TWENTY-SECOND ANNUAL REPORT

OF THE

UNITED STATES GEOLOGICAL SURVEY

TO THE

SECRETARY OF THE INTERIOR

1900-01

CHARLES D. WALCOTT
DIRECTOR

IN FOUR PARTS

PART I.—DIRECTOR'S REPORT AND A PAPER ON ASPHALT AND BITUMINOUS ROCK DEPOSITS

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DEPARTMENT OF THE INTERIOR, UNITED STATES GEOLOGICAL SURVEY

REPORT

OF THE

DIRECTOR

FOR THE

FISCAL YEAR ENDING JUNE 30, 1901

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., August 31, 1901.

SIR: I have the honor to transmit herewith a report of the operations of the United States Geological Survey for the year ending June 30, 1901.

In this connection permit me to thank you for the wise counsel and earnest support with which you have ever been ready to aid me in the administrative work of the Survey.

I am, with respect,

Your obedient servant,

Chas. D. Walcott,

Director.

Hon. E. A. HITCHCOCK,
Secretary of the Interior.

TWENTY-SECOND ANNUAL REPORT OF THE UNITED STATES GEOLOGICAL SURVEY.

CHARLES D. WALCOTT, DIRECTOR.

INTRODUCTION.

The work of the Geological Survey during the fiscal year 1900–01 was mainly a continuation of that of previous years, described in former reports. The organization was changed somewhat (see p. 48), but in a general way similar results were reached, which added materially to the sum of geologic and geographic knowledge. The detailed record of accomplishment, both in field and in office, will be found on later pages, under the heading "Work of the year" (p. 53). In this introduction some subjects of special interest will receive consideration.

COOPERATIVE SURVEYS.

Cooperation in scientific work may consist in a mutual understanding or exchange of information or in the expenditure by both parties of certain sums of money for the advancement of investigation or work in which both are interested. Understandings to promote the common purpose of advancing knowledge and aiding development have existed between State geologists and the Federal Survey since the latter was organized. The results of the United States Survey's work have always been at the disposal of State officials at proper times and under reasonable conditions relating to publication, and these courtesies have generally been returned in kind.

Some more definite agreements were entered into early in the history of the Federal Survey. Thus in 1884 it was agreed between the Director, Major Powell, and the board of commissioners of the State of Massachusetts that the topographic work in the State should be divided; that the State should pay one-half the expense of field work and the Federal Survey one-half, the latter to engrave the maps and give transfers of the plates to the State commissioners.

Under terms varied to suit the conditions of each special case, agreements involving cooperation of some sort have been made between the Director and State officials of Maine, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Maryland, West Virginia, North Carolina, Georgia, Alabama, Ohio, Wisconsin, North Dakota, Colorado, Nevada, Idaho, and Arizona. The object on the part of the State was to direct and promote topographic mapping, to procure scientific information which it was not equipped to obtain, or to avail itself in some other way of the special facilities of the Federal Survey; while the object of the Director was to maintain cordial relations among organizations having an essentially common purpose, to encourage the development of scientific work of value to the people of the country, and to supplement the appropriations made by Congress by additional sums from the States, in order that the work might be expedited and be given greater detail in areas where the public interest was greatest.

The States benefit by cooperation in geology and allied scientific activities by the resulting reduction in expense of administration and the possibility of a specialization in detail otherwise unobtainable. In order that the exploitation of the economic resources of each State may be kept as prominently as possible before the eyes of its citizens and the industrial world, a number of States have provided their own bureaus for such purposes. On the other hand, since such resources are not limited by State boundaries, and since the broader geologic facts on which the development of the economic problems is necessarily based must frequently be looked for and studied through a number of States, each has an interest in knowing what its neighbors possess, and such knowledge will enable the different States to avoid duplication of research into fundamental facts. Since each State possesses a considerable range of natural resources, it is usually impossible for the State geologists to discuss all of these in the most full and satisfactory manner. The best work results from the investigations of specialists, and the individual States can rarely afford to obtain the services of a considerable number of experienced and high-priced experts. There has thus naturally followed a method of cooperation in geologic work whereby the States have devoted their energies to the exploitation of such economic resources as might prove of greatest immediate benefit to their citizens, while the United States Geological Survey has been employed in general areal mapping and in studying the more specialized problems whose solution has had to be sought through several States.

Upon the completion of the field investigations or surveys, for which alone cooperation is accepted, the resulting reports and maps are published by the Government, and thus become available to the State. If cooperation be, for example, for a topographic map only, the State benefits by the fact that this will surely be followed more promptly than otherwise would be the case by the geologic map and investigations, and by the study of mineral water and timber resources, for which the topographic maps are primarily prepared as bases.

The Federal Bureau benefits by the great increase in funds available for the extension of its legitimate operations. This Bureau is charged with the duty of making a topographic and geologic map of the entire area of the United States, as well as of studying its water resources and reporting on its other economic products. The expense of this work to the Federal Treasury is reduced by the amount appropriated by the various States for cooperative surveys. All agreements for cooperation being on the basis of equal expenditure, they necessarily reduce by one-half the cost to the Federal Government of conducting its operations. An additional benefit of cooperation is the hastening of the completion of the topographic map, which thus renders it available at an earlier date as a base for the further studies of economic resources—geology, hydrography, and the classification of lands.

From the experience gained, certain conditions essential to the success of cooperation have been established. All work which is in part paid for by the Federal Survey and which may be published by it or on its authority must be controlled by the Director. He selects assistants to perform such work, or approves their selection. In its execution the work is subject to the supervision and approval of the appropriate chief of division of the Federal Survey. Payments for continuous service on account of State cooperation can, under civil-service rules, be made to a State official only in case he also receives a Federal appointment. Each year plans and estimates for the season and a report of operations and results are requested, as is customary in the United States Survey. All agreements for cooperation are drawn in such manner as not to conflict with the organic law of the Survey in regard to collections, furnishing information, or giving expert testimony.

One important point to be considered in all such work is that the general plans and methods of the Federal Survey can not be set aside on account of State cooperation. At the present time the funds available for cooperation are so limited that its further extension is dependent upon increase of appropriations by Congress. It is against the policy of the Survey that work on important areas or subjects should be stopped in order that cooperation with individual States may be extended. The Director is willing to enter into a cooperative agreement only when the interests of the country as a whole will be benefited. In the execution of the work certain features must necessarily be taken up first, and if this order is in line with what the State desires cooperation may be had to the greatest advantage both to the State and to the Federal Government. The general policy and work of the Survey can be changed only by direction of Congress.

History of Cooperation.

The idea of cooperation in public surveys between the Federal and State governments originated in connection with a plan to make a topographic map of the State of Massachusetts, and it is believed was first suggested by Mr. Henry F. Walling, topographer of the United States Geological Survey, and later elaborated in a paper read before the American Society of Civil Engineers at the Buffalo meeting in 1884. The suggestion was followed up by Prof. Nathaniel S. Shaler, of Harvard, at whose instance an appropriate bill was introduced in the Massachusetts legislature, which was passed in the same year. The first topographic survey commissioners appointed by the governor of Massachusetts were Gen. Francis A. Walker, Prof. N. S. Shaler, and Mr. H. L. Whiting. In their report to Governor Oliver Ames, dated January, 1888, the commissioners state, among other things:

In conclusion, your commissioners would repeat the statement that the topographical survey of the State has been completed within about three years, the time originally estimated, for $40,000, the amount originally appropriated; and by the successful cooperation with the organized Federal department of the Geological Survey, the cost to the Commonwealth has been but $4.80 per square mile, a result unparalleled in the history of such work.

It is pertinent to state in this place that there has been some misunderstanding in recent years, as shown in public print and otherwise, as to the relation between the town boundary survey of Massachusetts and the topographic survey. The former is a successor of the latter. As shown above, the cooperative survey was completed within the time estimated by this Bureau, though since its completion the State of Massachusetts has continued to make appropriations, large in the aggregate, for the purpose of determining and marking the town boundaries, a work which has no relation to the topographic survey.

The total cost of mapping the State of Massachusetts was $107,845. This is exclusive, however, of much of the primary triangulation, which was executed by the United States Coast and Geodetic Survey. The total average cost of this work was at the rate of $12.90 per square mile.

At the time of the inauguration of the cooperative survey in Massachusetts the State of New Jersey was engaged in making a topographic map of its area, under the direction of Mr. George H. Cook, State geologist. Commenced independently of the work of this Bureau, the State survey of New Jersey was conducted on similar lines and with all desirable accuracy. From small and desultory beginnings in 1872, it attained systematic form and method under the supervision of Assistant Geologist John C. Smock, and under the immediate direction of Mr. C. C. Vermeule, topographer in charge, in the year 1882. On July 15, 1884, following the example of Massachusetts, the State of New Jersey asked the National Survey to cooperate in completing the map of the State. This Bureau took up the work, but on lines different from those on which cooperation has been conducted elsewhere. About half of the area of the State having been accurately mapped, the results were turned over to the Federal Bureau, which took charge of the organization and of the personnel and carried the work to completion in 1887, under the direction of Mr. Vermeule, who followed the methods employed prior to the arranging of cooperation. The State geologist reports that the total expense of making the topographic survey was $54,744 58. Of this sum the United States Geological Survey expended $35,073.98. The total cost of mapping the State was at the rate of $6.93 per square mile, exclusive, however, of three-fourths of the primary triangulation, which had been previously executed by the United States Coast and Geodetic Survey.

The cooperative survey of Connecticut was commenced in July, 1889, under Messrs. William H. Brewer, John Bacon, and James H. Chapin, commissioners. It was completed in 1891, the total expense having been $24,599.21 and the average rate per square mile $9.79. Among other things, in their final report to the governor, the commissioners state, after commenting on the completion of the work within the time and sum estimated:

> We believe that the maps are in more detail and are more nearly correct than any other maps heretofore prepared in this country at so small an expense.

The topographic survey of Rhode Island was provided for by act of general assembly passed March 22, 1888, and immediately thereafter Governor John W. Davis appointed as commissioners Messrs. Winslow Upton, John W. Ellis, and David W. Hoyt. Field work was commenced in June, 1888, and the survey of the entire State was completed in the fall of the same year. The total cost of this work was $9,732.51, or at the rate of about $8.97 per square mile.

Cooperation with the State of New York was commenced in the year 1892 by an allotment of $3,000 from the general survey fund of the State engineer and surveyor. This work has been continued without interruption since that date by the following appropriations:

1893-94	$24,000
1895	4,000
1896	15,000
1897	15,000
1898	25,000
1899	19,500
1900	19,500
1901	25,000

The work has been conducted by this Bureau in cooperation with State Engineers Martin Schenck, Campbell W. Adams, and the present incumbent, Edward A. Bond. The average cost of this work to date has been about $11.95 per square mile, including triangulation.

Cooperation with the State of Maryland was commenced in the year 1896, through the allotment by State Geologist William Bullock Clark of the sum of $1,000. The same amount was allotted by him in 1897. In each of the years 1898, 1899, and 1900 the State legislature appropriated $5,000 toward this work.

Cooperation with the State of Maine was commenced in the year 1899 under Commissioners Leslie A. Lee, William Engel, and S. C. Hichborn. The appropriation for the two years 1899–1900 was $5,000, and the same amount has been appropriated for the two years 1901–1902.

Cooperation with the State of Pennsylvania was commenced in the year 1899 by the appropriation for the two years 1899–1900 of the sum of $40,000, which has been expended under the supervision of the State commissioners, George W. McNees, Simon Harrold, and F. D. Barker.

Cooperation with the State of Alabama was commenced on March 11, 1899, by allotment from the funds of the State geological survey, by Eugene A. Smith, State geologist, of the amount of $1,000. The same amount has been annually allotted since that date for this work.

Cooperation with the State of Ohio was commenced during the current year by the appropriation of the sum of $25,000 for the year 1901, which is being expended under the supervision of Governor George K. Nash.

Cooperation with the State of North Carolina was commenced during the current year by the allotment of $20,000 for the two years 1901–1902 by Governor Charles B. Aycock from the funds of the State agricultural commission. The State is represented in this cooperation by State Geologist J. A. Holmes.

Cooperation with the State of West Virginia was commenced during the current year as a result of the appropriation by the last legislature of the sum of $30,000 for the two years 1901–1902. The same is being expended under the general direction of State Geologist I. C. White.

Methods of Cooperation.

In the establishment and conduct of cooperative surveys certain methods which have been developed through an experience of eighteen years are followed.

The Director is requested by citizens of a State which may be interested in procuring topographic, geologic, or hydrographic surveys to inform them as to his ability to accept such offers of cooperation as the State may be prepared to make, it being understood that efforts to secure cooperation must originate with the residents of the State. This Survey furnishes such information concerning the details of previous cooperative arrangements as may be sought, and in other ways assists the State officials and legislators to attain the object desired by them. This usually consists of the introduction of a special bill or an item in the general appropriation bill providing for a cooperative survey to be conducted under the supervision of a State official or commission, who (1) shall have control of the expenditure of the money appropriated, (2) shall make agreements with this Bureau as to the methods of conducting the work, and (3) shall recommend the order in point of priority in which various portions of the State shall be surveyed. It is invariably stipulated that the field operations shall be under the supervision of the Director of the Geological Survey. This Survey furnishes expert assistants, who take charge of the work and who discuss the results for publication or draft the manuscript maps. All details of the work are performed by them under rules and by methods which experience has shown to be the most economical and judicious, and which tend at all times to maintain a uniformity of treatment for the whole of the United States. This Survey accepts the recommendations of the State officials for the employment of such temporary assistants as may prove qualified for the work, thus insuring the employment of residents of the State, so far as practicable. The law usually specifies that a sum equal to that appropriated by the State shall be expended in the same time by the United States Geological Survey. Neither time nor money is wasted in preliminaries. There is no organization to create. Immediately after the appropriation is made and the contract is signed, work is commenced along the desired lines, without the delays consequent on procuring men and determining upon methods and machinery.

The following sample legislative act provides a lump appropriation for the complete topographic map of a State. In this case a commission was created to conduct the work. The general assembly of Connecticut at its general session of 1889 passed the following resolutions:

Resolved by this assembly, That the governor be, and he is hereby, authorized to appoint a commission, to consist of three citizens of this State, qualified by education and experience in topographical science, to confer with the Director or representative of the United States Geological Survey and to accept its cooperation with this State in the preparation and completion of a contour topographical survey and map of this State, which is hereby authorized to be made, and it is hereby provided that said map shall accurately show all town and county boundary lines in this State as existing at the time of its completion. Said commission shall serve without pay, but all its necessary expenses shall be approved by the comptroller and paid out of the State treasury. Said commission shall have power to arrange with the Director or representative of the United States Geological Survey concerning the survey and map herein provided for, its scale, method of execution, form, and all details of the work in behalf of this State, and may accept or reject the work presented by the United States Geological

Survey. Said commission may expend, in the prosecution of this work, a sum equal to that which shall be expended therein by the United States Geological Survey, but the total cost to this State of said survey shall not exceed the sum of twenty-five thousand dollars.

An example of a law to secure cooperation with this Bureau in a State where there was an existing official who could be charged with the work, and where the appropriations could be provided only for each legislative session, is the following:

LAWS OF NEW YORK.

CHAPTER 96. An act authorizing the State engineer and surveyor to continue to cooperate with the Director of the United States Geological Survey in making a topographic survey and map of the State of New York, and making an appropriation therefor.

Became a law March 17, 1899, with the approval of the governor. Passed, three-fifths being present.

The people of the State of New York, represented in Senate and assembly, do enact as follows:

SECTION 1. In order to continue the execution and speedy completion of a topographic survey and map of this State the State engineer and surveyor is hereby authorized to confer with the Director of the United States Geological Survey and to accept the cooperation of the United States with this State in the execution of a topographic survey and map of this State, which is hereby authorized to be made; and that said State engineer and surveyor shall have the power to arrange with said Director or other authorized representative of the United States Geological Survey concerning the details of such work, the method of its execution and the order in point of time in which these surveys and maps of different parts of the State shall be completed: *Provided*, That the said Director of the United States Geological Survey shall agree to expend on the part of the United States upon said work a sum equal to that hereby appropriated for this purpose. In arranging details heretofore referred to, the State engineer and surveyor shall, in addition to such other provisions as he may deem wise, require that the maps resulting from this survey shall be similar in general design to the West Point sheet edition of October, eighteen hundred and ninety-two, made by the United States Geological Survey, and shall show the outlines of all counties, towns, and extensive wooded areas, as existing on the ground at the time of the execution of the survey; the location of all roads, streams, canals, lakes, and rivers, and shall contain contour lines showing the elevation and depression for every twenty feet in vertical interval of the surface of the country; that the resulting map shall wholly recognize the cooperation of the State of New York, and that as each manuscript sheet of the map is completed the State engineer and surveyor shall be furnished by the United States Geological Survey with photographic copies of the same, and as the engraving on each sheet is completed the State engineer and surveyor shall be furnished by said Director with transfers from the copperplates of the same.

SEC. 2. The sum of twenty thousand dollars, or so much thereof as may be necessary, is hereby appropriated for the purposes specified in this act out of any moneys in the treasury not otherwise appropriated, to be paid by the treasurer upon the warrant of the comptroller to the order of the State engineer and surveyor.

SEC. 3. This act shall take effect immediately.

STATE OF NEW YORK,
Office of the Secretary of State, ss:

I have compared the preceding with the original law on file in this office, and do hereby certify that the same is a correct transcript therefrom and of the whole of said original law.

JOHN T. MCDONOUGH,
Secretary of State.

In some cases, as that of the State of Ohio, an item in the general appropriation bill, similar to the following, was considered sufficient:

For cooperation with the United States Geological Survey in the preparation and completion of a contour topographic survey and map of this State, to be paid upon vouchers approved by the governor, the governor is hereby authorized to arrange with the director or representative of the United States Geological Survey concerning this survey and map, its scale, method of execution, form, and all details of the work in behalf of this State, and may accept or reject the work executed by the United States Geological Survey, the sum of twenty-five thousand dollars.

It is hereby provided that said map shall accurately show the outlines of all townships, counties, and extensive wooded areas in this State as existing on the ground at the time of the execution of these surveys; the location of all roads, railroads, streams, canals, lakes, and rivers, and shall show by contour lines the elevation and depression of the surface of the country: *Provided further*, That the State shall pay not to exceed one-half of the cost of survey as completed.

In the case of Connecticut, on the passage of such an act the governor of the State appointed a commission, on June 19, 1889. An agreement was signed and field work was immediately commenced. The report of the commission to the governor, dated January, 1893, four years later, contains the following statements:

The maps are now practically finished; the copperplates are engraved and the atlas sheets are all printed and in the hands of the commissioners. * * * The area of the State is 4,674 square miles * * * and the total expenditure on behalf of the State was $24,599.21. * * * It will be perceived that the cost of the survey to the State is at an average of a little less than $5 per square mile.

The agreement signed between the Director of this Bureau and the governor of North Carolina furnishes an example of such contracts, all of which are essentially alike:

AGREEMENT BETWEEN THE GOVERNOR OF NORTH CAROLINA AND THE DIRECTOR OF THE UNITED STATES GEOLOGICAL SURVEY FOR THE EXECUTION OF THE COOPERATIVE TOPOGRAPHIC SURVEY OF THE STATE OF NORTH CAROLINA.

(1) The preparation of the map shall be under the supervision of the Director of the United States Geological Survey, who shall determine the methods of survey and map construction.

(2) The order in which, in point of priority, different parts of the State shall be surveyed shall be agreed upon in detail by the governor of North Carolina, or his representative, and the Director of the United States Geological Survey.

(3) The work shall be based upon the triangulation of the United States Coast and Geodetic Survey, and wherever such primary control is deficient it shall be supplemented by the cooperative topographic survey, which shall permanently monument all important positions.

(4) The survey shall be executed in a manner sufficiently elaborate to prepare a map upon a scale of 1:125,000, exhibiting the hydrography, hypsography, and public culture, and all township and county boundary lines, as marked upon the ground at the time of its completion, in form similar to the sheets already completed in this State; said maps to be sufficiently detailed to serve as base maps on which may be represented the character of the soils and forests of the areas surveyed. The preliminary field maps shall be on such scale as the Director of the United States Geological Survey may select to secure accuracy in the construction of the final map.

(5) The hypsography shall be shown by contour lines with vertical intervals of 10 to 100 feet, as may be hereafter mutually agreed upon.

(6) The heights of important points shall be determined and furnished to the governor of the State.

(7) The outlines of wooded areas shall be represented upon proofs of the engraved map, to be furnished the governor of the State.

(8) For convenience the United States Geological Survey shall, during the progress of field work, pay the salaries of the permanent employees engaged thereon, while the traveling, subsistence, and field

expenses shall be paid for the same time by the State. For office work on the map the salaries shall be divided between the two agreeing parties in such a way as to equalize all expenses, provided that the total cost to the State of North Carolina of the field and office work from date until June 30, 1903, shall not be more than twenty thousand dollars ($20,000), and provided that the United States Geological Survey shall expend an equal amount upon the same work during the same period of time, subject to appropriations to be made by the Congress of the United States.

(9) During the progress of the work free access to the field sheets and records of the topographers and draftsmen shall be afforded the governor of North Carolina, or his representative, for examination and criticism; and should the said governor of North Carolina deem that the work is not being executed in a satisfactory manner, then he may, on formal notice, terminate this agreement.

(10) The resulting map shall fully recognize the cooperation of the State of North Carolina.

(11) When the work is completed, the governor of the State of North Carolina shall be furnished by the United States Geological Survey with photographic copies of the manuscript sheets; and when the engraving is completed, and at all times thereafter when desired, he shall be furnished by the said Survey with transfers from the copper plates of the map for use in printing editions of said maps.

CHARLES B. AYCOCK,
Governor State of North Carolina.

RALEIGH, N. C., *1901.*

CHARLES D. WALCOTT,
Director United States Geological Survey.

WASHINGTON, D. C., *March 15, 1901.*

In the case of the State of Pennsylvania the appropriation act provided for cooperation in making geologic as well as topographic surveys and determining "the location of the coal, oil, natural gas, clay-bearing and other geological formations." Of a total annual appropriation of $20,000 made by Pennsylvania for the years 1899 and 1900, $18,000 was devoted to topographic mapping and $2,000 to geologic mapping and research.

The acts of appropriation made by the legislature of the State of New York providing for cooperation in hydrographic surveying are typical of such arrangements. The act of the legislature was as follows:

The people of the State of New York, represented in senate and assembly, do enact as follows:

The treasurer shall pay on the warrant of the comptroller, for the State engineer and surveyor, one thousand dollars, to be used with the

United States Geological Survey in hydrographic work connected with the measurements of the volume of streams and flow of water in the State of New York.—*Act of legislature, April 13, 1900, par. 11, chap. 420, Laws of 1900.*

Cooperation in Topographic Surveys.

The appropriations made by the States for cooperative surveys are accepted only for actual field work, in which are included the services of temporary employees, who are usually residents of the State, and the living and traveling expenses of the field force. Thus the amount appropriated by the State is returned to the people thereof. The appropriation of the Federal Government is devoted chiefly to paying the salaries of the permanent employees, a small portion of it being expended on general administration and a considerable portion on field and office work. The field work of the cooperative topographic surveys is invariably in charge of topographers or assistant topographers of the United States Geological Survey, who are appointed, on the recommendation of the United States Civil Service Commission, by the honorable Secretary of the Interior. All assistant surveyors, as levelmen, transitmen, etc., and such helpers as rodmen, teamsters, and cooks, are employed, under regulations of the Department of the Interior, in the locality in which the work is being done and under the terms of a signed application and agreement, which they must file when seeking such employment.

TOPOGRAPHIC MAPS.

The topographic map is the base upon which the field investigations of the geologists and hydrographers are recorded, and which makes possible a broader and more general study of the results than is otherwise practicable. It was at once realized by State officials to whom such investigation had been assigned that an accurate and comprehensive performance of their duties was impossible without an adequate topographic base map. The expense of making such maps, however, was found to exceed in most instances the resources procurable from State aid, and the lack of skilled men required in making such surveys was a barrier not easily surmounted. Competent topographers are rare, and there is little inducement for young engineers of ability to make this their profession outside of the work of the General Government while there is so little opportunity for steady employment elsewhere. By cooperating with the Federal Survey it was apparent that the opportunities for systematic mapping would be greatly increased in the States availing themselves of the personnel and administrative knowledge of the Survey.

Accordingly, the first important step in the development of the existing system of cooperation was in connection with the extension of topographic mapping. The benefits to the State from cooperation are numerous. It gains a complete topographic map of its area, which is of importance to the development of its numerous economic resources and greatly facilitates the study and perfection of all engineering plans and works. Among other uses of the topographic maps are the following:

1. *Educational.*—(*a*) By promoting an exact knowledge of the country; (*b*) by serving teachers and pupils in geographic studies.

2. *Practical.*—As preliminary maps for planning engineering projects. Highways, electric roads, railroads, aqueducts, and sewerage plants may be laid out on them, and the cost of preliminary surveys may be saved. Areas of catchment for water supply, sites for reservoirs, and routes of canals may be ascertained from these maps.

3. *Political.*—In all questions relating to political or legislative matters. For these purposes they afford accurate information as to the relations of boundaries and towns to natural features.

4. *Administrative and military.*—In all questions relating to Federal or State administration of public works, as canals, reservations, parks, highways, and as military base maps on which to plan works of offense, defense, camps, marches, etc.

5. *Statistical.*—As base maps for the graphic representation of all facts relating to population, industries, products, or other statistical information.

6. *Economic.*—As a means for showing the location, extent, and accessibility of lands, waters, forests, and valuable minerals. In this respect these maps are indispensable to State and Federal bureaus, and to owners, investors, and corporations.

In addition, as an incident in the making of a topographic map, monuments are established throughout the State, the positions of which are accurately determined by geodetic methods and which serve as datum points for all other Government, private, and cadastral surveys. There are also established throughout the State bench marks or permanent monuments which furnish datum elevations for the future determinations of height in connection with all public or private engineering works. Meridian marks are established at each county seat, which aid local and county surveyors in determining the declination of their compasses and which thus greatly facilitate the search for old property lines.

The Geological Survey is engaged in mapping the United States on two scales, dependent on the degree of detail in the topography, the amount of habitation, and the subsequent probable use of the maps for geologic and engineering purposes. The scale generally employed throughout the country is 1:125,000, or about 2 miles to 1 inch. The slopes and shapes of the surface forms and all differences of elevation are indicated by lines of equal elevation, called contour lines, with intervals varying between 25 and 100 feet, according to the ruggedness of the surface. The other scale, which is double the above and gives practically all the detail desirable in the general map of the region, is that usually adopted where cooperation is in force. This is the scale of 1: 62,500, or about 1 mile to 1 inch, the contour interval varying between 10 and 20 feet, according to the slopes. These topographic maps are based upon geodetic determination of positions, either by means of an accurate system of primary triangulation or by primary traverse based upon astronomic locations. The fundamental positions so determined are marked by monuments of stone or by metal posts bearing suitable bronze tablets. Spirit levels of a high degree of accuracy are run with such frequency as to permit of the establishment of permanent metal bench marks in every 3 to 6 linear miles, while numerous elevations of less accuracy are obtained by levels run in all directions.

The maps that result from these cooperative surveys show, in different colors, both in the manuscript and in the published edition, the following principal facts:

1. Public culture, printed in black, which includes the exact plan of every road, lane, path, railroad, street, dam, public boundaries, names, etc.

2. The hydrography, or water, printed in blue, including all lakes, rivers, streams, swamps, marshes, reservoirs, springs, etc.

3. The relief, or surface forms, printed in brown, including the shapes of the hills, valleys, and ravines, their elevations and depressions, and the slopes of every rise or fall in the surface of the land.

The topographic maps produced by cooperative surveys are engraved on copper and printed from stone. The cooperating States have the benefit of this publication without further expense, and the residents of the State, as well as its officials, may purchase the maps at rates of 5 cents per sheet or $2 per hundred.

The following table shows the States in which cooperative surveys have been completed or are in progress, the scale of all work completed under cooperation being in every instance 1 : 62,500, and the contour interval 10 to 20 feet. As indicated by the column "Area mapped," in some cases large portions were mapped prior to the inception of cooperation. A considerable portion of the amounts in the column "Total cost" was expended by the Federal Bureau prior to the making of cooperative arrangements.

Cooperative topographic surveys in various States.

State.	Area.	Area mapped.	Total cost to June, 1901.	Appropriated by State.
	Square miles.	*Square miles.*		
Massachusetts	8,315	All.	$107,845	$40,000
Connecticut	4,990	All.	48,555	25,000
Rhode Island	1,250	All.	9,732	5,000
New Jersey	7,815	All.	54,744	19,670
Pennsylvania	45,215	10,785	130,260	38,000
New York	49,170	25,502	303,936	151,000
Maine	33,040	4,767	38,985	10,000
Maryland	12,210	10,307	57,250	17,000
Ohio	42,050	1,864	12,000	25,000
North Carolina	52,250	12,252	....	20,000
West Virginia	24,780	17,227	....	30,000

Though not clearly shown in the above table, because of the facts already stated, it is estimated that the cost of mapping any considerable area, as a State, on the scale of 1:62,500 and with a contour interval of 20 feet will vary between $10 and $15 per square mile, according to the ruggedness of the country. The average cost of mapping on a scale of 2 miles to 1 inch and with a contour interval of 50 to 100 feet varies between $5 and $8 per square mile, according to the character of the country. In every case where cooperation is in force the cost to the State and to the Federal Government each is only half of the above amounts.

Cooperation in Hydrographic Investigations.

In the preceding paragraphs principal attention has been given to cooperation in the preparation of topographic maps, since this has been longest continued and larger sums have been expended for this purpose. In the hydrographic investigations, however, various States have asked for assistance, and correspondence has been had with others, indicating that in the future there will doubtless be considerable activity along this line. This is particularly the case in the arid portions of the United States, where the Government is the great land owner, and to a less extent in the mountainous sections of the East, where water power is being rapidly developed.

In the investigation of the water resources of the United States excellent results have been obtained through cooperation, especially in those States where water is practically the only mineral of economic value. In the arid regions water is recognized as the foundation of land values, since there is more land than can be judiciously used with the limited supply of water. In certain humid States water has great value, through the development of power and for municipal uses. A number of States have awakened to the fact that their continued development and increase in population is to a large extent dependent upon the more complete utilization of their water resources for power and the protection of their streams from pollution. Cooperation, in making known the facts, is therefore welcome, as by this means skilled and impartial examinations are made possible on an economic basis.

The methods by which cooperation is being had in the investigation of the water resources are similar to those followed in topographic mapping. The funds furnished by the State legislature or by State officials are supplemented by an equal amount allotted from the appropriation for gauging streams and determining the water supply of the country. The field work is carried on under the general system which has resulted from an experience extending over many years. The engineers or hydrographers are especially trained for this work. At the same time the details of the field work are intrusted as far as practicable to local men, economy of time and effort being assured by following established methods and precedents.

In cooperating with the various States separate items of appropriation and a distinct agreement are usually made for the hydrographic investigations, in order to simplify the correspondence and bookkeeping, since in the Geological Survey the Divisions of Geology, Topography, and Hydrography are separate in their administration and bookkeeping. The following paragraphs give briefly the present condition of the cooperation in the more important localities:

In Maine the sum of $500 has been secured by private subscription and placed at the disposal of the governor's council for cooperation in measuring the rivers of chief importance in the development of water power.

In New York the appropriation by the legislature is quoted on pages 25–26.

In the State of Pennsylvania the following act was introduced in the legislature:

AN ACT MAKING AN APPROPRIATION TO THE HYDROGRAPHIC DIVISION OF THE UNITED STATES GEOLOGICAL SURVEY.

SECTION 1. *Be it enacted by the senate and house of representatives of the Commonwealth of Pennsylvania in general assembly met, and it is hereby enacted by the authority of the same*, That the sum of two thousand dollars, or so much thereof as may be necessary, be, and the same is hereby, specifically appropriated to the Hydrographic Division of the United States Geological Survey for the two fiscal years beginning the first day of June, anno Domini one thousand nine hundred and one, for the prosecution of its work in this Commonwealth in gathering data and determining the volume of water carried and the commercial value thereof to this Commonwealth of the Delaware, Susquehanna, and other important streams.

Said appropriation to be paid on the warrant of the auditor-general, on a settlement made by him and the State treasurer, upon vouchers signed by the person in charge of the hydrographic survey in the Commonwealth of Pennsylvania; but it is hereby provided that these expenditures shall not be in excess of the amounts expended upon the same work by the Hydrographic Division of the United States Geological Survey from its own funds within the limits of this Commonwealth, and the results obtained from this work shall be made available by publication to the citizens of this Commonwealth.

In North Carolina cooperation has been had with the State geologist along lines similar to those followed in other cases.

In North Dakota the act authorizes the board of trustees of the agricultural college to cooperate in executing certain surveys and to arrange the details of the work on a basis of equal expenditure, and makes the professor of geology of the college the State director of such surveys.

In Colorado cooperation is had with the State engineer.

In Nevada the legislature created a State board of irrigation, consisting of the governor, surveyor-general, and the attorney-general, and authorized this board to expend $2,000 in stream measurements and investigations. In accordance with this act the following agreement was made:

AGREEMENT BETWEEN THE STATE BOARD OF IRRIGATION OF THE STATE OF NEVADA AND THE HYDROGRAPHIC DIVISION OF THE UNITED STATES GEOLOGICAL SURVEY FOR COOPERATION IN THE INVESTIGATION OF WATER SUPPLIES AND IRRIGATION POSSIBILITIES IN NEVADA.

For the year 1901 the United States Geological Survey hereby agrees to conduct investigations upon the Truckee, Carson, Walker, and Humboldt rivers in accordance with the attached plan; and for this investigation will expend for field work during the year 1901 not less than one thousand dollars ($1,000) from the appropriation made by the Congress of the United States for its use.

The State board of irrigation also agrees to contribute to the expense of this investigation under the provision of an act of the legislature of the State of Nevada to provide for the measurement of streams, the survey of reservoir sites, the determination of irrigation possibilities, and the best methods of controlling and utilizing the water resources of the State of Nevada, in cooperation with the United States Geological Survey and the United States Department of Agriculture and the Nevada Experiment Station (approved March 16, 1901), the sum of one thousand dollars ($1,000), the sum to be contributed by the State of Nevada to be available for the purpose of this investigation when this agreement has been signed by the governor of the State of Nevada and the resident hydrographer of the United States Geological Survey.

REINHOLD SADLER,
Governor of Nevada.
L. H. TAYLOR,
Resident Hydrographer.

Approved:
CHAS. D. WALCOTT,
Director, U. S. G. S.

In Arizona an agreement has been entered into with the commissioners of Maricopa County, representing the largest interests in the Salt River Valley.

In California the following bill was passed by the legislature, but failed to become a law:

AN ACT TO PROVIDE FOR THE JOINT INVESTIGATION WITH THE FEDERAL GOVERNMENT OF THE WATER RESOURCES OF THE STATE, AND OF THE BEST METHODS OF PRESERVING THE FORESTS THEREOF, APPOINTING A BOARD OF WATER AND FOREST COMMISSIONERS TO CONDUCT SUCH INVESTIGATIONS ON BEHALF OF THE STATE, AND MAKING AN APPROPRIATION FOR THE EXPENSES OF SUCH INVESTIGATIONS.

The people of the State of California, represented in senate and assembly, do enact as follows:

SECTION 1. There is hereby constituted a board of water and forest commissioners composed of three citizens of the State, who shall be appointed by the governor on or before April 1, 1901. No two of such commissioners shall be residents of the same county.

SEC. 2. Such commissioners shall hold office for the term of two years.

SEC. 3. Before entering upon the discharge of the duties of his office, each of said commissioners shall take an oath or affirmation to support the Constitution of the United States and of this State, and to faithfully and honestly discharge his duties as such commissioner, and shall execute and file with the secretary of state an official bond, with good and sufficient sureties, to be approved by the governor, in the penal sum of $20,000 conditional for the faithful performance of his duties under this act.

SEC. 4. Such commissioners shall receive no salary. They shall have power to employ a secretary at a salary of not exceeding $100 per month, and shall be allowed a contingent fund of not exceeding $200 per month to defray office and actual traveling expenses, and shall at the close of their term account to the governor for all moneys received and disbursed by them. Such commissioners may receive donations to assist them in carrying out the purposes of this act, accounting as such commissioners for such donations.

SEC. 5. Said commissioners shall have power to enter into such contracts as may seem best to them with the lawfully authorized representatives of any department of the Federal Government for the purpose of making topographic surveys and a joint investigation of and report on the water resources of the State, the best methods of developing the same, and the best methods of preserving the forests: *Provided, however*, That their expenditures for such purposes shall not be in excess of the amounts to be expended by the department of the Federal Government in collaboration with which any specific work is done. They may also in like manner and subject to the same conditions make such experiments for preserving the forests of the State as may seem best to them and to the representatives of the branch of the Federal Government authorized to undertake such experiments.

SEC. 6. In order to carry out the purposes of this act, any person or persons employed hereunder are authorized to enter and cross all lands within this State, provided in so doing no damage is done to private property; it shall be a misdemeanor, punishable as provided in such cases, for any person or persons to willfully and maliciously remove or destroy any permanent marks or monuments made or erected by any such persons.

SEC. 7. The sum of $107,200 is hereby appropriated as a special fund for the purposes specified in this act, and the controller of State is hereby authorized and directed to draw warrants upon such fund from time to time upon the requisition of two of such commissioners, and the State treasurer is hereby authorized and directed to pay such warrants.

SEC. 8. This act shall take effect immediately.

Cooperation in Geologic Surveys.

Cooperation in geologic work has been of less extent than for topography. In one form or another, however, cooperation in geologic surveys has recently been urged upon the Federal Survey by a number of States, and it seems probable that wide relations of the kind will be established.

In 1890 an understanding was had between the Director and the State geological board of New Jersey, that the State survey should map the later rock formations, which occupy much the larger area, but are readily mapped on account of the simplicity of the geologic structure, whereas the Federal Survey should map the comparatively small but very complex area of the earlier metamorphic rocks.

In the case of Pennsylvania, already referred to under another heading (see page 25), a new departure was made, inasmuch as financial cooperation on the part of the State was conditioned by the stipulation that the Federal Survey should carry on geologic as well as topographic work. The State survey having been discontinued, the scientific control rests wholly with the Director, while the State's interest is guarded by a commission.

A limited cooperation in areal geologic mapping has also been established with the State of New York.

The Geologic Branch has occasionally conferred with State geologists with a view to producing uniformity of action among State and Federal geologic surveys. The result has been, in some instances, the establishment of a closer system of cooperation between the Federal and State surveys, providing a financial and administrative basis upon which to extend the geologic surveys and investigations of this Survey over certain portions of the State.

FOREST RESERVES.

The survey and examination of the forest reserves has advanced during the year. The results, with details of the work, may be found on pages 145–146, 161–166, 176–178.

ALASKA.

Explorations and surveys were carried forward in Alaska, and all the parties had a successful field season. Early in April two parties started for the Yukon via Dawson and crossed to the Koyukuk at the mouth of Allen River, where they found the supplies sent on in 1900. A successful reconnaissance has been made to the divide between the Yukon drainage and the Arctic Ocean, and passes have been found that can be readily traversed. It is expected that one of these parties will reach the Arctic coast.

HYDROGRAPHIC SURVEYS.

The estimate for continuing the hydrographic surveys, as given in Senate Document No. 152, Fifty-sixth Congress, second session, was $250,000. An increase was recommended by the Secretary of the Interior from $100,000 to $175,000. The Senate increased this amount to $200,000, but in conference the amount was left at the sum appropriated for the preceding year, namely, $100,000.

After a long and spirited debate, the House of Representatives voted not to increase the appropriation for this important work, not on account of the methods of work pursued by this Survey, but because it was thought best to await the formulation of a practical, comprehensive scheme for irrigation and hydrographic surveys before any special work should be begun. The sum of $100,000 is sufficient to meet only a small number of the applications for Federal aid in hydrographic work, which come from all sections of the country.

INSULAR SURVEYS.

Attention is called to the statement in relation to insular surveys contained in the Twenty-first Annual Report, pages 47 to 58. These surveys are of great importance to the future development of our insular possessions, and it is recommended that they be taken up at as early a date as practicable.

NEW BUILDING.

During the year the Survey took possession of an addition to the Hooe Building, containing 14,000 square feet of floor space. The space was all occupied and many rooms in the old part were still left in a condition too crowded to permit of the best results on the part of the men occupying them. An addition is now being erected on the east of the Hooe Building that will close up 11 windows and darken 7 rooms to the extent of making them of little use without artificial light, except for storage, and 4 others will be considerably darkened. The total area of floor space darkened is 2,194 square feet. There is nothing that can be done to improve the situation except to rent the new addition or secure more room elsewhere.

While it is possible for the Survey to use almost any building that is fairly well lighted, it would be conducive to economy and efficiency to construct one for its accommodation. The chemical and other laboratories should be so equipped as to meet all demands that may be made upon them. The vibrations felt in the upper story of the present building are so great that accurate measurements of electric currents are almost impossible. This condition seriously interferes with and almost precludes many researches which are of the utmost importance in geologic physics. The quarters of the Division of Engraving and Printing should be so planned as to meet the wants of that division. The rooms for the geologists and other experts should be so arranged that each individual may work in quiet and without distraction from any source.

Topographers require space and light in which to arrange field maps and prepare their final drawings for the engraver. Geologists require light, space, and quiet satisfactorily to apply themselves to work of original research. The large collections of specimens which must be studied during the office season need to be placed within convenient reach. For those who use the microscope a steady northern light is necessary. For the best results each man should be shut off from his neighbor when engaged in writing.

None of these important conditions are realized in the present arrangement in an adequate way, nor will they be by renting space needed for immediate use by the overflow. The renting of the east addition to the Hooe Building will effect an improvement in present conditions, but the retention of the building at an annual rental of from $27,000 to $28,000 will still leave the Survey in quarters that are not adapted to its needs and purposes. To relieve the situation, which is injurious both to the service and to the men, a commodious new building is essential. It should provide for the following force and equipment:

EXECUTIVE OFFICES.

	Feet.	
For the Director, an office with 500 square feet; a laboratory and workroom with space for working library and map and specimen cases, 1,000 feet; a room for clerical assistants, 300 feet; total for Director's use	1,800	
Room for chief clerk	400	
Room for Miscellaneous Division	800	
Rooms for editor of publications	800	
Room for editor of topographic maps	1,000	
Room for editor of geologic maps	1,000	
Three rooms for Division of Accounts	1,600	
Two rooms for stationery and telephone switch	700	
		8,100

TOPOGRAPHY.

		Feet.	
For the 4 chiefs of sections, 1 room each of 300 feet		1,200	
4 stenographers' rooms, 200 feet each		800	
35 rooms, 4 windows each, for 140 topographers, each room 400 feet		14,000	
1 map and record room		1,000	
1 storage room		600	
1 instrument room		1,000	
			18,600

ILLUSTRATIONS, INCLUDING PHOTOGRAPHIC LABORATORY.

For 1 chief draftsman	300		
For 10 assistant draftsmen, 10 windows	1,000		
1 storage room	300		
		1,600	
For photographic operating room	1,000		
Printing and silvering room	500		
Two dark rooms	500		
Toning, fixing, and wash room	500		
Enlarging room	400		
Storage room	500		
		3,400	
			5,000

ENGRAVING AND PRINTING.

Press room for 10 presses	3,500	
Room for 40 engravers	5,000	
Room for curing paper	3,000	
Room for transferring	1,000	
Room for map printing	1,000	
Room for binding folios	500	
Room for copper-plate cases	1,000	
Room for photolithographing	1,000	
Room for planing lithograph stones	1,000	
Room for storing property and supplies	1,500	
Room for chief engraver	500	
Room for storing maps	1,000	
Room for instrument shop, plate working, and electrotyping	1,500	
		21,500

LIBRARY.

Room for books of library	7,500	
Room for pamphlets	500	
Room for maps	1,000	
Room for librarian	300	
Room for assistants	600	
		9,900

MINERAL RESOURCES.

Room for chief of division	400	
Room for laboratory	500	
Room for assistants	1,500	
Room for records and files	500	
Room for storage	600	
		3,500

GEOLOGY.

50 rooms for 50 geologists, allowing proper space for working library, map cases, specimen cases, and microscopic investigations, 400 feet each	20,000

PHYSICS AND CHEMISTRY.

	Feet.	
Office and library	725	
Physical laboratory	3,000	
Balance room	400	
General chemical work	1,000	
Special chemical work	500	
Storage room	500	
Assay room	750	
Workshop	750	
		7,625

PETROGRAPHY.

Room for grinding thin sections	300	
Room for mounting thin sections	300	
		600

HYDROGRAPHY.

Room for chief hydrographer	300	
3 rooms for assistants, 400 feet each	1,200	
1 room for records	500	
		2,000

DOCUMENTS.

Storage space for annual reports, monographs, and bulletins	3,000	
Storage for atlas sheets	2,000	
Storage for geologic folios	2,000	
Clerical assistants	500	
		7,500

PROPERTY STORAGE.

General property storage	2,000

RECAPITULATION.

Executive offices	8,100
Topography	18,600
Illustrations	5,000
Engraving and printing	21,500
Library	9,900
Mineral resources	3,500
Geology	20,000
Physics and chemistry	7,625
Petrography	600
Hydrography	2,000
Documents	7,500
Property storage	2,000
Engine and electric-light plant	1,500
Carpenter shop	725
Halls, closets, etc. (33 per cent)	36,000
Total	144,550

SPACE NOW OCCUPIED.

	Feet.
Hooe Building	61,180
Annex	18,693
Total	79,873
Total rent paid	$22,400

Annual rate of rent per square foot, 28.5 cents.

Museum of Practical Geology.

The attention of the Director has frequently been called to the desirability of having a museum of practical geology, kept up to date, so connected with the Geological Survey that the officers of the Survey would have ready access to it, while at the same time it would be of constant service in answering questions of scientific and practical men who might visit it for the purpose of obtaining information in relation to any mineral product.

There exists at the present time at the National Museum a geologic collection of great value, but it is located at a long distance from the Survey and is not so complete as is desirable. There should be a building or buildings provided that would accommodate the Geological Survey and also all the geologic collections of the Government. It is not necessary that these collections should be removed from the custody of the National Museum, but it is important that they should be properly installed and cared for independently of the general collections of that Museum.

The Geological Survey has some 40,000 correspondents who give information in relation to the mineral resources of the United States. There is little doubt that a plan for a museum of practical geology would receive the hearty cooperation of the mineral producers of the country, and that a representative display of economic minerals could be obtained at a cost very little in excess of the actual necessary correspondence and freight charges on specimens.

Such a collection would be very useful in the work of the Survey and would possess great educational value for visitors. It is desirable, in view of the large outlay being made by the Government for geologic surveys and the collection of mineral statistics, that any person interested in any mineral products should be able to obtain statistical information at the seat of Government and to see there specimens of all products in which he is interested. For example, a person wishing to obtain information in relation to marble, either as a producer or as a consumer, should be able personally to examine specimens of marble from the principal quarries of the United

States and by inquiry to learn all that is known of any particular marble.

Roughly estimated, there should be provided at least 100,000 square feet of floor space for the proper exhibition of the collections of practical geology, and for laboratories, storage rooms, etc. The exhibit would include, in addition to what has just been stated, the rocks, minerals, and fossils now included in the National Museum collections.

Another very important function of the museum of practical geology should be to furnish to the Architect of the Capitol, the Supervising Architect of the Treasury, and all persons in charge of the construction of Government buildings information in relation to the quality of the various granites, sandstones, marbles, etc., that enter into the construction of public buildings.

A building suitable for the purposes of the Survey and a museum of practical geology should provide at least 250,000 square feet of floor space and be so constructed as to permit of additions in the future.

COOPERATION WITH THE CENSUS OFFICE.

Soon after the Director of the Twelfth Census had been appointed, and immediately upon the organization of the census work, Mr. Henry Gannett, the chief geographer of the Geological Survey, was appointed as chief geographer of the Census Office, without compensation, a position which Mr. Gannett also occupied at the Tenth and Eleventh censuses. The geographic work of the census has been carried on under Mr. Gannett's direct supervision.

In the organization of the Manufactures Division of the Twelfth Census, the Geological Survey was requested by the Director of the Census Office to cooperate with that Office in the preparation of reports on those industries which were closely allied to mining. In accordance with this request, Mr. Edward W. Parker and Mr. Jefferson Middleton, statisticians of the Geological Survey, were appointed as expert special agents, without compensation, in the Division of Manufactures in the Census Office, and Mr. Charles Kirchhoff, a per diem special agent of the Geological Survey, was also appointed an expert special agent of the Census Office. Mr. Parker assumed charge of the investigation of the subjects of petroleum refining, coke manufacture, and salt production; Mr. Middleton was assigned to the subject of brick and other clay manufactures, and Mr. Kirchhoff to the refining of copper, lead, and zinc. Two of these reports, those on the manufacture of coke and the refining of petroleum, have been completed and the reports have been published in bulletin form. The other reports are well advanced and will be completed at an early date.

In order to assist in the preparation of the report on agriculture, Mr. F. H. Newell was permitted to accept an appointment as special agent of the Census Office, without compensation. On December 5, 1899, he was placed in charge, under the supervision of Mr. L. G. Powers, chief statistician of agri culture, of the collection and tabulation of the statistics on irrigation of the Twelfth Census. Mr. Newell occupied a similar position on the Eleventh Census and prepared a number of bulletins, as well as the final report, on agriculture by irrigation. Since that time he has brought together in the course of his official duties for the Geological Survey a large amount of additional information concerning the water resources of the country and their utilization in agriculture, all of this being available for the use of the Twelfth Census. He has devoted considerable time and thought to the preparation of schedules for correspondence and to the tabulation of results, and has carefully considered the presentation of conclusions, as far as these are at present available.

COOPERATION IN EXPOSITION WORK.

The popular relations which exist between the United States Geological Survey and the economic interests of the country are well illustrated by the requests which have been made upon the Survey for cooperation in various branches of exposition work at the Pan-American Exposition. In the first place, in a building prepared by the United States Government and containing illustrations of the various features of the administration of national affairs there is a large exhibit of the Geological Survey as one of the bureaus of the Department of the Interior. The exhibit of the Department has been under the control of Prof. F. W. Clarke, chief chemist of the United States Geological Survey, who has attained unusual skill in this work through experience in a similar capacity at every exposition since the Philadelphia Centennial. In addition to showing at the Pan-American Exposition all the relations of the Geological Survey to the public service, Professor Clarke was called upon to pass upon the exhibits of mining and mineralogy at the Paris International Exposition of 1900 in the capacity of international juror.

The economic work of the Geological Survey was further recognized at the Pan-American Exposition by the request for the cooperation of the Geological Survey in collecting, classifying, and arranging the general exhibit of minerals and mining. In complying with this request, advantage was taken of the familiarity of the Division of Mining and Mineral Resources, under the charge of Dr. David T. Day, with the mineral-producing areas of the United States, the lists of producers, etc.

A special exhibit of the work of the United States Geological Survey was requested by the department of graphic arts, where the Survey's methods of collecting datafor its topographic and geologic maps, of preparing and distributing these maps, etc., were shown by a large exhibit prepared by Mr. S. J. Kübel, chief of the Division of Engraving and Printing. It is believed that this exhibit of the methods involved in map making and the results attained will have the effect of raising the standard of map making for the entire United States. The Exposition also obtained the services of Mr. Kübel and Professor Clarke in the capacity of jurors of awards.

It is becoming evident that in the preparation of international exhibits the facilities of the National Government will be demanded more and more, especially within branches like the United States Geological Survey, which have agencies for obtaining information impartially from the entire country. A similar request by the Louisiana Purchase Exposition Company for the organization of the department of mining and metallurgy, under the direct supervision of the United States Geological Survey, has been granted; and with the knowledge of what has proved most instructive at former expositions, an effort will be made not only to show directly the mineral products of the United States and of other countries, but to set forth as thoroughly as may prove practicable the geologic conditions upon which our stores of minerals depend, with the idea of using this exhibit as a means of broad and comprehensive publication. The conditions under which our mineral deposits have been formed will be shown, as far as practicable, in order that future search for minerals in this and other countries may be conducted in the least expensive and most efficient manner. The efforts which have already been made in this direction at other expositions have had valuable results—as, for example, in the case of the exhibition at the Pan-American Exposition of samples from all deposits in which the element osmium has been found, with statements concerning the conditions of occurrence that have proved significant. There has already been a much more intelligent search for this mineral, which is now needed in commercial quantities, with most satisfactory results. The progress in this direction already indicates that half a ton of this element will be obtained annually from the United States, whereas less than one ounce has been the product in previous years.

COOPERATION WITH THE BOARD ON GEOGRAPHIC NAMES.

The Geological Survey has occasion to engrave, print, and publish several thousand geographic names each year. These published names are widely copied and followed by newspapers, map makers, teachers, and others. It is therefore deemed important that considerable care be taken to insure accuracy, to ascertain the actual names which have been given to and which belong to various geographic features, the particular feature to which each name applies, and the manner in which it is spelled or written. Other bureaus, notably the Coast and Geodetic Survey, the Light-House Board, the Hydrographic Office, the General Land Office, the Census Office, and the Post-Office Department, seek and use like information. In the interest of uniformity and accuracy, therefore, and of economy in securing these qualities, President Harrison in 1890 created, by Executive order, the United States Board on Geographic Names and directed that "to this Board shall be referred all unsettled questions concerning geographic names which arise in the Departments, and the decisions of the Board are to be accepted by these Departments as the standard authority in such matters."

In extending its topographic and geologic surveys into regions not previously so mapped, the Geological Survey has occasion to use many names that are but imperfectly known or recorded. Such names are investigated by the Survey, and the doubts and difficulties cleared up before they find permanent record on the engraved plates. Work in this field has been extensively carried on by Mr. Marcus Baker, who for the last ten years has been the Secretary of the United States Board on Geographic Names. When a study made by the Geological Survey for its own purposes and to meet its own needs reveals divided or doubtful or disputed usage, this unsettled question is referred to the Board on Geographic Names for decision. Thereupon the Board decides, and the form adopted by it becomes the standard authority, not only for the Geological Survey, but for all the Executive Departments. By this means the results derived from the work in one office are made available in an authoritative form for all.

In recent years explorations and surveys have been actively prosecuted in Alaska by several of the Executive Departments. The Geological Survey has participated in this, and, like the other organizations, has found great complexity, difficulty, and confusion in the Russian, Eskimo, and English names. To resolve this confusion and obtain results urgently needed, not merely by the Geological Survey, but by all branches of the Government, Mr. Baker was directed in 1900 to prepare a geographic dictionary of Alaska. This work had been projected and begun by the Board as early as 1891, and considerable progress had been made in collecting material. But it went no further till resumed by the Geological Survey in June, 1900. The dictionary is now finished and has gone to the printer. It will be published as Bulletin No. 187.

ORGANIZATION OF THE MISCELLANEOUS DIVISION.

On February 28, 1901, a committee was appointed and instructed to examine methods of conducting business in vogue in other branches of the public service and in large private establishments and report the result, and to make recommendations for such modifications in the Survey methods as seemed desirable.

In accordance with the committee's suggestions, on May 1 some changes were made in the methods of conducting the general correspondence of the office and in the system of files. For greater convenience in controlling the routine work of the office, a single division, the Miscellaneous, has been organized for handling the general records and correspondence, the mail, express, and freight matter, the property, supplies, etc. The changes give promise of proving satisfactory. The personnel of the new division, with the duties of each person, will be found on pages 206–207.

ACKNOWLEDGMENTS.

As in previous years, the Geological Survey is indebted to the Smithsonian Institution and to several of the Government bureaus for cordial cooperation. These include the National Museum, the Coast and Geodetic Survey, the General Land Office, the Bureau of Forestry of the Department of Agriculture, and the Government Printing Office. The work done by the Survey corps during the year was large in amount and of good quality. Special mention should be made of the services of the chief clerk and the chief disbursing clerk, who took charge of the administrative and business affairs of the Survey during the Director's absence in the field during the season of 1900; of the Editorial Division, by which an unprecedented amount of work was satisfactorily accomplished; and of the Division of Engraving and Printing, whose chief and assistants continued to produce topographic and geologic maps and folios which are much admired in all countries.

Through the courtesy of the Daniel Process Company the Engraving Division has, during the past year, been again allowed to use its process. By its means the work of that division is greatly simplified, much time and labor are saved, and correctness is assured. I trust that action will be taken by Congress at the coming session to secure to this Bureau, by purchase, the permanent privilege of using the process.

PLAN OF OPERATIONS.

The plan of operations for the fiscal year 1900–01 was laid before the Secretary of the Interior on June 14, 1900, and was approved by him on the same date. This detailed plan is on file in the Department. The work of the year, hereinafter reviewed, was executed in conformity with the plans submitted and approved.

APPROPRIATIONS.

For and during the fiscal year 1900–01 there was appropriated for the work of the United States Geological Survey the sum of $997,310. The acts making the appropriations set apart separate amounts for specific branches of work and for the salaries of persons connected with these branches. For convenience of reference these separate appropriations are here brought together and classified.

The legislative, executive, and judicial act contained the following items:

For salaries of Director, chief clerk, chief disbursing clerk, librarian, and photographer, together with clerks, messengers, watchmen, et al		$31,390
For rent		11,200
Total		42,590

The sundry civil act included the following items:

For pay of skilled laborers, etc		13,000
For topographic surveys	$240,000	
For pay of two geographers and two topographers	9,200	
Total for topographic work		249,200
For geological surveys	150,000	
For pay of four geologists	13,700	
Total for geologic work		163,700
For paleontological researches	10,000	
For pay of two paleontologists	4,000	
Total for paleontological work		14,000
For chemical and physical researches	10,000	
For pay of one chemist	3,000	
Total for chemical work		13,000
For general investigations in Alaska		25,000
For gauging streams, etc		100,000
For preparation of illustrations		14,000
For preparation of report on mineral resources		50,000
For purchase of books and distribution of documents		2,000
For engraving and printing maps		70,000
For rent		11,200
For survey of the forest reserves		130,000

There was appropriated in the same act, for engraving, printing, and binding publications of the Geological Survey, $37,000; this sum to be disbursed, not by the Geological Survey, but by the Public Printer. The items are as follows:

For engraving illustrations for report of the Director	$7,000	
For engraving illustrations for monographs and bulletins	10,000	
For printing and binding monographs and bulletins	20,000	
Total for engraving, etc		37,000

The deficiency act approved February 9, 1900, contained the following item:

For continuation of the investigation of the coal and gold resources of Alaska	35,000

The general deficiency act approved March 3, 1901, contained the following items:

For engraving and printing maps	10,000
For purchase of books and distribution of documents	5,620
For furnishing new addition to Hooe Building—Geological Survey, 1901	12,000
Grand total	997,310

ORGANIZATION.

For convenience of administration the following revised scheme of organization of the work and business of the Survey was adopted at the beginning of the year. By this scheme the work is primarily divided into four branches, in each of which there are a number of divisions.

Organization of the Geological Survey.

Branch.	Division.
Geologic	Areal Geology. Pleistocene Geology. Pre-Cambrian and Metamorphic Geology. Economic Geology: Section of Metalliferous Ores. Section of Nonmetalliferous Economic Deposits and Nonmetamorphic Iron Ores, Bauxite, etc. Paleontology. Mining and Mineral Resources. Hydrography. Physical and Chemical Research.
Topographic	Triangulation. Topography. Geography and Forestry.

Organization of the Geological Survey—Continued.

Branch.	Division.
Publication	Illustrations.
	Editorial:
	Section of Textual Publications.
	Section of Geologic Maps.
	Section of Topographic Maps.
	Engraving and Printing.
Administrative	Disbursements and Accounts.
	Library.
	Documents.
	Miscellaneous.

ALLOTMENTS.

ALLOTMENTS TO GEOLOGIC WORK.

The total amount available for geologic work for 1900–01 was $166,700, of which $2,000 were contributed by the State of Pennsylvania and $1,000 by the State of New York for cooperative work. The following table exhibits the allotments that were made to the heads of the several geologic parties:

Allotments to geologic parties.

Party, etc.	Amount.
Executive office	$12,680
Emerson, B. K. (Massachusetts)	350
Dale, T. N. (New York and Vermont)	2,300
Williams, H. S. (Connecticut, Maine, and Devonian faunas)	2,750
Hobbs, William H. (Connecticut)	500
Glenn, L. C. (New York cooperation)	1,000
White, David (Pennsylvania, Maryland)	2,515
Clark, William B. (Maryland)	1,000
Campbell, M. R. (Pennsylvania, New York, Indiana, California)	7,200
Hayes, C. W. (Tennessee, Kentucky, West Virginia, Alabama, Arkansas, Louisiana, Cuba)	4,500
Keith, Arthur (Tennessee, North Carolina, and Virginia)	3,850
Vaughan, T. W. (Georgia, Florida, Mississippi, Cuba)	2,100
Prosser, Charles S. (Ohio)	400
Van Hise, C. R. (Michigan, Minnesota, and eastern United States)	11,000
Chamberlin, T. C. (northern United States)	7,000
Hill, R. T. (Texas, New Mexico)	5,000

Allotments to geologic parties—Continued.

Party, etc.	Amount.
Taff, J. A. (Indian Territory)	4,200
Emmons, S. F. (Utah, Colorado)	8,450
Cross, C. W. (Colorado)	8,100
Weed, W. H. (Montana)	5,100
Hague, Arnold (Yellowstone National Park)	3,000
Lindgren, Waldemar (Oregon, Idaho)	5,300
Diller, J. S. (Oregon, California)	4,500
Darton, N. H. (North Dakota, South Dakota, Nebraska, Kansas)	2,200
Spurr, J. E. (Nevada, Utah, California)	7,000
Turner, H. W. (Nevada, California)	4,750
Ransome, F. L. (Colorado, Arizona, Washington)	3,000
Smith, George Otis (Washington)	4,600
Willis, Bailey (Montana, Washington, Missouri, Arkansas)	$7,100
Lawson, A. C. (California)	200
Branner, J. C. (California)	500
Becker, George F. (California and Chemical Laboratory)	10,600
Eldridge, George H. (United States at large)	3,000
Gilbert, G. K. (United States at large)	6,750
Girty, George H. (United States at large)	2,400
Director (field expenses)	2,500
Stose, George W. (map editing)	2,350
Contingent	6,955
Total	166,700

ALLOTMENTS TO PALEONTOLOGIC WORK.

The total appropriation for paleontologic work for 1900–01 was $14,000, which was allotted to the various sections of the work as follows:

Allotments to paleontologic work.

Section, etc.	Amount.
Mesozoic	$2,600
Cenozoic	2,600
Paleobotanic	4,600
Preparation of monographs on vertebrate fossils	3,500
Contingent	700
Total	14,000

ALLOTMENTS TO TOPOGRAPHIC WORK.

The appropriation for topographic work for 1900–01 was $249,200, which was allotted to the several sections of the work as follows:

Allotments to topographic work.

Section, etc.	Amount.
Administration	$16,800
Atlantic section	90,000
Central section	50,000
Rocky Mountain section	35,500
Pacific section	37,500
Instruments, repairs, etc	13,000
Contingent	6,400
Total	249,200

ALLOTMENTS TO FORESTRY WORK.

The appropriation for the survey and investigation of the forest reserves was $130,000, which was allotted as follows:

Allotments to forestry work.

Section, etc.	Amount.
Topographic surveys:	
Rocky Mountain section	$45,000
Pacific section	45,000
Forest surveys	25,000
Office expenses	9,600
Contingent fund	5,400
Total	130,000

MISCELLANEOUS ALLOTMENTS.

CHEMISTRY.

For pay of all persons connected with the chemical work, and for the purchase of chemical supplies, apparatus, etc., the entire appropriation of $13,000 was allotted.

HYDROGRAPHY.

The appropriation of $100,000 for gauging streams, etc., was allotted as follows: $40,000 to the measurement of streams,

$30,000 for surveys of reservoir sites and the preparation of land-classification maps, and the remainder, $30,000, to the preparation of reports on the best methods of utilizing the water supply and to the investigation of underground currents and artesian wells (see volume on Hydrography of this Annual Report and the series of Water-Supply Papers).

The appropriation was apportioned as follows:

Apportionment of appropriation for hydrography.

HUMID REGION.		
New England and New York	$3,000	
Pennsylvania, Maryland, and Virginia	3,500	
North Carolina and South Carolina	7,000	
Georgia, Florida, Alabama, Tennessee, and Mississippi	7,000	
Ohio, Indiana, and Illinois	3,000	
		$23,500
SUBHUMID REGION.		
North Dakota and South Dakota and portion of Wyoming	$7,000	
Nebraska	3,000	
Missouri, Kansas, and Indian Territory	3,000	
Texas	2,000	
		15,000
ARID REGION.		
Arizona and California	$20,000	
Colorado	6,000	
Idaho	4,000	
Montana	8,000	
Nevada	4,500	
New Mexico	2,000	
Utah	5,000	
Washington and Oregon	4,000	
Wyoming	8,000	
		61,500
Total		100,000

MINERAL RESOURCES.

The entire appropriation for the preparation of the report on mineral resources, $50,000, was allotted to the gathering and compilation of statistical data for the calendar year 1900 and the preparation of a report on the same, which will, in compliance with law, be issued as a distinct publication.

ENGRAVING AND PRINTING MAPS, ETC.

The appropriations for engraving and printing maps, purchase of books and distribution of documents, preparation of illustrations, pay of skilled laborers, etc., and the special appropriations, were expended for the specific purposes named in the act.

WORK OF THE YEAR.

The general organization of the Survey, by branches and divisions, has been given (p. 48). The approved plan of operations was carried out in all essential particulars, the variations being such as were found necessary to meet conditions that could not be foreseen.

GEOLOGIC BRANCH.

Administration of the Geologic Branch.

At the beginning of the year just closed the reorganization of the Geologic Branch on the plan of distinguishing between executive control and scientific supervision took effect. By this plan all geologists hold immediate executive relations with the Director, but in each of the great fields of geologic research a specialist is chosen and to him is given the immediate control of all the work of the Survey which falls within that field, and the authority to determine all scientific questions pertaining to that specialty, in whatever branch or division of the Survey they may arise, subject always to the final decision of the Director, if that is regarded as necessary or desirable.

The following geologists thus directed the scientific work, so far as practicable, during the fiscal year, and they are continued in the same relations:

Bailey Willis, geologist in charge of areal geology.

T. C. Chamberlin, geologist in charge of Pleistocene geology.

C. R. Van Hise, geologist in charge of pre-Cambrian and metamorphic geology.

S. F. Emmons, geologist in charge of metalliferous ores.

C. W. Hayes, geologist in charge of nonmetalliferous economic deposits and nonmetamorphic iron ores, bauxite, etc.

T. W. Stanton, paleontologist in charge of paleontology.

D. T. Day, geologist in charge of mining and mineral resources.

George F. Becker, geologist in charge of physical and chemical research.

In order to define more clearly the relations between chiefs of divisions and geologists in charge of parties, the following circular was issued, after the subject had been fully discussed and the statement adopted in joint conference of the Director with Messrs. Chamberlin, Van Hise, Emmons, and Willis:

DEFINITION OF SCIENTIFIC CONTROL UNDER CHIEFS OF DIVISIONS OF GEOLOGY.

Under the organization of the Geologic Branch, approved by the Secretary of the Interior, which went into effect July 1, 1900, the following divisions were established:

Division of Areal Geology. Bailey Willis, geologist in charge.
Division of Pleistocene Geology. T. C. Chamberlin, geologist in charge.
Division of Pre-Cambrian and Metamorphic Geology. C. R. Van Hise, geologist in charge.
Division of Economic Geology:
  Section of Metalliferous Ores. S. F. Emmons, geologist in charge.
  Section of Nonmetalliferous Economic Deposits and Nonmetamorphic Iron Ores, Bauxite, etc. C. W. Hayes, geologist in charge.
Division of Paleontology. T. W. Stanton, paleontologist in charge.
Division of Mining and Mineral Resources. D. T. Day, geologist in charge.
Division of Physical and Chemical Research. G. F. Becker, geologist in charge.

The limits of scientific control under the new organization were not defined in detail, and this has led to some misunderstanding as to the relations of chiefs of divisions to the heads of parties. The following definitions have been prepared with a view of informing not only chiefs of divisions, but also the heads of parties, of the extent of the scientific control and of the necessity for cooperation on the part of all engaged in scientific work in the Survey:

1. In regard to the special subjects assigned him, the authority of a geologist in charge shall be coextensive with the operations of the Survey, but in the adoption and execution of plans the extent of his authority shall be determined by the Director and shall in general be limited to those cases in which his special knowledge of the results to be obtained makes his executive control especially advantageous.

2. The authority of a geologist in charge shall be geographically coextensive with the operations of the Survey.

3. Each chief of division shall confer with his fellow-chiefs with a view: (*a*) To adjustment of proposed plans; (*b*) to calling attention to opportunities or questions coming to his notice but not within his sphere; (*c*) to promoting cooperation, which is a fundamental principle of the organization.

4. Each chief shall seek to effect such exchange of information and

views with any geologist carrying on work under his scientific directions as will give the results their highest practicable scientific value and justify his approval on the basis of definite knowledge of field and office work.

5. Where geologic investigation of any field involves questions which come within the spheres of two or more chiefs of divisions, their cooperation is imperative. In such cases, therefore, they shall by mutual agreement determine upon either (*a*) a plan of joint action, by which each will supervise those matters falling within his sphere, or (*b*) a plan of supervision by one, in case the interest of that one greatly preponderates, the other chief or chiefs acting in an advisory capacity.

6. The position of chief of division shall confer no prerogative of authorship in relation to the work of any other geologist or assistant geologist. It shall confer the right and duty to consider for recommendation all manuscripts which relate to subjects coming within the scope of one's authority as chief, and no manuscript shall be accepted for publication without such recommendation of favorable nature.

7. The position of chief of division places upon the incumbent the obligation to keep himself informed of progress in his branch, and it will necessarily give him opportunity for broad studies—an opportunity which is his chief return for the time, thought, and energy he must devote to the work of others.

8. It shall be the duty of every chief of division, in the early part of each year, to prepare for submission to the Director a general plan of work in his special lines, enumerating, in order of their importance or necessity, the regions where such work seems desirable and suggesting the geologists to whom each piece of work should be assigned. Any geologist thus named shall be invited to consider the piece of work, and after conference with the chief of division to submit detailed estimates for its execution, as hereinafter specified in section 9. In case the Director shall place executive authority in the hands of a chief of division, such assistants as may be engaged under his special authority shall report directly to the chief of division. In such case the chief of division shall prepare and submit to the Director specific plans and estimates for the work of such assistants, and shall report the results thereof.

9. For the larger part, the planning and execution of the work of the Survey shall be intrusted directly to chiefs of parties. Any geologist or assistant geologist may be assigned to duty as chief of party, and in this relation he may have assistants, who shall report to him. The chief of party shall prepare plans and estimates for the work committed to him, and shall submit these first to those chiefs of division concerned, for advice and suggestion, and, with their indorsement, later to the Director over his own signature. The Director's approval only may confer authority to execute plans. Allotments shall be made

to the chief of party directly or to the chief of division when he is made an executive officer, and in either case the chief shall be responsible to the Director for disbursements and for execution of plans. In preparing material for study or publication, the chief of party shall continue conferences with the chiefs of divisions concerned. Completed manuscript shall be sent by assistants to the chief of party concerned, and he shall send such manuscript, as well as his own, to the Director, who will refer it to one or more chiefs of division, each of whom shall make such recommendations as the treatment of his subject may require. When approved for publication, each manuscript shall be accompanied by a formal letter of transmittal, signed by the chiefs of division who shall have passed upon it.

10. Inasmuch as adjustment of plans and allotments of appropriations require the attention of some one geologist, this duty shall be assigned to the assistant in geology to the Director, who is not, however, thereby given any special authority over the plans or work of his fellow-chiefs or other geologists.

Appropriation for Geology.

The appropriation for geology for the fiscal year 1900–01 was $150,000 for geologic surveys in various portions of the United States and $13,700 for salaries of geologists. Salaries of geologists employed in Alaska were charged to the special appropriation for that work to the amount of $9,400, and geologists detailed, on request, to special work in Cuba were paid, while so engaged, from the revenues of the island, to the amount of $1,078.68. The general appropriation for geology was thus relieved of these payments on the salary account. In addition to the appropriation for geology, $2,000 was contributed by the State of Pennsylvania and $1,000 by the State of New York, making a total of $166,700 available for geologic work. Owing to the pursuance of economical plans and methods by chiefs of parties, a considerable contingent fund was available in the spring of 1901, and all geologic parties were able to take the field as early as other conditions permitted.

Summary of Work of Geologic Branch.

Division of Areal Geology.—Mr. Bailey Willis devoted himself during a greater part of the year to the duties of assistant in geology to the Director, which have been principally of an executive nature. A portion of his time was given to questions placed before him as geologist in charge of areal geology, and a still smaller part has been available for scientific studies.

In June, 1900, Mr. Willis visited points in the Joplin district, Granby, Mo., and Fayetteville, Ark. On August 13 he proceeded to the State of Washington, and was engaged until September 20 in a reconnaissance of Columbia River and Lake Chelan and vicinity, part of the time in company with Professor Salisbury.

A second trip was made to the Joplin district of Missouri in December and January for the purpose of conferring with Professor Van Hise. On this trip a brief investigation of geologic conditions in southwestern Arkansas was made, and conference was held with several geologists in Missouri and Kansas.

The trip to the Cascade Range proved very instructive. A critical study of the physiography resulted in an analysis of the episodes of uplift by which the Cascade Range has attained its present altitude. Upward movements of the range were traced down to late Pliocene or very possibly early Pleistocene time, and valuable data were obtained for a discussion of the dynamics of that particular mountain growth. It is proposed to publish these results as a bulletin of the Survey, to be prepared jointly by Mr. Willis and Mr. George Otis Smith.

On June 10, 1901, Mr. Willis proceeded via Laramie, Wyo., to Blackfoot, Mont., to undertake a geologic reconnaissance of the forty-ninth parallel from St. Marys River westward across the Rocky Mountains to the west crossing of Kootenai River. At Laramie he conferred with Prof. Wilbur C. Knight in regard to a survey of the Laramie quadrangle. Having organized his party, consisting of Prof. Stuart Weller, assistant paleontologist, Mr. George I. Finlay, assistant geologist, and three camp hands with pack train, Mr. Willis left Blackfoot on June 21 and proceeded via St. Marys Lakes to the forty-ninth parallel and entered upon the reconnaissance assigned him.

During the year Mr. George I. Adams, assistant geologist, made a survey of the Fayetteville quadrangle, Arkansas, under Mr. Willis's immediate direction. Mr. H. F. Bain and

Mr. Adams examined the Joplin, Mo., zinc district. Their reports will be found under their names in the work of the "Central region."

In the office Mr. Willis served as chairman of the committees on Geologic Names and Illustrations, as member of the committees on Building, Examination of Records, and Publications, and as custodian of property for the Geologic Branch, and he also considered and adjusted plans for geologic work.

Continuing the duties as editor of geologic texts for folio publication, Mr. Willis read the descriptions of the following quadrangles: Danville, Ill.-Ind.; Walsenburg, Colo.; Huntington, W. Va.; Washington, D. C.; Spanish Peaks, Colo.; Coos Bay, Oreg.; La Plata, Colo., and Coalgate, Ind.

The principal question which came before Mr. Willis in stratigraphic geology involves the distinction between lithologic units and faunal units and their respective values in correlation. Following the plan and definitions laid down in the Tenth Annual Report, Part I, the Geological Survey is mapping local lithologic formations chiefly by their physical characteristics. Pursuing a time-honored custom, geologists of the Survey and others not infrequently correlate these local formations chiefly by their contained fossils. It has come to be recognized that a stratigraphic series may be divided in one way according to its lithologic characters and in another way according to its contained fossils, and that confusion and controversy are likely to result from failure to distinguish between the criteria employed. Furthermore, there is much obscurity in literature in consequence of the indiscriminate use of such words as "formation," "series," and "system" and the related terms of time divisions. The Director having charged Mr. Willis with an investigation into current procedure in these matters, a considerable part of July, 1900, was spent by him in a study of the subject and in the preparation of a discussion of the same, and copies of this discussion were sent to several of the leading geologists of the Survey for comment. After further consideration the matter was presented to the Geological Society of Washington, and this action resulted in energetic discussion, in which a number of the leading geologists took part, including Profs. H. S. Williams, C. R. Van Hise, and T. C. Chamberlin.

Division of Pleistocene Geology.—Prof. T. C. Chamberlin, geologist in charge, directed the field operations and examined those manuscripts submitted for publication which related particularly to Pleistocene questions. Having previously established close relations with a number of assistants specially trained in glaciology, Professor Chamberlin has maintained an intimate personal connection with the work. Not only in the office, but also in the field, the workers in Wisconsin and Michigan have had the benefit of his experience and advice, and he and his associates have responded promptly to calls upon them for assistance in Pleistocene studies in New York, Pennsylvania, and Massachusetts.

Prof. R. D. Salisbury, assistant in charge of Pleistocene geology with Professor Chamberlin, devoted himself chiefly to the Pleistocene deposits of New Jersey, under the auspices of the State survey. Dr. Salisbury made a joint study with Dr. Shattuck, of the Maryland survey, of certain critical points in the District of Columbia, Maryland, and New Jersey, in May. The study was completed before the close of the month and a joint report was rendered. The purpose of this investigation was to harmonize, so far as practicable, the interpretation of the Pleistocene deposits by the officers of the Maryland and the United States surveys.

Professor Salisbury also accompanied Mr. Willis in a trip up Lake Chelan, Washington, and to the Cascade Pass, at the head of Stehekin River. Preliminary observations were made on the glacial phenomena, including the terraces of Lake Chelan and the Columbia and the moraine of the Okanogan Glacier, and a basis was laid for future studies of the region.

The reports of assistants in Pleistocene geology will be found under their own names in the account of the work in the "Central region." They are Messrs. Leverett, Taylor, Alden, J. H. Smith, and Tight.

Division of Pre-Cambrian and Metamorphic Geology.—Prof. C. R. Van Hise, geologist in charge, spent the greater part of his time, when in the field, in a study of the structure of the Lake

Superior Basin, in which he was assisted by Mr. J. Morgan Clements. He also joined Mr. C. K. Leith in examining the Mesabi iron district, and visited the Joplin, Mo., zinc district, where he shared with Mr. Willis the control of the work of Messrs. Bain and Adams.

In the office Professor Van Hise devoted about one-half the available time to revision of a monograph on metamorphism, which he had hoped to finish by the end of the year, but which is still not ready for the printer because of the largely increased responsibilities that have come to him as geologist in charge of all the work on the pre-Cambrian and metamorphic rocks. It was necessary for him to prepare an introductory chapter on the lead and zinc of the Ozark region, to accompany Messrs. Bain and Adams's report on that region, and a very large amount of time was taken in supervising and furthering the work of the other men who are engaged in various lines of investigation of the pre-Cambrian and metamorphic rocks.

Professor Van Hise has been chief of party for his assistants, Messrs. Clements and Leith, and also for Prof. William H. Hobbs, Prof. Florence Bascom, Prof. W. S. Bayley, and Dr. H. F. Bain. The reports of their individual work will be found under their names.

