canyon Basin by a recent alluvial divide only a few feet high. There is no doubt that the basin was very recently a part of the Colorado drainage. The area of the basin is estimated at 730 square miles, but the position of the northern boundary is very uncertain and this area is a very rough approximation.

THE LEE CANYON BASIN.

The Lee Canyon Basin is of very recent origin, occupying the northwestern end of the Las Vegas Valley, being separated from the main drainage of that valley by a divide less than 15 feet high. It was once the channel of the drainage of the Pintwater and Indian Spring Basins, as above noted. Because of its recency the basin has no importance to the present inquiry. Its area is 300 square miles.

THE SHEEP RANGE BASIN.

The Sheep Range Basin lies between the Sheep and Desert Ranges and east of the Pintwater Basin. Its northern third has never been mapped and is almost unknown. It may have drained into the Pintwater or directly into the Colorado drainage, or it may have been always inclosed. In any case, its small area of less than 300 square miles renders it unimportant.

THE SPRING VALLEY BASIN.

The Spring Valley is a trough valley of regular and normal type lying east of the southern part of the Steptoe Valley (see p. 20) and parallel thereto. Its northern end has never been mapped accurately and has not been visited by the writer. It is considered probable that the valley once drained either northward into the Goshute Basin or northwestward into the basin of the Great Salt Lake, but it can not be said definitely that this is the case. The area of the basin is about 1,550 square miles, this area being somewhat approximate, owing to uncertainty as to the position and nature of the northern boundary.

THE DESERT VALLEY DRY LAKES.

In the Desert Valley, southwest of the town of Pioche, Nev., is a group of small playas or "dry lakes." These playas and the trough in which they lie were very recently tributary to the Colorado River drainage and are now cut off therefrom only by low alluvial divides. Neither they nor their basin has any importance from the present point of view.

THE GANNETT BASIN.

Near the station of Gannett, east of Las Vegas, on the San Pedro, Los Angeles & Salt Lake Railway, a former tributary of Muddy Creek has been dammed by alluvium with the formation of a small and shallow basin of very recent origin. Its drainage area is less than 150 square miles and both this small size and its recent origin render it of no importance.

THE OPAL MOUNTAIN BASIN.

The Opal Mountain Basin lies in an isolated trough between the McCollough Range and the Opal or Eldorado Range in the extreme southern corner of Nevada. It appears to be mainly structural and those divides which are superficially alluvial are high and probably ancient. The writer is inclined to regard the basin as pre-Lahontan, but has never visited it and can not advance a decided opinion. If overflow ever did occur it was unquestionably into the Colorado River. The area of the basin is 580 square miles. It contains a playa of unknown area and character.

THE TROUGH VALLEYS OF CALIFORNIA AND THE MOJAVE DESERT.

South of the Lahontan Basin, the western boundary of the Great Basin is still the crest of the Sierra Nevada, which continues to run nearly north and south until just north of the thirty-fifth parallel, where the Sierras bend slightly westward to form the lower and more diffuse Tehachapi Mountains. These merge to the south into another main uplift, that of the San Bernardino Mountains, but the trend is here northwest and southeast, instead of north and south.

These trends of the basin boundary are paralleled by the troughs within it. In the northern part of this division are four great troughs running very nearly north and south and hence parallel to the Sierra. In the southern portion are two similar troughs, but running northwest and southeast in parallelism to the crest of the San Bernardinos. Between the two sets of troughs is a considerable area of more complex structure and less pronounced relief. Of the northern troughs the westernmost, under the crest of the Sierra, contains the Owens Valley, with the Mono and Searles Basins to the north and south, respectively. The next trough to the east is the Panamint Valley, with what are essentially its northern extensions in the Saline, Eureka, and Deep Springs Valleys. The third trough is that of Death Valley, and the fourth and last is that of the Amargosa Valley, with the Pahrump and Ivanpah Valleys cut off from its southern end. The intermediate zone of less concentrated uplift is mainly drained by the Mojave River, though the Kane, Willard, Granite Mountain, and Owl Basins lie within it and seem to have been permanently undrained. The two southern troughs parallel to the San Bernardinos belong partly by the Mojave drainage and partly to the former drainage of the Colorado River, being cut by alluvial divides in the same manner as the trough valleys of Nevada south and east of the Lahontan Basin.

THE MONO BASIN.

The Mono Basin is here classed as belonging to the westernmost or Owens Valley trough of this division, but its structural affiliations are quite as close with the basins of the Nevada transition zone and the classification adopted is entirely arbitrary. It occupies a structural depression of considerable depth, contains the saline Mono Lake, and has always been without outlet. The Quaternary history of the basin has been studied by Russell,[1] to whose report the reader is referred for details. One part of the structural basin, the Aurora Basin, is now cut off from the valley of Mono Lake by a divide nearly 300 feet high, but this divide was below the waters of the greater lake which occupied the valley during the Lahontan period, and the independent history of the Aurora Basin is post-Lahontan only. The area of the present Mono Basin is 675 square miles. With the Aurora Basin, the total is 770 square miles.

THE OWENS BASIN.

The Owens Valley occupies the central and largest portion of the trough just east of the Sierra. Its general slope is southward and it is occupied for most of its length by the Owens River, which empties into Owens Lake at the southern extremity of the valley. South of the lake is an alluvial divide only 166 feet above the present surface of the lake. This divide is apparently of some antiquity, but it is considered practically certain that the lake overflowed it during the Lahontan period and discharged southward into the Searles Basin described below. The independent history of the Owens Basin is therefore comparatively short, and the considerable salinity of Owens Lake acquires unusual interest for the interpretation of the geochemical history of the Great Basin.

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[1] U. S. Geol. Sur., 8th Annual Report, Part I, pp. 261–394 (1889).

At its northern end Owens Valley now receives the drainage of Long Valley, and doubtless once received that of Adobe Valley, now a region of several local depressions. Except for the loss of Adobe Valley the basin has suffered very little by stream decay, having been saved by its proximity to the Sierra. The present area of the Owens Basin is 2,550 square miles; with the Adobe Valley it is 2,825 square miles.

THE SEARLES BASIN.

The Searles Basin lies directly south of the Owens, and the greater portion of its area is a direct continuation of the Owens Valley trough. The deepest depression, however, lies eastward beyond the Argus Range, which is here cut by a narrow canyon of erosion—Salt Wells Canyon. This deepest depression is the so-called Searles Lake. The tributary area to the west is known in various parts as the Indian Wells, China Lake, and Salt Wells Valleys. The bottom of the Searles depression is a body of white crystalline salts almost 12 square miles in area and with a maximum depth of about 75 feet. (Pl. V, fig. 1.) Under this are saline muds and sands, sometimes more or less cemented. The salts are mainly the chloride, carbonate, and sulphate of sodium, with lesser amounts of borax and of salts of potassium, the latter being largely in the brine which saturates the salt body. The potassium and other salts are believed to be very valuable commercially, and preparations are now under way for their exploitation.

The Salt Wells Canyon is pre-Lahontan, but the lake which occupied Searles during the Lahontan period stood a little over 600 feet above the present salt flat and extended through this canyon and a considerable way into the valley to the west. Both then and since this latter valley has acted as a settling basin for alluvium, and this is believed to have much to do with the exceptional purity of the Searles salt body. A series of old lake and estuarine beds clinging to the walls of Salt Wells Canyon records a period of some length during which the lake stood at a moderate elevation, perhaps 300 feet above the present surface, and permitted the partial filling of the canyon, which was then an estuary. This same intermediate level and several others, both above and below it, are recorded in a complex series of lake terraces, tufa deposits, etc., which surround the basin. (Pl. V, fig. 2.) These relicta of the ancient lake have suffered much more by erosion than have the similar records of Lakes Lahontan and Bonneville, but the significance of this fact is yet obscure.

It will be recalled that the Owens Valley probably once overflowed into Searles through the Salt Wells Valley, and it is quite possible that Searles itself had a period of overflow. The highest of the lake strands about the basin is a trifle over 600 feet above the floor and the divide at the southern end of the basin between it and the drainage of the Panamint is at very nearly the same elevation. It is possible that the lake spilled for a time over this divide into the Panamint. The question could doubtless be settled by a careful study of this divide and the approaches to it, but the study has not been made, and it is not now possible to be certain. In any case, the lake can hardly have overflowed for long, since the divide is not an alluvial dam, and, if anything, has probably been lowered rather than raised by post-Lahontan rainwash. Furthermore, the series of terraces below the divide indicates a long and varied independent existence of the lake, and the absence of tufa on or near the highest terrace suggests that when the lake did overflow (if it did) it was essentially fresh.

