Issued April 4, 1913.

# United States Department of Agriculture,

BUREAU OF SOILS—CIRCULAR NO. 79.

MILTON WHITNEY, Chief.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF SOILS,
*Washington, D. C., March 27, 1913.*

SIR: I have the honor to transmit the manuscript of a report covering the resurvey of the Sutter Basin—a poorly drained section of the Marysville area, California, surveyed in 1909—and to recommend its publication as Circular No. 79 of this bureau.

Very respectfully,

MILTON WHITNEY,
*Chief of Bureau.*

Hon. D. F. HOUSTON,
*Secretary of Agriculture.*

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## SOILS OF THE SUTTER BASIN: A REVISION IN THE SURVEY OF CERTAIN SOILS IN THE MARYSVILLE AREA, CALIFORNIA.

### INTRODUCTION.

The Marysville area, California, was surveyed in 1909, and the report upon the area was issued by this bureau October 25, 1911. This area extends for a distance of some 60 miles from north to south, its southern extremity lying about 5 miles south of the city of Sacramento.

The Sutter Basin occupies characteristically an area of depression of V-shaped outline lying in the middle western part of the area covered by this survey, between the Sacramento and the Feather Rivers.

Owing to the fact that at the time of the survey large areas of the basin lands and adjacent alluvial soils occupying the immediate flood plain of the rivers were covered by overflow from floods of unusual severity, considerable difficulty was experienced in studying

and mapping soil conditions in such portions of the area. Moreover, in the larger proportion of the basin not protected from overflow or provided with means of drainage and periodically occupied by a large body of water, the soils were not differentiated with the detail upon the map or as closely studied with reference to agricultural possibilities as were the adjacent soils now utilized for agriculture. Subsequently, however, a proposed engineering project of considerable magnitude, involving protection of the lands of the basin by an extensive system of levees and artificial overflow channels and the draining of the lands by installation of pumping plants, has led to a request for further study of the soil conditions within the basin. A revision of the central and southern portion of the basin covered by the project has therefore been undertaken.

## TOPOGRAPHY.

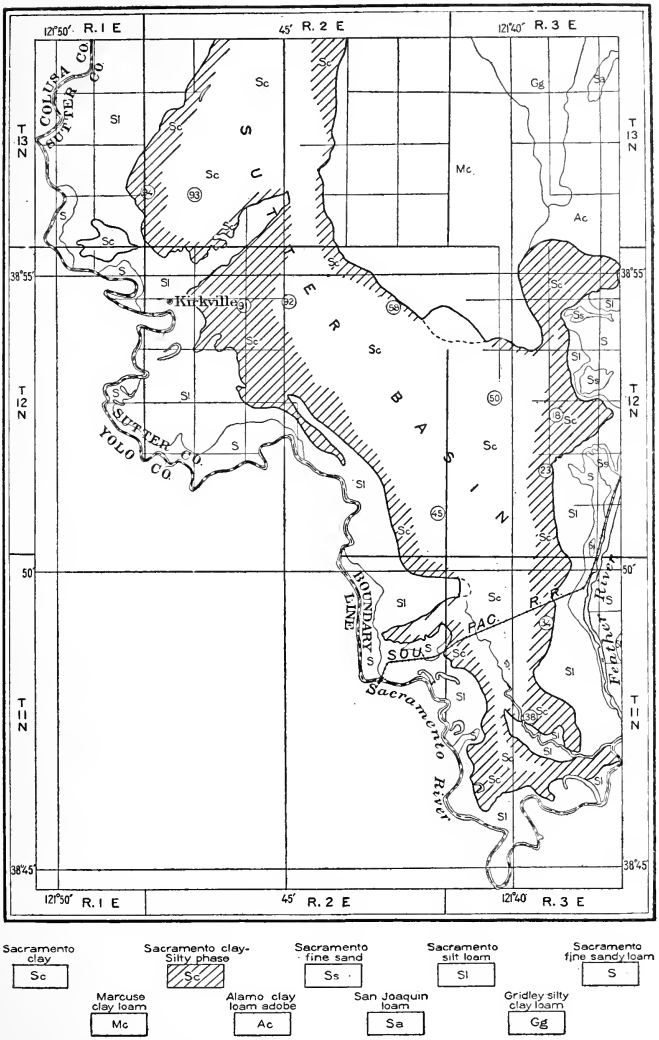
The surface of the basin lies at an elevation of 10 to 15 feet below that of the recent alluvial soils immediately adjacent to the stream channels. It consists of sedimentary deposits laid down by the waters of periodic floods in the streams mentioned, and is of a level plain, save for occasional lagoons or remnants of former stream channels and small isolated knolls. In the vicinity of the streams inclosing the basin and in the apex formed by their junction a dense growth of timber and brush occurs, but the surface of the basin itself is generally treeless. Large areas are entirely barren of vegetation, while others are covered with a dense growth of tule (Scirpus lacustris) and weeds.