Division of Economic Geology; Section of Metalliferous Ores.—Mr. S. F. Emmons, geologist in charge, spent the greater part of the field season in conference in the field with the geologists working under his direction. About the 1st of July he went from Denver, Colo., to the Grand Encampment Mountains of Wyoming and made a reconnaissance examination of the copper district there, for the purpose of determining the nature of work to be done by the Survey. About the middle of the month Mr. Emmons joined Mr. Boutwell in the Bingham district, in the West or Oquirrh Mountains, and worked with him from that time until the 10th of August, when Mr. Arthur Keith took charge of the work.

After describing the nature of the work to Mr. Keith, Mr. Emmons proceeded to Butte, Mont., to consult with Mr. Weed on the work he was doing there, and thence proceeded, via the Great Northern Railroad, to Spokane to examine the cross section of the Rocky Mountains on that line.

On the 15th of September Mr. Emmons again visited Butte, for conference with the Director in regard to the carrying out of the Butte work. It was then decided that the importance of the district justified its treatment in monographic form, and that Mr. Weed should devote his entire time, as soon as he completed other unfinished work, to the study of the mines of this district, carrying it on both winter and summer until completed.

From Butte Mr. Emmons returned to Bingham, whence Mr. Keith had already departed for his work in North Carolina, and remained with Mr. Boutwell for a time, planning the best method of completing the field work. He then made a trip to southwestern Utah and southeastern Nevada to examine the important deposits of the Horn Silver and Delamar mines.

Early in October Mr. Emmons returned to Salt Lake and Denver, and after a short visit to Leadville to arrange work for the coming season, proceeded to Joplin, Mo., joining Messrs. Bain and Adams, then engaged in an examination of the lead and zinc deposits of that region. After a few days spent in the mines there, to familiarize himself with the peculiarities of the region, he proceeded with Mr. Bain to western central Arkansas to examine certain deposits of zinc, antimony, and gold.

The greater part of Mr. Emmons's time in the office was taken up with administrative duties. Preliminary reports on the Grand Encampment district and on the mines examined in Arkansas were submitted, and short papers were published in the Transactions of the American Institute of Mining Engineers on The Ore Deposits of the Horn Silver and Delamar Mines in Utah and Nevada, and The New Type of Contact Deposits in the Boundary District of British Columbia. A number of reports on economic subjects were submitted to Mr. Emmons during the year for critical examination and recommendation.

Division of Economic Geology; Section of Nonmetalliferous Economic Deposits and Nonmetamorphic Iron Ores, Bauxite, *etc.*—The work of Mr. C. W. Hayes, geologist in charge, consisted during the year of two kinds: First, systematic, areal, and economic studies; and second, brief visits to various localities for the purpose of examining mineral deposits.

The months of August and September were devoted to the mapping of the Columbia quadrangle, in middle Tennessee, and the study of the deposits of rock phosphate in that and adjoining quadrangles, assistance in this work being rendered by Mr. E. O. Ulrich. A few days were spent in an examination of the clay resources of western Tennessee for the purpose of making plans for more detailed work in that region. Mr. Hayes then visited the salt and sulphur deposits of northwestern Louisiana, some of the oil fields of Texas, and the bauxite district of Arkansas. In November, 1900, portions of West Virginia were visited to determine the advisability of carrying on work in the coal field during the coming season, and an examination was made of certain reported deposits of iron ore in eastern Kentucky. In February Mr. Hayes proceeded to northern Alabama to obtain information regarding the development of the coal-mining industry.

In March, Mr. Hayes was detailed to make a reconnaissance of the economic geology of the island of Cuba, on request of Maj. Gen. Leonard Wood, transmitted through the War Department to the Secretary of the Interior, and Messrs. T. Wayland Vaughan and Arthur C. Spencer were detailed as assistants in this work. Mr. Hayes left Washington on March 19 and remained in Cuba about five weeks.

In the office Mr. Hayes's work consisted largely of the preparation of manuscript for folios and other publications. After the 1st of January he was occupied very largely in supervising the preparation of a series of reports, consisting of eleven papers, summarizing the present knowledge of the various coal fields of the United States. These were prepared under the joint supervision of the Division of Mining and Mineral Resources and the Section of Nonmetalliferous Economic Deposits, to supply information in constant demand regarding this subject. Considerable time throughout the year was given by Mr. Hayes to conferences with various geologists who are engaged on the study of the nonmetalliferous minerals, and to the examination of material submitted for publication.

Division of Paleontology.—Mr. T. W. Stanton was charged with the general administration of this division. A summary of the work accomplished is given on pages 99–107.

Division of Mining and Mineral Resources—Dr. David T. Day directed the work of this division, a report on which will be found on pages 108–124.

Division of Physical and Chemical Research.—Dr. George F. Becker was in charge of the work of this division, a report on which will be found on pages 133–135.

Detailed Statement of Work of Geologic Branch.

DIVISIONS OF GEOLOGY.

EASTERN REGION.

DISTRICT OF THE ATLANTIC COASTAL PLAIN.

Clark party (*Maryland*).—In cooperation with the State geological survey of Maryland, work was continued on the formations of the Atlantic Coastal Plain in that State under the direction of Prof. William B. Clark, State geologist.

The Cretaceous formations were examined in the counties to the south and north of Baltimore, and the classification hitherto adopted for this division of the geologic column was found to apply in the adjacent districts. Much collecting was also done from the Potomac group.

The investigation of the Eocene formations of Maryland and Virginia was brought to a conclusion, and an elaborate report on the Eocene deposits and their contained faunas was prepared for publication by the Maryland survey.

The Neocene deposits received much attention, and the classification established for these formations in Maryland was readily extended across Delaware into New Jersey. A large area in southern Maryland has already been mapped in detail and much progress has been made in the study of the contained faunas.

The Pleistocene formations of Maryland have also been studied in detail by Dr. George B. Shattuck, and a comprehensive classification has been proposed for them, conforming in its essential features to that recognized earlier by Messrs.

W J McGee and N. H. Darton. It is, however, at variance with that established by Prof. R. D. Salisbury for the New Jersey deposits, and a joint conference between Messrs. Salisbury and Shattuck was held in the field in accordance with the Director's suggestion. A report of this conference was submitted to Prof. T. C. Chamberlin, who, after consideration, reported upon the subject to the Director.

Much work has also been carried on by the Maryland survey, under the direction of Professor Clark, throughout the Piedmont Plateau and the Appalachian region of Maryland, the results of this work being available to the United States Survey. Areal mapping on the 1-inch scale has been extended over portions of both of these regions and is entirely in harmony with the work done by members of the United States staff.

Professor Clark was assisted during the year by Messrs. G. B. Shattuck, Arthur Bibbins, G. C. Martin, and B. L. Miller.

Vaughan party.—See under "Division of Paleontology," pages 105–106.

DISTRICT OF THE APPALACHIAN MOUNTAINS AND NEW ENGLAND.

Kemp party (New York).—Prof. J. F. Kemp was engaged in surveying an area lying in the southeastern part of the Adirondack Mountains and comprising the Elizabethtown, Mount Marcy, Lake Placid, and Ausable quadrangles, and also the Fort Ann quadrangle. The formations involve pre-Cambrian gneisses, of both igneous and sedimentary origin, and limestones. Field work was completed, with the exception of the review of details, to be made this summer, and the manuscript is nearly ready for publication.

Professor Kemp also prepared a paper on The Geological Relations and Distribution of Platinum and its Associated Metals, for publication as a bulletin.

Dale party (New York, Vermont).—Prof. T. N. Dale continued surveys in eastern New York and western Vermont, cooperating with Professor Kemp in adjoining areas. Professor Dale's work was in the Castleton, Equinox, and Pawlet quadrangles, and related to the slate and marble belts of the district. He was assisted by Mr. F. H. Moffit.

In the office he prepared for folio publication the maps of the three quadrangles surveyed, so far as practicable, and he began an article on the physiography of the Taconic region. He also compiled two bibliographies, one on the literature of the Vermont marble belt, the other on that of marble in general.

Wolff party (*Vermont, Massachusetts, New Jersey*).—In consequence of absence in Europe, Prof. J. E. Wolff was not able to devote any time to the field work intrusted to him. Office work was devoted to the final preparation of the pre-Cambrian parts of the Taconic folio (Vermont and Massachusetts) and to some work on the material of the Franklin (N. J.), folio.

Emerson party (*Massachusetts*).—Prof. B. K. Emerson, prosecuting his studies of the gneisses of Massachusetts, was occupied chiefly in Worcester County. He prepared a detailed map and monographic report of this area, but is hindered from presenting them for publication by two important questions, one of interpretation and one of correlation, the answering of which will require further work in this area.

In order to prepare the Ware (30′) folio for publication, Professor Emerson carefully restudied portions of the area, and is prepared to present the map and text for this quadrangle and those for the Quinsigamond quadrangle as soon as the reduced topographic maps shall have been printed. He proposes, in accordance with the instructions of the Director, to spend the summer in the study of the Warwick quadrangle, when solutions may be found for the questions alluded to above.

Williams party (*Connecticut, Maine, Devonian faunas*).—Prof. H. S. Williams is paleontologist in charge of Devonian faunas, and is also chief of party of certain surveys which are being carried on in Maine and Connecticut.

The field work in the Farmington quadrangle, Connecticut, on the crystallines, was completed during the summer by Dr. H. E. Gregory and Prof. L. G. Westgate, and a reconnaissance was made connecting the Farmington quadrangle with the Tolland and with the Massachusetts areas across the border.

The petrographic work on the collections was also advanced during the year by Professor Westgate, and a small amount of work was done by Dr. Gregory.

Investigations were continued in Maine and the eastern province. Additional collections were made from the Chapman and Edmunds Hill areas by Mr. O. O. Nylander to perfect the faunas of the Chapman formation. During the month of August Professor Williams was engaged in making collections of the Fox Islands Paleozoic fossils at North Haven, Me., and in studying the sections. The Cobscook Bay areas about Eastport and at several intervening places were examined. The stratigraphy between the Silurian and the Perry localities was also critically studied, and collections of the fossil faunas were obtained. In both of these regions, although the fossils are chiefly of Silurian age, evidence of higher formations was brought to light.

In September the Arisaig region was studied, and fossils were collected for the purpose of comparison with the Maine collections and faunas. Arrangements were made with the director of the Canadian survey to have full collections of this Arisaig fauna made, perfected, and examined, and as soon as possible thoroughly worked up with illustrations. Arrangements were also made with Professor Adams, of Montreal, to provide full illustration of the St. Helens Island faunas, the collection to be worked up in Professor Williams's laboratory. A preliminary classification and listing of the faunas from Maine and Arisaig was accomplished.

The paleontology of the Olean (N. Y.) quadrangle was examined and the classification of the stratigraphy was determined and reported upon. Conferences were had with Mr. Campbell regarding problems of the same nature in the Tioga quadrangle.

A report of the Arkansas correlations (made for the State survey) was published in a volume of that survey during the year. In this report the age of the formation which has been known as the Eureka black shales was determined. The report was applied by Mr. Ladd in interpreting the black shales in the quadrangles under his supervision.

During the year investigations were made looking to an interpretation of the history of the interior continental basin during Neopaleozoic time. A large number of statistics regarding the geographic distribution and the geologic range of the Devonian faunas were gathered, tabulated, and analyzed, and a report on the progress thus far made in interpreting Devonian history was prepared.

The problem of correlating the sections of the eastern province with those of the intercontinental basin led to the specific study of the question of the Silurian-Devonian boundary in American geology. Numerous discussions were held with paleontologists acquainted with this subject, and the importance of pushing the Arisaig faunas to completion was realized and provision for publication was made.

Discussions were also had regarding the principles of classification as based upon the evidence of fossil faunas. A number of conferences on this subject were held in Washington, and a systematic formulation of the laws of faunal classification was reported.

Mr. H. F. Cleland made a thorough collection of the Hamilton fossils at Cayuga Lake, and a report by him on the series of faunules in this section of the Hamilton formation will be published as a bulletin of the Survey. He also made observations upon the sections in the valley of Seneca Lake.

Dr. E. M. Kindle was engaged in May to assist in the field work of the summer and in the laboratory.

The following papers were prepared for publication during the year:

The Paleozoic faunas of northern Arkansas, by H. S. Williams: Ann. Rept. Geol. Survey Arkansas for 1892, Chapter VI, pp. 256–362.

Distribution of faunas and formations in the interior continental basin of North America during Neopaleozoic time, by H. S. Williams. To be published as a bulletin of the United States Geological Survey.

A study of the fossil faunules of the Hamilton formation in central New York, by H. F. Cleland. To be published as a bulletin of the United States Geological Survey.

A preliminary report on Devonian sections in Kentucky, Virginia, and West Virginia, by Edward M. Kindle. To be published as a bulletin of the United States Geological Survey.

Hobbs party (Connecticut).—Prof. William H. Hobbs continued his surveys in southwestern Connecticut. He reports, through his chief of party, Professor Van Hise, that about 200 square miles were covered in the Danbury, Derby, Norwalk, and Bridgeport (15′) quadrangles.

Bascom party (*Pennsylvania, Maryland*).—Prof. Florence Bascom, having completed the mapping of the metamorphic rocks about Philadelphia and entered into an arrangement with the Maryland State geological survey under the established cooperation, studied the crystallines of Cecil County and traced their relations to the rocks about Philadelphia. Professor Bascom's work is immediately under the supervision of Professor Van Hise.

Keith party (*North Carolina*).—During the greater part of the field season Mr. Arthur Keith's attention was directed to special problems connected with the report on the Cranberry district. These were, in the Abingdon quadrangle, to determine the age of the series of tuffs, slates, and breccias associated with volcanic rocks along the Virginia-North Carolina border, and to trace the Cambrian basalt flow from the Roan Mountain quadrangle northeast through the Cranberry and Abingdon quadrangles. Formation boundaries were reinspected and adjusted on the new base maps of the Morganton and Mount Mitchell (N. C.) quadrangles, and the field season closed with special work in the Asheville and Greeneville quadrangles.

In the office a general physiographic description of the Appalachian Mountains was written for publication in the Appalachian Park report. Matters connected with the publication of the Washington, D. C., and Maynardville, Tenn., folios received much attention, and portions of the Cranberry areal map were revised and the final drafts and sections made. The descriptive text of the latter was completed and the material turned in for publication. All material upon the Asheville (N. C.) and Abingdon (Va.-Tenn.-N. C.) quadrangles was assembled and the areal maps were completed to date. A general review of all information concerning the age of the Ocoee strata was also completed.

DISTRICT OF THE ALLEGHENY PLATEAUS.

Glenn party (*New York*).—In cooperation with the State paleontologist of New York, Prof. J. M. Clarke, and under the direction of Mr. M. R. Campbell, a study of the stratigraphy of southwestern New York was undertaken, and the work of the

Federal Survey was carried on by Prof. L. C. Glenn. The formations of the Olean quadrangle were determined and mapped. Professor Glenn was assisted by Mr. Charles Butts, and conferences were held with Prof. H. S. Williams in regard to the problems of correlation. The stratigraphy of western New York presents very complex relations between the rock formations on the one hand and their contained faunas on the other. Thus the studies have a bearing on broad problems in correlation. The area is a productive oil field and the investigation included a study of the occurrence of the oil in relation to geologic structure.

Campbell party (*Pennsylvania, New York, Indiana*).—Under the scheme of cooperation which was agreed upon between the Federal Survey and the State of Pennsylvania, work was begun in that State by the party under the direction of Mr. M. R. Campbell on July 1, 1900. Mr. John D. Irving and Mr. Myron L. Fuller, assistant geologists, were assigned to Mr. Campbell as his assistants.

July and August were spent in the areal survey of the Uniontown and Masontown quadrangles, including the southern end of the Connellsville coke field and the eastern edge of the coal field which underlies Greene and Washington counties. The areal mapping of the outcrop of the Pittsburg coal was done with great care. The intention was not only to show the outcrop of this valuable bed, but also to determine the "lay" of the bed beneath the surface and to show its attitude by means of contour lines.

In September the survey of the Gaines and Elkland quadrangles, in the northern part of Pennsylvania, was begun. The indurated rocks were studied and mapped, and Mr. Alden examined the surficial deposits. A study was also made of the Gaines oil field, but owing to the smallness of this field and the simplicity of the general geologic problems work in this part of the State was completed by October 1.

During the early part of the season cooperative geologic work was in progress in New York under Mr. Campbell's direction. Prof. L. C. Glenn mapped the Paleozoic formations of the Olean quadrangle, and Mr. Frank Leverett made a survey of the surficial deposits of the same area.

October was spent in surveying the Boonville and Petersburg quadrangles, in southwestern Indiana, the geologic work being nearly of the grade of exactness of that in Pennsylvania. This material has not been prepared for publication, but will be put in shape as soon as new base maps are ready.

Office work consisted of the preparation of folios covering the territory surveyed. Messrs. Glenn and Leverett prepared the material for the Olean folio, and Messrs. Fuller and Alden assembled the data for the Gaines and Elkland folios. Mr. Fuller submitted a report upon the Gaines oil field, which will be published as a bulletin.

Mr. Irving prepared the Uniontown-Masontown folio, and it has been submitted for publication.

White party (Maryland, Pennsylvania).—During the year Mr. David White continued the study of the stratigraphy and paleobotany of the older Coal Measures of the Appalachian trough, with the special object of correlating the various formations and economically important horizons. Large collections were made at many localities, and the study of these collections occupied by far the greater part of the time spent in the office.

Nearly two and one-half months were devoted to field work in western Maryland and Pennsylvania. Collections representing the horizons of the workable coals were obtained from the Broadtop coal field of Huntingdon and Bedford counties, Pa. The stratigraphy and paleobotany of the lowest of the Allegheny Coal Measures and of the Pottsville formations were examined in the Frostburg (Md.) basin and along the margins as well as across the principal anticlines of the Pennsylvania bituminous basins in Somerset, Cambria, Blair, Clearfield, McKean, and Elk counties. Many of the isolated coal basins of Potter, Lycoming, and Bradford counties, in Pennsylvania, were visited, and data for the correlation of the coals were obtained.

The Mount Savage fire clay of western Maryland was traced through the principal gaps in Somerset County. It was found to belong, both paleontologically and stratigraphically, to the Mercer group of the Upper Pottsville. The fire clays near

Bennington and Wopsononock, in Cambria County; Sandy Ridge and the Upper Clearfield Valley, in Clearfield County, and near Brookville, Jefferson County, were found to belong to the same group. Occasional developments of these highly refractory clays are found also in Center and Cameron counties, while specimens of inferior quality were obtained from the same horizon at the mines of Fourmile Run, in McKean County. Farther west, in northwestern Pennsylvania and in Ohio, the Mercer group contains thin limestones and iron ores with black shales at the same horizon. The interbedded coals are seldom workable. The lithology of the group points toward quiescent base-level sedimentation, while the paleobotany indicates a relatively long time interval for the group, notwithstanding its inferior thickness.

The coals worked in the isolated basin in Gaines, Tioga, and Potter counties, and the lower (Bloss) coals worked in the Blossburg basins, Tioga County, in the Ralston (B coal) and McIntyre basins of Lycoming County, and in the Barclay field (B coal) of Bradford County were found to be contained in the same group.

A brief reexamination of the Coal Measures in the Tipton Run coal field of Blair County, Pa., not only confirmed the evidence of the Allegheny age of the coals, as reported the preceding year, but enabled Mr. White definitely to determine the character of the fault by which a section containing Allegheny, Pottsville, and Mauch Chunk formations has dropped about 1,400 feet into the midst of the Pocono, with which it was formerly correlated.

Besides current examinations of materials from various localities from which collections were made by the areal geologists, considerable progress was made in the preparation of a monograph of the floras of the Pottsville formations in the Appalachian trough. The Calamariæ and most of the ferns in several hundred collections from the Central district (Maryland, West Virginia, Virginia, and Kentucky) were fully described. Some time was also given to the identification or description of Paleozoic plant materials in the collections of the National Museum.

CENTRAL REGION.

GREAT LAKES DISTRICT—GLACIATED AREA.

Leverett party (Michigan, New York).—Assisting Professor Chamberlin, Mr. Leverett examined the Pleistocene formations of the central and western portions of the southern peninsula of Michigan, and made a special study of the glacial formations of the Olean and Salamanca quadrangles, New York. From the 1st of July to the middle of October he was engaged in field work in the central and western parts of the southern peninsula of Michigan, in territory contiguous on the south and west to that examined contemporaneously by Mr. Frank B. Taylor. It embraced the greater part of Livingston, Ingham, Eaton, Barry, Allegan, Ottawa, and Kent counties.

On October 18 he was detailed to examine the Pleistocene features of the Olean and Salamanca quadrangles for the purpose of preparing a contribution to the geologic folio of that area. This occupied him until November 5. The time succeeding this to November 18 was occupied in the revision of manuscript on the Pleistocene geology of the Danville (Ill.) geologic folio.

Field work was then resumed and continued to the close of the calendar year, the work being in Cass, Kalamazoo, Jackson, and Washtenaw counties, in southern Michigan.

January and February, 1901, were spent in revising the manuscript of a monograph on the Glacial Formations and Drainage Features of the Erie and Ohio Basins. Some part of this period was also given to the preparation of his report on the Olean-Salamanca district. After a brief visit to Washington in the early part of March for consultation with reference to the illustrations for the monograph named, the remainder of March was spent in the preparation of illustrations for this monograph. On April 10 field work was resumed in southern Michigan and continued until May 4, the work being principally in Branch, Hillsdale, and Lenawee counties. The rest of May was spent in preparing maps for his monograph and in completing the report on the Olean-Salamanca district.

The month of June was spent in field work in southern Michigan and adjacent portions of Indiana.

The work in southwestern New York showed a notable conformity of the ice front to the local topography. The ice was found to have protruded in well-defined lobes or tongues down the valleys to a distance of several miles beyond the position of the ice front on the intervening ridges. The distribution of drift on the valley slopes indicates a rise of the glacial surface of nearly 100 feet to the mile in passing northward from the limits of the drift into the drift-covered region. It is probable, therefore, that the glacial border had at least that amount of rise.

The work in Michigan brought out clearly the relations of the three glacial lobes, Michigan, Saginaw, and Huron-Erie. Each of the lobes discharged its drainage into valleys leading across the southern counties of Michigan and thence to the Kankakee, Illinois, and Mississippi rivers. The cusps or reentrants between the lobes were gradually extended northward with the withdrawal of the Saginaw lobe, and the interlobate moraines on each side of the Saginaw lobe appear to have been at any given time but slightly extended to the north from the reentrant angles. Instead of a long, interlobate moraine, there is a series of short spurs forming a zigzag chain that outlines the point of junction of adjacent lobes at each stage of halting, marked by a morainic loop.

The mapping of the glacial formations in Michigan has considerable value in outlining the distribution and extent of each class of soil, and also forestry conditions. The records of wells gathered serve not only to reveal the character of the deeper portion of the drift, but to determine the available water supply. This investigation is also of value in determining the location of beds of marl and clay, which may be of service to the cement industry.

Taylor party (Michigan, Massachusetts).—Mr. F. B. Taylor, special assistant to Professor Chamberlin, executed surveys which consisted, essentially, in an examination of the Pleistocene deposits in east-central Michigan and in a study of the Pleistocene deposits of the Housatonic quadrangle in western Massachusetts, to which he was specially detailed late in the season. From June 1 until October 12 Mr. Taylor worked on the glacial deposits of Michigan. The region examined may be designated in general that of "the Thumb and the Saginaw Basin," extending thence southward and westward into conjunction with the territory examined concurrently by Mr. Leverett. After mapping the glacial features of northwestern Oakland County, Mr. Taylor worked westward in the northern parts of Livingston, Ingham, and Eaton counties, this work occupying June, July, and the first half of August. The remainder of the time in Michigan was devoted to the study of the deposits of Ionia and Clinton counties and parts of Shiawassee and Gratiot counties.

Among the leading subjects of special study were the closely set, slender moraines of Ionia and adjacent counties and the channel made by the glacial waters discharged from the Saginaw ice lobe southwesterly to Lake Michigan and similar channels across the Thumb, formed by the discharge of the glacial waters ponded about the head of Lake Erie after these had abandoned the Wabash outlet.

On October 12 Mr. Taylor was detailed to work up the Pleistocene features of the Housatonic quadrangle, to be published as a contribution to the atlas folio of that region. This work was continued without interruption until December 12, but was not entirely completed. The main results of this examination were the finding of a series of faint moraines marking halting places of the ice front in glacial times. Eight such moraines were detected, and indications were found of two or three more which may probably be satisfactorily discriminated by further study. In general, the trend of these moraines is northeast-southwest, while their courses in detail show a well-marked serration of the ice front, due to the minor elements of topography. Their general features indicate that the configuration of the main ice lobe was determined essentially by the Hudson Valley.

In the early part of January Mr. Taylor assisted Mr. Leverett in the preparation of the monograph on the Glacial Formations and Drainage Features of the Erie and Ohio Basins, by contributing the data resulting from his extensive private investigations in the Lake Erie Basin. For a portion of the winter Mr. Taylor was not in the employ of the Survey. Between the middle of March and the 1st of May he gave six weeks to the preparation of his report and map on the glacial geology of the Housatonic quadrangle. On May 16 he was again detailed to further study of the Housatonic area, which was continued to the close of the fiscal year.

Alden party (*Wisconsin, Pennsylvania*).—Mr. William C. Alden, assisting Professor Chamberlin, devoted himself mainly to the systematic study of the Pleistocene formations in the quadrangles in southern Wisconsin, to be subsequently named, together with a study of the Gaines and Elkland quadrangles of northern Pennsylvania, for which he was detailed during the autumn, and in the preparation of the report on this and previous work.

After a few days spent in reconnaissance work in the vicinity of Sheboygan and Manitowoc, Wis., the mapping of the Whitewater, Delavan, and Koshkonong quadrangles, in southern Wisconsin, was undertaken systematically and prosecuted uninterruptedly until September 22. On this date Mr. Alden was detailed to study the Pleistocene formations of the Gaines and Elkland quadrangles, in Potter and Tioga counties, whose pre-Pleistocene formations were under examination by the party directed by Mr. M. R. Campbell. The field work there was completed October 27. The manuscript report on this was prepared during the winter and submitted March 20. The manuscripts for the Chicago and Milwaukee folios were finally revised during the winter. That for the Racine folio was begun, and the mapping for the Whitewater folio was nearly completed at the close of the fiscal year.

Smith party (*Pennsylvania*).—Mr. James H. Smith was engaged by Professor Chamberlin during the last of July, August, and early September to make certain specific studies on the Pleistocene formations of Lehigh Valley, Pennsylvania, under the special direction of Professor Salisbury. The area examined included parts of Luzerne, Carbon, Lehigh, and Northampton counties. The special subjects of study were the old glacial deposits outside the recognized terminal moraine and the gravel deposits connected with the different glacial stages.

Tight party (*Ohio, West Virginia, Kentucky*).—Under Professor Chamberlin, Prof. W. G. Tight was engaged, by special arrangement, during July and August and portions of September, October, and November, in a study of the changes of drainage that the rivers of southeastern Ohio and adjacent portions of West Virginia and Kentucky underwent during the early Pleistocene period. During the winter months a report embodying the results of this study, and embracing also the results of several years' previous study at private expense, was prepared and submitted.

LAKE SUPERIOR IRON DISTRICT.

Bayley party (*Michigan*).—During the year Prof. W. S. Bayley, under the direction of Professor Van Hise, spent a month in the Menominee district of Michigan on final revisionary work. His entire time during the year was given to the preparation of a monograph on the Menominee district, which will be submitted for publication during the present fiscal year.

Clements party (*Minnesota*).—Mr. J. Morgan Clements, assistant to Professor Van Hise, completed field work on the Vermilion district of Minnesota. His office work consisted of the preparation of a monograph on this district. An advance summary of the geology of the productive part of the district, with a map, was inserted in a general paper by Professor Van Hise on the Iron Ores of the Lake Superior Region, published in the Twenty-first Annual Report, Part III.

Leith party (*Minnesota*).—The areal mapping of the Mesabi iron-bearing district of Minnesota was begun by Mr. C. K. Leith on July 1, under the direction of Professor Van Hise, and continued until the middle of November. With the assistance of excellent private maps of the district which were placed at his disposal, and with the cooperation of the mining men of the area, Mr. Leith mapped the present productive part of the district, which extends from Hibbing on the west to Biwabik on the east, and also an area between Biwabik and Birch Lake. The length of the range mapped was about 60 miles and the average width 4 or 5 miles, making about 250 square miles.

In the office Mr. Leith continued his work in summarizing North American pre-Cambrian literature for the current year.

He finished his investigation upon rock cleavage. This paper is to be published as an appendix to Professor Van Hise's monograph on metamorphism. The remainder of his time has been given to work on material collected in the Mesabi district with reference to a monograph on that area. This district is one of such importance that a section on the iron ores of the Mesabi district was inserted in Professor Van Hise's paper on the Iron Ores of the Lake Superior Region, appearing in the Twenty-first Annual Report, Part III. Mr. Leith also prepared a map of the productive part of the district, which is to be published with the Mesabi section.

SOUTHERN-CENTRAL DISTRICT.

Prosser party (*Ohio*).—The plans for work by Prof. Charles S. Prosser on the Columbus quadrangle were not carried out, owing to the fact that it became necessary for him to devote most of his time to the work of the Maryland survey.

Preliminary work in Ohio has shown that the stratigraphic geology of the State needs careful revision, and a part of this investigation has been undertaken by Professor Prosser for the State survey, the results of which will be available for the United States survey. In connection with this investigation the two following papers were published last year:

Names for the formations of the Ohio Coal Measures: Am. Jour. Sci., March, 1901, 4th series, Vol. XI, pp. 191–200.

The classification of the Waverly series of central Ohio: Jour. Geol., April–May, 1901, Vol. IX, pp. 205–232.

Ulrich party (*Tennessee*).—Assisting Mr. Hayes, Mr. Ulrich made a detailed study of the stratigraphy and paleontology of the Columbia (Tenn.) quadrangle during the months of August and September. In the office he assisted Mr. Hayes in the preparation of manuscript for folios and other publications, and made a study of the material collected during the field season.

Bain party (*Missouri*).—Mr. H. F. Bain spent the entire season, from early in July until late in November, in economic field work on the lead and zinc deposits of the Ozark region. The largest part of this time was devoted to the southwestern district of Missouri, which was studied with some thoroughness. The field work in the other districts was of a reconnaissance nature. In conjunction with Mr. George I. Adams, Mr. Bain prepared a report of observations, which is to be published, with an introductory chapter by Professor Van Hise, in the Twenty-second Annual Report, Part II.

Adams party (Arkansas, Missouri).—Under direct instructions from Mr. Willis, Mr. George I. Adams surveyed the areal geology of the Fayetteville quadangle and studied the stratigraphy of the Joplin, Mo., district. About the middle of November he proceeded to Madison, Wis., to cooperate with Mr. Bain in the preparation of his report on the zinc district, under the supervision of Professor Van Hise. Upon his return to Washington, in December, Mr. Adams continued the preparation of his report until ordered South to make an investigation of the Texas-Louisiana and Kansas-Indian Territory oil and gas fields. In June he commenced field work in the Great Plains region, in cooperation with the Division of Hydrography.

Taff party (Indian Territory, Arkansas, Texas).—With Mr. Sydney H. Ball, as field assistant, and Dr. G. H. Girty, paleontologist, in June, 1900, Mr. J. A. Taff entered upon a special investigation of Ordovician and Silurian rocks in parts of the Atoka, Tishomingo, Stonewall, and Ardmore quadrangles. This work was completed by July 11, and Dr. Girty left the party. Immediately a detailed areal survey of the rocks in the Tishomingo quadrangle was begun, which, with a review of a small area of Ordovician and Silurian rocks in the Atoka quadrangle, was completed on October 20, 1900.

Mr. Taff then proceeded to make a special survey of the Cretaceous chalk and marl deposits of southwestern Arkansas, to determine their extent and their quality as material for hydraulic cement. Preliminary to this work Mr. Taff joined Dr. C. Willard Hayes, geologist in charge of nonmetallic products, and made an examination of the chalk deposits in the vicinity of Whitecliffs, Ark. He also visited the southern extension of the same chalk deposits in Texas, at Dallas, Austin, and San Antonio, where hydraulic cement plants had been erected. The survey of these chalk deposits was completed, and Mr. Taff returned to the office at Washington, D. C., on December 24, 1900.

Besides minor official duties, the principal of which were compilation of notes on the Tishomingo quadrangle, correspondence in connection with the preparation of cement and coal reports, and the preparation of cement materials for analyses, the following office work was accomplished: (1) Preparation of preliminary text on stratigraphy for the Tishomingo folio; (2) completion of the text for the Coalgate folio, of which about one-third had been written; (3) preparation of report on the chalk and chalk-marl deposits and cement materials of southwestern Arkansas; (4) preparation of report on the Southwestern coal region, including the coal fields of Arkansas, Indian Territory, and northern Texas; (5) text for the Atoka folio (in preparation).

GREAT PLAINS DISTRICT.

Darton party (*North Dakota, South Dakota, Colorado, Kansas, Nebraska*).—The greater part of Mr. Darton's work during the year was performed in connection with the Division of Hydrography, and consisted of the study of geologic problems bearing on the relations of deep-seated underground waters in the central Great Plains region.

In continuing work on the Black Hills geology Mr. Darton extended detailed mapping over the Sundance and Edgemont quadrangles, and a reconnaissance was made of the Hay Creek and of portions of the Moorcroft and Matotepee quadrangles. The problems were mainly stratigraphic, but much attention was given to the relations of the intrusive rocks. In this work Dr. W. S. Tangier-Smith was associated with Mr. Darton as assistant geologist and mapped the greater portion of the Edgemont and Hay Creek quadrangles. The mineral resources of the region are coal, gold, tin, gypsum, and pockets of petroleum. Special attention was given to the question of underground water supply, and the position and capabilities of the water-bearing beds were determined. Work on the eastern side of the Black Hills was continued by Prof. C. C. O'Harra, who completed the mapping of the sedimentary formations of the Rapid quadrangle.

In September a brief reconnaissance was made of a portion of the Hartville quadrangle, and later in the season Dr. Tangier-Smith mapped in detail the Mesozoic, Paleozoic, and pre-Cambrian formations of the quadrangle. Special attention was given to the rich iron ore near Hartville and to the gold and copper prospects in that vicinity. A comparison was made of the stratigraphy of the Carboniferous and Mesozoic formations with those of the Black Hills and a very satisfactory correlation was effected.

During the later part of the season of 1900 Mr. Darton made an examination of a wide area of the Great Plains in eastern Colorado and western Kansas, with a view to ascertaining the structure and stratigraphic succession and their bearing on the prospects for underground waters. Much new light was thrown on the relations of the Neocene formations, the distribution and structure of the various members of the Cretaceous, and the results of test borings at various points. Fossil bones were found in the Monument Creek Tertiary beds, which will probably aid greatly in determining the age of the formation. Considerable attention was given to a comparison of the stratigraphy of the Lower Mesozoic and Upper Carboniferous formations along the foothills of the Rocky Mountains with that of the Black Hills, and some very valuable data were obtained. Dr. Tangier-Smith made an extended reconnaissance of portions of the Timpas and Higbee quadrangles.

In eastern North Dakota work was continued by Prof. C. M. Hall, who mapped in detail the geology of the Casselton and Fargo quadrangles and obtained much information bearing on prospects for underground waters in that region.

In South Dakota Prof. E. H. Barbour made a few short journeys to ascertain the succession and limits of the Tertiary formations south of the Cheyenne River.

During the month of June, 1901, Mr. Darton made a series of detailed sections of the White River Tertiary formations in the Big Bad Lands to ascertain the succession of the beds which have yielded the great series of remains of titanotheres. In this work Mr. Darton had the assistance of Mr. J. B. Hatcher, who has made extensive collections in the Bad Lands region. The results of this investigation will be presented in a monograph by Prof. H. F. Osborn on the Titanotheriidæ.

The office work of the season comprised the preparation of various folios and reports for publication. A Preliminary

List of Deep Borings in the United States 400 Feet or more in Depth, was completed and transmitted for publication as Water-Supply Paper No. 57. The Camp Clarke, Scotts Bluff, Oelrichs, and Norfolk folios were completed and transmitted for publication, and Dr. Tangier-Smith prepared the map and manuscript of the Hartville folio and made a manuscript map of his work on the Edgemont and other quadrangles.

Mr. Darton also made considerable progress with a report on the geology and underground water resources of the Central Great Plains region, but another season's field work will be required before this report can be completed. A large amount of information was given in person and to correspondents regarding prospects for underground waters in many portions of the United States.

WESTERN REGION.

ROCKY MOUNTAIN DISTRICT.

Weed party (*Montana, Texas*).—During July and August Mr. W. H. Weed was occupied in office work, in the study of material and the preparation of a report on the Elkhorn mining district, Jefferson County, Mont. In September he proceeded to Butte, Mont., to begin a detailed study of the copper mines of that district. Two months were spent in this work, when a return to Washington was necessitated. In the latter part of November a leave of absence was granted Mr. Weed for a trip across Mexico from the Rio Grande to the Gulf of California. On his return to Texas he was ordered to make an examination of the El Paso tin deposits. A brief report on the locality was published as Bulletin No. 178. Returning to Washington for equipment, Mr. Weed left for Butte, Mont., on January 25, and was thereafter continuously engaged in a study of the underground workings of that locality. In this work he was ably assisted by Mr. Reno Sales as assistant geologist, Mr. H. W. Teague as draftsman, and Mr. W. E. Parkins as field assistant, while temporary employment was given Mr. Alfred Longley.

The Butte work has been taken up in great detail, as the geologic structure is complicated and the Survey report will be accepted as an authoritative statement of geologic conditions in a district where the ownership of great ore bodies depends on geologic structure.

During the year a report on Mineral Vein Formation at Boulder Hot Springs, Montana, was issued (Twenty-first Annual, Part II), and a paper on Types of Copper Deposits in the Southern States was printed in the Transactions of the American Institute of Mining Engineers.

Hague party (Yellowstone National Park).—Mr. Arnold Hague was engaged in work for the Geological Survey a little less than half the time. In the summer he attended the International Congress of Geologists at Paris as a delegate from the United States, and after his return he prepared, at the request of the United States commissioners to the Exposition, a concise account of the congress for their report to Congress. During the winter a trip was made at his own expense to Porto Rico for the purpose of investigating its volcanic phenomena and the uplift of the entire region in Tertiary time.

The greater part of Mr. Hague's time in the office was devoted to the preparation of Part I of Monograph XXXII, on The Geology of the Yellowstone National Park. The work progressed steadily. To Dr. T. A. Jaggar was assigned the duty of preparing an exhaustive chapter on the "Microscopical petrography of the Absaroka Range," and during the winter his report, with accompanying illustrations, was received and accepted.

Dr. William Hallock, of Columbia University, resumed work on the chapter on "The physics of geysers," which had been laid aside, owing to the pressure of professional work.

Cross party (Colorado).—Mr. Whitman Cross continued his surveys of the San Juan Mountains, Colorado, with special reference to the Needle Mountains, Engineer Mountain, and Silverton quadrangles. He was assisted throughout the field season by Mr. Ernest Howe, assistant geologist; from July 15 to August 11 by Mr. George H. Girty; and from August 3 to September 8 by Mr. George W. Stose.

During the first part of the field season the Paleozoic beds of the southwest corner of the Needle Mountains quadrangle were studied and mapped, and were traced along the eastern zone of the Engineer Mountain quadrangle from south to north, thence into the northwestern section of the Needle Mountains quadrangle, and across the border into the Silverton area. The party was at work in the Silverton quadrangle from August 23 to September 25, and the entire area of the quadrangle has now been examined.

Extraordinary snowstorms on September 23 and 24 abruptly closed the season's work in high altitudes, and Mr. Cross left at once for the East. Mr. Howe took charge of the party and went down the Animas Canyon, studying the Archean and Algonkian formations until October 16.

The work carried out in the Needle Mountain quadrangle was practically a reconnaissance of the entire western third of the area. The Paleozoic formations below the Hermosa (Carboniferous) were carefully studied in the southwestern section. Evidence of a Lower Carboniferous formation, now almost entirely removed by erosion, was obtained, chiefly through Mr. Girty's knowledge of the invertebrate fauna. This formation is not present as a mappable unit, but the character of the break between the Hermosa (Carboniferous) and the Ouray (Devonian) has been demonstrated. These two formations are apparently conformable in most exposed sections; but on tracing out the horizon at which the Lower Carboniferous must occur, it is hoped that remnants of it may be found in some localities. In the lowest member of the Paleozoic a shell, identified by Mr. Walcott as *Lingulella ella*, was found. This demonstrates the presence of Cambrian beds, and it will be possible to map the formation in course of future work.

In the northwestern section of the quadrangle a preliminary study of the Algonkian quartzites was made, a number of divisions were established, which can be mapped, and much progress was made toward unraveling the complicated folding and faulting of these beds. The section made by Mr. Howe in the Animas Canyon will be of much value in mapping the Archean area of the Needle Mountains.

Before Mr. Girty left, the Lower Paleozoic formations referred to as identified in the Needle Mountain quadrangle were traced up the Animas Valley and their geologic boundaries were determined. The gneisses and schists of the West Needle Mountains were examined and provisionally mapped. The Algonkian quartzites which cross from the Needle Mountain area were studied.

The western portion of the Silverton quadrangle, not previously visited, was examined in detail and mapped as far as possible upon the inadequate topographic sheet made some years ago. A large part of this area is characterized by landslides, which have obscured the solid-rock geology. The region is also one of extreme decomposition of the igneous rocks, and one requiring very careful work with an adequate map, because of the important ore deposits of several types which have been extensively developed.

In accordance with the plans for the summer of 1901, Mr. Cross took the field early in June and carried out a reconnaissance from the San Juan River south of the Mesa Verde, in New Mexico, to the vicinity of Durango, at the southern base of the San Juan Mountains, in Colorado. He was accompanied during this trip by Mr. F. H. Knowlton, paleobotanist. The special object of the reconnaissance was the examination of the Upper Cretaceous coal-bearing formations, with a view to establishing new formation units and to determining, if possible, the age of these formations. Paleontologic material of value was collected during this reconnaissance, and it is hoped that the study of this material by Mr. Knowlton will enable him to determine whether any of these coal formations belong to the Laramie, or whether they are of somewhat lower horizons.

Throughout the winter Mr. Howe was on leave of absence, at Harvard University. Mr. Cross's time in the office was mainly spent in the preparation of folio material. The descriptive text of the La Plata folio was completed, and the La Plata folio was issued in June. The text of the Rico folio was also nearly completed. The preparation of the La Plata text, describing the Cretaceous formations, involved the preparation of material for the Durango folio in regard to the entire Upper Cretaceous section

Much time was spent by Mr. Cross in the study of the field notes of the seasons of 1899 and 1900, concerning the geology of the Silverton quadrangle, as a preparation for the season of 1901.

During the year Mr. Cross served as member of the committees on Petrographic Reference Collection, Chemical Laboratory, and Photographic Laboratory. He was also appointed a member of the committee to prepare papers for the civil-service examination held in April.

Ransome party (Colorado, Arizona, Idaho, Washington).—In the spring of 1900 Mr. Ransome was detailed to make an economic investigation of the Rico district, Colorado, as a sequel to the report on the general geology of that region by Messrs. Cross and Spencer. The field work in the Rico district was begun on July 1, 1900, with Mr. A. M. Rock as field assistant, and was finished in September. Mr. Ransome then resumed the investigation of the economic geology of the Silverton quadrangle, Colorado, with Mr. Rock as field assistant, carrying on the work in cooperation with the study and mapping of the areal geology by Mr. Whitman Cross. The field work in this region was completed early in October, and two weeks were then devoted to a short reconnaissance of the mining regions of Clear Creek and Gilpin counties, Colo., with the view of probable future work in those districts and for the sake of comparison with the ore deposits of the Silverton region.

Returning to Washington late in October, Mr. Ransome was engaged until May 1, 1901, in preparing reports on the Silverton and Rico districts. The report on the former region will be issued as Bulletin No. 182, under the title A Report on the Economic Geology of the Silverton Quadrangle. That on the Rico district will be published in the Twenty-second Annual Report, Part II, under the title The Ore Deposits of the Rico Mountains, Colorado.

On May 6, 1901, Mr. Ransome left Washington to undertake the detailed mapping of the Globe (15′) quadrangle, Arizona, with special reference to the study of the ore deposits, and to make a geologic reconnaissance of that portion of the Northwest boundary lying between Lake Osoyoos and the Kootenai

River. On June 10 he left Globe, Ariz., after making preliminary reconnaissances and mapping about one-fourth of the quadrangle, and went to Spokane, Wash., to organize the reconnaissance of the Northwest boundary section assigned to him. It is his intention to return and complete the survey of the Globe district late in the autumn.

Boutwell party (Utah).—Mr. J. M. Boutwell on the 1st of July proceeded, under instructions from Mr. Emmons, to Salt Lake City to make some preliminary examinations in the Wasatch Mountains previous to taking up work in the Bingham district. About the middle of the month he was joined by Mr. Emmons, and headquarters were established in Bingham Canyon for the purpose of making a survey of the Bingham district in the West or Oquirrh Mountains. In August Mr. Arthur Keith came out to take charge of the work after Mr. Emmons's departure, but could devote only one month of his time to the work. Mr. Boutwell carried on the work at Bingham and made occasional trips in the Wasatch Mountains and on the shores of Salt Lake for the purpose of comparative study from July 1 to December 8. During the summer Dr. Girty was engaged in a study of the Carboniferous fauna of the Wasatch region, and spent a week with Messrs. Keith and Boutwell at Bingham, making collections of fossils from the beds of that region.

Keith party (Utah).—On August 10 Mr. Arthur Keith joined Mr. Boutwell in the Bingham Canyon district of Utah and took charge of the party. His field work in the Bingham district was, however, limited to one month, the work having been carried on there by Mr. J. M. Boutwell for three weeks previous to his arrival and until early in December after his departure, as already stated.

Mr. Keith's attention was chiefly given to determining the sequence of the formations, mapping their areas, and deciphering the structural relations. He also examined the more important mines of the district. The problems proved unexpectedly complicated, and the gathering of many of the details, especially in regard to the smaller mines and claims, devolved upon Mr. Boutwell after Mr. Keith's departure.

In the office a draft of the areal map of the Bingham mining district was completed and a provisional stratigraphic section was constructed.

Hill party (Texas, New Mexico).—During the field season Mr. R. T. Hill devoted much of his time to work in the Trans-Pecos region of Texas and New Mexico. The study of the region, commenced the year before, was continued, Mr. Hill traversing with wagon outfit nearly 800 miles of the little-known region lying north of the Southern Pacific Railway.

Mr. Hill outfitted at Marathon, Tex., early in July, his party consisting, besides himself, of Mr. Prentice B. Hill, general assistant, a teamster, and a cook. During the month of August he was assisted by Mr. John K. Prather as collector.

The month of July was devoted to the study of the Comanche and Glass mountains to the north and northeast of Marathon, and their relations to the Pecos Valley. August was mostly devoted to the group of mountains known as the Davis Mountains. In the latter part of this month the study of the south end of the great salt lake basin bordered on the east by the Delaware Mountains and on the west by the Sierra Diablo Plateau was commenced. In the latter part of August the salt lake basin was crossed by way of the foot of Guadelupe Peak to the Pecos Valley. From Carlsbad, on the Pecos, the country westward to Cloud Croft, N. Mex., the summit of the Sacramentos, was studied.

During September a study was made of the Sacramento, Gallinas, Jicarilla, and Captain mountains and of the great desert valley which lies between these mountains and the Organ-Oscura Range. These reconnaissances, together with the side trips, were carried out by aid of plane-table topographic sketches. Numerous geologic sections were made, resulting in the solution of the broader geologic and economic problems of the region. The great Tularosa-Malpais lava flow—perhaps the most recent in the United States—was also mapped and studied.

Among the economic features studied were the salt lakes of El Paso County, Tex., the gypsum formations of eastern New Mexico, the Cretaceous coal fields in the vicinity of Capitan and White Oaks, the gold and copper mines of the Gallinas and Jicarilla ranges, and the gypsum-soda desert known as the White Sands.

These three months practically resulted in the completion of the reconnaissance of the Trans-Pecos Mountain region between Santa Fe, N. Mex., and the Great Bend of the Rio Grande, which, together with last season's work, will afford abundant data for a valuable report upon that region.

Reconnaissances were also made westward in New Mexico and as far as Tucson, Ariz., in order to obtain a general idea of the continuance of the related features in this direction and to observe where future work should be extended.

Many valuable data were procured concerning the Sacramento forest belt, various irrigation districts, and underground waters.

During the office season Mr. Hill was occupied in working up his notes made during the field season and preparing articles for publication thereon. A monograph on the geology and physiography of the Trans-Pecos region of Texas is in preparation by Mr. Hill.

Weeks party (Utah, Nevada, California).—At the beginning of the fiscal year Mr. F. B. Weeks was in Salt Lake City preparing for field work. He left that city on July 8 with camp outfit and made a reconnaissance geologic survey thence, through Utah, Nevada, and southeastern California, to a point about 30 miles south of Owens Lake, and returning by way of Death Valley, southern Nevada, to Uvada, Utah, reached Salt Lake City on November 10.

Mr. Weeks returned to Washington about November 18 and immediately resumed work on the Catalogue of Geologic Formation Names, examining the literature to January 1, 1901. This work was completed about January 15, 1901. He then began the work of combining all the bibliographies and indexes previously published, for the years 1892–1899, and adding the material for the year 1900. This work was completed soon after the close of the fiscal year. It is now in the hands of the printer, and will be published as Bulletins No. 188 and No. 189.

The manuscript of the Catalogue of Geologic Formation Names is completed except that it needs to be reexamined for uniform arrangement and there needs to be added a chapter describing the plan and scope of the publication and a discussion of the subject of geologic classification and nomenclature.

During the year Mr. Weeks published Bulletin No. 172, Bibliography and Index of North American Geology, etc., for 1899, and a brief paper in the Twenty-first Annual Report, Part VI, on An Occurrence of Hübnerite at Osceola, Nevada. He also served on the Committee on Geologic Formation Names during the year.

For the six months December 20 to June 20 Mr. Weeks had the assistance of Miss Katherine Kelly, who copied on the typewriter the eight to ten thousand cards which form the Catalogue of Geologic Formation Names, and did most of the work of arranging the bibliographies previously published, which will form a part of the Bibliography for the years 1892-1900

PACIFIC DISTRICT.

Smith party (*Washington*).—During the field season Mr. George Otis Smith was engaged in mapping the Ellensburg quadrangle. He was aided by Mr. Frank C. Calkins as geologic assistant. Aside from the importance of the district on account of the study of the underground waters of the North Yakima district, this quadrangle proved an interesting area, since it furnished the key to the physiographic history of the Cascade Mountains, and results were obtained which will be of material assistance in the future work in this range. In October and November Mr. Smith assisted Mr. Arthur Keith in areal mapping in North Carolina and Tennessee.

After Mr. Smith's return to Washington he prepared a report on the Geology and Water Resources of a Portion of Yakima County, Washington, for publication as a Water-Supply Paper; a report on the Coal Fields of the Pacific Coast, for publication in the Twenty-second Annual Report, and a paper treating of the geology and physiography of central Washington, to be published as part of a bulletin entitled Contributions to the Geology of the Cascade Mountains, Mr. Bailey Willis contributing the other part.

Work was also done on the maps and text of the Mount Stuart and Ellensburg folios. The completion of these folios, however, was delayed by necessary topographic revision and the press of other work.

During the year Mr. Smith served on the Petrographic Reference Collection Committee, and also as an examiner of civil-service papers.

The latter portion of June, 1901, was spent in the State of Washington, beginning the geologic reconnaissance of the western portion of the northwestern boundary, Mr. F. C. Calkins again serving as field assistant.

Lindgren party (Oregon).—During July Mr. Waldemar Lindgren was on leave of absence without pay. On August 1 he reported for duty and commenced a reconnaissance of the mining regions of eastern Oregon. Arriving at Baker City, Oreg., after some days of necessary preparations, he began field work, and finished on November 24. Mr. Lindgren returned to Washington on November 30.

The months of December and January were spent in office work, consisting mainly in the revision of the text of the Colfax (Cal.) folio, the revision of older collections to obtain space for new ones, and the preparation of a special collection representing the Boise (Idaho) folio, for the National Museum. A paper was also prepared for the Transactions of the American Institute of Mining Engineers, entitled, Contact Metamorphic Deposits, which was presented at the meeting of the Institute on February 18.

The months of February, March, April, and the first part of May were likewise devoted to office work, consisting of the preparation of a paper for the Twenty-second Annual Report, Part II, entitled, The Gold Belt of the Blue Mountains of Oregon. From May 16 to June 20, inclusive, Mr. Lindgren was absent on leave, returning on the latter date to complete his preparations for the field work of the present summer.

The reconnaissance of the mining region of eastern Oregon is the principal work accomplished during the year. It covers an area of about 6,000 square miles, extending from the Snake River westward toward John Day Valley, and embracing all of the mining districts which recently have come into prominence. A topographic and geologic sketch map of this region was prepared, the former in part with the aid of data obtained from the Baker City and Sumpter sheets, recently completed by the Topographic Branch of the Survey.

The general geologic structure of the region was as carefully studied as the time would admit, and the study showed the presence of a series of Carboniferous (?) and Triassic strata, greatly disturbed and intruded by heavy masses of granitic post-Triassic rocks. The whole series has an east-northeast strike and a varying dip, and is surrounded by enormous areas of Tertiary lavas. The primary mineral deposits, apparently all post-Triassic and pre-Tertiary, consist chiefly of gold-quartz veins in strongly defined systems, with northeasterly trend, analogous in development and metasomatic features to those of California and central Idaho. Besides these, the Triassic lavas contain more irregular replacement deposits of copper ores, consisting of bornite, chalcocite, and chalcopyrite.

All the important mines and prospects containing these two classes of ores were visited and have been fully described in the report mentioned.

Diller party (*Oregon*, *California*).—Mr. J. S. Diller devoted July and the greater part of August to the completion of the Port Orford quadrangle, Oregon, surveying the region of Sixes River, Elk River, and Johnson Creek, which are economically the most important parts of the quadrangle on account of their gold mines and the prospects for coal.

During the latter part of August, September, and the first half of October special attention was given to the physiography of the Klamath Mountains. The party traveled southward along the coast from Rogue River in Oregon to Russian River in California, turning aside at Crescent City and Eureka to make trips into the interior. The Coast Range of California was crossed near Ukiah, and a reconnaissance was made northward among the foothills of the Sacramento Valley, to determine, if possible, the relation of the Klamath Mountain peneplains to the Sacramento Valley and the Sierra Nevada.

On May 15 Mr. Diller started northward through the Coast Range from San Francisco, Cal., to extend the observations upon the morphogeny of that region as far north as the Oregon line. On completion of this work, in the latter part of June, the party began investigations at Crater Lake to determine the temperature of its deep waters and their outlet, as well as to extend observations upon the glacial and volcanic phenomena of that remarkable feature.

In the office a paper was prepared on the Morphogeny of the Klamath Mountains, which was read at the Albany meeting of the Geological Society of America. Later the paper was enlarged, and is now ready for publication as a bulletin of the Survey.

The rocks of the Port Orford quadrangle were studied and the maps and part of the text for that folio were prepared.

The geologic map of the Crater Lake region, in Oregon, was drawn and the report was nearly completed. It will probably be offered for publication by the Survey as a folio.

To meet the demands upon the Geological Survey for specimens for educational purposes, a number of additional small collections of remnants, containing about 60 specimens, were made up, and twenty-two were sent to institutions willing to bear the cost of transportation. Thirteen such collections are yet on hand, and when disposed of the material of the Educational Series will be entirely exhausted. Chips for thin sections were supplied to twelve institutions, upon application.

The routine work involved in the care of the petrographic laboratory was considerable, although Mr. Diller was relieved of much of this by Miss Park, stenographer, who kept the records very satisfactorily.

Messrs. F. C. Ohm and William Ohm were employed continuously throughout the year in the petrographic laboratory, making thin sections. Mr. W. S. Robbins was employed most of the time in the same laboratory, but during the summer and after April 1 he was assigned to other duties. During the year there were 3,956 sections prepared in the laboratory; 619 specimens were sawed, and 138 were polished for study.

Turner party (*California*).—Mr. H. W. Turner commenced field work in the Yosemite quadrangle about the middle of July and finished the revision work of that quadrangle about August 10. Mr. H. R. Johnson served as field assistant. The party proceeded from the Yosemite quadrangle to the Mount Lyell quadrangle and was occupied in geologic work on that quadrangle until about September 12, during which time approximately 250 square miles were geologically mapped, although a portion of this area probably needs revision, as the exact character of the rocks was not then understood. During this time nearly all of the mines and prospects of this region were visited. The interesting discovery was made that some of the limestone of the east slope of the Sierra is of Carboniferous age and that the schists and slates of the Mount Dana region are pretty certainly of early Mesozoic age, since they overlie the Carboniferous rocks and are almost certainly older than the Cretaceous.

From the middle of September to about the middle of October Mr. Turner, assisted by Mr. Johnson, was engaged in office work at San Francisco. About the middle of October he proceeded, with Mr. Johnson as assistant, to the Silver Peak region, in Esmeralda County, Nev, and remained there until the latter part of November. During this period the revision of the geologic map of the Silver Peak quadrangle was completed and a reconnaissance was made of a portion of Esmeralda County.

Subsequently, in the San Francisco office, Mr. Turner prepared a paper on the Mining Geology of Esmeralda County, which was transmitted for publication. Considerable time was also devoted to writing up the geology of the Silver Peak quadrangle and studying the thin sections of the rocks.

Branner party (*California*).—During the last year the work in charge of Prof. J. C. Branner in the Coast Ranges of California was confined almost entirely to the Pescadero quadrangle. This work was distributed over all four of the smaller quadrangles of which the Pescadero is composed—the Palo Alto, Halfmoon Bay, Pescadero, and Santa Cruz; some work was also done in the Mount Hamilton quadrangle.

Work done under the direction of Professor Branner in the Salinas Valley, Monterey County, and in Los Angeles, San Diego, and Ventura counties, has thrown much light on the geology of the Pescadero quadrangle and on that of the Coast Ranges generally. The separation of certain of the Tertiary beds in the area under study can be made only on paleontologic evidence, and in this part of the work Professor Branner was ably assisted by Mr. Ralph Arnold. The faulted condition of the soft rocks, the deep decomposition of the beds, and, in places, the thick covering of underbrush or of redwood forests render the working out of geologic details in many parts of the area slow and difficult.

Campbell party (*California*).—On February 15, Mr. M. R. Campbell proceeded to southern California to study the salt and borax deposits of the Mohave Desert region. Six weeks were devoted to this work by Mr. Campbell, with Mr. R. B. Rowe as field assistant. During this time over 600 miles were traversed and most of the important deposits of that part of the State were investigated.

UNITED STATES AT LARGE.

Eldridge party.—Mr. George H. Eldridge passed three-fifths of the fiscal year in preparing an extended report on the asphalt and bituminous rock deposits of the United States, the data for which had been gathered during the fall, winter, and spring preceding. The remainder of the year was occupied with the report on the Florida phosphate deposits, which will require yet a month or two for completion.

Gilbert party.—During the year the chief work of Mr. G. K. Gilbert was the preparation of a report on geologic investigations in Alaska made in connection with the Harriman expedition. This report was completed. The first part describes the glaciers examined, discusses their variations in size as shown by comparison with earlier observations and by various kinds of physical evidence, and treats incidentally of the origin of certain features of glacial drift. The second part treats of the Pleistocene glaciation of the region visited, discussing the extent of the ancient glaciers and ice fields, the magnitude of the erosive work performed by them, and some of the principles of glacial erosion.

Mr. Gilbert also wrote a brief text for a special map of Niagara River, issued by the Survey in connection with the Pan-American Exposition.

The last weeks of May and the first days of June were spent by Mr. Gilbert in preparation for field work in the Great Basin. Mr. Willard D. Johnson, topographer, being detailed to Mr. Gilbert, reported for duty on June 1. They outfitted at Salt Lake and work was commenced in Utah. The general subject assigned is a review of the question of the mode of origin of the mountain ranges and intervening valleys of the Great Basin region.

Girty party.—See under "Paleontology," pages 99–100.

ALASKA.

SEWARD PENINSULA.

Brooks party.—Mr. Alfred H. Brooks assembled his party for work in the Nome region on June 6, 1900. The party consisted of Mr. George B. Richardson and Mr. A. J. Collier, geologic assistants, and six camp hands. They embarked for Golofnin Bay, Alaska, on the Coast Survey steamer *Pathfinder*. From Golofnin Bay they ascended the Fish and Niukluk rivers to the Koksuktapaga, using canoes for transportation. At this point Mr. Richardson was detailed to examine the Ophir Creek, Koksuktapaga, Topkok, and Solomon River mining regions. He accomplished the task by September 15, and then spent about ten days in the Nome region proper. The rest of the party portaged supplies and canoes from the Upper Niukluk to Kruzgamepa. From the headwaters of the latter river Mr. Collier, aided by two men, made a study of the geology of the Kigluaik Mountains, while Mr. Brooks, with one man, made a trip to Nome for the purpose of studying the geologic section. After the party had reassembled, a hasty reconnaissance was made of newly discovered gold fields, known as the Kugruk district. In this region a reconnaissance topographic map was constructed, with traverse planetable, embracing an area of about 1,000 square miles.

Port Clarence was reached on September 1, at which point Mr. Collier was put in charge of a detached party of two men, which made a trip to the Penny River region and later joined Mr. Richardson at Nome. Having accomplished their respective tasks, both of these subparties sailed for San Francisco on September 27, on the U. S. S. *Pathfinder*.

From Port Clarence Mr. Brooks, by the courtesy of Captain Tuthill, secured transportation for himself and one camp hand to York on the U. S. S. *Bear*. Some ten days were spent at York and vicinity. Reconnaissance mapping, both topographic and geologic, was extended to include Cape Prince of Wales.

After returning to Port Clarence late in September, a hasty trip was made into the Bluestone region, where important gold placers had been discovered in August. From Nome Mr. Brooks returned to Seattle on the U. S. S. *Patterson.*

The results of the season's work were a geologic reconnaissance of an area of about 6,000 square miles, topographic reconnaissance maps of areas lying outside of the region, surveyed by Mr. Barnard, aggregating about 1,500 square miles, and a study of the occurrence of placer gold on nearly one hundred different creeks included in nine different gold districts. The most important conclusion reached is that there is a second belt of gold-bearing rocks lying about 30 miles north of the Nome region proper. This fact points toward the conclusion that the gold-bearing region of Seward Peninsula is much larger than was at first supposed.

The discovery of the occurrence of stream tin at York is of scientific interest and has a possible commercial interest. Many important data were also obtained regarding the structural geology of the region and its physiographic development and glacial history.

The office work of the winter consisted chiefly in study and formulation of the data acquired during the previous summer's investigations. The results have been submitted in a report entitled A Reconnaissance of the Nome and Adjacent Gold Fields of the Seward Peninsula, which will be published soon by authority of a resolution of Congress. Agreeable to a popular demand for the results of the investigation, a paper describing the new gold fields was read before the American Institute of Mining Engineers and subsequently published in the May number of Mines and Mining. A brief note was also published describing the placer tin at York.

In the preparation of the Nome report mentioned above, Mr. Brooks was assisted throughout the winter by Messrs. Richardson and Collier. The latter prepared a chapter on the flora of the region, based on collections made by himself and kindly determined by Mr. Frederick V. Coville, of the Department of Agriculture. Mr. Collier also compiled a summary of the available meteorologic data relating to the region. The climatic conditions and the distribution of timber and grasses have such an important bearing on the development of the region that it was thought best to include these two chapters in the report.

Mr. Brooks also prepared a brief description of the occurrence of stream tin at York, for publication in the volume on Mineral Resources, 1900.

During the month of May Mr. Brooks was occupied in writing a summary of the coal measures of Alaska, for publication, along with other similar summaries, in the Twenty-second Annual Report. While the report is, for the most part, a compilation, yet some important facts have been brought to light regarding the distribution of the coal-bearing rocks in Alaska.

In accordance with instructions of the Director, Mr. Brooks submitted on March 21 a comprehensive plan for geologic and topographic surveys in Alaska, embracing a period of ten years on the basis of the present appropriation of $60,000.

Peters-Mendenhall party.—Mr. W. C. Mendenhall, assigned to work in Seward Peninsula as member of the party in charge of Mr. W. J. Peters, topographer (see pp. 167–168), proceeded to Seattle in May, 1900, and embarked on the Coast Survey steamer *Pathfinder* for Golofnin Sound.

The original plan of operations for the party had contemplated the ascent of Koyuk River, the portage over it to some stream flowing northward to Kotzebue Sound, and the return over some route not specified to Golofnin Sound. In order to make the mapping more continuous and valuable over an area which promised to develop economically within the near future, this plan was modified when the party reached the field, and it was decided to ascend, in order, Fish, Tubutulik, and Koyuk rivers, and to map their basins topographically and geologically in such detail as was possible. This plan was carried out, and the result was a compact and rather continuous reconnaissance map over a territory somewhat less in area than that which it was contemplated to cover in the original plans. The field work being completed, Mr. Mendenhall and others of the party returned to Golofnin Sound on September 26, reembarked on the *Pathfinder*, and were landed in San Francisco on October

15. Mr. Mendenhall returned to the office early in November and immediately began the elaboration of the summer's results. This work had advanced through its earlier stages, when, in anticipation of an appropriation by Congress to become available sufficiently early to permit of parties entering northern Alaska over the ice, plans for such a trip were formulated and submitted to the Director for approval. During this period of anticipation of an early departure from Washington, work on the report was pushed with all possible speed, but later it became evident that funds would not be available in time for the winter trip, and the plans submitted for it were abandoned. The preparation of the summer's report was then continued, and the manuscript and illustrations for it were submitted on the 1st of April.

Then plans for a summer's work in the Kowak River Basin were taken up and perfected on the basis of a working season of approximately three months. A party for this work was organized, and it left Seattle for the field of operations about May 18.

COPPER RIVER DISTRICT.

Schrader party.—Mr. F. C. Schrader was assigned to work in Alaska during the field season of 1900, to conduct a survey of the Chitina copper district of the Copper River region. He was assisted by Mr T. G. Gerdine, assistant topographer, and by Mr. Arthur C. Spencer, assistant geologist.

Leaving Washington in May, Mr. Schrader's party reached Valdes, Alaska, in June. Owing to the impassability of the trail leading through the Coast Range into the Copper River Basin, the party was obliged to remain in Valdes until early in July. During July, August, and September reconnaissance survey work was carried on about the headwaters of the Chitina and Copper rivers, embracing observations on McCarthy Creek, Nikolai Creek, Nizina River, Tana River, Tebay Creek, and other tributaries of less importance. In October Copper River was descended to the coast, and a geologic reconnaissance and triangulation about Prince William Sound was made. November was occupied in part by office work at Orca, Alaska, while waiting for a vessel, and by the return to

Washington. The months of December and January were devoted to work on the Copper River report, which will be published soon by authority of a resolution of Congress. In February preparations were made for the field work of 1901, and early in March Mr. Schrader left Washington for Alaska, being assigned to duty as geologist with the party under Mr. W. J. Peters, topographer, for exploration in northwestern Alaska.

FIELD AND OFFICE WORK BY THE DIRECTOR.

The general administrative work of the Survey occupied the greater part of the Director's time. At the request of the Secretary he made a detailed examination of the eastern and southern boundaries and adjacent areas of the Lewis and Clarke Forest Reserve, Montana, during the months of July and August. A report was submitted recommending certain changes in portions of the eastern and western boundaries. Incidental to the examination of the forest reserve, observations were made and notes taken on the geology of the region passed over.

In the office the monographic study of the Cambrian faunas was continued as opportunity permitted.

The Director was assisted by Miss Jean F. Kaighn, confidential clerk, and by many others in the Survey as occasion required.

DIVISION OF PALEONTOLOGY

The work of the paleontologist borders closely on that of the geologist. Most of the paleontologists were engaged from time to time in assisting geologists to determine and correlate various formations.

Girty party (*Carboniferous*).—Dr. George H. Girty spent one month of the field season of 1900 in Indian Territory, determining horizons and checking paleontologic with stratigraphic evidence. Another month was spent in Colorado, where he acquainted himself with the conditions of geologic work in the Rocky Mountains and the methods employed to meet them. Dr. Girty also spent three weeks in studying the sequence of fossil faunas in the Wasatch Mountains, in Utah, between Ogden and Provo, and one week at Bingham Canyon, making collections from the strata that were being mapped by Mr. Keith's party. Another month was spent in northeastern Ohio, tracing the different formations of the Waverly group from Cuyahoga County to the Pennsylvania line, where his work had been dropped the year before.

In the office Dr. Girty devoted considerable time to revising a report on the stratigraphic paleontology (Carboniferous) of Colorado, incorporating collections made during the previous summer, supplying a bibliography, etc. He also spent some time in verifying and bringing up to date a card catalogue of North American Carboniferous invertebrates. He also examined and reported upon a number of collections of fossils for various members of the Survey, in connection with their areal geologic work. Some of the reports were of a preliminary character and others were complete, ready for publication.

Stanton party (Cretaceous).—Mr. Stanton left Washington for California early in July to study and collect from the Cretaceous rocks of the Pacific coast, especially the Horsetown and Chico beds. He spent five days in Colorado en route, so that he did not reach Redding until the 14th. From Redding he proceeded to Ono, on the north fork of Cottonwood Creek, Shasta County, where one of the standard sections of the Horsetown and Chico beds is well exposed and fossils are abundant. The Cretaceous rocks were studied for several miles around Ono, the examination extending to Horsetown and Texas Springs and to the exposures near Redding. This occupied his time for a month, during which important collections were obtained.

During the last half of August Mr. Stanton made a trip into southern Oregon to study the Cretaceous rocks at a number of localities where the exact correlation of the beds had been somewhat doubtful. On this trip he visited Grave Creek, Jacksonville, Phœnix, Ashland, and Siskiyou, and obtained conclusive evidence that the Cretaceous rocks near all of these places belong near the base of the Chico.

Returning to California, he spent the first nine days of September in the neighborhood of Lowrey, on Elder Creek, Tehama County, where all the divisions of the Cretaceous section are greatly developed. Continuing southward for the purpose of crossing the Cretaceous belt west of the Sacramento Valley at a number of points, he spent five days working from Fruto, Glenn County, as a center, and a week at Sites, Colusa County, from which place he extended his observations 30 miles southward by a wagon trip.

On September 21 he went to San Francisco, and remained there until the 24th, examining the paleontologic collections in the University at Berkeley, the State Mining Bureau, and the Academy of Sciences.

The remainder of the month and the first three days of October he spent in southern California, with Los Angeles as headquarters, from which, under the guidance of Dr. Stephen Bowers, of the State Mining Bureau, he made trips to Cretaceous localities near Chatsworth Park, in Los Angeles County, and near Corona, in Riverside County.

The stratigraphy was studied and collections were made at all the localities mentioned, 16 boxes of fossils being shipped from the field during the season.

In the office the study of fossils sent in for examination and report by the geologists of the Survey and by correspondents of the Survey and the National Museum occupied a considerable portion of Mr. Stanton's time, reports having been prepared on 33 such lots or collections during the year. He also furnished to Dr. John C. Merriam a brief report on the Cretaceous invertebrates collected by him in the John Day Valley, Oregon, which has been printed in his Contribution to the Geology of the John Day Basin.

In February work was resumed on the study and description of the Lower Cretaceous faunas of the Texas region, for the monograph which has been in preparation for some years, and that work was continued to the end of the year, with only the ordinary interruptions occasioned by routine matters.

Ward party (Triassic).—During the month of July Professor Ward was in London and Paris, consulting in the libraries of those cities such literature as would be of interest to him in his work, more particularly in connection with the Compendium of Paleobotany. He was also in attendance during the Paris meeting of the International Association for the Advancement of Science, Arts, and Education. In August he attended the meetings of the International Geological Congress, which closed on the 27th, and on the 29th he joined an expedition of the Geological Congress to the great coal basins of central France, from which one of the largest Carboniferous floras of the world had been obtained. The sources of the extensive collections of fossil plants that have been made from these regions were visited and their mode of occurrence was carefully studied. He returned from his visit abroad the 22d of October, and gave the remainder of the month to delayed correspondence and accumulated work. November to February were devoted almost entirely to the work of the Compendium of Paleobotany. This work went on during the entire winter. In April it reached a point where it might be conveniently left in the hands of his clerk, Miss L. M. Schmidt, for continuance. On the 18th he received the report of Prof. William M. Fontaine on the Jurassic plants of Oregon, collected by himself, and the types were turned over to the Division of Illustrations to be drawn. Conformably to instructions received from the Director, Professor Ward left Washington on the 3d of May for Holbrook, Ariz., to study the Older Mesozoic or saliferous deposits of the Little Colorado drainage, and particularly to make paleontologic collections from them. The valley of the Little Colorado was followed for a distance of more than 100 miles, nine days being occupied in the journey from Holbrook to Tanners Crossing, where the road from Flagstaff to Tuba and Lees Ferry crosses the Little Colorado. Near this place Professor Ward discovered fossil bones, and this general region seemed to promise the best results. Camp was accordingly made at this point. Investigations were extended 30 or 40 miles to the northeast of the camp, beyond Tuba City, and also farther down the Little Colorado, to the beginning of the canyon at the base of Coconino Point and the foot of the Colorado Plateau. The geologic section of the river and across the valley was examined in detail. The collections made in the lower Little Colorado Valley were taken to Flagstaff and shipped from there to Washington. Early in June an expedition was conducted to Red Butte and the Grand Canyon, and later a somewhat thorough study was made of the upper Little Colorado Valley and especially of the region of the petrified forests. Many sections were made. The work was concluded before the close of the fiscal year.

During the year Miss Schmidt continued work on the bibliography of paleobotany, and also arranged in the catalogue of paleobotany some 50,000 slips.

Knowlton party (*Cretaceous and Tertiary*).—Dr. F. H. Knowlton did not undertake field work during the year, but spent the entire time on material already in hand. It was deemed better to do this than to accumulate collections that could not be studied for some time.

From July 1 to November 20, with some unimportant exceptions, his time was spent in work on a monograph on the Flora of the Puget Formation, mention of which was made in the Twenty-first Annual Report. This work then embraced about 500 manuscript pages and included descriptions of 259 species. His work on this flora was then suspended on account of the impossibility of procuring illustrations, and also to give opportunity for work on various small collections, reports on which were asked by geologists.

In November Dr. Knowlton undertook the study of a small collection of fossil plants from the John Day Basin of Oregon, obtained by Dr. John C. Merriam, of the University of California. As the National Museum has had in its possession since 1884 much larger collections from this general region which were unstudied, this was deemed a good opportunity to take up the study of all known material from this basin, with the view of presenting the results in the form of a bulletin of the Survey. This material, numbering several thousand specimens, was carefully studied and some 200 pages of manuscript were prepared, in which were included descriptions of many new species. As this study progressed it became more and more evident that the results could not be fully and satisfactorily presented without including a review of the whole Tertiary flora of the Pacific coast. The relationships of the John Day flora are clearly with that of the Auriferous gravels and allied formations of California, and consequently it becomes necessary to go over this material before the former can be completed. Very little work has been done on the Auriferous gravels flora since 1878, when Lesquereux published his report on it, and much unstudied material obtained by Diller, Lindgren, and Turner during the last ten years is in hand. The months of April and May were given to the study of this California material. During the coming field season it is proposed to have Dr. Knowlton visit and collect fully from the John Day Basin and the Auriferous gravels and allied formations in California, for the purpose of accumulating material that may serve as a basis for a complete presentation of the Tertiary floras of the Pacific coast.

The month of June was spent in southern Colorado and northern New Mexico, in company with Mr. Whitman Cross, in collecting and studying the distribution of the various Upper Cretaceous and Lower Tertiary floras of that region. Reports were also made upon a number of small collections of fossil plants during the year.

Dall party (*Tertiary*).—Dr. William H. Dall continued his special studies of the Tertiary faunas of the United States. Work was done on two very large collections—one made at Plum Point, Md., in the local Miocene horizon, the other from the banks of Shell Creek, Florida, in the Pliocene. The Plum Point collection has been completely segregated, and the Maryland survey has found it so rich as to consult it at frequent intervals for species not found in its own collection. All available facilities have been afforded the members of the Maryland survey for study and comparison of specimens and the figuring of sundry types not elsewhere accessible. The work on the Shell Creek collection is in progress, and from these and other material received during the year about 50,000 duplicates have been segregated from the reserves and placed in storage.

Mr. T. W. Vaughan cooperated with Dr. Dall to some extent during the year. When in the city Mr. Vaughan continued the work of selecting a study series, segregating duplicates, and labeling the reserves in the Eocene collection (see next heading, "Vaughan party").

The desirability of verifying certain fossils described by Emmons and Adams led to a visit by Dr. Dall to the collections at Williams and Amherst colleges, where the types were preserved, two weeks being occupied in this work.

Numerous collections of fossils sent in during the year by members of the Survey were studied and their age was reported on for determination of the horizons. The most important of these was a large collection from southern Oregon and northern California, obtained by Mr. J. S. Diller and his party, on which a written report was submitted.

Mr. Ralph Arnold, of Stanford University, a pupil of Dr. Branner, has been making a special study of the Pleistocene of southern California, and as the working up of this fauna is important for students of later California geology, Dr. Dall assisted Mr. Arnold to the extent of his ability, especially in the critical identification of doubtful species. Many valuable specimens have been contributed by him to the collections of the National Museum.

Dr. Dall's special work, on the revision of the Tertiary of the southeastern region of the United States, especially Alabama and Florida, was continued in the intervals of other work. Part V of the text has been printed and issued, comprising some 270 pages and 12 plates, making a total so far of about 1,250 pages and 47 plates issued. The continuation of the work as far as accomplished has included the revision of a number of families, including the Crassatellitidæ and the great group of Lucinacea.

During the year Dr. Dall was assisted by Dr. Frank Burns, whose time has been chiefly employed in collecting and selecting, cleaning, sorting, and preparing the specimens collected.

Vaughan party.—July and the first part of August were spent in arranging and identifying fossil corals belonging to the Geological Survey and deposited in the National Museum. The manuscript on a collection of corals from Porto Rico, written for the Fish Commission, was completed. On August 15 Mr. Vaughan left Washington for the field, going first to Jackson, Miss., where about a week was spent in making an extensive collection of Eocene fossils belonging to the Jackson group. A study was also made of the local stratigraphy and the geologic section revealed there.

From Jackson Mr. Vaughan went to Vicksburg and made as large a collection of the Vicksburgian Oligocene fossils as possible. Leaving Vicksburg, he went to Natchitoches and

Montgomery, La. Collections were made at both of these places, and also at St. Maurice, La. The horizons represented are Eocene—Jacksonian and Lower Claibornian.

He then made a special study of the section of Upper Oligocene and Miocene as exposed along Apalachicola River from the southern boundary of Georgia as far down as Blountstown. Special attention was given to deposits of fuller's earth near River Junction. A trip was made to Bainbridge, Ga., to make collections of corals from some horizons of undetermined age, and to make a careful study of the relations of the Lower and Upper Oligocene formations. His work in this vicinity was very successful, and he succeeded in getting good collections of fossils from at least three horizons.