At the present time the tributary valley west of Searles has suffered greatly by stream decay and has come to contain a large number of more or less local playas, the most important of which is China Lake. All these are shallow and recent and would again become tributary to Searles if the rainfall were to increase only very slightly. Including them and the whole of its present tributaries the area of the basin is 2,030 square miles. With the entire Owens Basin the area is 4,850 square miles, which almost certainly represents its area during the Lahontan period.

THE PANAMINT BASIN.

The Panamint Valley occupies the southern portion of the trough east of that of the Owens Valley, being the second trough east of the Sierra. It has two tributary valleys, the Leach Valley in the southeast corner and a part of the Coso Valley to the northwest, from both of which the drainage is still entirely open. The floor of the Panamint is divided by a low alluvial divide into two sections, each of which contains a playa, the northern one having a present or very recent drainage into the southern. Both of these playas are saline, the southern one especially so. Stream decay has also produced a number of small local playas in both ends of the valley, all of which are recent and unimportant.

The most interesting feature in the topography of the Panamint is the possible former drainage from the Searles Basin, as discussed above. However, as there noted, this inflow was at most very brief and has probably not affected very greatly the geochemical history of the valley. Excepting the pass into Searles all outlets from the Panamint are high and all are far above any possible lake level. The history of the valley has been essentially one of independence. The present drainage areas of the various playas are impossible of accurate estimation. Very seldom is there any drainage at all. The total area of the basin is 1,950 square miles, including all tributaries except Searles. Including Searles and Owens the area would be 6,800 square miles, but it must be remembered that this greater area was tributary to the Panamint only very transiently, if at all.

THE SALINE VALLEY.

The Saline Valley occupies what is essentially a northern extension of the Panamint trough, though cut off therefrom by a prominent cross uplift. The basin is entirely surrounded by high structural divides, the lowest pass being nearly 4,000 feet above the deepest depression. There is no possibility of overflow since the basin has had its present structure. In the southeast corner of the basin are two small subsidiary basins, previously tributary, but now cut off by stream decay and alluvial damming. One of these contains a playa known as the Racetrack. The other contains a very small playa unnamed. The deepest depression of the Saline Basin is occupied by a very saline playa having an area of about 12 square miles and carrying a deposit of common salt, the commercial exploitation of which is now being attempted. The area of the basin, including the small subsidiary basins above mentioned, is 845 square miles.

THE EUREKA BASIN.

The Eureka Basin lies just north of the Saline Valley (last discussed) and is very similar thereto, except that the only playa it contains is small and not saline. The lowest pass is over 2,000 feet above the present bottom, all divides are structural and ancient, and there is no possibility of overflow during or since the Lahontan period. This basin and the Saline Valley are perhaps the best and simplest known examples of the inclosed basin of structural origin, and would probably well repay careful scientific study.

Cowhorn Valley, in the mountains west of the Eureka Basin, is now cut off behind a low alluvial divide, but was formerly tributary. Including this, the area of the Eureka Basin is 590 square miles. It is probable that the Deep Springs Valley (next below) was also tributary to the Eureka during Lahontan time. Including it, the total area is 775 square miles.

THE DEEP SPRINGS VALLEY.

West of the northern end of the Eureka Valley lies the similar, though smaller, basin of the Deep Springs Valley. In the main, the surrounding divides are high and structural, but the eastern wall of the basin is breached by the narrow canyon of Soldier

Pass, opening into the Eureka Basin. The present divide in this canyon is over 400 feet above the bottom of the Deep Springs Valley, but has probably been raised to some extent by post-Lahontan alluvium. It is not possible to be certain that this canyon ever served as a line of discharge, but the writer considers it probable that it did, especially since the basin drains high and well-watered mountain slopes on which the Lahontan period rainfall must have been quite high. It is probable, therefore, that the basin was once tributary to the Eureka Basin. The drainage area of the Deep Springs Valley is 185 square miles. It contains a small variable lake, fed largely by springs.

THE KANE BASIN.

Mention has already been made of the zone of less concentrated uplift which lies south of the great north and south troughs of Owens, the Panamint, Death Valley, and the Amargosa. Of the four permanent basins which the zone contains, the largest and westernmost is that of Kane Lake. It lies immediately south of Searles and might be considered a part of the Owens-Searles trough, being separated therefrom by the cross uplift of the El Paso Mountains. The southeastern divide of the basin runs across a region of less definite topography bordering the Mojave Desert, and is frequently inconspicuous. It is possible that the basin once discharged over some undetermined point on this quarter of its rim, but the general difference in elevation between rim and flat is about 600 feet and discharge is not considered probable. The present bottom of the basin is a playa with an area of about 15 square miles and having a considerable salinity. There are also several local playas north, east, and southeast of the main playa, but all are recent and unimportant. Into the southwest corner of the basin opens the high Tehachapi Valley, on the crest of the mountains of that name. Stream decay and alluvial damming have cut off a portion of this valley, with the formation of a local playa of little antiquity and slight importance. The area of the Kane Basin, including the Tehachapi Valley, is approximately 900 square miles, a moderate possible error being introduced by uncertainty as to the exact position of the southeastern divide.

THE WILLARD BASIN.

The Willard Basin is a small basin lying just east of the Kane and not unlike it. The divide which separates it from the Mojave drainage is neither well defined nor well known, and previous outflow is distinctly a possibility. The deepest depression is occupied by the playa of Willard Lake, which offers no exceptional features. The basin area is somewhat uncertain, because of lack of exact knowledge of the divides, but is certainly less than 250 square miles.

THE GRANITE MOUNTAIN BASIN.

The Granite Mountain Basin is a small structural basin south of the Leach Valley extension of the Panamint and between the Leach and Granite Mountains. It is little known, but is believed to be entirely surrounded by high and permanent divides. Its floor carries several playa areas, the mutual relations of which are unknown. The basin area is 150 square miles.

THE OWL BASIN.

The easternmost and smallest of the four permanent basins of the transition group is a tiny mountain valley just south of Death Valley and which contains the Owl Lake playa. It has never been mapped or scientifically studied, and its nature is almost entirely unknown. Its inclosed condition is believed to be structural and pre-Lahontan, but a previous drainage into Death Valley is not impossible. In any case its area of less than 60 square miles makes it of little importance.

THE DEATH VALLEY BASIN.

East of the Panamint trough lies the great trough of Death Valley, the deepest depression on the continent and with its tributary drainage, the third of the three greater divisions of the Great Basin, the other two being Bonneville and Lahontan. In itself the trough of Death Valley is not especially large, nor is it exceptional for anything except depth. It derives its unusual interest to the present inquiry from the fact that it at present receives the drainage of the Amargosa River and but recently received that of the Mojave River as well. These river systems are briefly described in the two following sections. It is sufficient here to note that they entered the Death Valley trough at its southern extremity through a common channel.

The floor of Death Valley is an immense playa occasionally constricted but not broken by tongues of alluvium pushed outward from the mountains. (Pl. VI, fig. 1.) This playa is very nearly of one level, but there is apparently a very shallow depression close to the eastern wall of the valley, northeast of Bennetts Wells, and which is usually occupied by a shallow lake of saturated brine. Wet-weather drainage lines reach this sink both from the north and south, the latter carrying what remains of the water of the Amargosa. The whole playa is extremely saline, much of it is constantly moist and muddy, and all ground waters are nearly saturated brines. In places on the playa common salt has crystallized in the surface clays in such a way as to form a broken crust or "salt reef" not unlike in appearance the "ice pillars" produced by frost in moist clay soils (Plate VI, fig. 2). The irregularities of this broken crust have sometimes an altitude of several feet and are quite without parallel in North America, though Dr. Ellsworth Huntington informs the writer that similar forms occur on the salt desert of Lob Nor in central Asia. The north arm of Death Valley contains a playa-like flat which is comparatively nonsaline and has a present drainage southward. All other tributaries are mountain streams of usual type.

The most interesting question concerning the Death Valley depression is that of its age. The Panamint Range, which forms its western boundary, is unquestionably ancient and the great apron which fringes its valleyward slope seems also to be very old. But the Funeral Mountains to the east are apparently much more recent, beds of apparently Tertiary age are prominent within them, and it is quite possible that they and the present topography of the valley originated quite within the period we are discussing. Neither space nor available data permit the discussion of this question in detail. It must suffice for the writer to express his personal opinion that this movement though mainly post-Tertiary and probably still in progress, is essentially pre-Lahontan and has not affected the fundamentals of the valley topography.