## SOILS.

The soil material covering the floor of the basin is being added to with each successive flood, the annual increment of sediment amounting in localities particularly favorable to its deposition to as much as 2 inches. Except for areas of limited extent protected from overflow, upon which attempt has in some cases been made to utilize the land for crop production, the soils of the basin have been utilized only for grazing. The lower lying lands are not suitable for this purpose except during the dry season. The soils are predominantly of heavy texture and, in their natural undrained condition, of compact structure.

Occurring within and immediately adjacent to the portion of the basin covered by the revision of the earlier survey the following soil types, as differentiated in the original survey, were mapped:

Sacramento fine sand, Sacramento fine sandy loam, Sacramento silt loam, Sacramento clay, and Marcuse clay loam.




Sacramento clay — Sc
Sacramento clay-Silty phase — Sc
Sacramento fine sand — Ss
Sacramento silt loam — Sl
Sacramento fine sandy loam — S
Marcuse clay loam — Mc
Alamo clay loam adobe — Ac
San Joaquin loam — Sa
Gridley silty clay loam — Gg

FIG. 1.—Soils of Sutter Basin.

In figure 1 is reproduced upon a small scale a portion of the soil map covering the part of the area in which the basin occurs. Upon this is indicated the location and extent of the types mentioned as drawn in the original survey and also as delineated in the revised survey, the soil boundaries as originally drawn where departing from those as recognized in the revised survey being indicated by dotted lines.

Of these the only soil type involved to any important extent in the more detailed study undertaken in the revision of this portion of the area is that which has been recognized as the Sacramento clay.

Concerning this type, it has in the report upon the Marysville area been described in the following words:

> The Sacramento clay consists either of 6 feet or more of black clay or of 18 inches of a light-brown silt loam overlying the clay. * * * Where the Sacramento clay is a clay throughout, the surface cracks badly upon drying, the cracks often being from 18 inches to 2 feet in depth.
>
> Occupying as it does the lowest parts of the area, the drainage of this type is very poor. The entire area is overflowed continuously for several months in each year, and portions are never free from standing water. During the periods of high water in the rivers the water flows into the basins through natural openings along the banks, and here it remains until the flow of the streams decreases in the late summer. Then the water finds its way into the streams through the same channels by which it entered.

With regard to the utilization of the type for agricultural purposes the following further statements are made:

> Excepting for a small patch of beans near Verona there was not a single acre of the Sacramento clay under cultivation this year (1909). The crop referred to was practically a failure. Consequently there is no data on which to form a judgment of the probable fertility of the type when reclaimed from overflow.

Some doubt was, however, expressed as to whether the soil could be effectively drained and cultivated, even if protected from overflow and were pumping plants of adequate capacity for removal of excess surface and subsoil waters installed. This doubt arose from the compact structure and high silt and clay content evident in the field and substantiated by the results of mechanical analysis of typical samples. It must be borne in mind that the statement embodied in the original report as to the value of this soil type for agriculture was based on the existing conditions, and that although a fleeting reference was made to possible drainage and resulting conditions such a possibility received no serious study, and the statement must be interpreted on that basis.

The water-logged and nonaerated condition of the soil as observed in the field under the unfavorable conditions occurring at that time greatly intensified the conditions of poor physical structure and rendered it doubly difficult to judge of the adaptability of the soil

to agriculture under altered conditions. Passage of subsoil waters vertically and laterally through the soil and subsoil material will take place much more slowly than would be the case with soil material of lighter texture and less compact structure. Moreover, when protected from overflow the floor of the basin will during flood periods be several feet below the high water level of the adjacent streams. Under such conditions a tendency toward the maintenance of a high-water table may be anticipated. The level of the water table must therefore be maintained at such a depth as to permit utilization of the soil for agricultural purposes by removal of the subsoil waters through effective operation of the pumps.