A special study was made of the fuller's earth deposits of southern Georgia and Florida, between Apalachicola River and Tallahassee, and collections were made from other localities. From Tallahassee Mr. Vaughan went to Jacksonboro, Ga., to study one of Lyell's type localities and make a collection of fossils there. The locality was rediscovered without difficulty and a fair collection of fossils was obtained. He then proceeded to Waynesboro, Ga, and thence to Shell Bluff, on Savannah River. The age of this locality has given rise to much discussion. A fair collection of fossils was made here, so that all of the strata, probably excepting the upper 10 to 14 feet, can be definitely correlated with known horizons of our Tertiary sections elsewhere. They are Claibornian in age, and belong below the horizons of the Claiborne sands. From Waynesboro Mr. Vaughan returned to Washington.

In the office Mr. Vaughan's work consisted in large part of the preparation of a monograph on the post-Eocene fossil corals of North America and of the identification of specimens submitted to him.

On March 18 Mr. Vaughan left Washington for Cuba, on detail as assistant to Mr. C. W. Hayes, in a reconnaissance of the island with special reference to its mineral resources (see p. 62). He returned to Washington on June 24 and spent the remainder of the fiscal year in the office.

Osborn party (Vertebrates).—The preparation of the paleontologic monograph entitled The Titanotheres was begun on

January 2, 1901, with the assistance of Messrs. W. K. Gregory and A. E. Anderson, and was pushed forward as rapidly as possible. On June 30, so far as can be judged, the work was about half completed. The collections in the National Museum, American Museum, Yale, Harvard, and Princeton museums, Field Columbian Museum, and Carnegie Museum were studied, and numerous new illustrations were prepared. In order to secure a firm geologic basis for the paleontologic work, a special exploration of the White River Oligocene was undertaken during the month of June by Messrs. N. H. Darton, of the Survey, and J. B. Hatcher, of the Carnegie Museum, accompanied by Prof. Eberhard Fraas, of Stuttgart, as a volunteer. Exact stratigraphic data were secured, and the horizons of all the important type species were located.

In connection with the monograph entitled The Sauropoda explorations were carried on at the expense of the American Museum in Wyoming, and large additional collections were procured. In order to ascertain the exact requirements of the geologic and stratigraphic portions of this memoir, Professor Osborn made a special exploration of the Jurassic exposures, accompanied by Professor Fraas, who has made a prolonged study of the Jurassic of Europe. The fresh-water and marine sections examined were the classic localities of Canyon and Morrison, in Colorado; the section west of the Rockies, especially on Green River, Utah; the rim section of the Black Hills, and all the sections in the Como region of Wyoming. Professor Fraas is satisfied that an exact correlation between the American and European Jurassic can be established, and he is preparing a paper on this subject.

Special attention was given to the exploration of the Trias of Arizona, under the direction of Prof. Lester F. Ward, of the Survey, and Mr. Barnum Brown, one of Professor Osborn's assistants. The collections were sent to the National Museum. Correspondence was also held with Messrs. Whitman Cross and Robert T. Hill regarding the age of the so-called "American Jurassic." It is hoped that this disputed problem will soon be settled by the exact geologic and paleontologic investigations which are now in progress.

DIVISION OF MINING AND MINERAL RESOURCES.

In view of the extension of the duties of the Division of Mineral Resources, its title was changed to Division of Mining and Mineral Resources, in order that the title might indicate more clearly the fact that the work of this division of the Geological Survey is devoted to the interests of the mining community of the United States, and especially to distributing information which will be of direct economic value to those who are engaged in developing our mineral resources, as well as those seeking information concerning the occurrence of useful minerals.

The principal feature of the work of the Survey in this direction during the year which has recently closed, as a result of the increased facilities given by Congress, was the investigation of the conditions of occurrence of certain important economic minerals, particularly asphaltum, in its distribution over the entire United States—work commenced during the previous year by Mr. George H. Eldridge. Mr. Eldridge is also extending his work to the investigation of the petroleum resources of the Pacific slope, with a view to determining the general conditions under which petroleum occurs in that region. The experience here gained will be applied promptly to the newly discovered petroleum fields in the Beaumont region of Texas. Analogous investigations have been carried out concerning the distribution of borax and of salt in southern California by Mr. Marius R. Campbell, geologist. In connection with the Division of Economic Geology (nonmetalliferous section), a report on the coal fields of the United States, in which the subject is considered from a commercial standpoint, has been prepared and will be published at an early date.

The work directed by Congress of examining the conditions of occurrence of the precious metals of the United States has also been undertaken, with the result of obtaining a list of the gold and silver mines of the United States and all possible information concerning the characteristics of each mine, with a view to collecting the statistics supplementary to the report of the Director of the Mint during the coming year. In this the basis of work will be a statement of the production of each mine, as well as a statement of the conditions governing the occurrence of the precious metals in each district.

By the request of the Director of the Census, the collection of the statistics of coke, petroleum refining, and salt manufacture was directed by Mr. E. W. Parker, and that of clay products by Mr. Jefferson Middleton, of this division. Two of these investigations have been completed and the results published; the others are well advanced.

By the request of the president and director-general of the Pan-American Exposition, the work of organizing the exhibits illustrative of the mineral resources of the United States and Canada was taken up by this division of the Survey. The department was organized by Dr. David T. Day, in addition to his regular work, with the result that the mineral resources of the region of the Great Lakes, with which an exposition at Buffalo must be especially concerned, have been set forth with unusual thoroughness.

In addition to the various special agents who have aided in the work, Dr. Day was assisted by Mr. Edward W. Parker and Mr. Jefferson Middleton, statisticians; Miss Evangeline E. Crowell, Miss Helen M. Hough, Mrs. Lotta L. Kimball, Mrs. Mary M. Raborg, and Mr. George T. Sabourin, clerks; and Miss Belle W. Bagley, Miss Altha T. Coons, Miss Julia M. Corse, Miss Agnes Gerry, and Mr. Theodore Johnson, statistical experts.

The statistics of mineral production as collected by the Division of Mining and Mineral Resources show that the value of all of the mineral products in the calendar year 1900 exceeded one billion dollars and eclipsed all other records in our history. The value of these mineral products was almost equally divided between the metallic and nonmetallic substances. The value of all the metallic products obtained was $549,934,370; the value of the nonmetallic minerals produced was $516,519,036. These, with one million dollars' worth of estimated unspecified products, made a total of $1,067,533,406, an increase of nearly one hundred million dollars over 1899, and of over four hundred millions as compared with 1898. The increases were general throughout the different branches of the mineral industry, and in a few cases where the product in 1900 was less than it was in 1899 the values sometimes showed increases notwithstanding the decreased output.

The details of production of the various mineral substances are briefly stated in the following paragraphs:

METALS.

Iron and steel.—The great record-breaking output of pig iron in 1899, which was 13,620,703 long tons, valued at $245,172,654, was maintained and even exceeded in 1900, notwithstanding the general feeling that the output of 1899 would not be equaled in 1900. The production of pig iron for 1900 was 13,789,242 long tons, valued at $259,944,000. This is an increase of 168,539 tons, or 1.24 per cent, and of $14,771,346, or 6.02 per cent. This gain is insignificant, however, when compared with the gain in 1899 over 1898. In the former year the gain over the latter was 1,846,769 long tons, or 15.69 per cent, while the value increased $128,615,654, or 110.35 per cent. This great increase, especially in the value, was the result of abnormal conditions and of course could not be expected to be maintained. In fact, in the face of the large production of 1899, which appeared to be an overproduction, it is astonishing that the output and value of this commodity should have kept up. The average price per ton of pig iron increased from $18 in 1899 to $18.85 in 1900. This was very close to the maximum price of $19 reached in 1887. The average price per long ton in recent years has been as follows: 1897, $9 85; 1896, $10.47; 1895, $11.14; 1894, $9.76; 1893, $11.90.

The production of Bessemer steel ingots decreased from 7,586,354 long tons in 1899 to 6,684,770 tons in 1900. This is a loss of nearly a million tons and makes the production in 1900 about the same as that of 1898, when it was 6,609,017. The production of open-hearth steel in 1900 was 3,398,135 long tons, which is an increase from 2,947,316 tons in 1899. The production of Bessemer steel rails increased from 2,240,767 long tons in 1899 to 2,383,654 tons in 1900.

Iron ores.—The production of iron ores in the United States during 1900 amounted to 27,553,161 long tons, as compared with 24,683,173 in 1899, a gain of 2,869,988 tons, or 12 per cent. The value of the iron ores mined in 1900 was $66,590,501, as compared with $34,999,077, a gain of $31,591,427, or 90.26 per cent.

The production of 1900, as of 1898 and 1899, not only exceeded all previous records for this country but the outputs of iron ores during these years have never been equaled by any other country, the nearest approach to our output being in 1900 by the German Empire, when 18,667,950 long tons were produced.

Copper.—The great activity of 1899 in the copper industry was continued during 1900. The product increased from 568,666,921 pounds in 1899 to 606,117,166 in 1900, a gain of 37,450,245 pounds, or 6.59 per cent, while the value decreased from $101,222,712 in 1899 to $98,494,039 in 1900, a loss of $2,728,673, or 2.7 per cent. While the average price per pound during 1900 was high compared with that obtaining during the last decade, it was nevertheless lower than the price in 1899. The average price per pound in 1900 was 16.25 cents; in 1899 it was 17.8 cents, and in 1898 11.75 cents. While in 1900 some of the leading producers did not mine as much metal as in former years, others largely increased their output. There was great activity in the opening up of old mines and the development of new properties, but few reached the production stage in 1900.

Lead.—The lead smelting and refining industry in 1900 was marked by an unprecedented increase in production over the preceding year. The output increased nearly 30 per cent, from 210,500 short tons in 1899 to 270,824 short tons in 1900. The value increased from $18,945,000 to $23,561,688. The increased production is attributed to the stimulating effect of the high prices which prevailed, and which were artificially established and maintained by the consolidated interests of the smelting and refining works. It is believed that the consumption did not increase in proportion to the increase in production.

Zinc.—The production of zinc decreased from 129,051 short tons in 1899 to 123,886 in 1900, a decrease of 5,165 tons, or 4 per cent. The value showed a still greater decline, from $14,840,865 in 1899 to $10,654,196, or a decrease of

$4,186,669, or 28.21 per cent. The product in 1900 was considerably more than that of 1898, though the value was about the same, namely, 115,399 short tons, valued at $10,385,910.

Gold.—The gold product continued to increase, rising from 3,437,210 fine ounces in 1899 to 3,829,897 fine ounces in 1900, while the value rose from $71,053,400 in 1899 to $79,171,000. In 1898 the gold product was valued at $64,463,000.

Silver.—The coining value of the silver product in 1900 was $74,533,495, as compared with $70,806,626 in 1899. The commercial value of the product was $35,741,140, or 47.95 per cent of the coining value.

The production in 1900 was 57,647,000 fine ounces, while in 1899 it was 54,764,500 ounces. The average value per ounce, commercially, in 1900 was 62 cents; in 1899 it was 60 cents, and in 1898 it was 59 cents.

Quicksilver.—The production of quicksilver continued to decrease, notwithstanding the developments in what is known as the Terlingua district of Texas. The output in 1900 was 28,317 flasks of 76½ pounds net, as compared with 30,454 flasks in 1899 and 31,092 flasks in 1898. The value declined from $1,452,745 in 1899 to $1,302,586 in 1900. The production in 1900 includes a small amount, 200 flasks, reported from Oregon

Aluminum.—The Pittsburg Reduction Company, operating under the Hall patents, continues the only producer of metallic aluminum in the United States. The production in 1900 was about 6,000,000 pounds, valued at $1,920,000, as compared with 5,200,000 pounds in 1899, valued at $1,716,000.

Antimony.—The amount of antimony obtained from ores of domestic production in 1900 was 151 short tons, valued at $27,180, as compared with 234 short tons, valued at $43,000, in 1899. This is a decrease of 35.47 per cent in production and 36.79 per cent in value. The domestic product is but a small proportion of the antimony consumed in the United States, the total product obtained from imported ores being estimated at 1,750 short tons, valued at $346,980, in 1900, as compared with 1,275 tons, valued at $251,875, in 1899. The total consumption, however, in 1900 was estimated to have been 3,577 short tons, valued at $634,917. The difference between this total and the domestic product—1,827 short tons, valued at $287,937—was imported as crude antimony, or regulus.

Manganese ores.—The production of manganese ores increased from 9,935 long tons in 1899 to 11,771 tons in 1900, thus recovering partially from the decline in 1899 from 1898. This was an increase of 1,836 tons, or 18.48 per cent, and $18,011, or 21.89 per cent. The average price per ton was $8.52 in 1900, as compared with $8.28 in 1899. The bulk of the manganese ores in 1900 used by the steel makers came from foreign countries.

Nickel.—The production of nickel dropped from 22,541 pounds in 1899 to 9,715 pounds in 1900. All of the domestic product was obtained as a by-product in the smelting of lead ores at Mine La Motte, Mo. The value of the product decreased from $8,566 in 1899 to $3,886 in 1900.

Platinum.—The production of crude platinum continues to increase, although the quantity produced remains small. In 1900 the product was 400 ounces, worth $2,500, as compared with 300 ounces, valued at $1,800, in 1899.

FUELS.

Coal.—The aggregate production of anthracite and bituminous coal in 1900 amounted to 240,965,917 long tons, equivalent to 269,881,827 short tons, with a value of $306,891,364, as compared with 226,553,564 long tons, or 253,739,992 short tons, in 1899, valued at $256,077,434. The increase in 1900 over the preceding year was 14,412,353 long tons, or 16,141,835 short tons, in amount, and $50,813,930 in value.

The output of anthracite coal in Pennsylvania amounted to 51,221,353 long tons, or 57,367,915 short tons, valued at $85,757,851, against 53,944,647 long tons, or 60,418,005 short tons, in 1899, valued at $88,142,130. The decrease in the production of anthracite amounted to 2,723,294 long tons, or 3,050,090 short tons, in amount and $2,384,279 in value, and was due entirely to the protracted labor troubles, which practically suspended mining operations in the anthracite regions during the summer and early fall of 1900.

The total product of bituminous coal, which includes lignite or brown coal, cannel, splint, semianthracite, and semibituminous, and the small anthracite product of Colorado and New Mexico, amounted to 189,744,564 long tons, or 212,513,912 short tons, valued at $221,133,513, as compared with 172,608,917 long tons, or 193,321,987 short tons, in 1899, valued at $167,935,304, showing an increase in the bituminous product of 17,135,647 long tons, or 19,191,925 short tons, in amount and $53,198,209 in value.

In connection with the coal-mining industry in 1900 was the comparatively large increase in the value of the product, which was principally noticeable in the case of bituminous coal. The total increase in product was 16,141,835 short tons, or 6.4 per cent, while the value increased $50,813,930, or 19.8 per cent. The increase in value in 1900 was nearly $2,800,000 more than the increase in the value from 1898 to 1899, when the product increased 33,765,325 tons, or more than double the increase of 1900 over 1899.

Another interesting feature in connection with the coal-mining industry of the United States is the continued increase in the percentage of bituminous coal mined by mechanical methods. During 1900 there were undercut by the use of machines 52,790,523 short tons, or 24.65 per cent of the total bituminous product. The total product of bituminous coal in 1900 increased a little less than 10 per cent over the preceding year, while the machine-mined product increased over 20 per cent.

The total number of men employed in all the coal mines of the United States in 1900 was 448,706, who made an average of two hundred and twelve working days, as compared with 410,635 men with an average of two hundred and fourteen days in 1899.

In considering the coal product, these reports include not only the coal marketed, either by shipments to a distance or sold locally, but also that consumed by the mine employees and by the mine owners themselves, operating the properties, this being known technically as colliery consumption. There are occasional exceptions where operators use only slack or waste, which would otherwise be thrown on the dump and not regarded. These exceptions are few and the amount is comparatively small. The coal consumed in the manufacture of coke is also included in this report. The coal shipped, sold to local trade and used by employees, and consumed in the manufacture of coke is considered the marketable product. The colliery consumption averages about 9 per cent of the total anthracite product and about $1\frac{1}{2}$ per cent of the bituminous. The marketable product in 1900 amounted to 260,689,081 short tons, as compared with 244,612,654 short tons in 1899. The increased production of coal in the United States in 1899 placed this country in unquestioned supremacy among the coal-producing countries of the world. In 1898 the production of Great Britain, which has been for several years the only rival of the United States as a coal producer, exceeded that of the United States by about 6,300,000 tons. In 1899 the production of the United States increased nearly 34,000,000 short tons, while that of Great Britain increased a little over 20,000,000 short tons, so that the product of the United States in that year exceeded that of Great Britain for the first time, with a lead of a little over 7,200,000 tons. In 1900 the production of the United States exceeded that of Great Britain by more than 17,500,000 short tons. In this connection it is interesting to note that practically all of the coal produced in the United States is consumed in this country for domestic, transportation, or manufacturing purposes. The exports of coal from the United States in 1900 were less than 9,000,000 short tons, but little more than 3 per cent of the total product.

Coke.—The unprecedented activity which prevailed in the iron and steel trade in the United States during 1899 continued into the spring of 1900, and although the summer of 1900 developed a weak and unsettled condition in the iron and steel trade, it was not sufficient to overcome the advance made in the earlier months of the year. Sympathizing with the increased iron and steel production, the production of coke increased from 19,668,569 short tons in 1899 to 20,533,348 short tons in 1900, a gain of 864,779 short tons. The value of the product increased much more in proportion, from $34,670,417 in 1899 to $47,443,331 in 1900, a gain of $12,772,914. The increase in production over 1899 amounted to 4.4 per cent; the value increased 37 per cent. The value of the coke product in 1900 was more than double that of 1897—three years before—or of any year prior to that date. The year 1900 showed important developments in the introduction of by-product coke ovens. This was exhibited more by the increase in the number of new plants constructed during the year than by any increase in production of by-product coke. The amount of coke made in by-product ovens was 1,075,727 short tons, as compared with 906,534 short tons in 1899. The number of by-product ovens in operation or completed by December 31, 1900, amounted altogether to 1,085. The number of by-product ovens in course of construction at the close of the year was 1,096, or 11 more than all the ovens completed during the eight years since the first by-product oven was constructed in the United States.

Petroleum.—The production of petroleum increased from 57,070,850 barrels in 1899, valued at $64,603,904, to 63,362,704 barrels in 1900, valued at $75,752,691. This was a gain of 6,291,854 barrels, or 11.02 per cent, and $11,148,787, or 17.26 per cent. This product of 1900 is the largest ever attained by this country, the next largest output having been in 1896, when 60,960,361 barrels were produced. This great output was attained notwithstanding the fact that the greatly increased output of California and the new discoveries in Texas occurred so late in the year as not to enter into the output of 1900 to any extent. The average value per barrel for the entire country during 1900 was $1.19½; while for 1899 it was $1.13⅕, and for 1898 it was 79⅘ cents.

Natural gas.—The value of the natural gas product increased from $20,074,873 in 1899 to $23,606,463 in 1900, a gain of $3,531,590, or 17.59 per cent. Not only did the value increase in 1900, but also the quantity sold, and the introduction of meters and other appliances for the more careful manipulation of gas wells and pipe lines has brought about a large saving in the amount of gas required to produce a given heating effect.

STRUCTURAL MATERIALS.

Stone.—The value of all kinds of building stone produced in the United States in 1900 amounted to $47,958,539, as compared with $44,090,670 in 1899, an increase of $3,867,869.

This increase was shared by all classes of building stone, the most conspicuous increase being in the production of limestone, the value of which in 1900 was about $1,600,000 more than that of 1899.

The export of slate, which was a conspicuous feature of this branch of the building-stone industry in 1898 and 1899, fell off nearly one-third in 1900, the value of the exports decreasing from $1,363,617 to $950,543.

Clays.—The activity in all branches of the clay-working industries in 1899, noted in the last report, was continued during 1900. The value of all clay products in 1900, as reported to this office, was $96,212,345, as compared with $95,797,370 in 1899 and $73,892,884 in 1898. The figures here given for 1899 are those collected by the Twelfth Census. The brick and tile product in 1900 was valued at $76,413,775, as compared with $78,547,120 in 1899, while the pottery products were valued in 1900 at $19,798,570, as compared with $17,250,250 in 1899.

The clay mined and sold by those not manufacturing the product themselves in 1900 amounted to 1,221,660 short tons, valued at $1,840,377, as compared with 843,279 short tons, valued at $1,645,328, in 1899.

Cement.—The total product of cement in the United States in 1900 was 17,231,150 barrels, as compared with 15,520,445 barrels in 1899, a gain of 1,710,705 barrels, or 11.02 per cent. The value of all cement made in 1900 was $13,283,581, as compared with $12,889,142 in 1899.

The Portland-cement industry in 1900 showed a large increase over that of 1899, the production being 8,482,020 barrels, as compared with 5,652,266 barrels in 1899, a gain of 2,829,754 barrels, or 50.1 per cent. The value of this product increased from $8,074,371 in 1899 to $9,280,525 in 1900. The average price per barrel in 1899 was $1.43, while in 1900 it was but $1.09. The number of producers reporting was 36 in 1899 and 50 in 1900.

The production of natural-rock cement fell from 9,868,179 barrels in 1899 to 8,383,519 barrels in 1900, a decrease of 1,484,660 barrels, or 14.9 per cent, while the value fell from $4,814,771 in 1899 to $3,728,848 in 1900, a decrease of $1,085,923, or 22.55 per cent. The average price per barrel was 48.8 cents in 1899 and 44.5 in 1900. In 1899 the number of establishments was 75 and in 1900 it was 76.

In addition, in 1900 there were produced 365,611 barrels of slag cement, valued at $274,208, or 75 cents per barrel.

ABRASIVE MATERIALS.

Corundum and emery.—The combined product of corundum and emery in 1900 amounted to 4,305 short tons, valued at $102,715, a decrease from 4,900 short tons, valued at $150,600, produced in 1899.

Garnet.—The amount of abrasive garnet produced in 1900 was 3,185 short tons, valued at $123,475, an increase from 2,765 short tons, valued at $98,325, in 1899.

Grindstones.—The production of grindstones in 1900, based on the value of the product, was the largest on record, exceeding that of 1882, the year of largest previous production, by a little over $1,000. The value of the grindstones made in 1900 was $701,121, as compared with $675,586 in 1899.

Infusorial earth and tripoli.—The production decreased from 4,334 short tons, valued at $37,032, in 1899, to 3,615 short tons, valued at $24,207, in 1900.

Millstones.—The production in 1900 was the largest since 1889, but the industry is still of insignificant importance when considered with what it was twenty years ago. The substitution of the roller process for buhrstones in flour mills has practically eliminated the use of buhr for this purpose. The value of the buhrstones, or millstones, produced in 1900 was $32,858, as compared with $28,115 in 1899.

Oilstones.—The value of the oilstones and whetstones made in the United States in 1900 was $181,011, a decrease from $208,283 in 1899. The production in 1899 was the largest in the history of the industry.

CHEMICAL MATERIALS.

Borax.—The production in 1900 consisted of 24,235 tons of crude and 1,602 tons of refined, with a total value of $1,018,251. No separation was made of the refined and crude borax produced in 1899, the total output amounting to 20,357 short tons, valued at $1,139,882.

Bromine.—The production increased from 433,004 pounds, valued at $108,251, in 1899, to 521,444 pounds, valued at $140,790, in 1900. The bromine is obtained from the mother liquor made in the salt works in Michigan, Ohio, and West Virginia.

Fluorspar.—The production in 1900 amounted to 18,450 short tons, valued at $94,500, as against 15,900 short tons, valued at $96,650, in 1899. Most of the production is now obtained from Marion and Crittenden counties, Ky. The decrease in the value in 1900 was due to the larger amount of the material sold in a crude or unmanipulated condition.

Gypsum.—The production of gypsum, particularly for the manufacture of calcined plaster, continues to show remarkable gains. The output of crude gypsum in 1900 amounted to 594,462 short tons, the value of which in its first marketable condition amounted to $1,627,203, as compared with 486,235 short tons in 1899, valued at $1,287,080, and 291,638 short tons, valued at $755,280, in 1898. From this it will be seen that the production, both in amount and value, in 1900 was more than double that of 1898, two years before. The remarkable increases in the last two years are attributed to the substitution of plaster of paris for ordinary lime mortar in the manufacture of wall plaster in large buildings; also to the manufacture of staff for temporary buildings, such as are used for exposition purposes. In arriving at the value of the gypsum product, that which is sold crude is taken at its value crude, while that which is made into calcined plaster is taken for the calcined plaster produced and sold.

Marls.—The production remains practically stationary, at 60,000 short tons, valued at $30,000.

Phosphate rock.—The production of phosphate rock decreased from 1,515,702 long tons in 1899 to 1,491,216 long tons in 1900, while the value increased from $5,084,076 to $5,359,248. The decrease in production is attributed to the scarcity of vessels for the foreign trade and the high ocean freight rates, a direct result of the taking away of many vessels from the carrying trade to be used in the transportation of troops, etc., to South Africa. There was also a disinclination shown among the manufacturers of superphosphates to purchase crude rock in large quantities at the advanced prices prevailing in 1900.

Pyrite.—The production of pyrite, used in the manufacture of sulphuric acid, increased from 174,734 long tons, valued at $543,249, in 1899, to 204,615 long tons, valued at $749,991, in 1900.

Salt.—The salt product includes the salt in brine in the manufacture of soda ash, caustic soda, etc., at chemical works in Michigan, New York, and Pennsylvania. Including this factor, the production in 1900 amounted to 20,869,342 barrels, of 280 pounds net, a gain from 19,708,614 barrels in 1899. The value increased from $6,867,467 to $6,944,603. These figures indicate that the combinations effected by many of the larger producers in New York, Michigan, Ohio, Kansas, Utah, and California have not increased the cost to the consumers.

Sulphur.—Compared with the amount of sulphur imported into the United States and the sulphur contents of the pyrites used for acid making, the domestic production of sulphur continues insignificant. It amounted in 1900 to 3,525 short tons, valued at $88,100, against 4,830 short tons, valued at $107,500, in 1899. All of the product was from Louisiana and Utah.

PIGMENTS.

Barytes.—The production increased significantly, from 41,894 short tons in 1899 to 67,680 short tons in 1900, with an increase in value from $139,528 to $188,089. The increased production was due practically to the development of properties in Tennessee.

Cobalt oxide.—Sympathizing with the decreased production of nickel in 1900, the output of cobalt oxide also decreased, from 10,230 pounds in 1899 to 6,471 pounds in 1900. The value declined proportionately, from $18,512 to $11,648.

Metallic paint.—The production of metallic paint (iron ore ground for pigment) in 1900, exclusive of mortar colors, amounted to 23,218 short tons, as against 23,423 short tons in 1899, a decrease of 205 tons. The value increased from $249,945 in 1899 to $261,831 in 1900, a gain of $11,886. The production of mortar colors increased from 5,736 short tons, valued at $65,156, in 1899, to 6,689 short tons, valued at $79,911, in 1900, an increase of 953 short tons in amount and $14,755 in value.

Ocher, umber, and sienna.—The production of ocher in 1900 amounted to 17,015 short tons, valued at $186,707, as compared with 14,124 short tons in 1899, valued at $140,168, a gain of 2,891 short tons and $46,539.

The production of umber increased from 473 short tons in 1899, valued at $4,151, to 1,452 short tons in 1900, valued at $26,927, which is the greatest value for this product reported in recent years.

The production of sienna in 1900 was 957 short tons, valued at $14,771, as compared with 588 short tons in 1899, valued at $8,205.

The combined production of ocher, umber, and sienna in 1900 was 19,424 short tons, valued at $288,405, as compared with 15,185 short tons in 1899, valued at $152,524.

Venetian red.—The production of venetian red in 1900 was 14,696 short tons, as compared with 11,991 short tons in 1899, a gain of 2,705 short tons. The value of this product in 1900 was $236,574, as compared with $210,361 in 1899. The average production during the last four years has been about 12,600 short tons annually.

White lead, red lead, litharge, and orange mineral.—The returns to the Geological Survey for 1900 indicate that there was a general falling off in the production of lead pigments in that year. The production of white lead in oil decreased from 170,214,565 pounds in 1899 to 151,874,933 pounds in 1900. Dry white lead decreased from 50,178,486 pounds in 1899 to 44,544,971 pounds in 1900. The production of red lead decreased from 22,157,694 pounds to 21,486,825 pounds; litharge, from 21,937,704 pounds to 18,984,145 pounds, and orange mineral, from 2,024,302 pounds to 1,973,016 pounds. In the cases of red lead and orange mineral these decreases were offset by advances in values. The values were: White lead in oil, $8,977,268 in 1899 and $8,430,996 in 1900; white lead dry, $2,340,689 in 1899 and $2,226,960 in 1900. The red-lead product was valued at $1,192,927 in 1899, as compared with $1,198,008 in 1900. The litharge product declined both in quantity and in value, the latter from $1,159,968 in

1899 to $990,391 in 1900. The value of the orange-mineral product was $146,720 in 1899 and $146,288 in 1900.

Zinc white.—The production of zinc white showed a remarkable increase, from 40,146 short tons to 48,840 short tons, with an increase in value from $3,211,680 to $3,667,210.

MISCELLANEOUS.

Asbestos.—Nearly the entire product continues to come from the Sall Mountain mines in White County, Ga., small amounts only having been obtained in 1900 from California and Massachusetts. The total product in 1900 was 1,054 short tons, valued at $16,310, an increase from 681 short tons, valued at $11,740, in 1899.

Asphaltum.—Under this title are included all the numerous varieties of bitumens or hydrocarbons occurring in the United States and not discussed in the chapter on petroleum. The production in 1900 was less than for several years past, amounting to 54,389 short tons, valued at $415,958. The production in 1899 was 75,085 short tons, and in 1898, 76,337 short tons. The year of largest production was 1892, when it reached a total of 80,503 short tons.

Bauxite.—The production in 1900 amounted to 23,184 long tons, valued at $89,676, a decrease from 35,280 long tons, valued at $125,598, in 1899.

Chromic iron ore.—A product of 140 long tons of chromic iron ore, valued at $1,400, was reported in 1900. No production of this material had been reported since 1896, when an output of 786 long tons, worth $6,667, was obtained.

Feldspar.—The production of feldspar decreased from 27,202 short tons, valued at $238,545, in 1899, to 21,353 short tons, valued at $173,659, in 1900.

Fibrous talc.—This variety of talc, or soapstone, occurs in but one locality in the United States, Gouverneur, St. Lawrence County, N. Y. It is used principally as a makeweight in the manufacture of medium grades of paper. The production has shown a tendency to increase for several years. In 1900 it amounted to 63,500 short tons, valued at $499,500, as compared with 54,655 short tons, valued at $438,150, in 1899. The production in 1900 was the largest on record.

Flint.—Sympathizing with the decreased production of feldspar, the flint product, which is used for pottery manufacture, also decreased, from 36,852 short tons, valued at $229,345, in 1899, to 32,495 short tons, valued at $179,351, in 1900.

Fuller's earth.—The production of fuller's earth in the United States has decreased annually since 1897, when it reached its maximum. In 1900 the production amounted to 9,698 short tons, valued at $67,535, as compared with 12,381 short tons, valued at $79,644, in 1899. The maximum production of fuller's earth was obtained in 1897, with an output of 17,113 short tons.

Graphite.—The production of graphite in 1900 amounted to 5,507,855 pounds of crystalline graphite and 611 short tons of amorphous, as compared with 2,900,732 pounds of crystalline and 2,324 short tons of amorphous graphite in 1899. The total value of the product in 1900 was $197,579, and in 1899 $167,106.

Limestone for iron flux.—The amount of limestone used for fluxing in blast furnaces in 1900 was 7,495,435 long tons, as compared with 6,707,435 long tons in 1899. The value, however, decreased from $4,695,205 in 1899 to $4,500,000 in 1900.

Magnesite.—This product comes entirely from California. The production in 1900 amounted to 2,252 short tons, valued at $19,333, which was the maximum both in amount and in value. In 1899 the product amounted to 1,280 short tons, valued at $18,480.

Mica.—The output of sheet mica in 1900 includes a considerable amount of rough or uncut mica shipped from the West and sold in the uncut condition. This makes the amount of the production in 1900 appear much larger than that of any preceding year. There was, however, an important increase in the production of sheet mica, particularly in the small sizes, which have been found available for the manufacture of electric insulators. Including the uncut mica marketed, the total sheet mica product in 1900 amounted to 456,283 pounds, valued at $92,758. The scrap mica produced in the same year was 5,453 short tons, valued at $54,302. These figures are compared with 108,570 pounds of sheet mica, valued at $70,587, and 1,505 short tons of scrap, worth $30,878, in 1899.

Mineral waters.—The amount of commercial natural mineral waters sold in 1900 was about 8,000,000 gallons more than in the preceding year, with a loss of a little over $700,000 in value. In 1899 the amount of natural mineral waters sold was 39,562,136 gallons, worth $6,948,030. In 1900 the product sold was 47,558,784 gallons, worth $6,245,172. The decrease in value is attributed to a larger production of low-priced waters and a falling off in the amount of high-priced waters sold.

Monazite.—A production of 908,000 pounds, valued at $48,805, was reported for 1900, as compared with 350,000 pounds, worth $20,000, in 1899.

Precious stones.—The value of the gems and precious stones found in the United States in 1900 was $233,170, as compared with $185,770 in 1899. The principal features connected with this industry in 1900 were the continued mining of fine blue sapphires in Fergus County, Mont., the development of fancy-colored sapphires in Granite County, and the systematic working of beryl deposits in Mitchell County, in the same State; also an increased production of turquoise in Nevada and New Mexico and the mining of purple-pink garnets in Macon County, N. C. The discovery of a new locality for colored tourmalines in California is of interest.

Pumice stone.—The company organized to develop the pumice deposits of Nebraska and Wyoming became involved in litigation in 1899 and produced no pumice in 1900.

Rutile.—The production increased slightly, from 230 pounds, valued at $1,030, in 1899, to 300 pounds, valued at $1,300, in 1900.

Soapstone.—Exclusive of the product of fibrous talc from Gouverneur, N. Y., the production of soapstone and talc amounted to 27,943 short tons, valued at $383,541, in 1900. This was the largest output on record, exceeding that of 1899, the year of previous largest production, by 3,178 short tons in amount and $52,736 in value.

DIVISION OF HYDROGRAPHY.

This division was continued in charge of Mr. Frederick H. Newell, whose assistants in the various subdivisions of investigations were Messrs. Arthur P. Davis, C. H. Fitch, N. H. Darton, Cyrus C. Babb, H. A. Pressey, Edwin G. Paul, Gerard H. Matthes, and Charles R. Olberg. In addition there were employed in the field a number of assistants, designated "resident hydrographers," whose names are given below in connection with the work in various localities.

Mr. Arthur P. Davis, in charge of reservoir surveys, was absent on leave during the first part of the fiscal year, continuing investigations in Central America for the Isthmian Canal Commission, under the Department of State. Upon his return to the United States he was again assigned to problems of water storage, particularly in Arizona, and began the investigation of the cost of water storage on Salt and Verde rivers at points easterly from Phœnix.

Mr. Charles H. Fitch, topographer, in charge of diversion surveys, was occupied mainly in an examination to determine the feasibility of diverting the waters of St. Mary River easterly into the drainage basin of Milk River, thus rendering available for use in northern Montana the waters which are now lost by flowing northerly across the international boundary. He also made a reconnaissance of the conditions for diverting the water of upper Green River, in western Wyoming, of North Platte River, in southern Wyoming, and of Madison River, in southern Montana. In the work on St. Mary River he was assisted by Mr. Gerard H. Matthes.

Mr. N. H. Darton continued his field work in the vicinity of the Black Hills, in Wyoming and South Dakota, and began the preparation of a map of the Central Plains region, on which to compile all available information concerning the geologic conditions that govern the occurrence of water in that drought-stricken area. Investigations in connection with his work were also continued by Prof. James E. Todd in South Dakota, Prof. C. M. Hall in North Dakota, and Prof. C. C. O'Harra in the vicinity of Rapid, S. Dak.

Mr. Cyrus C. Babb continued the survey and examination of the Uinta Indian Reservation, in northeastern Utah, for the purpose of ascertaining the water supply and the practicability of irrigating the agricultural lands of that reservation. This work was brought to a close and a report prepared.

Mr. H. A. Pressey was occupied mainly with the examination of the streams of the southern Appalachian area, including the localities where it is proposed to establish a national forest reserve or park. The results of these investigations have been prepared for publication as Water-Supply Papers. He also continued the investigation of the flow of New York streams, the field work being carried on by Mr. Robert E. Horton.

Mr Edwin G. Paul continued in charge of the instrumental equipment and the rating of meters, and, in addition, filled the position of resident hydrographer for Pennsylvania and Maryland.

The measurement of rivers in various parts of the United States was carried on systematically, as in former years, the results being shown in the volume on Hydrography of the Twenty-second Annual Report and in the series of Water-Supply and Irrigation Papers. The data obtained at the river stations for the year 1900 are given in Papers Nos. 46 to 52 of that series.

There is given below, in general geographic order, a brief description of the operations in the various States, or groups of States, and also the names of the engineers or resident hydrographers under whose charge the work has been done.

HUMID REGION.

Maine.—Systematic work in the measurement of the rivers of this State was begun, through cooperation with the State, by means of a contribution from citizens placed in the hands of the governor's council.

Rhode Island.—Measurement of Blackstone and Pawtucket rivers was begun, in cooperation with Brown University, the field work being carried on by the students of Prof. John E. Hill.

Connecticut.—Measurements of Housatonic River and its tributaries were made in cooperation with the Sheffield Scientific School, of Yale University, field work being carried on by students of Prof. H. A. Graves.

New York.—An appropriation for cooperation in the measurement of the streams of this State was made by the legislature, the work being carried on in connection with the State engineer and surveyor, the details having been intrusted to Mr. Robert E. Horton. The principal streams measured are those issuing from the Adirondacks and tributary to the Hudson. In addition river stations have been established in the Catskill region in cooperation with the board of public works of New York City.

A series of investigations as to the relative accuracy of various forms of current meter under different conditions was made by Prof. E. C. Murphy at the hydraulic laboratory of Cornell University, Ithaca. These have shown the percentage of error and have brought about improvements in methods of measurement and computation.

New Jersey.—Occasional measurements of streams were made in this State, the work being under the charge of Mr. George B. Hollister, of Rutherford, who has given particular attention to the preparation of short reports designed to call to public attention the results of the work of this division. Mr. M. O. Leighton, of Montclair, also prepared a report relating largely to the streams of New Jersey, and particularly to the subject of stream pollution.

Pennsylvania.—Systematic measurements of Susquehanna and Delaware rivers were carried on by Mr. Edwin G. Paul, the results being of value not only in connection with the development of water power, but also in the discussion of the influence of forests upon the streams. With a view to assisting in this latter phase of the matter, the State commissioner of forests, Mr. J. T. Rothrock, has urged the passage of an appropriation bill by the State legislature for cooperation.

Maryland.—The study of the streams of this State was continued through the assistance rendered by Prof. William B. Clark, State geologist.

Virginia and West Virginia.—Various streams were examined and measured by Prof. D. C. Humphreys, of Lexington, Va., the results being applicable in the consideration of water-power projects.

North Carolina and South Carolina.—Work in these States was continued under the direction of Prof. J. A. Holmes by Mr. E. W. Myers. Particular attention was also given to the streams which issue from the western part of the State within the area where it has been proposed to establish a national forest reserve.

Georgia.—The State geologist, Prof. W. S. Yeates, continued cooperation, and systematic investigation was kept up, the work being under the immediate charge of Prof. B. M. Hall.

Alabama.—The State geologist, Prof. Eugene A. Smith, continued cooperation in stream measurements, and made studies of the underground waters.

Tennessee.—The streams of the eastern portion of this State have been measured by Prof. B. M. Hall and his brothers, in connection with related work in Georgia, Florida, and Alabama.

Ohio.—Cooperation was continued with Dr. C. O. Probst, secretary of the State board of health, river measurements being made by Mr. Benjamin H. Flynn. Prof. C. N. Brown, of the Ohio State University, and his assistants also rendered aid.

Indiana.—Measurements of Wabash River were made at Lafayette by Prof. William D. Pence, of Purdue University.

Upper Mississippi Valley.—Facts concerning the flow of Mississippi River and its tributaries were obtained mainly through the assistance of the Weather Bureau and the Corps of Engineers, United States Army. Prof. Charles S. Slichter, of Madison, Wis., also began the preparation of a report on underground waters with particular reference to this area.

SUBHUMID REGION.

North Dakota.—Cooperation in studying the resources of the State has been brought about by an act of the State legislature, which authorizes the board of trustees of the agricultural college to assist in executing certain surveys, naming the professor of geology of the college as State director of such surveys. Prof. C. M. Hall, who holds this position, has thus been officially recognized as the agent of the State in continuing the work previously begun by this Survey.

South Dakota.—Mr. N. H. Darton, geologist, continued his examination of artesian conditions, particularly in the vicinity of the Black Hills. Prof. James E. Todd, of Vermilion, extended the mapping of the underground waters, and Prof.

Cleophas C. O'Harra assisted in similar work. Measurements were also begun on Big Sioux River, in the eastern part of the State, and a reconnaissance was made by Mr. Gerard H. Matthes of possible reservoir sites near the headwaters, for regulating the flow.

Nebraska.—Systematic measurements of the rivers of this State were continued by Mr. O. V. P. Stout and his assistants, cooperation being had with Mr. Adna Dobson, State engineer.

Kansas and Oklahoma.—Work in this area was continued by Mr. W. G. Russell, as in previous years.

Texas.—Measurements of various important rivers were made by Prof. Thomas U. Taylor, and studies of the irrigation systems of the State were continued.

ARID REGION.

As in former years, the greater portion of the funds available for hydrographic investigations were devoted to the arid region, where the Government is the great landowner, and where the utilization of vast areas is dependent upon the question of water supply. Various reservoirs were surveyed and examination was made of the possibility of diverting large rivers. In this thinly settled region the expense of such field work is notably greater than in the East, but results of practical value have been accomplished, as shown by public appreciation and by notable developments rendered possible by the data obtained.

Arizona.—The measurements of Gila River near the San Carlos dam site were continued, and a survey was made of what is known as the McDowell reservoir site, on Verde River. The depth to bed rock at this point was determined by diamond drilling. On the conclusion of this work the machinery was moved to what is known as the Tonto dam site, on Salt River, and this in turn was investigated as to the capacity and cost of storage of water. The results are of importance in the development of the fertile but arid Salt River Valley, of which Phœnix is the principal city, and contributions toward defraying the expenses of this investigation were made by the county of Maricopa, through the water-storage commission.

California.—In this State the largest amount of field work was undertaken, the operations being under the direction of Mr. J. B. Lippincott, who was assisted by several expert engineers. Contributions to this work were made by the California Water and Forest Association, and vigorous attempts were made by this association to secure an appropriation from the State legislature. The bill for cooperation was passed, but failed to become a law, and a reduction of the investigations which had been planned was therefore necessary. By Mr. A. E. Chandler examinations were made of Clear Lake and Cache Creek, and the results have been published in Water-Supply Paper No. 45; also of Kern River, by Frank H. Olmstead, and of Yuba River, by Dr. Marsden Manson, the results being published in Water-Supply Paper No. 46. Other surveys not yet published are those on Stoney Creek, by Bert Cole, and those on Kings and Salinas rivers, by Prof. Charles D. Marx, Homer Hamlin, and others. Low-water measurements of the streams were continued, and computations were made of the daily discharge of important tributaries of the Sacramento and San Joaquin, as well as of streams of the southern part of the State. Considerable attention was devoted to water power, the transmission of power by electricity, and the utilization of this in pumping water from under ground for lands beyond the reach of gravity canals. In this Mr. Lewis A. Hicks and Mr. Robert McF. Doble acted as consulting engineers.

Colorado.—Mr. A. L. Fellows continued the systematic measurement of the important rivers of this State, receiving aid from the State engineer, Mr. Addison J. McCune, and his assistant, Mr. John E. Field. He also made an examination of various reservoir sites and began work on the problem of the diversion of Gunnison River to the Uncompahgre Valley.

Idaho.—Various tributaries of Snake River were measured by Mr. N. S. Dils, assistance being had from the State engineer, Mr. D. W. Ross. A detailed study of the artesian conditions in the vicinity of Lewiston was made by Prof. I. C. Russell, the report being printed as Water-Supply Papers Nos. 53 and 54.

Montana.—The river measurements in this State were made by Prof. Samuel Fortier, who also prepared a report on the conveyance of water in irrigation canals, this being printed as Water-Supply Paper No. 43. In this State a considerable amount of field work was carried on by Mr. C. H. Fitch and his assistant, Mr. Gerard H. Matthes, looking toward the diversion of St. Mary River easterly near the international boundary and into the headwaters of Milk River.

Nevada.—In addition to the regular measurements of important rivers, Mr. L. H. Taylor continued the survey of the drainage basin of Truckee River and prepared maps and reports showing cost and benefits of water storage. He also began a similar examination of Carson River, pursuant to a State appropriation for cooperation.

New Mexico.—A few stations along the Rio Grande were maintained by Mr. Philip E. Harroun, and data were also obtained from the International (Water) Boundary Commission, through the courtesy of the chairman of the commission, Gen. Anson Mills, and the consulting engineer, Mr. D. P. Cunningham.

Oregon.—Measurements of the rivers in this State were continued in connection with similar work in the State of Washington.

Utah.—Measurements of streams were continued by Prof. George L. Swendsen, of Logan, and data were also obtained from Mr. Caleb Tanner relating to the streams of the northern part of the State. Mr. Cyrus C. Babb brought to a close the detailed surveys on the Uinta Indian Reservation.

Washington.—Hydrographic work was continued in this State by Mr. Sydney Arnold, of North Yakima, and by Mr. William J. Ware, of Port Angeles. A report was also prepared by Mr. George Otis Smith relating to the artesian conditions in the North Yakima Valley, this being printed as Water-Supply Paper No. 55.

Wyoming.—Stream measurements were continued by Mr. A. J. Parshall, State engineer, and a reconnaissance was made of the headwaters of Green River and North Platte River as preliminary to more detailed surveys for determining the feasibility of diverting these streams.

RESULTS.

The data obtained by field work relating to the year 1900 have been published in Water-Supply Papers Nos. 47 to 52, inclusive, and the conclusions drawn from these have been prepared for the volume on Hydrography of this Annual Report, this dual form of publication being necessary, as in previous years, by reason of the bulk of the material and the law governing the size and character of the reports.

During the last fiscal year Water-Supply Papers Nos. 40 to 55 were sent to the printer. Of these, No. 40 is by Prof. Thomas U. Taylor, and relates to the Austin, Tex., dam and its destruction, giving the hydrographic data for Colorado River. Nos. 41 and 42, by Prof. E. C. Murphy, continue the discussion of the efficiency and economic use of the windmill, particularly in making available by pumping the waters which occur under ground. No. 43, by Prof. Samuel Fortier, gives data concerning the conveyance of water in irrigation canals. No. 44, by Mr. Henry Gannett, shows the profiles of rivers in the United States. No. 45 relates to water storage in Clear Lake and the development of irrigation along Cache Creek. No. 46 gives a description of Kern River by Mr. Frank H. Olmstead, and of Yuba River, by Dr. Marsden Manson. As has been stated, Nos. 47 to 52 give, in six parts, the operations at river stations for the year 1900. Nos. 53 and 54, by Prof. I. C. Russell, relate to the underground waters of Nez Perce County, Idaho; and No. 55, by George Otis Smith, discusses the underground waters of Yakima Valley.

Manuscripts for other Water-Supply Papers are in hand, the principal of these being, by Mr. J. B. Lippincott, on the wells of San Bernardino Valley; by B. H. Flynn, on Ohio River; by N. H. Darton, on deep wells, and on the relation of deep waters to health; by L. H. Taylor, on Truckee River; by H. A. Pressey, on the southern Appalachian streams; by E. C. Murphy, on the accuracy of current-meter measurements; and by William Starling, on Mississippi River.

DIVISION OF PHYSICAL AND CHEMICAL RESEARCH.

Office force.—During the fiscal year 1900–01 this division was under the charge of Mr. George F. Becker. The chemical laboratory was in charge of Prof. F. W. Clarke, assisted by Dr. W. F. Hillebrand, Dr. H. W. Stokes, and Mr. George Steiger. From March 1 Dr. E. T. Allen was also a member of the chemical force. The first step toward the organization of a physical laboratory was taken in October, when Dr. Arthur L. Day was temporarily appointed physical geologist for a period of three months. In January his appointment was made permanent. A civil-service examination was arranged for an assistant physicist, but no candidate applied, and it has not been practicable as yet to make even a temporary appointment to this position.

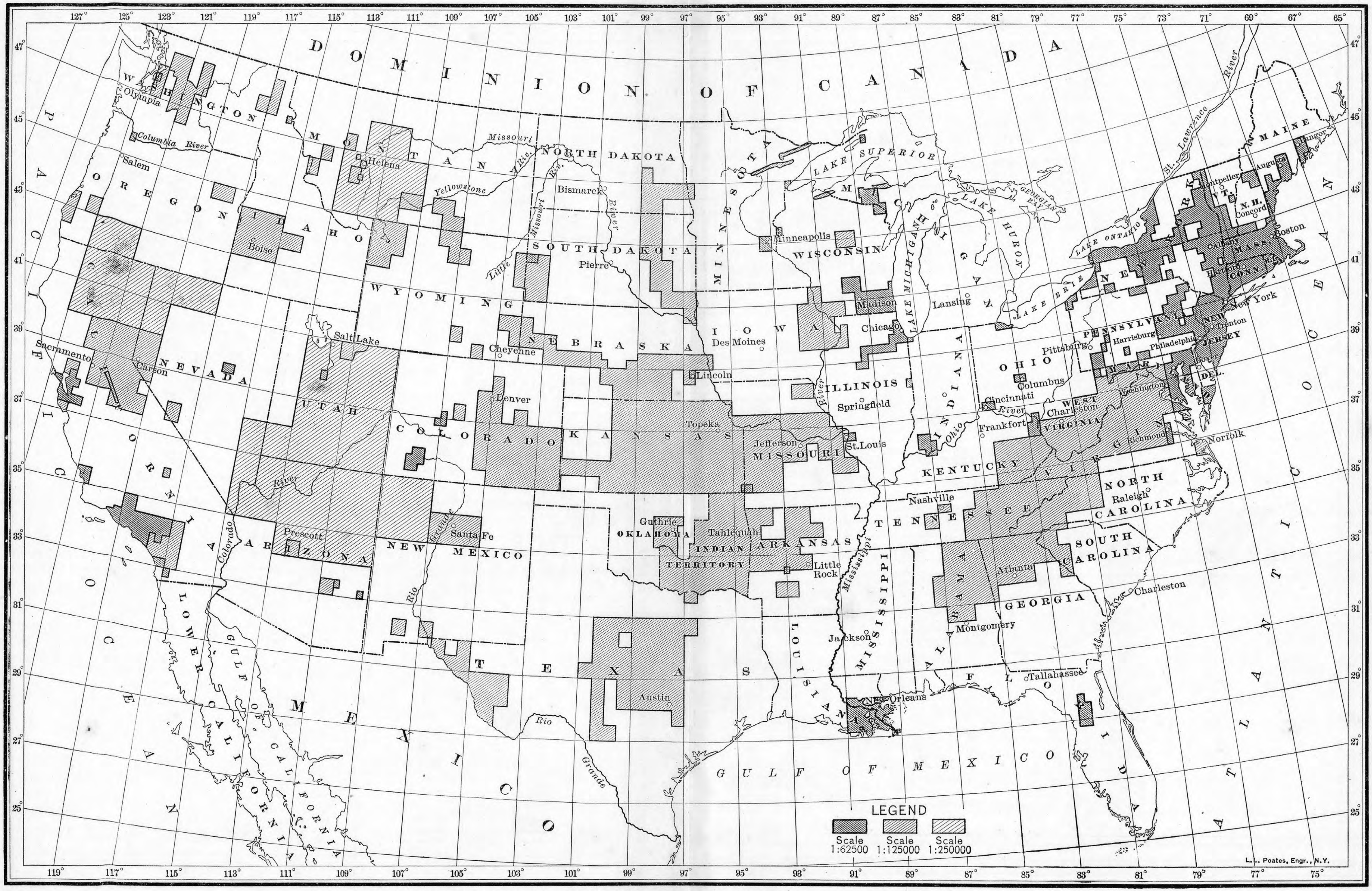
Laboratories.—Early in the year an addition was made to the building occupied by the Survey and quarters were assigned to this division in the new structure. The fitting of the new laboratories for use occupied much time and seriously interfered with routine work. The physical laboratory had to be organized throughout, for only a small number of instruments were available at the beginning of the year. These formed the remains of an earlier equipment which had been stored for several years in the Smithsonian Institution, and with one or two exceptions they were either obsolete or unfit for further use. It was necessary, therefore, to purchase or order instruments, and such as were not procurable in this country were ordered from abroad. A considerable amount of apparatus has been received and some valuable electric measuring instruments are now being made for the Survey in Germany under the courteous supervision of officials of the Physikalisch-Technische Reichsanstalt of Charlottenburg. An excellent storage battery has also been acquired and installed. Unfortunately the only space that could be assigned to the physical laboratory is extremely defective in stability. Street-car lines pass the building on either side, and the vibrations felt in the upper story are so great that accurate measurements of electric currents are almost impossible. While this fact does not prevent some investigations, it seriously interferes with and almost precludes many researches which are of the utmost importance in geologic physics.

Chemical and physical work accomplished.—A large part of the work of the chemical laboratory necessarily and properly consists in analyses made to aid field geologists in mapping and discussing the areas upon which they are engaged. During the year 187 analyses were reported as complete, together with some 360 qualitative determinations of ores, minerals, etc. The most important analyses are those of series of rocks from California, Nevada, Colorado, Oregon, Massachusetts, Texas, Minnesota, etc.

Messrs. Clarke and Steiger continued their work upon the ammonium-chloride reaction. This is an extremely ingenious and important method of investigating the true constitution of a large class of inorganic minerals. The work has been completed with reference to chabazite, stilbite, and heulandite.

In October Dr. Stokes was assigned to an investigation explanatory of the secondary enrichment of ores at a moderate distance beneath the earth's surface. This is a field which has scarcely been touched upon by chemical geologists, but which has been recognized by the mining geologists of the Survey as one of extreme importance. Dr. Stokes first undertook the study of the relations of pyrite to marcasite and incidentally of analogous and associated sulphides. He succeeded in finding new and simple methods of determining quantitatively the relative proportions of pyrite and marcasite in any mixture of the two, and drew various other important conclusions from this section of the investigation, a report on which will appear as Bulletin No. 186 of the Survey. Dr. Hillebrand and Dr. Stokes also jointly published an important paper on the determination of ferrous iron.

In the physical laboratory, equipment occupied nearly the entire time of the chief physicist. One important advance which he was able to make was in having a plate ruled for the printing of cross-section paper which is of a degree of accuracy far greater than any known to exist heretofore. Such paper is indispensable to accurate work in the physical laboratory and will prove of great service. At the suggestion of the geologist in charge, he also made experiments designed to elu-



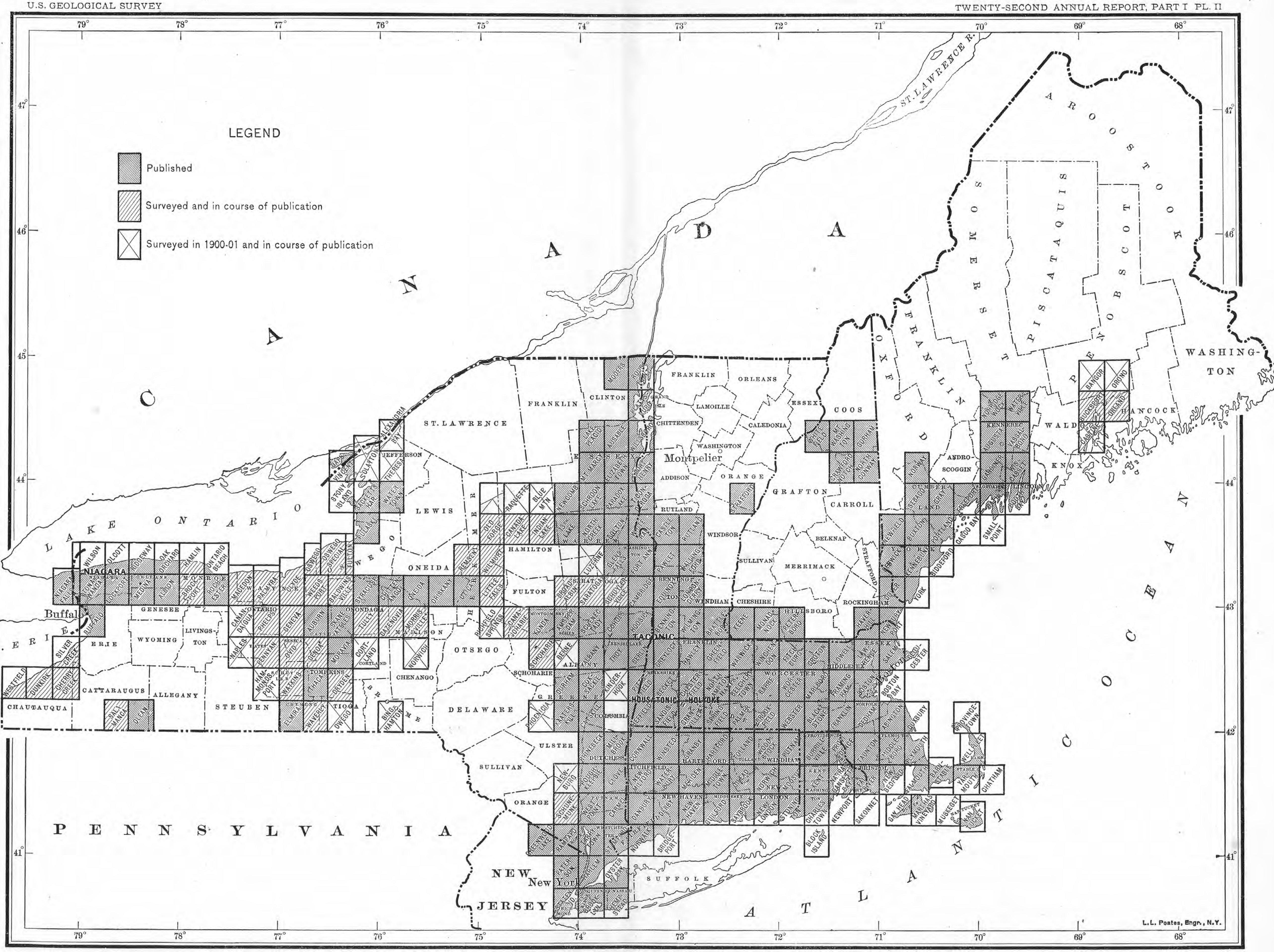
MAP SHOWING AREAS COVERED BY TOPOGRAPHIC SURVEYS

AND THE VARIOUS SCALES EMPLOYED FOR EACH AREA

Scale

100 0 100 200 300 miles

1901



MAP OF MAINE, NEW HAMPSHIRE, VERMONT, MASSACHUSETTS, RHODE ISLAND, CONNECTICUT, AND NEW YORK, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

cidate the origin of ribbon structure in auriferous ores. These show that crystallization, of itself, exerts a force sufficient to separate sheets of rock or of glass in opposition to gravity.

Miscellaneous.—During July and August, 1900, Professor Clarke was absent from Washington as a member of the international jury of awards at the Paris Exposition. During April and a part of May, 1901, he also served as representative of the Department of the Interior at the Pan-American Exposition in Buffalo. During the early months of the fiscal year, Mr. Becker was occupied in completing a report on the geology of the Philippine Islands. He spent the months of May and June in completing field work on the Gold Belt of California. Both of these pieces of work remained over from details antedating his appointment to the charge of this division, and are now completed. During the winter general superintendence and the preparation of certain physical tables occupied his available time.

TOPOGRAPHIC BRANCH.

Organization and Summary.

The organization of the Topographic Branch remained the same as in the previous year. For purposes of administration there were four sections—the Atlantic section, Mr. H. M. Wilson, geographer in charge; the Central section, Mr. John H. Renshawe, geographer in charge; the Rocky Mountain section, Mr. E. M. Douglas, geographer in charge; and the Pacific section, Mr. Richard U. Goode, geographer in charge.

Changes in the topographic corps were the appointment of Messrs. E. S. Ela and A. D. Oberly, assistant topographers; the reappointment of Mr. Dabney C. Harrison, topographer; the resignation of Mr. Redick H. McKee, topographer, and Mr. A. D. Oberly, assistant topographer; and the death of Mr. W. W. Gilbert, assistant topographer, on April 19, in Axton, N. Y. Mr. Gilbert was a young man of promise and had rendered efficient service during his connection with the Topographic Branch.

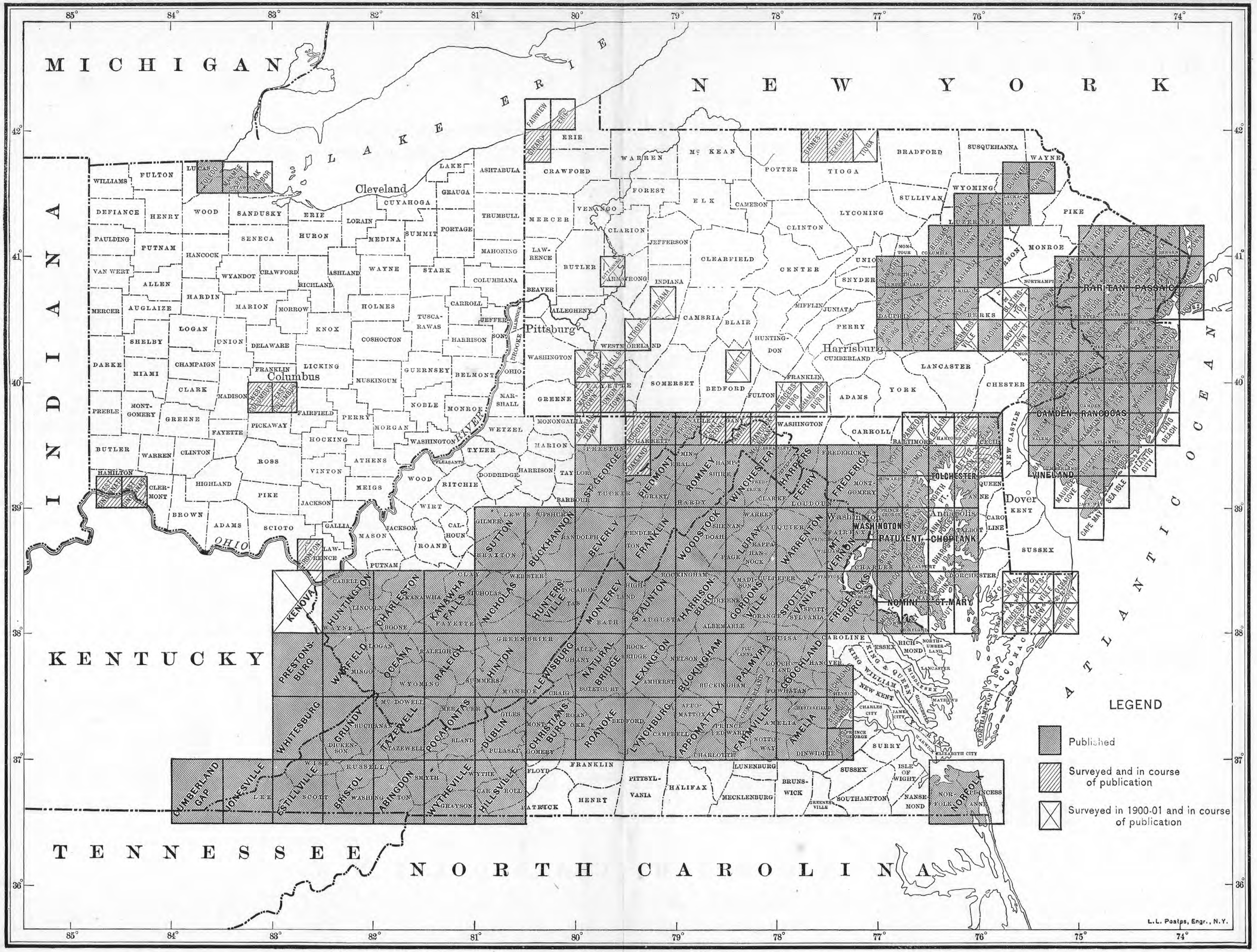
Cooperative agreements were arranged with five States, $19,500 being allotted by the State engineer and surveyor of New York; $18,000 by the State survey commission of Pennsylvania; $2,500 by the State survey commission of Maine; $5,000 by the State geologist of Maryland, and $1,000 by the State geologist of Alabama. The above amounts were all from appropriations made by the legislatures of the States mentioned for cooperation with the Geological Survey. In addition, the State legislature of Ohio appropriated $25,000 to be available February 15, 1901, but no detailed mapping was commenced prior to the beginning of the usual field season.

In connection with the topographic surveys, the surveys of forest reserves, and Alaskan surveys, the following results were obtained:

Primary azimuth observations were made at 4 triangulation stations; 37 meridian lines were established; 271 triangulation stations were occupied; 2,088 miles of primary traverse were run; 35,123 square miles were covered by detailed topographic mapping, this area being distributed through 32 States and Territories; and 12,407 miles of levels were run and 1,338 permanent bench marks were established, these bench marks being iron posts, bronze or aluminum tablets, or copper or aluminum plugs. In connection with the Alaskan surveys, about 6,500 square miles were mapped topographically and about 150 linear miles of stadia traverse and 274 linear miles of reconnaissance traverse were run. With reference to the land surveys, 23 miles of the boundary of the Black Hills Reserve and 109 miles of the boundary of the Bighorn Reserve were surveyed and marked.

The present condition of the topographic work, distinguished as to scale, is shown on the general map of the United States, Pl. I, and the detailed distribution of this work in the various States and Territories is shown on the twenty-three accompanying maps (Pls. II–XXIV). On the latter are indicated the engraved sheets; also the areas surveyed prior to and during the fiscal year 1900–01.

The following tables give the details relating to topography and spirit leveling for the fiscal year:



MAP OF PENNSYLVANIA, NEW JERSEY, DELAWARE, MARYLAND, VIRGINIA, WEST VIRGINIA, AND OHIO, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

Topographic surveys of the United States Geological Survey in 1900–01, including levels run and permanent bench marks established.

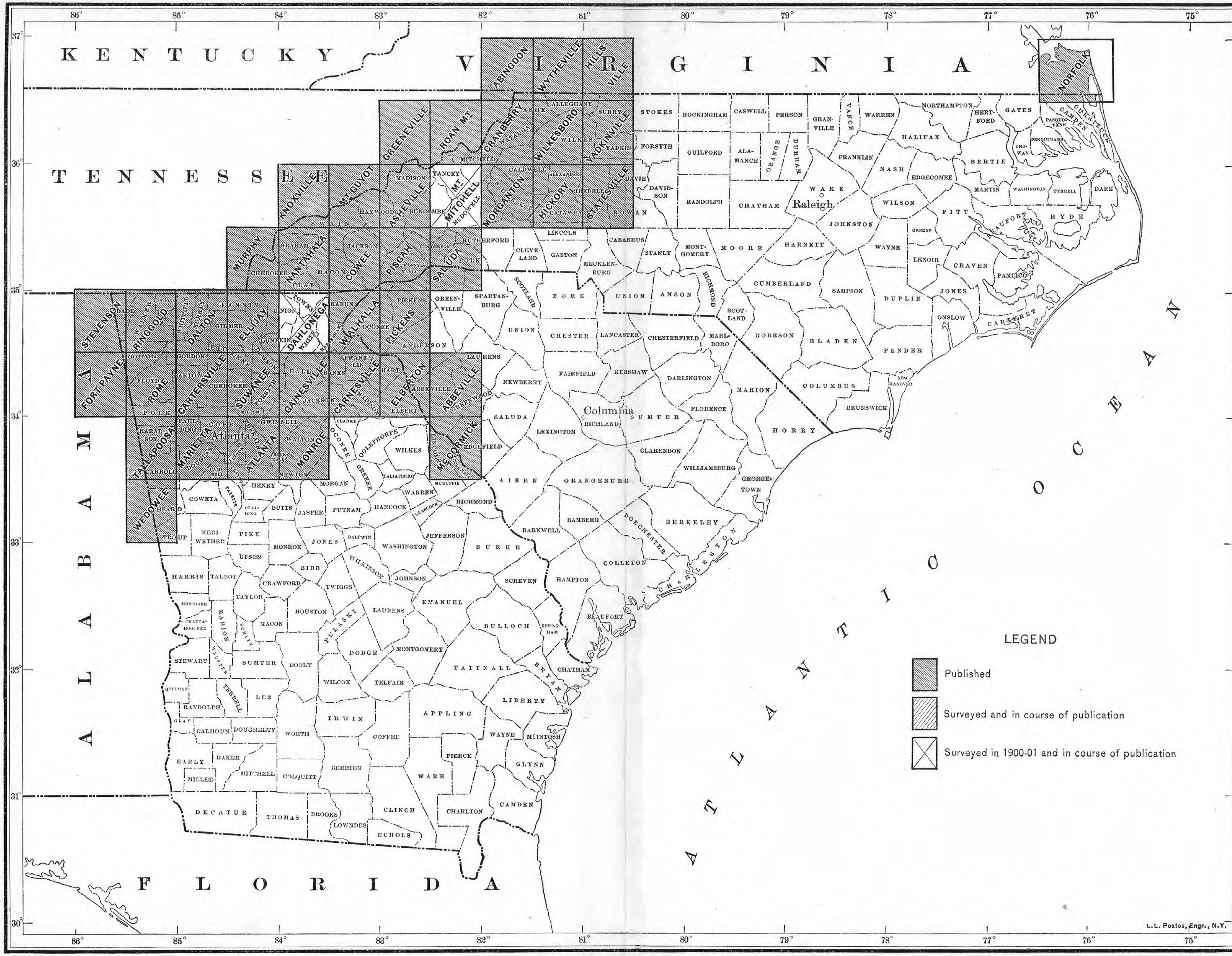
State or Territory.	Contour interval.	Scale of publication.		Total area surveyed.	Levels.	
		1:62500.	1:125000.		Distance run.	Number of bench marks.
	Feet.	*Sq. miles.*	*Sq. miles.*	*Sq. miles.*	*Miles.*	
Alabama	50	....	1,006	1,006	302	41
Arizona	20–50–100	403	986	*a* 1,391	352	120
Arkansas	50	....	1,954	1,954	407	57
California	50–100	1,207	3,640	4,847	1,089	216
Colorado	20–50–100	261	115	*b* 378	27	7
Delaware	20	111	....	111	22	2
Georgia	100	....	948	948	267	33
Idaho	50	163	118	281	122	21
Indiana	20	849	....	849	572	37
Iowa	20	....	800	800	162	19
Kansas	10	60	....	60	75	7
Kentucky	20–50	326	768	1,094	313	27
Maine	20	531	....	531	286	8
Maryland	10–20	1,441	....	1,441	1,400	18
Massachusetts	20	....	....	*c* 303	65	....
Minnesota	20	258	....	258	176	....
Missouri	10–20	416	1,784	2,200	480	70
Montana	50–100	38	1,995	2,033	524	141
New York	20	3,802	....	3,802	2,144	155
North Carolina	100	....	652	652	107	14
Ohio	20	40	....	40	45	4
Oregon	100	....	675	675	172	22
Pennsylvania	20	2,838	....	2,838	1,932	100
South Dakota	50	....	870	870	80	21
Tennessee	100	....	290	290	178	6
Texas	25	....	910	910	136	39
Utah	100	....	653	653	155	35
Virginia	20	39	....	39	....	....
Washington	100	....	1,096	1,096	180	28
West Virginia	20	205	132	337	165	10
Wisconsin	20	217	1,362	1,579	333	51
Wyoming	100	....	857	857	139	29
Total	....	13,205	21,611	35,123	12,407	1,338

a 2 miles on scale of 1:20000. *b* 2 miles on scale of 1:21120. *c* 303 miles on scale of 1:20000.

Present condition of topographic surveys and the new areas surveyed in 1900–01.

[Areas which were resurveyed are not included in this table.]

State or Territory.	Total area.	Area surveyed in 1900–01.	Area surveyed to Apr. 30, 1901.	
	Square miles.	*Square miles.*	*Square miles.*	*Per cent.*
Alabama	52,250	1,006	16,551	31
Arizona	113,020	1,391	59,121	52
Arkansas	53,850	1,954	18,454	34
California	158,360	4,847	57,849	37
Colorado	103,925	261	34,276	33
Connecticut	4,990	....	4,990	100
Delaware	2,050	111	755	37
District of Columbia	70	....	70	100
Florida	58,680	....	1,821	3
Georgia	59,475	....	14,522	24
Idaho	84,800	281	14,025	17
Illinois	56,650	....	4,485	8
Indian Territory	31,400	....	30,885	99
Indiana	36,350	849	1,459	4
Iowa	56,025	800	8,685	16
Kansas	82,080	60	62,806	77
Kentucky	40,400	1,094	11,527	29
Louisiana	48,720	....	7,492	15
Maine	33,040	531	4,767	14
Maryland	12,210	1,441	10,307	84
Massachusetts	8,315	....	8,315	100
Michigan	58,915	....	1,964	3
Minnesota	83,365	258	3,512	4
Mississippi	46,810	....	29	....
Missouri	69,415	2,200	32,007	47
Montana	146,080	2,033	38,221	26
Nebraska	77,510	....	26,228	35
Nevada	110,700	....	28,949	26
New Hampshire	9,305	....	2,396	26
New Jersey	7,815	....	7,815	100
New Mexico	122,580	....	27,777	23
New York	49,170	3,802	25,502	52
North Carolina	52,250	....	12,252	23
North Dakota	70,795	....	6,327	9
Ohio	41,060	40	1,864	5
Oklahoma	39,030	....	4,146	11
Oregon	96,030	675	14,813	15
Pennsylvania	45,215	2,838	10,785	24



MAP OF NORTH CAROLINA, SOUTH CAROLINA AND GEORGIA, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

Present condition of topographic surveys and the new areas surveyed in 1900-01—Continued.

State or Territory.	Total area.	Area surveyed in 1900-01.	Area surveyed to Apr. 30, 1901.	
	Square miles.	*Square miles.*	*Square miles.*	*Per cent.*
Rhode Island	1,250		1,250	100
South Carolina	30,570		3,900	13
South Dakota	77,650	870	17,143	22
Tennessee	42,050	290	18,681	44
Texas	265,780		58,427	22
Utah	84,970	653	64,280	76
Vermont	9,565		2,844	30
Virginia	42,450		29,227	69
Washington	69,180	690	9,161	13
West Virginia	24,780	337	17,564	71
Wisconsin	56,040	1,362	9,440	17
Wyoming	97,890	857	17,181	18
Total	3,024,880	31,531	866,847	29

Division of Triangulation.

ATLANTIC SECTION.

Mr. S. S. Gannett, topographer, exercised a general supervision of the primary control executed during the season in this section, under the general direction of Mr. H. M. Wilson, geographer in charge.

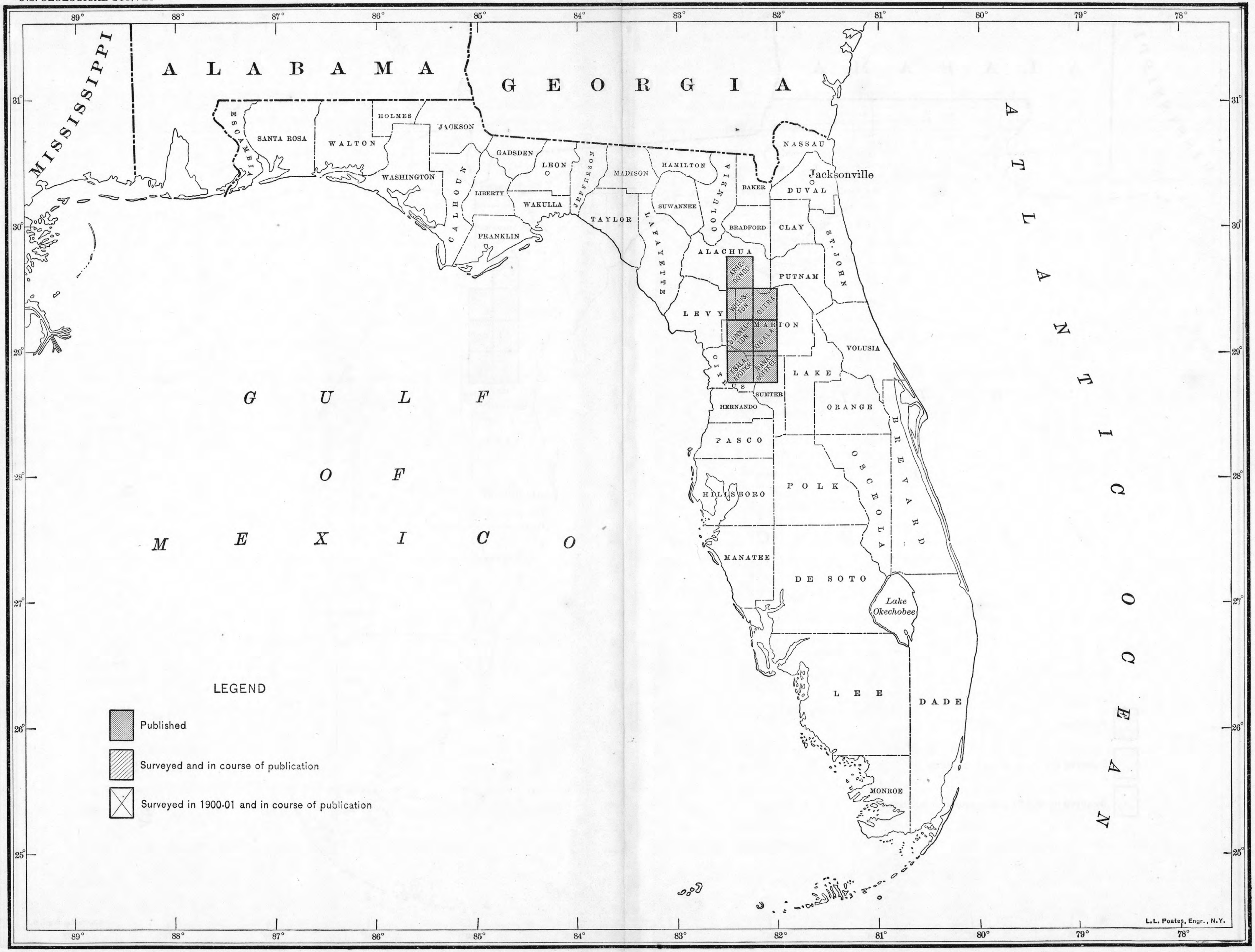
Primary triangulation was in progress at various times during the summer by eight different parties, and primary traverse at different times by four of the same parties. This work was distributed over portions of ten States—Maine, New York, New Jersey, Pennsylvania, Delaware, Maryland, West Virginia, Ohio, North Carolina, and South Carolina. The total area covered by this primary control was 25,415 square miles, of which 9,750 square miles were controlled by primary traverse. The result of this control was to make available ninety-one additional quadrangles in which to prosecute future topographic surveys. In the progress of this work 149 triangulation stations were marked and their geodetic positions were determined.