The drainage area now tributary to the Death Valley flat, including that part of the Amargosa where the channel is still unclogged, is very nearly 7,970 square miles. The cut-off portions of the Amargosa drainage add an additional 5,430 square miles, and the Mojave drainage, past and present, aggregates 10,160 square miles, making a grand total of 23,560 square miles in the entire Lahontan period basin.

AMARGOSA DRAINAGE SYSTEM.

The main trunk of the Amargosa River occupies the fourth and easternmost of the system of troughs parallel to the Sierra Nevada. In Lahontan times its remotest tributaries headed far north in the trough valleys of Nevada, touching the fringe of the Lahontan drainage at the divides which head the branches of the Ralston Valley. The tributaries from these two branches were joined a little to the south by a third flowing westward from Cactus Flat and the augmented stream continued southward west of Stonewall Mountain and the Pahute Mesa, across the Sarcobatus Flat and through a narrow pass in the Bullfrog Hills into the Amargosa Desert and the valley still followed by the river. Somewhat north of the thirty-sixth parallel the great trough divides, its main branch rising southeastward toward the Pahrump and Ivanpah Valleys, practically parallel with the Nevada-California line, while a lesser though deeper branch diverges a little to the west between the great Amargosa Range on the west and the Resting Springs and Kingston Mountains on the east.

It was this western branch which was followed by the Amargosa River, the eastern trough being occupied by a northward-flowing tributary which joined the greater river near what is now the station of Death Valley Junction on the Tonopah & Tidewater Railroad. Just north of the Avawatz Mountains the Amargosa was joined by the Mojave and the united river turned sharply to the west through an apparently structural pass between the Avawatz Range and the south end of the Amargosa Mountains, thus entering the southern end of the Death Valley depression. This Quaternary Amargosa was a river of no small proportions beside which its present descendant is indeed puny. Stream decay and the building of alluvial dams have robbed it of over half its length and nearly three-fourths of its drainage area, and the former great valley is cut into a multitude of shallow basins and local playas, each with its tiny tributaries and its "alkali" flat. At the northern end of the Ralston Valley an area of nearly 1,750 square miles has been cut off by an alluvial divide about 150 feet high, itself losing its former tributary from Cactus Flat. Next southward a segment of the early valley has been cut off to form the basin of Stonewall Flat, while just beyond, under the shadow of Stonewall Mountain, lie two other playas, and westward in the formerly tributary valley between Jackson and Montezuma Peaks lies a third, all now cut off behind recent alluvial divides. From these basins south to the Bullfrog Hills is the basin of Sarcobatus Flat, with an area of nearly 800 square miles and carrying besides its main playa many smaller and more local ones, and several once tributary valleys now cut off to form small basins. Once this flat discharged southward through a valley north of the Bullfrog Hills, but this is now closed by two alluvial divides with a small inclosed basin between. Southward of this divide the channel of the Amargosa proper is still essentially clear, though many more or less local playas and saline flats have been left along the filled floor of the trough and in small tributary valleys. However, another considerable tributary has been lost by the cutting off of over 1,400 square miles of the eastward-trending trough already noticed and which now forms the Pahrump Basin. Alluvial divides have not only cut this valley from the main drainage, but have split it into three parts, the Stewart Valley to the north, the Pahrump Valley proper in the middle, and the Mesquite Valley at the south. The divide which bars the latter is of considerable elevation and may conceivably be pre-Lahontan. If so the basin belongs to the class of the permanently inclosed, but the writer does not incline to this opinion and prefers to regard it as formerly a part of the Amargosa. South of the Pahrump lies the Ivanpah Basin, but this is probably pre-Lahontan and is separately discussed on page 45.

The mutilation of the Amargosa, though due essentially to aridity and stream decay, may quite possibly have been affected favorably or unfavorably by local and recent movement. The detailed history of the valley is extremely complex and, though as interesting as it is intricate, is scarcely germane to the present study. Apparently both Tertiary and Quaternary have seen a chain of lake basins, whose alternate filling and cutting has gone on under the complex interaction of frequent though moderate movement and of continuous and complicated climatic change. These changes have been incessant and are still in progress, but it is not believed that during or since the Lahontan period they have affected the essentials of the topography or caused the persistent concentration of drainage elsewhere than in the Death Valley sink.

The area of the Amargosa drainage is given in connection with Death Valley on page 43.

THE MOJAVE DRAINAGE SYSTEM.

The Amargosa was and is essentially a single stream occupying a long, narrow trough. The Quaternary Mojave was more dendritic. Rising in the northern slopes of San Bernardino Peak, it cut, like the Humboldt, directly across the main structural features of the region, entered at Soda Lake a north-south trough which is perhaps related to that of the Amargosa, and followed this north to the junction with the Amargosa and the western turn into Death Valley. How far this course was determined by the structure of the country and how far it was anterior to and imposed upon it, it is impossible to say. The writer is strongly inclined to consider it largely the latter. In any case, from each trough that it cut and each plain that it tapped it received its greater or lesser tributaries each with its own dendritic drainage, or perhaps its chain of lakes. All of this is now changed. Perhaps more than any other American area the Mojave Desert shows the effects of lessened rainfall. It is a country where lakes are dead and streams are dying and where only the occasional arroyos galvanized into vigor by rare and sudden storms maintain the semblance of a drainage. The Mojave River has lost all its tributaries, and its main stream, though fed by the well-watered slopes of San Bernardino Peak, flows no farther than Soda Lake and seldom even so far. Dams of dune sand and alluvium have blocked the greater valleys and cut the flatter areas into a checkerboard of minor basins. "Dry lakes" lie in nearly every township. Indeed, so numerous are they that the writer possesses authentic information concerning nearly 50 of them. It would scarcely be profitable to review all of these in detail. Larger or smaller, relatively old or relatively young, all were once part of the Mojave and all are post-Lahontan. Rodriguez, Rosamond, Rabbit, and Harper Lakes in the west, and Coyote, Coolgardie, Cronese, Garlic, and Langford Lakes to the north, are among the most important and all are of the same type.

Some of the larger and older playas are somewhat saline, but this salinity is recent and superficial. Even in Soda Lake, which is the present terminus of the Mojave River, waters a score of feet under the surface are practically fresh. North of Soda Lake there is a river channel, but no river. Local rainfall and an occasional brief overflow from Soda Lake have created a small playa at Silver Lake, about 20 miles north. North of this is a dam of recent dune sand and then the valley of the Amargosa and free drainage into Death Valley.

It has been considered useless to compute the area of the various basins into which the Mojave drainage has been divided. The total is 10,160 square miles.

THE IVANPAH BASIN.

The Ivanpah Valley lies in the extreme southern end of that offshoot of the Amargosa trough which carries the Pahrump Basin (see p. 44). However, the divide which separates it from this trough is high and structural, as are all the other divides which limit the basin. It is practically certain that its inclosed and independent condition is both ancient and permanent. The bottom of the valley now contains two playas of usual character and separated by a very low alluvial divide. There are also in the northeastern end of the basin two small basins and playas, now independent but believed once to have been tributary either by free drainage or by overflow, probably the latter. The total basin area is 900 square miles.

THE MESQUITE TROUGH.

Mention has already been made of the two structural troughs which lie north of and parallel to the San Bernardino Mountains. The southernmost of these is structurally continuous and open from the Mojave Desert to the Colorado River, but, like the similar troughs of central Nevada, it is higher in the center than at the extremities, this elevation determining a water parting, which is superficially alluvial but nevertheless quite ancient. This divide crosses the trough in the neighborhood of Wilburs Well, located by the surveys of the General Land Office in township 3 north, range 5 east, San Bernardino base and meridian. West of this point the trough was once a tributary of the Mojave, and now contains a series of playas due to this tributary's decay. East of the divide the trough once drained to the Colorado River, but alluvial damming has now cut it into a half dozen basins each independent and inclosed and each with its typical playa. It has not been considered necessary to attempt the delineation and study of each of these local basins in detail. The most important are those of Mesquite, Dale, and Palen Lakes. The exact heights of the various divides are unknown, but all are believed to be recent and the basins they form are thought to have belonged quite recently to the Colorado drainage and to have, therefore, slight importance to the present inquiry. The total area of present inclosed drainage in this trough and east of the Wilburs Well divide is 3,520 square miles.

THE BRISTOL TROUGH.