This factor in the possibilities in development of the lands of the basin thus becomes the dominant question in connection with the more detailed mapping of the soils of the basin, undertaken in the revision of this portion of the area.

It will be remembered that in the original report it is recognized that a belt of the main body of the Sacramento clay lying along its outer boundary varied from the typical soil in having a layer of silt of varying thickness overlying the typical clay. In the revised map this belt has been differentiated as a silty phase and its boundaries placed on the map. Only minor changes in the boundary of the contact of the body originally mapped as Sacramento clay with adjacent soil types, as originally drawn, have been made. In the main essentials, therefore, the revised map confirms the original as to the differentiation and recognition of soil types.

In considering the utilization of the soils as recognized in the surveys opinion is based upon knowledge of soils in general as well as on a rather hurried study of what is being done on essentially the same soils in adjoining districts that have been reclaimed from overflow and artificially drained under somewhat similar conditions. The time and opportunities available for this purpose were both limited, and in none of the districts used for comparison were samples collected, nor had the areas been completely covered by soil surveys. It is believed, therefore, that a conclusion based on a broader study of what is being done on heavy clay soils elsewhere in the United States will be of greater value. To this end a compilation has been made of the salient facts concerning certain heavy clay soils of the United States, especially heavy alluvial soils that have been mapped, subjected to mechanical analyses, and studied in the field by the Bureau of Soils. Special attention has been paid to alluvial soils because their origin, topography, and relation to drainage are like those of the Sacramento clay. After this compilation was made only the heaviest, as shown by mechanical analysis, were selected for comparison.

The following soils were selected:

The Trinity clay, the Sharkey clay, the Iberia clay, the Wabash clay, the Waverly clay, the Miller clay, the Dunkirk clay, the Cameron clay, and the Houston clay. The last is the only one selected that is not an alluvial soil.

Table I shows the combined percentages of silt and clay and of clay alone in both soil and subsoil in each of these clays. In Table II are given the clay and silt contents of 11 samples of the Sacramento clay for comparison. Table I states briefly the agricultural use that is made of each soil and its agricultural possibilities in the various areas in which it has been mapped.

TABLE I.—*Silt and clay content of certain heavy soils.*

| Type and location. | Soil. | | Subsoil. | |
|---|---|---|---|---|
| | Silt and clay. | Clay. | Silt and clay. | Clay. |
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Trinity clay:[1] | | | | |
| Brazoria, Houston, and Ellis Counties, Tex. | 91–94 | 59–68 | 94–97 | 62–70 |
| Sharkey clay:[2] | | | | |
| Concordia Parish, La. | 91–98 | 39–63 | 93—99 | 45–70 |
| Adams County, Miss. | 98 | 49 | 96 | 46 |
| Iberia Parish, La. | 97 | 62 | 97 | 70 |
| Iberia clay:[3] | | | | |
| Iberia Parish, La. | 97 | 39 | 98 | 50 |
| Wabash clay:[4] | | | | |
| Jackson County, Mo. | 97 | 43 | 97 | 39 |
| Cooper County, Mo. | 97–98 | 28–41 | 96–98 | 29–34 |
| Allen County, Kans. | 94 | 40 | 89–95 | 38–41 |
| O'Fallon area, Ill.-Mo. | 94 | 21–42 | 95 | 17–44 |
| Waverly clay:[5] | | | | |
| Posey County, Ind. | 95–98 | 28 | 96–98 | 3–31 |
| Boonville area, Ind. | 92–96 | 35–40 | 87–95 | 36–49 |
| Miller clay:[6] | | | | |
| Waco area, Tex. | 94–97 | 47–62 | 94–97 | 55–62 |
| De Soto Parish, La. | 95–97 | 63–66 | 97–98 | 59–85 |
| Miller County, Ark. | 86 | 52 | 94 | 71 |
| Dunkirk clay:[7] | | | | |
| Tompkins County, N. Y. | 92–97 | 14–54 | 95–97 | 28–48 |
| Cameron clay:[8] | | | | |
| Brownsville, Tex. | 92–99 | 47–52 | 97–99 | 43–62 |
| Houston clay:[9] | | | | |
| Cooper area, Tex. | 95 | 38 | 95 | 39 |
| Paris area, Tex. | 94 | 39 | 89 | 40 |
| Sacramento clay:[10] | | | | |
| Woodland area, Cal. | 91–96 | 50–54 | 96–98 | 45–55 |
| Stockton area, Cal. | 90 | 50 | 62 | 17 |

[1] Cultivated to considerable extent. Considered a very productive soil for corn and cotton.