New York.—Messrs. Sledge Tatum, topographer; Oscar Jones, assistant topographer, and E. L. McNair, field assistant, were in charge of parties engaged in extending triangulation in various portions of this State during the months of April to September, inclusive. During April and May Mr. W. T. Griswold, topographer, was in charge of a party engaged in similar work, and at various times during the season Mr. S. S. Gannett, topographer, was engaged in triangulation in this State. The results of the field work of these parties furnished the control of 9,460 square miles, included within the limits of forty-four 15-minute quadrangles, and distributed throughout various portions of the following seventeen counties: Orange, Sullivan, Ulster, Delaware, Otsego, Oneida, Madison, Chenango, Cortland, Broome, Herkimer, Essex, Hamilton, Franklin, Clinton, Lewis, and St. Lawrence. In the course of this work 142 miles of primary traverse were run, the positions of 67 stations were established, and meridians were marked by posts at 8 county seats, namely, Goshen, Delhi, Cooperstown, Utica, Hamilton, Norwich, Binghamton, and Malone.

New Jersey.—A portion of the triangulation above described as extended over southern New York was based on Coast and Geodetic Survey positions in northern New Jersey, thus necessitating the occupation of 3 triangulation stations within the limits of this State.

Pennsylvania.—Messrs. A. H. Thompson, geographer, and D. H. Baldwin, assistant topographer, were in charge of parties engaged in extending primary triangulation in the central and western portions of this State throughout the season. Mr. Tatum was engaged in similar work in western Pennsylvania during portions of April and May, and Mr. Gannett during portions of August and September. The result of the field work of these parties was the occupation and monumenting of 47 stations, which furnished primary control for fifteen 15-minute quadrangles. These cover portions of the following ten counties: Adams, Cumberland, Bedford, Blair, Cambria, Huntingdon, Greene, Washington, Allegheny, and Beaver. In addition, 1 meridian was marked by posts at Washington county seat, and the Westchester quadrangle was controlled by 50 miles of primary traverse by Mr. Tatum, in March, 1901.

Maryland.—During the month of May Mr. George T. Hawkins, topographer, was in charge of a party engaged in extend-



MAP OF FLORIDA, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

ing control by means of primary traverse within the limits of this State. In the course of this work he ran 175 linear miles and secured control for eight 15-minute quadrangles, covering portions of the following counties: Caroline, Talbot, Dorchester, Wicomico, Worcester, and Somerset.

Delaware.—In conjunction with the above extension of primary control in Maryland, Mr. Hawkins ran 38 linear miles of primary traverse in Sussex County, and secured control for one additional quadrangle.

Maine.—During a portion of the month of August Mr. Gannett extended primary triangulation over 640 square miles, controlling three 15-minute quadrangles within the county of Penobscot, and occupying 7 primary triangulation stations.

Ohio.—During the months of July to November Mr. W. T. Griswold, topographer, was engaged in extending primary triangulation over the eastern portions of the State. In the course of this work he occupied 17 stations and secured control for 1,370 square miles, distributed over six 15-minute quadrangles and covering portions of Monroe, Belmont, Harrison, Jefferson, Carroll, and Columbiana counties.

During October and November Mr. McNair was in charge of a party extending control by means of primary traverse over the northeastern portion of the State. In the course of this work he ran 266 linear miles of such traverse, thus securing control for 2,500 square miles included within eleven additional 15-minute quadrangles and covering portions of seven additional counties—Cuyahoga, Summit, Medina, Wayne, Stark, Portage, and Geauga.

These parties also established 3 meridian marks at the county seats of St. Clairsville, Canton, and Wooster.

West Virginia.—In conjunction with the extension of primary triangulation by Mr. Griswold in Ohio, he incidentally secured similar control within the limits of this State for 675 square miles, covering three quadrangles, and included in portions of four counties—Marshall, Ohio, Brooke, and Hancock. In the course of this work he occupied 8 stations.

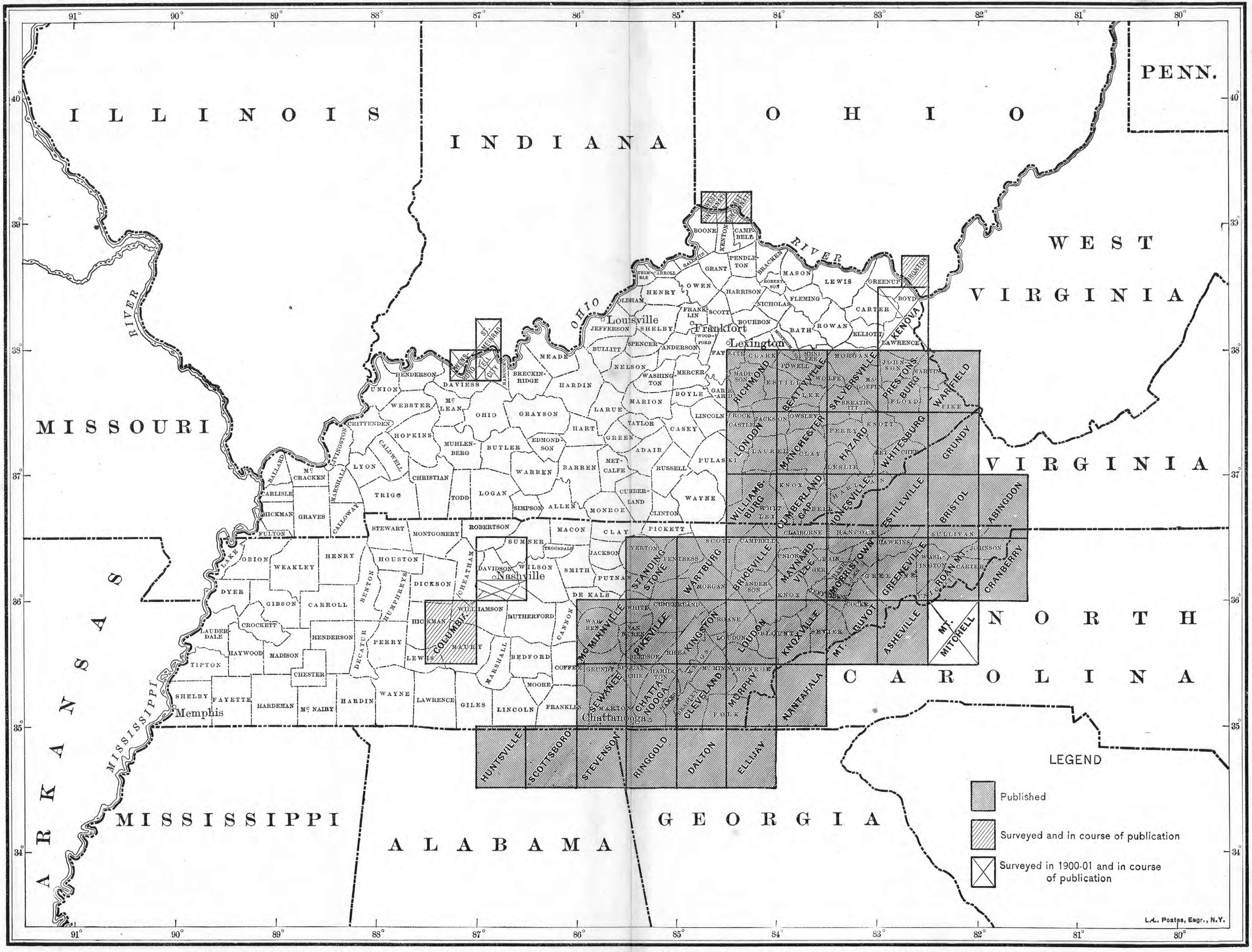
North Carolina.—During the months of September and October Mr. Jones was in charge of a party engaged in extending primary control over the eastern portions of this State. In the course of this work he ran 242 linear miles and secured control for 4,000 square miles, included within four 30-minute quadrangles and covering portions of eleven counties—Craven, Jones, Lenoir, Wayne, Greene, Wilson, Edgecombe, Martin, Pitt, Beaufort, and Washington.

South Carolina.—During the months of October and November Mr. Tatum was in charge of a party engaged in extending control by means of primary traverse over the central portion of the State. In the course of this work he ran 249 linear miles of such traverse, thus securing control for 1,000 square miles, covering one 30-minute quadrangle, included within portions of Richland, Chester, Union, Spartanburg, Fairfield, Newberry, and Lexington counties. Meridian lines were established at Columbia, Winnsboro, Lexington, Chester, and Union.

CENTRAL SECTION.

Ohio.—Primary control in central and western Ohio was obtained by traverse run along the Baltimore and Ohio Railroad from Mount Lookout, Cincinnati, to Columbus; thence along the Hocking Valley Railroad to Toledo; thence back to Columbus, following the line of the Toledo and Ohio Central Railroad. This work, amounting to 374 miles, was done by Mr. George T. Hawkins, topographer, in September and October, 1900, and was supplemented in the spring of 1901 by Mr. J. R. Ellis, field assistant, who ran lines of traverse along the highways in the northern-central portion of the State, approximately on the meridians and parallels forming boundaries of the 15-minute quadrangles, the total number of quadrangles controlled being fourteen, included within portions of fourteen counties—Wood, Sandusky, Hancock, Seneca, Wyandot, Hardin, Marion, Union, Delaware, Franklin, Fayette, Clinton, Warren, and Hamilton. Meridians were established at seven county seats—Washington Court-House, Marysville, Bowling Green, Upper Sandusky, Findlay, Kenton, and Delaware.

Kentucky-Indiana.—A traverse was run from the Coast and Geodetic Survey astronomic pier at Henderson, along the Louisville, Henderson and St. Louis Railroad to Hawesville, crossing the Ohio River by triangulation; thence along the Cannelton branch of the Louisville, Evansville and St. Louis



MAP OF KENTUCKY AND TENNESSEE, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

Railroad to Lincoln City, Ind. Four 15-minute quadrangles, in Henderson, Daviess, and Hancock counties, Ky., and in Perry and Spencer counties, Ind., were thus controlled in parts of August and September, 1900, by Mr. Hawkins. This work amounted to 96 miles. Meridians were established at Owensboro and Hawesville, Ky., and at Cannelton, Ind.

Missouri.—Two 30-minute quadrangles in the northeastern portion of the State, in the counties of Lewis, Knox, Adair, Schuyler, Scotland, and Clark, were controlled by a traverse beginning at West Quincy; thence running westward along the Omaha, Kansas City and Quincy Railroad to Kirksville; thence south to Glenwood via the Wabash Railroad; thence eastward to Wayland via the Keokuk and Western Railroad. The field work, amounting to 160 miles, was done in July, 1900, by Mr. Hawkins, who also established meridians at Edina, Memphis, Kirksville, Kehoka, and Lancaster.

Missouri-Kansas.—Three 30-minute quadrangles in southwestern Missouri, in the counties of Green, Dade, Barton, Jasper, and Lawrence, and one in southeastern Kansas, in Barbour and Cherokee counties, were controlled by Mr. Hawkins by a traverse of 223 miles along the Kansas City, Fort Scott and Memphis Railway from Springfield, Mo., to Fort Scott, Kans., and along the St. Louis and San Francisco Railroad from Springfield, Mo., to Oswego, Kans. Meridian lines were established at Columbus, Kans., and at Lamar and Carthage, Mo.

Arkansas.—The Bearden quadrangle, in Ouachita County, was controlled by a traverse of 55 miles from Gurdon southeastward along the St. Louis, Iron Mountain and Southern Railway to Camden, thence northeastward along the St. Louis and Texas Railway to Harlow. This work was done by Mr. Hawkins, who likewise established a meridian at Camden.

ROCKY MOUNTAIN SECTION.

South Dakota-Wyoming.—Two new stations, controlling one 30-minute quadrangle in Fall River County, in the southern part of the Black Hills, were occupied by Mr. A. F. Dunnington, topographer, who also extended triangulation northward from parallel 44° 30′ to 45° between meridians 103° and

104° 30′. Eight stations, controlling two 30-minute quadrangles in Butte County, S. Dak., and one in Crook County, Wyo., were occupied, and a meridian line was established at Bellefourche, S. Dak.

Montana.—In the fall of 1900 Mr. R. H. Chapman, topographer, located by secondary triangulation and the three-point method many mines, shaft houses, tunnel mouths, etc., the positions of 104 new points being determined, all in the vicinity of Butte, Silverbow County.

Arizona.—Triangulation was extended eastward from Globe through Graham County into New Mexico. Five 30-minute quadrangles were controlled by 12 occupied stations and 9 intersected points. The field work was in the main performed by Mr. Jeremiah Ahern, topographer.

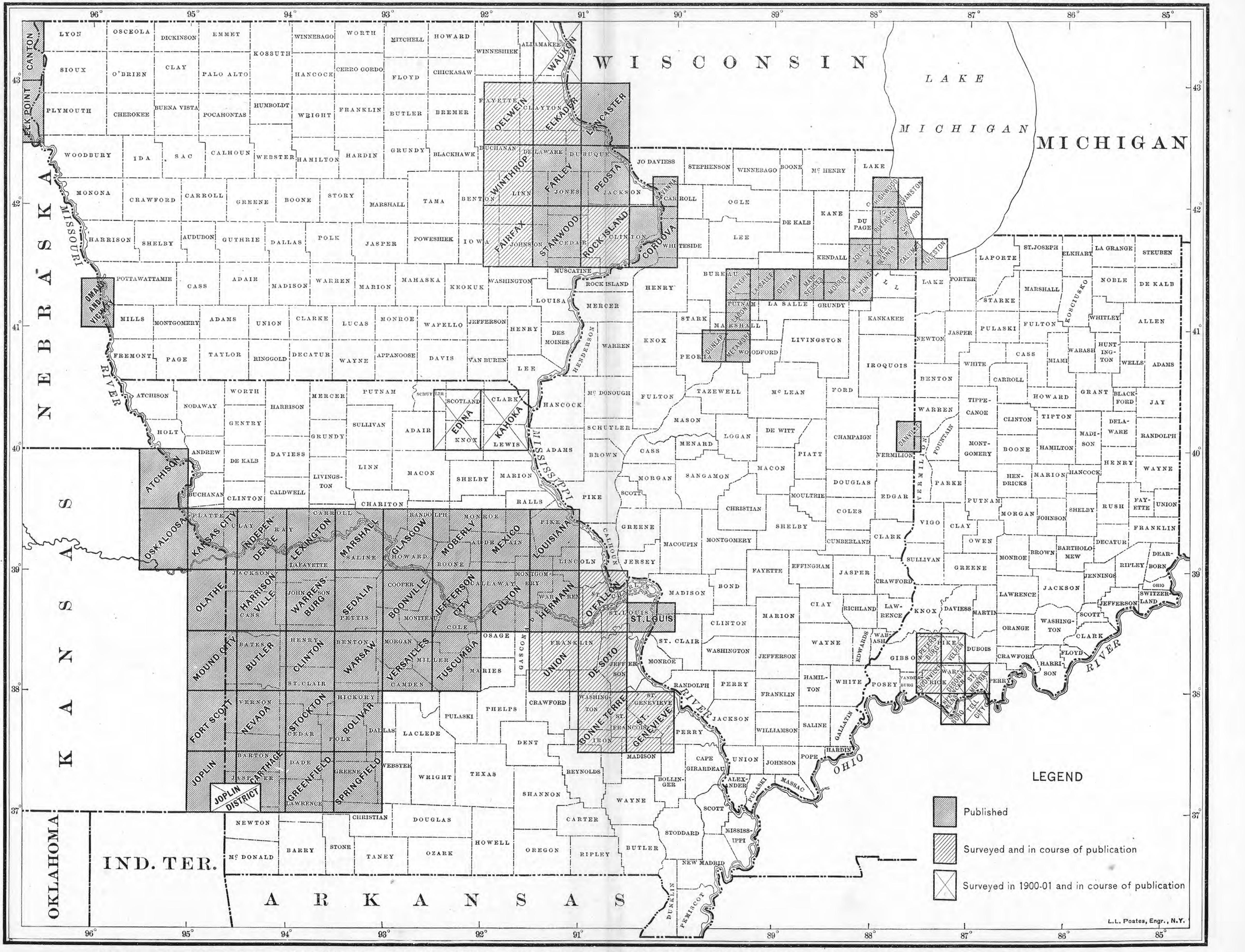
PACIFIC SECTION.

Idaho.—In order to control the Cœur d'Alene mining district, triangulation was extended eastward from stations in the Spokane base system in June, 1900, by Mr. C. F. Urquhart, topographer, who established 5 new stations in the counties of Kootenai and Shoshone.

Washington.—Triangulation in northern-central Washington, in the counties of Ferry and Okanogan, was extended westward from meridian 119 to meridian 120, controlling four 30-minute quadrangles and connecting the work based upon the Spokane system with that based upon the Ellensburg system. During the summer 6 new and 5 old stations were occupied by Mr. Urquhart.

California.—Four three-point stations, for the control of the Randsburg mining district, in Kern and San Bernardino counties, were occupied by Mr. R. U. Goode, geographer, during the latter part of September, 1900. This work is based upon four stations established by the Wheeler Survey.

Alaska, Nome district.—Triangulation was extended northwestward from Golofnin Bay from stations of the Coast and Geodetic Survey. Nine stations, controlling 1,000 square miles, were occupied by Mr. R. B. Robertson, field assistant, under the direction of Mr. E. C. Barnard, topographer. Angles were measured with a new 4-inch Vernier theodolite reading to thirty seconds.



MAP OF INDIANA, ILLINOIS, IOWA AND MISSOURI, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

FOREST RESERVES.

ROCKY MOUNTAIN SECTION.

Lewis and Clarke Reserve (*Montana*).—Mr. R. H. Chapman, topographer, extended the triangulation of previous years northward and westward nearly to Kalispel, occupying 14 stations for the control of five 30-minute quadrangles in Flathead County.

Flathead Reserve (*Montana*).—Mr. H. L. Baldwin, jr., topographer, occupied 9 stations, controlling two 30-minute quadrangles partly within the Flathead Reserve and in Teton and Flathead counties.

Prescott Reserve (*Arizona*).—In the fall of 1900 Mr. Baldwin extended triangulation northwestward from Camels Back and Black Mesa, stations established the preceding year by Mr. A. H. Thompson, geographer. Eight new stations, controlling two 30-minute quadrangles in Maricopa and Yavapai counties, were occupied.

Bighorn Reserve (*Wyoming*).—Mr. Frank Tweedy, topographer, extended triangulation southeastward from the vicinity of Sheridan, occupying 8 new stations for the control of the Sheridan and Fort McKinney quadrangles in Sheridan and Johnson counties.

PACIFIC SECTION.

Pine Mountain and Zaca Lake Reserve (*California*).—For the control of this reserve 9 new primary stations were occupied and 7 points located by intersection in Ventura, Los Angeles, and Santa Barbara counties by Mr. Urquhart during portions of May, June, November, and December.

Sierra Reserve (*California*).—Three 30-minute quadrangles in the high Sierras were controlled in the summer of 1900 by Mr. E. T. Perkins, jr., topographer, who extended triangulation southward from Mounts Conness, Lyell, Hoffman, and Devil. In addition to these stations, 10 new stations were occupied and numerous prominent points located by intersection in the counties of Fresno, Madera, Mono, Tulare, and Tuolumne.

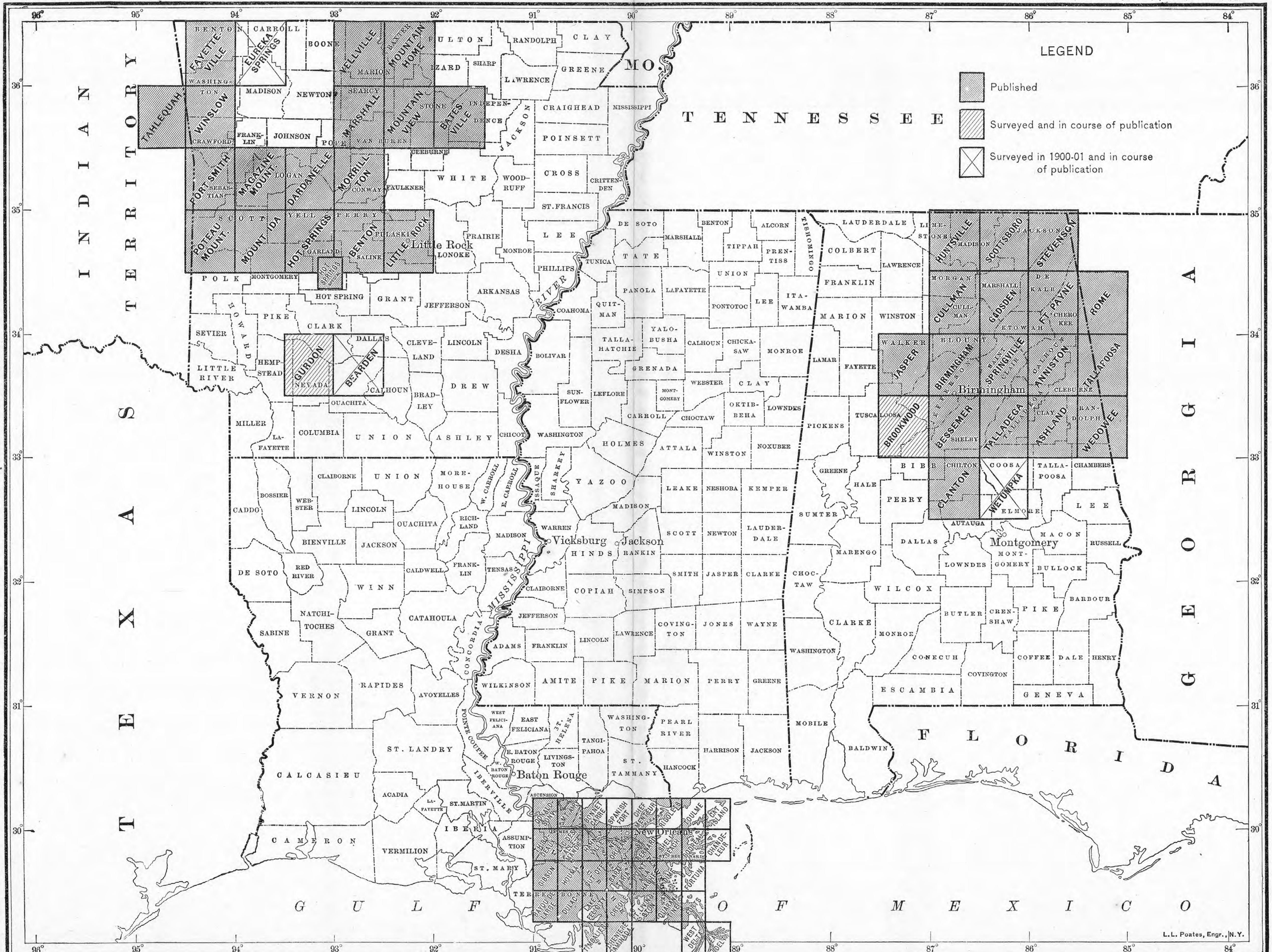
San Jacinto Reserve (*California*).—Three stations in San Diego and Riverside counties, controlling the southeastern part of this reserve, were occupied by Mr. Perkins in April, 1901.

Division of Topography.

ATLANTIC SECTION.

Topographic work was carried on during the season by fifteen parties, working in twelve States—New York, Pennsylvania, Delaware, Maryland, Maine, Massachusetts, West Virginia, Kentucky, Ohio, Georgia, North Carolina, and Tennessee. The survey of fifty quadrangles was completed, of which forty-five were on the scale of 1:62500, with a contour interval of 20 feet; three were on the scale of 1:125000, with a contour interval of 50 to 100 feet, and two were on the scale of 1:20000, with a contour interval of 20 feet. In addition, the survey of thirty-five quadrangles was partially completed, of which twenty-nine were on the scale of 1:62500, with a contour interval of 20 feet; one was on the scale of 1:125000, with a contour interval of 50 feet, and five were on the scale of 1:20000, with a contour interval of 20 feet. The total area surveyed was 12,100 square miles, of which 9,007 were on the scale of 1:62500, while 2,790 were on the scale of 1:125000, and 303 were on the scale of 1:20000. In addition, 1,341 square miles were revised for culture only. Levels were run over 6,811 linear miles, resulting in the establishment of 368 permanent bench marks.

New York.—Work was carried on under the cooperative topographic agreement made with the State engineer and surveyor of New York, whereby the State appropriated $19,500 for the work and the Director of the United States Geological Survey allotted a like amount. There were maintained on such work during the season eight parties. Mr. J. H. Jennings, topographer, was placed in charge of a group of four parties, under the direction of Messrs. A. C. Roberts, topographer, W. W. Gilbert, assistant topographer, J. M. Whitman, jr., field assistant, and Mr. Jennings himself. These parties commenced field work about the middle of April and were disbanded in November. During the season they completed the mapping of eight quadrangles: Canandaigua, Norwich, Penn Yan, Hammonds-



MAP OF ALABAMA, MISSISSIPPI, ARKANSAS, AND LOUISIANA, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

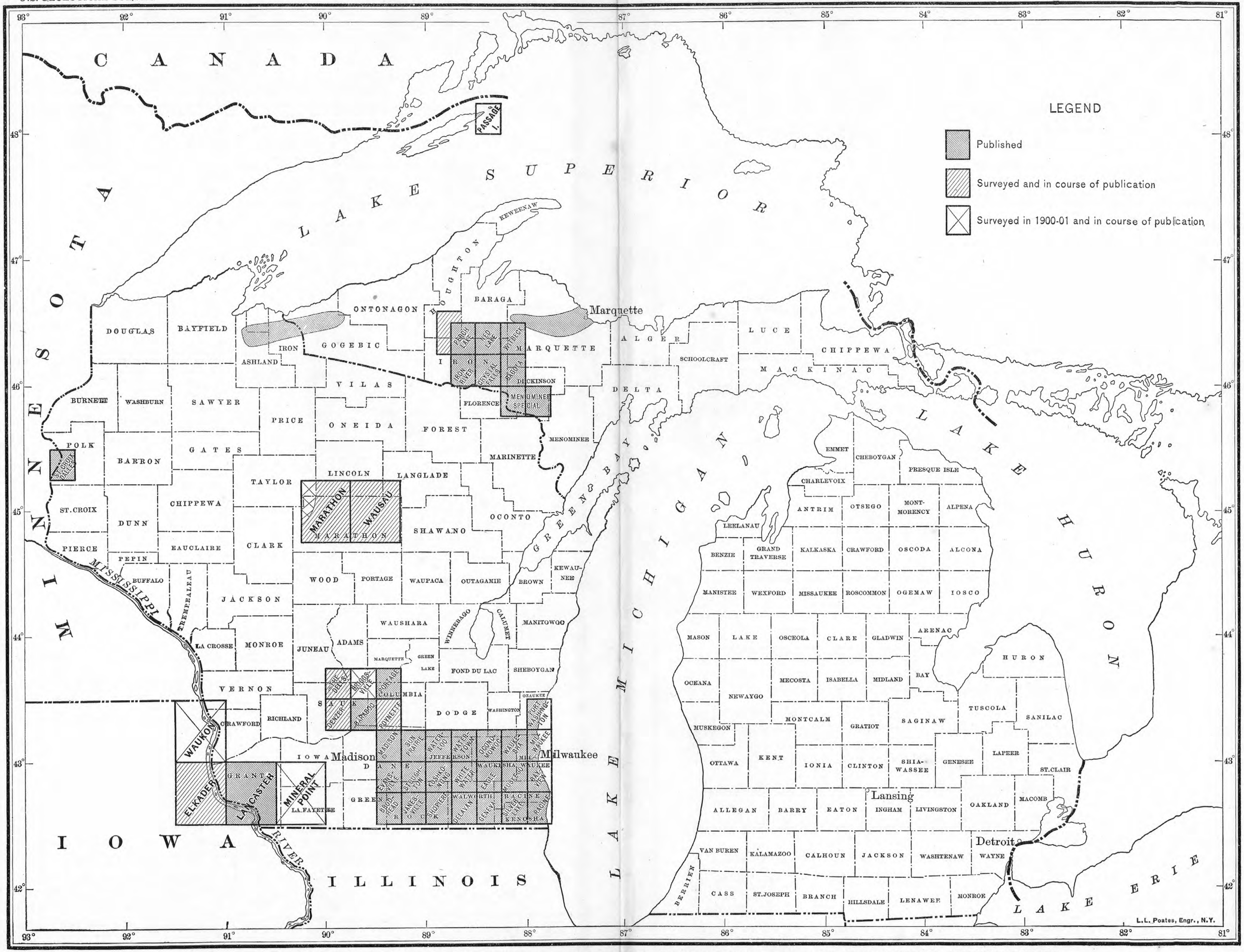
port, Owego, Naples, Richfield Springs, and Cortland, covering portions of Ontario, Chenango, Livingston, Tioga, Yates, Steuben, Schuyler, Otsego, Herkimer, and Cortland counties, and the partial mapping of Binghamton, Appalachian, Pitcher, Harford, Buffalo, and Niagara quadrangles, covering portions of Broome, Tioga, Chenango, Cortland, Erie, and Niagara counties. Mr. W. H. Lovell, topographer, completed the survey of Clayton, Theresa, Grindstone, Luzerne, and Alexandria Bay quadrangles, covering portions of Jefferson, St. Lawrence, Warren, and Saratoga counties, also the partial mapping of the Gloversville quadrangle, in Fulton and Hamilton counties. Mr. C. C. Bassett, topographer, completed the survey of the Newburg, Phœnicia, and Kinderhook quadrangles. in Orange, Ulster, Greene, Columbia, and Rensselaer counties, and the partial mapping of the Gilboa quadrangle, in Schoharie, Greene, and Delaware counties. Mr. Glenn S. Smith, topographer, completed the survey of the Berne quadrangle, covering portions of Albany and Schoharie counties, and the partial mapping of the Big Moose quadrangle, covering portions of Hamilton and Herkimer counties. Mr. A. H. Bumstead, topographer, completed the survey of the Blue Mountain quadrangle, commenced the previous season by Mr. A. M. Walker, topographer, and covering portions of Hamilton and Essex counties.

The map work in New York was on the scale of 1:62500, with a contour interval of 20 feet, and embraced an area of finished topography aggregating 3,802 square miles. In connection with the above, 1,796 miles of primary levels were run and 101 permanent bench marks were established.

During the months of June to August, inclusive, Mr. C. H. Semper ran three lines of precise levels, one from a bench mark of this Survey near Tupper Lake Junction northward to a bench mark of the Deep Waterways Commission at Fort Covington; another from the Remsen bench mark northwestward to a bench mark of the Deep Waterways Commission near Cape Vincent. The routes of these levels were over the lines of the New York Central and the Rome, Watertown and Ogdensburg railroads, respectively. The third line of levels was run over the line of the Erie Railroad, from a bench mark previously established by this Survey at Binghamton to Port Jervis, and thence to a bench mark of the Coast and

Geodetic Survey at Poughkeepsie. In all 348 miles of levels were run, in the course of which 54 bench marks were established.

Pennsylvania.—Work was prosecuted under the cooperative topographic agreement entered into between the State survey commissioners of Pennsylvania and the Director of the United States Geological Survey, whereby the State appropriated $18,000 for the work and the Director of the Survey allotted a like amount. There were maintained on such work during portions of the season seven parties. Mr. Frank Sutton, topographer, was placed in general charge of a group of three parties, headed by Messrs. J. H. Wheat, topographer; T. G. Basinger, assistant topographer, and himself. Messrs. W. N. Morrill and A. C. Roberts, topographers, spent the months of May and June on the same pieces of work under Mr. Sutton's direction. During the season these parties completed the mapping of four quadrangles—Indiana, Latrobe, Connellsville, and Brownsville, covering portions of the counties of Indiana, Westmoreland, Fayette, Washington, and Allegheny. They also completed the control and partial mapping of the Waynesburg, Beaver, Rural Valley, and Elders Ridge quadrangles, covering portions of Greene, Beaver, Allegheny, Armstrong, and Indiana counties. Mr. W. L. Miller, topographer, spent the months of May, June, July, and August, and Mr. W. C. Hall, topographer, the month of September, in charge of a party which completed the mapping of the Kittanning quadrangle, covering portions of Armstrong, Butler, and Clarion counties. Mr. R. D. Cummin, topographer, spent the season in charge of a party which completed the mapping of the Mercersburg and Chambersburg quadrangles, covering portions of Fulton and Franklin counties; also the control and partial mapping of the Carlisle quadrangle, covering portions of Cumberland, York, and Adams counties. Mr. A. M. Walker, topographer, completed the mapping of the Everett and Tioga quadrangles, covering portions of Bedford and Tioga counties, and the mapping of part of the Hollidaysburg quadrangle, in Blair, Huntingdon, and Bedford counties. Mr. Hersey Munroe, topographer, was engaged for the season, and was assisted during the months of September, October, and November by



MAP OF MICHIGAN AND WISCONSIN, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

Mr. W. R. Harper, assistant topographer, in completing the mapping of the Wernersville, Slatington, and Boyertown quadrangles, covering portions of Lebanon, Berks, Lancaster, Northampton, Lehigh, Bucks, and Montgomery counties; also the partial mapping of the Westchester quadrangle, covering portions of Chester, Delaware, and Newcastle counties. Mr. Glenn S. Smith, topographer, spent the month of October in mapping a small portion of the Galeton quadrangle, in Tioga and Potter counties.

The area surveyed in Pennsylvania was mapped on the scale of 1:62500, with a contour interval of 20 feet, and aggregated 2,760 square miles of finished topography. In connection with this 1,932 miles of spirit levels were run and 100 permanent bench marks were established.

Maryland-Pennsylvania-Delaware.—Work was prosecuted under the cooperative agreement entered into between the State geologist of Maryland and the Director of the United States Geological Survey, whereby $5,000 was appropriated by the State and a like sum was allotted by the Director of the Survey. There were maintained on this work during the season two parties. Mr. W. Carvel Hall, topographer, was in general charge of this work. During the months of April, May, and June he was assisted by Messrs. W. N. Brown, assistant topographer, and A. C. Roberts, topographer, who completed the mapping of the Belair quadrangle, covering portions of York County, Pa., and Harford County, Md. During the months of April to August, inclusive, he was assisted by Mr. Walter R. Harper, assistant topographer, in securing control for the sheets on the eastern shore. In addition to the Belair sheet, this party completed the mapping of the Parkton, Princess Anne, Salisbury, Snow Hill, Ocean City, Green Run, and Pittsville quadrangles, covering portions of York County, Pa.; Baltimore, Harford, Somerset, Worcester, and Wicomico counties, Md.; Accomac County, Va., and Sussex County, Del. Field work on the Pittsville quadrangle was executed largely by Messrs. T. G. Basinger and George H. Guerdrum, assistant topographers. The same party completed the resurvey of the Gunpowder quadrangle, and the partial mapping of the Crisfield and Deal Island quadrangles, covering portions of Somerset County.

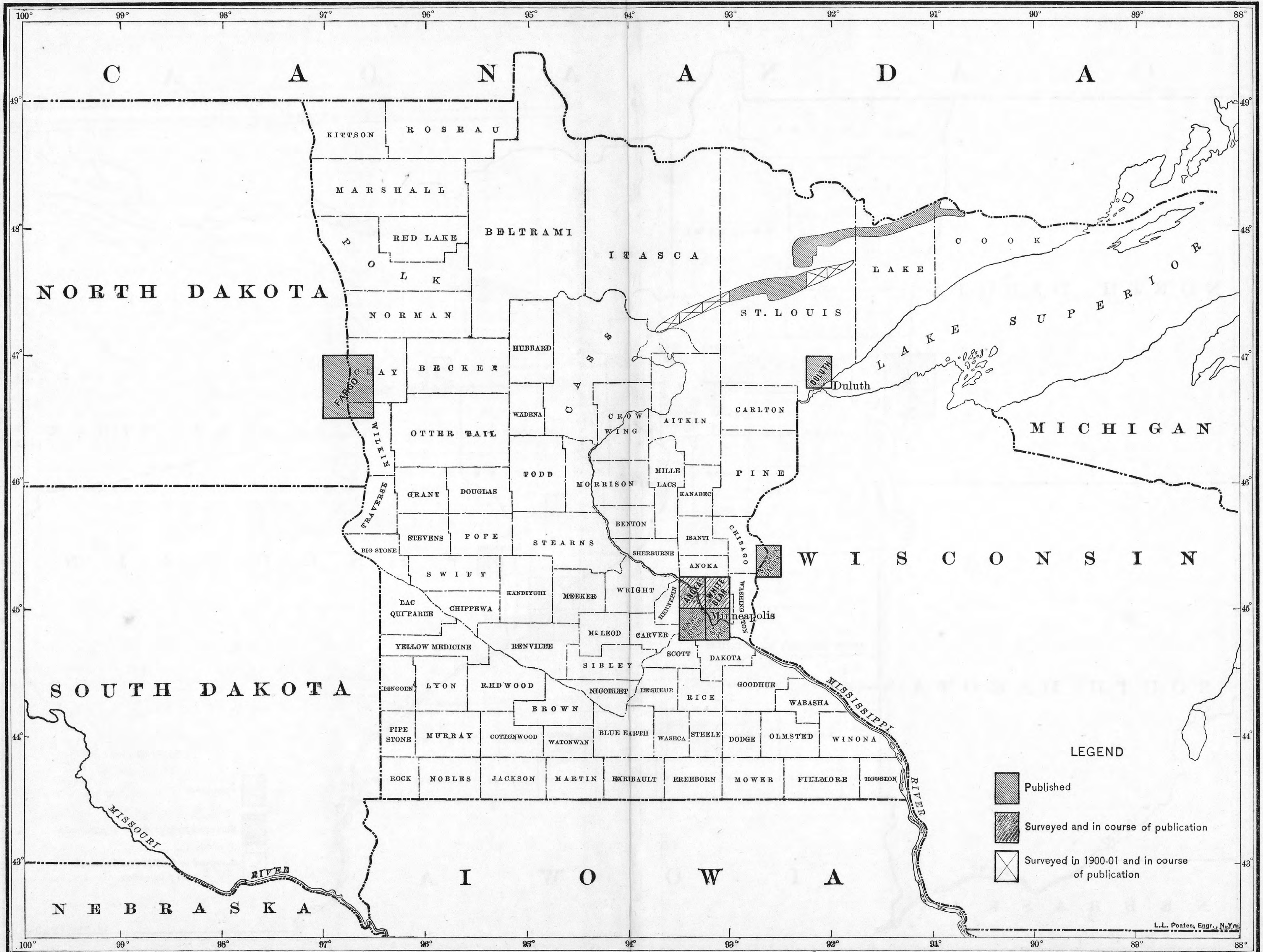
Mr. Basinger for two months, and Mr. J. Morrison Harris, field assistant, for the remainder of the season, were in charge of revision, for culture only, of the following sheets: Point Lookout, Leonardtown, Indian Head, East Washington, Owensville, Wicomico, Prince Frederick, Brandywine, Laurel, Drum Point, and Piney Point, covering portions of the counties of St. Mary, Calvert, and Prince George.

All of the above work was on the scale of 1:62500, with a contour interval of 20 feet, and embraced an area within the three States of 2,985 square miles of completed topography. The spirit leveling aggregated 1,422 linear miles and 20 permanent bench marks.

Maine.—Work was prosecuted under the cooperative agreement between the topographic survey commissioners of the State of Maine and the Director of the United States Geological Survey, whereby the State appropriated $2,500 for the seasons of 1900 and 1901 and the Director of the Survey allotted a like amount. There was maintained on such work during the season one party, under the general charge of Mr. E. B. Clark, topographer, from May to August, inclusive, and under the general charge of Mr. W. H. Lovell, topographer, from September to November, inclusive. This party completed the survey of the Bangor, Orono, and Castine quadrangles, in Penobscot, Hancock, and Waldo counties.

The scale of work was 1:62500, with a contour interval of 20 feet, and the area mapped was 531 square miles, in connection with which 286 miles of spirit levels were run and 8 permanent bench marks were established.

Massachusetts.—Mr. J. H. Wheat, topographer, assisted by Messrs. E. B. Clark, A. H. Bumstead, and Robert Muldrow, topographers, and Messrs. T. G. Basinger and Robert Coe, assistant topographers, were engaged from April to June, inclusive, and from October to November, inclusive, in mapping the Boston and vicinity special sheet, covering portions of Middlesex, Suffolk, Essex, and Norfolk counties, all within the metropolitan district. The scale of field work was 1:20000,



MAP OF MINNESOTA, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

with a contour interval of 20 feet. The area mapped was 303 square miles, and is included within two 15-minute quadrangles—Boston and Boston Bay—and portions of five others—Abington, Dedham, Franklin, Lawrence, and Salem.

West Virginia-Pennsylvania.—From June to November, inclusive, Messrs. J. M. Whitman, jr., field assistant, and A. M. Walker, topographer, were engaged in completing the mapping of the Morgantown quadrangle, covering portions of Greene, Fayette, Monongalia, and Preston counties. The scale of field work was 1:62500 and the contour interval 20 feet. The area mapped was 230 square miles, in connection with which 65 miles of spirit levels were run.

Kentucky-West Virginia-Ohio.—From June to November, inclusive, Mr. W. N. Morrill, topographer, was in charge of a party engaged in mapping the Kenova quadrangle, covering portions of Greenup, Carter, Boyd, Elliott, Lawrence, Wayne, and Cabell counties. The scale of field work was 1:125000, with a contour interval of 50 feet. The area mapped was 898 square miles, in connection with which 365 miles of spirit levels were run and 28 permanent bench marks were established.

Ohio.—Mr. Morrill, with his party, was engaged during part of the month of November in mapping the Ceredo 15-minute quadrangle, in Lawrence County. The field work was on the scale of 1:62500, with a contour interval of 20 feet. The area mapped, which is included within the limits of the Kenova 30-minute quadrangle, was 40 square miles. In connection with the work 45 miles of spirit levels were run and 4 permanent bench marks were established.

Georgia-North Carolina.—Mr. Albert Pike, topographer, assisted by Mr. G. H. Guerdrum, assistant topographer, resurveyed the Dahlonega quadrangle, covering portions of Towns, Union, Rabun, White, Habersham, Lumpkin, Hall, and Clay counties. They were engaged on this work from June 1 to December, including a portion of the latter month. The scale of this work was 1:125000, with a contour interval of 100 feet. The area mapped was 980 square miles, in connection with which 267 miles of spirit levels were run and 33 permanent bench marks were established.

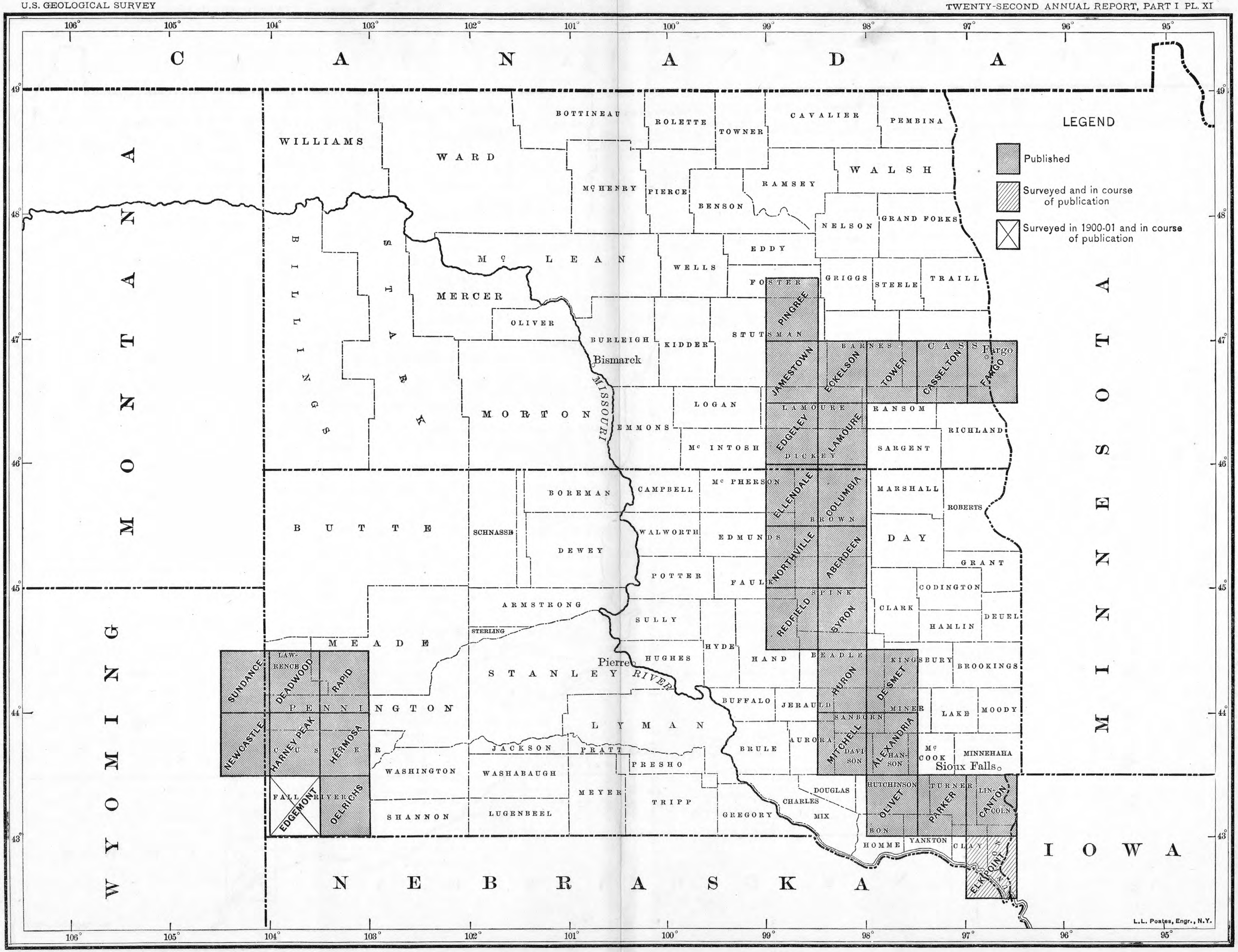
North Carolina-Tennessee.—Mr. W. N. Brown, assistant topographer, was in charge of a party working from June to November, inclusive, engaged in the mapping of the Mount Mitchell quadrangle, covering portions of the counties of Madison, Yancey, Unicoi, Mitchell, Buncombe, and McDowell. The scale of field work was 1:125000, with a contour interval of 100 feet. The area mapped was 619 square miles, in connection with which 107 miles of spirit levels were run and 14 permanent bench marks were established.

Tennessee.—Mr. W. L. Miller, topographer, assisted by Messrs. D. H. Baldwin and Robert Coe, assistant topographers, was engaged during the months of September, October, and November in mapping a portion of the Nashville quadrangle, covering parts of the counties of Williamson, Davidson, Rutherford, Wilson, Sumner, Robertson, and Cheatham. The scale of the work was 1:125000, with a contour interval of 50 feet. During this time 293 square miles were mapped, in connection with which 178 miles of spirit levels were run and 6 permanent bench marks were established.

CENTRAL SECTION.

During the season eleven topographic parties were employed in the States of Indiana, Kentucky, Missouri, Kansas, Arkansas, Alabama, Wisconsin, Iowa, and Minnesota. Fourteen complete quadrangles and portions of two others were surveyed, also an irregular area of 258 square miles in the Mesabi Range of Minnesota. In addition, revision of cultural features was done on four 15-minute quadrangles in the glacial district of southeastern Wisconsin, covering an area of 900 square miles. The total area surveyed was 9,032 square miles, of which 2,126 square miles were on the scale of 1:62500 and 6,906 square miles were on the scale of 1:125000. Spirit levels were carried over 2,620 linear miles, from which 291 permanent bench marks were established.

Indiana.—Field work was commenced in this State on June 15 by Mr. C. W. Goodlove, topographer, and was continued until the 20th of December, during which time the De Gonia Springs, St. Meinrad, and Velpen quadrangles were surveyed. This area included parts of Pike, Dubois, Warrick, and Spen-



MAP OF NORTH DAKOTA AND SOUTH DAKOTA, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

cer counties and covered 705 square miles, on the scale of 1:62500, with a contour interval of 20 feet. In connection with this work 460 miles of levels were run and 28 permanent bench marks were established.

Indiana-Kentucky.—On June 15 Mr. Charles E. Cooke, topographer, began field work in the southern part of Indiana, adjoining on the south the district which had been assigned to Mr. Goodlove, and continued until the early part of November, closing the season in the vicinity of Owensboro, Ky. During this time he completed the mapping of the Tell City and Owensboro quadrangles, including parts of Spencer, Warrick, and Perry counties, Ind., and Hancock and Daviess counties, Ky., covering an area of 470 square miles, on the scale of 1:62500, with a contour interval of 20 feet. In connection with this work 225 miles of spirit levels were run and 18 permanent bench marks were established.

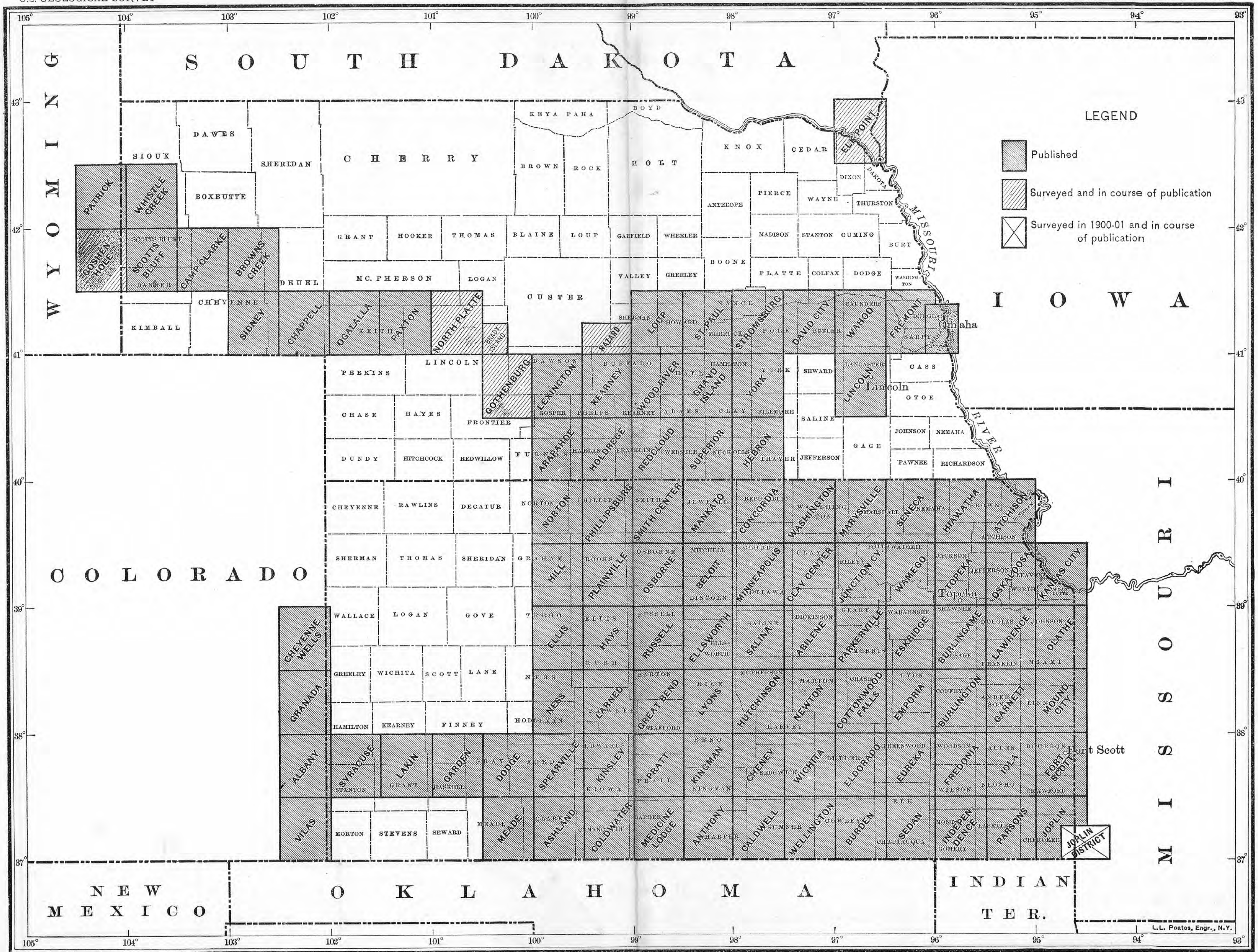
Missouri-Iowa.—Field work in the northeast corner of Missouri and extending across Des Moines River into Iowa was commenced by Mr. Paul Holman, topographer, in the latter part of June and was continued until the middle of November, when the Edina and Kahoka quadrangles were completed. The district surveyed includes parts of Schuyler, Knox, and Lewis counties in Missouri and a part of Lee County in Iowa, and covers an area of 1,824 square miles, on the scale of 1:125000, with a contour interval of 20 feet. During the progress of the work 292 miles of levels were run and 58 permanent bench marks were established.

Missouri-Kansas.—About July 1 Mr. William H. Griffin, topographer, and his assistant, Mr. Basil Duke, topographer, began field work in the Joplin mining district and continued there until December 20, during which time an area of 476 square miles was surveyed, lying mainly in Jasper and Newton counties, Mo., and extending into Cherokee County, Kans. The work was on the scale of 1:62500, with a contour interval of 10 feet, and in connection therewith 281 miles of spirit levels were run and 20 permanent bench marks were established.

Arkansas.—Mr. H. B. Blair, topographer, commenced field work in the northwestern part of the State the middle of June and continued until the 1st of November, being assisted after October 15 by Mr. Duncan Hannegan, topographer. During the season the Eureka Springs quadrangle was surveyed, covering parts of Benton, Carroll, Washington, and Madison counties, and comprising an area of 959 square miles, on the scale of 1:125000, with a contour interval of 50 feet. In connection with this work 233 miles of levels were run and 28 permanent bench marks were established.

Field work was commenced about June 15 in the southwestern part of Arkansas by Mr. Duncan Hannegan, topographer, and continued until October 15, when the Bearden quadrangle was completed and Mr. Hannegan joined Mr. Blair, as previously indicated. In this district 995 square miles were surveyed, on the scale of 1:125000, with a contour interval of 50 feet, covering parts of Clark, Dallas, Ouachita, and Calhoun counties. During the progress of topographic work 174 miles of spirit levels were run, from which 29 permanent bench marks were established.

Alabama.—Field work was commenced about the end of June by Mr. Nat. Tyler, jr., topographer, on the Wetumpka quadrangle. Mr. Tyler continued in this district until September 15, when he was transferred to Wisconsin, having surveyed 300 square miles, covering the area west of Coosa River. On September 15 Mr. Robert Muldrow, topographer, having completed field work in Wisconsin, was transferred to Alabama, relieving Mr. Tyler. The work was continued under Mr. Muldrow's directions until January 1, when the party was disbanded on account of continuous bad weather and impassable roads. Operations were resumed April 1 and continued until the middle of June, when the quadrangle was completed. The area surveyed comprised 1,006 square miles, on the scale of 1:125000, with a contour interval of 50 feet, lying in parts of Coosa, Chilton, Autauga, and Elmore counties. In order to furnish a reliable datum for the levels of this district, a double-rodded line was carried from the permanent bench mark of this Survey at Anniston, Calhoun County, along the railroad, via Talladega and Sylacauga, to Kellyton, in the northeast corner of the quadrangle. This line was 58 miles in length, and 11 bench marks were established. In connection with the



MAP OF NEBRASKA AND KANSAS, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

topographic work in this quadrangle 244 miles of spirit levels were run and 30 permanent bench marks were established.

Wisconsin.—Field work was resumed in the Wausau district of the central part of the State on June 20 by Mr. Robert Muldrow, topographer, and was continued until about the middle of July, when the Marathon special quadrangle, commenced in the season of 1899, was completed. The area surveyed was 150 square miles, on the scale of 1:125000, with a contour interval of 20 feet, lying in parts of Taylor and Marathon counties. In connection with this work 10 permanent bench marks were established. Mr. Muldrow then began work on the resurvey of the Briggsville quadrangle, and continued there until September 15, when he was transferred to Alabama, as stated elsewhere. In the Briggsville quadrangle 125 square miles were surveyed by Mr. Muldrow, on the scale of 1:62500, with a contour interval of 20 feet, lying in parts of Adams, Marquette, Sauk, and Columbia counties. In connection with this work 92 miles of levels were run and 6 permanent bench marks were established.

Mr. R. C. McKinney, topographer, began field work on the Mineral Point quadrangle, lying in the southwestern part of the State, on June 15 and continued until the middle of October, when this work was completed. The area surveyed included 881 square miles, on the scale of 1:125000, with a contour interval of 20 feet, and covered parts of Grant, Iowa, and Lafayette counties. In connection with the topographic work 171 miles of spirit levels were run and 27 permanent bench marks were established. Mr. McKinney then began work on the north half of the Briggsville quadrangle and continued until about November 10, surveying an area of 92 square miles, and thus completing the quadrangle.

On September 15 Mr. Tyler, having been transferred from the Alabama district, as mentioned elsewhere, resumed revision work in the glacial district in the eastern part of the State, in the Racine, Silver Lake, Eagle, and Geneva quadrangles, completing this work November 5. The area covered comprises 900 square miles, on the scale of 1:62500, with a contour interval of 20 feet, lying in parts of Waukesha, Walworth, Racine, and Kenosha counties.

Iowa.—Mr. M. Hackett, topographer, resumed field work in the vicinity of Independence and continued in that district until about August 1, surveying about 220 square miles on the scale of 1:125000, with a contour interval of 20 feet, thus completing the northern half of the Winthrop quadrangle, which had been commenced in the season of 1899. The area surveyed lies in Buchanan County.

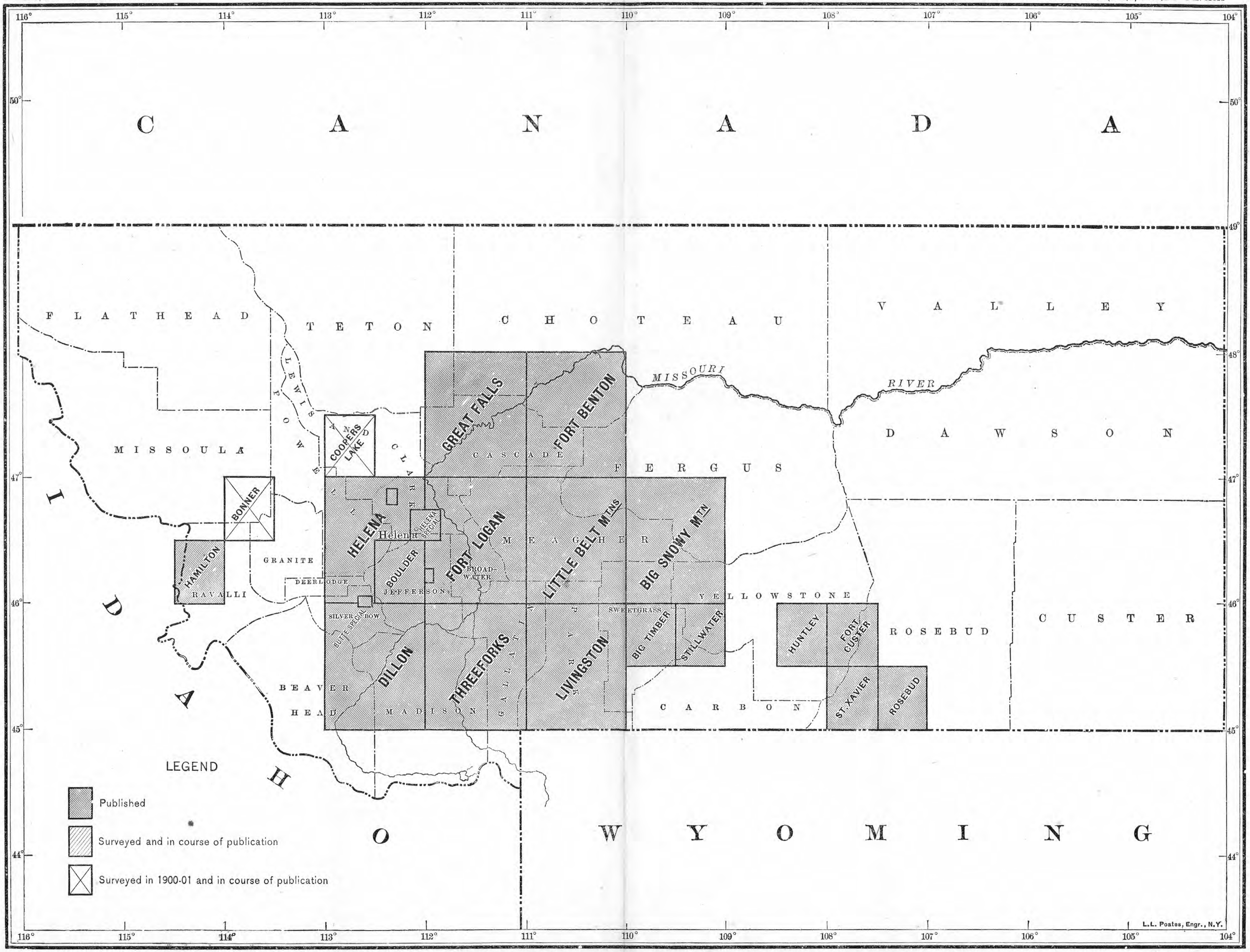
Iowa-Wisconsin—Upon completion of the Winthrop quadrangle, mentioned above, Mr. Hackett began work in northeastern Iowa and southwestern Wisconsin, and continued until November 22, when the Waukon quadrangle was completed. The area surveyed lies in parts of Allamakee and Clayton counties, Iowa, and Warren and Crawford counties, Wis., and covers 871 square miles. The work was done on the scale of 1:125000 and with a contour interval of 20 feet. In the course of the work 214 miles of spirit levels were run and 26 permanent bench marks were established.

Minnesota.—Mr. E. C. Bebb, topographer, resumed work in the Mesabi region of Minnesota about June 15, and continued until November 2, when the district was completed, 258 square miles having been surveyed, on the scale of 1:62500, with a contour interval of 20 feet. The area so surveyed was an irregular strip covering the iron-bearing formation of the Mesabi Range in St Louis and Itasca counties. In connection with this work 176 miles of spirit levels were run.

ROCKY MOUNTAIN SECTION.

Topographic work was conducted at various times during the year by seven parties, in Colorado, South Dakota, Wyoming, Montana, Texas, and Arizona, resulting in the completion of nine quadrangles, two others being partially completed. The total area surveyed was 4,240 square miles, of which 3,572 was on the scale of 1:125000, 664 on the scale of 1:62500, and 4 on special scales. Levels to the extent of 681 miles were run and 201 permanent bench marks were established.

South Dakota.—Mr. A. F. Dunnington, topographer, with Mr. Pearson Chapman, assistant topographer, between July 1 and November 1 completed the survey of the Edgemont quad-



MAP OF MONTANA, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

rangle, in Fall River and Custer counties. The area surveyed was 870 square miles, on the scale of 1:125000, with a contour interval of 50 feet, and included the southwestern part of the Black Hills and the adjacent plains. In connection with the above 80 miles of levels were run and 21 permanent bench marks were established.

Wyoming.—Mr. Frank Tweedy, topographer, organized a party at Sheridan, on July 1, for the survey of the Fort McKinney quadrangle, in Johnson County, and completed field work on November 3. The area surveyed was 857 square miles, on the scale of 1:125000, with a contour interval of 100 feet. The leveling for this area was completed in 1899.

For the control of the Hay Creek quadrangle, in Crook County, 139 miles of levels were run and 29 permanent bench marks were established.

Montana.—On June 25 Mr. W. H. Herron, topographer, commenced the survey of the Bonner quadrangle, in Missoula, Ravalli, and Granite counties, and completed the same November 1. The area mapped was 820 square miles, on the scale of 1:125000, with a contour interval of 100 feet, in connection with which 90 miles of levels were run and 33 permanent bench marks were established. In addition, 36 miles of levels were run and 8 permanent bench marks were established within the Anaconda and Boulder quadrangles, in Powell and Jefferson counties.

Colorado.—Mr. W. J. Lloyd, topographer, during June completed the survey of the Greeley quadrangle, comprising portions of Larimer and Weld counties. The area surveyed was 115 square miles, on the scale of 1:125000, with a contour interval of 20 feet.

Mr. W. M. Beaman, topographer, commenced work on the eastern part of the Needle Mountain quadrangle, in San Juan and La Plata counties, on June 20, and completed the same on November 3. The area surveyed was 146 square miles, on the scale of 1:62500, with a contour interval of 100 feet. In addition to leveling previously done in this quadrangle, 27 miles were run and 7 permanent bench marks were established.

Mr. Arthur Stiles, topographer, on July 27 commenced the resurvey of the Silverton quadrangle. Early in November, after having completed the mapping of 115 square miles, or about half of the quadrangle, he was forced by inclement weather to discontinue work. During the season he also completed the Silver Basin special map, covering an area of about 2 square miles within the Silverton quadrangle, on the scale of 1:21120 (3 inches to 1 mile), with a contour interval of 50 feet.

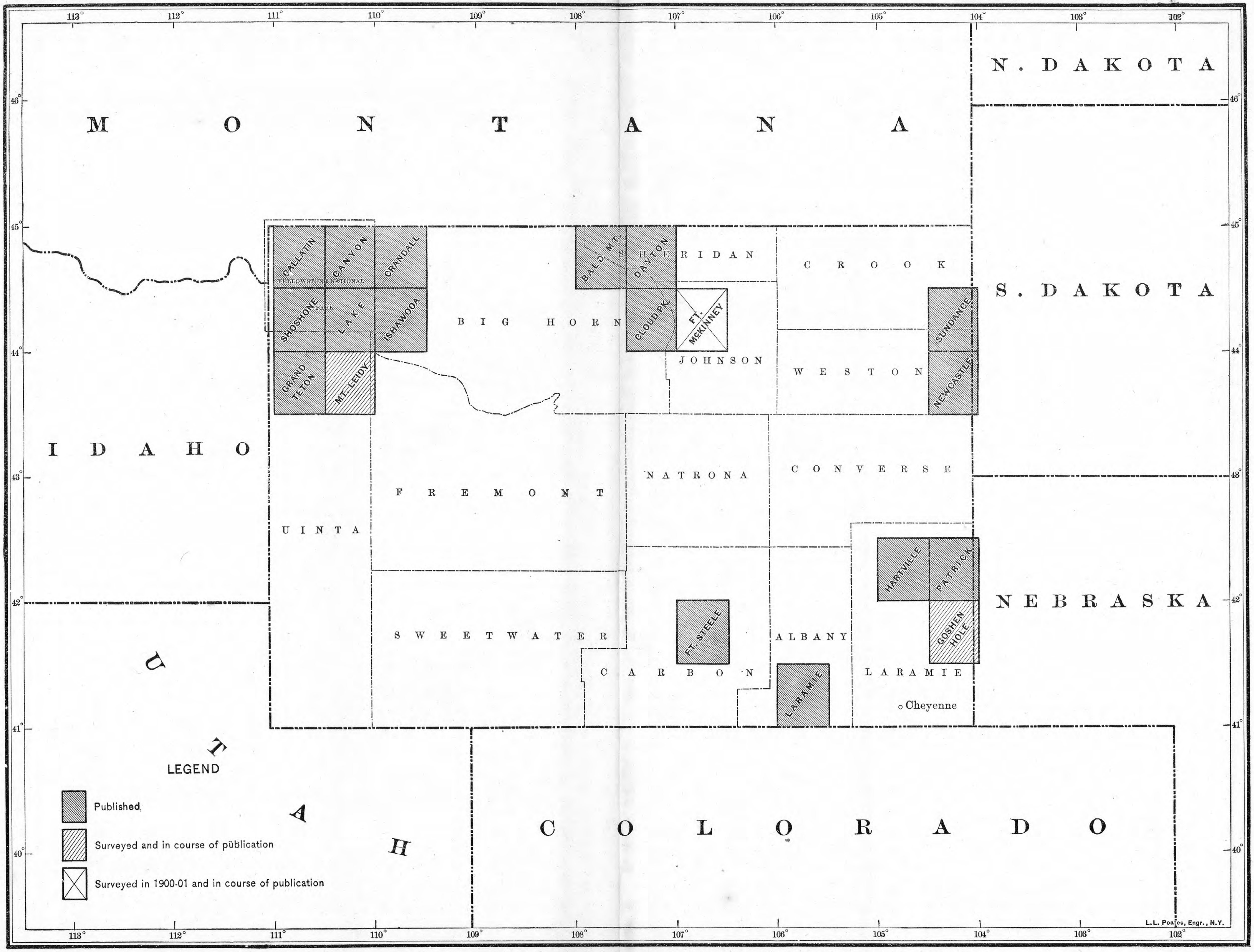
Texas.—At the close of the last annual report work was in progress on the resurvey of the Burnet quadrangle, in Burnet and Llano counties. This was discontinued early in June, but was again taken up by Mr. Beaman on November 14, and the survey of the whole quadrangle was completed on April 19. The area mapped was 910 square miles, on the scale of 1:125000, with a contour interval of 25 feet.

On April 2 Mr. Arthur Stiles, topographer, and Mr. R. H. Sargent, assistant topographer, having completed work assigned them in Arizona, were detailed to the Gainesville quadrangle, a part being in Cooke County, Tex., and the remaining portion in the Chickasaw Nation, Ind. T. Up to May 1 only the preliminary control work had been undertaken.

For the control of the Paris and Bonham quadrangles, in Grayson, Fannin, and Lamar counties, 46 miles of levels were run and 15 permanent bench marks were established; also for the control of the Fredericksburg quadrangle, in Gillespie, Kendall, and Kerr counties, 90 miles of levels were run and 26 permanent bench marks established.

Arizona.—At the close of the last report 25 square miles of the Globe quadrangle, in Gila and Pinal counties, had been surveyed by Mr. W. J. Lloyd, topographer. This work was discontinued early in June, in order that Mr. Lloyd might take up work in the north. The latter having been completed, he returned to the Globe survey and completed the same on March 8. The total area surveyed during the fiscal year was 223 square miles, on the scale of 1:62500, with a contour interval of 50 feet.

On November 28 work was commenced on the Clifton quadrangle, in Graham County, under the direction of Mr. Jeremiah Ahern, topographer. Up to May 1, 180 square miles had been completed, on the scale of 1:62500, with a contour interval of 50 feet, and also a special map of an area of about 1½ square



MAP OF WYOMING, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

miles of the Morenci mining district, on the scale of 1,000 feet to 1 inch, with a contour interval of 20 feet.

Leveling for this area was commenced at San Carlos on October 8, and carried forward by Mr. Thomas Winsor, levelman, until the latter part of November, when the party was disbanded on account of the serious illness of Mr. Winsor, who died on December 2, after three years of faithful and efficient work on the survey. Mr. John T. Stewart, levelman, was then detailed to complete the work, which embraced 173 miles of levels and 64 permanent bench marks.

PACIFIC SECTION.

Topographic work was prosecuted by seven parties in Montana, Idaho, Oregon, and California. The survey of nine quadrangles was completed, of which five were on the scale of 1:62500, with a contour interval of 50 feet, and four were on the scale of 1:125000, with a contour interval of 100 feet. The total area surveyed was 3,208 square miles, of which 1,091 square miles were on the scale of 1:62500 and 2,117 square miles were on the scale of 1:125000. Levels were run over 767 linear miles, in connection with which 132 permanent bench marks were established, 20 of which were by vertical angulation.

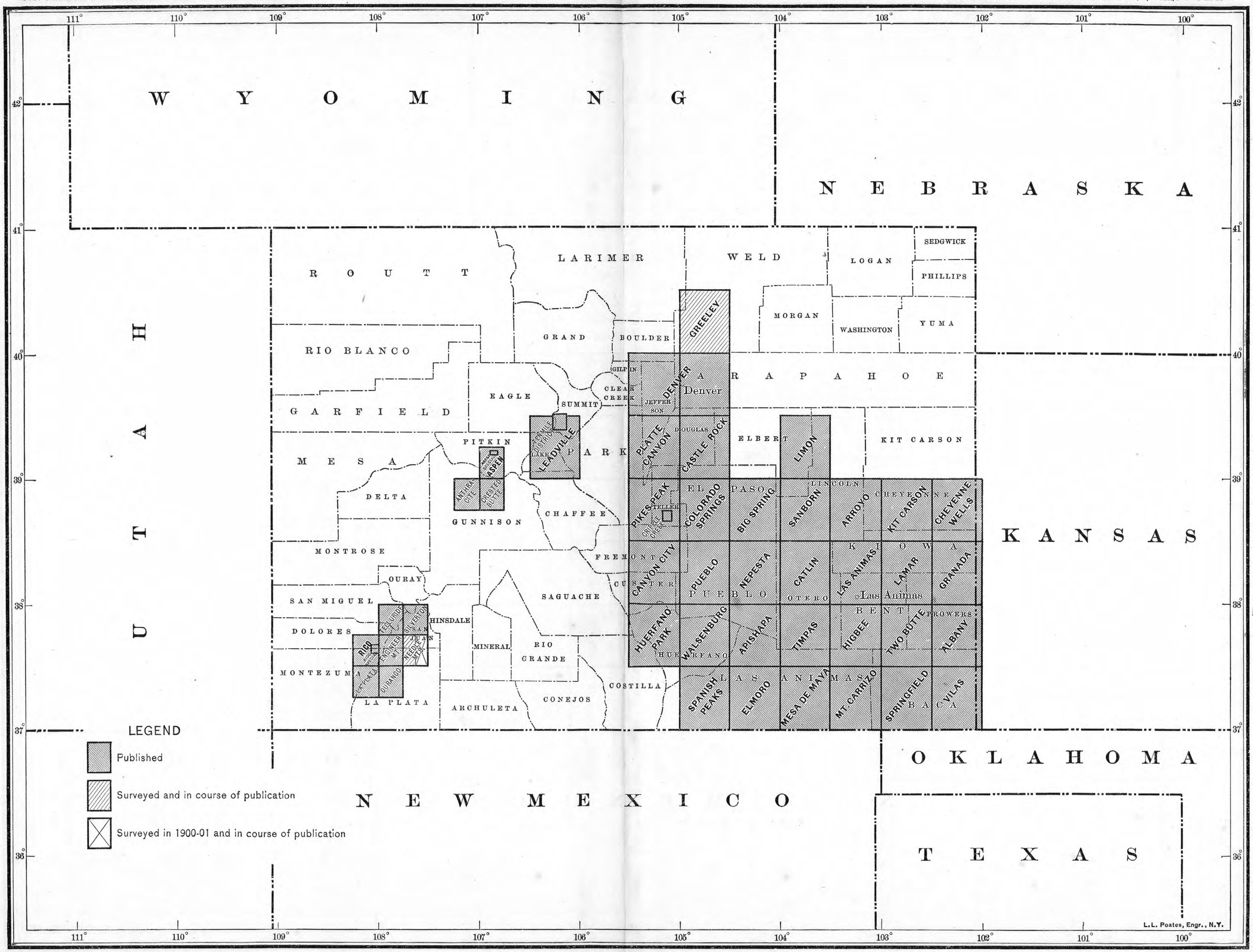
Idaho-Montana.—Mr. Van. H. Manning, topographer, was detailed for the survey of a special area in the Cœur d'Alene mining district, in Shoshone County, Idaho. Field work was commenced on June 15, and was continued by Mr. Manning until the last of October, and by other members of the party until November 10. An area of 201 square miles, 38 of which were in Missoula County, Mont., was mapped on the scale of 1:62500, with a contour interval of 50 feet. In connection with this work 122 miles of levels were run and 21 permanent bench marks were established.

Idaho.—Mr. D. L. Reaburn, topographer, on his return from Alaska, was engaged from November 1 to 20 in an attempt to map a small area necessary to complete the survey of the Rathdrum quadrangle, but deep snow in the mountains prevented further work after 8 square miles had been surveyed. Mr. Reaburn resumed field work in this locality early in April, and was so occupied until May 13, during which period he mapped 110 square miles, thus completing the survey of the quadrangle.

Oregon.—Mr. L. C. Fletcher, topographer, and Mr. J. E. Rockhold, assistant topographer, were assigned to the Sumpter quadrangle, a portion of which had been surveyed during the previous season. Field work was commenced on June 14 and was continued by Mr. Fletcher until October 16 and by Mr. Rockhold until November 10, during which periods the mapping of the quadrangle, comprising portions of Grant, Union, and Baker counties, was completed. There were surveyed 675 square miles, on the scale of 1:125000, with a contour interval of 100 feet, in connection with which 172 miles of levels were run and 22 permanent bench marks were established.

California.—Messrs. R. H. McKee and A. B. Searle, topographers, and A. F. Hassan, assistant topographer, were detailed for the survey of the Redding quadrangle. Field work was prosecuted by Mr. Searle from June 27 to December 9, by Mr. McKee from July 4 to December 19, and by Mr. Hassan from June 27 to October 10. Mr. McKee mapped an area of 482 square miles and Mr. Searle an area of 423 square miles, thus completing the quadrangle, the work of the former being in the southern portion of the area and that of the latter in the northern portion, Mr. Hassan assisting both of them at different times. In connection with the above, 192 miles of levels were run and 24 permanent bench marks were established. The work done was in Shasta County and was on the scale of 1:125000, with a contour interval of 100 feet.

Mr. R. B. Marshall, topographer, commenced work in southern California on June 6, and was thus engaged until January 15. The area assigned to him was the quadrangle defined by latitude 34°–34° 30′ and longitude 118° 30′–119°. The northeast quarter, designated the Santa Susanna quadrangle, was surveyed on the scale of 1:62500, with a contour interval of 50 feet; and the southeast quarter, designated the Calabasas quadrangle, was surveyed in a similar manner. The western half was surveyed on the scale of 1:125000, with a contour interval of 100 feet, and will be combined with the Santa



MAP OF COLORADO, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

Susanna and Calabasas quadrangles and published as the Camulos 30-minute quadrangle. The total areas surveyed were 442 square miles on the scale of 1:62500, with a contour interval of 50 feet, including 40 square miles partially mapped by Mr. W. S. Post, topographer, in 1893, and 419 square miles on the scale of 1:125000, with a contour interval of 100 feet. In connection with the above, 149 miles of spirit levels were run and 24 permanent bench marks were established. In addition, 18 bench marks were established by vertical angulation. On the completion of this work Mr. Marshall was granted leave of absence from January 16 to April 13, and Mr. J. G. Hefty, field assistant, was placed in charge of the party. Up to April 30 this party completed the Hueneme quadrangle, comprising an area of 138 square miles, and also mapped an area of 65 square miles in the Santa Paula quadrangle, the work being on the scale of 1:62500, with a contour interval of 50 feet. In connection with this work 73 miles of spirit levels were run and 11 permanent bench marks were established, 2 of them by vertical angulation. The area surveyed in this locality is included in Ventura and Los Angeles counties.

Upon the completion of duties previously referred to, Messrs. Fletcher, Rockhold, and Hassan proceeded to southern California for work in the Randsburg quadrangle, in San Bernardino and Kern counties. They commenced, respectively, on October 25, November 16, and October 15, and the survey of the quadrangle was completed on December 26, an area of 245 square miles being mapped, on the scale of 1:62500, with a contour interval of 50 feet. In connection with the above, 59 miles of levels were run and 12 permanent bench marks were established.