The second trough north of the San Bernardino Mountains is occupied by the basins of Bristol, Cadiz, and Danby Lakes, the first receiving also the drainage of a high valley running toward the northeast between the Providence and Piute (or Pahute) Ranges. The exact interrelations of these lakes and their basins are not fully known, but they are believed to be analogous to those of the trough last discussed, and to have drained quite recently into the Colorado River. The divide between the westernmost or Bristol Basin and the Mojave is the local uplift of Ash Hill and is believed to have originated in connection with a center of recent vulcanism a little to the west. This divide, though of no considerable antiquity, is believed to be pre-Lahontan. The only chance of importance of these basins to the present inquiry lies in the possibility that one or more of them may have been inclosed longer than is assumed and may have been an area of salt accumulation during a considerable period. The surveys of the region are so few and so inaccurate that this possibility can not be absolutely denied; though it is believed to be remote. Danby Lake is known to contain a considerable deposit of common salt, but this is believed to be of recent and secondary origin. The total area of the basins of all three lakes is approximately 4,150 square miles.

THE SALTON BASIN.

South of and parallel to the San Bernardino Range is another structural trough similar to those north of it but deeper, and open southward to the Gulf of California. This trough is now cut off from the Gulf by a low divide of alluvial material and its deepest depression is occupied by the Salton Sea, the surface of which is over 200 feet below sea level. W. P. Blake, who made the first scientific examination of the basin[1] and discovered its negative elevation, concluded that the trough had once contained an arm of the sea and had been cut off by the gradual out-building of the delta of the Colorado River from the eastern shore. The delta having been built above the water level, the river might have flowed northward into the basin or southward into the Gulf. As a matter of fact it has done both. Being an alluvial river of very variable bed, it has flowed alternately to the basin and to the Gulf, probably many times in each direction. The present Salton Sea was created by an accidental

[1] Pacific Railway Reports, Vol. 5 (1856).

turning of the river toward the basin in 1905 and 1906, a condition which it cost millions to remedy. Had no attempt been made to return the river to its seaward bed, or had this attempt been unsuccessful, the basin would have filled until it overflowed into the Gulf or until the Colorado turned southward of its own accord. In either case desertion by the river would have left an inclosed sea to slowly evaporate as the Salton Sea is now doing. That this history was actually enacted in the recent past is indicated by a deeply cut old beach line surrounding the basin at about 40 feet above sea level and a series of lesser and lower strands marking stages of retreat. The similarity of conditions then and now is attested by the fact that this older series of strands can not be distinguished from the strands which have been formed by the retreat of the present Salton Sea.

This interpretation of the recent history of the Salton Basin may require modification in detail. For instance, there has been some degree of post-Tertiary movement along the north side of the basin, and the exposed beds have been found to contain saline strata which exactly simulate beds deposited in continental inclosed lakes or playas. It is difficult to reconcile this with the hypothesis of long marine occupation of the trough. In this and other directions Dr. Blake's theory may need revision, but its essentials will probably stand. In any case, it is apparent that both the topography and the history of the Salton have been very different from that of the basins previously discussed. The major factor has been, not varying climate but a vagrant Colorado. This difference of history makes the usual criteria of little value.

The size and nature of the drainage basin, its mutilation by stream decay, the probabilities of inflow or overflow, are here of little importance. Of course, salt accumulation is quite possible either by the evaporation of marine water, the assistance of the river, or the ordinary continental processes, but the problem is in no case one of topography and is therefore beyond the scope of the present paper.

A word should perhaps be devoted to the delta of the Colorado.[1] This is a broad, alluvial plain, of no visible relief, and traversed by a network of bayous. The position occupied by the divide between gulf and basin is entirely indeterminate, and there is no rainfall to develop it. The lower channel of the Colorado is exceedingly variable and the delta is dotted with lakes and marshes, which are souvenirs of its presence. So far as known, all of these are essentially fresh, except some small ponds near the so-called Volcano Lake, and the salinity of these is due to recent and present fumarole activity. One of the lakes contains a considerable percentage of potash alum, which will doubtless be developed when transportation and political condi-

[1] For information concerning the delta I am indebted mainly to the papers of Dr. D. T. MacDougal and to personal communication from him.

tions become sufficiently favorable. Down the west side of the delta runs the so-called Rio Hardy or Hardy Colorado, which is fed by seepages or direct channels from the larger river to the east. West of the Cocopa Mountains and close to this Rio Hardy is a shallow basin separated from the river only by a wide and flat plain of very little elevation. In times of flood the Hardy sometimes covers this plain and fills the depression. On the retreat of the river there is formed an inclosed lake known as Laguna Maquata. When low it is quite saline, but the salinity is destroyed whenever a flood reconnects it with the Hardy.

The area of the Salton Basin can not be accurately computed because of the character of the delta and the uncertainty in the position of the divide across it. It is probably about 8,000 square miles.

THE BASINS OF THE NEW MEXICO-TEXAS TROUGH.

The central portion of New Mexico has a structure very similar to that of the Great Basin. A somewhat warped and folded plateau has yielded to great north-south fractures, producing parallel ranges and trough valleys as in Nevada and California. The most prominent of these troughs is that occupied by the valley of the Rio Grande north of El Paso. This was once a series of separate basins or "bolsons," but the divides have been cut by the river and the entire valley is now essentially drained, though stream decay has recently created a number of local and unimportant playas. East of this trough lies another which, not possessing a vigorous through-flowing stream, has not been cut down or kept clean, and contains the several inclosed basins next to be discussed.

THE OTERO BASIN.

The middle portion of this trough is occupied by the Otero Basin, lying between the Sacramento Mountains on the east and the San Andreas Mountains on the west. The writer has published elsewhere [1] a report of a reconnoissance of this basin from the present viewpoint, and it is necessary here only to review the essentials of the topography. East and west the basin is limited by the high walls of the trough. To the north it merges with the Gallinas highland and the Chupedera Mesa, both high and certainly pre-Lahontan. At the southern end the divide is alluvial and though apparently ancient, is probably less than 300 feet above the present deepest depression. It is quite possible that the basin has overflowed this divide and drained into the Rio Grande, but there is no direct evidence of this, and the writer does not consider it probable. In any case, a series of ancient strands about the present bottom indicates an inclosed history of some duration. The present deepest depression is a large and very gypsiferous playa, the southern end of which carries a deposit of hydrous sodium sulphate believed to be of secondary origin. There are several small local playas of no importance.

The most interesting and unusual feature of the basin is a great area of gypsum dunes, south and east of the main playa. The study of these dunes has yielded con-

[1] Circular 61, Bureau of Soils, U. S. Dept. of Agr. (1912). The reconnoissance was made in the company of Dr. Ellsworth Huntington.

FIG. 1.—BOTTOM OF DEATH VALLEY, CAL.

[Showing the salt-covered mud flat northwest of Furnace Creek Ranch.]

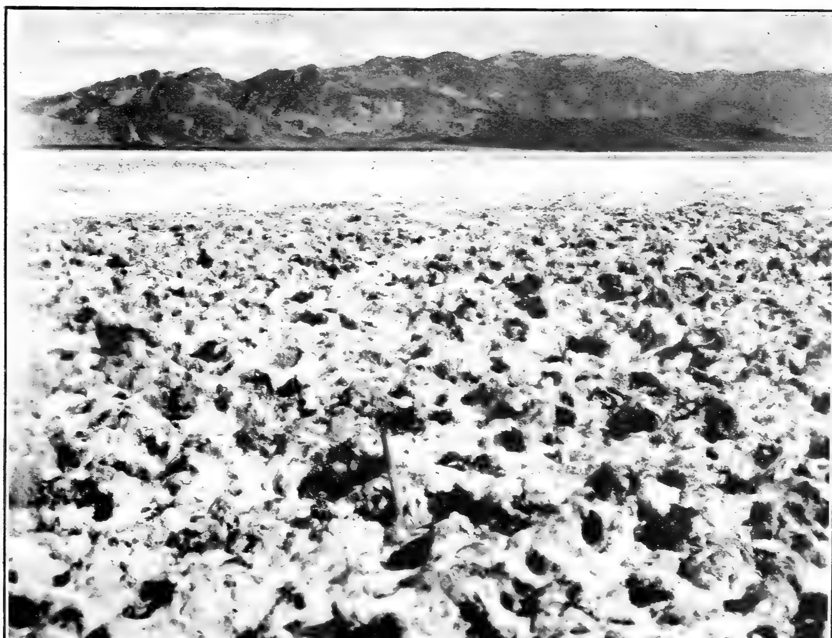

FIG. 2.—ROUGH CRUST OF IMPURE SALT ON THE FLOOR OF DEATH VALLEY, CAL.

clusions of some geologic interest but quite foreign to the present subject. The area of the Otero Basin is a little over 7,000 square miles.