[2] Poorly drained naturally, and artificial drainage not yet undertaken. When naturally drained, as is the case in small patches, produces good crops of corn and cotton.

[3] Considered a good soil. Cultivated to considerable extent and produces good crops of sugar cane and corn.

[4] Where poorly drained is difficult to handle. Where well drained is an excellent corn soil. Leveed in O'Fallon (Ill.-Mo.) area, and produces good crops of corn and wheat.

[5] Is extensively cultivated and considered an excellent corn soil.

[6] Where drained either naturally or artificially is a good corn, cotton, and, in Louisiana, a good sugar-cane soil.

[7] Where drained, is an excellent oat, mangel, grass, silage, corn, and fair wheat soil.

[8] When drained and cultivated under irrigation produces good yields of cotton, corn, sugar cane, and vegetables.

[9] One of the most fertile soils in the United States and practically all in cultivation. Topography undulating.

[10] Where reclaimed from overflow and drained an important soil in the production of grains, forage, and hay crops, dairying and stock raising.

TABLE II.—*Sacramento clay, Sutter Basin. Soils with thin silt cover or none at all.*

| Sample No.[1] | Soil. | | Subsoil. | |
|---|---|---|---|---|
| | Silt and clay. | Clay. | Silt and clay. | Clay. |
| 45 | 94 | 34 | 97 | 54 |
| 50 | 92 | 37 | 83 | 48 |
| 58 | 93 | 34 | 60 | 33 |
| 93 | 97 | 28 | 98 | 48 |
| 18 | 95 | 16 | 84 | 37 |
| 23 | 95 | 23 | 85 | 36 |
| 34 | 95 | 33 | 93 | 42 |
| 38 | 97 | 36 | 97 | 49 |
| 91 | 93 | 36 | 75 | 29 |
| 94 | 97 | 27 | 95 | 38 |
| 92 | 95 | 52 | 93 | 52 |

[1] Location of samples by field number given upon map, fig. 2.

An inspection of these tables shows that the Sacramento clay even in its heaviest phase is no heavier than the other clays in the table and not so heavy as the Miller clay. These latter, however, are being cultivated and produce good crops when drained and protected from overflow. There seems to be no reason, therefore, to consider the Sacramento clay incapable of being drained on account of its high silt and clay content, or of too heavy texture to be successfully cultivated when protected from overflow and drained by means of pumping plants of sufficient capacity.

It must be borne in mind, however, that the Bureau of Soils has not considered the feasibility from an engineering standpoint of draining this region or of protecting it from overflow, that being a matter lying outside the province of this bureau.

## ALKALI.

The question of the accumulation of injurious amounts of alkali salts in the tract under discussion has not at any time assumed a critical aspect, although the matter has been the subject of some apprehension. With regard to this subject the original report states as follows:

> Scattering areas of alkali soil occur in the higher portions of this type near the boundary of the Sacramento silt loam. The content of alkali is seldom large enough to be dangerous.

In the revision of the work covering this area of soil it was found that the body of Sacramento clay as originally mapped was not affected with excessive amounts of alkali and that the adjoining soil types in that part of the basin under discussion appeared from the few check field determinations made to contain about the same amounts of salts as was found when the soils were originally mapped.

In the earlier report, however, note is made of the occasional occurrence of soil areas along the western side of the area of Sacramento clay and lying between Cranmore and Knights Landing in which the average amount of total alkali salts present in the dry soil to the depth of 6 feet is less than 200 parts per 100,000 (an amount ordinarily considered harmless), but in which the bulk of the salts have become concentrated in the immediate surface. Under such conditions the surface concentration may prove sufficient to prevent development of seedling or shallow-rooted plants, and the earlier report expresses some apprehension of difficulty in bringing such areas under successful cultivation.

A rather extensive area is indicated upon the alkali map accompanying the earlier report, lying near the southern lower-lying portion of the Sutter Basin, in which the average salt content is somewhat greater than that previously stated and sufficient to cause injury to the more sensitive crops, but in which the salts are more uniformly distributed throughout the soil profile.