FOREST RESERVES.

The organization continued as heretofore, certain reserves being assigned to the Rocky Mountain topographic section, under Mr. E. M. Douglas, geographer, and the remaining reserves being assigned to the Pacific section, under Mr. Richard U. Goode, geographer.

ROCKY MOUNTAIN SECTION.

The marking of the Wyoming portion of the Black Hills Forest Reserve boundary line, which was commenced in 1899, was completed.

The marking of the Bighorn Reserve boundary was commenced, and the topographic mapping of the eastern (1900) addition to that reserve was completed. Work was continued in the Flathead, Lewis and Clarke, and Uinta reserves and commenced in the Prescott Reserve.

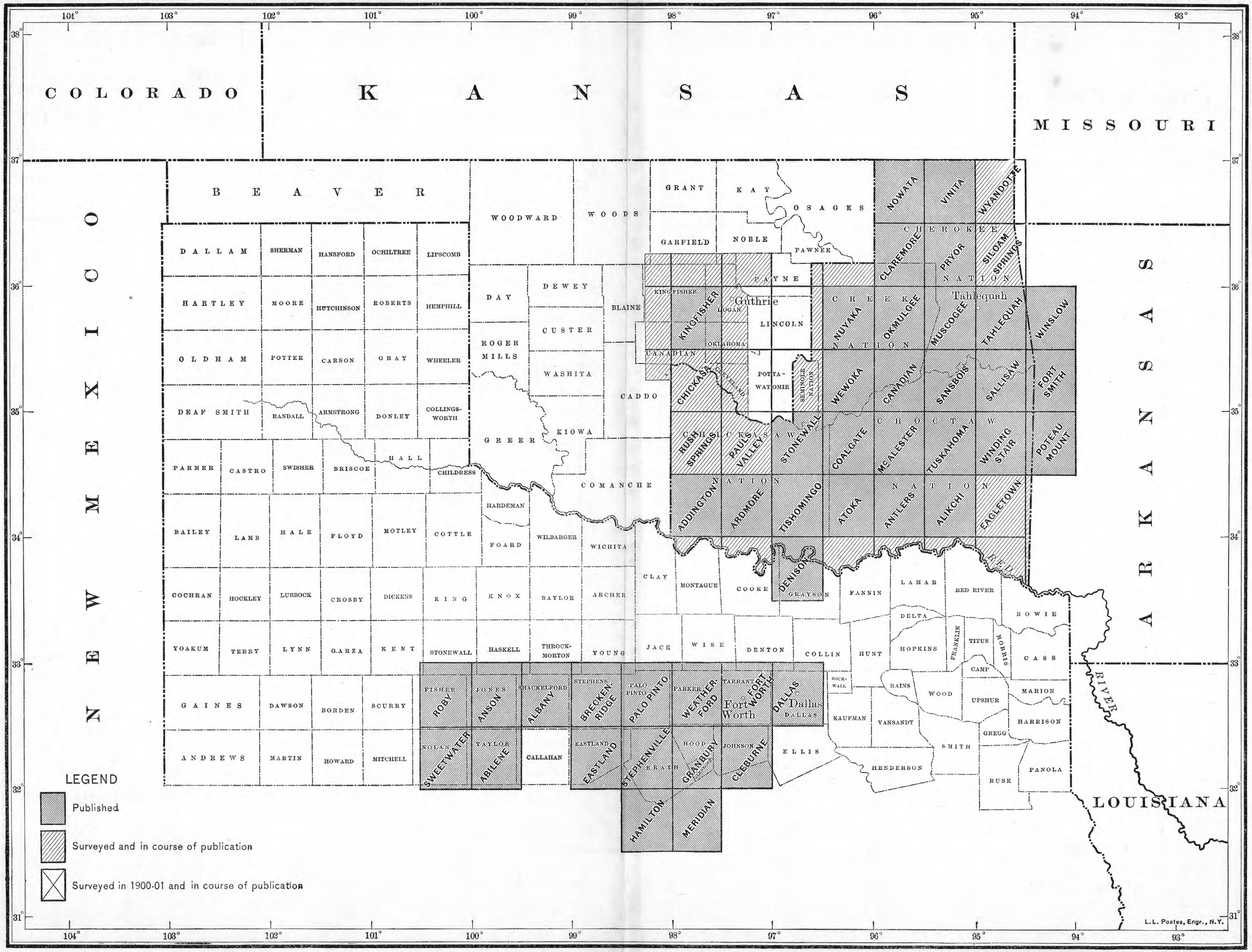
The summary of results is as follows: 2,814 square miles surveyed on the scale of 1:125000, 732 miles of levels run, 191 bench marks established, 132 miles of boundary lines surveyed and marked. The survey of three quadrangles was completed, that of three others being partially completed.

Black Hills Reserve (*South Dakota-Wyoming*).—The portion of the boundary line which remained unsurveyed, amounting to 23 miles, was surveyed and marked by Mr. W. H. Thorn, United States surveyor, who commenced the work on May 18 and completed it in the latter part of June.

Bighorn Reserve (*Wyoming*).—The marking of the boundary of this reserve was commenced early in July by Mr. Thorn and was continued until November 18. One hundred and nine miles of the line were surveyed and marked by 97 specially designed iron posts.

Lewis and Clarke Reserve (*Montana*).—Mr. T. M. Bannon, topographer, organized a party at Great Falls on July 5 for the survey of the Coopers Lake quadrangle, in Lewis and Clarke and Powell counties, and by November 4 had completed the same and also extended the work into the southeastern part of the reserve, being a portion of the Dearborn quadrangle. The total area mapped was 884 square miles, on the scale of 1:125000, with a contour interval of 100 feet. In connection with this work 237 miles of levels were run and 72 permanent bench marks were established. An accurate sea-level elevation for a datum could not be obtained within the area, therefore a considerable part of the leveling was out of the reserve.

Flathead Reserve (*Montana*).—Mr. François E. Matthes, topographer, with Mr. R. H. Sargent, assistant topographer,



MAP OF INDIAN TERRITORY, OKLAHOMA AND NORTHERN TEXAS, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

commenced work on the Chief Mountain quadrangle, in Teton and Flathead counties, on July 16, and continued until October 10, during which period there was surveyed an area of 291 square miles, including a portion of the Duck Lake quadrangle. This work was on the scale of 1:125000, with a contour interval of 100 feet. In connection with the above, 161 miles of levels were run and 28 permanent bench marks were established.

Uinta Reserve (*Utah*).—Messrs. Jeremiah Ahern and W. J. Lloyd, topographers, were assigned to work in this reserve. Mr. Ahern during the period from June 25 to October 1 completed the Coalville quadrangle, mapping an area of 145 square miles, and in addition surveyed 88 square miles of the Hayden Peak quadrangle. Mr. Lloyd between June 26 and October 10 surveyed 420 square miles of the Hayden Peak quadrangle. The above work was on the scale of 1:125000, with a contour interval of 100 feet, and was included in Summit, Morgan, and Wasatch counties. In connection with this work 155 miles of levels were run and 35 permanent bench marks were established.

Prescott Reserve (*Arizona*).—In the latter part of October Mr. François E. Matthes, topographer, with Mr. R. H. Sargent, assistant topographer, organized a party at Prescott for the survey of the north half of the Bradshaw Mountain quadrangle, in Yavapai and Maricopa counties. Mr. T. M. Bannon, topographer, commenced work on the south half of the same quadrangle on December 10, and on January 22 Mr. Arthur Stiles, topographer, was detailed to assist in this work. The whole quadrangle, which comprises the greater part of the Prescott Reserve, was completed on April 15, the area surveyed being 986 square miles, on the scale of 1:125000, with a contour interval of 100 feet. Leveling for this area included the running of 179 miles and the establishment of 56 permanent bench marks.

PACIFIC SECTION.

Topographic work was prosecuted in or adjacent to the following reserves: Washington, Mount Rainier, San Gabriel, Pine Mountain and Zaca Lake, and San Jacinto. The total area mapped was 3,729 square miles, of which 3,412 were on the scale of 1:125000 and 317 were on the scale of 1:62500. In connection with the above, 796 miles of levels were run and 155 permanent bench marks were established.

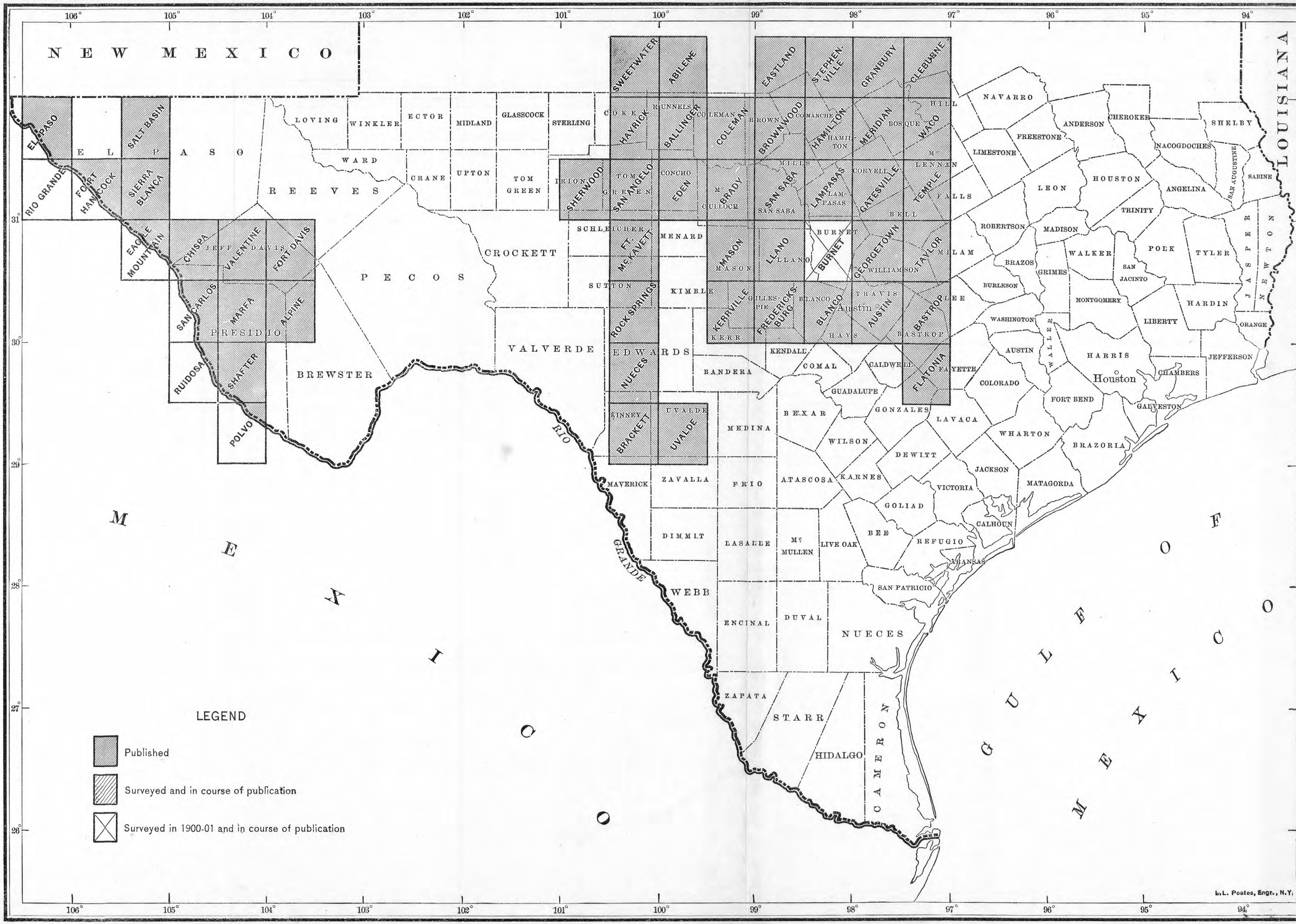
Washington Reserve (Washington).—Mr. R. A. Farmer, topographer, was detailed for the survey of the Leavenworth quadrangle, in Chelan County, and commenced work on June 11. On August 23, Mr. Farmer was injured by an accident which prevented further field work on his part, and the party was disbanded on September 17. An area of 473 square miles was mapped, on the scale of 1:125000, with a contour interval of 100 feet, in connection with which 84 miles of levels were run and 13 permanent bench marks were established.

Additional levels in the Washington Forest Reserve to the extent of 55 miles, with 8 permanent bench marks, were run from Marblemount eastward over the trail toward Slate Creek Pass.

Mount Rainier Reserve (Washington).—Mr. A. E. Murlin, topographer, commenced work upon the resurvey of portions of the Snoqualmie and Mount Stuart quadrangles on June 11, and was thus engaged until September 25, during which time an area of 406 square miles was mapped, 384 square miles being within the limits of the Snoqualmie quadrangle and 22 in the Mount Stuart quadrangle. After the weather conditions became such as to prevent further work in this locality, Mr. Murlin proceeded to southern California.

Mr. A. H. Sylvester, topographer, was assigned to the survey of the Mount Aix quadrangle, and was so engaged from June 11 to the end of September, during which time an area of 217 square miles was mapped, in Yakima and Kittitas counties, on the scale of 1:125000, with a contour interval of 100 feet. In connection with this work 41 miles of levels were run and 7 permanent bench marks were established. After the close of the season in Washington Mr. Sylvester was assigned to duty in southern California.

San Gabriel Reserve (California).—Mr. W. T. Turner, topographer, was assigned to the charge of a party in this reserve, and commenced work on July 5. He finished the mapping of the Rock Creek and San Antonio quadrangles, in Los Angeles and San Bernardino counties, on September 29, thus complet-



MAP OF SOUTHERN TEXAS, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

ing the mapping of the entire reserve. The work was on the scale of 1:62500, with a contour interval of 50 feet, and included an area of 245 square miles, in connection with which 6 permanent bench marks were established by vertical angulation.

Pine Mountain and Zaca Lake Reserve (*California*).—Mr. Turner, upon the completion of the work in the San Gabriel Reserve, commenced the mapping of the Tejon quadrangle. He finished the north half, embracing an area of 490 square miles, on December 28, when he proceeded to Washington, D.C., leaving the party in charge of Mr. S. N. Stoner, field assistant. Mr. Stoner immediately commenced the survey of the Mount Pinos quadrangle, and up to April 30 mapped an area of 298 square miles.

Messrs. A. E. Murlin and A. H. Sylvester, topographers, on the completion of work previously referred to in the State of Washington, proceeded to southern California. A considerable loss of time resulted before operations were begun on account of delay in the arrival of the outfit, which had been shipped by freight. Actual field work was commenced on November 3, and on January 30 Mr. Murlin completed the southeast quarter of the Tejon quadrangle. Mr. Sylvester was assigned to the southwest quarter, but before completing it was compelled to stop work on account of deep snow in the mountains. He thereupon took up work elsewhere for the period February 10 to March 20, and did not complete his area until April 16. The combined area mapped by Messrs. Murlin and Sylvester within the Tejon quadrangle amounted to 490 square miles.

The work in this reserve above referred to was on the scale of 1:125000, with a contour interval of 100 feet, and comprises portions of Los Angeles, Ventura, and Kern counties. In connection with the survey of the Tejon quadrangle 70 miles of levels were run and 17 permanent bench marks were established. In addition 15 bench marks were determined by vertical angulation.

From February 10 to March 20, and again from April 16 to May 15, Mr. Sylvester was engaged upon the Ventura 15-minute quadrangle, and during this period mapped an area of 72 square miles in Ventura County, the scale of the work being 1:62500, with a contour interval of 50 feet.

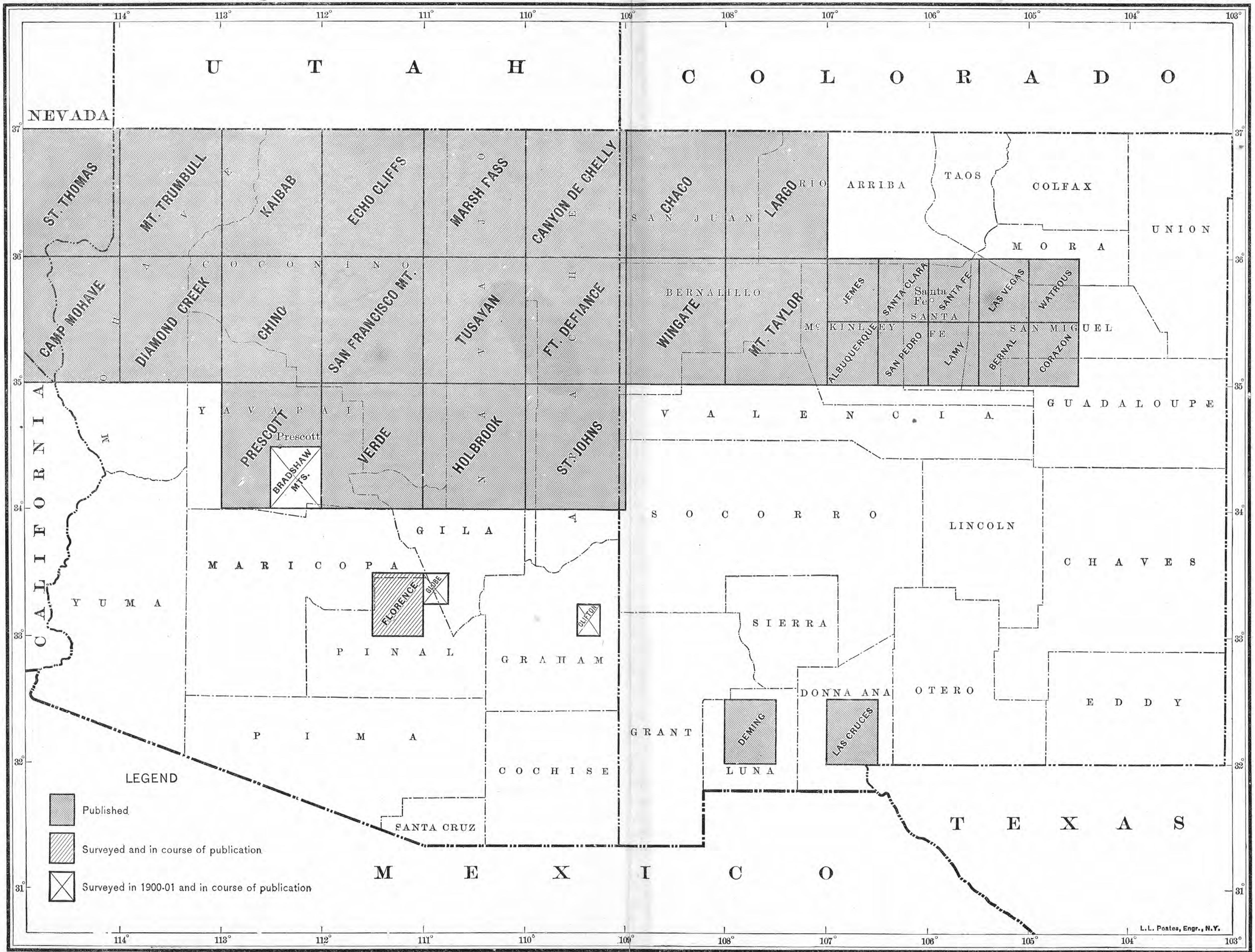
For the control of the Ventura and Mount Pinos quadrangles and adjacent territory 156 linear miles of levels were run and 24 permanent bench marks were established.

San Jacinto Reserve (California).—Field work in this reserve was commenced on May 19, in the Ramona quadrangle, by a party under Mr. E. T. Perkins, jr., topographer. Mr. Perkins remained with the party until June 6, when he was assigned to work elsewhere, leaving the party under the charge of Mr. A. I. Oliver, field assistant. Mr. Perkins returned to southern California and resumed charge of the party on October 15, remaining in this locality until April 9, with the exception of the period from January 13 to March 21, when he was in San Francisco and Sacramento, engaged in office and other official duties.

Mr. A. B. Searle, topographer, was assigned to work in the Ramona quadrangle on December 26, and contined until April 15. On the return of Messrs. Perkins and Searle to Washington, D. C., for office work Mr. Oliver continued field work until the quadrangle was completed, about the middle of May. Mr. Perkins mapped an area of 318 square miles, Mr. Searle 220 square miles, and Mr. Oliver 450 square miles, in Riverside and San Diego counties, on the scale of 1:125000, with a contour interval of 100 feet. Within and adjacent to the San Jacinto Forest Reserve 390 miles of levels were run and 65 permanent bench marks were established.

ALASKAN SURVEYS.

Topographic work in Alaska was prosecuted by three parties. The efforts of one of these parties were devoted exclusively to topography and the other two were organized for combined topographic and geologic work. In this connection acknowledgment is made of the valuable assistance rendered by the United States Coast and Geodetic Survey. Ten officers and twenty men were carried on the steamers *Patterson* and *Pathfinder*, of the above-mentioned organization, from Seattle to Alaska, and were landed at various convenient points near Nome. The parties were also brought back in the same vessels to Seattle and San Francisco at the close of the season. In addition, considerable information resulting from the work



MAP OF ARIZONA AND NEW MEXICO, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

of the Coast and Geodetic Survey parties operating in the vicinity of Nome and Valdez has been furnished for incorporation in the topographic maps.

Acknowledgment should also be made of the courtesies extended by the commanding and other officers at Fort Davis, near Nome, who did everything in their power to advance the work in hand, especially by the loan of a pack train of five mules.

DETAILED SURVEYS IN THE VICINITY OF NOME.

The party for the survey of the Nome district was under Mr. E. C. Barnard. The organization was as follows: E. C. Barnard, topographer in charge of topographic party No. 1; D. L. Reaburn, topographer in charge of topographic party No. 2; J. G. Hefty, field assistant, in charge of topographic party No. 3; R. B. Robertson, field assistant, in charge of triangulation party. The combined party landed at Fort Davis on July 29, having sailed from Seattle on the steamer *Patterson* June 19, and was engaged in active work until October 7, when the separate parties reassembled at Nome and embarked on the *Patterson* for the return trip, arriving at Seattle October 29. The results of the season's work were the extension of the triangulation by the party under Mr. Robertson over an area of 1,000 square miles, including the determination of the geodetic position of 14 points, and the mapping by the topographic parties of an area of 3,500 square miles, for publication on the scale of 1:250000, with a contour interval of 200 feet. Of the area mapped Mr. Barnard's party covered 1,100 square miles, Mr. Reaburn's party 1,400 square miles, and Mr. Hefty's party 1,000 square miles.

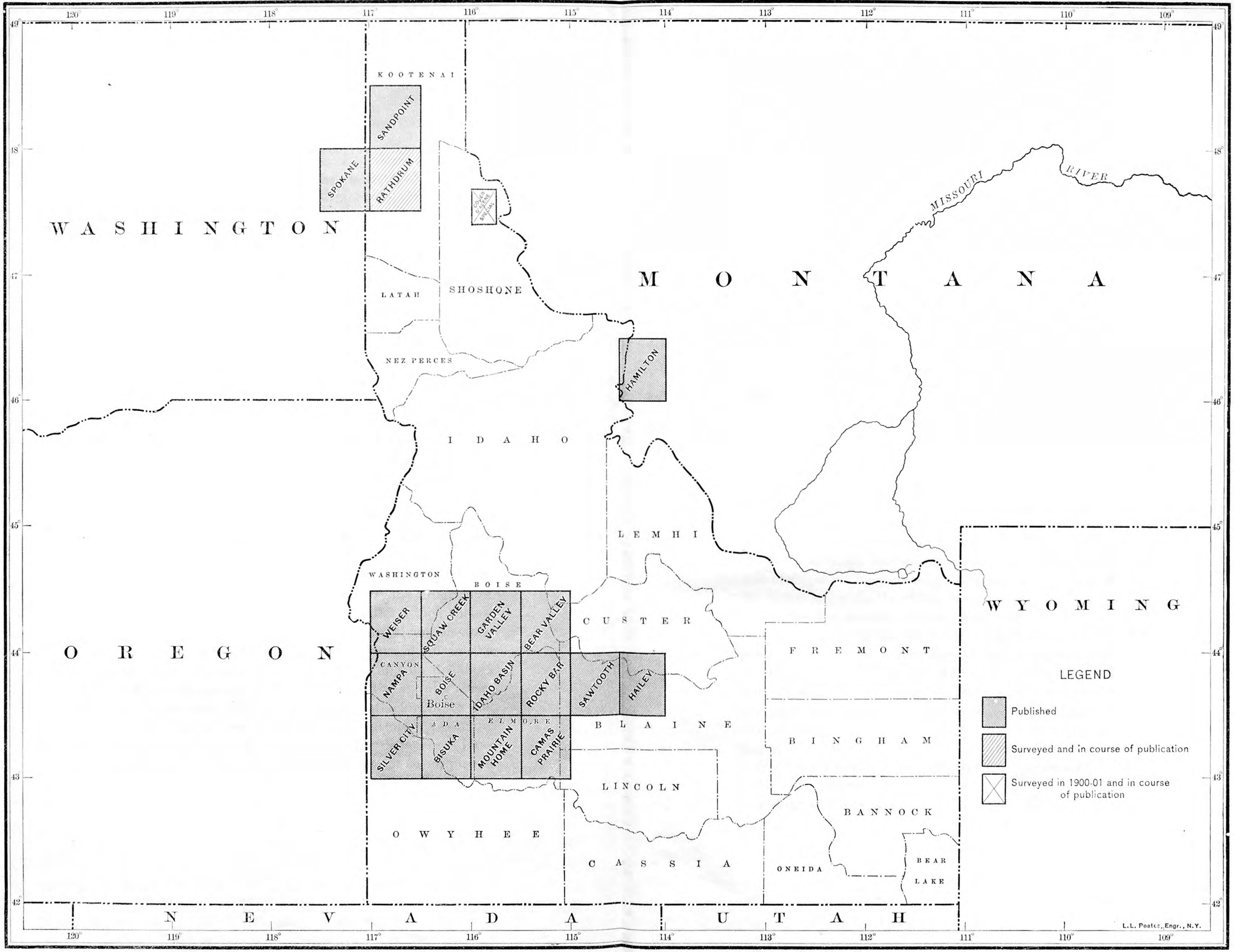
The methods of work by the party were practically those adopted for general use in other parts of the United States, modified to suit existing conditions. Progress in plane-table work was made during rain by substituting celluloid for the ordinary drawing paper.

RECONNAISSANCE SURVEY OF FISH, TUBUTULIK, AND KOYUK RIVERS.

The party organized for the exploration of the region tributary to the above-mentioned rivers was in charge of Mr. W. J. Peters, topographer, with Mr. W. C. Mendenhall, assistant geologist, and Mr. J. H. Knowles, field assistant. The party left Seattle on June 13 in the steamer *Patterson* and was landed at Golofnin Bay June 28. The interval between July 4 and 27 was occupied in the survey of Fish River and return to Cheenik, on Golofnin Sound. The distance from Cheenik to head of loaded-canoe navigation was found to be about 76 miles. A small steamer conveyed the party along the coast from Cheenik to the mouth of Tubutulik River, which was reached on July 29. The ascent of the river began August 1, and the party was engaged until August 20 in surveys along and adjacent to its course. The river was ascended to a point 48 miles above the mouth, where the limit of practicable canoe navigation was reached.

The return downstream began August 18, and the mouth of Tubutulik River was reached August 20. On August 24 the traverse of this river was begun, and with the exception of two days, August 27 and September 4, was continued uninterruptedly until September 9. On this date the advance by canoes was discontinued with the expectation of making further explorations on foot, but snow and rain storms prevented. The river was ascended to a distance of 136 miles from its mouth. On September 14 the return trip down the river was commenced, and Golofnin Bay was reached on September 23. On September 26 the party was picked up by the *Pathfinder*, and conveyed to San Francisco, where it arrived October 14.

Latitude and azimuths were obtained during the progress of the surveys by observations with a Saegmueller 4-inch theodolite, especially designed and constructed for reconnaissance work. The plane-table triangulation was carried on in the valleys of Fish and Tubutulik rivers, depending on distances obtained by developments from short bases, the angular measurements being made with a micrometer attachment to the alidade. The rivers were meandered by using a prismatic compass for directions and a stenometer for distances. Latitude and magnetic declinations were obtained at seven places.



MAP OF IDAHO, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

SURVEYS IN VICINITY OF COPPER AND CHITINA RIVERS.

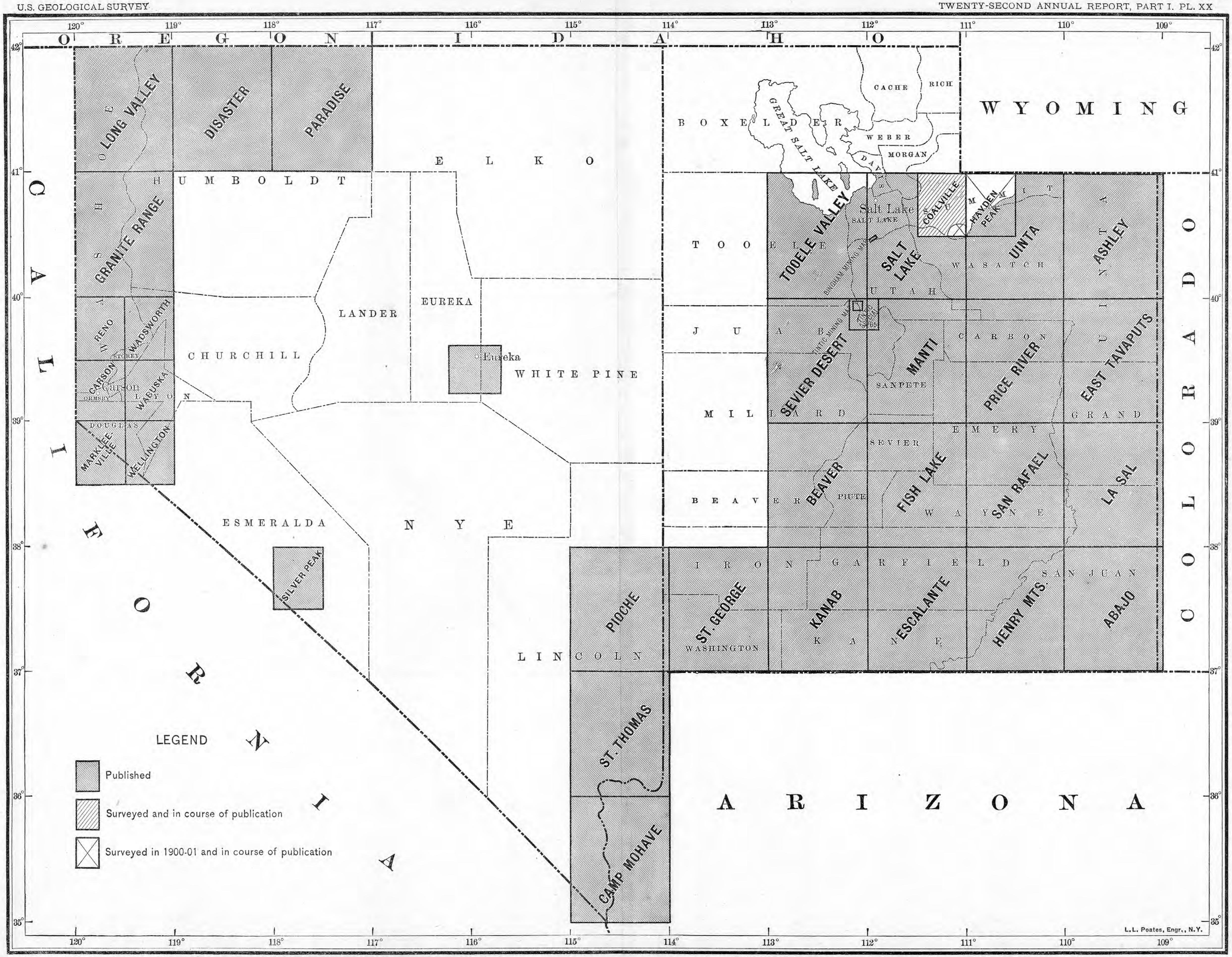
The party detailed for these surveys consisted of Mr. F. C. Schrader, geologist in charge; T. G. Gerdine, topographer; A. C. Spencer, assistant geologist; and D. C. Witherspoon, field assistant, with eight camp hands. The party landed at Valdez on June 13, having sailed from Seattle on June 5. Work was commenced on June 15 at Valdez, where a base line was measured and observations for latitude and azimuth were made. From Valdez a stadia line was carried along the route of the military trail into the interior. As progress along the stadia line was more rapid than supplies could be forwarded, on June 25 Mr. Gerdine returned to Valdez and, with two assistants, expanded triangulation from the base already measured to Rocky Point, a distance of about 25 miles, with a view of connecting Valdez with a United States Coast and Geodetic Survey triangulation station.

On July 3 work was resumed along the stadia line, which followed the military trail to Tonsina River bridge, a distance of 86 miles from Valdez. From Tonsina River the line left the military trail and followed along the old trail down the north bluff of Tonsina River to a point near its junction with Copper River, a distance of about 25 miles. On July 20 Copper River was crossed about 2 miles above the mouth of the Tonsina. On July 21 the stadia line was continued to a point about 8 miles east of Copper River crossing. At this place the party divided, Mr. Schrader, with Mr. Witherspoon as topographic assistant, going into the Kotsina River Basin. Mr. Gerdine, with Mr. Spencer, continued the work by means of a stadia line to a point distant 22 miles from Copper River crossing and about 14 miles east of the junction of Copper and Chitina rivers. On July 28 and 29 a base line was measured at this point and the necessary astronomic observations were made. From the base line a triangulation was expanded, thus locating a number of points, which were platted on a plane-table sheet, and the topographic work was continued by the usual plane-table methods. In this way an area of about 2,500 square miles was mapped, including territory drained by Kotsina, Kuskulana, Lakina, Kennicott, McCarthy, and Nizina rivers, and also the basin of Chitina River from its mouth to a point about 16 miles east of the junction of the east and south forks. On September 10 the two parties reassembled at the junction of the east and south forks of the Chitina.

On September 13 a party under Mr. Spencer, with Mr. Witherspoon as topographer, left the junction of the rivers and traveled in a direction very nearly due west for a distance of 12 miles to the Hanagita trail. From this trail the party reached Taral, on Copper River, September 28. The area mapped along this line was about 500 square miles.

On September 13 Mr. Schrader, with Mr. Gerdine and three assistants and six pack animals, started up the south fork of Chitina River, the object being to cross by the glacier at the head of the stream to the coast. The stream was ascended for 34 miles, when a severe storm was encountered and the party was forced to return to Taral, reaching that place on October 1. On October 2 Mr. Schrader and Mr. Gerdine, with two assistants, left Taral, traveling by boat down Copper River. This party reached Orca, near the mouth of the Copper, on October 9, and was engaged from October 11 to 26 in examining and sketching parts of islands and coast lines in Prince William Sound. On October 2 Mr. Spencer, with Mr. Witherspoon as topographic assistant and four camp hands, left Taral, Mr. Witherspoon carrying a stadia line down Copper River and connecting with Coast and Geodetic Survey points near the mouth of the Copper. This party reached Orca on October 16. From October 19 to November 2 Mr. Witherspoon was engaged in triangulation in Prince William Sound.

From October 27 to November 12 Mr. Gerdine was engaged in office work at Orca. The party sailed from Orca on November 13 and arrived at Seattle on November 21.



MAP OF NEVADA AND UTAH, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

Office Work.

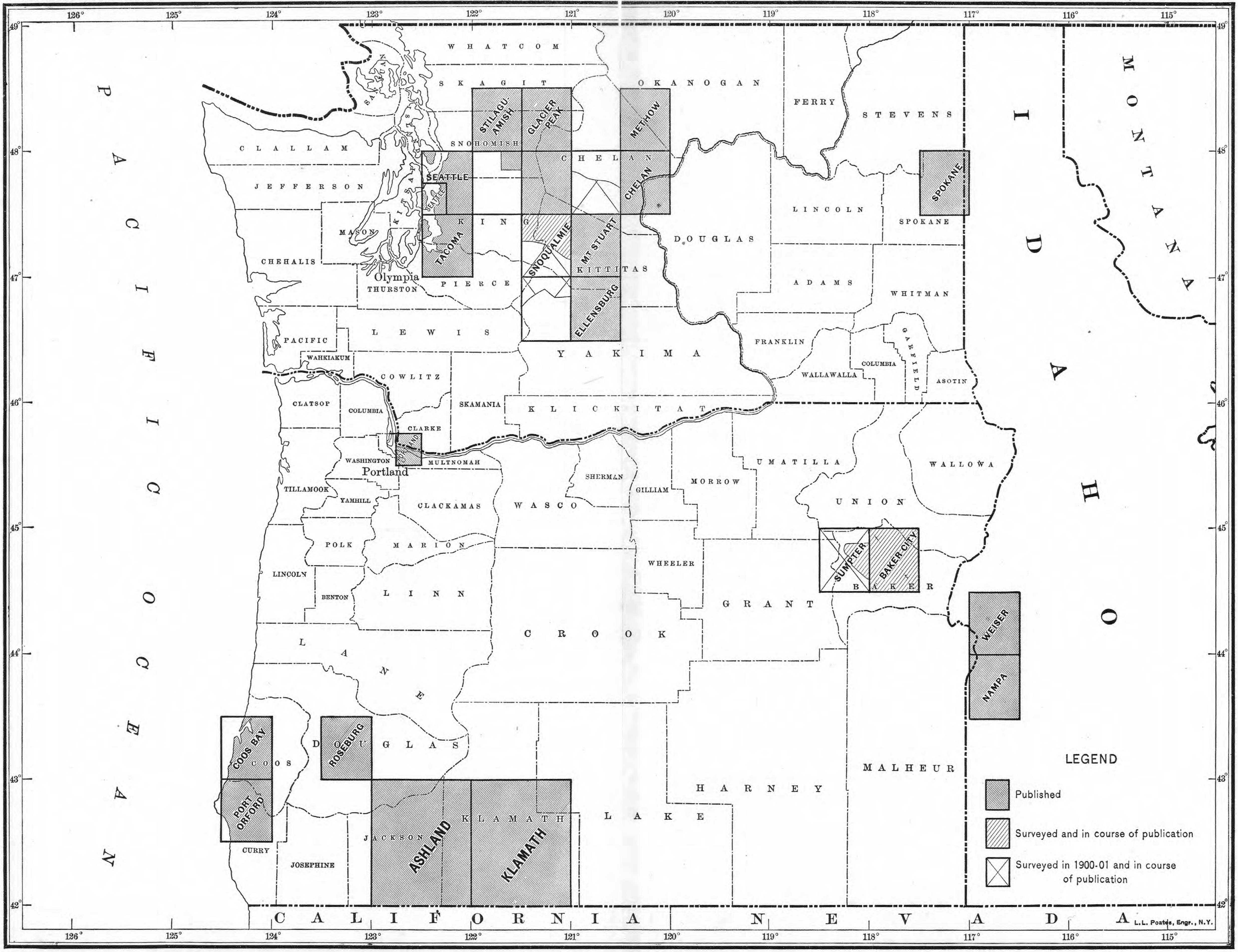
The table herewith shows the atlas sheets, numbering 95, the drawing of which was completed in the office during the year:

Topographic sheets completed in office during 1900–01.

State and sheet.	Scale.	Contour interval.
ALABAMA:		*Feet.*
Wetumpka	1:125000	50
ARIZONA:		
Bradshaw Mountain	1:125000	100
Globe	1:62500	50
Morenci Special	1:120000	20
ARKANSAS:		
Eureka Springs	1:125000	50
Bearden	1:125000	50
CALIFORNIA:		
San Antonio	1:62500	50
Rock Creek	1:62500	50
Santa Barbara	1:62500	50
Calabasas	1:62500	50
Randsburg	1:62500	50
Tejon	1:125000	100
Camulos	1:125000	100
Ramona	1:125000	100
Redding	1:125000	100
Southern California, Sheet I	1:250000	250
COLORADO:		
Greeley	1:125000	20
Needle Mountain	1:62500	100
Silver Basin Special	1:21120	50
GEORGIA–NORTH CAROLINA:		
Dahlonega (resurvey)	1:125000	100
IDAHO:		
Rathdrum	1:125000	100
Cœur d'Alene	1:62500	50
INDIANA:		
De Gonia Springs	1:62500	20
St. Meinrad	1:62500	20
Velpen	1:62500	20
INDIANA–KENTUCKY:		
Tell City	1:62500	20
Owensboro	1:62500	20

Topographic sheets completed in office during 1900–01—Continued.

State and sheet.	Scale.	Contour interval.
		Feet.
IOWA:		
Winthrop	1:125000	20
IOWA–WISCONSIN:		
Waukon	1:125000	20
KENTUCKY–WEST VIRGINIA–OHIO:		
Kenova	1:125000	50
MAINE:		
Bangor	1:62500	20
Orono	1:62500	20
Castine	1:62500	20
MARYLAND:		
Gunpowder	1:62500	20
Snow Hill	1:62500	20
Green Run	1:62500	20
Leonardtown (revision)	1:62500	20
Point Lookout (revision)	1:62500	20
Princess Anne	1:62500	20
MARYLAND–DELAWARE:		
Salisbury	1:62500	20
Ocean City	1:62500	20
Pittsville	1:62500	20
MARYLAND–PENNSYLVANIA:		
Parkton	1:62500	20
Belair	1:62500	20
MASSACHUSETTS:		
Boston and vicinity	1:20000	20
MINNESOTA:		
Mesabi District Special	1:62500	20
MISSOURI–IOWA:		
Edina	1:125000	20
Kahoka	1:125000	20
MISSOURI–KANSAS:		
Joplin District	1:62500	10
MONTANA:		
Bonner	1:125000	100
Coopers Lake	1:125000	100
NEW YORK:		
Canandaigua	1:62500	20
Norwich	1:62500	20
Pennyan	1:62500	20
Hammondsport	1:62500	20



MAP OF WASHINGTON AND OREGON, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

Topographic sheets completed in office during 1900–01—Continued.

State and sheet.	Scale.	Contour interval.
NEW YORK—Continued.		*Feet.*
Owego	1:62500	20
Naples	1:62500	20
Richfield Springs	1:62500	20
Cortland	1:62500	20
Clayton	1:62500	20
Alexandria Bay	1:62500	20
Theresa	1:62500	20
Grindstone	1:62500	20
Luzerne	1:62500	20
Newberg	1:62500	20
Phœnicia	1:62500	20
Kinderhook	1:62500	20
Blue Mountain	1:62500	20
Berne	1:62500	20
NORTH CAROLINA–TENNESSEE:		
Mount Mitchell	1:125000	100
OREGON:		
Sumpter	1:125000	100
PENNSYLVANIA:		
Indiana	1:62500	20
Latrobe	1:62500	20
Connellsville	1:62500	20
Brownsville	1:62500	20
Kittanning	1:62500	20
Tioga	1:62500	20
Everett	1:62500	20
Mercersburg	1:62500	20
Chambersburg	1:62500	20
Wernersville	1:62500	20
Slatington	1:62500	20
Boyertown	1:62500	20
SOUTH DAKOTA:		
Edgemont	1:125000	50
TEXAS:		
Burnet (resurvey)	1:125000	25
UTAH:		
Coalville	1:125000	100
WEST VIRGINIA–PENNSYLVANIA:		
Morgantown	1:62500	20

Topographic sheets completed in office during 1900–01—Continued.

State and sheet.	Scale.	Contour interval.
WISCONSIN:		*Feet.*
Briggsville (resurvey)	1:62500	20
Marathon Special	1:62500	20
Mineral Point	1:125000	20
Racine (revision)	1:62500	20
Silver Lake (revision)	1:62500	20
Eagle (revision)	1:62500	20
Geneva (revision)	1:62500	20
WYOMING:		
Fort McKinney	1:125000	100

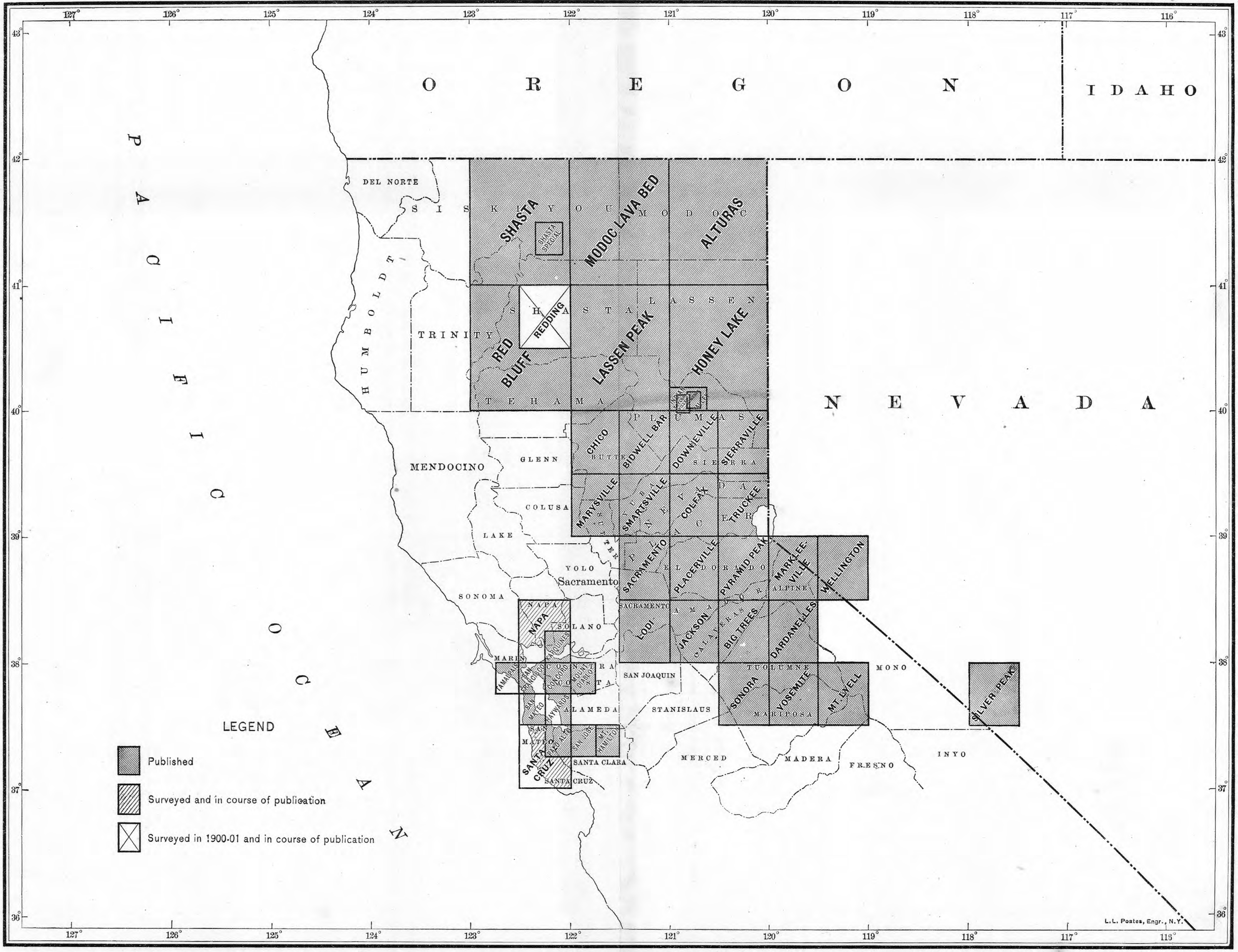
In addition to the above, 3 sheets covering the work in Alaska were drawn and photolithographed.

In connection with the work of surveying and marking the boundaries of the Black Hills Forest Reserve, 17 land-survey plats with duplicate copies of field notes were prepared, ready to be submitted to the Commissioner of the General Land Office.

The office computation of the triangulation and primary traverse was under the charge of Mr. S. S. Gannett, as heretofore. The results of this work have been summarized and will be published as Bulletin No. 181. A list of the bench marks established by spirit leveling will also be published, as Bulletin No. 185.

Mr. S. A. Aplin remained in charge of the topographic records and the purchase and repair of instruments, as formerly. The cataloguing of notebooks and the filing of field material progressed in a systematic manner, and during the year about 1,000 books were so catalogued, which number includes the original records of triangulation, topographic, and leveling parties.

During the year Mr. Ernest Kübel was employed as mechanician of the Survey, and the repairs to instruments have been made by him as far as possible. Other repairs were made by Messrs. G. N. Saegmüller, of Washington, D. C., and W. & L. E. Gurley, of Troy, N. Y. The stock of instruments was



MAP OF NORTHERN CALIFORNIA, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

increased during the year by the purchase of two 8-inch micrometer theodolites, two 4-inch transit theodolites fitted for astronomic work in Alaska, two 6-inch transits, and twelve telescopic alidades, together with other instruments to replace those worn out.

Assistance during the year in the work under Mr. Aplin's charge was rendered by Mr. Powell P. Withers.

Division of Geography and Forestry.

GEOGRAPHY.

Mr. Henry Gannett, geographer of the Survey, continued to give consideration to such geographic matters as were referred to him. Mr. Marcus Baker, cartographer, gave most of his time to geographic work.

During the year Mr. Gannett prepared a paper on Profiles of Rivers in the United States, which was issued as Water-Supply Paper No. 44; also papers on the forests of Oregon and Washington. The work of preparing a dictionary showing the origin of place names in the United States has been progressing rapidly, as well as the preparation of geographic dictionaries of Texas, West Virginia, Cuba, and Porto Rico, the last mentioned having been completed and published as Bulletin No. 183. Mr. Gannett is at present engaged in the preparation of a topographic folio on Glaciers and Their Phenomena, which is nearly ready for transmittal.

During the year Mr. Baker's energies were almost exclusively given to work on geographic nomenclature, the main part of it being the preparation of a Geographic Dictionary of Alaska. This work was begun about ten years ago by the United States Board on Geographic Names, and several thousand names were entered on cards. On these cards a little work was done from time to time, but finally it ceased altogether. About a year ago it was decided that the work should be resumed by the Survey, and since then it has proceeded systematically. The manuscript is now in the hands of the printer, and will be published as Bulletin No. 187.

The dictionary aims to clear up the confusion as to Alaskan geographic names by giving the origin, application, meaning, and approved form of writing of all the geographic names in Alaska.

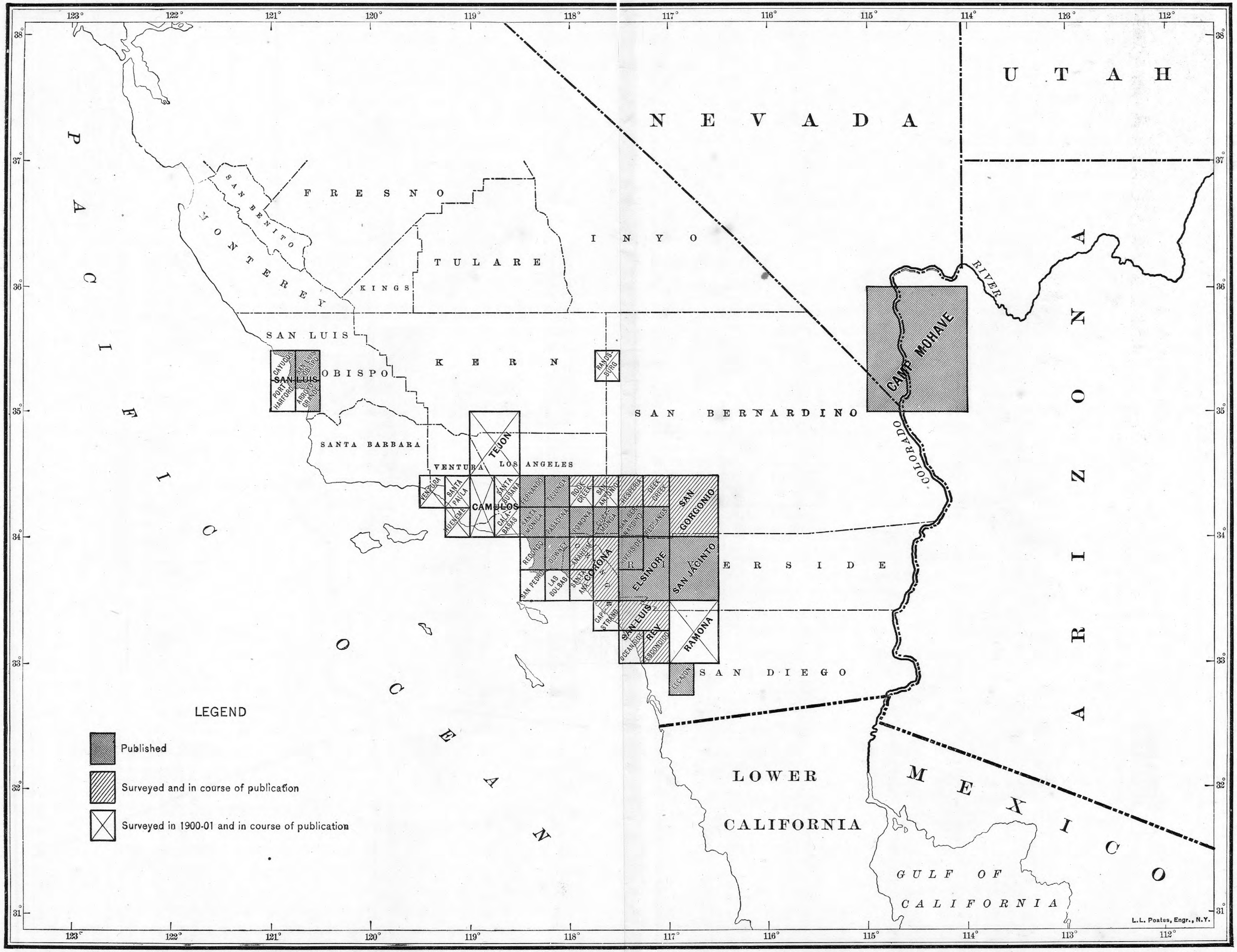
Early in the year Mr. Baker completed the proof reading of Bulletin No. 174, relative to the Northwest Boundary of the United States. He also prepared during the year a short article on Alaskan Geographic Names, which was published in the Twenty-first Annual Report, Part II.

Mr. Baker continued to serve throughout the year as secretary of the United States Board on Geographic Names, having so served continuously since October, 1891. A second edition of the Second Report of that board was printed and distributed during the year. Also the board approved and sent to the President in February last a special report on Geographic Names in the Philippine Islands, which was printed by order of Congress.

After December Mr. Baker had the assistance of Mr. Wilson S. Wiley as clerk and typewriter.

FORESTRY.

Olympic Reserve.—Work was resumed in the Olympic Reserve early in the season by Messrs. Arthur Dodwell and Theodore F. Rixon, and was carried to completion, the area examined during the season being approximately 1,100 square miles. The examination of this reserve, which occupied two men, with assistants, three seasons, was for reconnaissance work, extremely minute and thorough. It included the preparation of a map, suitable for publication on a scale of 4 miles to 1 inch, of an area of 3,600 square miles of a region hitherto almost entirely unknown. Over all this area the total amount of timber and the amount of each species of economic importance were estimated, with the average diameter, height, clear height, and condition of the timber. The work included also the classification of the lands, including timbered lands, grass lands, barren lands, and burned and cut areas, an examination of the streams with reference to their availability for driving logs, and an examination of the country with reference to the building of logging railways and other facilities for logging the region.



MAP OF SOUTHERN CALIFORNIA, SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING.

The report, which reached the office in the form of carefully tabulated notes, was prepared for publication by Mr. Gannett.

Central Washington.—The area lying between the Washington and Mount Rainier reserves, and including the entire breadth of the Cascade Range, was examined during the last season by Messrs. Fred G. Plummer and H. D. Langille. The area includes approximately 4,650 square miles. Much of it had been surveyed and mapped by the United States Geological Survey. The remaining portion, comprising perhaps one-third, was mapped by Messrs. Plummer and Langille in connection with their work of examining the forests.

Northern Sierra Nevada.—The area represented on the atlas sheets known as Sierraville, Downieville, Bidwell Bar, Truckee, Colfax, and Smartsville, comprising the entire breadth of the Sierra Nevada between latitude 39° and 40°, was examined by Mr. J. B. Leiberg, who devoted to it the entire season. This area comprises approximately 6,000 square miles. It presents great diversity in its forests, owing to the fact that it has been the scene of much of the early mining, and consequently has been badly burned, cut, and culled, and the conditions for reproduction of the forest which it presents are of great interest and importance.

Sierra Forest Reserve, California.—During the last season the northern portion of the Sierra Forest Reserve, comprising about two-thirds of the reserve, was examined by Mr. George B. Sudworth, in cooperation with the Division of Forestry of the Department of Agriculture. This region, which has been little affected by fires or cutting, presents special features of interest, as it contains a large proportion of the remaining groves of *Sequoia gigantea.*

Mr. Sudworth's report has been prepared, but is withheld for the present for the completion of the examination of the reserve, when it will be presented as a whole.

Appalachian region.—By act of Congress passed in the winter of 1899–1900 authority was given to the Department of Agriculture to make an examination of the forests of the southern Appalachian region with a view to the establishment of an Appalachian Forest Reserve. Under this authority Mr. H. B. Ayres, of this office, was detailed to the Department of Agriculture, working under the joint instructions of this office and the Department of Agriculture, for the purpose of making such examination. He was assisted by Mr. W. W. Ashe, of that Department. During the season examinations were made of almost the entire mountain region of North Carolina, together with adjacent portions of South Carolina, Georgia, and Tennessee, an irregular area comprising approximately 6,000 square miles. The results are of special interest because the examinations on which they are based are the first that have been made on an extended scale in the mixed forests of the East. Mr. Ayres's report has been prepared, but its manner of publication has not been decided upon.

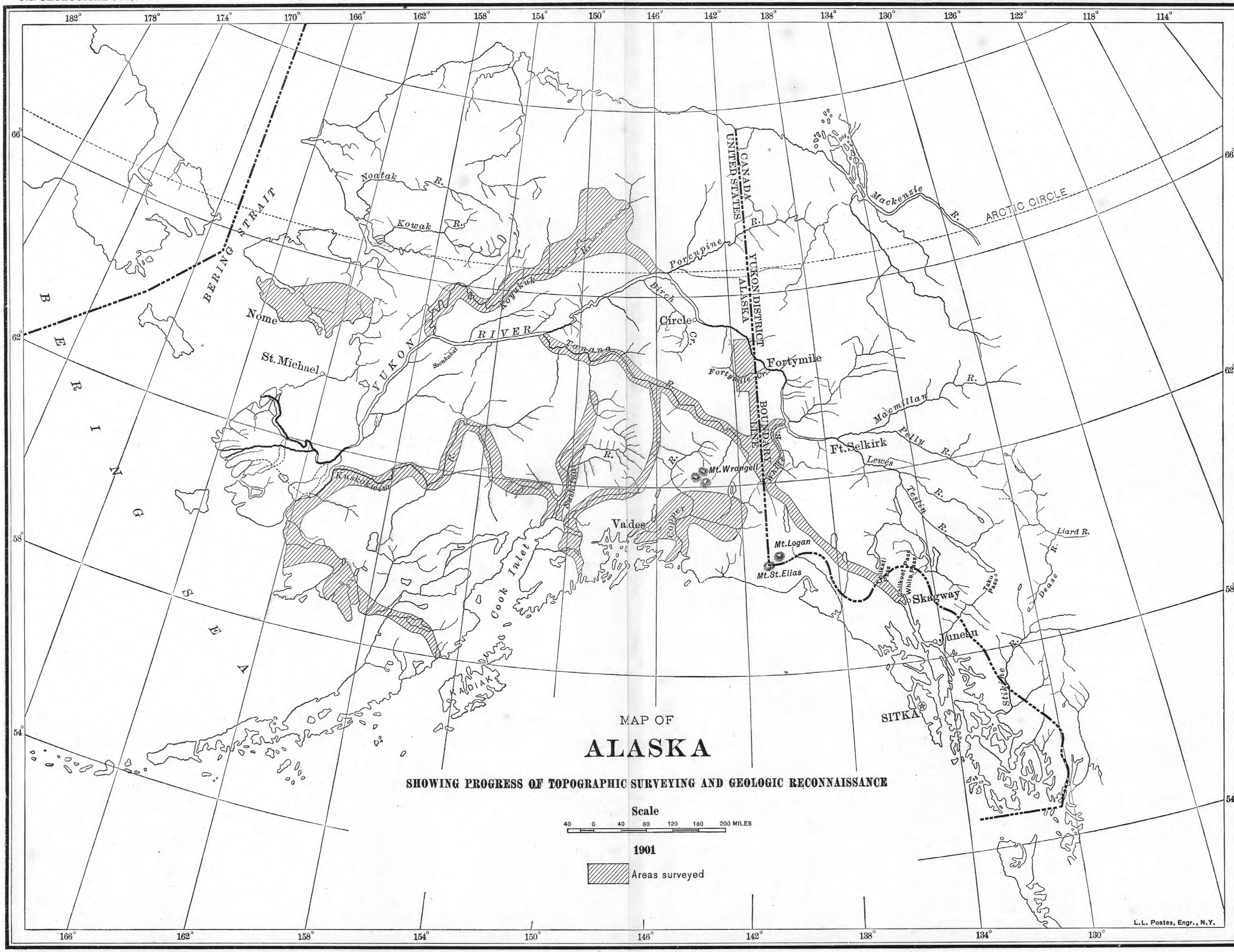
Oregon.—During the field season the work of collecting information concerning the forests of the State of Oregon was continued and completed by Mr. A. J. Johnson. As a result we have now an approximate estimate of the stand and distribution of timber in the State, together with a classification of its lands. From Mr. Johnson's notes and map a report has been prepared by Mr. Gannett.

Office work.—Work in the office related in part to the examination of forested regions and in part to general geography, as already detailed. As above noted, the reports on the Olympic Reserve and on the State of Oregon were prepared in the office. The classification of lands and the estimates of standing timber in Washington were revised, in view of the examinations of the mountain regions recently made.

PUBLICATION BRANCH.

Division of Illustrations.

The Division of Illustrations remained in charge of Mr. John L. Ridgway, who was assisted by Messrs. H. Chadwick Hunter, H. Hobart Nichols, F. W. von Dachenhausen, D. W. Cronin, J. H. Pellen, and Paul Morris, Misses Frances Wieser and Mary M. Mitchell, and Mr. L. B. Jay, laborer. During the latter part of the fiscal year Mr. A. A. Aguirre was employed at piecework, and a number of paleontologic drawings were made from time to time by Dr. J. C. McConnell.


MAP OF
ALASKA
SHOWING PROGRESS OF TOPOGRAPHIC SURVEYING AND GEOLOGIC RECONNAISSANCE
Scale
40 0 40 80 120 160 200 MILES
1901
Areas surveyed
BERING STRAIT
BERING SEA
Nome
St. Michael
YUKON RIVER
Noatak R.
Kowak R.
Koyukuk R.
Porcupine
Birch Cr.
Circle
Fortymile
Fortymile Cr.
Tanana R.
Kuskokwim
Sushitna R.
Mt. Wrangell
Valdes
Copper
Cook Inlet
KADIAK
Mt. Logan
Mt. St. Elias
CANADA
UNITED STATES
YUKON DISTRICT
ALASKA
BOUNDARY LINE
White
Mackenzie R.
ARCTIC CIRCLE
Macmillan R.
Pelly R.
Ft. Selkirk
Lewes
Teslin R.
Liard R.
Dease R.
Chilkoot Pass
White Pass
Taku Pass
Skagway
Juneau
SITKA
Stikine R.
L.L. Poates, Engr., N.Y.

Improvements were made in several directions. By an improved method of photography finished drawings are now produced that excel in accuracy those made by the former method of drawing directly from the specimens. Considerable time is saved, also, by this process.

Much benefit resulted from the appointment of a committee to pass upon all material submitted for illustrations, before their final preparation, for the purpose of eliminating all illustrations not absolutely essential.

The great number of cuts which have been accumulating for years have been recatalogued and filed in new cases.

During the year 2,944 drawings were prepared. They may be classified as follows:

Geologic and topographic maps	273
Geologic and topographic landscapes	43
Sections and diagrams	496
Photographs prepared for reproduction	601
Paleontologic drawings	723
Color drawings	14
Miscellaneous drawings	794
Total	2,944

Drawings, including many of the above, were transmitted to accompany the following reports: Twenty-first Annual Report, Parts I to VII; Twenty-second Annual Report, Part II; Monograph XL; Bulletins Nos. 178, 180, 181, 182, 184; Water-Supply and Irrigation Papers Nos. 40–46, 53–55; Report on Copper River region, Alaska; Reports on Cape Nome and Norton Bay regions, Alaska.

The following processes, with the number of subjects reproduced by each, were used in the reproduction of the drawings transmitted:

By chromolithography	148
By lithography	15
By line engraving	716
By half tone	686
By photogelatin	22
By wax engraving	41
By three-color process	3

Proofs of illustrations to the number of 1,451 were received and criticised, and an examination was made at the Government Printing Office of the printed editions of 53 chromolithographic plates to accompany Survey reports.

Photographic Laboratory.

During the year the Photographic Laboratory continued under the direction of Mr. Norman W. Carkhuff, who was assisted by Messrs. John Erbach, Charles A. Ross, Nelson H. Kent, and Ernest A. Shuster, jr.

As compared with the previous year, nearly double the number of negatives were made, and the number of prints was slightly greater.

Experiments made toward obtaining a satisfactory paper for the printing of maps led to the introduction of an inexpensive paper capable of showing perfect contours, of printing black lines on a white ground, and of being printed by either natural or artificial light. The experiment was also made of furnishing to the Division of Illustrations black prints with a view to their use for reproduction.

A process for photographing fossils was in constant use, and with considerable success.

The work of indexing the Survey collection of negatives progressed favorably. It will probably be completed during the present year.

The Survey lantern-slide collection has been placed in the Photographic Laboratory, and is being indexed in a manner to render ready reference possible. Several schools have made use of this collection by having slides and prints made for educational purposes

Members of the Survey using cameras in the field consulted freely with the chief photographer relative to such work and to the outfits best adapted to it.

Careful record of all work done is kept, and the cost of a given piece of work can be determined in a few minutes.

Following is a tabulated statement of the work of the laboratory for the year ending June 30, 1901:

Work of the photographic laboratory for the year 1900–01.

Month.	Negatives made.			Prints.	Slides made.	Slides labeled.	Prints mounted.	Prints bleached.	Transparencies.
	Wet.	Dry.	Total.						
1900.									
July	76	79	155	1,154	......	......	123	3	......
August	44	61	105	734	......	......	6	1	......
September	78	397	475	1,421	......	......	4	......	......
October	61	350	411	434	......	......	10	5	3
November	29	101	130	409	22	26	2	......	......
December	120	777	897	1,475	......	......	1	......	......
1901.									
January	173	607	780	1,857	24	......	35	1	......
February	183	219	402	1,005	186	......	12	2	......
March	171	172	343	1,566	109	......	31	......	112
April	192	4	196	1,454	......	......	......	......	......
May	118	128	246	1,398	......	......	......	......	......
June	155	541	696	1,929	......	......	35	......	......
Total	1,400	3,436	4,836	14,836	341	26	259	12	115

Sizes of negatives and prints made in 1900–01.

Size.	Negatives.	Prints.
28 by 34	213	1,151
22 by 28	83	468
20 by 24	634	2,210
14 by 17	177	579
11 by 14	226	611
8 by 10	239	827
$6\frac{1}{2}$ by $8\frac{1}{2}$	315	2,303
5 by 7	1,702	3,563
4 by 5	1,247	3,124
Total	4,836	14,836

Editorial Division.

TEXTUAL PUBLICATIONS.

Mr. Philip C. Warman remained in charge of this section. He was assisted throughout the year by Messrs. George M. Wood and L. F. Schmeckebier, and for a portion of the year by Mr. Wilson S. Wiley. In May, when the work began to increase greatly, the services of Mrs. Annie B. Wood were procured for a limited period.

Lists of the manuscripts prepared for the printer, proofs read and corrected, and indexes made during the year are given herewith. The large totals—the largest in the history of the Survey—testify to the assiduity of the professional corps. The small force engaged solely in the editorial work would probably be unable to handle satisfactorily this large amount of manuscript and proof if it were not favored by the chiefs of some of the divisions in the way of copy preparing, proof reading, and index making in their divisions. Such assistance is rendered especially by the Division of Hydrography and the Division of Mines and Mineral Resources.

During the year considerable time was devoted now and then to the completion of a catalogue and general index of Survey publications to date. This has been published as Bulletin No. 177.

Manuscripts edited during the year 1900–01.

Publication.	Pages (usually typewritten).
Twenty-first Annual Report (in part)	6,284
Twenty-second Annual Report (in part)	2,688
Bulletin No. 175	259
Bulletin No. 176	212
Bulletin No. 177	4,506
Bulletin No. 178	15
Bulletin No. 179	1,500
Bulletin No. 180	132
Bulletin No. 181	506
Bulletin No. 182	572
Bulletin No. 183	158
Bulletin No. 184	132
Bulletin No. — (Fuller)	130
Water-Supply Paper No. 40	59
Water-Supply Paper No. 41	80
Water-Supply Paper No. 42	66
Water-Supply Paper No. 43	122
Water-Supply Paper No. 44	247
Water-Supply Paper No. 45	68
Water-Supply Paper No. 46	64

Manuscripts edited during the year 1900–01—Continued.

Publication.	Pages (usually typewritten).
Water-Supply Paper No. 47	217
Water-Supply Paper No. 48	331
Water-Supply Paper No. 49	189
Water-Supply Paper No. 50	235
Water-Supply Paper No. 51	167
Water-Supply Paper No. 52	81
Water-Supply Paper No. 53	125
Water-Supply Paper No. 54	80
Water-Supply Paper No. 55	113
Geologic Folio No. 60	202
Geologic Folio No. 64	80
Geologic Folio No. 66	148
Geologic Folio No. 67	98
Geologic Folio No. 68	62
Geologic Folio No. 69	78
Geologic Folio No. 70	138
Geologic Folio No. 71	93
Geologic Folio No. 72	101
Geologic Folio No. 73	58
Mineral Resources for 1900	850
Copper River Report	191
Cape Nome and Norton Bay Report	544
Five-place Logarithms	69
Description of Niagara River	61
Total number of manuscript pages edited	22, 111

Proof sheets read and corrected during the year 1900–01.

Publication.	Final printed pages.
Twenty-first Annual Report (in part)	5, 250
Monograph XL	160
Bulletin No. 172	153
Bulletin No. 173	676
Bulletin No. 174	91
Bulletin No. 175	154
Bulletin No. 176	127
Bulletin No. 177	858

Proof sheets read and corrected during the year 1900–01—Continued.

Publication.	Final printed pages.
Bulletin No. 178	28
Bulletin No. 181	240
Bulletin No. 183	55
Water-Supply Paper No. 39	68
Water-Supply Paper No. 40	50
Water-Supply Paper No. 41	72
Water-Supply Paper No. 42	69
Water-Supply Paper No. 43	86
Water-Supply Paper No. 44	100
Water-Supply Paper No. 45	48
Water-Supply Paper No. 46	57
Water-Supply Paper No. 47	99
Water-Supply Paper No. 48	95
Water-Supply Paper No. 49	95
Water-Supply Paper No. 50	94
Water-Supply Paper No. 53	85
Water-Supply Paper No. 54	52
Water-Supply Paper No. 55	69
Geologic Folio No. 60	14
Geologic Folio No. 61	7
Geologic Folio No. 63	11
Geologic Folio No. 64	7
Geologic Folio No. 65	8
Geologic Folio No. 66	10
Geologic Folio No. 67	10
Geologic Folio No. 68	6
Geologic Folio No. 69	6
Geologic Folio No. 70	7
Geologic Folio No. 71	7
Geologic Folio No. 72	9
Geologic Folio No. 73	5
Mineral Resources for 1900 (in part)	80
Copper River Report	92
Cape Nome and Norton Bay Report	190
Five-place Logarithms	69
Total number of pages of proof read and corrected	9,469

Indexes prepared during the year 1900–01.

Publication.	Pages indexed.
Twenty-first Annual Report, Part I	582
Twenty-first Annual Report, Part II	509
Twenty-first Annual Report, Part III	625
Twenty-first Annual Report, Part IV	741
Twenty-first Annual Report, Part V	689
Twenty-first Annual Report, Part VI	633
Twenty-first Annual Report, Part VI—Continued	622
Twenty-first Annual Report, Part VII	649
Monograph XL	148
Bulletin No. 175	141
Bulletin No. 176	114
Bulletin No. 181	228
Water-Supply Papers Nos. 35–39 (joint index)	457
Water-Supply Paper No. 40	49
Water-Supply Papers Nos. 41–42 (joint index)	143
Water-Supply Paper No. 43	81
Water-Supply Paper No. 45	45
Water-Supply Paper No. 46	54
Copper River Report	92
Total number of pages indexed	6,602

GEOLOGIC MAPS.

This section continued in charge of Mr. George W. Stose, who was assisted throughout the year by Messrs. O. A. Ljungstedt and H. S Selden. On January 4, 1901, Mr. H. V. Leménager was added to the force and continued with the division to the close of the fiscal year. Owing to the increasing work of the division it became necessary to classify the work and assign special duties to each man. Mr. Ljungstedt has charge of the drafting of sections and diagrams for the folios, and has supervision of the proof reading in Mr. Stose's absence. Mr. Selden, assisted by Mr. Leménager, does most of the proof reading of the maps and the general drafting.

Mr. Stose's time is required by the editorial work, and he only supervises the proof reading and the making of drawings. In addition to the editing of original maps and the correspondence and conferences with the chiefs of division and the geologists which this involves, he edited some texts, and served on the Committee on Map Editing and Printing and the Committee on Geologic Formation Names. Messrs. Bailey Willis and P. C. Warman edited the texts of the folios throughout most of the year, but after Mr. Willis's departure for the field the reading of the texts for geology was done by Mr. Stose. He was also appointed acting chairman of the Committee on Geologic Formation Names during Mr. Willis's absence. During the month of August and the first part of September he assisted Mr. Cross in the field in the survey of the Engineer Mountain and Silverton quadrangles, Colorado.

Twelve geologic folios were completed during the year, Nos. 60, 61, and 63 to 72, inclusive. The list of published folios is as follows:

Geologic folios published.

No.	Name of folio.	State.	Limiting meridians.	Limiting parallels.	Area in square miles.	Price in cents.
1	Livingston	Montana	110°-111°	45°-46°	3,354	25
2	Ringgold	Georgia Tennessee	85°-85°30′	34°30′-35°	980	25
3	Placerville	California	120°30′-121°	38°30′-39°	932	25
4	Kingston	Tennessee	84°30′-85°	35°30′-36°	969	25
5	Sacramento	California	121°-121°30′	38°30′-39°	932	25
6	Chattanooga	Tennessee	85°-85°30′	35°-35°30′	975	25
7	Pikes Peak (including Cripple Creek map).	Colorado	105°-105°30′	38°30′-39°	932	25
8	Sewanee	Tennessee	85°30′-86°	35°-35°30′	975	25
9	Anthracite-Crested Butte.	Colorado	106°45′-107°15′	38°45′-39°	465	50
10	Harpers Ferry	Virginia West Virginia Maryland	77°30′-78°	39°-39°30′	925	25
11	Jackson	California	120°30′-121°	38°-38°30′	938	25
12	Estillville	Virginia Kentucky Tennessee	82°30′-83°	36°30′-37°	957	25
13	Fredericksburg	Maryland Virginia	77°-77°30′	38°-38°30′	938	25
14	Staunton	Virginia West Virginia	79°-79°30′	38°-38°30′	938	25
15	Lassen Peak	California	121°-122°	40°-41°	3,634	25
16	Knoxville	Tennessee North Caroiina	83°30′-84°	35°30′-36°	969	25
17	Marysville	California	121°30′-122°	39°-39°30′	925	25
18	Smartsville	California	121°-121°30′	39°-39°30′	925	25
19	Stevenson	Alabama Georgia Tennessee	85°30′-86°	34°30′-35°	980	25
20	Cleveland	Tennessee	84°30′-85°	35°-35°30′	975	25
21	Pikeville	Tennessee	85°-85°30′	35°30′-36°	969	25

Geologic folios published—Continued.

No.	Name of folio.	State.	Limiting meridians.	Limiting parallels.	Area in square miles.	Price in cents.
22	McMinnville	Tennessee	85°30′–86°	35°30′–36°	969	25
23	Nomini	Maryland; Virginia	76°30′–77°	38°–38°30′	938	25
24	Three Forks	Montana	111°–112°	45°–46°	3,354	50
25	Loudon	Tennessee	84°–84°30′	35°30′–36°	969	25
26	Pocahontas	Virginia; West Virginia	81°–81°30′	37°–37°30′	950	25
27	Morristown	Tennessee	83°–83°30′	36°–36°30′	963	25
28	Piedmont	Maryland; West Virginia	79°–79°30′	39°–39°30′	925	25
29	Nevada City Special:					
	Nevada City	California	121°00′25″–121°03′45″	39°13′50″–39°17′16″	11.65	50
	Grass Valley	California	121°01′35″–121°05′04″	39°10′22″–39°13′50″	12.09	50
	Banner Hill	California	120°57′05″–121°00′25″	39°13′50″–39°17′16″	11.65	50
30	Yellowstone National Park:					
	Gallatin	Wyoming	110°–111°	44°–45°	3,412	75
	Canyon	Wyoming	110°–111°	44°–45°	3,412	75
	Shoshone	Wyoming	110°–111°	44°–45°	3,412	75
	Lake	Wyoming	110°–111°	44°–45°	3,412	75
31	Pyramid Peak	California	120°–120°30′	38°30′–39°	932	25
32	Franklin	Virginia; West Virginia	79°–79°30′	38°30′–39°	932	25
33	Briceville	Tennessee	84°–84°30′	36°–36°30′	963	25
34	Buckhannon	West Virginia	80°–80°30′	38°30′–39°	932	25
35	Gadsden	Alabama	86°–86°30′	34°–34°30′	986	25
36	Pueblo	Colorado	104°30′–105°	38°–38°30′	938	50
37	Downieville	California	120°30′–121°	39°30′–40°	919	25
38	Butte Special	Montana	112°29′30″–112°36′42″	45°59′28″–46°02′54″	22.8	50
39	Truckee	California	120°–120°30′	39°–39°30′	925	25
40	Wartburg	Tennessee	84°30′–85°	36°–36°30′	963	25
41	Sonora	California	120°–120°30′	37°30′–38°	944	25
42	Nueces	Texas	100°–100°30′	29°30′–30°	1,035	25
43	Bidwell Bar	California	121°–121°30′	39°30′–40°	919	25
44	Tazewell	Virginia; West Virginia	81°30′–82°	37°–37°30′	950	25
45	Boise	Idaho	116°–116°30′	43°30′–44°	864	25
46	Richmond	Kentucky	84°–84°30′	37°30′–38°	944	25
47	London	Kentucky	84°–84°30′	37°–37°30′	950	25
48	Tenmile District.	Colorado	106°08′–106°16′08″	39°22′57″–39°30′25″	62.2	25
49	Roseburg	Oregon	123°–123°30′	43°–43°30′	871	25
50	Holyoke	Massachusetts; Connecticut	72°30′–73°	42°–42°30′	885	50
51	Big Trees	California	120°–120°30′	38°–38°30′	938	25
52	Absaroka:					
	Crandall	Wyoming	109°30′–110°	44°–45°	1,706	25
	Ishawooa	Wyoming	109°30′–110°	44°–45°	1,706	25
53	Standingstone	Tennessee	85°–85°30′	36°–36°30′	963	25
54	Tacoma	Washington	122°–122°30′	47°–47°30′	812	25
55	Fort Benton	Montana	110°–111°	47°–48°	3,234	25
56	Little Belt Mountains.	Montana	110°–111°	46°–47°	3,295	25
57	Telluride	Colorado	107°45′–108°	37°45′–38°	236	25

Geologic folios published—Continued.