THE ESTANCIA BASIN.[1]

The Estancia Valley lies at the northern end of the trough in which is the Otero Basin and where this trough begins to merge with the plateau of northern New Mexico. It is separated from the Otero Basin by the Gallinas and Chupedera uplift and the northern and western boundaries are similarly structural. The eastern boundary is much lower and in several places is less than 250 feet above the bottom of the valley. Overflow in this direction and into the Pecos Valley is possible but not probable. The bottom of the valley is diversified by a number of shallow and irregularly-shaped depressions, believed by Meinzer to have been scooped by the wind from the beds deposited in the bottom of an ancient lake. Some of these depressions now contain salt or brackish lakes. There is the usual series of old strands about the valley.

At present the drainage of the valley is almost entirely by underflow and impossible to define. The area is about 2,050 square miles. In the northeastern corner is the small basin of White Lake, now cut off by desiccation but once a tributary. Including this the area is about 2,100 square miles. Both of the areas given are only approximate because of the comparatively low relief of the surrounding highlands and the difficulty of accurately defining the divides.

THE ENCINO BASIN.

The Encino Basin lies east of the Estancia Basin and is very similar to it. The surrounding divides, though poorly defined, are relatively high and the basin has probably been permanently inclosed. It contains the usual saline depression, believed by Meinzer to be wind-formed, and is surrounded by the usual series of old strands. Its area is about 300 square miles, great accuracy being unobtainable because of uncertainty as to the position of the divides.

THE PINOS WELLS BASIN.

The Pinos Wells Basin lies just south of the Encino Basin and is similar thereto in every way except that the eastern divide is much lower and the lake strands are lacking. The writer is of the opinion that this basin was once tributary to the Pecos Valley and has only recently been inclosed. It is not impossible that this basin is a part of a former eastward overflow channel of the Estancia Basin and, if the Estancia Basin ever did overflow, it was probably by this path. The area of the Pinos Wells Basin is about 325 square miles.

THE SALT BASIN.

Directly southeast of the Otero trough, though probably not structurally related thereto is another similar trough which contains the so-called Salt Basin, historic as the scene of the "salt riots" of 1878. The divides which surround this basin are essentially structural and ancient and though several passes are superficially alluvial, all are over 600 feet above the flat. The basin is believed to have been permanently inclosed. The floor is a nearly level plain dotted with hillocks of dune sand and with small saline lakes and playas. The present drainage is insignificant and the areas tributary to the various lakes can not be computed with any exactness. The area of the basin as a whole is about 8,600 square miles.

[1] The description of the Estancia, Encino, and Pinos Wells Basins is drawn largely from the report of Meinzer, U. S. Geol. Surv.; Water Supply Paper 275 (1911).

THE TROUGH VALLEYS OF ARIZONA AND SONORA.

Arizona south of the Gila River and the northern and western portions of Sonora form another region of great parallel ranges and valleys essentially similar to the Great Basin though somewhat more complex in the details of its structure. The trough form of the valleys is especially well developed north of the international line, being typified by the Lechuguilla and Tule "Deserts" and the Mohawk and Ajo Valleys to the west; the Quijotoa, Baboquivari, and Santa Cruz Valleys in the center, and the San Pedro, Arivaipa, and San Simon Valleys to the east. South of the line the topography is less simple and the dendritic drainage of the Altar River has cut transversely across range and valley in a way which strongly suggests the character of the Quaternary Mojave.

The great troughs of the northern section resemble those already discussed in that they are usually higher in the middle than at the ends, thus creating in each a water parting north of which drainage was once to the Gila, while southward it joined the Altar or flowed directly to the Gulf. Without exception the troughs are essentially open in one direction or the other and in the whole region there is no known basin of structural origin. Furthermore, most of the drainage lines are still open and, paradoxically, because the aridity has been too complete. The process of alluvial damming so characteristic of the troughs of the Great Basin has been impossible because the rainfall has been too meager to move the alluvium. Even the minimum of rainfall necessary for the formation of local playas has been lacking. Two streams, the San Pedro and the Altar, have their sources in higher and better watered regions, and manage to maintain a precarious existence over part of their former channels. The Sonoita, the Santa Cruz, and a few other streams have a transient and truncated wet-weather flow. With these rare and shrunken exceptions there is no drainage at all. An occasional cloudburst in the mountains is imperceptible a dozen miles below. Yet because of the very paucity of drainage the region is not one of great salt accumulation. It is too arid to be saline. The drainage has not decayed but vanished, and there is water neither for chemical rock decay and salt solution, nor for the carrying to areas of concentration of such salts as do chance to be freed. Such salt accumulations as there are are in the better watered valleys rather than in the worse.

The Quaternary history of this region is a field for speculations of peculiar interest, and not without their present importance. Climatic changes have been continent-wide and probably world-wide, and the evidences of a previous lesser aridity are unmistakable in the region to the north. Is it not probable, therefore, that the present unmitigated aridity of this southern area has replaced a time of less extreme conditions when a more moderate desiccation permitted and caused the formation of playas and alluvial dams? This region then, was perhaps what the Great Basin is now, and salt accumulations descended from such a period are by no means impossible. But whether or not these speculations have a basis of truth, they are as yet without supporting evidence. No direct indication of such a moderately arid period has been discovered, and the country is so inhospitable that it has not invited the efforts of speculative geologists. For the present the matter must remain open and it would seem useless to search here for hypothetical salt accumulations when there are other regions, the promise of which rests less on speculation and more on fact.

THE COCHISE BASIN.

In the eastern part of the region just discussed there is one basin of more usual type. The Arivaipa-Sulphur Springs Valley, being better watered than its more westerly analogues, has had a history more nearly parallel to that of the Great Basin valleys, and the central portion of it has been cut off by alluvial dams to form the Cochise Basin. Northward the valley drains to the Gila and southward to the Rio Yaqui. The northward divide is the lower and probably the more recent, and there is little question that the basin once had free drainage in this direction. The area of the basin is approximately 1,250 square miles. It contains a playa of usual character.

THE LORDSBURG-MEMBRES REGION AND THE CHIHUAHUA BOLSONS.

In the southwestern corner of New Mexico are two trough valleys not essentially dissimilar to the Arizona trough valleys which border them on the west, but of much less regular structure. The western of these troughs contains the present Lordsburg and San Luis Valleys and belongs in many ways with the Cochise Basin and the San Simon Valley, in the group last discussed. Once it drained northward into the Gila and it is now cut off therefrom only by a low alluvial divide. Internally the valley shows a topography essentially similar to that of the valleys of the Great Basin. The structural trough has two branches, each of which once contained a considerable stream, the two uniting somewhat south of their mutual discharge into the Gila. Stream decay and alluvial dams have cut these tributaries into chains of shallow basins and local playas, notable among which are the Llano de los Playas, or Playas Valley, lying southeast of the Pyramid Mountains, and the Lordsburg Dry Lake near the railroad junction of that name. All of these subsidiary basins are recent and unimportant and their individual areas have not been computed. The total area of inclosed drainage in the trough is about 2,900 square miles.

East of this trough is another irregular trough valley now containing the valley of the Membres River and the Florida Plains. In this trough the inclination is reversed and the former drainage was southward across the international line. Indeed, there is now scarcely any barrier to southward drainage and a very moderate increase of rainfall would suffice to reestablish the outflow. Stream decay has produced a few local playas, but none of any importance.

Southward of the line the ancient drainage line reaches the Laguna Guzman, which is the sink of the northernmost of the Chihuahua bolsons. The area of the Membres Valley and its tributaries within the United States is over 5,000 square miles. In Mexico an area of 6,800 square miles is or has been tributary to the Laguna Guzman, making a total of about 11,800 square miles for the area of this bolson.

These bolsons are wide, shallow basins once tributary to the Rio Grande and now cut off therefrom only by low dams of alluvium and dune sand. They are products of the decay of the drainage system which once served the broad featureless plains between the Rio Grande and the Sierra Madre. All are very recent and unimportant. The larger ones contain intermittent or permanent lakes fed by the perennial streams which head in the well-watered highlands of the Sierra Madre. The region of the bolsons extends from the western boundary of Chihuahua southeastward to the edge of the drainage system of the Rio Salado, about half way across the State of Coahuila, but this region is divided into two parts by the still vigorous drainage system of the Rio Conchos. The northwestern portion is the smaller and contains the bolsons of the Laguna[1] Guzman (already discussed), the Laguna de Santa Maria, the Rio Carmen, and the Laguna de Patos, as well as many smaller playas and transient ponds. The more important bolsons of the southern division are those of Laguna Palomas, Laguna de Coyote, Laguna Parras, Laguna Viesca, Laguna de Jaco, and Laguna de Agua Verde. Areas have not been computed in detail. The total area covered by all the bolsons, including the Guzman, is probably not less than 125,000 square miles.