Assuming that means be provided of effectively removing surface waters and of permanently maintaining the level of the water table at a desirable depth, it is believed the removal of a portion of the salts in the drainage waters and a wider distribution and consequent dilution of the remaining salts throughout the soil column would soon take place. Under such conditions as stated the alkali problem would not constitute a serious consideration.

## OCCURRENCE OF SEEPAGE WATERS.

In the report of the earlier survey it is suggested, as previously noted, that some difficulty might be anticipated in maintaining a favorable position of the water table, owing to seepage through the levees.

In this report it is assumed that that matter will be taken care of by the engineers who provide for draining the area. In the 15 or 20 reclaimed tracts along the Sacramento River covered by similar soils, and visited during the progress of the later investigations, this anticipated difficulty had not been realized to any degree prohibitive of utilization of the land for agricultural purposes. In one case it was observed that the great weight of the material forming the levee had compressed considerably the soil on which it was lying and had apparently rendered it more compact and less pervious. It was further noted that water over the Sacramento clay does not appear to move laterally through the soil with ease, except where there is a stratum of material of light texture in the subsoil.

## CROP ADAPTATIONS.

The surface soil material of that part of the area of the Sacramento clay differentiated in the revised survey as a silty phase consists of recent alluvial deposits having a high silt content deposited by streams over the basal material of the Sacramento clay. Where extending to the depth of 8 inches or more it is recognized as of distinctly more friable structure, responding more readily to tillage, is adapted to a wider range of crops than the heavier bodies of the typically developed Sacramento clay occupying the central portions of the basin, and would in further soil surveys in the region in which it might be encountered probably warrant recognition as a distinct soil type. The nearer the clay is to the surface the more difficult is tillage and the narrower is the range of crops to which the land is suited. It is observed, however, that where protected from overflow, drained, and aerated through tillage, the heavier clay type quite readily assumes a granulated structure and becomes amenable to cultivation. This process has not, of course, immediately taken place, and drainage with a favorable condition of soil structure is more slowly established than is the case with that portion of the tract in which the superficial recent alluvial silty covering exists.

In the opinion formed during revision of the survey the area covered by the silty phase may be successfully utilized for the production of alfalfa, small grains, corn, broom corn, sorghum, and other forage crops, and root crops, including sugar beets. Beans could probably be grown upon the lighter and deeper bodies, and it would seem that the soil might be well adapted to the culture of asparagus and of cabbage, cauliflower, and other of the later and heavier types of truck crops. Of the fruits, pears could probably be grown and prunes might succeed where the deeper subsoil consists of alluvial sediments of lighter texture than the Sacramento clay. Under similar conditions it is quite possible that hops also might prove a profitable crop. However, available data bearing upon this subject would indicate the surface soils of the soil types successfully devoted to this industry in the principal foreign and domestic hop-producing districts to contain ordinarily from 2 to 25 per cent of the mechanical separate, coarse and medium sand, from 8 to 20 per cent of very fine sand, from 25 to 50 per cent of silt, and from 10 to 25 per cent of clay. The total silt and clay content combined rarely exceeds 70 to 80 per cent. These constitute soils of essentially lighter texture than would be indicated in either the typical Sacramento clay or the silty phase of this type recognized in the revised survey.

The areas of Sacramento clay of the heavier texture and more compact structure occupying the central portion of the basin would de-

mand a heavier farming equipment and call for somewhat more thorough tillage and careful management. Under favorable conditions of protection from overflow, drainage, and cultural practice, however, the character of the soil is such as to show it to be adapted to the culture of small grains, broom corn, sorghum, and other similar forage crops, and root crops. Profitable production of the sugar beet would necessitate deep plowing and thorough tillage but is successfully carried on in other sections of California and elsewhere upon soils of equally heavy texture. Vegetables, such as cabbage, cauliflower, etc., could probably be grown for home use and possibly upon a commercial scale, but conditions would appear to be more favorable for such crops upon the adjacent soils of lighter texture. Under the circumstances stated the soil should be capable of sustaining a dairying and stock-raising industry, and where the water table can be maintained at a favorable depth below the surface alfalfa should be successfully grown. The culture of rice, a recently introduced crop in the Sacramento Valley, might prove well worthy of trial.

The culture of alfalfa (where favored by sufficient depth of the water table), sugar beets, grains, forage crops, dairy and stock farming would seem to present the most stable and promising means of utilizing the lands of the tract under discussion when successfully reclaimed and drained.

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