No.	Name of folio.	State.	Limiting meridians.	Limiting parallels.	Area in square miles.	Price in cents.
58	Elmoro	Colorado	104°-104°30′	37°-37°30′	950	25
59	Bristol	Virginia; Tennessee	82°-82°30′	36°30′-37°	957	25
60	La Plata	Colorado	108°-108°15′	37°15′-37°30′	237	25
61	Monterey	Virginia; West Virginia	79°30′-80°	38°-38°30′	938	25
62	Menominee Special.	Michigan	An irregular area about 20 miles long.		125	25
63	Mother Lode District (the Gold Belt).	California	NW.-SE. rectangle, about 70 miles long and 6 miles wide.		428	50
64	Uvalde	Texas	99°30′-100°	29°-29°30′	1,040	25
65	Tintic Special	Utah	111°55′-112°10′	39°45′-40°	229	25
66	Colfax	California	120°30′-121°	39°-39°30′	925	25
67	Danville	Illinois; Indiana	87°30′-87°45′	40°-40°15′	228	25
68	Walsenburg	Colorado	104°30′-105°	37°30′-38°	944	25
69	Huntington	West Virginia; Ohio	82°-82°30′	38°-38°30′	938	25
70	Washington	District of Columbia; Virginia; Maryland	76°45′-77°15′	38°45′-39°	465	50
71	Spanish Peaks	Colorado	104°30′-105°	37°-37°30′	950	25
72	Charleston	West Virginia	81°30′-82	38°-38°30′	938	25

Ten folios are in various stages of engraving, as follows:

Atoka, Ind. T.
Austin, Tex.
Coalgate, Ind. T.
Coos Bay, Oreg.
Housatonic, Mass.-Conn.-N. Y.
Marietta, Ga.
Maynardville, Tenn.
New York City, N. Y.-N. J.: Harlem. Paterson. Staten Island. Brooklyn.
Raleigh, W. Va.
Rome, Ga.-Ala.

During the year thirteen folios were transmitted to this division which have not yet been engraved. They are:

Alexandria, S. Dak.
Chicago, Ill.-Ind.: Chicago. Calumet. Desplaines. Riverside.
Camp Clarke, Nebr.
Cartersville, Ga.
Cranberry, Tenn.
Dalton, Ga.-Tenn.
Hartville, Wyo.
Mitchell, S. Dak.
Norfolk, Va.
Oelrichs, S. Dak.-Nebr.
Olivet, S. Dak.
Parker, S. Dak.
Scotts Bluff, Nebr.

Among the folios published during the year are two double folios—the Mother Lode District folio, consisting of four narrow maps printed two on a sheet, which, when mounted together, form a strip 68 inches long; and the Washington folio, consisting of two maps printed side by side. The latter has also an extra sheet representing physiographic geology, which is of special interest in the Coastal Plain region about Washington. The artesian-water conditions are represented on the economic sheet. The Walsenburg and Spanish Peaks folios have each a special sheet showing the igneous geology in detail. The purpose of these special sheets is to show the numerous large dikes which radiate from the center of eruption in the Spanish Peaks and to classify them according to age and composition, which have been worked out with great care. The wonderful wall-like dikes crossing the country for miles, and standing out like vertical walls 100 feet high, are illustrated by several striking photographs.

The folios which present special economic problems are the Mother Lode District, La Plata, Tintic Special, and Colfax folios, representing gold and silver deposits, and the Danville, Walsenburg, Huntington, Spanish Peaks, and Charleston folios, representing coal deposits.

TOPOGRAPHIC MAPS.

Mr. S. J. Kübel was continued in charge of the editing of topographic maps. He was assisted in this work by Messrs. James McCormick, H. W. Elmore, and J. W. Brashears. Mr. McCormick is in immediate charge of the editing, while Messrs. Elmore and Brashears are engaged in proof reading and in keeping the records. The inspection of manuscript maps for illustrating annual reports, monographs, bulletins, etc., is also the special work of Mr. McCormick.

The work of this section consisted of the editing of new topographic atlas sheets, corrections to published maps, examination of manuscript maps with special regard to their nomenclature, and general charge and supervision of all of the manuscripts of the published and unpublished maps of the Survey.

The editing and proof reading of the topographic maps constitute the principal duties of this section, but two other classes of work require considerable attention:

The manuscript maps intended to be reproduced as illustrations for the various publications of the Survey in book form—

annual reports, monographs, bulletins, folios, etc.—were examined and revised, with special reference to the geographic names thereon, to the number of 140, as follows:

Twenty-first Annual Report, Part II	11
Twenty-first Annual Report, Part III	31
Twenty-first Annual Report, Part IV	8
Twenty-first Annual Report, Part V	37
Twenty-first Annual Report, Part VII	18
Water-Supply and Irrigation Paper No. 44	[1]12
Water-Supply and Irrigation Paper No. 45	6
Water-Supply and Irrigation Paper No. 46	4
Water-Supply and Irrigation Paper No. 53	5
Water-Supply and Irrigation Paper No. 55	6
Bulletin No. 175	2
Total	140

The Survey issues a series of circulars designed to convey information concerning the topographic maps made and for sale by the Survey. Each of the circulars contains information pertaining to a certain limited portion of the United States, usually from one to three or four States, and each is illustrated by an index map of these States giving the names of the published maps and indicating the areas which they cover. The index maps heretofore used to illustrate these circulars were photolithographs of rough tracings and proved unsatisfactory. It was therefore determined that the large Survey base map of the United States, which is engraved on copper, should be adapted to this use. To do this required a rearrangement of the circulars in great part, their increase in number from 15 to 20, and incidentally a rewriting of the entire text of each, all of which was done in this section.

Division of Engraving and Printing.

Mr. S. J. Kübel was continued in charge of this division as chief engraver, and was assisted by Mr. H. C. Evans, foreman of copperplate engravers; R. H. Payne, in charge of stone transfer work; Messrs. J. Eckert and F. P. Droney, in charge of lithographic power presses; and Mr. O. Schleichert, in charge of stone engraving.

The number of employees and their designations are as follows: 23 copperplate engravers, 1 photomechanical engraver,

[1] Maps and profiles.

6 lithographic engravers, 46 printers, transferrers, and assistants, and 1 mechanician.

The appropriation of $70,000, together with a deficiency allotment of $10,000, sufficed to carry on the work and also to provide a stock of paper in time to insure its proper "seasoning" before use.

As stated in the Twenty-first Annual Report, there were, on July 1, 1900, in the custody of the editor of topographic maps, for publication, manuscript atlas sheets and special maps to the number of 125. Two of these, the Boonville and Petersburg (Ind.) were withdrawn for additional field work, leaving 123. The engraving of 40 of these was in various stages of progress. During the year just closed 94 new sheets were received from the Topographic Branch, and two others, the Navesink (N. J.–N. Y.) and Cincinnati (Ohio–Ky.), were made from atlas sheets heretofore published. This gives a total of 219 atlas sheets and special maps, which are listed below in three groups:

Group I comprises 87 sheets which were published during the year or were in press at the close of the year.

Group II comprises 25 sheets which were in process of engraving at the close of the year.

Group III comprises 107 sheets which at the close of the year had not yet been transmitted to the engravers.

Thus it appears that at the close of the year there were in hand for publication 132 atlas sheets and special maps, and that the engraving of 25 of these was in various stages of progress.

Group I.—*Topographic atlas sheets and other maps engraved and printed, or in press, during the fiscal year 1900–01.*

Quadrangle and State.	Position of SE. corner.				Contour interval.	Scale.
	Latitude.		Longitude.			
	°	′	°	′		
Accident, Md.–Pa.–W. Va	39	30	79	15	20	1:62500
Addington, Ind. T	34	00	97	30	50	1:125000
Alikchi, Ind. T	34	00	95	00	50	1:125000
Antlers, Ind. T	34	00	95	30	50	1:125000

Group I.—*Topographic atlas sheets and other maps engraved and printed, or in press, during the fiscal year 1900–01*—Continued.

Quadrangle and State.	Position of SE. corner.		Contour interval.	Scale.
	Latitude.	Longitude.		
	° ′	° ′		
Ardmore, Ind. T	34 00	97 00	50	1:125000
Asheville, N. C.–Tenn.[1]	35 30	82 30	100	1:125000
Bald Mountain, Wyo	44 30	107 30	100	1:125000
Baldwinsville, N. Y	43 00	76 15	20	1:62500
Bingham Mining Map, Utah			50	1:20000
Bucksport, Me	44 30	68 45	20	1:62500
Camden, N. J.–Pa.–Del	39 30	75 00	20	1:125000
Canadian, Ind. T	35 00	95 30	50	1:125000
Chelan, Wash	47 30	120 00	100	1:125000
Chestertown, Md	39 00	76 00	20	1:62500
Cincinnati, Ohio–Ky.[2]	39 00	84 15	20	1:62500
Claremore, Ind. T	36 00	95 30	50	1:125000
Cloud Peak, Wyo	44 00	107 00	100	1:125000
Columbia, Tenn	35 30	87 00	50	1:125000
Dayton, Wyo.[1]	44 30	107 00	100	1:125000
Deadwood, S. Dak.[1]	44 00	103 30	100	1:125000
Denison, Tex.–Ind. T	33 30	96 30	50	1:125000
Dryden, N. Y	42 15	76 15	20	1 62500
East Columbus, Ohio	39 45	82 45	20	1:62500
Elkland, Pa	41 45	77 15	20	1:62500
Ellensburg, Wash	46 30	120 30	100	1:125000
Elsinore, Cal	33 30	117 00	100	1:125000
Erie, Pa	42 00	80 00	20	1:62500
Fairview, Pa	42 00	80 15	20	1:62500
Fayetteville, Ark.–Mo	36 00	94 00	50	1:125000
Flatonia, Tex	29 30	97 00	25	1:125000
Gaines, Pa	41 45	77 30	20	1:62500
Girard, Pa	41 45	80 15	20	1:62500
Glacier Peak, Wash	48 00	121 00	100	1:125000
Grand Teton, Wyo	43 30	110 30	100	1:125000
Green Run, Md.–Va	38 00	75 00	10	1:62500
Gurdon, Ark	33 30	93 00	50	1:125000
Hamilton, Mont.–Idaho	46 00	114 00	100	1:125000
Harney Peak, S. Dak.[1]	43 30	103 30	100	1:125000
Havre de Grace, Md.–Pa	39 30	76 00	20	1:62500
Hermosa, S. Dak.[1]	43 30	103 00	100	1:125000
Lancaster, Wis.–Iowa–Ill	42 30	90 30	20	1:125000

[1] Resurvey. [2] Double sheet, comprising East Cincinnati and West Cincinnati sheets.

Group I.—*Topographic atlas sheets and other maps engraved and printed, or in press, during the fiscal year 1900–01*—Continued.

Quadrangle and State.	Position of SE. corner.				Contour interval.	Scale.
	Latitude.		Longitude.			
	°	′	°	′		
Masontown, Pa	39	45	79	45	20	1:62500
Maumee Bay, Ohio–Mich	41	30	83	15	20	1:62500
Methow, Wash	48	00	120	00	100	1:125000
Mount Leidy, Wyo	43	30	110	00	100	1:125000
Mount Lyell, Cal	37	30	119	00	100	1:125000
Muscogee, Ind. T	35	30	95	00	50	1:125000
Newcastle, Wyo.–S. Dak	43	30	104	00	50	1:125000
Nicholas, W. Va. [1]	38	00	80	30	100	1:125000
Nowata, Ind. T	36	30	95	30	50	1:125000
Nuyaka, Ind. T	35	30	96	00	50	1:125000
Oak Harbor, Ohio	41	30	83	00	20	1:62500
Oakland, Md.–W. Va	39	15	79	15	20	1:62500
Okmulgee, Ind. T	35	30	95	30	50	1:125000
Old Forge, N. Y	43	30	74	45	20	1:62500
Orland, Me	44	30	68	30	20	1:62500
Paxton, Nebr	41	00	101	00	20	1:125000
Peosta, Iowa–Ill. [2]	42	00	93	30	20	1:125000
Pingree, N. Dak	47	00	98	30	20	1:125000
Pryor, Ind. T	36	00	95	00	50	1:125000
Rancocas, N. J	39	30	74	30	10	1:125000
Redlands, Cal. [1]	34	00	117	00	50	1:62500
Riverside, Cal	33	45	117	15	25	1:62500
Rock Island, Iowa–Ill. [3]	41	30	90	30	20	1:125000
St. Croix Dalles, Wis.–Minn	45	15	92	30	20	1:62500
Sandpoint, Idaho	48	00	116	30	100	1:125000
San Jacinto, Cal	33	30	116	30	100	1:125000
San Luis Rey, Cal	33	00	117	00	100	1:125000
Sansbois, Ind. T	35	00	95	00	50	1:125000
Spokane, Wash.–Idaho	47	30	117	00	100	1:125000
Stanwood, Iowa [4]	41	30	91	00	20	1:125000
Stilaguamish, Wash	48	00	121	30	100	1:125000
Stonewall, Ind. T	34	30	96	30	50	1:125000
Taconic, N. Y.–Mass.–Vt	42	30	73	00	40	1:125000
Tahlequah, Ind. T.–Ark	35	30	94	30	50	1:125000
The Dells, Wis	43	30	89	45	20	1:62500

[1] Resurvey.
[2] Maquoketa in Twenty-first Annual.
[3] Davenport in Twenty-first Annual.
[4] Tipton in Twenty-first Annual.

GROUP I.—*Topographic atlas sheets and other maps engraved and printed, or in press, during the fiscal year 1900–01*—Continued.

Quadrangle and State.	Position of SE. corner.				Contour interval.	Scale.
	Latitude.		Longitude.			
	°	′	°	′		
Tishomingo, Ind. T	34	00	96	30	50	1:125000
Toledo, Ohio	41	30	83	30	20	1:62500
Toleston, Ind	41	30	87	15	10	1:62500
Tujunga, Cal	34	15	118	00	50	1:62500
Tuskahoma, Ind. T	34	30	95	00	50	1:125000
Uniontown, Pa	39	45	79	30	20	1:62500
Vinita, Ind. T	36	30	95	00	50	1:125000
Watkins, N. Y	42	15	76	45	20	1:62500
West Columbus, Ohio	39	45	83	00	20	1:62500
Wewoka, Ind. T	35	00	96	00	50	1:125000
Winslow, Ark.-Ind	35	30	94	00	50	1:125000

Résumé by States.

Arkansas	4
California	7
Delaware	1
Idaho	3
Illinois	3
Indiana	1
Indian Territory	20
Iowa	4
Kentucky	1
Maine	2
Maryland	5
Massachusetts	1
Michigan	1
Minnesota	1
Missouri	1
Montana	1
Nebraska	1
New Jersey	2
New York	5
North Carolina	1
North Dakota	1
Ohio	6
Pennsylvania	10
South Dakota	4
Tennessee	2
Texas	2
Utah	1
Vermont	1
Virginia	1
Washington	6
West Virginia	3
Wisconsin	3
Wyoming	6
Total	111
Deducting sheets counted in more than one State	24
Balance	87

GROUP II.—*Topographic atlas sheets and other maps in process of engraving, 1900–01.*

Baker City, Oreg.
Brownsville, Pa.
Connellsville, Pa.
Denzer, Wis.
De Soto, Mo.
Elkader, Iowa-Wis.

Elk Point, S. Dak.-Nebr.-Iowa.
Eureka Springs, Ark.-Mo.
Florence, Ariz.
Globe, Ariz.
Hancock, W. Va.-Md.-Pa.
Indiana, Pa.
Kittanning, Pa.
Latrobe, Pa.
Marysville Special, Mont.
Navesink, N. J.-N. Y.
Ocean City, Md.-Del.
Oelwein, Iowa.
Portage, Wis.
Poynette, Wis.
Princess Anne, Md.-Va.
Salisbury, Md.-Del.
Snow Hill, Md.-Va.
Sumpter, Oreg.
Tioga, Pa.

GROUP III.—*New topographic atlas sheets awaiting editorial examination before approval for engraving, 1900–01.*

Alexandria Bay, N. Y.
Anoka, Minn.
Bangor, Me.
Bastrop, Tex.[1]
Belair, Md.-Pa.
Berne, N. Y.
Blue Mountain, N. Y.
Bonner, Mont.
Bonneterre, Mo.
Boston and vicinity, Mass.[1]
Boyertown, Pa.
Bradshaw Mountains, Ariz.
Briggsville, Wis.
Broadalbin, N. Y.
Burnet, Tex.[1]
Calabasas, Cal.
Camden, Ark.
Camulos, Cal.
Canandaigua, N. Y.
Capistrano, Cal.
Castine, Me.
Chambersburg, Pa.
Clayton, N. Y.
Clifton, Ariz.
Clyde, N. Y.
Coalville, Utah.
Cœur d'Alene Special, Idaho-Mont.
Corona, Cal.
Cortland, N. Y.
Dahlonega, Ga.-N. C.[1]
Deep Creek, Cal.
Degonia Springs, Ind.
Eagletown, Ind. T.
Edgemont, S. Dak.
Edina, Mo.
Everett, Pa.
Fort McKinney, Wyo.
Geneva, N. Y.
Genoa, N. Y.
Gothenburg, Nebr.
Greeley, Colo.
Grindstone, N. Y.
Gunpowder, Md.
Hammondsport, N. Y.
Hesperia, Cal.
Joplin district, Mo.
Kenova, Ky.-W. Va.-Ohio.
Kinderhook, N. Y.
Llano, Tex.[1]
Luzerne, N. Y.
Marathon, Wis.
Mercersburg, Pa.
Millbrook, N. Y.-Conn.
Mineral Point, Wis.-Ill.
Morenci Special, Ariz.
Morgantown, W. Va.-Pa.
Morrisville, N. Y.
Mount Mitchell, N. C.-Tenn.[1]
Napa, Cal.
Naples, N. Y.
Needle Mountain, Col.
Newburg, N. Y.
North Platte, Nebr.
Norwich, N. Y.
O'Fallon, Mo.
Orono, Me.
Ovid, N. Y.
Owego, N. Y.
Owensboro, Ind.-Ky.
Palmyra, N. Y.
Parkton, Md.-Pa.
Pauls Valley, Ind. T.
Penn Yan, N. Y.
Phelps, N. Y.
Phoenicia, N. Y.
Pittsville, Md.-Del.
Ramona, Cal.
Randsburg, Cal.
Raquette Lake, N. Y.
Redding, Cal.

[1] Resurvey.

Richfield Springs, N. Y.
Rock Creek, Cal.
Rush Springs, Ind. T.-Okla.
Ste. Genevieve, Mo.-Ill.
St. Meinrad, Ind.
San Antonio, Cal.
San Gorgonio, Cal.
Santa Cruz, Cal.
Santa Susana, Cal.
Saratoga, N. Y.
Schunemunk, N. Y.
Siloam Springs, Ind. T.-Ark
Slatington, Pa.
Sodus Bay, N. Y.
Southern California.
Tejon, Cal.
Tell City, Ky.-Ind.
Theresa, N. Y.
Union, Mo.
Velpen, Ind.
Wassau Special, Wis.
Waukon, Iowa-Wis.
Waverly, N. Y.
Wedowee, Ga.-Ala.
Weedsport, N. Y.
Wernersville, Pa.
White Bear, Minn.

The progress in the publication of maps on the scale of 1:125000 by the reduction and combination of those originally published on the scale of 1:62500 is shown in the following table:

Progress in publication of maps on scale 1:125000 by reduction and combination.

Name of sheet, scale 1:125000.	Names of sheets, scale 1:62500, reduced and combined.	Stage of progress in publication.
Holyoke, Mass.-Conn	Chesterfield, Granville, Northampton, Springfield.	Published previous to July, 1898.
Nomini, Md.-Va	Leonardtown, Montross, Piney Point, Wicomico.	Do.
Housatonic, Mass.-Conn.-N. Y.	Becket, Pittsfield, Sandisfield, Sheffield.	Published during fiscal year 1898-99.
Niagara, N. Y	Lockport, Niagara Falls, Olcott, Tonawanda, Wilson.	Do.
Patuxent, Md.-D. C	Brandywine, East Washington, Owensville, Prince Frederick.	Do.
Raritan, N. J	Hackettstown, Highbridge, Lake Hopatcong, Somerville.	Published during fiscal year 1899-1900.
Passaic, N. J.-N. Y	Morristown, Paterson, Plainfield, Staten Island.	Do.
San Luis, Cal	Arroyo Grande, Cayucos, Port Harford, San Luis Obispo.	Do.
Camden, N. J.-Pa.-Del	Chester, Glassboro, Philadelphia, Salem.	Published during fiscal year 1900-01.
Rancocas, N. J	Hammonton, Mount Holly, Mullica, Pemberton.	Do.
Taconic, N. Y.-Mass.-Vt.	Bennington, Greylock, Berlin, Hoosick.	Do.
Navesink, N. J.-N. Y	New Brunswick, Asbury Park, Cassville, Sandy Hook.	In process of engraving.

[1] Resurvey.

Following is a list of 46 atlas sheets, heretofore published, which were revised, corrected, and new editions published during the year or in press at the end of the year:

List of atlas sheets revised, corrected, and approved for new editions, 1900–01.

Asbury Park, N. J.
Atoka, Ind. T.
Bayview, Wis.
Blackstone, Mass.–R. I.
Brandywine, Md.
Buffalo, N. Y.
Canyon, Y. N. P.
Cassville, N. J.
Coalgate, Ind. T.
Denver, Colo.
Drum Point, Md.
Elcajon, Cal.
Elizabethtown, N. Y.
Elkton, Md.
Equinox, Vt.
Escondido, Cal.
Fort Ann, N. Y.
Gallatin, Y. N. P.
Hartville, Wyo.
Housatonic, Mass.–N. Y.–Conn.
Lake, Y. N. P.–Wyo.
Laurel, Md.
Leonardtown, Md.
Los Angeles, Cal.
Milwaukee, Wis.
Montross, Md.–Va.
Muskego, Wis.
Nantucket, Mass.
New Brunswick, N. J.
Niagara Falls, N. Y.
North Point, Md.
Oelrichs, S. Dak.–Nebr.
Owensville, Md.
Oyster Bay, N. Y.–Conn.
Pasadena, Cal.
Pikes Peak, Colo.
Piney Point, Md.–Va.
Point Lookout, Md.
Prince Frederick, Md.
Raleigh, W. Va.
Relay, Md.
Sandy Hook, N. J.
Shoshone, Y. N. P.–Wyo.
Tonawanda, N. Y.
Waukesha, Wis.
Wicomico, Md.

Corrections were also made on the following-named sheets:

Topographic sheets corrected during the fiscal year 1900–01.

Abilene, Tex.
Appomattox, Va.
Austin, Tex.
Beattyville, Ky.
Becket, Mass.
Bennington, Vt.
Birmingham, Ala.
Boothbay, Me.
Briceville, Tenn.
Brooklyn, N. Y.
Burden, Kans.
Cambridge, N. Y.
Cartersville, Ga.
Charleston, W. Va.
Chattanooga, Tenn.
Cheney, Kans.
Cincinnati, Ohio.
Cleveland, Tenn.
Clove, N. Y.
Cohoes, N. Y.
Cordova, Iowa.
Eldorado, Kans.
Farley, Iowa.
Fort Livingston, La.
Fort Smith, Ark.
Goochland, Va.
Grass Valley Special, Cal.
Greylock, Mass.
Hahnville, La.
Harlem, N. Y.
Hempstead, N. Y.
Hinton, W. Va.
Holyoke, Mass.
Independence, Mo.
Joliet, Ill.
Kanawha Falls, W. Va.

Karquines, Cal.
Knoxville, Tenn.
Leadville, Colo.
Lewisburg, Va.
Lynchburg, Va.
Mahanoy, Pa.
Marietta, Ga.
Marshall, Mo.
Marsh Pass, Ariz.
Menominee Special, Mich.
Minneapolis, Minn.
Mount Diablo, Cal.
Mount Trumbull, Ariz.
Newcomb, N. Y.
Nomini, Md.
Norristown, Pa.
Oceanside, Cal.
Olivet, S. Dak.
Ottawa, Ill.
Paradox Lake, N. Y.
Parker, S. Dak.
Paterson, N. J.
Peosta, Iowa.
Philadelphia, Pa.
Plainfield, N. J.
Port Henry, N. Y.
Rapid, S. Dak.
Rhinebeck, N. Y.
Rigolets, La.
Rochester, N. Y.
Rome, Ga.
Rosebud, Mont.
Sandisfield, Mass.-Conn.
San Mateo, Cal.
Santa Monica, Cal.
Seattle, Wash.
Springfield, Mo.
Staten Island, N. Y.
St. Paul, Minn.
St. Xavier, Mont.
Syracuse, N. Y.
Thirteenth Lake, N. Y.
Toulme, La.-Miss.
U. S. Base Map.
West Point, N. Y.

Topographic atlas sheets printed and the number of copies delivered during the fiscal year 1900–01.

Name of sheet.	Copies.	Name of sheet.	Copies.
Abajo, Utah	908	Betterton, Md	2,621
Abbeville, S. C	1,113	Big Snow Mountain, Mont	709
Accident, Md	2,607	Big Timber, Mont	1,070
Addington, Ind. T	2,550	Birmingham, Ala	1,585
Albany, N. Y	2,592	Blackstone, Mass	2,605
Alikchi, Ind. T	2,525	Boothbay, Me	3,261
Anamosa, Iowa	2,601	Buckingham, Va	2,108
Anniston, Ala	2,520	Bucksport, Me	2,571
Arroyo, Colo	878	Buffalo, N. Y	2,558
Asbury Park, N. J	2,551	Calumet, Ill	2,551
Ashley, Utah	1,066	Camas Prairie, Idaho	870
Aspen, Colo	1,039	Canada Lake, N. Y	2,605
Atchison, Kans	1,093	Canadian, Ind. T	2,597
Atlanta, Ga	2,013	Canton, S. Dak	2,545
Atoka, Ind. T	2,589	Canyon, Y. N. P	2,583
Bald Mountain, Wyo	2,607	Canyon City, Colo	904
Baldwinsville, N. Y	2,569	Canyon de Chelly, Ariz	1,075
Barnstable, Mass	2,587	Cartersville, Ga	2,559
Bayview, Wis	2,540	Carthage, Mo	1,079
Berlin, Mass	2,562	Cassville, N. J	2,578

Topographic atlas sheets printed and the number of copies delivered during the fiscal year 1900–01—Continued.

Name of sheet.	Copies.	Name of sheet.	Copies.
Castleton, Vt	2,578	Flintstone, Md	2,612
Cecilton, Md	2,581	Fort Ann, N. Y	2,495
Chappell, Nebr	2,612	Fort Logan, Mont	860
Chelan, Wash	2,580	Fort Payne, Ala	2,624
Chesterfield, Mass	2,606	Fort Scott, Mo	903
Cheyenne Wells, Colo	1,118	Fort Steele, Wyo	1,069
Chicago, Ill	2,660	Gaines, Pa	2,604
Chino, Ariz	1,042	Gallatin, Y. N. P	2,662
Cincinnati, Ohio	3,006	Genesee, Cal	897
Claremore, Ind. T	2,510	Girard, Pa	2,653
Cloud Peak, Wyo	2,550	Glacier Peak, Wash	2,560
Coalgate, Ind. T	2,609	Granada, Colo	1,182
Coldwater, Kans	2,090	Grand Teton, Wyo	2,540
Columbia, Tenn	2,538	Granite Range, Nev	908
Concord, Cal	2,103	Grass Valley Special, Cal	1,007
Coos Bay, Oreg	2,606	Great Falls, Mont	1,095
Corazon, N. Mex	1,069	Greeneville, Tenn	2,062
Cripple Creek, Colo	2,107	Hamilton, Mont	2,612
Cullman, Ala	1,100	Harney Peak, S. Dak	2,570
Danville, Ill	2,105	Hartville, Wyo	2,571
Dayton, Wyo	2,494	Havre de Grace, Md	2,629
Deadwood, S. Dak	2,626	Hermosa, S. Dak	2,548
Delavan, Wis	1,122	Hickory, N. C	2,070
Denver, Colo	2,553	Hillsville, Va	1,084
Desplaines, Ill	2,654	Hoosick, N. Y	2,600
Dryden, N. Y	2,650	Housatonic, Mass	2,529
Dunkirk, N. Y	2,567	Huerfano Park, Colo	1,050
East Columbus, Ohio	2,623	Iola, Kans	1,098
East Tavaputs, Colo	1,091	Jonesville, Ky	1,055
Easton, Pa	2,550	Kansas City, Mo	1,108
Elkland, Pa	2,564	Kingston, Tenn	912
Elkton, Md	2,612	Kinsley, Kans	1,165
Ellensburg, Wash	2,545	Lake, Y. N. P	2,590
Elsinore, Cal	2,595	Lakin, Kans	2,616
Equinox, Vt	2,571	Lamy, N. Mex	1,081
Erie, Pa	2,634	Lancaster, Wis	2,638
Fairview, Pa	2,638	La Sal, Utah	1,060
Fayetteville, Ark	2,591	Lasalle, Ill	1,078
Fernando, Cal	2,643	Las Vegas, N. Mex	1,115
Flatonia, Tex	2,549	Lexington, Va	2,110

Topographic atlas sheets printed and the number of copies delivered during the fiscal year 1900–01—Continued.

Name of sheet.	Copies.	Name of sheet.	Copies.
Little Falls, N. Y	2,637	Okmulgee, Ind. T	2,594
Little Rock, Ark	1,103	Olathe, Mo	914
Los Angeles, Cal	2,613	Old Forge, N. Y	2,500
Macedon, N. Y	2,608	Oriskany, N. Y	2,088
Marshall, Mo	945	Orland, Me	2,570
Marysville, Cal	1,077	Oyster Bay, N. Y	2,569
Masontown, Pa	2,579	Palo Alto, Cal	2,529
Maumee Bay, Ohio	2,587	Paradox Lake, N. Y	2,554
Maurice Cove, N. Y	2,125	Pasadena, Cal	2,524
Maynardville, Tenn	2,661	Pawpaw, Md	2,598
Menominee Special, Mich	2,632	Paxton, Nebr	2,579
Methow, Wash	2,595	Peosta, Iowa	2,606
Milwaukee, Wis	2,523	Pikes Peak, Colo	2,607
Monadnock, N. H	2,587	Pikeville, Tenn	1,102
Montross, Md	542	Pingree, N. C	2,500
Morganton, N. C	265	Pioche, Nev	1,025
Morristown, Pa	2,618	Pittsfield, Mass	2,645
Mound City, Mo	907	Pocahontas, Va	2,080
Mountain Home, Idaho	1,078	Port Henry, N. Y	2,515
Mount Diablo, Cal	2,595	Pryor, Ind. T	2,575
Mount Guyot, Tenn	2,104	Rancocas, N. J	2,607
Mount Hamilton, Cal	2,553	Reading, Pa	2,509
Mount Lyell, Cal	2,535	Reno, Nev	1,093
Muscogee, Ind. T	2,611	Riverside, Cal	2,566
Muskego, Wis	2,607	Riverside, Ill	2,636
Nantahala, N. C	285	Roanoke, Va	2,121
Nantucket, Mass	2,495	Romney, W. Va	834
New Brunswick, N. J	2,586	St. Croix Dalles, Wis	5,172
New York and vicinity	5,725	St. George, W. Va	1,095
Newcastle, Wyo	2,522	Sallisaw, Ind. T	2,625
Niagara Falls, N. Y	2,551	Salt Lake, Utah	1,624
Nicholas, W. Va	2,639	San Francisco, Cal	2,605
Nomini, Md	2,063	San Francisco Mountain, Ariz	1,116
North Creek, N. Y	2,118	Sandisfield, Conn	2,602
Nowata, Ind. T	2,570	Sandpoint, Idaho	2,595
Oak Harbor, Ohio	2,513	Sandy Hook, N. J	2,500
Oakland, Md	2,505	Sansbois, Ind. T	2,633
Oceanside, Cal	2,589	Santa Fe, N. Mex	1,082
Oelrichs, S. Dak	2,614	Schenectady, N. Y	2,065
Ogalalla, Nebr	2,675	Schoharie, N. Y	2,570

Topographic atlas sheets printed and the number of copies delivered during the fiscal year 1900-01—Continued.

Name of sheet.	Copies.	Name of sheet.	Copies.
Schroon Lake, N. Y	2,082	Tujunga, Cal	2,649
Schuylerville, N. Y	2,523	Tuscumbia, Mo	2,120
Sea Isle, N. Y	2,135	Tuskahoma, Ind. T	2,580
Sewanee, Tenn	1,113	Two Buttes, Colo	584
Shickshinny, Pa	2,089	Uniontown, Pa	2,622
Silverton, Colo	295	Utica, N. Y	2,631
Smartsville, Cal	1,085	Versailles, Mo	2,095
Spokane, Wash	2,585	Vinita, Ind. T	2,522
Stamford, N. Y	2,595	Wadsworth, Nev	1,088
Staunton, Va	2,121	Walhalla, Ga	890
Stonewall, Ind. T	2,560	Warrenton, Va	2,100
Stony Island, N. Y	2,126	Waterville, Me	2,534
Sutton, W. Va	2,124	Watkins, N. Y	2,500
Suwanee, Ga	1,125	Watrous, N. Mex	1,495
Syracuse, Kans	2,616	Waukesha, Wis	2,571
Taconic, N. Y	2,486	Weiser, Idaho	1,085
Tahlequah, Ind. T	2,538	West Columbus, Ohio	2,626
Talladega, Ala	1,106	Wewoka, Ind. T	2,601
Tamalpais, Cal	2,090	Whitefield, N. H	2,600
Taylorsville, Cal	1,099	Whitehall, N. Y	885
Tishomingo, Ind. T	2,580	Whitesburg, Ky	2,979
Toledo, Ohio	2,556	Whitings, N. J	2,072
Toleston, Md	2,675	Wilson, N. Y	2,574
Tonawanda, N. Y	2,513	Windingstair, Ind. T	2,610
Tooele Valley, Utah	1,586	Yellville, Ark	1,114
Troy, N. Y	2,073	Total	534,366
Tuckahoe, N. J	1,094		

Folios completed and delivered during the year 1900-01.

Name of folio.	Copies.	Name of folio.	Copies.
Charleston, S. C	5,000	Tintic, Utah	5,971
Colfax, Cal	5,233	Uvalde, Tex	5,087
Danville, Ill	5,093	Walsenburg, Colo	5,059
Huntington, W. Va	5,248	Washington, D. C	6,000
La Plata, Colo	5,000	Topographic folio No. 3	5,108
Monterey, Va	5,178	Total	68,989
Mother Lode District, Cal	6,012		
Spanish Peaks, Colo	5,000		

Geologic folios in hand June 30, 1901.

Atoka, Ind. T.	Housatonic, Mass.
Brooklyn, N. Y.	Maynardville, Tenn.
Coalgate, Ind. T.	Paterson, N. J.
Coos Bay, Oreg.	Raleigh, N. C.
Harlem, N. Y.	Staten Island, N. Y.

Miscellaneous maps, circulars, etc., printed and delivered during 1900–01.

	Copies.
Niagara River and vicinity	31,000
United States oil and gas map	3,258
Map circulars	62,622
Circular letters	14,058
Blank forms	11,199
Photolithographs on map paper	6,020
Photolithographs on drawing paper	269
Photolithographs on celluloid	95
Coal-production diagram	3,038
Nome, Alaska	1,034
Discharge diagram	528
Signal flags	500
Alaska map	150
Labels	23
Total	133,794

Totals derived from the foregoing tables.

Engraving of atlas sheets:	
Sheets finished	87
Sheets partly finished	16
Sheets corrected	120
Sheets printed	257
Engraving of folios:	
Folios in hand	11
Folios completed	13
Delivered:	Copies.
Atlas sheets	533,665
Geologic folios	63,988
Miscellaneous	131,794
Grand total, all material delivered	729,447

Increase in output over last fiscal year.

	Copies.
Atlas sheets	216,183
Geologic folios	8,249
Miscellaneous sheets	39,733
Total	264,165

INSTRUMENT SHOP.

The shop was in general charge of Mr. S. J. Kübel, and the direct work of repairing instruments and of copperplate making and electrotyping was in charge of Mr. Ernest Kübel, mechanician, assisted by two laborers, Henry Matthews and Henry Colbert. Besides the supervision of the more intricate details of plate making and electrotyping, the mechanician's work especially consisted of overhauling and repairing, for field use, all surveying instruments sent from the Topographic Branch. Repairs were made as follows:

Telescopic alidades	74
Wye (Y) levels	33
Transits	1
Gradienters	2
Box compasses	14
Drafting compasses and pens	12
Hand levels	2
Circular levels	6
Steel tape lines	12
Plane-table boards fitted	75
Sight alidades, 6–6″, 3–7″, 8–10″, 1–12″	18
Shoes fitted on tripod legs	208
Striding levels	12
Plane-table board plates	35
Clinometer compasses	3
Odometers	2
Level tripods	31
Traveling tripods	41
Johnson movement tripods	89
Theodolite tripods	9

The construction of a current meter, repairs to others, and certain work for the Photographic Laboratory and the Engraving Division also occupied much of the mechanician's time.

Following is a summary of the copperplate making and electrotyping:

Number of new plates made	200
Number of plates resurfaced	76
Number of electrotype bassos made	30

ADMINISTRATIVE BRANCH.

Division of Disbursements and Accounts.

This division remained in charge of Mr. John D. McChesney, chief disbursing clerk, throughout the year. The high degree of efficiency mentioned in the Director's last report was maintained. A summarized statement of disbursements follows, and a detailed statement is preserved in the office.

Financial Statement.

Amounts appropriated for and expended by the United States Geological Survey for the fiscal year ending June 30, 1901.

	Geological Survey, 1901.	Geological Survey, 1900 and 1901.	Salaries, office of Geological Survey, 1901.	Geological maps of the United States, 1901.	Surveying forest reserves.	Furnishing new addition to Hooe Building, Geological Survey, 1901.	Total.
Balance available from preceding year					$25,620.42		
Appropriations: Acts approved Apr. 17, 1900; June 6, 1900; Mar. 3, 1901, and from other sources	$245,720.00	*a* $415,000.00	$31,390.00	$80,170.00	130,000.00	$12,000.00	$939,900.42
Amounts expended, classified as follows:							
A. Services	160,094.80	242,012.81	31,291.93	57,275.10	94,635.26		585,309.90
B. Traveling expenses	9,622.81	28,371.35		22.10	7,737.99		45,754.25
C. Transportation of property	492.83	4,244.08		5.64	1,534.82		6,277.37
D. Field subsistence	10,272.38	38,497.69			13,436.67		62,206.74
E. Field supplies and expenses	9,980.40	38,452.36			18,862.73		67,295.49
F. Field material	3,850.70	14,598.27			3,376.63		21,825.60
G. Instruments	1,327.80	7,748.90			258.02		9,334.72
H. Laboratory material	1,585.68	4,513.35					6,099.03
I. Photographic material	3,039.30	2,589.84			244.78		5,873.92
K. Books and maps	2,842.21	534.15			137.00		3,513.36
L. Stationery and drawing material	622.18	1,878.73			475.10		2,976.01
M. Illustrations for reports	566.65						566.65
N. Office rent	10,879.80						10,879.80
O. Office furniture	872.00	776.15			205.40	727.10	2,580.65
P. Office supplies and repairs	1,208.62	1,687.86			114.05		3,010.53
Q. Storage	53.10	416.96			191.34		661.40
R. Correspondence	98.27	111.25		.40	142.07		351.99
S. Materials for engraving and printing maps				20,603.54			20,603.54
T. Railroad accounts settled at United States Treasury:							
Passenger	457.26	1,028.30			1,077.26		2,562.82
Freight	78.36	1,053.25			1,112.05		2,243.66
Total expenditures	217,945.15	388,515.30	31,291.93	77,906.78	143,541.17	727.10	859,927.43
Balance unexpended July 1, 1901	27,774.85	26,484.70	98.07	2,263.22	12,079.25	11,272.90	79,972.99
Probable amount required to meet outstanding liabilities	27,774.85	26,484.70		2,263.22	12,079.25	11,272.90	79,874.92

a $35,000 coal and gold resources of Alaska, act of Feb. 9, 1900, was accounted for in statement of last fiscal year.

Analysis of disbursements.

Opposite the following heads appear the total expenditures under the various appropriations:

1. Salaries, Office of Geological Survey	$31,291.93
2. Salaries of scientific assistants	29,487.95
3. Skilled laborers and various temporary employees	12,993.66
4. Topography	235,394.43
5. Geology	136,126.73
6. Paleontology	7,308.79
7. Chemical and physical researches	9,342.68
8. Preparation of illustrations	13,472.65
9. Mineral resources of the United States	37,087.91
10. Books for library, etc	2,842.21
11. Gauging streams, etc	94,529.50
12. Rent of office rooms, Washington, D. C	10,879.80
13. Mineral resources of Alaska	16,994.14
14. Engraving and printing geological maps of the United States	77,906.78
15. Surveying forest reserves	143,541.17
16. Furnishing new addition to Hooe Building, Geological Survey	727.10
	859,927.43

The Library.

The library of the Survey was continued under the charge of Mr. Charles C. Darwin, who was assisted by Miss Julia L. McCord, Miss M. E. Latimer, and Mr. Thomas K. Gallaher.

The following tabulated statement shows the receipts during the year and the contents of the library on June 30, 1901:

CONTENTS OF THE LIBRARY JUNE 30, 1901.

BOOKS.

On hand June 30, 1900:			
Received by exchange	33,314		
Received by purchase	12,716		
		46,030	
Received during the past year:			
By exchange	1,257		
By purchase	421		
		1,678	
			47,708

PAMPHLETS.

On hand June 30, 1900:			
Received by exchange	60,279		
Received by purchase	14,448		
		74,727	
Received during the past year:			
By exchange	2,000		
By purchase	300		
		2,300	
			77,027

MAPS.

On hand June 30, 1900	28,935	
Received during the year	250	
		29,185
Total		153,920

Division of Documents.

This division remained in charge of Dr. W. D. Wirt.

The publications received were: Twentieth Annual Report, Parts II, V (with atlas), and VII, and separates from same; Twenty-first Annual Report, Parts I, II, and VI, and separates from same; Monographs XXXIX and XL; Bulletins Nos. 164 to 176, inclusive; Water-Supply and Irrigation Papers Nos. 34 to 44, inclusive; Geologic Folios Nos. 59 to 71, inclusive; Topographic Folio No. 3; and 254 atlas sheets, the combined editions of which number 538,653 sheets.

During the year 138,631 volumes, 42,936 folios, and 327,603 maps were sent out.

The proceeds from the sale of publications amounted to $7,347.18, of which $4,764.78 was received for maps.

Miscellaneous Division.

Until the 1st of May the correspondence and records remained under the immediate charge of Dr. W. F. Morsell, with one assistant, Mrs. E. V. M. Clarke. Up to that time the old record system was in force, and notwithstanding the many difficulties attending its application to the increased volume of business consequent on the growth of the Survey, an amount of work larger in volume and more exacting in character than that of any previous twelve months in the history of the Survey was disposed of. On May 1 a new plan of recording and handling the general correspondence, etc., of the Survey was put into effect. This change involved a reorganization of the correspondence and records section into a miscellaneous division, including an increase of force and the introduction of the vertical letter-filing system. Mr. A. F. Dunnington was detailed to take charge, under the supervision of the chief clerk, Col. H. C. Rizer, with Miss Marian Thorwarth and Mr. Joseph C. Gawler as assistants; Dr. Morsell as appointment and correspondence clerk; Mr. J. E. Allen, property clerk; Mr. A. B. Anderson, registered mail, express, and freight clerk; Mr. L. G. Freeman, stationery clerk; and Messrs. J. P. Hendley, R. M. Hart, and A. C. Cosden, assistants. Mrs. Clarke remained in charge of the old records.

The records of the ten months before Mr. Dunnington took charge show that there were received, briefed, recorded, referred, etc., 4,761 letters, while the estimated number of letters sent is 4,800. The business of the appointment and attendance desk included a large amount of correspondence. During the two months of May and June there were received, recorded, and referred 3,390 letters, while the estimated number sent is 3,500, making for the whole year a total of 8,151 letters received and 8,300 (estimated) sent. During the months of May and June there were shipped and received by express and freight 497 pieces.

There were made during the year appointments to the number of 102; extensions and other reappointments, 81; promotions, 124; separations (expirations of limited appointments not included), 24, 4 of which were by death; reductions, 1; total changes in personnel, exclusive of a large number of expirations of limited appointments, 332, as against 283 during the year 1899–1900 and 188 in 1898–99. The ratio of increase during the ensuing year promises to be still greater.

THE ASPHALT AND BITUMINOUS ROCK DEPOSITS OF THE UNITED STATES

BY

GEORGE H. ELDRIDGE

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THE ASPHALT AND BITUMINOUS ROCK DEPOSITS OF THE UNITED STATES.

By George H. Eldridge.

INTRODUCTION.

In presenting the following account of the asphalt and bituminous rock deposits of the United States, the desire has been to afford a general conception of the nature of the materials discussed, their mode of occurrence, and the stratigraphy and structure of the attendant geology. The information presented is, in the main, the outcome of the writer's personal investigation of the deposits, but wherever the results of others have been deemed advantageous to a clearer conception of the subject they have been freely incorporated in the text. In the same way the maps prepared by others have also been employed. Especially, however, does the writer wish to acknowledge his indebtedness to Prof. I. C. White, of West Virginia; Mr. S. D. Averitt, of the State Agricultural College of Kentucky; Judge John E. Stone, of Leitchfield, Ky.; Mr. C. O. Baxter, of St. Louis, Mo.; Col. James F. Randlett, U. S. A., at the time of the investigation in command of Fort Duchesne, Utah; Prof. A. S. Cooper, State mineralogist of California; Mr. H. W. Fairbanks, of the University of California; Mr. W. E. Dennison, of San Francisco, Cal., and to A. W. Dow, inspector of asphalts for the District of Columbia, to whom the greater part of the samples collected by the writer were submitted for analysis. The value of the results of the investigation has been enhanced also by the interest which the managers of the various properties have taken in the investigation, and it is a pleasure to acknowledge their uniform courtesy.

This report is a general and comparative review of the deposits of asphalt and bituminous rock in the United States. There will be no attempt to discuss the many varieties of material from a chemical standpoint, nor their merits for paving and other uses; these fall within the province of the chemist and technical expert. In the course of the discussion, however, numerous references to such points will be found.

The following classification of hydrocarbons and allied substances has been adopted.[1]

[1] In the main the classification is that of Prof. W. P. Blake in an article entitled Uintaite, albertite, grahamite, and asphaltum, described and compared, with observations on bitumen and its compounds: Trans. Am. Inst. Min. Eng., Vol. XVIII, p. 563 et seq.

CLASSIFICATION OF HYDROCARBONS AND ALLIED SUBSTANCES.

TABLE I.—*Classification of natural hydrocarbons.*

Hydrocarbons.	Gaseous			Marsh gas. "Natural gas."
	Bituminous	Fluid		Naphtha. Petroleum.
		Viscous (malthite)		Maltha. Mineral tar. Brea. Chapapote.
		Elastic		Elaterite (mineral caoutchouc). Wurtzilite.[1]
		Solid	Asphaltite	Albertite. Impsonite. Grahamite. Nigrite. Uintaite (gilsonite).
			Coal	Lignite. Bituminous coal. Semibituminous coal. Anthracite coal.
	Resinous			Succinite (amber). Copalite. Ambrite, etc.
	Cereous			Ozocerite. Hatchettite, etc.
	Crystalline			Fichtelite. Hartite, etc.

TABLE II.—*Classification, or grouping, of natural and artificial bituminous compounds.*[2]

Bituminous compounds.	Natural.	Mixed with limestone ("asphaltic limestone").	Seyssel, Val de Travers, Lobsan, Illinois, Utah, and other localities.
		Mixed with silica and sand ("asphaltic sand").	California, Kentucky, Utah, and other localities. "Bituminous silica."
		Mixed with earthy matter ("asphaltic earth").	Trinidad, Cuba, California, Utah.
		Bituminous schists	Canada, California, Kentucky, Virginia, and other localities.
		Fluid	Thick oils from the distillation of petroleum. "Residuum."
	Artificial.	Viscous	Gas tar. Pitch.
		Solid	Refined Trinidad asphaltic earth. Mastic of asphaltite. Gritted asphaltic mastic. Paving compounds.

[1] Wurtzilite might, perhaps, better be classed with the asphaltites.

A mere glance at the above tables will convince one of the impossibility of establishing hard and fast lines between the substances enumerated. The classification, however, with its few modifications of the original, seems to the writer to be the most satisfactory of the several attempts met with in a review of the literature of the subject.

It will be observed that there has been omitted from the table one of the commonest terms in daily use, "asphalt" or "asphaltum." By many disinterested authorities this word is restricted to the solid forms of the purer bitumens, forms including those grouped by Professor Blake under the general derivative, asphaltite. This usage is reasonable, and by adhering to it confusion will be avoided in both science and trade. Industrially, however, the word asphalt is unfortunately made to include almost every compound of bitumen with a foreign material, chief among the latter being sand and limestone.

Mr. Clifford Richardson, in his Nature and Origin of Asphalt, a contribution (October, 1898) from the laboratory of the Barber Asphalt Paving Company, gives the following definition of asphalt:

> The natural bitumen, which is known as asphalt, is composed, as far as we have been able to learn, of saturated and unsaturated dicyclic, polycyclic, or alicyclic hydrocarbons and their sulphur derivatives, with a small amount of nitrogenous constituents. Asphalt may, therefore, be defined as any hard bitumen, composed of such hydrocarbons and their derivatives, which melts on the application of heat to a viscous liquid; while a maltha or soft asphalt may be defined as a soft bitumen, consisting of alicyclic hydrocarbons, which, on heating or by other natural causes, becomes converted into asphalt. The line between the two classes can not be sharply drawn.

"Bitumen," also, is a term that has been omitted from the table, although its adjective, "bituminous," is employed. The word "bitumen," the original derivation of which the writer has been unable to discover, has in the main been used through ages past to include the three varieties of hydrocarbon compounds known as petroleum, maltha, or mineral tar, and the solid substances included under the asphaltites, and often designated, one or another of them, asphalt. The adjective "bituminous" will frequently be applied throughout this report to a sandstone or other rock impregnated with bitumen, as thus understood; and if such bitumen is asphaltic, that is, has any of the characteristics of the so-called asphalts, the compound may receive the name "asphaltic sandstone," "asphaltic limestone," etc.

The changes which, on careful reflection, the writer has deemed it desirable to make in the classification of Professor Blake are: (1) To remove the two gaseous products from the bituminous bracket to a group by themselves—this notwithstanding their intimate relation to the higher liquids of the series, the naphthas and petroleums; (2) to add two new asphaltites, impsonite and nigrite, and (3) to place in the coals lignite, which was altogether omitted from the Blake table.

In view of the criticism regarding the classification presented herewith that will doubtless be made, the writer begs to remark that at the best it can be but tentative, for knowledge of the hydrocarbons is yet meager when compared with the possibilities that are suggested to those engaged in their investigation. Moreover, the list itself will require revision, as from time to time new compounds are found that differ from others already known sufficiently to warrant distinguishing specific names. For a geological discussion of these occurences, however, the present classification will, it is believed, suffice.

Of the substances embraced within the foregoing tables the present report has to do only with the following: The viscous, elastic, and cereous hydrocarbons; the asphaltites; and the natural bituminous compounds, designated asphaltic limestones, sandstones, earths, and schists or shales. Petroleum enters into the discussions incidentally, but to describe its occurrence is not a part of the purpose. The remaining products of the table are either without important representation in the United States or their consideration would be irrelevant to the subject of the report.

GENERAL FEATURES OF THE HYDROCARBONS.

The relations, chemical or other, between the hydrocarbons of Table I, were they worked out, would doubtless show the utmost complexity, for complexity exists even in the substances themselves, nearly all of which are separable by the action of solvents or by fractional distillation into two or more components that are in turn divisible into series of hydrocarbons in many instances of great extent. No attempt will be made, however, to bring together even the more important results of analytical study, the writer contenting himself with the following general statements, based upon those found in Dana's System of Mineralogy, edition of 1892, upon the writings of Blake, Wurtz, Peckham, Day, Dawson, Hitchcock, and others, and upon his own observations.

In Dana hatchettite and ozocerite are found among the simple hydrocarbons as members of the paraffin series C_nH_{2n+2}, while fichtelite, hartite, and a number of others occur in this division of the hydrocarbons, but of series other than the paraffin, and in many instances altogether of doubtful reference.

The resinous compounds belong to the class of oxygenated hydrocarbons, the membership in which is very extended and of great variety. Concerning this class, Dana remarks that it embraces "chiefly the numerous kinds of native fossil resins, many of which are included under the generic term 'amber;' also other more or less closely related substances. In general, in these compounds, weak acids (succinic acid, formic acid, butyric acid, cinnamic acid, etc.), or acid anhydrides, are prominent."

Between the coals—especially the bituminous and cannel varieties—and the resinous and asphaltite divisions of this table, relations are readily found; indeed, for a number of years, only two or three decades

TABLE III.—*Resemblances and differences between the asphaltites, with asphaltum, wurtzilite, and ozocerite added for comparison.*[1]

[The portion in italics is taken from Dana's System of Mineralogy, sixth edition.]

Substance.	Structure.	Fracture.	Color.	Luster.	Hardness.	Specific gravity.	Fusibility.
Asphaltum (mineral pitch).			*Brown or brownish black*	*Like black pitch*		*1 to 1.8*	*Melts at 90° to 100°*
Albertite[2] (name from the Albert mine, New Brunswick).	Prismatic at right angles to walls.	Conchoidal; brittle.	*Jet black.* Black; streak black; powder black to faint brown.	*Brilliant; pitch-like*	*1 to 2* 3	*1.097* 1.08 to 1.11 Jackson and Hayes.	*Incipient in candle flame; softens in boiling water.* In spirit flame intumesces and emits gas, but does not melt like asphalt. Melts in closed tube. Adheres to paper.
Impsonite[3] (name from the Impson Valley, Ind. T.).	Crushed	Hackly; brittle	Jet black	Bright		1.175	Does not melt, but softens and decomposes simultaneously, like coal; this in a retort. In tube softens but does not melt; cokes. *Does not soften in boiling water.* In candle flame shows incipient fusion and takes fire, burning for a short time after removing from flame.
Grahamite[4] (name from the Messrs. Graham, miners).	For 2 or 3 inches from walls, coarsely granular, with cuboidal cleavage; then 15 inches of columnar structure on either side, columns at right angles to walls; then 18 inches in center, compact and massive.	Conchoidal; brittle.	*Pitch black.* Black, but streak and powder dark chocolate brown.	*Brilliant.* Brilliant; center less so than the two other portions of vein.	*2*	*1.145* 1.145	*Melts imperfectly with decomposition of surface, but in this state interior may be drawn into threads.* Heated above 400° F. it softens. Endures a temperature far above the fusing point of asphalts in general. Behaves much like coking coal.
Nigrite[5] (name from niger, black).	Cuboidal to massive	Conchoidal to cuboidal.	Jet black; streak same	Brilliant			Less fusible than uintaite. Melts only on liberal fluxing with oil or gum.
Uintaite[6] (gilsonite, trade name, after S. H. Gilson, an early prospector; name from the Uinta Mountains, Utah).	Cuboidal and penicillate for 6 inches next to walls; balance compact and massive.	Conchoidal; brittle.	*Black; streak and powder brown.* Black, but powder and streak brown, with shade of red; streak lighter than that of albertite.	*Brilliant—which is retained after melting.* Brilliant.	*2 to 2.5* 2 to 2.5	*1.065 to 1.070* 1.065 to 1.070	*Easily fusible in candle flame; burns and acts like sealing wax, leaving sharp impression.* Readily fusible in candle flame; apparently unchanged by successive melting and cooling.
Wurtzilite[7] (name from Dr. Wurtz).	Massive, compact	Conchoidal; sectile and elastic. Shavings bent too far snap like glass.	Jet black by reflected light. In thin plates deep red.	Brilliant	2 to 3	1.0227	Nonfusible in boiling water, but softens, toughens, and becomes more elastic. In candle flame softens and melts, takes fire and burns with bright flame.
Ozocerite (name from ὄζειν, to smell, and κηρός, wax).	Massive, compact, homogeneous.	Waxy	Jet black in United States. White, yellow, brown, and green in other countries.	Dead oily black	1	***0.85–95***	Fuses at 56° to 63° C

Solubility in—

Substance.	Heavy oils and fats, lubricating petroleum.	Light oils.	Benzine.	Naphtha.	Turpentine.	CS_2.	Alcohol.	Ether.	Chloroform.	Acids.	Alkalies.	Remarks.
Asphaltum (mineral pitch).					*Mostly or wholly*		*Partly*	*Partly or wholly.*				
Albertite[2]					*30 per cent*		*Trace*	*4 per cent*				Becomes electrified when rubbed. Composition close to jet.
Impsonite[3]					Almost insoluble	35 per cent +	Trace	5.34 per cent				
Grahamite[4]			*Partly.* Partly.	*Partly.* Partly.	*Mostly.* Swells and nearly all dissolves.	*Wholly.* Readily soluble except ash.	*Not at all.* Completely insoluble.	*Partly.* Partly.	*Wholly.* Readily soluble except ash.	Colored brown by strong sulphuric acid.	Not acted upon.	*Jenney has manufactured grahamite from petroleum.*
Nigrite[5]	Soluble if reduced to powder, especially if to oil be added resin, and the whole heated.											Solubility in reagents has not been investigated.
Uintaite[6]	*Readily soluble.* Readily soluble.	*Less so.*			*Freely in hot; less in cold.* Readily when aided by heat.	Entirely (Day)	*Soluble.* Not readily, but by repeated treatment up to 54.6 per cent.	*Slowly when in powder.* Not wholly.	Partially			*A nonconductor. Electrically excited by friction.* Electrically excited by friction. Soluble also in melted wax, ozocerite, spermaceti, stearin, etc. (Blake); also (Day) in petroleum ether and glacial acetic acid. Composition close to torbanite.
Wurtzilite[7]								4.17 per cent in ethyl oxide.		Partially in hot HNO_3.		Negative electricity developed by friction. Resists the usual solvents of bitumen.
Ozocerite		Soluble[7]	Wholly?	Wholly?	Soluble[8]		Somewhat in boiling alcohol. 3 per cent.[8]	Some varieties wholly soluble.	Soluble[8]			The solubilities are more with reference to foreign varieties. Negatively electrified when rubbed.[8]

[1] All these materials occur in vein form; asphaltum occurs also in superficial deposits.
[2] Dawson.
[3] Eldridge as to occurrence.
Day as to properties—solubility, etc.
[4] Wurtz.
[5] Occurrence described by Mr. C. A. Peterson, St. Louis.
[6] Eldridge as to occurrence.
Blake and Day as to properties—fusibility, solubility, and specific gravity.
[7] Eldridge as to occurrence; Blake as to properties.
[8] Redwood.

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ago, grahamite, on account of its composition, was regarded by men high in authority as a true coal, notwithstanding its wholly different mode of occurrence. A discussion of the coals will not be entered upon in the present report.

Albertite, grahamite, uintaite, etc., are now accepted as closely related varieties of asphaltum. This relationship is evident both in their chemical composition and in their mode of occurrence, yet they are readily distinguished by their behavior toward solvents, by the action of heat upon them—their fusibility, so called—and by other properties. The accompanying table of resemblances and differences (Table III) has been prepared from the authorities above referred to.

Wurtzilite, in outward appearance, bears a striking resemblance to the asphaltites, but is distinguished from them by its behavior toward solvents and by its marked sectile and elastic properties. Yet, while uintaite itself is exceedingly brittle, one of its leading features, developed in the manufacture of black japans and varnishes made from it, is this very property of elasticity, attainable in such perfection in no other hydrocarbon compound except elaterite and wurtzilite.

Elaterite, though elastic, is quite distinct from wurtzilite. Dana, in remarking upon the results attained by the authorities which he consulted, states that this substance "appears to be partly a carbohydrogen near ozocerite and partly an oxygenated insoluble material."

The viscous bitumens of the table vary markedly in consistency. Maltha has the greatest fluidity, brea and chapapote the least—these are, in fact, solids. Each member of the group shades into the next on either side, even maltha into petroleum and chapapote into the asphaltites. From this it will be inferred that the application of the several terms is decidedly indefinite. In regard to brea and chapapote, usage seems to make them synonymous, unless it be that the solidity of chapapote is a degree greater than that of brea, by no means an assured distinction.

The viscous compounds stand between the solid asphaltites on the one hand and petroleum on the other. "The fluid kinds," observes Dana, "change into the solid by the loss of volatile matter by a process of oxidation which is said to consist first in the loss of hydrogen and finally in the oxygenation of a portion of the mass."

Richardson, in his Nature and Origin of Asphalt, observes:

> Asphalts are distinguished by the large amount of sulphur they contain, and it is to its presence that many of the important characteristics, and perhaps, in part, the origin of this form of bitumen, is due. The soft asphalts or malthas contain much less sulphur than the harder ones, or if the former are rich in sulphur they are then in a transition stage and will eventually become hard. But a small portion of the constituents of a hard asphalt are volatile even in vacuo, but they can be separated by solvents into an oily portion, which is soft or softens readily when heated, and a harder portion, which does not melt by itself without decomposition, and is a brittle solid, but soluble in the oily or softer portions. The harder and least soluble portion always contains the larger part of the sulphur. It seems, therefore, that sulphur is the effectual hardening agent of [many] natural asphalts, in the same way that it is of artificial asphalts which are produced by heating a soft natural bitumen with sulphur.

But Mr. Richardson adds that "some natural bitumens occur which have become hardened in another way and perhaps by oxygen." This refers particularly to the asphaltites.

Boussingault's[1] investigation, in 1837, into the composition of asphalt also developed some results of especial interest. He took for his experiments the viscid bitumen of Pechelbronn, France. At a temperature of 230° C., in an oil bath, he separated an oily liquid, to which he gave the name "pétrolène," regarding it as the liquid constituent of bitumen, which, mingled in varying quantities with a solid substance, "asphaltène," forms the bitumens of different degrees of fluidity. He describes asphaltene as brilliant black in color and luster, with a conchoidal fracture, and heavier than water. Toward a temperature of 300° C. it becomes soft and elastic. It begins to decompose before it melts, and burns like the resins, leaving an abundance of coke.[2]

Dana, in his System of Mineralogy, quotes several analyses of petrolene by Boussingault, one of which gives C. 87.45, H. 12.30.

COMPARATIVE ANALYSES AND BITUMEN DETERMINATIONS OF THE MATERIALS DISCUSSED.

The determinations tabulated below are such as have been available to the writer, and are either from the laboratory of the United States Geological Survey or from reports examined in a review of the general literature of the subject. It is evident that all have been made for special purposes, and hence their tabulation presents a heterogeneous assemblage of figures. Notwithstanding this, they afford an idea of some of the features of the materials to be discussed.

In the selection of analyses for the tables an effort has been made to present average types of materials. To anyone at all familiar with the subject, the wide variations from the figures given are well known, and by such the determinations will be considered as indicative of the nature of the materials rather than as representative of their economic value.

Following is the statement of Mr. A. W. Dow, the analyst, regarding the character of the bitumens, and also a more detailed description of the mineral residues in and from the samples of asphalt, numbered 12 to 93, in Table IV:

The figures given as the penetration of the bitumens are the District of Columbia standard—that is, the distance a No. 2 sewing needle will penetrate into the sample, stated in hundredths of a centimeter, under a weight of 100 grams, in five seconds, and at a temperature of 77° F. To designate the size of the sand grains the word "mesh" is made use of. This refers to the number of meshes per linear inch in the sieve that will just retain the sand grains. As an illustration: An 80-mesh sand is one that will all pass a 70-mesh per linear inch sieve, but will be retained on an 80-mesh per linear inch sieve.

Sample No. 12.—Bitumen a very thick asphaltic oil or maltha. Mineral residue

[1] Annales Chim. et Phys. (II), Vol. LXIV, pp. 141–151.

[2] Quoted from Blake, Trans. Am. Inst. Min. Eng., Vol. XVIII, p. 566.

TABLE IV.—*Bitumen determinations, etc., of the materials discussed in the present report.*

Kind of rock.	Localities and materials.	Water.	Ash.	Sulphur.	Vol. bit.	F. C.	Bit. sol. in CS_2.	Res. from CS_2 F. C.	Bit. sol. in alcohol.	Bit. sol. in ether.	Bit. sol. in chloroform.	Bit. sol. in naphtha.	Insol. in petroleum.	Org. mat. not sol. in CS_2, or nonbit.	Asphalt (bitumen).	Sand, limestone, clay.	C.	H.	N.	O.	Petrolene.	Asphaltene.	Residue.	Authorities.
Asphaltites and asphalts.	Trinidad:																							
	Crude lake pitch	28.50	25.40				39.10							6.90										Richardson. Nature and Origin of Asphalt. Laboratory Barber Asphalt Co. 1898.
	Lake boring, 135 feet; dried		35.90				54.66					31.53		9.44										Do.
	Land; dried		36.40				52.36					29.02		11.24										Do.
	Land bitumen			5.10													83.68	10.84	0.45					Do.
	Lake bitumen			6.16													82.33	10.69	.81					Do.
	Bermudez:																							
	Refined. Water from crude, 11.68		1.03									72.61		2.79	96.18									Do.
	Bitumen			5.87													82.88	10.79	.75					Do.
	Cuban:																							
	Soft	.13	19.51	8.35	64.03	7.98	87.84	12.16																Petroleum and its Products, Redwood. Vol. I, p. 218.
	Hard	.11	16.60	8.92	8.34	66.03	7.74	72.26																Do.
	Asphalto, Cal.:																							
	Crude		9.57				85.49			69.98														G. Q. Simmons, analyst. Quoted in Bull. 3, Cal. State Mining Bureau, 1893, p. 52. From Standard Asphalt Company's mines; manager reports average bitumen=75 per cent.
	Refined		9.77				90.16			86.45														Do.
	Crude, 93						31.15									68.85							Sandy shale: some bituminous organic matter.	A. W. Dow, inspector asphalts, D. C., analyst for U. S. Geological Survey.
	Ventura; Cañon del Diablo, Cal.: asphaltum	2.56	76.28		14.78	6.38									21.16									E. W. Hilgard in 10th Ann. Rept. Cal. State Mining Bureau, 1890, p. 766.
	Punta Gorda, Cal.: asphaltum	.71	69.38		18.72	11.19									29.91									G. E. Colby, analyst. Quoted Bull. 11, Cal. State Mining Bureau. P. 50. 1896.
	La Patera mine, Cal.: asphaltum		43.30				55.10					31.60		1.60										Richardson. Relative Merits of Asphalt. Laboratory Barber Asphalt Paving Co. 1897.
	Waldorf mine, Cal.: crude asphaltum	1.80	22.00	.60							76.20			Tr.							64.15	35.85		F. Salathé, analyst. 13th Ann. Rept. Cal. State Mining Bureau, 1896, p. 40.
	La Graciosa Hills, Santa Maria district, 76						41.74									58.26							Sandy shale and clay: greenish; some bit. org. matter.	A. W. Dow, inspector asphalts, D. C., analyst for U. S. Geological Survey.
	La Graciosa Hills, Santa Maria district, Cal., 77						29.15									70.85							do	Do.
	Ozocerite, Utah			0					Sol.								85.25	15.09	0					Richardson. Nature and Origin of Asphalt. Laboratory Barber Asphalt Paving Co. 1898.
	Wurtzilite, Utah			5.83													80.00	12.23	1.78					Do.
	Uintaite (gilsonite), Utah			1.79													89.28	8.66	.79					Do.
	Uintaite (gilsonite), Utah		.10	1.32	56.46	43.43											88.30	9.96	O+N.32					Wm. C. Day. Jour. Franklin Inst., Vol. CXL, No. 837, September, 1895.
	Albertite, Nova Scotia		.10	Tr.													86.04	8.96	2.93	1.97				Wetherill. Trans. Am. Philos. Soc. Phila., 353. 1852.
	Impsonite, Ind. T	.25	{(1.31) 1.45	(1.38) 1.47}	42.33	55.97											86.57	7.26	1.48	2.00				Wm. C. Day. Am. Jour. Sci., September, 1899, p. 221. In art. by Taff.
	(?) Page, Ind. T	.09	.95	1.67	23.06	75.90																		Laboratory U. S. Geological Survey.
	(?) Fourche Mountain, Ark	2.51	.56	1.38	17.78	79.15																		Do.
	Grahamite, W. Va		2.26	Tr.	47.11	52.89											76.45	7.83	Tr.	13.46				Wurtz, analyst. Quoted by Fontaine in Am. Jour. Sci., 3d ser., Vol. VI, 1873, p. 415.
	Grahamite, Huasteca, Mex	.36	5.86	.83	61.32	31.63																		Wm. Wallace, analyst. Quoted by J. P. Kimball in Am. Jour. Sci., 3d ser., Vol. XII, 1876, p. 286.
Sandstones	Eastern Kentucky. (Average)				4.98											95.02							Quartz: fine to coarse; sharp.	Laboratory U. S. Geological Survey.
	Western Kentucky. (Average)				6.35											93.65							do	Do.
	Higginsville, Mo				8.42											91.58							Quartz and mica: fine.	Do.
	Buckhorn district, Ind. T., 12						10.42									89.58							Quartz: medium; subangular.	A. W. Dow, inspector asphalt, D. C., analyst for U. S. Geological Survey.
	Buckhorn district, Ind. T., 24						6.60									93.40							Quartz: medium to fine; round.	Do.
	Santa Cruz district, Cal., 52–60						14.47									85.53							Quartz: fine; sharp; black grains.	Do.
	Santa Cruz district, Cal				18.16	2.58										79.26							Quartz: fine; sharp; some mica and magnetite.	W. D. Johnston, analyst Cal. State Mining Bureau. 7th Ann. Rept., 1887, p. 52.
	San Luis Obispo district, Cal., 70–72						12.08									87.92							Quartz: fine to coarse: ang. to round.	A. W. Dow, inspector asphalts, D. C., analyst for U. S. Geological Survey.
	Los Alamos district, 87						29.75									70.25							Quartz: fine; sharp; minute rods.	Do.
	Region of the Sisquoc, 82						14.32									85.68							Quartz: medium; sharp; black grains.	Do.
	Region of the Sisquoc, bitumen																				80.74	19.26		Thos. Price & Son, analysts. Quoted in 13th An. Rept. State Mining Bureau, 1896, p. 40.
	Carpinteria, Cal., 90						18.57									81.43							Quartz: medium: sharp; black grains.	A. W. Dow, inspector asphalts, D. C., analyst for U. S. Geological Survey.
	Carpinteria, Cal., maltha			1.32													85.72	11.83	1.21					Richardson. Municipal Engineering Magazine. New York, June–August, 1897.
Limestones	Buckhorn district, Ind. T.:																							
	Coal Measures 16						14.53									85.47							Limestone: light gray	A. W. Dow, inspector asphalts, D. C., analyst for U. S. Geological Survey.
	Ordovician, 17–18						5.20									94.80							do	Do.
	Ordovician, 32						3.47									96.53							do	Do.
	Texas, Uvalde County, 45						14.47									85.53							do	Do.

Faces page 224.

clear quartz sand, grains rounded and a little pitted on the surface, size nearly all 80 and 100 mesh, some little passing 100 mesh.

Sample No. 16.—Bitumen asphaltic in character; penetration about 25. Mineral residue light-colored limestone of following composition:

	Per cent.
Silica, SiO_2	10.70
Iron and alumina oxides, Fe_2O_3 and Al_2O_3	2.89
Calcium oxide, CaO	45.91
Magnesium oxide, MgO	.37
Carbon dioxide, CO_2	36.50
Organic matter; does not smell bituminous on burning	2.65
Undetermined	1.88

Samples No. 17 and No. 18.—Bitumen asphaltic in character; penetration about 28. Mineral residue whitish limestone of following composition:

	Per cent.
Silica, SiO_2	4.93
Iron and alumina oxides, Fe_2O_3 and Al_2O_3	1.98
Calcium oxide, CaO	50.68
Magnesium oxide, MgO	1.04
Carbon dioxide, CO_2	39.72
Organic matter not bituminous	1.42

Sample No. 24.—Bitumen asphaltic in character, very adhesive; penetration 75. Mineral residue clear quartz sand, grains rounded and slightly pitted, size nearly all 80 and 100 mesh, some little passing 100 mesh.

Sample No. 28.—Bitumen very thick asphaltic oil or maltha. Mineral residue whitish limestone of following composition:

	Per cent.
Silica, SiO_2	0.50
Iron and alumina oxides, Fe_2O_2 and Al_2O_3	.21
Calcium oxide, CaO	54.64
Magnesium oxide, MgO	.50
Carbon dioxide, CO_2	42.40
Organic matter not bitumen	.47
Undetermined	1.28

Sample No. 32.—Bitumen asphaltic in character, very adhesive; penetration about 50. Mineral residue whitish limestone of the following composition:

	Per cent.
Silica, SiO_2	3.22
Iron and alumina oxides, Fe_2O_3 and Al_2O_3	.45
Calcium oxide, CaO	52.44
Magnesium oxide, MgO	.85
Carbon dioxide, CO_2	41.10
Organic matter not bitumen	.95

Sample No. 45.—Bitumen quite hard, but asphaltic; penetration about 8. Mineral residue whitish limestone of following composition:

	Per cent.
Silica, SiO_2	0.78
Iron and alumina oxides, Fe_2O_3 and Al_2O_3	.45
Calcium oxide, CaO	53.92
Magnesium oxide, MgO	.36
Carbon dioxide, CO_2	43.00
Organic matter	.94

Sample No. 52.—Bitumen asphaltic in character, very adhesive; penetration about 35. Mineral residue mostly clear quartz, with considerable black and a few yellow grains; grains angular, 80, 90, 100, and passing 100 mesh in size.

Sample No. 53.—Bitumen asphaltic in character; penetration about 25. Mineral residue mostly clear quartz with considerable black and yellow sand; grains angular, 80, 90, 100, and passing 100 mesh in size, identical in appearance with No. 52.

Sample No. 56.—Bitumen asphaltic in character, very adhesive; penetration about 50. Mineral residue clear quartz; sand grains angular, ranging from 40 to passing 100 mesh, mostly 80, but little passing 100 mesh.

Sample No. 57.—Bitumen asphaltic, very adhesive; penetration about 55. Mineral residue clear quartz sand; grains angular, ranging from 60 to passing 100 mesh in size, but little passing 100 mesh.

Sample No. 60.—Bitumen asphaltic, very adhesive; penetration about 70. Mineral residue nearly all clear quartz sand; grains angular, all about 100 mesh in size.

Sample No. 70.—Bitumen asphaltic, very adhesive; penetration about 60. Mineral residue clear quartz sand; mixed angular and rounded grains graded from 20 to passing 100 mesh, mostly 80 mesh.

Sample No. 72.—Bitumen asphaltic, very adhesive; penetration about 80. Mineral residue clear quartz sand; mixed angular and round grains ranging from 40 to passing 100 mesh, the coarser grains predominating.

Sample No. 76.—Bitumen, about 6 penetration. Mineral residue sandy shale; sand grains angular, 60 to passing 100 mesh.

Sample No. 77.—Bitumen hard; penetration about 6. Mineral residue sandy shale; sand grains angular, 60 to passing 100 mesh.

Sample No. 82.—Bitumen nearly flows; penetration about 120. Mineral residue clear quartz sand; grains angular, some very sharp, graded in size from 40 to passing 100 mesh, 80 and 100 mesh predominating.

Sample No. 87.—Bitumen hard; penetration about 6. Mineral residue clear and opaque grained sand; grains angular, 80 to passing 100 mesh in size. In this residue there are spicules of various size, possibly those of the sponge, ranging from one-tenth to one two-hundredth millimeter in diameter and some over one millimeter in length; also some infusoria shells resembling sea urchins in shape, about one-twentieth millimeter in diameter.

Sample No. 90.—Bitumen a very thick oil or maltha. Mineral residue clear quartz sand with few black grains; grains angular, mostly 40 and 60 mesh, some little finer.

Sample No. 93.—Bitumen hard; penetration about 6. Mineral residue sandy shale.

Composition of certain European asphalt rocks.

	Val de Travers (Switzerland).	Lobsan (Alsace).	Seyssel (Ain, France).	Maëstu (Spain).	Ragusa (Sicily).
Water and other matters volatilized at 100° C	0.35	3.40	0.40	0.80	0.40
Bituminous matter	8.70	11.90	9.10	8.85	8.80
Sulphur in organic combination, or free state	.08	4.49			Tr.
Iron pyrites	.21	4.44			
Alumina and oxide of iron	.30	1.25	.05	.90	4.35
Magnesia	.10	.15	.05	.45	3.85
Lime	49.50	38.90	50.50	49.00	5.70
Carbonic acid	40.16	31.92	39.80	39.40	8.15
Combined silica					11.35
Sand	.60	3.05	.10	.60	57.40
Total	100.00	100.00	100.00	100.00	100.00

DISTRIBUTION OF THE ASPHALTS AND BITUMINOUS ROCKS OF THE UNITED STATES.

The distribution of asphalts and bituminous rocks in the United States is wide. The asphaltites are found in West Virginia, Indian Territory, Colorado, and Utah; bituminous limestones in Indian Territory, Texas, and Utah; bituminous sandstones in Kentucky, Missouri, Indian Territory, Texas, Utah, and California;[1] earthy bitumen of great purity, occurring as veins, in California; brea, it is possible, occurs in all petroleum areas, but in the present investigation it was found only in Indian Territory, Wyoming, and California, although small bodies are reported to occur in Montana. The localities of these several occurrences are shown on the general map of the United States, Pl. XXV.

The stratigraphic range of the bitumens and their compounds is as wide as their geographic distribution. Their oldest association observed is with the Ordovician shale of the Tenmile region in eastern Indian Territory, where impsonite, an asphaltite closely related to albertite, occurs in vein form. Other veins of like material, as well as a bituminous sandstone, occur in the series of Ordovician sandstones overlying the shales along the Indian Territory-Arkansas line. In central Indian Territory, in the Buckhorn district, are other bituminous sandstones, also of Ordovician age, though perhaps not to be correlated with the foregoing. Above these, in direct succession, is the summit limestone of the Ordovician, at least for this locality—a massive bed of variable thickness, the maximum being approximately 400 feet. The entire body of rock is varyingly impregnated with bitumen, the more highly enriched portions to an average of 6 to 8 per cent. In this same locality the Lower Coal Measures also, at one or more horizons, are richly infiltrated with bitumen, one of their limestones carrying an average of 14 per cent. The Lower Coal Measures are unconformable with the underlying formations, and the occurrence of bitumen at the several horizons suggests a common source and origin for it, and an inflow to its present reservoirs, perhaps subsequent to the laying down of all the sediments involved, if not, indeed, subsequent to their folding. On the other hand, from the presence in the Coal Measure conglomerate of an occasional pebble, believed to be of Ordovician bituminous sandstone, particularly observed by Mr. Taff, there may have been two or more distinct flow periods.