THE ROCKY MOUNTAIN BASINS.

The crests of broad mountain ranges are frequently regions of poorly determined drainage and wherever the crest of the Rockies is flat and imperfectly defined, advancing desiccation has left small valleys and local depressions partially or entirely without outward drainage. All such basins are more or less recent and nearly all are small. Only two require specific notice.

THE SAN LUIS BASIN.

The San Luis Valley or San Luis Park lies in south-central Colorado at the head of the great trough of the Rio Grande. It is separated from the valley of this river by a broad and featureless alluvial plain, crossed by an inconspicuous divide. The present drainage of the valley is not sufficient to overflow this divide, and accumulates

[1] Laguna is the Spanish word for lake; rio is that for river.

in a group of small and variable lakes. The inclosed condition of the valley is undoubtedly very recent and due only to stream decay. The area of the present basin is about 2,800 square miles.

THE RED DESERT BASIN.

The Red Desert Basin, or group of basins, lies in south-central Wyoming, on the very crest of the Rocky Mountains, occupying a broad plain bordered on three sides by mountain ranges but essentially open toward the south. At a time by no means remote this southern divide was nonexistent and the basin drained, probably freely but at least by overflow, into the Little Snake River and thence to the Colorado. The present barrier is a series of low divides which are superficially alluvial and probably entirely so. The basin is by no means a unit but is cut by alluvial or structural divides into a complex series of smaller basins each with its playa and its greater or lesser drainage. The past and present relations of these basins are not known in detail, but it is improbable that their discharge ever concentrated in a single basin or a single channel of escape. The region is more a decayed drainage system than a single basin.

None of these basins is ancient, and none would have any importance were it not for the fact that part of the western slope of the area is formed by the Leucite Hills, a zone of volcanic activity in which are large masses of leucitic rocks containing considerable proportions of potash.[1] How fully the drainage of these hills has been localized and retained can not be determined from present data. The writer inclines to the opinion that both retention and concentration have been comparatively slight, but the evidence is far from conclusive, and the region can not be disregarded. It should be noted that the presence of extensive deposits of sodium salts in the basins of the Red Desert and in other small basins both west and east of it is no proof of long-continued concentration. The shales and sandstones which make up the greater portion of the areas tributary to these basins contain large quantities of occluded sodium salts, which rapidly find their way into the drainage and to the places where it concentrates.

West of the Red Desert and on the westward slope of the Leucite Hills are several small and local basins now without overflow and which share the topography and geochemical characteristics of the western part of the Red Desert proper.

The total area of the Red Desert Basin is approximately 3,600 square miles, but it is apparent from the above discussion that importance lies not in the total area, but in the areas and topographies of the various subsidiary basins and in what proportion of leucitic country chanced to be tributary to each. These facts can not be determined from the information now available.

THE GREAT VALLEY OF CALIFORNIA.

Through the heart of California, between the Sierra Nevada and the Coast Range, runs a great filled trough which differs from the "basin troughs" east of the Sierra only in its greater size and in the fact that its western wall is breached by the Golden Gate, giving free egress to the sea. Southward through the north end of this valley flows the Sacramento River, and northward from the south end comes the San Joaquin, both rivers uniting to form the Straits of Suisan and entering the sea through San Francisco Bay and the Golden Gate. In essence both the Sacramento and San Joaquin Valleys are regions of free seaward drainage, but rainfall is low, and is insufficient to keep the valleys entirely clear. Local playas and "alkali" spots

[1] See Schultz and Cross, U. S. Geol. Sur., Bull. **512** (1912).

are not uncommon, and, especially in the San Joaquin, shallow local depressions have become small inclosed basins or lakes like Kern and Tulare, which overflow only at times. Here, as in the Great Basin, evidences of stream decay are everywhere. None of these local basins are structural, none have walls high enough to be even directly perceptible, and none have any significant antiquity. The saline accumulation gets no further than the formation of "alkali" soil, and has no significance to the present inquiry.

THE FILLED LAKES OF THE CALIFORNIA RANGES.

In the mountains of these ranges, as of most others, are many small depressions which are or have been filled by lakes. In the course of time these lakes have been slowly filled by alluvium, and at the same time their outlets have been slowly lowered by stream corrasion, until at last the rising alluvium met the falling water surface and the lakes have become flat-filled valleys with a more or less vigorous original or through-flowing drainage. Examples of this process, locally modified, have already been mentioned—the Antelope Valley in Oregon (p. 25), the Smith Valley in Nevada (p. 18), and the Tehachapi Valley in California (p. 42). Literally hundreds of others in all stages of development may be found in the Sierra, the Coast Range, the Cascades, and elsewhere. Plate I, fig. 1.

Where the drainage is sufficiently vigorous, either because through-flowing or for some other reason, these filled lakes do not interest us. In many cases, however, an original drainage, never very vigorous, has not been able to maintain itself and has been imprisoned within the valley. Probably the most extreme instance of this is the basin of the Carriso Plains in the southeastern corner of San Luis Obispo County, Cal.[1] Nearly 500 square miles of this valley, once tributary to the San Juan Creek, have been cut off by alluvial deposition and stream decay probably complicated by local movement, and have developed an internal drainage concentrating in Soda Lake, which is now a playa saturated with a strong salt solution in which sodium sulphate predominates. Of course this condition is quite recent, and, from the present viewpoint, quite unimportant.

THE BASINS AND PONDS OF THE COLORADO PLATEAU.

The northern third of Arizona, the northwestern quarter of New Mexico, and adjoining portions of Utah and Colorado make up the Great Colorado Plateau. Subjected to some movement and considerably dissected by the Colorado and its tributaries, this plateau nevertheless retains wide areas in which relief is small and slope imperceptible, and over which drainage is at best sluggish and uncertain. These areas have suffered greatly from the prevalent desicca-

[1] Arnold and Johnson, U. S. Geol. Sur., Bul. **380**, 369 (1909).

tion. Valleys dammed by alluvium, local depressions dried below their outlets, ponds like those of the Great Plains and coulées, as well developed as those of Washington, all abound. Many of these inclosed areas are of considerable salinity, but all are recent and most are tiny, and it does not seem necessary to discuss them in detail. In area they vary from ponds or playas that drain a few acres to the large but shallow basin of the plains of San Augustine in western New Mexico, compassing perhaps 1,500 square miles. This latter basin and the smaller ones in its vicinity probably once drained into the Rio Grande instead of the Colorado, but otherwise they do not differ from their western analogues. In the absence of full and detailed knowledge of the entire plateau region it is impossible to deny categorically the existence of basins, the size or antiquity of which would give them present interest. However, it seems very probable that, with one exception, no such exist. This exception will now be described.

THE HUALPAI BASIN.

In its southwestern portion the Colorado plateau has been more modified than elsewhere, both by movement and erosion, and here lies the Hualpai or Red Lake Valley, occupying a depression in the making of which both movement and erosion have had a hand. There is little doubt that this valley once drained northward to the Colorado, but this drainage may have been a long time ago. The present divide, though alluvial, is high and may be pre-Lahontan. The writer, while inclining to the opinion that it is, does not care to advance any conclusion. The area of the basin is approximately 1,450 square miles and its deepest depression contains a playa which is not known to be especially saline.

THE PONDS AND COULÉES[1] OF EASTERN WASHINGTON.

The central and eastern part of Washington is largely a great lava plateau, somewhat warped and cracked by the movement which was more pronounced farther south and west, but preserving much of its original character. Being of little relief and in general of poorly developed drainage, this plateau has suffered severely by desiccation and is now dotted with literally hundreds of small inclosed basins, due primarily to inequalities in the lava surface and resembling in every way the small pans of the Christmas Lake, Abert and Alkali Valleys, as discussed on pages 22 to 26. Some of these depressions now carry permanent or intermittent lakes, most are slightly or moderately saline, but all are recent and owe their inclosed condition to the decay of the drainage system to which they once belonged. So far as known none drain an area of over a few square miles and none are important.