West and south of the Arbuckle Mountains the Coal Measures again carry bitumen in some of their members—grits and limestones. These horizons, however, may be quite different from those in the Buckhorn region.

[1] Since the writer's field investigation indefinite accounts of bituminous sandstones in Alabama and Illinois have appeared in certain newspapers.

In the vicinity of Higginsville, Mo., the Warrensburg sandstone, occupying what Mr. Arthur Winslow, the State geologist, considers a channel of erosion in the Coal Measures, but assigned to the Carboniferous, is also infiltrated with bitumen to about 6 per cent.

In West Virginia the grahamite vein, which has brought much renown to the region of its occurrence, occupies a vertical fissure in the Waynesburg sandstone and adjoining beds above and below, horizons in the Upper Productive and Upper Barren Coal Measures of the Carboniferous age.

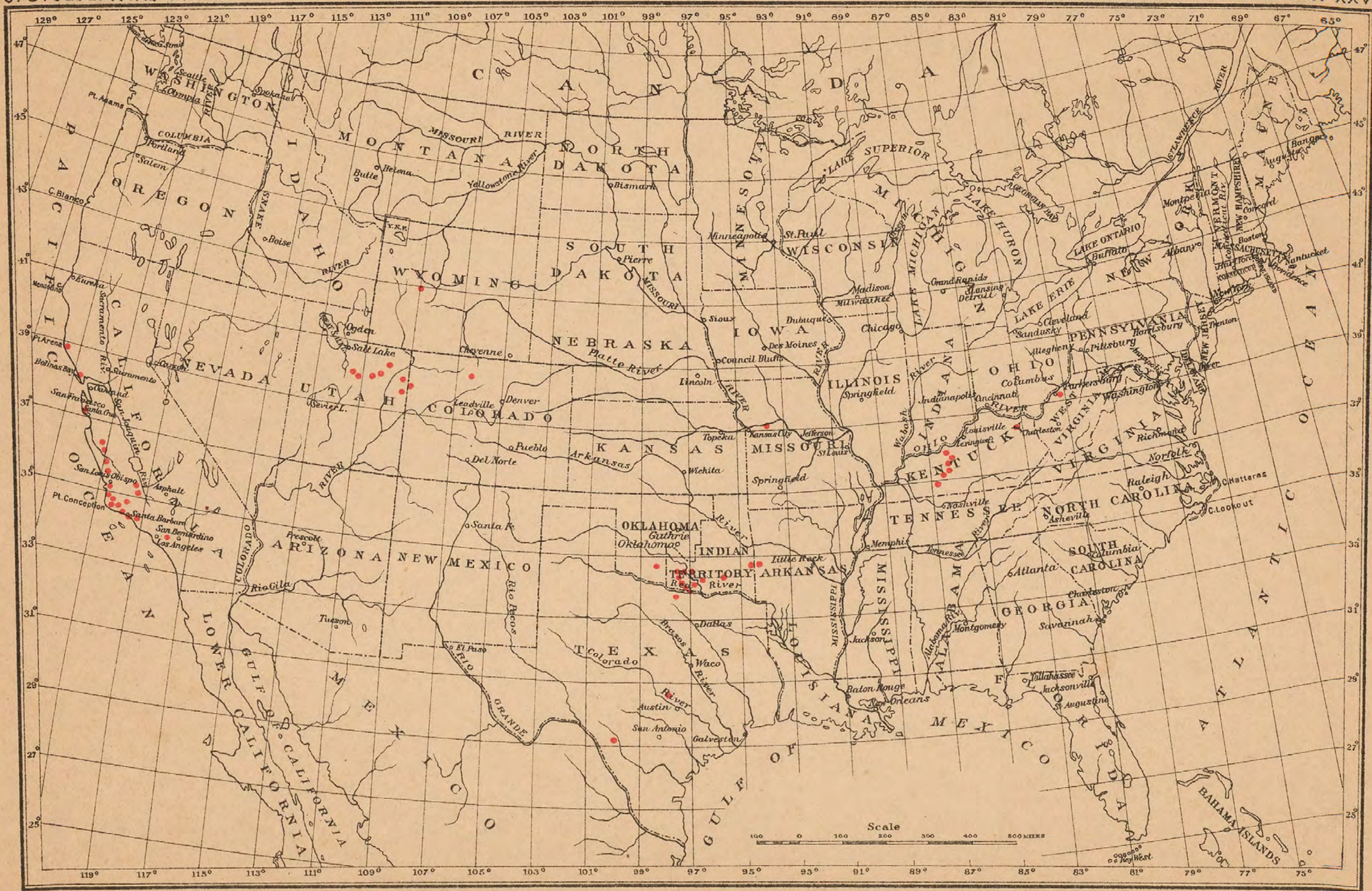
The bituminous sandstones of Kentucky are closely successive members of the Chester formation and the basal portion of the Coal Measures, and all, at one point or another, are impregnated to a degree sufficient to render them economically available for paving purposes, their contents ranging between 5 and 8 or 9 per cent.

The Permian, or what is at present accepted as the Permian, in central Indian Territory has been penetrated by fissures through which petroleum has risen into its superficial sandy members, and has also been converted to brea as surface deposits. This occurs at Wheeler, a settlement about 40 miles west of Ardmore. The locality is practically that of the enriched Coal Measure sandstones south of the Arbuckle Mountains, and there is little doubt that a common source supplied all the different horizons that now constitute the exposed storage reservoirs of the former fluid petroleum.

The Trinity sand of the Lower Cretaceous is a bitumen-bearing formation at many points in its area of outcrop in southern Indian Territory and northern Texas. This is particularly the case where it rests upon the Carboniferous, an occurrence that is significant of the derivation of its bitumen from a source perhaps identical with that from which the several members of the Coal Measures have derived theirs.

The Glen Rose formation, also a member of the Trinity division of the Lower Cretaceous, in one of its limestones carries the bitumen of the deposits of Post Mountain, near the town of Burnet, Burnet County, Tex. The Anacacho formation of the Texas Upper Cretaceous, corresponding to a horizon near the base of the Montana of the Rocky Mountain section, carries the rich bituminous limestones extensively quarried in the vicinity of Anacacho Mountain, 18 miles west of Uvalde, in southern Texas. In this connection the presence of important oil horizons in the Montana formation of the Florence oil field in Colorado is not unworthy of note.

The Middle Park formation of Middle Park, Colorado, largely a terrane of eruptive material and a correlative of the Denver of the plains—a formation for the present termed post-Laramie, without assignment to Cretaceous or Tertiary—also carries bitumens. The deposit occurs in the northern portion of Middle Park, almost in the



ASPHALT AND BITUMINOUS ROCK DEPOSITS IN THE UNITED STATES

JULIUS BIEN & CO. N.Y.

heart of the Rocky Mountains. It is here an asphalt resembling gilsonite and occupying an irregular fissure or series of fissures in the clays, sandstones, and conglomerates of the formation referred to. The occurrence is, so far as known, limited to the immediate region in which it is found, and is thus comparatively isolated, the nearest asphalt being the gilsonite found along the Colorado-Utah line, 150 miles distant.

The bitumens of the Tertiary horizons are apparently confined to the West—to Colorado, Utah, and California. The various divisions of the Eocene in eastern Utah and just across the line in Colorado are noted both for the variety of their asphalts and for the size of their veins. It is in this region, of the White and Green rivers and the celebrated Book Cliffs, that the great veins of uintaite are found and that the minor seams of wurtzilite, ozocerite, and nigrite occur. Bituminous limestones are also of wide distribution, though confined to the Green River shales. The asphaltites occur in fissures both in this formation and in those overlying, especially the Bridger and Uinta. Maltha springs also occur, and even petroleum is reported in one of the upper members of the Cretaceous, a few miles east of the Utah-Colorado line. The Green River shales are noted throughout the West for their bitumen contents, and it is surmised that they are the source of the asphalts, at least, of this vast area. The variation in the ultimate material as it to-day fills one fissure or another is perhaps due in part to a change somewhat allied to fractional distillation in petroleum technology and in part to the degree to which oxygen absorption has been carried on. In any event, the variety of bitumen found can hardly excite wonder when considered as to the origin of the material and the differentiations that take place in artificial distillation. It is, indeed, to be expected.

The occurrence of bitumens in the Neocene is confined to California. The rocks of this period here embrace a heavy series of shales with local sandstones, tuffs, etc.—the Monterey formation; a conspicuous body of massive sandstone with a minor proportion of shales, known as the San Pablo formation, but in doubt as to its position as a member of the Miocene or Pliocene, and hence in the region of its occurrence regarded as Middle Neocene; and a succession of sandstones, conglomerates, and clays, probably Pliocene, but for the present termed Upper Neocene, with the specific name Paso Robles assigned to it.

In addition to the foregoing, there are certain and important sandstones and sand aggregates of somewhat doubtful age, but where encountered seeming to lie beneath the shales of the Monterey rather than in them, and often against and upon granite. Such is their occurrence in the vicinity of Santa Cruz, and again at one or two points in the range bordering the Salinas Valley on the east. These sandstones are locally heavily impregnated with bitumen, and near

Santa Cruz are extensively quarried for paving purposes in San Francisco and elsewhere.

The Monterey formation is of particular importance, in that for almost the entire length of the State its terrane is more or less conspicuously marked with petroleum or maltha seepages, while its sandy members may appear as minor storage reservoirs of oil, this now altered at the outcrop to a material of pasty consistency, and forming with the sand grains an asphaltic compound of considerable richness. Such sandy beds occur at Point Arena, in the San Antonio Valley, and in the region of the Sisquoc. The shales of the Monterey are not only generally bituminous, but some of their more arenaceous and porous members are also especially rich, doubtless having received an inflow of petroleum from their adjoining and less open associates. It is in the shales of the Monterey, too, as well as in the Middle Neocene, that veins of the more solid bitumens, mixed with clastic material derived from the country rock, are found. Except for the clastic material, the bitumen would resemble in structure the asphaltites, though still differing from them in other features. Veins of this description are conspicuous in the vicinity of Santa Maria, Santa Barbara, and Asphalto. Near the latter place the asphaltic material is intimately related to, even associated with, petroleum.

The San Pablo formation, at least that portion of it in the San Luis Range, has been converted into a vast storage reservoir. It is the surface terrane over an area of nearly 50 square miles a short distance southwest of San Luis Obispo, and perhaps half its outcrop here shows impregnation with bitumen in greater or less degree, locally to a high degree. In the same region scattered bodies of the Paso Robles formation have also been infiltrated where resting on the San Pablo or the Monterey.

The San Pablo is also, perhaps, represented in the region of the Sisquoc, 40 miles southeast of Santa Maria, where along the southern base of the San Rafael Range is a highly enriched body of sandstone, of doubtful correlation from its structural association with recognized Monterey sandstones, but possibly of the age suggested. It is locally one of the richest sandstones in California.

In the region of the Graciosa Hills, 6 to 10 miles south of Santa Maria, there rests upon the Monterey, unconformably, a heavy body of loosely coherent sands or sandstone commonly regarded as Pliocene. Cracks have developed in the formation, which have been filled with bitumen carrying from 30 to 60 per cent of clastic matter. The material resembles in general appearance that already referred to as of vein form in the Middle Neocene near Asphalto. Here, however, it has not yet been found in association with petroleum.

Post-Pliocene sandstones are found with small gash veins and other irregular but more or less extensive bodies of the solid bitumens in the region of More's Landing, 7 miles west of Santa Barbara. A material in many ways resembling gilsonite was found as a minute pocket in the sandstone, but the mass of the bitumen is of the solid variety, mixed with 20 to 30 per cent of clastic material. Twelve miles east of this occurrence is the important petroleum-producing region of Summerland. Pleistocene or recent sands have been heavily charged with bitumen at Carpinteria, 12 miles east of Santa Barbara. They have been for the most part removed, but the continuous flow of maltha in the floor of the quarry would quickly impregnate an equal body were the excavation to be filled with fresh sand from the adjoining ocean beach.

Superficial deposits of brea are well distributed over the United States. Those observed by the writer were in Indian Territory, Wyoming, and California, the first no longer increasing from active springs, the others still forming. The source of their malthas is naturally extremely varied. In addition to the above, there are doubtless many others of but little less importance scattered through the oil regions of the country.

ORIGIN OF THE DEPOSITS.

The origin of the hydrocarbons as such and in the bituminous compounds discussed in the pages that follow may be traced, the writer believes, to petroleum. This is, in the first place, a natural inference from chemical relations. The fact that there may be a wide variation in the composition and physical aspect of the bitumens, whether of asphaltites or of sandstones, matters not, for important differences are found in petroleums themselves; the variation in the asphaltites, indeed, may be somewhat more marked, for in the passage from petroleum to its derivatives the process may have stopped at any point, with a corresponding development of physical as well as chemical distinctions. But in the geological investigation of the asphaltites, bituminous sandstones, and related materials, the view of their origin suggested by chemistry has in many ways been reenforced. The asphaltic earths, and solid bitumens in part, are frequently associated with active petroleum springs, or are found in regions renowned as oil producing. The sandstones and limestones are found resting upon formations conspicuous for their yield at other points; indeed, in one instance they were found upon a formation actively yielding directly beneath them, and this at the present day. The sandstones, therefore, can hardly be regarded other than as storage reservoirs for the oil thus received; the limestones, it is sometimes thought, may have been the locus of origin as well as of storage. In California, an interesting result of the investigation is that a reservoir may have been filled from an overlying formation as well as from one underlying, the deposits resting on granite being cited in corroboration.

The asphaltites and closely associated hydrocarbons, ozocerite for example, can hardly have been derived otherwise than by the draining of petroleum pools or strata richly saturated with oil. In the case of gilsonite, the absence of every trace of petroleum in the inclosing sandstones and its evident prevalence in the underlying Green River shales indicates the latter series as the one-time source of the oil which on entering the fissures was converted into the asphaltites. Moreover, locally, for a foot or two adjacent to the veins, the sandstone is filled with interstitial gilsonite, which is evidence of infiltration from the petroleum-filled fissure into the sandstones rather than into the fissure from the rock on either side. The channels by which the shales were drained are cracks that extend from the bottom of the main portion of the fissures, in some instances several hundred feet, into the underlying bitumen-bearing beds, but even here the draining of the strata must have been marvelously rapid to have been so complete as the conditions indicate before being interfered with by the closing of the fissures from the settling or readjustment of the shale, always a rock of exceeding instability. The writer believes, however, that the filling of the fissure could have been derived from no other source. The origin of the cracks is, of course, well understood. They occur in all formations and in all localities and are a concomitant feature of folding, though perhaps at times developed from shrinkage.

In the filling of all reservoirs, whether fissures or sandstones, the investigator is struck with the almost inevitable slowness of the process and the vastness of the area of fine-grained sediments that must have been drained to yield the supply absorbed. Then, too, in the case of the asphaltites the hardening must have been very gradual, the material passing through a viscous stage, during which fragments dropped from the walls into the bitumen and yet were supported, even as a rock is supported upon the surface of a thickening maltha pool at the present day. After solidification was complete the crushing strains from readjustment of the strata became manifest in the penicillate structure developed in the asphalt next to the walls of the vein. It is probable that during the filling of the crack this readjustment was continuously going on, but it could become evident only after the vein material had been hardened sufficiently to record it.

WEST VIRGINIA.

GRAHAMITE.

Definition.—Grahamite is a solid, black, brittle hydrocarbon, in weathered fragments showing a hackly or penicillate structure. Comparison with other asphaltites is afforded in Table III, showing resemblances and differences (p. 222). The name, after the Messrs. Graham, interested in mining it, was given by Dr. Henry Wurtz, chemist, of New York.

Locality.—Grahamite has been identified at but a single locality in the United States, that of its original discovery, in Ritchie County, W. Va., about 25 miles a little south of east from Parkersburg. Although once extensively mined,[1] the deposit was abandoned over twenty-five years ago, and to-day there is presented to view nothing but an open fissure in the hillsides, overgrown with trees and shrubs and affording but a suggestion of the features that prevailed at the time of its exploitation. The locality may be reached by a narrow-gauge road which leaves the main line of the Baltimore and Ohio Railroad at Cairo, 29 miles east of Parkersburg.

Topography.—The region in which the grahamite occurs is one of rolling hills and sharp valleys, with an average difference in their ele-

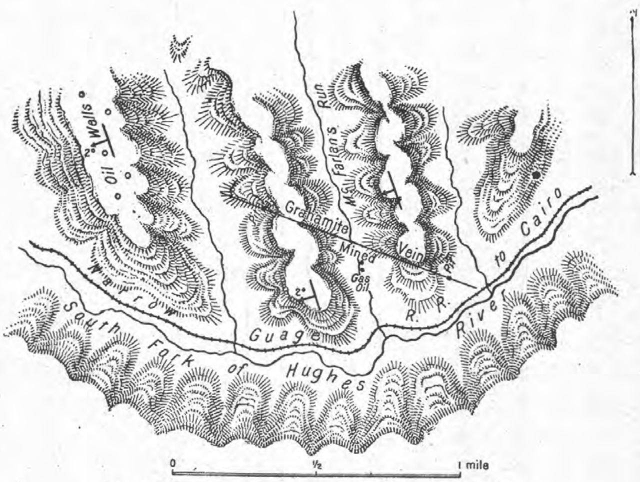


FIG. 1.—Sketch of grahamite region, West Virginia.

vation of 300 to 400 feet. It has been developed by erosion from a platform-like country, modified somewhat by an occasional fold in the strata. The approximate horizontality of the beds has permitted extreme irregularity in the directions assumed by the channels of erosion, and hence, also, in the trend and summit areas of the intervening ridges. The valleys are so sharply cut as to have almost precluded the presence of bottom lands, and it is on the summits only that extended areas of cultivation are found. The topography increases somewhat in ruggedness as distance from the Ohio River is gained.

Geology.—An area of many thousand square miles, embracing adjacent portions of Ohio, West Virginia, and Kentucky, has for its superficial formation the Coal Measures of the Carboniferous, capped here

[1] See paper by Prof. J. P. Leslie in Proc. Am. Philos. Soc., March 20, 1863; also Report upon a Mineral Formation in West Virginia, by Mr. Henry Wurtz, chemist, New York (a private report); a paper by Prof. William M. Fontaine in Am. Jour. Sci., October 14, 1873, 3d series, Vol. VI; and Prof. I. C. White, on the Origin of grahamite, Bull. Geol. Soc. America, Vol. X, 1898.

and there, according to Fontaine, by the Permian. The successive divisions of the Coal Measures in ascending order are encountered in passing from the west to the east, a general southeasterly dip of from 2° to 8° prevailing, with, however, occasional modifications. In the region of the grahamite deposit the horizon attained in outcrop has been determined by Fontaine, White, and others to be that of the Waynesburg sandstone of the Upper Productive Coal Measures, while a well drilled within 300 feet of the fissure to a depth of 1,652 feet has penetrated to the Pocono. Overlying the series and forming the ridge crests of the locality, Professor Fontaine has recognized the Dunkard Creek series of the Permian.

Appended is the section obtained in the well, from records furnished Professor White.[1]

Record of Ritchie mines well, in feet.

	Thickness.	Depth.
Unrecorded (cased 7⅝ inches at 247 feet)		600
Black slate	57	657
Red rock	15	672
Black slate and shale	28	700
Red rock	40	740
Limestone and shells	10	750
Red rock	10	760
Light red shale	5	765
Red rock	20	785
Blue sand and limestone	15	800
Sand, gray, with show of oil	30	830
Hard shell of flint and limestone	10	840
Sand and slate (cased 6¼ inches)	30	870
Slate	10	880
Sand with limestone	10	890
Slate, dark	55	945
Sand, gray, with shell to bottom	15	960
Slate, light	10	970
Sand, gray	10	980
Coal	5	985
Slate, black	5	990
Sand, gray	15	1,005
Slate and sand	10	1,015
Slate	5	1,020
Sand, light gray and soft	25	1,045
Slate, dark	5	1,050
Sand	20	1,070
Slate	20	1,090
Sand, white (gas enough to run boiler)	15	1,105
Unrecorded	37	1,142
Sand, white	33	1,175
Break of slate	5	1,180
Sand, white	30	1,210
Slate	150	1,360
Sand, gray and coarse	20	1,380
Slate	8	1,388

[1] Origin of grahamite, by I. C. White: Bull. Geol. Soc. Am., April 25, 1898, Vol. X, p. 278.

		Thickness.	Depth.
Sand, gray and coarse		12	1,400
Shell		2	1,402
Slate, black		88	1,490
White sand ("salt," gas) ..25 Sand (oil at 1,530),.......15	Cairo oil sand	40	1,530
Sand		26	1,556
Slate		4	1,560
Sand, base of Pottsville		23	1,583
Limestone (Greenbrier)		67	1,650
Top of "Big Injun" sand (Pocono)		..	1,652

Professor White adds that this well begins 140 feet below the Washington coal, and thus a few feet under the base of the Waynesburg sandstone.

The strike in the immediate locality of the grahamite vein is N. 20° W.; the dip is between 1° and 2° W., the strata entering, perhaps, into a slight anticlinal fold that has brought about the structural conditions requisite for the productive oil wells just beyond the western end of the grahamite fissure. Other and parallel folds lie to the west of this one, the nearest, distant 6 or 7 miles, known as the Oil Break anticline, also with several oil pools along its axis.

Occurrence.—The grahamite mined occurred as the filling of a vertical crack in the Waynesburg sandstone and adjoining beds above and below, horizons in the Upper Productive Coal Measures of the Carboniferous, and the Upper Barren series of the Permian. The trend of the crack is N. 70° to 74° W., diagonally across the strike of the inclosing strata, which is about N. 20° W. The dip of the beds is between ½° and 2° W. The length of the crack is perhaps less than a mile; its maximum observable width midway is 4 feet, decreasing toward either end; its extent in depth is believed by Professor White and others familiar with the field to be at least 1,500 to 1,600 feet, based on the idea that the grahamite-converted oil was derived from the Cairo oil sands occurring at that level. One argument somewhat against this, however, must not be lost sight of, namely, that many shale and slate beds intervene between the surface and the depth mentioned, and that there is a tendency of cracks in such strata to close. The crack displays great evenness of walls in the heavy Waynesburg sandstone that extends upward for quite 100 feet from the level of the run in which was the main opening. The width of the crack is well maintained, too, in this height. Below the run the condition of the cut does not permit observation. Professor Fontaine, however, in the years when the mine was more accessible, observed within the fissure, in descending order, beneath the Waynesburg sandstone—

	Feet.
Gray shale (boring for oil, near by, begins in this)	55
Sandstone	30
Gray shale	20
Red shale to bottom.	

Above the Waynesburg sandstone the cut still shows 30 to 40 feet of shale with a thin coal seam (Fontaine's Washington coal) about midway; over this is a sandstone, 6 to 10 feet thick, succeeded in turn by more shale, this series repeating itself, with variation in the thickness of its members, to the summit of the ridge, 75 to 100 feet higher, but shale largely predominating.

Passing from the heavy Waynesburg sandstone into the overlying shales, the walls of the crack become increasingly irregular as the transition progresses, and in the friable upper half of the shale the vein is difficult to trace. The crack, however, reappears, clearly defined, in 6 to 10 feet of sandstone succeeding, but its width is here less than 18 inches. Above this the vein is traceable by fragments of sandstone impregnated with grahamite, but the prospect pits, in their present condition at least, show barely a trace of the mineral itself, if, indeed, any at all. The northwestern opening on the vein is on the opposite side of the ridge from the foregoing, between one-third and one-half mile distant. Here, in the upper 15 feet of an old shaft, caves have exposed a one-eighth inch thread of grahamite irregularly outlined in friable shales, and it is said that the little mineral mined here occurred in small pockets in most uncertain succession.

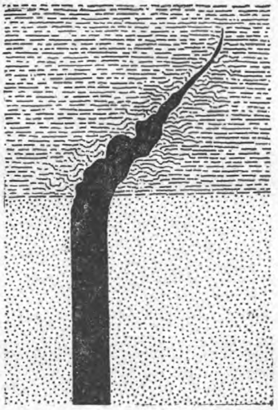


FIG. 2.—The grahamite vein at its passage from the Waynesburg sandstone to the overlying shale. This is also illustrative of the general action of asphaltite veins under like stratigraphic conditions.

In the southeasterly direction from the main opening the vein is said to have been extensively mined. Cuts, long since caved and overgrown with brush, confirm this for the vertical range of the 100 feet of sandstone, but the shaly cap of the hill has remained undisturbed.

This is explained in the face of the cuts, where at the contact of sandstone and overlying shale the conditions shown in fig. 2 are found. The sandstones have permitted a clean vertical fracture, the walls preserving their regularity and distance from each other, here 2½ feet, with remarkable precision. The shales, on the other hand, refused to open in a crack of even the slightest regularity, any tendency in this direction being overcome by the crushing together of the strata so yielding by nature.

With such action of the vein in the shales overlying the Waynesburg sandstone, it is quite reasonable to infer that the same condition prevails in like shales below; in short, that in the 1,500 or 1,600 feet of possible depth the grahamite vein is many times interrupted in its full and normal development, even though the fissure remained open sufficiently for the upward passage of the asphalt-forming material.

From the easternmost opening on the vein the trend S. 70° E. would carry the fissure across the main valley of the region, that in which the railroad lies, but it is said that prospecting has failed to reveal its presence in this direction, and it may be that the crack rapidly narrowed and disappeared in the measures now removed from the valley. That it has not been found in the bottom of the valley may be due to cover, although here again the question of shales is involved.

The development of this vein in this particular locality and series of beds must have been wholly adventitious. No other similar veins have been discovered in the oil regions of the east, and the strata adjacent to the crack at the surface offer no explanation.

A feature of interest, however, bearing upon the derivation of the grahamite from the oil of the deep-lying sands of the locality has been reported to Professor White by Mr. W. K. Jacobs, superintendent of the Cairo Oil Company, to the effect that wells drilled near the fissure obtain good sand, but that this acts like a drained or exhausted field and produces oil in small quantity only; yet when wells are located from 800 to 1,000 feet distant from the fissure good producers are obtained; hence, continues Professor White, there can be no doubt that the fissure made by tension from the Burning Springs–Eureka uplift was filled with petroleum largely from the Cairo oil sand at 1,330 feet below the present surface. Attention has been called, however, to the possible behavior of a crack opened in a series of beds of which shales constitute a conspicuous proportion, and the difficulty that oil would have in penetrating upward such a distance through a fissure that can hardly have escaped many interruptions to its continuity. Yet whence otherwise could the material have been derived?

In the consideration of the grahamite vein the similarity of occurrence to the great cracks filled with the allied hydrocarbon, gilsonite, in eastern Utah, is at once apparent.

Dr. Wurtz's account of the vein.—The following summary of an account of an examination of the Ritchie grahamite vein, by Dr. Henry Wurtz,[1] was published in 1869. It is of especial interest for the reason that the examination was made while the mine was in operation. Dr. Wurtz says:

The structure shows four distinct, though somewhat irregular, divisional planes, having a general parallelism with the walls. Next to the walls the structure of the mineral is coarsely granular, with an irregularly cuboidal jointed cleavage, very lustrous on the cleavage surfaces; that in immediate contact with the walls usually adhering thereto very tenaciously, as if *fused* fast to the granular sandstone.

Next these two outside layers, which are very irregular and from 2 to 3 inches or more in thickness, is found, on each side of the vein, a layer averaging from 15 to 16 inches in thickness, which is composed of a variety highly columnar in structure and very lustrous in fracture, the columns being long and at this place at right

[1] On the grahamite of West Virginia and the New Colorado resinoid: Proc. Am. Assoc. Adv. Sci. for 1869, Vol. XVIII, p. 124.

angles to the walls. It is this variety that was given to Professor Lesley, as would appear from his description. Finally, in the center of the vein, varying in thickness but averaging about 18 inches, is a mass differing greatly in aspect from the rest, being more compact and massive, much less lustrous in fracture, and with the columnar structure much less developed, in places not at all. The fracture and luster of this portion of the vein are clearly *resinoid* in character.

The general aspect of the mass, as well as all the results of a minute examination of the accompanying phenomena, lead irresistibly to the conclusion that we have here a fissure which has been filled by an exudation, in a pasty condition, of a resinoid substance derived from or formed by some metamorphosis of unknown fossil matter contained in deep-seated strata intersected by the fissure or dike. It is not necessary to suppose a degree of fluidity greater than that of semifused pitch or inspissated tar. Such a soft doughy mass, though flowing but slowly, would *in time* be forced by a very moderate pressure into every portion and into every crevice of the fissure. The peculiar structure described is such as would result from the fissuring of a fused or semifused viscous mass by the refrigeration produced by contact with the cold and, it may be, wet walls of the fissure; the outside granular layers being due to rapid cooling, and the columnar fracturing at right angles (or nearly so) to the walls (as, for example, in the case of a dike of columnar basalt) to a more gradual reduction of temperature, connected, without doubt, with the well-known tendency of such materials as are susceptible of the vitreous or viscous fusion to assume in time a concretionary or nodular structure. This tendency is strongly apparent in the brilliant variety, having produced multitudes of those curious markings on fissured surfaces which were mistaken in the case of the albertite for *fossil impressions*. The transverse columnar structure is called by Lesley "pencil cleavage."

Toward the extremities of the outcrop, where the sheet of mineral is thinner, this pencillate structure extends throughout the mass.

In sinking a small shaft here, 28 feet deep, Mr. J. Carville Stovin, the engineer in charge at the time, found a detached fragment 3½ feet long of the north wall of the dike embedded in the mineral 24 inches distant from said wall and 29 inches vertically below the *hiatus* in the wall, marking its point of detachment; while exact measurements, both of itself and of the cavity left (on removing the mineral which occupied its original space), showed that it had become entirely inverted in position during its descent. The pitch-like semifluidity which I have contended for is here strongly illustrated by the small depth of descent of this mass of quartzose sandstone through a material whose density could not have been half of its own; while its distance from the wall and inverted position suggests that at the time of its detachment the dough-like mass was still rising, or in some sort of motion at least, in the dike fissure.

I myself observed similar *horses* of the wall rock, of small size, similarly embedded in the mineral at several points.

The horizontal extent of visible outcrop actually measured by me was 530 fathoms, thinned out at east end to 30 inches and at west end to 8 inches; but as these points were at least 70 to 80 fathoms vertically higher than the bottom of the ravine, the width (averaging about 50 inches) at the latter depth points to a rapid widening of the fissure in descent.

Comparison with grahamite in Mexico.—An occurrence of grahamite, also, at the Cristo mine, in the Huasteca, Vera Cruz, Mexico, has been described by Dr. J. P. Kimball.[1] Following is a summary by way of comparison:

The deposit consists of two continuous parts, the one occupying a nearly vertical fissure traversing the fossiliferous shales and the other part conformably overlying

[1] Am. Jour. Sci., 3d series, Vol. XII, 1876, p. 277.

these shales, which are slightly inclined. We have here the phenomena, first, of a deep-seated fissure transverse to the bedding of the formation and filled out with grahamite; and second, a nearly horizontal and originally superficial deposit of the same material overspreading the shale formation for a limited distance from the fissure. The latter occurrence is an overflow from the fissure, and, as it lies between the two formations, is to be referred to a period subsequent to the deposition of the shales and before the conglomerate was spread upon them in the form of pebbly detritus. It thus happened when the shales formed the surface at this point, just as asphaltum is now commonly formed upon the surface, as a residuum from the evaporation and oxidation of liquid or pasty malthas issuing from sluggish springs or oozing from more extended sources, as from a certain stratum or rift in the rocks.

The vein occupying the fissure has a columnar structure transverse to its sides and shrinkage partings or joints parallel to its sides. It has thus far proved remarkably homogenous in structure and free from admixture of rock or clay. Its dip is 64° to the west. Near the point where it passes out of sight under the river bed it is joined at an acute angle by a narrower and tapering vein, of which the maximum width is 9 inches.

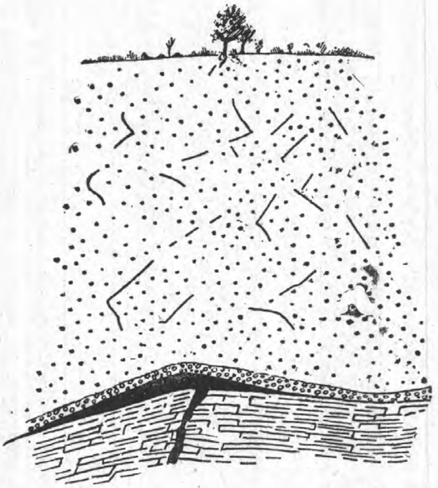


FIG. 3.—Section of grahamite vein in the Huasteca, Mexico.

The fissure occupies the axis of a gentle anticlinal, with a dip of 14° W. on the west side and 4° E. on the opposite side. As the overflow conforms to the steeper dip, it appears that the fissure must have been made at the time of the elevation of the shales, and soon afterwards filled with asphaltum, which continued to form after it had been filled. That no great period was required for this operation is shown by the fact that the overlying conglomerate also conforms to the stratification of the shales as well as to the outline of the overflow of the grahamite locally intervening.

The occurrence of such a fissure in shales, so imperfectly hardened and so easily weathered, affords another proof that the filling of the fissure immediately followed its formation—that is, after the emergence of the shales and before the deposition of the overlying alluvium.

Concerning the source of the filling of this fissure, the grahamite, Dr. Kimball remarks:

The sandstone formation is the source of a number of deposits of chapapote or asphaltum. Numerous deposits are said to occur north of the Panuco River. One deposit which I visited is found on the Tanelul ranch, occupying an elevated basin or cul-de-sac between two hills of the Alacranes range, here forming the boundary of the Capadero Valley. The point is some 2½ leagues east of the Cristo mine, and directly in range with the course of the Cristo fissure as far as traced. The chapapote has accumulated from the evaporation of liquid maltha, which now issues in the form or a sluggish spring, with a number of orifices. Here may be witnessed the same process by which the above-described overflow of the Cristo mine was originally formed. The source of the chapapote spring is the sandstone above mentioned, on which rest the grahamite-bearing shales of the valley below. It thus appears that the uplifted portions of the underlying sandstone are at present the source of chapapote springs depositing that mineral substance upon the surface. Ancient, and perhaps more copious, springs of the same kind issued from the depressed portions of this formation and forced their liquid maltha into the fissures and lesser interstices of the overlying shale, which, as I have already stated, is remarkably cleavable and imperfectly indurated. The tendency of such a body of shale or shaly clay, exceedingly fine in texture, to form shrinkage and cleavage partings is well known. Hence this formation, from its nature otherwise impervious, became the permanent receptacle of maltha or asphaltic petroleum issuing from the sandstone below; and probably the more freely under a hydrostatic pressure, in which water played a part, and the action of which is strikingly suggested by the configuration here observed of a stratigraphical basin bordered by elevated plateaus. The inspissation of maltha or pittasphalt, and even petroleum, to grahamite and other mineral bitumens, by the loss of hydrogen and the addition of oxygen, is a well-known occurrence which may be artifically illustrated in the laboratory.[1] While the asphaltum is observed to be the product of the immediate evaporation and oxidation of maltha at or near the surface, a slower and continued oxidation beneath the surface—in fissures, cavities, and interstices of the rocks—has produced grahamite, albertite, and other less hydrogenous hydrocarbons of the same type.

Dr. Kimball also mentions the fact that—

Smaller exhibitions of grahamite in the shale of the river banks at Tempoal and the Aguacates are of the same general nature as the deposit of the Cristo mine. They occupy interstices between divisional planes of the formation, thus forming veinlets which often pass from between one kind of the partings to another. Hence even the larger of these deposits or pockets are very capricious in position, while the smaller ones merely reticulate the rock. They seem to have no connection or channels.

KENTUCKY.

Bitumens in Kentucky occur as impregnations of sandstones. They are, perhaps, the result of exposure in outcrop of oil-bearing strata, the petroleum having thus been converted by loss of the lighter hydrocarbons and by oxidation into a product of asphaltic nature. The sandstones thus impregnated carry in freshly picked faces of the quarries from 4½ to 7½ per cent of bitumen, amounts that would, perhaps, show material increase at a distance from the exposed surfaces. The horizons at which the bitumens occur include the conglomerate at the base of the Coal Measures, a sandstone a little above, and the several sandstones of the Chester series of the Lower Carboniferous.

FORMATIONS AND GENERAL STRUCTURE.

For the purposes of this report the columnar section of the geological formations of Kentucky (fig. 4) affords sufficient insight into their succession and general composition; a detailed description of the series will not, therefore, be entered upon, excepting, hereafter, for those beds which are of immediate interest in the study of the bitumen. The surface distribution of the formations as well as the general structure is shown in the geological map and sections, Pl. XXVI. The eastern half of the State is occupied by a gentle dome-like eleva-

[1] W. P. Jenney, Am. Chem., Vol. V, p. 10.

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tion of the strata, known to geologists as the Cincinnati anticline. The major axis of the dome bears to the northwest and is coincident with the Kentucky River for 30 miles below the great bend. The minor axis is practically coincident with the river above the big bend. The bend, therefore, marks the position of the height or center of the dome. The profiles show the presence of two important faults, one coincident with the minor axis of the fold, and now occupied by the gorge of the Kentucky River; the other lying along the northwestern base of Pine Mountain in southeastern Kentucky.

The central area of this dome-like anticline is occupied by the formations of the Lower Silurian; around these are grouped, in successive rings of varying width, the several members of the Upper Silurian, the Devonian, the Lower Carboniferous (Mississippian)[1], and the Coal Measures. The area of exposure in each instance depends upon the dip of the beds, a formation's thickness, and the erosion which the country has undergone. The outcrops of the formations and the passage from one to another in crossing the State are followed with comparative ease, much assistance being derived from topographic features, which are pronounced and in accord with the material character of the terranes out of which they have been developed.

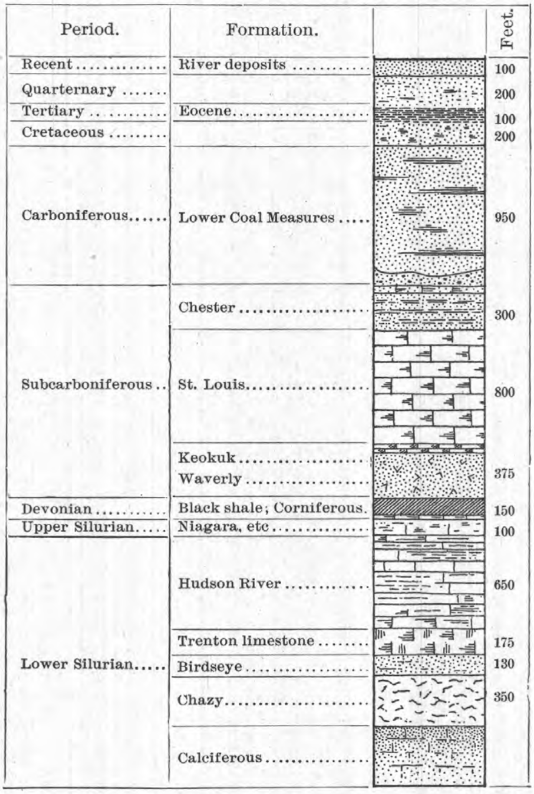


FIG. 4.—Geological series in western Kentucky (after Orton).[2]

The western half of Kentucky is occupied by a syncline which, to the east, passes into the anticline just described, but to the west has its connections buried beneath the Pleistocene deposits of the Ohio and Mississippi valleys. The formations that enter into this syncline and are exposed within Kentucky include only the Lower Carboniferous

[1] Subcarboniferous of the map.

[2] Petroleum, natural gas, and asphalt in western Kentucky: Geol. Survey Kentucky, 1891.

and the Coal Measures, both of which, however, are remarkably strongly developed. The center of the syncline, east and west, is in the vicinity of Green River, which is the principal drainage channel for the area. The basin is shallow, the normal dips being very gentle, usually under 8° or 10° and often but 3° or 4°. There are, however, minor folds of greater or less sharpness.

THE BITUMEN-BEARING SERIES.

The portion of the geological column of Kentucky of especial interest because of its outcropping, bitumen-bearing strata, is that embracing the lower 150 feet of the Coal Measures and Chester Division of the Lower Carboniferous.

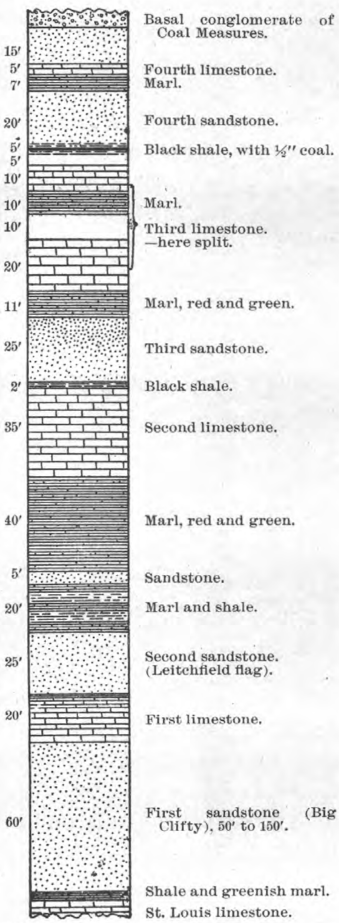


Fig. 5.—Section of the Chester at Stevensport, Ky. (after J. B. Hoeing).

The Chester series is said to be typically and fully represented at Stevensport, Ky.; for the section (fig. 5) at this point the Survey is indebted to Mr. J. B. Hoeing, of the Kentucky geological survey, who has kindly furnished it from his unpublished notes. The salient features of the formation are its sandstones, three or four in number, which are usually heavy bedded and form pronounced cliffs, and are, moreover, at one point or another, impregnated with bitumen. They are numbered from below up and may be distinguished from one another by the stratigraphic sequence of the different members of the series, of which many are characterized by predominant fossils. The lower sandstone may generally be identified by reference to the underlying St. Louis limestone. The formation varies, however, by the absence of one or more of its members, or by the increase or diminution in thickness of the beds that are present. This is particularly the case with regard to the third sandstone, which, indeed, may disappear entirely or be replaced by shales. In this case the fourth sandstone, as shown in the Stevensport section, has been designated the third, notwithstanding that its position is above the recognized third limestone. When the entire Chester above the third limestone has disappeared, as seems sometimes to be the case, the sandstone at the base of the Coal Measures, the equivalent of the Conglomerate, has even been referred to as the third sandstone. Fortunately the question is not involved in the discussion of the individual deposits of bituminous sandstone, all being referable to clearly defined horizons in Chester or Coal Measures. The only region in which it is of any moment in the present investigation is that of Tar Springs, in the western part of Breckinridge County. Here authorities differ somewhat as to the assignment of the heavy cliff-forming sandstone above Tar Spring; Orton[1] regards it as the third massive sandstone of the Chester; Mr. Averitt, who assisted the writer in the investigation of Kentucky bituminous rocks, associates it rather with the Coal Measures.

In this connection it is of interest to note that along Green River, north of Bowling Green, an unconformity between the Chester and the Coal Measures has been detected by Mr. Hoeing, of the Kentucky survey. This would account for variation at the summit of the Chester.

The members of the Coal Measures that have become impregnated with bitumen are the basal conglomerate or its equivalent sandstone and a sandstone a short distance above, immediately over the lower coal of the series, the whole comprised within a vertical range of 100 to 150 feet, locally, even less. The section, fig. 12 (p. 256), at Youngs Ferry, 12 miles north of Bowling Green, is typical of the succession of beds, except that the coal found just below the upper sandstone about 12 miles to the east, in the vicinity of Bee Spring, is here but doubtfully included. The series of bitumen-bearing beds is not delineated on the general map of Kentucky, but it would closely follow the line of the Coal Measures, forming a zone 5 to 20 miles broad just without, in the area of the Lower Carboniferous.

The western area of Coal Measures is that along which the sandstones of the bitumen-bearing terrane have thus far proved most productive, but even on the west of this the strata, from some cause, have never yet been found to yield. This may be due either to lack of thorough search, to stratigraphic or structural causes, or to an entire absence of oil originally in the formations of that locality. That bituminous sand stones have not yet been found in southeastern Kentucky may be due to one or more of the same causes. In the northeast the almost complete disappearance of the Chester and a marked decrease in the thickness of the conglomerate of the Coal Measures would account in large measure for the meager occurrence of bitumens there.

[1] Geol. Survey Kentucky, volume on petroleum, natural gas, etc., p. 207.

DEPOSITS OF BITUMINOUS SANDSTONE IN EASTERN KENTUCKY.

CARTER COUNTY DEPOSIT.

General features.—Bituminous sandstone was discovered in Carter County in February, 1899, by Mr. L. S. Vincent. The location of the deposit is one-half mile southeast of Soldier, a station on the Chesapeake and Ohio Railroad, 160 miles east of Louisville. The deposit lies on the eastern side of the divide between Tygart and Triplett creeks, the latter a tributary of the Licking River. Thus far prospecting has been confined to the ridge in the forks of Soldier Creek and the main Tygart, but outcrops of the bituminous sandstone have been found north of Soldier Creek, and the bed, enriched or not as it may prove to be, doubtless extends to the North Fork of Tygart, perhaps farther. The altitude of the Tygart-Triplett divide is 1,136 feet, the country gently falling away to the east and to the west. The physical features of the region are those of slightly dipping strata, influenced by the nature of the sediments cut, which are here sandstones, shales, and limestones, all in comparatively thin beds, 1 to 10 feet thick. The valleys are somewhat sharply eroded to depths between 200 and 300 feet, the hills presenting, however, even, or but slightly broken slopes and flat to rounded tops.

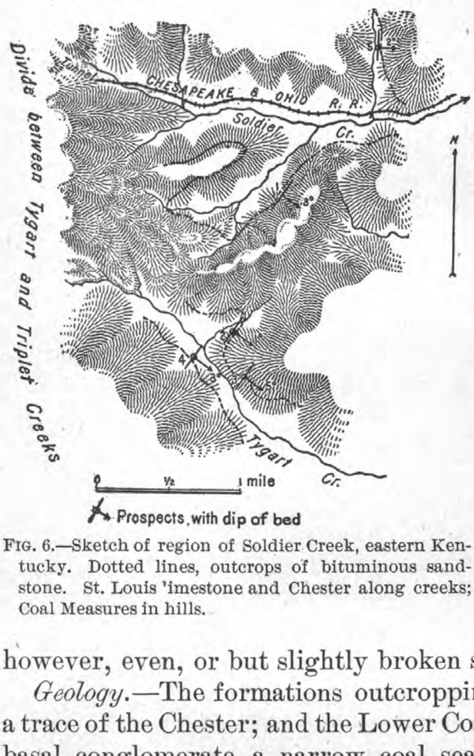


FIG. 6.—Sketch of region of Soldier Creek, eastern Kentucky. Dotted lines, outcrops of bituminous sandstone. St. Louis 'imestone and Chester along creeks; Coal Measures in hills.

Geology.—The formations outcropping are the St. Louis limestone; a trace of the Chester; and the Lower Coal Measures, represented by the basal conglomerate, a narrow coal seam, and from 50 to 100 feet of shales and thin sandstones. The first two formations lie along the streams; the last occupies the hills. The St. Louis limestone, brownish gray, often crystalline, and occurring in layers ranging from thin shales to strata 3 or 4 feet thick, may be recognized by its fossils. Its total thickness is unknown, as it extends below the bed of Soldier Creek, the deepest cut of the locality. The Chester is reduced to less than 10 feet of shale. It was not identified by the writer but has been by Mr. A. R. Crandall, geologist of the Kentucky survey. The conglomerate of the Coal Measures, here a sandstone or grit and carrying the bitumens of the region, is also reduced to a minimum, a thickness greater than 6 feet not having been encountered. That the shales of this formation also vary is evident from the different positions assumed by the coal seam included in them, fig. 7. At one point this occurs 20 inches above the basal sandstone; at another it lies directly upon the sandstone; at still another there is no trace of it, though the thickness of the shale exposed above the sandstone should have included the horizon of the coal.

The structure of the region is very simple, a gentle dip of 1° or 2°, with an occasional increase of short duration to 4° or 5°, always in a S. 55° E. direction, the strata lying on the southeastern slope of the Cincinnati anticline.

Occurrence.—The average example of the productive basal sandstone of the Coal Measures is composed of fine to coarse, sharp, quartz grains, held together by bitumen. Upon the extraction of this, the quartz grains fall to sand. The compactness of the rock varies with the size of the grain. This has affected the degree of impregnation, the medium-grained, moderately compact rock being the richest; when too tight, the bitumen has been unable to penetrate it freely. The amount of bitumen in the better grade of rock in the faces of the prospects at the time of examination varied from 4 to 6 per cent. Determinations in excess of this have, however, been obtained in the development of the pits, and it is not unlikely that the average of the shipping rock would be nearer the higher figure, perhaps even greater, upon attaining distance from the outcrop.

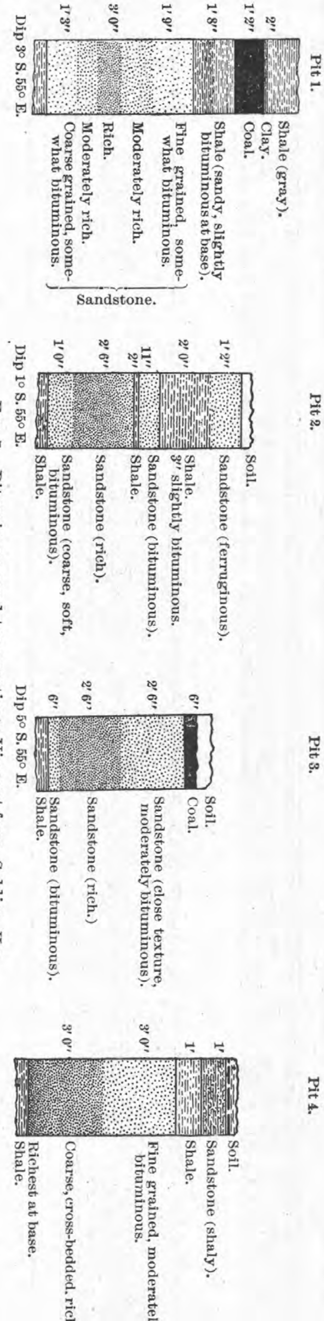


FIG. 7.—Bituminous sandstone sections, Vincent farm, Soldier, Ky.

Variation in richness occurs not only between different layers, but between different localities. For example, No. 2 prospect is noticeably richer in bitumen than No. 1, and moreover, it shows a thicker zone of increased enrichment. No. 4 prospect presents distinctly the poorest appearance of all the openings, yet without assignable cause except that the texture of the bed is coarser and looser, with perhaps a diminished supply of bitumen for the locality.

The richer portion of the bed is, at all openings, a zone about 3 feet thick, beginning at 10 or 15 inches above the bottom. Moreover, of this, there is a foot to 15 inches from the middle down that is especially rich, locally carrying as high as 9 or 10 per cent of bitumen. The passage from the richer to the poorer zones is gradual to moderately sharp. The uppermost layers of the sandstone are but slightly impregnated. Faint traces of bitumen, however, are found extending even into the overlying shale. Occasionally the especially compact and poorer portions of the bed have a slightly calcareous appearance, and it may be that the carbonate of lime has in such instances barred the bitumen from free circulation.

At No. 2 prospect there occurs, near the top of the richer zone, a shaly layer 1 to 3 inches thick. Although persistent across the face of the pit this shale is doubtless a local development. It, too, is varyingly charged with bitumen.

The northwesternmost exposure of the bituminous sandstone will probably be found near the top of the hill directly south of Soldier Station, a half mile east of the Triplett-Tygart divide. The northwestern prospect is a half mile southeast of Soldier Station, in a ravine directly tributary to the valley of Soldier Creek, and is favorably located with reference to transportation. It lies, however, 75 feet below the summit of the ridge in which it is opened; its position, therefore, will necessitate its being mined instead of quarried. The other openings are on the headwaters of Tygart Creek, across the divide from Soldier Creek, and are, therefore, less accessible. About one-third of a mile north of the railroad the bituminous sandstone again outcrops in a position of easy access.

DEPOSITS OF BITUMINOUS SANDSTONE IN WESTERN KENTUCKY.

The bituminous sandstone of western Kentucky outcrops in a zone from 5 to 20 miles wide bordering the area of Coal Measures on the east and south. Together with the Chester group the Coal Measures here form a more or less pronounced height of land rising from 200 to 300 feet above a broad, rolling, expanse of Lower Carboniferous limestone. This height of land, however, proves but the wide rim of an inner basin of considerable size eroded out of the Coal Measures by tributaries of the lower Green River and by the Tradewater River. The position of the basin is practically coincident with the trough of the broad syncline underlying western Kentucky, and the locus of the latter suggests itself as the governing factor in the development of the former. The rim of the topographic basin has been cut by the leading branches of the Green River. It is on the outer, or eastern and southern, slopes of this rim-like height of land, or well within some of the deeply eroded ravines entering it, that the exposures of the several strata that carry the bitumen are found. The openings, whether mere prospects or quarries, are comparatively few, but the enriched beds are met in outcrop in many localities in Breckinridge, Grayson, Edmonson, Warren, and Logan counties.

BRECKINRIDGE COUNTY DEPOSITS.

GEOLOGICAL HORIZON.

The deposits of bituminous sandstone in Breckinridge County, the most northerly found in western Kentucky, are located from 2 to 4 miles south of Garfield, a station on the Fordsville branch of the Louisville, Hendersonville and St. Louis Railway, 56 miles southwest of Louisville (see Pl. XXVII). The strata in which the deposits occur occupy a practically horizontal position, or at most one of very slight westerly dip, in the eastern edge of the high and extended upland formed of the Coal Measures and underlying Chester series. So far as exploited they are confined to the single horizon of what is regarded by the Kentucky survey[1] as the second Chester sandstone (see fig. 5). This view has been carefully confirmed by Mr. S. D. Averitt, who assisted the writer in the Kentucky field. Fig. 8 shows the succession of strata at and near the quarries of the Breckinridge Asphalt Company, on the farm of Mr. Taylor Compton, 2 miles south of Garfield. It may be regarded as the type section of the region as far as exposed. At the base is the first Chester limestone. That it is Chester is evidenced by the following fossils, collected by Mr. Averitt and identified by Dr. Girty of the survey:

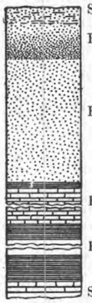


FIG. 8.—Section of bituminous sandstone and underlying beds at quarry of Breckinridge Asphalt Company, Compton farm, Garfield, Ky.

Pentremites godoni (Defrance).
Pentremites pyriformis (Say).
Zaphrentis spinulosa (E. & H.).
Crinoid stems.
Spiriferina spinosa (Nov. & Prat.)?.
Cleiothyris sublamellosa (Hall).
Archimedes distans (Ulrich).
Archimedes compactus (Ulrich).
Fenestella sp.

That it is the first limestone of the group is shown by the following facts: In the bed of Lost Run, 1½ miles south of the quarry, is found the shale at the bottom of the section; 2 miles farther south, in the bed of the same creek, the St. Louis limestone appears at a slightly lower level. The covered space shows traces of sandstone, so this is evidently the place of the first sandstone of the Chester group.

[1] Petroleum, natural gas, etc., by Edward Orton: Geol. Survey Kentucky, p. 209.

From this it follows that the heavy sandstone in the section, the top of which is impregnated with bitumen, is the second sandstone of the formation.

This sandstone, 40 to 50 feet thick and forming prominent cliffs wherever circumstances have favored, underlies the entire ridge that extends for 2½ miles southward from Garfield between the forks of the Lost River. It reappears in the ridge across the branch run, in the vicinity of Germantown, and can doubtless be traced thence, with interruption only in its bitumen-bearing portions, along the entire eastern face of the Coal Measures–Chester highland. Westward it extends beneath the highland. Eastward the country drops to a lower level and the entire Chester is finally eroded. To the north of Garfield the same section may again doubtless be found.

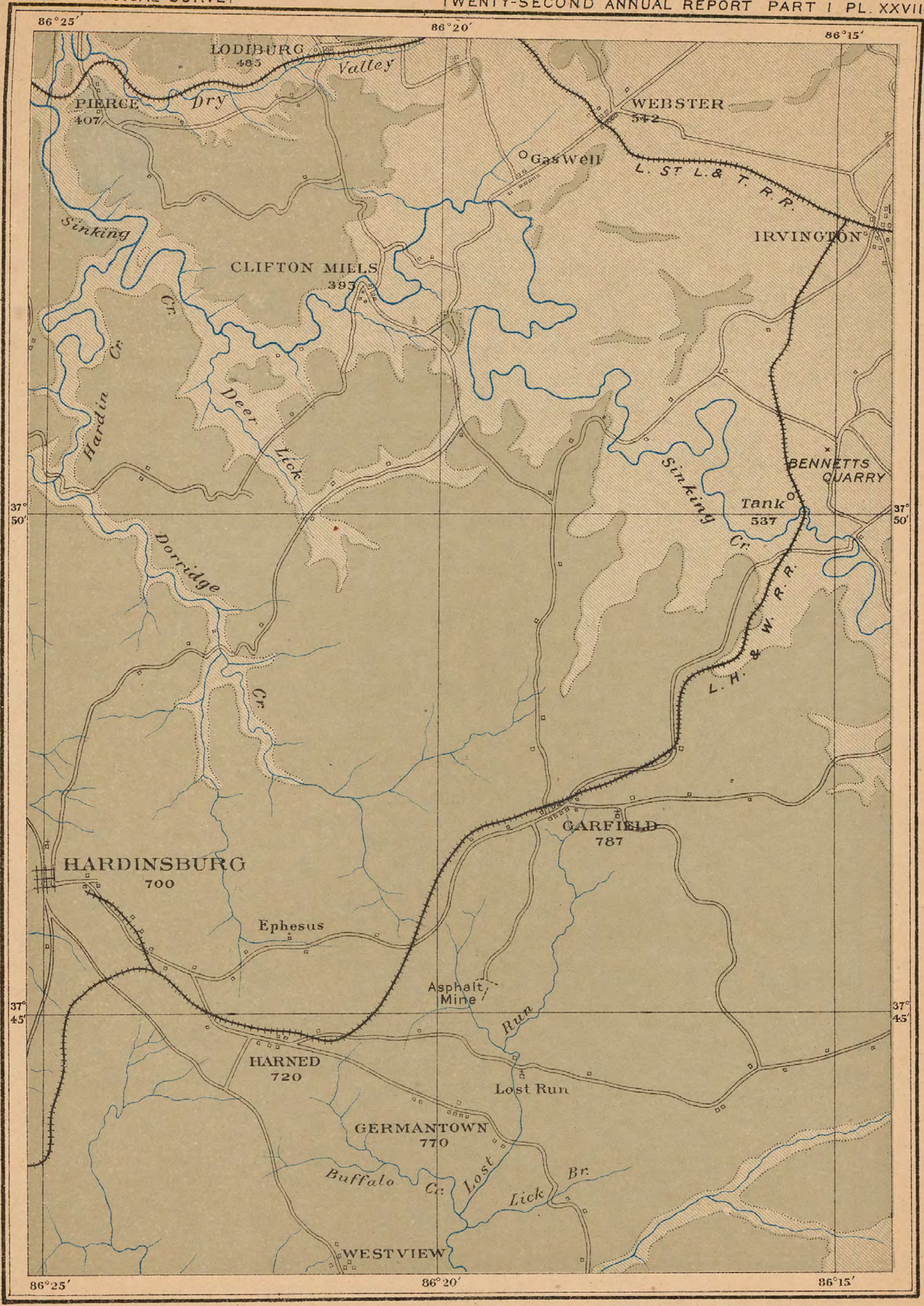
For an area of at least 3 or 4 miles immediately south of Garfield this sandstone forms practically the surface terrane.

About 20 feet below the top of this sandstone there is, locally, a sharp division plane (fig. 8). The portion above, except at the very top, which is shaly, has been strongly impregnated with bitumen; the portion below is barren. It is the impregnated zone of about 14 feet that has been the object of exploitation in Breckinridge County. Lying for a considerable area just beneath the tops of the hills, with but 10 to 20 feet of cover, it is most favorably situated for quarrying.

QUARRIES OF THE BRECKINRIDGE ASPHALT COMPANY.

The Breckinridge Asphalt Company has opened two quarries about 100 yards apart, near the point of the ridge between the forks of Lost Run, 2 miles south of Garfield. Each is about 200 feet in diameter and shows practically the same section of sandstone, any variation in thickness or in the degree of impregnation being such as may be expected between different points in the same bed. The sandstone is of sharp, fine-grained quartz. Of the 14 feet enriched, the lower 7 or 8 are said to carry an average of 8 per cent (varying between 6 and 10) of bitumen and constitute the shipping rock. The sample collected by the writer contained a little less than 6 per cent. Above this the amount of bitumen is considerably diminished and with exceptions the rock is treated as refuse. There is no distinct line of demarcation between the richer and poorer horizons, a wavy zone of gradation 2 or 3 feet in width existing between the two. This zone affords a certain amount of second-grade rock, to which is occasionally added material of equally low per cent that may chance to occur in the underlying portion of the bed. This second-grade rock is then occasionally made available by thoroughly mixing it with the highest grade from the mine.

A feature of interest—not only in the Breckinridge quarries, but in all visited—is the impoverishment that takes place for 6 or 8 inches on



PART OF BRECKENRIDGE COUNTY, KENTUCKY

From Kentucky Geological Survey, John R. Procter, Director

Scale

1 0 1 2 3 4 5 MILES

UPPER SUB-CARBONIFEROUS

CHESTER GROUP ST. LOUIS LIMESTONE

JULIUS BIEN & CO. N.Y.

either side of joint planes. Beyond this the rock maintains its average bitumen contents.

The areal extent of the bituminous sandstone which is quarried by the Breckinridge Asphalt Company has been the subject of special investigation by Mr. Marshall Morris, the general manager of the company. From the favorable position of the bed it has been possible to economically prospect it with the hand diamond drill. The results show that the area has its limits; that the thickness of the strata impregnated varies, and that there are close physical resemblances between the mass of sandstone thus impregnated and an oil pool as at present understood.

THE SMITH PROPERTY.

This property lies about 2 miles south of the Breckinridge Company's quarry and the same distance southeast of the railway station of Harned. Only a slight amount of prospecting has been done, showing 3 or 4 feet of bitumen-impregnated rock overlying another sandstone, which is barren, massive, and cliff forming, the whole practically horizontal or with slight dip westward. The overburden is here again less than 20 feet for a considerable area. Except for the thickness and topographic differences the condition of occurrence is the same as at the Breckinridge quarry. It should be added, however, that a thickness of 3 or 4 feet at the outcrop on a gentle slope does not necessarily indicate the thickness of the bed within the hill. In the Breckinridge quarries instances of increased thickness on entering are everywhere apparent, the increase being always at the top of the bed.

TAR SPRING.

On a branch of the small stream known as Tar Fork, 3½ miles south of Cloverport, Breckinridge County, is a spring from which issues globules of tar, which is apparently of the same nature as the bitumen in the sandstones of the State. The spring issues at the juncture of a massive, cliff-forming sandstone and the third limestone of the Chester series, that underlies, the latter identified by its fossils and its stratigraphic position with reference to still lower Chester beds at other comparatively near-by points. About 8 inches of soft, clayey shale separate sandstone and limestone. The sandstone around the spring is not bituminous. In regard to the horizon of this sandstone, Mr. Averitt observes that by some[1] it has been called the third sandstone of the Chester, but since the line of division between Chester and Coal Measures is not very distinct, and as *Pentremites sulcatus* is found in the limestone immediately below—a form characteristic of the third, or "Roofing," limestone—he has regarded the sandstone as the basal member of the Coal Measures, although it is not here conglomeratic. In

[1] See Orton, Report on petroleum, natural gas, etc.: Geol. Survey Kentucky, p. 207.

any event, it is very likely the fourth sandstone of the Stevensport section, whether this be associated with Chester or Coal Measures.

GRAYSON COUNTY DEPOSITS.

GEOLOGICAL FEATURES.

The general features of the geology of Grayson County are the presence of the Chester series of beds entire and about 300 feet of the Coal Measures, and the occurrence of an anticline that extends from Grayson Springs in a general direction N. 80° W. for 100 miles to the Ohio River opposite Shawneetown, in Illinois. Leitchfield, the county seat, occupies the crest of the arch, and in the vicinity of the town the strata are more sharply folded than they are farther out on the flanks of the anticline. The Coal Measures have been eroded from the crest of the arch and north of this, but to the south, from a line about 3 miles south of the axis, are encountered in ascending series to Bee Spring, just beyond the border of Grayson, in Edmonson County. These features are brought out in the accompanying section through Leitchfield, from the Breyfogle quarry in the northeast to the Schillinger No. 2 in the southwest. Were the section diverted to Bee Spring the succession of strata would be practically the same, with the addition of a few beds at the top of the series, present but not included in the sketch at the Schillinger No. 2 prospect. Deposits of bitumen occur in the first (Big Clifty) and second sandstones of the Chester, and in the sandstone over the Nolin coal in the Carboniferous. Reports are current, also, of deposits in still higher sandstones of the latter series; these have never been prospected, however.

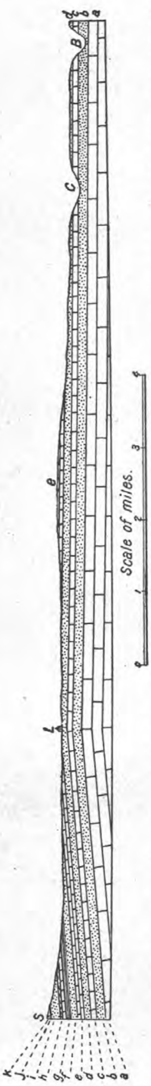


FIG. 9.—Section NE.-SW., through Leitchfield, Ky. Verticle scale 1/8 inch = 100 feet. S, Schillinger prospect No. 2; L, Leitchfield; C, Big Clifty Creek; B, Breyfogle quarry. *a*, St. Louis limestone; *b*, Big Clifty sandstone; *c*, First limestone; *d*, Second sandstone; *e*, Second limestone; *f*, Third sandstone; *g*, Leitchfield marls; *h*, Third or Roofing limestone; *i*, Basal sandstone of Coal Measures; *j*, Coal; *k*, Bituminous sandstone.

Actual exploitation in Grayson County has been as follows: Two openings by the Messrs. Schillinger Brothers, of Toledo, Ohio, southwest and north of Leitchfield 3 and 9 miles, respectively; one, the oldest, by Dr. William F. Breyfogle, 9 miles northeast of Leitchfield. Besides the deposits thus opened, many are reported at other localities in the county, but they are known only in outcrop, sometimes merely by seepages, and hence are all of undetermined value.

THE SCHILLINGER PROSPECTS.

Schillinger prospect No. 2.—This opening, which is that southwest of Leitchfield, lies about a mile west of Black Rock, a station on the Illinois Central Railroad, 76 miles southwest of Louisville. The opening is hardly more than a prospect in a depression in the hills about 200 yards south of the railroad, in strata that dip from 3 to 5 degrees in a N. 55° W. direction. Its location with regard to the surrounding topography would eventually necessitate a change to mining methods in its continued development. The rock is a medium-grained, massive sandstone, of a thickness of 8 or 10 feet, the lower 5 of which is impregnated with bitumen to an average of perhaps 6 per cent, distributed in greater proportion through the lower 3 feet of the mass. The upper half is valueless, at least at the outcrop.

This deposit is in the Coal Measures and rests directly upon the first coal seam—the main Nolin Coal, as it is known in Kentucky geology. This was determined by Mr. Averitt as follows: Referring to fig. 9, a short distance south of Leitchfield, the Leitchfield Flag or second Chester sandstone passes under 4 feet of marl immediately above which is the second limestone of the group, containing the same fossils that have been found in it in other places, namely, *Zaphrentis spinulosa* (E. & H.), *Cleiothyris sublamellosa* (Hall), *Pentremites sulcatus* (Roemer), *Pentremites obesus* (Lyon), *Monticulipora* sp. This limestone is in turn overlain by other marls, the whole forming the usual succession of beds at this horizon in western Kentucky. The marls in the present area are green in their lower portion, red in the central, and again green near the top.

In the upper portion of these marls is a space of about 5 feet, covered for the most part, but containing traces of other limestones. It is much weathered, and is almost shaly. The outcrops were poor, and no fossils were found. Above this is a sandstone, which seems to be limited to a small area around Leitchfield. In bedding it is very like the Leitchfield flag. It is fine-grained and somewhat greenish in color. It is regarded as the third sandstone of the Chester.

Above this is 20 feet of marl, sand, and shale, followed by the Leitchfield marls, here thicker and more extensive than anywhere else in the State.

The lower 10 feet of the Leitchfield marls are green, the second 10 feet are red, while the upper portion is yellowish. These marls are also known as the "upper workable marls." Above the marls is another succession of sands and shale with traces of marl near the top.

Over these is the Roofing limestone of the Chester. In it *Pentremites obesus* (Lyon) and *Allorisma* sp. were found; also *Productus elegans* (N. & P.).

Following the Roofing limestone is a massive sandstone of indefinite thickness, in some places 60 to 70 feet, coarse grained and friable. It occupies the place of the conglomerate at the base of the Coal Measures, although it is not conglomeratic in this immediate vicinity. Fire clay overlies, succeeded at Jones Spring, 3½ miles southwest of Leitchfield, by a vein of coal, with bituminous sandstone, again, resting upon the coal. This sandstone is found in several wells on different farms in this vicinity, usually at from 15 to 20 feet below the surface.

Throughout the whole region, including that of the Schillinger Prospect No. 2, the bituminous deposits are in the sandstone above the first coal seam—the main Nolin coal.

At the Schillinger Prospect No. 2, the coal is reported to be from 18 inches to 2 feet thick, and the fire clay beneath 9½ feet thick. The opening into the coal is now filled with débris.

Schillinger Prospect No. 1.—This prospect is about 9 miles north of Leitchfield, and 3½ west of the Breyfogle quarry. The deposit is in the Leitchfield flag, the second sandstone of the Chester. Its stratigraphic position is attested, Mr. Averitt states, by the succession of strata crossed between the town of Leitchfield, which is on the second sandstone, and the quarry; by the identity of the first and second limestones in this distance by their fossil contents; by the continuity of the sandstone between these, and, at the quarry, by the recognition of the No. 1 limestone with its characteristic fossils, *Pentremites godoni*, etc.

The No. 2 limestone passed on the way to the quarry affords the following fossils in profusion:

Crinoid stems, *Cleiothyris sublamellosa* (Hall), *Zaphrentis spinulosa* (S. and H.), *Pentremites sulcatus* (Roemer), *Archimedes proutanus* (Ulrich), *Spirifer increbescens* (Hall).

The limestone, as is so often the case, has several feet of marl both above and below it. Below the marl underlying this limestone, in the top of the Leitchfield flag, traces of bitumen are locally found. It is at the bottom of the sandstone, however, that the bitumen at the Schillinger Prospect No. 1 occurs. The sandstone is separated from the first limestone of the Chester by 6 or 8 inches of shale. In this limestone, just below the quarry, *Pentremites godoni* (Defrance) and oolitic masses are found. The sandstone in which the bitumen is found has a thickness of 8 feet, but only 3 feet is sufficiently rich to be worked. The sandstone differs from that in which the bitumen is found at the Breyfogle quarry in being fine grained and thin bedded. These differences are in fact characteristic of the first and second sandstones of this group, especially in this country, and this is a typical locality, as is shown in the names Big Clifty and Leitchfield flag.

THE BREYFOGLE QUARRIES.

This quarry, which is one of the largest in Kentucky, has now been idle for five or six years. It lies near Tar Hill post-office, 9 miles north-northeast of Leitchfield, and is 3 miles west of Big Clifty, a station on the Illinois Central Railroad, 62 miles southwest of Louisville.

The quarry is near the bottom of a sharp, deep, canyon-like ravine, the stream of which, a half mile below, empties into Big Clifty Creek, the main drainage channel of the region. Quarrying was conducted on both sides of the ravine for a length of 500 or 600 feet, but only a short distance into the hills was attained, owing to the very steep slopes and the consequent rapid increase in cover.

The geological horizon of the bitumen-bearing sandstone is that of the Big Clifty, the basal member of the Chester.

The following facts are offered by Mr. Averitt in evidence: From the court-house at Leitchfield (fig. 9), which rests on a stratum near the top of the Leitchfield flag or second sandstone of the Chester, this sandstone passes, at a distance of 1½ miles northeast, under about 5 feet of marl. Above this marl, which varies considerably in thickness, is the second limestone of the group, of an average thickness of 20 feet. The outcrops, especially in the upper part, near the overlying marl, are very fossiliferous, the following forms being found in abundance: *Zaphrentis spinulosa* (E. & H.), *Spirifer increbescens* (Hall), *Dielasma formosum* (Hall). The second limestone is the uppermost stratum found in this direction and forms the surface of a considerable area, the highest point being 3½ miles northeast of Leitchfield. From here one descends geologically to Big Clifty Creek, 8 miles northeast of Leitchfield. Passing down through the Leitchfield flag, there is found below 5 to 7 feet of marl, and below this the first limestone of the group. This is 40 feet thick and there are several good outcrops of it in the vicinity of Big Clifty Creek. It is somewhat thicker bedded than the second limestone of the group and contains the following fossils: *Archimedes distans* (Ulrich), *Archimedes proutanus* (Ulrich), *Zaphrentis spinulosa* (E. & H.), *Pentremites pyriformis* (Say)?, *Pentremites sulcatus* (Roemer)?, *Spirifer increbescens* (Hall)? In several places in this limestone specimens of oolitic limestone were also found.

Below this first limestone is the Big Clifty sandstone, or the lowest member of the Chester in the section. It is separated from the overlying limestone by a few feet of marl or shale. The bed of Big Clifty Creek is in the sandstone, but does not cut below it in this region. Passing up from the bed of the creek through the first limestone a level area several hundred acres in extent is found, over which the surface rock is Leitchfield flag. On the eastern side of this area is the deep ravine, near the bottom of which the Big Clifty sandstone is again exposed, here affording the deposits of bitumen opened in the Breyfogle quarry.

The sandstone can hardly be less than 40 or 50 feet thick, although the base is not exposed in the ravine. It lies with a gentle dip of 4 or 5 degees in a N. 28° E. direction, but cross-bedding gives it the appearance at some points of having a slightly steeper inclination. The bed is massive and, where conditions favor, it forms pronounced cliffs, becoming thus, with its characteristic topography of ridge and sharp ravine, a feature of the country for many miles. As in many other instances in the bituminous sandstones of both Chester and Lower Coal Measures, ripple marks of considerable size are common.

The sandstone is composed of medium to coarse grains of quartz, much coarser, as a rule, than the material of the Leitchfield flag. The latter rock is also generally thin-bedded, hard, and durable, and making an excellent flagging, all in marked contrast to the features of the Big Clifty sandstone.

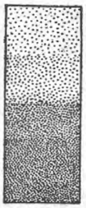


FIG. 10.—Section of bituminous sandstone at Breyfogle quarry, Big Clifty Creek, near Leitchfield, Ky. Horizon, Big Clifty sandstone of the Chester series.

The impregnated zone at the Breyfogle quarry, fig. 10, embraces a thickness of about 10 feet in the upper portion of the Big Clifty sandstone. Of this the lower 5 or 6 feet are of especial richness, carrying a somewhat variable amount of bitumen, indeed, but, perhaps, an average of 7 per cent. Upon passing under greater cover it is quite possible that the upper portion of the zone will show an increase in its contents. Between the two portions there is no definite line of division. An incidental feature at this quarry is the heavy cross bedding, irrespective of which, however, the bitumen appears to have impregnated the rock to a general level, thus making productive at one point a layer that is apparently unproductive at another. Another feature is the degree in which the bitumen seeps from the exposed faces of the quarry, even from levels in the sandstone where there are no visible division planes. Where crevices, either natural or formed by blasting, have remained open, such seepage becomes of added interest as a possible suggestion regarding the formation of gilsonite and other veins of related material. The bitumen, always of a highly gummy consistency after leaving its bed, is seen slowly trickling from the sides of the crevice, depositing one layer over another, yet the several layers blending in homogeneous mass but a short time after the flows. Held in the bitumen, also, are small rock fragments that have tumbled into the crevice and have been taken up by the slowly flowing mass. Such material is now hard, even semibrittle in instances.

The plant of the company was apparently complete, though now removed or gone to ruin. There still exists the remnants of an incline that was used in elevating the product of the quarry to the cars at the brow of the hill on the southeast of the ravine, and there are other evidences of the equipment common to quarries of bituminous sandstone.

EDMONSON COUNTY DEPOSITS.

BEE SPRING REGION.

The geological horizon of the bituminous sandstone of the Bee Spring region was traced by Mr. Averitt from Leitchfield, 15 miles north. The same succession of beds is encountered in this section as in the region of the Schillinger No. 2 Prospect, but in more extended order. The Roofing limestone of the Chester appears at Harold Hill, 5 miles south of Leitchfield. It is here about 6½ feet thick and rests upon 6 to 8 inches of marl. It has the same lithological and paleontologic characters as in other places in western Kentucky. Above the covered space in the section is 30 feet of massive sandstone, the basal sandstone of the Coal Measures. At Flat Rock Creek, 8 miles north of Bee Spring, this sandstone is found in a cliff 25 feet high, resting upon 5½ feet of shale and followed above by 20 feet of shale with traces of sandstone and 3 feet of fire clay near the top. Above the fire clay is the first or main Nolin coal, 2 to 3 feet thick in the Bee Spring region.

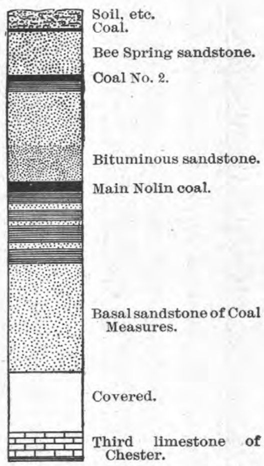


FIG. 11.—Section at Bee Spring, Edmonson County, Ky. Scale, 1 inch=40 feet.

The stratum above the first coal is sandstone, covered to a great extent, but thick bedded where it is exposed. The top of the sandstone is shaly. It is followed by an 18-inch vein of coal, known as coal No. 2. Overlying this is the Bee Spring sandstone, which is massive and coarse grained, disintegrates readily, and covers the strata below with its detritus. Resting upon the Bee Spring sandstone is coal No. 3, never more than 8 or 10 inches thick, and not worked. This is succeeded by sandy material which forms the surface in many of the hills in the vicinity of Bee Spring.

On account of the great number of local faults of small displacement and the covered nature of the region a detailed section is difficult to obtain, and that given shows only in a general way the stratigraphy of the region.

The bituminous deposit of this region is found in the sandstone just above the first or main Nolin coal. In many places it rests directly upon the coal; in other places, owing to covering, the relation is obscure.

There are many deposits of bituminous sandstone in this part of Edmonson County, and in many places small tar springs, rather than saturated sandstone, are found. One deposit of considerable extent is found 2 miles northeast of Bee Spring, on the farm of Mr. J. Meredith, and another 1½ miles south of Bee Spring. None of the deposits are worked and their value is undetermined.