Another and less usual type of inclosed basin is represented by the "coulées," or long, narrow valleys with steep walls and flat floors, the floors being dotted with lakes. Essentially these are old stream channels, the history of which, stripped of all details, is as follows. When the lava plain was uplifted and warped, numerous cracks formed

[1] The word "coulée" is here used as locally understood.

across it, usually without much vertical displacement on either side. As the rainfall was then (or later) much greater than at present, these cracks determined stream channels and became eroded to considerable depths and with a steep-walled, canyon topography. Later ice-dammed lakes occupied these valleys and supplied the alluvium which forms the present flat bottoms. With the disappearance of these lakes the valleys again became stream channels but apparently not for long. Desiccation intervened and the once through-flowing streams were split into a series of pools or playas. This is the present condition of the coulées. Some of the lakes overflow and are fresh, others do so seldom if ever and are brackish or saline. In Grand Coulée is one—Soap Lake—which is a nearly saturated brine and contains an extraordinarily large proportion of carbonate of soda. But interesting as is this history of the coulées, it indicates clearly the recency of the lakes which occupy them, and therefore their unimportance to the present inquiry. None of their areas have been computed.

THE PONDS OF THE GREAT PLAINS.

The western half of the Mississippi Valley is a great apron sloping imperceptibly upward to the mass of the Rockies. Over this in Quaternary time stretched a complexly dendritic drainage system, its finger tips reaching to the crest of the mountains and to every ridge and hill between, so that each township had its river and every acre its rill. But advancing aridity has respected this greatest river system no more than the lesser ones to the west. Its streams have been clogged and truncated and its remotest and slenderest tendrils withdrawn, until to-day there is a large area at the foot of the Rockies which has nearly no drainage at all. In all this region alluvial dams and sand dunes (the latter much more than the former) have advanced upon the defenseless drainage, damming the little streamlets in a dozen places, cutting off here and there a tributary of more considerable size, creating tiny and tinier basins now numbered by the thousands. These dot the whole plains region of Nebraska and Wyoming, the northwestern corner of Kansas, the eastern fourth of Colorado, the dune areas of southwestern Kansas, and the great plains of the Pecos Valley and the Llano Estacado, but they are perhaps best exemplified in the Sand Hills of Nebraska.[1] Here alluvium and dunes and have conspired against the drainage and with entire success. The region is a wilderness of rolling hills, originally dunes but now fixed by vegetation with the intermediate valleys dotted with lakes varying in area from a few acres to 2 or 3 square miles. There is usually an annual fluctuation in level of 1 or 2 feet from a maxi-

[1] For much of the information here given I am indebted to Prof. Raymond J. Pool, of the University of Nebraska.

mum in early spring to a minimum in late autumn. Most of the lakes do not overflow and many of them are brackish. All are unquestionably recent and due to sand accumulations which the drainage has never since been vigorous enough to clear away.

Farther south, where the rainfall is less, are playas instead of lakes, but otherwise conditions are the same. Everywhere the outposts of the drainage system have retreated and their channels have been barred. The bars are sometimes alluvial, sometimes eolian, more often both. The result is the same.

Of course none of the basins thus created could ever become the place of accumulation of any large quantity of salt. It is an essential of the process outlined that large basins can not be created, since their concentrated drainage would be sufficient to sweep away the dam. Where a stream of any size is permanently dammed by sand or alluvium it must be dammed in many places and split into many basins in order that evaporation may be sufficient to balance or overbalance the inflow. In places ponds may become quite saline, but the total amount of salt accumulated is always small.

It is of special interest in the present connection to note that some small saline ponds in western Nebraska have been found to contain very large proportions of potassium carbonate undoubtedly derived from the concentration of the run-off of burnt-over prairies. Were there a place where concentration of this kind had occurred for a long time or from a considerable area, a workable deposit of potassium salts might have accumulated. No such place has been discovered and it is probable that none exists.

LOCAL BASINS OF UNUSUAL ORIGIN.

For the sake of completeness it is necessary to note briefly a few areas of inclosed drainage which have originated from local and unusual causes. These are of two types—volcanic and eolian. The craters of extinct volcanos frequently contain inclosed lakes and there is at least one example of this in the United States—Crater Lake, Oreg. The Ragtown Soda Lakes, near Fallon, Nev., noted on page 15, are probably of similar origin, though the vulcanism was far less vigorous. Apparently the Zuni Salt Lake on the plateau of northwestern New Mexico is of the same type.[1] In both the latter cases the salinity of the inclosed lake is due to the concentration of water received from seepage or springs.

Basins due to "deflation," or eolian erosion, have only one prominent example in the United States. West of Laramie, Wyo., are three or four isolated depressions, one of which, Bates Hole, is of considerable size and depth. These have been studied by Blackwelder[2] who

[1] Darton, U. S. Geol. Survey, Bul. **260**, 565 (1905).

[2] Jour. Geol., **17**, 443 (1909).

regards them as due to wind erosion. The similar though smaller wind-eroded hollows of the Estancia Basin, New Mexico, were noted on page 49, and the writer has seen analogous depressions in the Alkali and Warner Basins, Oreg. Both volcanic and eolian basins are likely always to be too small to have importance for the present study. This is certainly true of all known American examples.

THE POSSIBILITIES OF POTASH.

In the preceding pages there are named specifically nearly 200 inclosed basins. Some of these are so obviously unimportant as to require no further mention. One hundred and twenty-six, which are somewhat more important, are given in Table I, with the area and a brief description of each, the arrangement being the same as that followed in the text. It is certain that any basins of possible value for potash will be included in this list, and it is just as certain that many that are included will have no possible value. Many of the latter are easily eliminated. First, it is obvious that no accumulation is to be expected in a basin which has recently overflowed either into the sea or into another basin. Applying this to the list of Table I, it is possible to eliminate from further consideration 62 basins, of which 16 were once tributary to Lahontan, 9 to Bonneville, 11 to the Amargosa and the Mojave, 7 to miscellaneous inclosed basins, and 19 more or less directly to the sea. These totals include 10 basins the previous drainage of which is not absolutely certain, though extremely probable. These are the Clover Basin, the Goshute-Steptoe Valley, the Murray Valley, the Ralston Valley, Stonewall Flat, Summer Lake, Long Valley (northwestern Nevada), Duck Flat, the Big Smoky Valley, and the Smiths Creek Valley. The nature of the doubt in each case can be ascertained by reference to the preceding chapter.

A second general elimination can be made on the ground of small area. It is difficult to set exactly the limiting area which a basin must have in order to be promising, but it seems probable that basins which cover less than 500 square miles may safely be disregarded. Their potash deposits, if existent, would doubtless be small, and detailed prospecting would scarcely be warranted at least until larger basins have been explored. Applying this criterion to the remaining basins of Table I, we eliminate 10 more, Alkali Lake, Garfield, Teels, Huntoon, Goldfield, Sheep Range, Willard, Granite Mountains, Owl, and Encino. It is possible also to eliminate 12 others which were very probably drained, but which, in any event, are smaller than the upper limit which we have set. These are Warm Springs, Allan Springs, Mesquite (part of the Pahrump), Acme, Luning, Mina, Monte Cristo, Kawich, Yucca, Aurora, Deep Springs, and Pinos Wells. The conclusion that these small basins lack practical value does not necessarily mean that they lack scientific interest. For instance, the small saline ponds of Alkali Lake are known to contain about 4 per cent of potash (K_2O) in their total dissolved solids, and the Teels Marsh carries a number of the minerals which are associated with potash brines at Searles. It is quite possible that some of these smaller basins may prove to contain potash accumulations of relatively high grade, but the amount of the material is likely to be too small to warrant commercial exploitation.

It is possible to eliminate two additional basins on special grounds. First, Bonneville, in spite of its great size, can be safely dropped from the list of possibilities. This is true on two grounds—previous overflow and the areal geology of the basin. The overflow in itself might not be sufficient, for there has been a considerable period since the overflow ceased and time has probably been available for extensive potash accumulation. But the Bonneville Basin is set almost entirely in sedementary rocks, which can not reasonably be expected to yield any important quantity of potash to the drainage. Furthermore, nearly all of the saline material accumulated within the basin is probably now in the Great Salt Lake, and the salts contained in this lake carry less than 2 per cent of potash (K_2O).

The last basin to be eliminated is the Otero, in central New Mexico. This was possibly once subject to overflow and is set almost entirely in nonpotash rocks, but its elimination is not based upon these facts so much as upon a detailed examination made of the basin specifically from the present point of view, and which resulted in a strongly negative conclusion.[1]

The basins which remain may be divided into three divisions: (1) Those in which the known topographic and geologic conditions are fully favorable, (2) those in which some conditions are favorable and some adverse, and (3) those concerning which there is sufficient uncertainty to render classification doubtful and decision as to promise impossible. The basins of these three divisions are given in Tables II and III and IV, respectively. Of those in Table III the topographic features are favorable in all cases but one—Owens. In this case the previous overflow into Searles introduces an unfavorable factor which has, however, been partially overcome by the length of time elapsed since this overflow ceased. At the present time the salts of Owens Lake contain approximately 2.25 per cent of potash (K_2O). With the other basins of Table III the unfavorable factor is in all cases a lack of potash-bearing rocks in the drainage basin, the Chewaucan Basin being set almost entirely in basalts and the others in Paleozoic sediments.

Of the uncertain basins of Table IV, the Salton is doubtful, because of the difficulty of interpreting the influence of the Colorado River

[1] Free, Circ. No. 61, Bureau of Soils, U. S. Dept. of Agr. (1912).

upon it; Rhodes is unpromising, because of its small drainage area and the probability that this area was really considerably smaller than that given, and the uncertainty concerning the Red Desert arises from lack of knowledge of its internal topography. In all other cases the doubt is due to uncertainty as to area or previous overflow, usually the latter. Details of all cases are contained in previous pages.

The basins of Table II are, so far as known, all favorable to potash accumulation and, other things equal, they should be promising in proportion to their area. These "other things" are believed to be really equal so far as accumulation is concerned. Questions of segregation and accessibility introduce many other factors which are beyond the province of this report and will not be discussed.

It is believed, however, that the introduction of these additional factors into the discussion would find its main effect in altering the order in which the basins stand in Table II rather than in adding basins thereto or subtracting them therefrom. The basins of greatest promise from all points of view are probably contained in Table II, with the possible addition of such of those of Table IV as further investigation may show to be favorable.

TABLE I.—*Areas of the undrained basins.*

Basin.	Description.	Area.
		Sq. m.
Lahontan		45,730
Black Rock	Part of Lahontan	10,500
Kumiva	do	445
Granite Spring	do	890
Jungo	do	340
Hot Springs	do	270
Honey Lake	do	2,660
Truckee	do	2,975
Lemmon Valley	do	90
Warm Springs	do	20
Humboldt-Carson	do	27,575
Fernley	do	215
Allen Springs	do	235
Sand Springs	do	200
Buena Vista	Part of Humboldt drainage.	4,000
Buffalo Springs	do	500
Gibson	do	1,150
Clover (Snow Water).	do	1,075
Walker	Part of Lahontan	3,850
Bonneville	Once tributary to Columbia River.	57,960
Steptoe	Part of Bonneville	6,590
Ruby	do	1,200
Butte Valley	do	740
Murray	do	720
White Valley	do	920
Rush Valley	do	700
Cedar Valley	do	300
Sevier	do	16,375
Round Valley	do	170
Christmas Lake	Probably landlocked	2,750
Silver Lake	Part of Christmas Lake Basin.	750
Chewaucan (Abert Lake).	Landlocked	1,500
Summer Lake	Part of Chewaucan Basin.	560
Alkali Lake	Landlocked	400
Warner	Landlocked	2,000
Harney	Tributary to Columbia River.	......
Catlow	Probably tributary to Harney.	2,000
Guano	Probably tributary to Catlow.	1,000
Surprise	Landlocked (max. area).	2,350
Long Valley	Probably tributary to Surprise.	775
Alvord	Probably landlocked	3,200
White Horse	Tributary to Alvord	300
Thousand Creek	do	1,300
Goose Lake	Tributary to Pitt River.	......
Madeline	Probably landlocked	900
Klamath Lakes	Tributary to Klamath River.	......
Dixie Valley	Landlocked	2,290
Fairview	Part of Dixie	290
Gabbs Valley	Landlocked	1,280
Acme	Probably tributary to Walker.	130
Luning	Probably tributary to Rhodes.	175
Mina	do	65
Rhodes (max. area)	Probably landlocked	670
Garfield	do	90
Teels	Landlocked	320
Huntoon	do	115
Monte Cristo	Doubtful	300
Columbus	Landlocked	1,350
Clayton	do	550
Big Smoky	do	3,325
Kingston	Tributary to Big Smoky.	1,190
Edwards Creek	Landlocked	990
Smiths Creek	Probably tributary to Edwards Creek.	500

TABLE I.—*Areas of the undrained basins*—Continued.

Basin.	Description.	Area.	Basin.	Description.	Area.
		Sq. m.			*Sq. m.*
Goldfield	Probably landlocked	330	Soda Lake	Part of Mojave drainage.	
Diamond	....do	2,800	Rodriguez Lake	....do	
Railroad Valley	Landlocked (max. area)	6,340	Harper Lake	....do	
Kawich	Probably tributary to Railroad.	370	Coyote Lake	....do	
Penoyer	....do	1,000	Cronese Lake	....do	
Gold Flat	Probably landlocked	640	Langford Lake	....do	
Emigrant	Probably landlocked (max. area).	1,000	Ivanpah	Landlocked	900
			Mesquite Lake	Tributary to Colorado River.	
Yucca	Probably tributary to Frenchman Flat.	300	Dale Lake	....do	
Frenchman Flat	Probably landlocked.	740	Palen Lake	....do	
Indian Spring	Tributary to Colorado River.	650	Bristol Lake	Probably tributary to Colorado River.	2,520
Pintwater	....do	730	Cadiz Lake	Tributary either to Danby Lake or to the Colorado River.	
Lee Canyon	....do	300			
Sheep Range	Doubtful	300			
Spring Valley	....do	1,550	Danby Lake	Probably tributary to Colorado River (max. area).	4,150
Gannett	Tributary to Colorado River.	150			
Opal Mountain	Probably landlocked	580	Salton	Complicated by marine invasion.	8,000
Mono	Landlocked	770			
Aurora	Part of Mono	95	Laguna Maquata	Connected with Rio Hardy (Colorado River).	
Owens	Once tributary to Searles.	2,825			
Searles	Landlocked (max. area)	4,850	Otero	Probably landlocked	7,000
Panamint	Landlocked (area does not include Searles or Owens).	1,950	Estancia	....do	2,100
			Encino	....do	300
			Pinos Wells	Probably tributary to Pecos River.	325
Saline Valley	Landlocked	845			
Eureka	....do	775	Salt	Landlocked	8,600
Deep Springs Valley.	Probably tributary to Eureka.	185	Cochise	Tributary to Gila River.	1,250
Kane	Probably landlocked	900	Lordsburg Dry Lake.	....do	
Willard	....do	250	Playas Valley	....do	
Granite Mountain	....do	150	Laguna Guzman (Membres Valley).	Tributary to Rio Grande.	11,800
Owl	....do	60			
Death Valley	Landlocked (inc. Mojave and Amargosa).	23,560	San Luis Valley	....do	2,800
Ralston Valley	Part of Amargosa drainage.	1,750	Red Desert	Probably tributary to Colorado River.	3,600
Stonewall Flat	....do	345	Carriso Plains	Tributary to Pacific Slope drainage.	500
Sarcobatus Flat	....do	755			
Pahrump Valley	Tributary to Amargosa (max. area).	1,400	Plains of San Augustine.	Tributary to Rio Grande.	1,500
Mesquite Valley	Probably tributary to the Amargosa.	350	Hualpai	Probably landlocked	1,450

TABLE II.—*Basins in which all known conditions are favorable to the accumulation of potash salts, given in order of area.*

Basin.	Area.	Basin.	Area.	Basin.	Area.
	Sq. m.		*Sq. m.*		*Sq. m.*
Lahontan	45,730	Warner	2,000	Saline	845
Death Valley	23,560	Panamint	1,950	Eureka	775
Railroad Valley	6,340	Hualpai	1,450	Mono	770
Searles	4,850	Columbus	1,350	Frenchman Flat	740
Alvord	3,200	Gabbs	1,280	Gold Flat	640
Diamond	2,800	Edwards Creek	990	Opal Mountain	580
Surprise	2,350	Kane	900	Clayton	550
Dixie	2,290	Ivanpah	900		

TABLE III.—*Basins in which some of the known conditions are unfavorable to the accumulation of potassium salts but which cannot be definitely rejected, given in order of area.*

Basin.	Area.	Basin.	Area.	Basin.	Area.
	Sq. m.		*Sq. m.*		*Sq. m.*
Salt Basin	8,600	Estancia	2,100	Chewaucan (Abert Lake)	1,500
Owens	2,825	Spring Valley	1,550		

TABLE IV.—*Basins the classification and promise of which is doubtful, given in order of area.*

Basin.	Area.	Basin.	Area.	Basin.	Area.
	Sq. m.		*Sq. m.*		*Sq. m.*
Salton	8,000	Bristol Lake	2,520	Emigrant (Timpahute)	1,000
Danby Lake	4,150	Catlow	2,000	Madeline	900
Red Desert	3,600	Penoyer	1,000	Rhodes	670
Christmas Lake	2,750	Guano Lake	1,000		

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