While the larger deposits are found in the sandstone above the first, or main Nolin coal, many traces of bitumen are said to occur in those above the second and third coals, respectively. Although deposits were not found in the present examination in these sandstones there is nothing to preclude their occurrence in them.

WARREN COUNTY DEPOSITS.

LOCATION.

The deposits already described are found along the eastern border of the Coal Measures; those that follow occur along the southern edge of this area. The deposits of bituminous sandstone in Warren County are confined to its extreme northern end, the Lower Coal Measure–Chester terrane entering it only to a limited extent (see Pl. XXVIII). But two quarries are opened within the county, neither, however, more than a prospect. They are located on what is known as the Cherry Farm, at Youngs Ferry, on Green River, 12 miles north of Bowling Green. At the time of the examination prospecting alone had been done, but it had been conducted with care and a considerable area underlain with the bituminous sandstones or their barren equivalents had been defined.

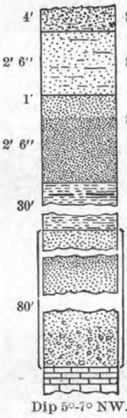


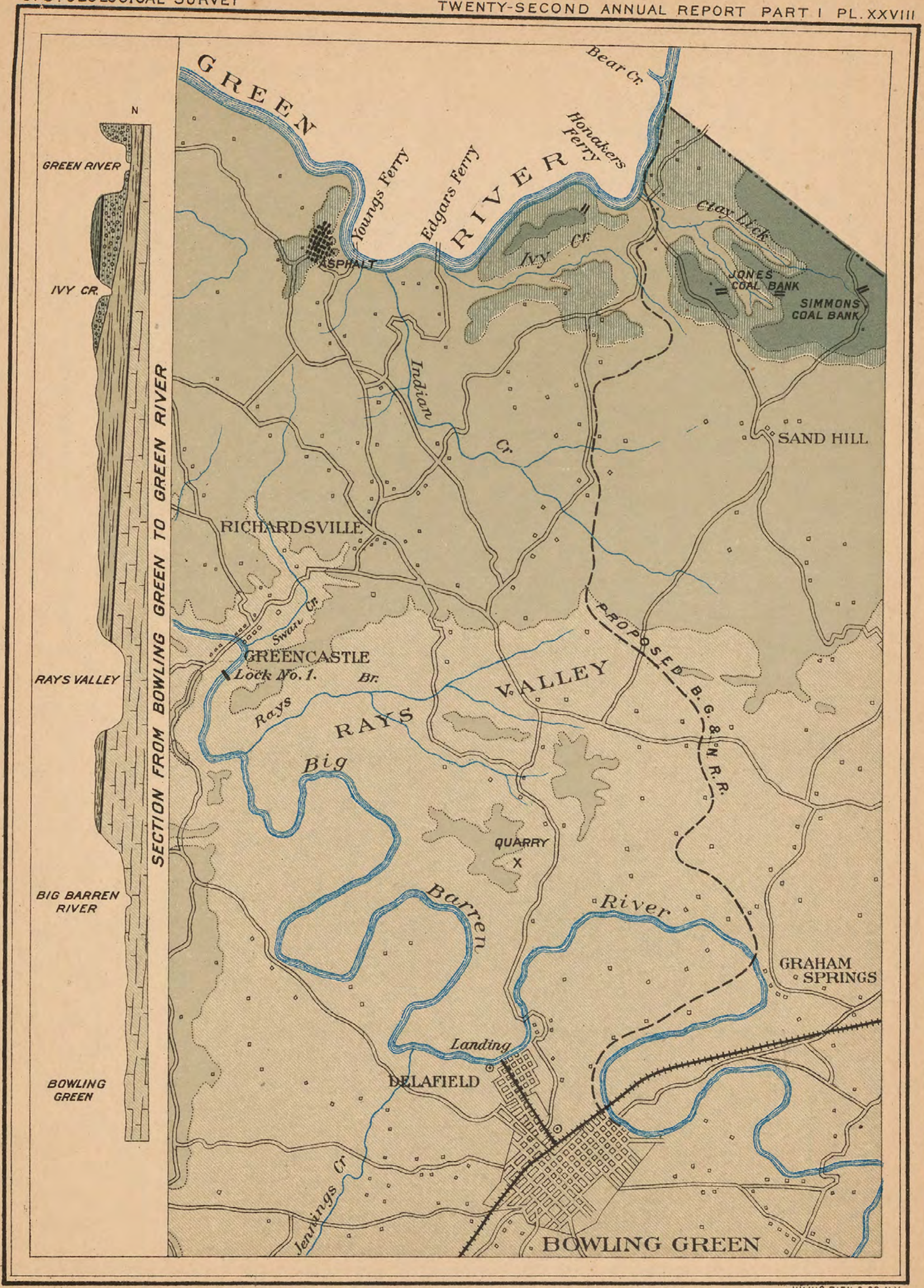
FIG. 12.—Section of bituminous sandstone at Youngs Ferry, Warren County, Ky.

STRATIGRAPHY.

The stratigraphy of the region is shown in fig. 12. It includes portions of the Chester and the Coal Measures, extending from the roofing limestone of the former to the first sandstone above the conglomerate in the latter.

This horizon has been established not only by the lithologic features of the beds in the locality itself, but by a section of the strata carefully followed by Mr. Averitt from Bowling Green to Green River. In this the successive measures from the well-known St. Louis limestone to the Roofing limestone of the Chester have been encountered, considerably at variance with the more northern sections, it is true, yet in general sequence and in the fossil contents of the limestones admitting of clear determination.

The Coal Measures, too, bear considerable resemblance to those of the Bee Spring section, although the homologue of the main Nolin coal was not here found. A seam is reported to occur, however, on what is believed reliable authority, in the series of beds between the conglomerate and overlying sandstone, that once outcropped in the



JULIUS BIEN & CO. N.Y.

PART OF WARREN COUNTY, KENTUCKY

From Kentucky Geological Survey, John R. Procter, Director

Bituminous sandstone location by George H. Eldridge

Scale

1 0 1 2 3 4 5 MILES

CARBONIFEROUS: Coal Measures; Conglomerate (*Locally bituminous*)

UPPER SUB-CARBONIFEROUS: Chester group; St. Louis limestone neighboring ravine, though now covered with débris. In this case similarity between the sections would be quite complete. Two beds of coal also outcrop in adjoining hills to that in which the bituminous sandstone occurs, one of which at least is of a higher horizon than this sandstone; the other is in some doubt.

The salient feature of the section at Youngs Ferry is the basal sandstone, heavily conglomeratic in the lower part but less above. This forms lofty and picturesque cliffs not only in the bluffs of Green River, but also in those of its tributary ravines. Above the conglomerate the hills are somewhat rounded, consistently with the shaly nature of the overlying beds and the thinner sandstones which there prevail. Below the conglomerate the banks are steep of slope, but in accord with a succession of limestones and shales. There is a general and pronounced dip of the beds 5° to 7° to the northwest, which also asserts itself in the topographic features of the hills. The general level of the hilltops is found by the engineer of the Green River Asphalt Company to be 292 feet above low water in Green River, while the maximum difference between low and high water is reported as 44 feet.

Two openings, about 300 yards apart, have been made in the bituminous deposits of this locality. One, the eastern, near the summit of the ridge, is being developed by the Green River Asphalt Company; the other, the western, is controlled by the Sicilian Asphalt Company, but has remained idle since the shipments of a few tons of trial rock.

DEPOSIT OF THE SICILIAN ASPHALT COMPANY.

This deposit, an impregnated zone in the basal conglomerate of the Carboniferous, is about 10 feet thick and occurs about 15 feet beneath the top of the stratum. The enriched rock continues for an undetermined distance to the west, but on passing eastward the bed seems to become barren; this, too, within a few hundred feet. The matrix of the impregnated zone is essentially quartz sand, a few pebbles being distributed through it in small assemblages here and there. As in other instances, the lower half of the zone is the richer, carrying at the old quarry breast about 7 per cent of bitumen. The bitumen continually seeps both from the face of the small opening and from the outcrop, forming small pools a few inches across at the base of the ledge. The horizon of the conglomerate is a little indefinite, but by those engaged in opening the eastern quarry is believed to be the same as theirs, that is, the first sandstones over the actual basal conglomerate, here somewhat modified by the presence of pebbles. This view is also held by Mr. Averitt, who made a detailed study of the locality. The slopes in the vicinity of the Sicilian quarry are so covered as to prevent a clear observation of conditions.

DEPOSIT OF THE GREEN RIVER ASPHALT COMPANY.

The deposit of the Green River Asphalt Company is in the bitumen-bearing sandstone overlying the main basal conglomerate, from which it is separated by 20 to 30 feet of yellow and gray shale. The bed, as exposed at the time of examination, showed a thickness uncovered of about 6 feet, all impregnated, but in varying degree, the lower 2½ feet of excellent promise. The sample taken by the writer within 5 or 6 feet of the outcrop, yet in normal-looking rock, yielded about 7 per cent of bitumen. At one point the upper portion of the bed, also, showed considerable enrichment, indicating that upon passing beneath cover the entire 6 feet might become available for shipping.[1] The matrix of the rock is a clear, sharp, quartz sand.

Of the two localities of bitumen-bearing beds, that developed by the Green River Asphalt Company is obviously the more favorably situated for economical working, for, by reason of its slight cover, it may be quarried. The Sicilian deposit, on the contrary, may require mining, the cover being heavy. The presence of pebbles, also, will affect the value of the latter rock. In the ridges to the northwest, into which the beds may be traced, the difference in the advantage of position will be materially lessened, as the dip carries both well beneath their summits.

The Green River Asphalt Company at the time of the writer's visit were preparing for an extensive mining and shipping plant. The locality is especially advantageous, in that the water transportation of Green River is available to Evansville, Ind., from which point the product may be sent by rail or boat in almost any direction.

LOGAN COUNTY DEPOSITS.

The deposits of bituminous sandstone in Logan County lie in its northern half, in the Chester division of the Lower Carboniferous. A single quarry, that of the Standard Asphalt Company, has been opened, about 5 miles northeast of Russellville, in the Big Clifty sandstone. There is also a prospect about 2 miles northwest of this at the same horizon. Mr. Averitt also reports one or two other deposits, unopened, at this horizon, near Homer, still farther north.

The St. Louis limestone is the superficial formation over a large portion of Logan County. Two or 3 miles north of Russellville, however, after a sharp rise of 50 to 100 feet just beyond Muddy Creek, this is overlain by 3 or 4 feet of greenish marl followed by the Big Clifty sandstone of the Chester, here 40 to 50 feet thick and very coarse grained. The Big Clifty now, according to Mr. Averitt, occupies all the higher ground to the county line, a single excepted area

[1] Mr. Averitt, who visited this quarry several months after the writer, found a face of 15 feet, all impregnated with bitumen.

being reported in a knob 7 miles north of Russellville, where traces of the first Chester limestone are present. The whole series of beds dips 3° or 4° north or northwest.

QUARRY OF THE STANDARD ASPHALT COMPANY.

The quarry of the Standard Asphalt Company is opened near the head of a sharp ravine in the Big Clifty sandstone. There are here exposed (see fig. 13) about 15 feet of bitumen-bearing sandstone, in a face 100 feet long. The upper 4 or 5 feet is lean. Below this the 10 feet of sandstone remaining carries an increased amount of bitumen, though the face clearly shows the rock to be more or less streaked. In the lower 5 feet, however, the bitumen contents at the face will probably average about 7 per cent. It is from this lower portion of the bed that the mass of the shipments is said to have come. Here, as elsewhere, the increase in the thickness of the enriched portion by the addition of layers at the top, upon entering the hill, is noticeable. Further development of the quarry will be attended with increased cost by reason of the opening being 40 or 50 feet below the crest of the hill. The outlet for the product of the mine is by Russellville.

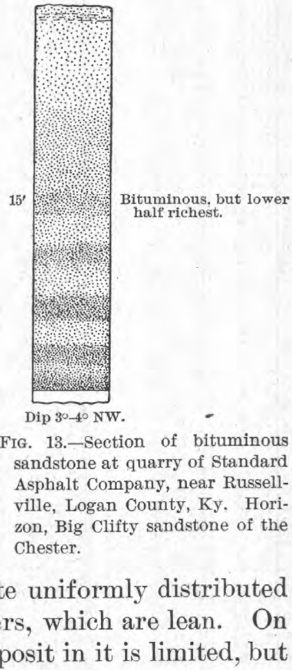


FIG. 13.—Section of bituminous sandstone at quarry of Standard Asphalt Company, near Russellville, Logan County, Ky. Horizon, Big Clifty sandstone of the Chester.

OTHER DEPOSITS.

Two and a half miles northwest of the Standard quarry is a prospect which shows 4 or 5 feet of bituminous sandstone of the Big Clifty horizon near the top of a knoll or ridge, 75 or 80 feet above Muddy Creek. The impregnated sandstone probably carries an average of 6 or 7 per cent of bitumen, quite uniformly distributed through the bed except in the uppermost layers, which are lean. On account of the narrowness of the ridge, the deposit in it is limited, but it is possible that it may be traced to areas less divided by ravines than the immediate bluffs of Muddy Creek. The region of the deposit is somewhat inaccessible.

MISSOURI.

The region about Higginsville, Lafayette County, is the only portion of Missouri in which bituminous rock has thus far been found, with a possible exception near Odessa, 15 miles west, where, also, evidences are said to exist. The only attempt at development has been by the Higginsville Quarry Company, on land near the Soldiers' Home, 1½ miles northwest of town, where a pit 20 feet in diameter has been made for trial purposes.

GEOLOGICAL FEATURES OF THE BITUMEN-BEARING HORIZON.

The region about Higginsville is high, rolling, fertile, and well settled, with topography developed from horizontal or slightly dipping strata.

The formations of the surrounding country are given in the following section by Mr. Arthur Winslow, from his "Report on the Higginsville Sheet," in Volume IX of the Reports of the Geological Survey of Missouri, page 22.

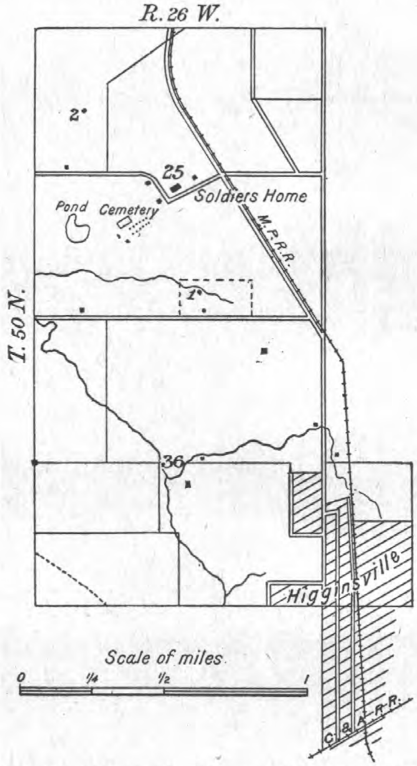


FIG. 14.—Higginsville, Mo., and adjacent region; from a local land plat. The entire area, except the southwest corner, is occupied by the Warrensburg sandstone. 1. Quarry, Higginsville Quarry Company. 2. Prospect.

The geological horizon of the bituminous deposit is the Warrensburg sandstone, of which, on page 45 of the same report, Winslow gives the following account:

It derives its name from the town of Warrensburg, a few miles south of Higginsville, where it obtains a great development. It consists of a great body of sandstone, changing irregularly into shale and shaly sandstone, with no coal or limestone beds interstratified. Its relations to the surrounding Coal Measures are peculiar; it does not overlie these strata, but cuts across them, apparently occupying a depression which once existed where the sandstone now is.

After adducing many facts in support of this view, Mr. Winslow continues:

The true stratigraphic and structural relations of this formation seem not to have been recognized. It appears generally to have been considered of Lower Coal Measure age and to have been correlated with the interstratified sandstones of the Lower Coal Measures. The peculiar conditions of occurrence of this formation have, however, received no satisfactory explanation in print, to the writer's knowledge.

The theory here advanced concerning this deposit is that it is of fluvial or lacustrine origin, that it fills a channel which was eroded in the surrounding regularly deposited strata during a temporary emergence of these strata from beneath the waters of the Coal Measure swamp.

Mr. Winslow then assigns his reasons for such conclusions.

The results of his broad observation of the lithologic character of this formation are embodied in the following:

It is a soft sandstone, always micaceous, generally very friable, frequently excessively false bedded, grading rapidly into arenaceous shale, almost always ferruginous, and of yellow and brown colors. It seldom has sufficient coherence to be of value for structural purposes, especially within this [Higginsville] sheet; in fact, it is sometimes so soft as to be excavated with pick and shovel. In the neighborhood of Warrensburg and at other points in the shale it becomes locally coherent and is extensively quarried for building purposes. It is there also of a gray or faintly yellow color, containing much less iron than at other points. * * * It is to be anticipated that the deposition of the sandy material was not confined entirely to the main channel, but that there were tributary channels and thus that tongue-like lateral extensions of the formations once existed. These are probably in part removed by erosion, in part remain concealed. The general direction of the main channel appears to be approximately north and south. The town of Higginsville rests upon it.

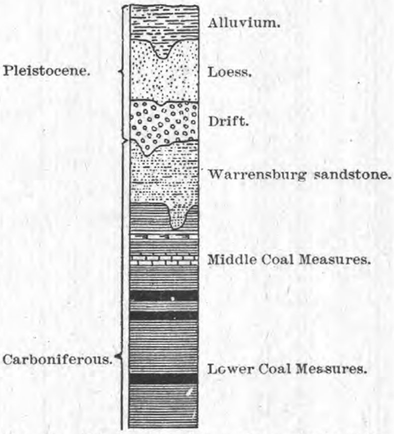


FIG. 15.—Diagram showing the geological formations exposed in the region of Higginsville, Mo.

HIGGINSVILLE QUARRY COMPANY.

Fig. 16 is a section of the quarry face. In lithologic features it accords with the foregoing description, except that the strata carry bitumen in variable amount, a sample from a stock pile derived from the richer middle beds of sandstone yielding 8½ per cent. The shaly layers, as well as the sandstones, are impregnated in a slight degree, being themselves more or less arenaceous. The quarry strata are overlain by blue and yellow shales and thin, shaly sandstones, but impregnation ceased practically at the upper layer of the quarried rock. Below, however, in the banks of the neighboring wash, strata of the same nature as in the face of the quarry appear, these impregnated to some extent with bitumen. It is, though, impossible to estimate the depth to which impregnation has affected the strata, or to surmise the actual lithologic features of the beds below. A neighboring well drilled many years ago for oil to a reported depth of 900 feet affords no record. The lateral extent of the bitumen-bearing sandstone is undetermined, as it is generally concealed beneath superficial detritus.

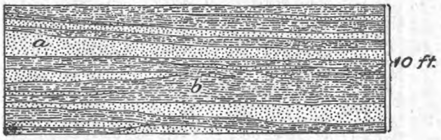


FIG. 16.—Quarry face, Higginsville Quarry Company, Higginsville, Mo. Sandstones and sandy shale alternate irregularly; all bituminous. *a*, sandstone; *b*, shale.

The uncertainty of thickness, the partings of shales, with their diminished supply of bitumen, the fineness of grain, and the composition of the rock itself, militate somewhat against its value as a paving material, although for extraction purposes it might be used. The primary constituents of the rock are extremely minute grains of quartz and brown mica, of which the latter mineral is abundant, imparting a shaly cleavage even to the sandstones.

INDIAN TERRITORY.

INTRODUCTORY.

The area of Indian Territory within which asphalt and bituminous rock deposits have been found lies wholly south of the Canadian River, but extends from Arkansas to Oklahoma (see Pl. XXIX). Its surface features vary according to the geological formations that underlie and the structure that has been developed. The eastern half is the more rugged, occupied as it is by the western end of the Ouachita Mountains. The western half, though relieved by the Arbuckle Mountains and Criner Hills, has a considerable proportion of prairie, modified by the characteristic erosion of streams cutting horizontal or gently rolling strata. The entire region is picturesque in the distribution of its timbered areas, its open prairies, and its cultivated fields of grain and cotton.

The geological formations outcropping south of the Canadian River, with their leading features, are tabulated below:[1]

Table of geological formations exposed south of Canadian River.

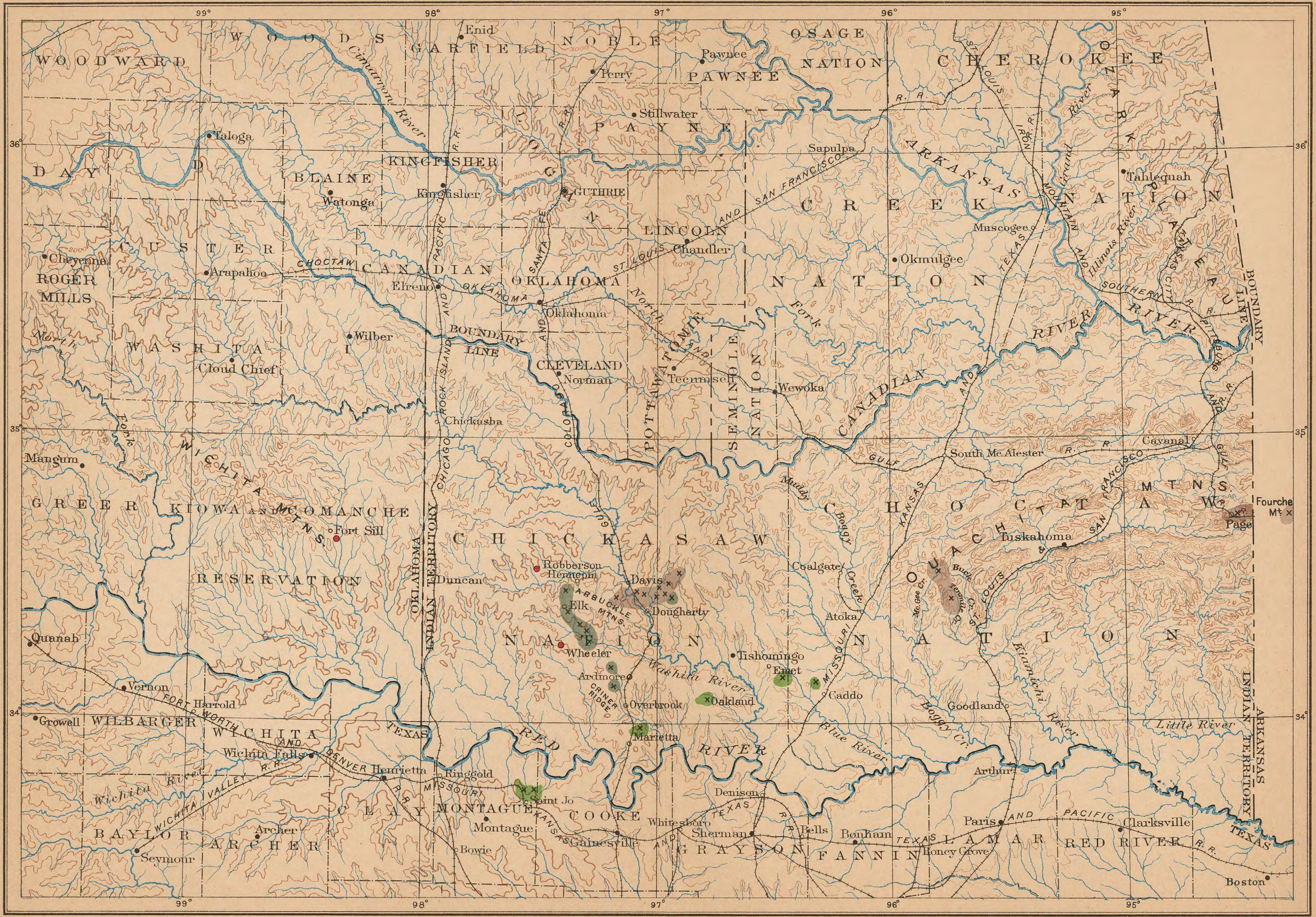
			Thickness.[2]
Pleistocene		River sands[3]	(?)
		Guertie sands	50
Cretaceous	Upper	Austin chalk	450
		Eagle Ford shales	550
		Dakota sandstone	200
	Lower	Bennington limestone	10
		Bokchito shales	150
		Caddo limestone	60
		Kiamichi clays	100
		Goodland limestone	25
		Trinity sandstone[4]	200–400
Carboniferous	Permian	Red Beds—sandstone[4] and shales	7,000
	Upper Coal Measures	A series of seven horizons of undetermined relations	2,135
		Thurman sandstone	80–260
		Boggy shale	3,000
		Savanna sandstone	1,150
		McAlester shale	2,000
	Lower Coal Measures	Hartshorne sandstone	200
		Atoka formation	3,100
		Wapanucka limestone	120
	Mississippian	Caney shale[4]	800
Silurian	Upper	Lower Helderberg limestone	140
		Niagara limestone	60
	Lower (Ordovician)[4]	Hudson River, Utica, Trenton: Shales and limestones	8,000
Archean?		Tishomingo granite	(?)

[1] In the compilation of the above table, as well as in many other instances in connection with the stratigraphy and structure of Indian Territory, the author has been generously aided by Messrs. Taff and Adams, of the Survey, whose especial region of research this Territory is. The entire classification of the Carboniferous and that of the upper half of the Lower Cretaceous is the work of Mr. Taff.

[2] Thicknesses are approximate, and subject to local variations.

[3] "Sands," "shales," etc., indicate the predominant feature of composition.

[4] Carry bitumen either in veins or as impregnations of limestones or sandstones.



JULIUS BIEN & CO. LITH. N.Y.

MAP OF INDIAN TERRITORY, OKLAHOMA AND TEXAS

Showing locations of bituminous rock, by G. H. Eldridge

- ASPHALT SPRINGS
- BITUMINOUS ROCK (CRETACEOUS)
- BITUMINOUS ROCK (COAL MEASURES)
- BITUMINOUS ROCK (ORDOVICIAN)

Scale

25 0 25 50 75 MILES

Contour interval 250 feet.

The geologic structure of southern Indian Territory is complex, but centers about the two or three well-developed folds of the Ouachita, Arbuckle, and Criner mountains. These folds are anticlines modified by secondary folding and by faulting. The general trend of the Ouachita system of folds is a little north of east; of the Arbuckle and Criner, northwest. The Criner flexure, however, is of barely greater importance than many that exist in the regions between the Ouachita and Arbuckle mountains, and in the surrounding prairies. It is an exposure of the more resisting Ordovician strata in the midst of a lower country underlain by Coal-Measure shales.

REGION OF THE OUACHITA UPLIFT.

TOPOGRAPHIC AND GEOLOGIC FEATURES.

The Ouachita uplift covers an area of about 4,000 square miles, lying between meridians 92° 30′ W. in Arkansas, and 96° W. in Indian Territory, and has a width north and south varying from 10 to 30 miles. It is coincident with the region of the Ouachita Mountains between the Canadian and Red rivers.

The topographic features are those of ridge and valley in rapid succession, marked by parallelism of arrangement in harmony with stratigraphy and structural development. The trend of the ridges is prevailing ENE., but curvature of line is also present, coincident with the directions assumed by the outcrops of the underlying strata. The ridges, as a rule, are occupied by the harder beds—sandstones and limestones—while shales prevail in the valleys. Sharpness of folding, the rapid succession of diversified strata, and erosion have produced an area of marked ruggedness. The valleys are but sparsely cultivated, and ridges and valleys are often heavily timbered.

The formations involved in the Ouachita uplift, and hence in the mountains coincident, are of Ordovician and Carboniferous ages, the latter lying about the periphery of the area occupied by the former. Along the southern side of the uplift the lower slopes of the fold are overlain, unconformably, by early Cretaceous beds of the Comanche series, these extending practically horizontally beneath the prairie to the south, and to the region of the Red River.

It is in the Ordovician that the asphalts of eastern Indian Territory occur. As at present accepted this consists of several thousand feet of a succession of heavy gray sandstones and gray to bluish shales, the whole overlain by a limestone in which Ordovician fossils have been recognized.[1] Beneath this series lies one of black shale, thin limestone bands, and cherts, which Mr. Taff considers the horizon of the Arkansas novaculites. This also is regarded as of Ordovician age.

The Ouachita uplift is not that of a simple anticline, but is rather an

[1] An albertite-like asphalt in the Choctaw Nation, Indian Territory, by Joseph A. Taff: Am. Jour. Sci., Sept., 1898, 4th series, Vol. VIII, p. 224.

elevated system of folds accompanied by minor crumpling and much fracturing, folds and faults preserving a greater or less degree of parallelism and following in their trend that of the general axis of uplift. Strikes and dips, however, vary according to locality and the position of a bed in the fold in which it is involved. In crossing the system, therefore, many changes in the trend of outcrops and many intricacies of structure are encountered, and the more in some places because of the severe crumpling, even overturning, to which the strata have been subjected.

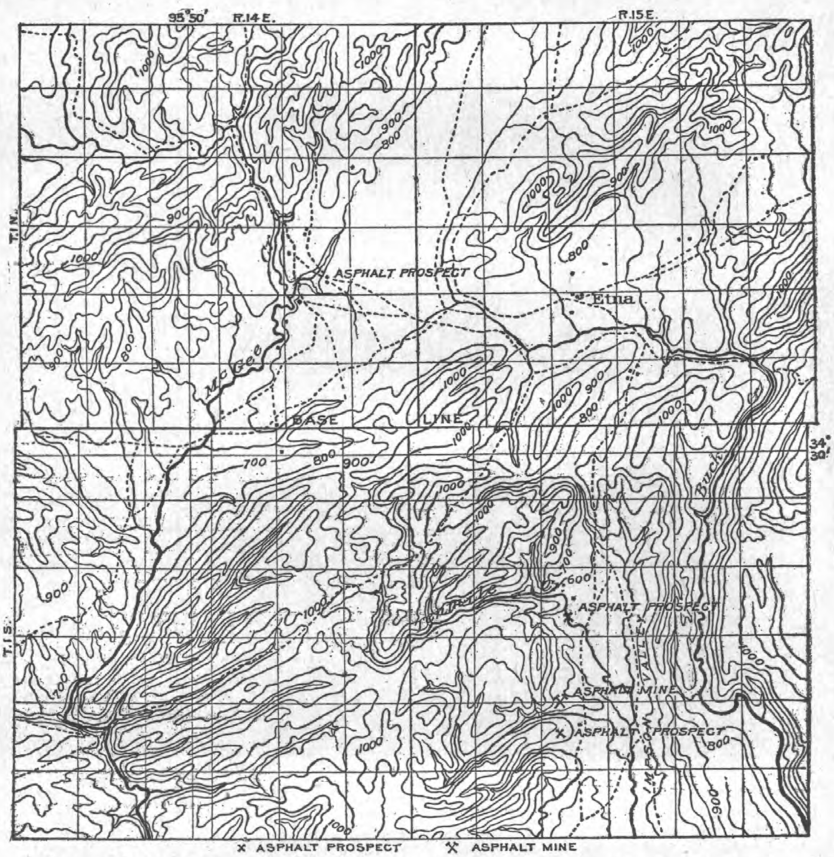


FIG. 17.—Map of Tenmile district, Indian Territory, showing location of asphaltites.

The known localities of asphaltic material in the region of the Ouachita uplift are: Tenmile Creek and adjacent country, a little southwest of the center of the Choctaw Nation; near Page, 70 miles east of this; and a few miles across the line from the last, in Arkansas.

TENMILE DISTRICT.

Geologic features.—The portion of Ouachita uplift of immediate interest in the present discussion is the western end of the general fold, and more particularly that part of it included within the area of Ordovician rocks, in the region of the headwaters of McGee, Buck, and Tenmile creeks, and of Jack Fork. Numerous flexures and faults appear, by which a reduplication of strata—sandstones and shales—has been induced, followed, under the influence of erosion, by the development of the ridge and valley topography so characteristic of the region. Of the faults Mr. Taff[1] says:

Three lines of faulting bearing northeast and southwest, and having displacements of many hundred feet, extend along the southeast sides of the group of hills through the center of T. 1 N., R. 14 E., of the Jack Fork Hills, in the center of T. 1 N., R. 15 E., and of the hill in section 3, T. 1 N., R. 15 E., respectively. The latter two lines of faulting extend from the ends of the hills southwestward into the plain toward the asphalt exposures. Another zone of faulting extends from the plain nearly 2 miles east of Etna, bearing southwestward, crossing the center of the south side of T. 1 N., R. 15 E., thence nearly due south along the west side of Impson Valley. The asphalt mines of this valley are located along this fractured zone.

Of the folds, that of immediate concern is an anticline of which the axis lies north and south along Impson Valley, the northern end of the valley and of the anticline being practically coincident. Broad regularity, perhaps, exists in the rise of the arch, but crumpling is present, and it is along the western side of the valley and of the fold that Mr. Taff has located the zone of faulting above referred to. Even to the casual observer there are evidences of crushing in the shales and sandstones occurring here.

THE ASPHALTITES.

Physical and chemical features.—The asphaltite of eastern Indian Territory is of the vein-forming variety, and at least in one instance more closely resembles albertite than any other member of the asphaltite group. This differs from albertite, however, sufficiently, it is thought, to warrant a distinctive name, and for this, impsonite is suggested, after the valley in which it is chiefly found. The mineral in color and streak is jet black; in luster, brilliant. Its original appearance was probably that of the other hard asphalts, homogeneous, amorphous, or structureless, of fracture conchoidal; but there has since been developed throughout the mass a hackly fracture, materially altering its aspect and increasing its brittleness, the mere pressure of the fingers now crumbling it to almost dust-like particles. Occasionally a trace of penicillate structure may be seen next to the vein walls.

In regard to the chemical and physical features brought out in a study of impsonite, Dr. William C. Day observes:

The material is extremely brittle, pulverizing almost at a touch; it takes fire readily. It shows no sign of conchoidal fracture. Heated in a tube, it does not melt, but softens, and gradually cokes progressively, without becoming liquid at any one time.

Distillation of the asphalt from a retort showed that it does not entirely melt at

[1] An albertite-like asphalt in the Choctaw Nation, Indian Territory, by Joseph A. Taff: Am. Jour. Sci., Sept., 1898, 4th series, Vol. VIII, p. 224.

any one time, but softens and decomposes simultaneously, like a coal. The distillate is dark red by transmitted light and shows a decided green fluorescence. For sake of comparison, a quantity of soft coal used for making coal gas and obtained from a gas works was distilled. This gave a more tarry distillate, but less in amount for equal weights of material. The odor of the distillate from the coal was markedly different from that from the asphalt. The coal was practically insoluble in carbon disulphide, while the asphalt was soluble to the extent of over 35 per cent.

The material, all things considered, resembles albertite more than any other of the asphalt substances, but it differs from it, too, in certain respects. For the sake of comparison, the data contained in Dana's Mineralogy on albertite are placed here side by side with the corresponding data pertaining to the material supplied by Mr. Taff:

ALBERTITE.		MR. TAFF'S MATERIAL.	
Specific gravity, 1.097.[1]		Specific gravity, 1.175.	
Color, jet black.		Color, jet black.	
Softens a little in boiling water.		Does not soften in boiling water.	
In the flame of candle, shows incipient fusion.		In flame of candle, shows incipient fusion and takes fire, burning for a short time after removal from the flame.	
Only a trace soluble in alcohol.		Only a trace soluble in alcohol.	
4 per cent soluble in ether.		5.34 per cent soluble in ether.	
30 per cent soluble in turpentine.		Almost insoluble in turpentine.	
Per cent of carbon as found by Wetherill	86.04	Per cent carbon	86.57
Per cent hydrogen (Wetherill)	8.96	Per cent hydrogen	7.26
Per cent nitrogen (Wetherill)	2.93		
Per cent nitrogen (Day)	1.84	Per cent nitrogen	1.48
Per cent sulphur (Wetherill)	Trace.		
Per cent sulphur (Day)	.17	Per cent sulphur	1.38
Per cent oxygen (Wetherill)	1.97	Per cent oxygen	2
Per cent ash (Wetherill)	.10	Per cent ash	1.31

Of the differences between albertite and the Taff asphalt the contrast in the solubility in turpentine is perhaps the most striking. While the material submitted by Mr. Taff resembles a coal in the way it softens and decomposes under the influence of heat, instead of entirely melting as asphalts generally do, the distillation products are markedly different from those of coals, in abundance, in fluorescence, and in odor.

As a result of examining the analytical figures given in Dana's Mineralogy for a long list of coals, I can find none which even approximate those found for the material in question. The solubility in carbon bisulphide classes the material with the asphalts rather than the coals. The analytical figures and the solubility show that the material resembles albertite from Nova Scotia more than any other of the asphalt-like bodies which have thus far been investigated.

Occurrence (*Moulton mine*).—The conditions under which the asphaltic mineral thus described, impsonite, occurs are best shown at the mine of Mr. George D. Moulton, in the Impson Valley, 25 miles east of Atoka, a station on the Missouri, Kansas and Texas Railroad, and 16 miles northwest of Antlers, on the St. Louis and San Francisco Railroad. More exactly located, the mine is in the northwest quarter of sec. 28, Tp. 1 N., R. 15 E. The developments consist of two shafts, 35 and 53 feet deep, respectively, and two levels 20 and 35 feet beneath

[1] The specific gravity of Nova Scotia albertite is 1.074 at 20.9° C.

the surface, the upper extending for 120 feet on the vein, the lower for 55 feet. On the latter level the two shafts connect by a crosscut 33 feet long. The entire opening is more of the nature of a prospect than a mine.

The mineral occurs as a vein of uncertain dimensions in a body of greenish clay shales that are included between sandstones 100 to 150 feet apart. The general strike of the measures in the immediate local-

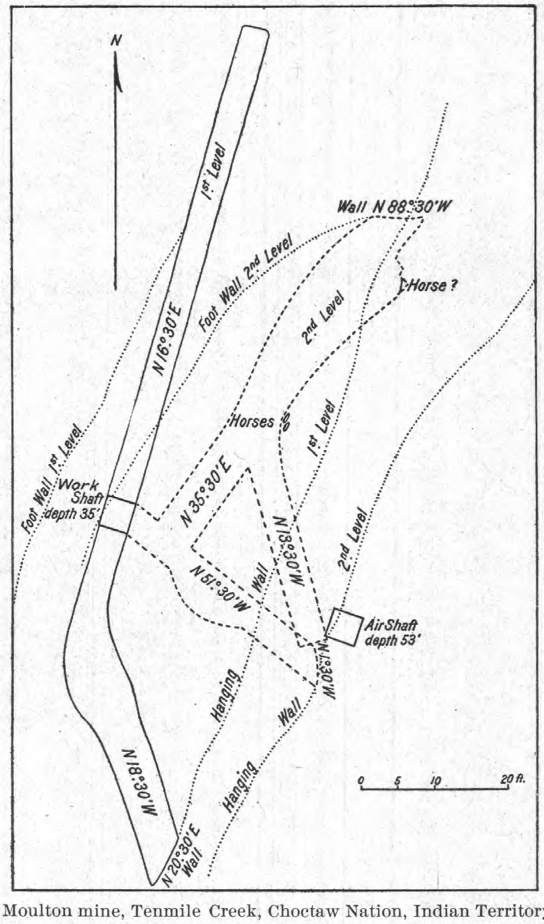


FIG. 18.—Plan of Moulton mine, Tenmile Creek, Choctaw Nation, Indian Territory. Solid line, first level; broken line, second level; dotted line, walls.

ity is about N. 10° E., a direction veering more to the east farther north. The dip of the strata is 85° west to vertical. The crack in the shales filled with the asphalt, for such is the nature of the deposit, has a N. 15° to 20° E. trend, and pitches eastward 45° to 65°, cutting the shales. There has been such movement, however, in both vein and country rock that the actual, broad conditions can only be inferred from the small exposure available for observation. The form of the deposit, uncertain in dimensions and of general irregularity of walls, is that common to all bodies of asphalt in shale. The sketch, fig. 18, is in a measure hypothetical, the outline of the body being inferred from observations in the drifts. From the nature of the occurrence it is impossible to say what may be the linear extent of the asphalt-filled fissure, and whether it be completely, and often, interrupted, or is a vein of considerable continuity but of variable width. The same uncertainty applies in depth. Throughout the opening the walls of the deposit are encountered with irregular trend and pitch.

From the examination of the mine and the region in which it is situated, the suggestion arises that the fissure that has been developed, if not itself of great continuity, may at least be one of a series in close proximity and distributed along the length of the faulted zone referred to above. In evidence of this are the three or four small asphalt bodies outcropping along the trend of the faulted zone, one a third of a mile south of Mr. Moulton's opening, the others a mile or two north. Such fracturing, of considerable linear extent, may also have considerable depth. The region, therefore, may be one of numerous fissures of broken and limited continuity.

The size of the particular deposit mined by Mr. Moulton is undetermined, nor, indeed, can it be known except in the course of development or careful prospecting. All that is assured is indicated in the sketch, fig. 18. The utility of the mineral in dipping varnishes, etc., seems assured.

Besides the deposits just referred to, other evidences of an apparently similar asphaltite exist in a small outcrop and prospect on McGee Creek, 5 miles west of Etna, and again in the wash of a tributary of this creek about 5 miles southwest of the latter occurrence. In the vicinity of the Moulton mine, also, maltha is found seeping from some of the sandstones, especially from one a half mile west in a ravine tributary to Impson Valley.

Comparison with albertite of New Brunswick.—By way of comparison with the asphaltite described in the preceding pages, which bears many semblances to albertite, the following description of the occurrence of this mineral at Hillsborough, New Brunswick, has been summarized from an account by Prof. C. H. Hitchcock:[1]

The rocks are of Lower Carboniferous age and belong to the Acadian coal series. The lowest rock in the Carboniferous series is the albertite shale. This contains a large amount of hydrocarbonaceous matter. Certain layers of it at the Caledonia Oil Works, by a rude process, have yielded 30 gallons of refined illuminating oil to the ton. The greater portion of the shale will sustain a fire without the aid of other fuel. It contains immense numbers of fossil fish, almost enough to make one imagine they gave the shale its inflammable character. This series can not be less than 1,000 feet thick.

The second group of strata is a conglomerate, separated from the first by a narrow

[1] The Albert coal, or albertite, of New Brunswick: Am. Jour. Sci., 2d series, Vol. XXXIX 1865, p. 267.

bed of sandstone. Bits of Albert coal and shale constitute component parts of certain coarse sedimentary strata of this group and render them oleaginous. The thickness is unknown, probably from 100 to 200 feet.

There appears to be an anticlinal axis passing through this region, trending nearly 10° north of east.

There appears also to be a fault along or near this axis, displaying the usual phenomena of anticlinal fissures, and its location may easily be accounted for. The shale was not strong enough to sustain the bending, hence its layers were much twisted and fissured along a central line.

The coal (albertite) shows the effects of the crushing process no less plainly. It is much broken, even to grains, and needs no pick for its removal from the vein. It will flow as easily as heaps of corn, and therefore pains are taken to tap the vein in the right place and at the proper time. If by oversight the main shaft is not walled up very tight, the coal will stream through the crevices between the beams, to the great inconvenience of the workmen.

The general course of the vein is N. 65° E., but the coal (albertite) is repeatedly heaved southward by small faults. Its inclination is northwestward from 75° to 80°, often vertical. The body of the vein is extremely irregular, constantly expanding and contracting, both laterally and vertically. What is too narrow to be worked in one level enlarges to 6 and 12 feet a hundred feet lower, or the reverse; but in general the width increases in following down the vein. At the time of Percival's examination the vein was not considered workable 170 feet west from the old shaft. At lower levels the yield is remunerative 700 feet west and 2,300 feet east of the new shaft, which lies several rods west of the first. Whenever a displacement is met with the vein is not lost, because a film of the coal remains in the slip to indicate the location of the heaved portion. The widest part of the vein is said to be 28 feet.

The narrow portions of the coal are invariably contained in a harder rock; where the rock is softer the vein is larger. "Horses" are common. In such cases the cavity above, out of which the horse fell, is found to be filled with coal, so that the width of the coal at that level is equal to the usual width plus the width of the horse. Numerous small branches run off into the shales from the main vein. These are short and might be described as irregular and branching spines from a main stem.

The vein character of the deposit is seen more distinctly in the smaller openings. On the East Albert property two shafts have been commenced near the anticlinal line in the conglomerate over the shale. These reveal, at the depth of 30 feet, nearly 6 inches width of a richer and more beautiful coal than the Albert, gradually thinning out to the width of coarse paper at the surface, and most unequivocally cutting vertically across nearly horizontal layers of sandstone.

In addition to the foregoing there is an extended statement by Dawson in his Acadian Geology for 1868, page 231; and other writers also have discussed from time to time the occurrence of this series of minerals.

PAGE DISTRICT.

ASPHALTITES.

A deposit of an asphalt, perhaps of the same nature as that of the Moulton mine, occurs about 1½ miles east of Page, a station on the Kansas City Southern Railroad, a short distance west of the Indian Territory-Arkansas line. This is about 70 miles east-northeast of the Moulton occurrence, but in the same system of folds.

Mr. Taff, in an interview has described the locality in which the mineral occurs as typical of the more mountainous portions of the

Ouachita uplift, the immediate geology being that of a southward-tilted interfault block of Ordovician sandstones and shales, of which the strike is east-west, in harmony with that for the general uplift itself. This interfault block is known as Black Fork Mountain. Mr. Taff reports the mineral as filling what was once an open fissure of irregular dimensions that resulted from local crushing, or from this in the development of the more extended faulting which borders the interfault block on the south. The fissure was apparently opened both along stratification lines and across them at varying angles. Shales being involved, irregularity of fissure and vein resulted.

According to Mr. Taff the locus of the deposit is at the intersection of a minor transverse fault and the prevailing system of fracture, which, with the strike, has an east-west direction. Sandstones are opposed by shales along both lines. Spurs are given off from the main body of asphalt into the adjacent country. The vein has been opened but slightly, but sufficient to permit an opinion as to the size and configuration of the deposit, but the inference from deposits of like nature in other regions is that it is limited and of uncertain and variable dimensions.

The following description of a hand specimen of the asphalt collected by Mr. Taff is said by him to be applicable to the deposit as a whole. In appearance the mineral is lustrous black, with a structure of pronounced schistosity, developed, probably, by the pressure and movements which are so commonly evidenced in veins of the higher native asphalts when associated in part or in whole with shale. In addition to schistosity, which may be described as developed perpendicular to the vein walls, there has also been induced a banded structure transverse to the schistosity, the lines between the several zones being very sharp, and making well-developed divisional planes. A remarkable feature of the banding is the angles at which the faces of schistosity, so to speak, are set in alternating zones. This is shown in the high reflection of light in one series interrupted by darkness in the other. The effect is reversed upon a slight change of position. The texture of the asphalt is coarse to fine, according to the coarseness or fineness of the schistosity. While the material is friable, it is as a whole somewhat hard and resisting to atmospheric influences. The streak is black, and but slightly soils the hands.

BITUMINOUS SANDSTONE.

About a mile west of the Page deposit Mr. Taff observed sandstones impregnated with bitumen, but did not examine into details. A small hand specimen shows the rock to be composed of fine, sharp quartz, with a cement of bitumen, although whether this is the entire binding material is undetermined. The rock carries, perhaps, 6 per cent of bituminous matter.

FOURCHE MOUNTAIN DISTRICT, ARKANSAS.

Near the west end of Fourche Mountain, about 14 miles east of the locality just described, and about 10 miles across the border, in Arkansas, Mr. Adams, of the United States Geological Survey, has again observed traces in outcrop of apparently the same mineral as above. The position is about on the same line of faulting as the foregoing deposit, and the topographic and geologic conditions are practically the same.

REGION OF THE ARBUCKLE UPLIFT.

GENERAL SYSTEM.

The Arbuckle uplift finds its chief topographic expression in the Arbuckle Mountains. These form a conspicuous feature in the landscape of western Indian Territory. They lie at the center of the Chickasaw Nation and topographically occupy an area about 12 by 30 miles, west of the Washita River. They attain an elevation of about 1,400 feet above sea level, or between 600 and 700 feet above the surrounding prairie. Their general configuration is that of an oblong, flattened dome, the major axis with a trend N. 50° W. They are deeply incised with drainage channels, though their present water supply is limited. Slopes and summit are varyingly timbered, or open and grassed. But the full area of the Arbuckle uplift extends far beyond the topographic limits of the mountains, particularly to the southeast, across the Washita, where the constituent folds have, with erosion, induced a region of especial ruggedness, although of less height than that to the west.

The constituent formations of the Arbuckle Mountains are in the main of Silurian age, and include limestones, sandstones, and shales. They have been identified by their fossils as belonging to the Lower Helderberg, to the Niagara, and to one or more divisions of the Ordovician, notably the Trenton. Carboniferous beds of Mississippian and Coal Measure epochs encircle the Silurian, the former rising to a considerable height upon the flanks of the central dome. This series also includes sandstones, an occasional limestone, and shales, the last underlying the prairies on all sides, and lending to the landscape marked contrast with the elevations composed of the more resisting, older strata. At the western end of the mountains, about 3 miles southeast of Hennepin, the lower slopes are crossed by a belt of steep dipping, crystalline, gray limestones and sandstones, which for a distance of at least 2 or 3 miles along the strike carry a considerable amount of disseminated glauconite grains, together with occasional traces of pyrite. The geological horizon of these beds was not determined beyond the fact that they appeared to lie below the great shale series of the Carboniferous.

The structure of the Arbuckle uplift is primarily that of a succession of folds of greater or less extent. Faulting on a considerable scale has also taken place. The trend of the folds is generally about N. 50° W., but variation on either side of this occurs. While the folds within the topographic limits of the Arbuckle Mountains have attained especial prominence, the system in its entirety is of far broader extent. For many miles out from the periphery of the mountains, the Carboniferous strata, including what may, indeed, prove to be sediments of Permian age, lie in highly inclined, often vertical, positions. The Coal Measure shales are especially crumpled in the broad valley to the south, high dips prevailing nearly everywhere. East of the Washita the folds still continue in both Silurian and Carboniferous, extending for a distance of 8 or 10 miles in this direction; here, however, the topographic development of the mountains is not now so pronounced, perhaps by reason of the severer crumpling which exists and the consequent easier removal of the beds by erosion. The nature of the Arbuckle uplift is well shown in the Lower Silurian strata in the series of canyons of the Washita River between the towns of Davis and Ardmore. The strength of the forces producing the uplift is clearly manifest in the sharpness and compression of the folds in their rapid succession, and in the minor thrust faulting that appears at many points. The western extent of the Arbuckle uplift is apparently a few miles west of the settlements of Hennepin and Elk, both which are situated on upturned Coal Measure shales. Beyond this the country is less rugged and its appearance indicates comparatively slight dynamic disturbance.

CRINER RIDGE.

Twenty miles south of the Arbuckle Mountains and about 6 southwest of Ardmore is a low ridge, of limited extent, known as Criner Ridge. Its geological features were not studied by the writer, but in the heart of the ridge are said to be exposed rocks of Silurian age,[1] which are probably of the same nature as those of the Arbuckle Mountains. Mr. Taff, as a result of late work, confirms this view. The structure is reported as complex, faults forming a notable feature, one especially prominent occurring along a portion of the northeast base of the ridge. The general strike of the beds for the region southwest of Ardmore is about N. 30° W. and the prevailing dip, though nearly vertical, appears to be northeast, indicating for the region a position on the southwestern side of a syncline between the Arbuckle Mountains and Criner Ridge, modified at the base of the latter by the fault referred to.

The persistency of the strike, N. 30° W., is distinctly evidenced in a

[1] Notes on a reconnaissance of the Washita Mountain system in Indian Territory, by R. T. Hill; Am. Jour. Sci., 3d series, Vol. XLII, Aug., 1891, p. 119.

band of conglomerate and sandstone which occurs in the shales of the Coal Measures, and from its resistance to weathering can be clearly traced as a low, comblike rise for many miles across the prairies. Doubtless, too, this conglomerate in a detailed study of the geology of the region under discussion would prove an important datum horizon. It is characteristic in its strength of development, its hardness, its gray to brown color, and its composition, the pebbles, including quartz, chert, and other fragmental matter, apparently derived, in part at least, from the harder members of the accompanying shales.

BUCKHORN DISTRICT.

GENERAL AREA OF WHICH THE DISTRICT IS A PART.

The region east of the Washita River, embracing the Buckhorn and several adjacent districts, is, in the extent, size, and richness of its bituminous deposits, one of the most important in the United States. It has an area of about 30 square miles directly tributary to the Atchison, Topeka and Santa Fé Railroad, Dougherty and Davis being the towns from which it is most easily accessible. The general position of the region is shown on Pl. XXIX, and a detailed map is given as Pl. XXX.

The geology of the region is a part of that of the Arbuckle Mountains both in structure and in stratigraphy. The two areas have been developed out of a single uplift, and the same series of beds is present both east and west of the Washita River. There is the single difference that in the eastern region certain strata have been heavily impregnated with bitumen that in the Arbuckle Hills have not been found productive. On the periphery of the latter area, however, other formations are bitumen-bearing, although in nearly every instance the deposits are of limited extent.

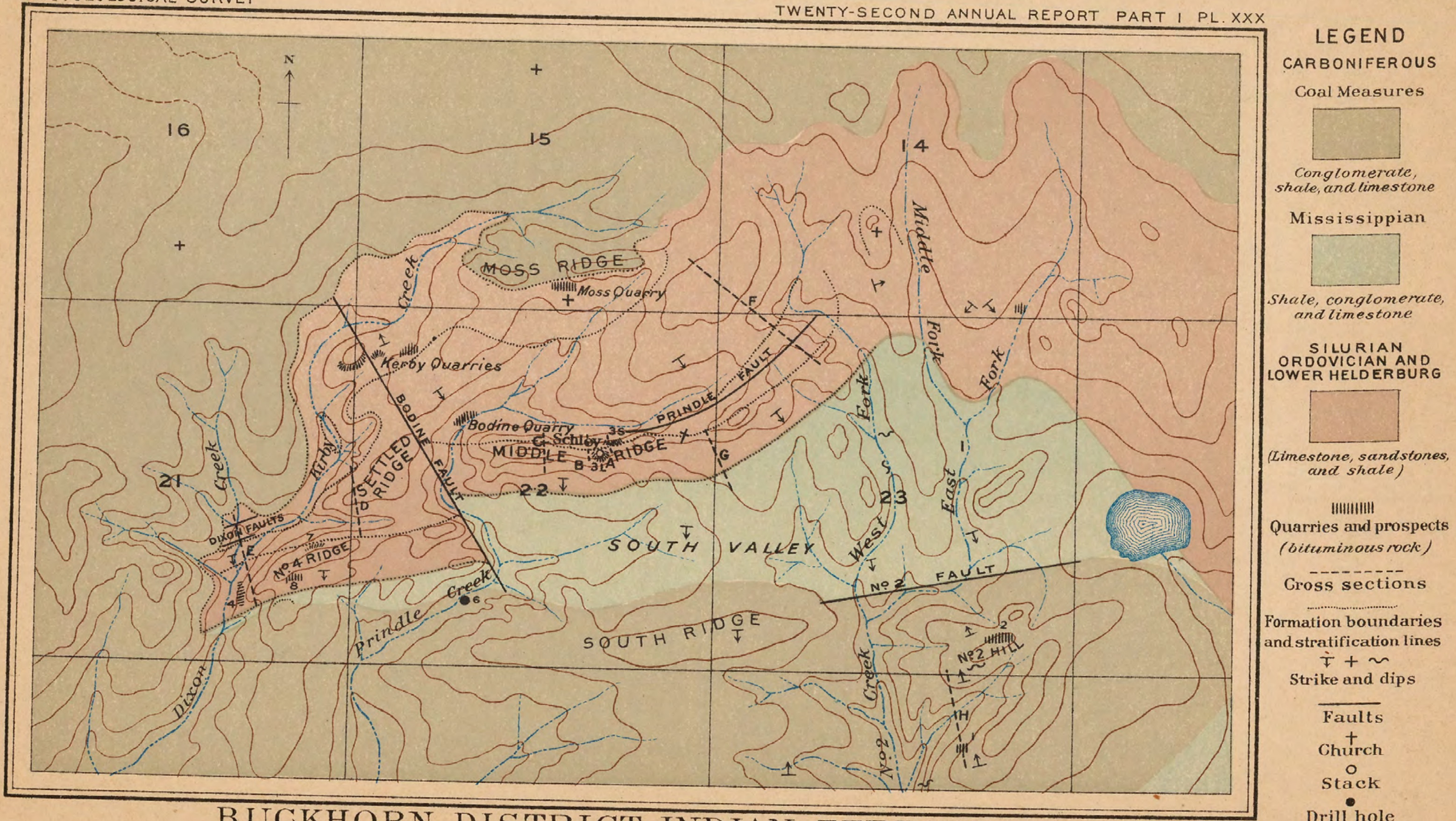
The topography of the region has been primarily influenced in its development by numerous folds of a secondary nature concomitant with the general uplift. Throughout, much crumpling took place, and the irregularity of the folding has imparted to the ridges of the present day a corresponding irregularity of trend, erosion following channels prepared for it by the lines of flexure and the variation of the sediments. Differences of elevation of 40 to 80 feet exist in the eastern half of the field, and of 100 to 300 feet in the more rugged, western half. Drainage is through Rock Creek, its tributary Buckhorn Creek, and a few laterals passing directly into the Washita. Rock and Buckhorn creeks carry excellent streams of water. The former occupies for the most part a sharply eroded, winding canyon or gorge in the resisting beds of lime and sandstone of Silurian age, while the latter flows through a synclinal trough in a broad expanse of Carboniferous shale. In the former instance, bottom lands are rare;

in the latter, the valley is open and under a high state of cultivation. The channels entering the Washita direct are sharply eroded and usually dry; they do not contain arable land. The western portion of the region under discussion bears a close relation in the trend and structure of its ridges to the Arbuckle Mountains proper, the walls of the Washita canyons clearly evidencing the continuity of the folds. In the eastern portion of the region, however, the folds, although of the same general system, display a certain degree of independence, and crumpling has been broad and comparatively gentle, yet withal pronounced. The region of bituminous rocks embraces but a small part of the entire area of uplift in this portion of the field, and it is, so far as known, confined to the northern side of the general flexure.

The name Buckhorn, which has been applied particularly to the eastern portion of the general area just referred to, is taken from a small post-office at its eastern extremity, or, it may be, from the creek of this name which borders the district on the south. There are no settlements within the confines of the district except that of Schley, developed in connection with the growth of the quarry industry, and the hamlet of Buckhorn above mentioned. Ranches are, however, scattered over portions of the region, and the valley of the Buckhorn is one of great fertility and much picturesque beauty.

THE FORMATIONS.

The geological series of the Buckhorn district embraces rocks of Ordovician, Lower Helderberg, Mississippian (?), and Coal Measure periods. The first two and the last have been identified by their fossils, determined by Dr. G. H. Girty, of the Survey; the Mississippian has not yet been recognized by its life. The assignment of a heavy body of limestone conglomerate and accompanying sandstones on the northern edge of the field to the Coal Measures is upon the authority of Mr. J. A. Taff, of the Survey, who has studied them in considerable detail. The nature of the several formations is indicated in sections A to I, profiles and vertical column, Pls. XXXI–XXXIII, and figs. 19–22. A marked variation is apparent in the thickness, succession, and composition of the beds, which may be due in part to sedimentation, in part to faulting; but there is also for the field in general a certain zone of comparatively slight variability and ready recognition that embraces about 200 feet in the middle of the series, and extends from the bituminous sandstone, the top of which is employed in the sections as their common datum-level (X of the vertical sections, Pl. XXXI), upward to the limestone known as the No. 3, so called from its constituting the rock of the No. 3 mine. The bituminous sandstone referred to may be known as the Bodine, from the pit in which it has been chiefly mined. It is a bed from 10 to 30 feet thick, is very persistent, and has been generally but variably impregnated. The limestone is also of importance as a horizon of reference, being individualized in its



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BUCKHORN DISTRICT, INDIAN TERRITORY

Scale

0 ¼ ½ 1 MILE

Contour interval 25 feet

lithologic features and its fossil contents, of marked persistency through the entire exposure of the Silurian terrane, and frequently bituminous. These two beds, with the more or less pronounced features of the intervening strata, form the most readily recognized zone of the field.

Sections in the Buckhorn district.—Following is the discussion of the sections shown on Pls. XXXI–XXIII:

SECTION A.

1. Limestone. Total thickness, 25 to 30 feet. Upper 5 feet coarsely crystalline; drab, weathering yellow-gray; distinctly fossiliferous; a trace of bitumen in the lower portion.

   The 10 feet below is in the main fine-grained. From 2 to 4 feet from the top, however, is a band carrying numerous small calcite bodies, round and elliptical, drab in color, and in general in marked contrast with the surrounding mass of rock. The rock is somewhat varyingly charged with bitumen up to a maximum of perhaps 6 per cent, a sample obtained from the upper portion of the No. 3 mine yielding 5 per cent. The calcite bodies are nearly or quite barren. It is obvious, therefore, that in proportion to their abundance the general average of the limestone in bitumen contents is lowered; this in addition to the variability in the per cent of the general rock mass itself. Veinlets of bitumen occur passing alike through the general rock and the calcite bodies. The lower 2 feet of this zone is less rich, and browner, than the overlying portion.

   The next 4 feet is fine to coarsely crystalline; light brown to black, more generally the former; fossiliferous, and bituminous. In this rock the bitumen is held between the crystals rather than within their individual masses. The upper layer of this band is faintly pisolitic. The lower portion shows brecciation as though from recementation of a fractured or disintegrated original. A birdseye appearance is locally imparted to the bed by the presence of numerous bodies of concentric structure, the origin of which is indefinite.

   The lower 5 to 10 feet of the bed are crystalline, drab, and nonbituminous.

   The entire bed of limestone is more or less jointed, an impoverished, chocolate-brown zone, ¼ to 2 inches wide, quite invariably lying on either side of the fracture planes. This limestone may conveniently be known as the No. 3 limestone, from its forming the mass of the rock of No. 3 mine of the Gilsonite Paving and Roofing Company. A hundred feet east of this section an outcrop of successive strata indicates for this limestone a possible thickness of 30 feet, but owing to local crushing this may be excessive. The features described for the mine sections above given are here repeated.
2. Hard, calcareous (?) quartzite; 2 feet.
3. Argillaceous shale, with calcareo-arenaceous layers; color, drab to yellow. Comminuted molluscan remains here and there.
4. Bituminous sandstone, as displayed at the quarry of the Gilsonite Paving and Roofing Company, composed of medium-sized, sharp, quartz grains, with bitumen filling the interstices. At the top is a layer of exceedingly hard quartzite, with a strong infiltration of carbonate of lime, similar to the conditions of occurrence at the easterly pit of the Kerby mines, three-fourths of a mile to the northwest. This cap is but irregularly impregnated with bitumen, the rock being conspicuously mottled black and white. The total thickness of the sandstone is here estimated to be at least 10 or 12 feet, 9 feet being exposed at the quarry. This sandstone, or one of the members of the same immediate series, is traceable over nearly the entire east and west length of the field, and is found to be varyingly charged with

bitumen, locally sufficiently so to give the rock an economic value. The name Bodine may be assigned it, from that of the pit at which it has been chiefly mined.

SECTION B.

1. Limestone. Heavy; crystalline; gray; the lower stratum, of about 15 feet, outcropping a short distance west of the section. No. 3 limestone, by trend from a recognized exposure should occur near the top of the series, yet no bitumen appears to exist in the succession here shown. The upper layer somewhat ferruginous and earthy.
2. Limestones prevail from this horizon up; quartzite-like sandstones prevail below.
3. The several quartzite-like sandstones are slightly ferruginous and, though weathered at the outcrop, are of a hard, solid nature. The cementing material for the grains is a homogeneous, white, clayey matter. A small per cent of carbonate of lime may also be present.

Shales fill the inter-quartzite spaces.

The lower portion of this series resembles the succession of quartzite and shale, Nos. 2 and 3 of Section A. The quartzites are fine-grained; the shale, yellow to drab.

4. Limestone. Crystalline; purple-gray; the bottom layer quartzitic.
5. Bituminous sandstone in fragmentary traces only.

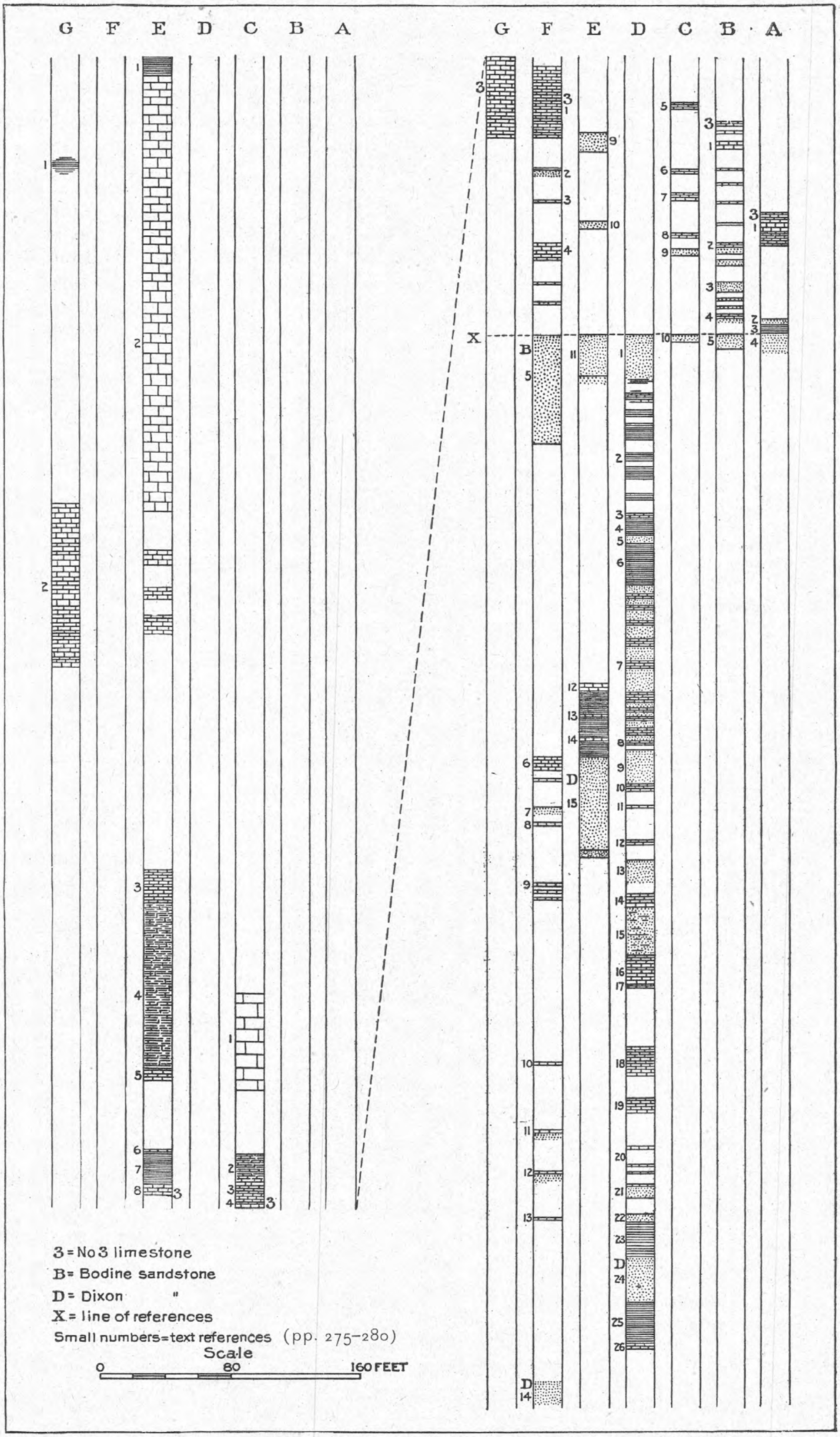
SECTION C.

1. Limestone. Massive; finely crystalline, but some bands coarser than others; unevenly bituminous throughout; traces of fossils. May be known as No. 4 limestone, from its occurrence as the rock mass of No. 4 mine.
2. Shale. Fine-grained; white; weathering brown; argillaceo-calcareous. A characteristic rock and one of considerable persistence.
3. Limestone. Fine-grained; white to buff.
4. Limestone. The No. 3; fossiliferous. (See Section A, Pl. XXXI.)
5. Limestone.
6. Limestone. Crystalline; brown; slightly bituminous.
7. Limestone. Crystalline; gray.
8. Limestone. Coarsely crystalline; purple-gray.

   The spaces between the outcrops 4–8 are indicated by the débris as occupied by strata of a calcareo-cherty nature.
9. This bed is the same as the upper member of the series of quartzites described under 3 of Section B.
10. Bituminous sandstone. Represented in vertical sections only. Similar in position to that of 4 and 5 in Sections A and B, respectively. Here opened in the Bodine pit and proved of high grade. The position given it in this section is in a degree estimated. (See description of Bodine pit.)

SECTION D.

1. Sandstone. Probably of the same horizon as 4 of Section A and 10 of Section C, but in the vicinity of this section (D) only locally and indifferently charged with bitumen. Color, normally light gray, but frequently found of yellow, red, and brown hues, and when impregnated with bitumen, bluish gray to black. Total thickness, 15 to 20 feet.
2. Shale with thin limestone, but very obscure.
3. Limestone. Gray, weathering brown; thin laminated, with fragments of fossils.
4. Shale, gray.
5. Quartzite. Thin laminated; a trace of bitumen.
6. Shale. Hard; fine breaking.



COLUMNAR SECTIONS, BUCKHORN DISTRICT, INDIAN TERRITORY.

7. Calcareous quartzites or hard sandstones. Thin laminated. Matrix or cementing material, crystalline carbonate of lime, the grains disseminated through it. Lower 50 feet, chiefly calcareous.
8. Limestone. Coarsely crystalline; friable; dark gray.
9. Quartzite. Extremely fine-grained; thin laminated; slightly calcareous.
10. Limestone. Coarsely crystalline; gray.
11. Limestone. Fine-grained; earthy; slightly ferruginous.
12. Limestone. Crystalline.
13. Quartzites. Heavy bedded.
14. Limestone. Crystalline; gray, weathering blue; slightly ferruginous between the crystals; 10 feet, in 6 to 8 inch beds.
15. Quartzitic sandstone. Fine-grained; thinly laminated; white, weathering slightly brown.
16. Limestone. Similar to 14.
17. Limestone. Coarsely crystalline; of gray, brown, dove, and ocher colors, which, however, are not persistent; ferruginous. A fine-grained yellow ocher deposit near the base, 3 inches thick.
18. Limestone. Crystalline; creamy gray, weathering blue; heavy bedded; ferruginous; slightly bituminous. Certain layers in it are pisolitic from ovoidal grains which display in some instances the peculiarity of having had their interiors removed and the cavities thus formed filled with bitumen that in a weathered portion is now brown and shrunken. Prospected.
19. Limestone. Crystalline; rough; brown to purple; crinoidal.
20. Several crystalline gray limestones in this space.
21. Quartzite or sandstone. Veined; somewhat conspicuous. At the creek bank, a short distance west, sharply overlain by a limestone which is slightly bituminous.
22. Sandstone. Locally persistent. At creek bank, a short distance west, slightly bituminous.
23. Shale. Near the base a prospect hole.
24. Sandstone. Heavy bed, of large areal extent, of bold outcrop. Soft, white or gray to yellow tinged, quartzose. A prominent stratum. May be designated the Dixon sandstone, from the Indian whose farm covers a considerable part of its area of outcrop.
25. Shale (vertical section). Gray to yellow; occasionally pyritiferous.

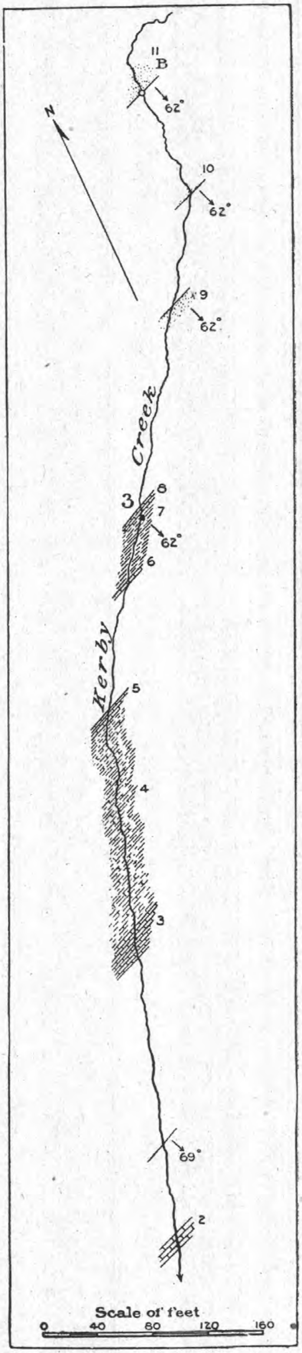


FIG. 19.—Meander of Dixon Creek; lower part, corresponding to upper half of vertical section E. Figs. 19 and 20 are continuous. B, Bodine sandstone; 3, No. 3 limestone. Numbers correspond to those in section E.

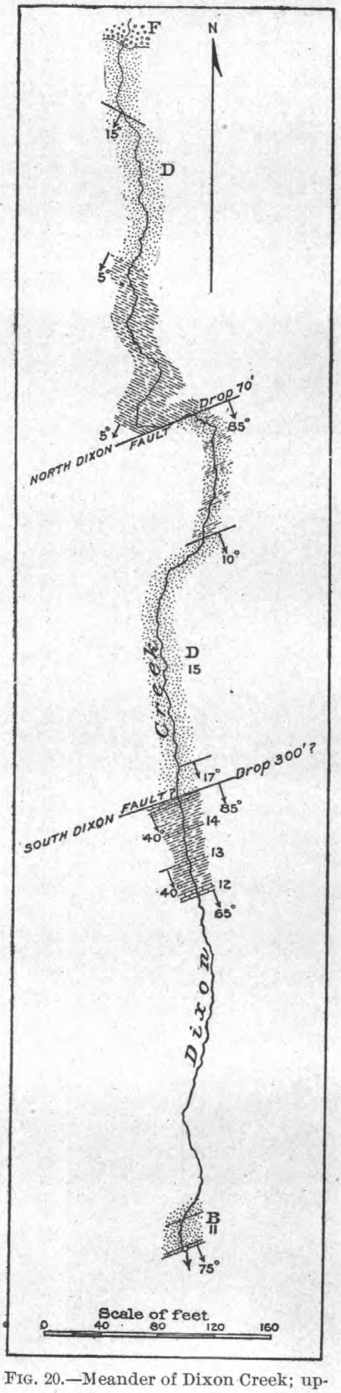
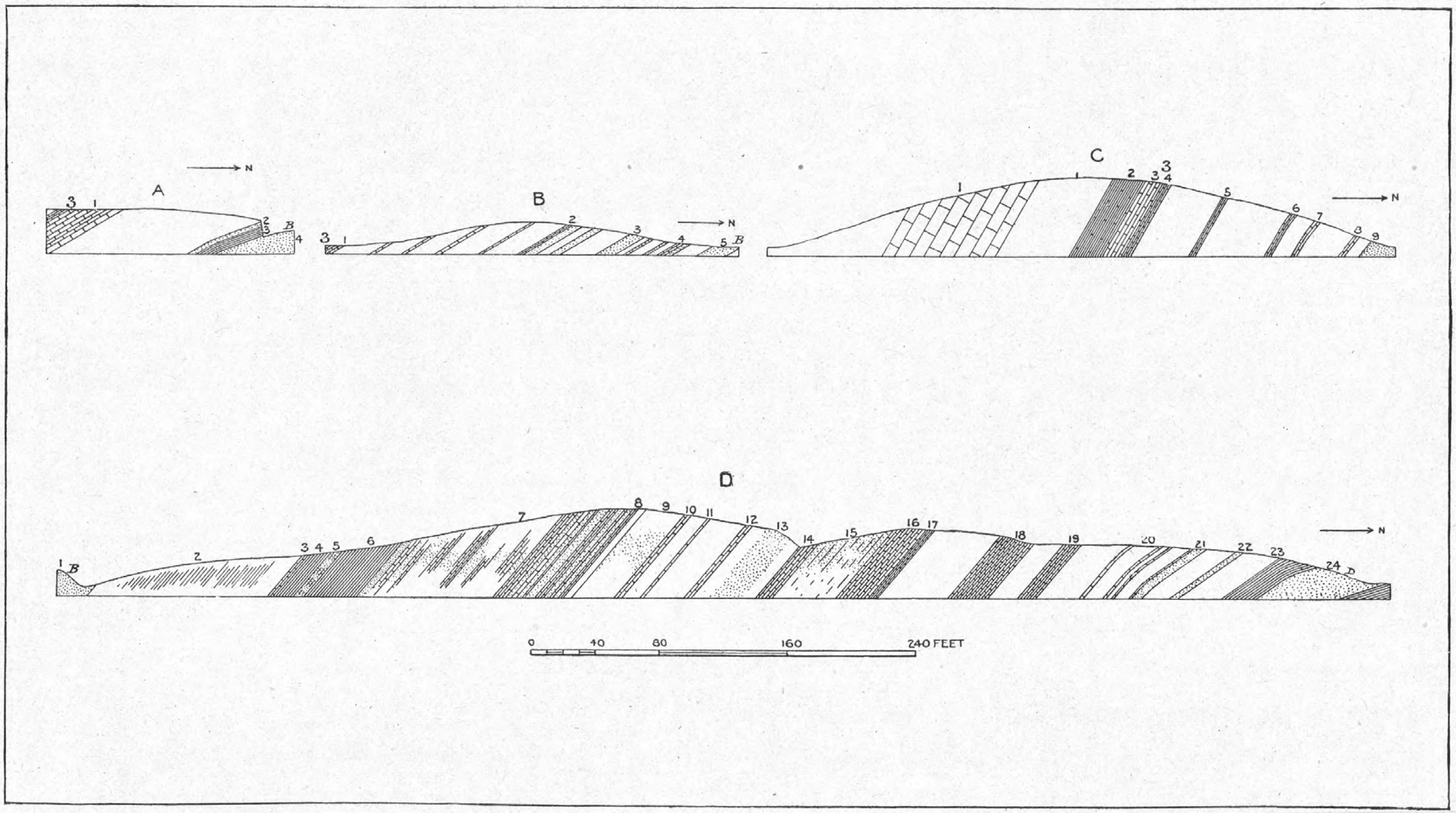


FIG. 20.—Meander of Dixon Creek; upper portion, corresponding to lower half of E of the vertical sections. Figs. 19 and 20 are continuous.

26. Limestone. Crystalline; 4 feet. This is the lowest horizon encountered in this field.

SECTION E.

1. Shales. Chert-like and extremely hard, but with recurring calcareous and earthy layers and an occasional fossiliferous limestone. The shales of fine even grain; gray, drab, and buff. The base of the Mississippian (Caney shale of Taff's classification of Indian Territory horizons) of this locality.
2. Limestone. Bituminous; a massive bed of nearly 350 feet where best exposed—at the No. 4 mine of the Gilsonite Paving and Roofing Company, near the western end of the central Buckhorn field. Though massive, it is well marked, especially in its upper portion, with stratification lines that divide it into layers from 2 to 10 feet thick. In texture it varies from that of hardened calcareous mud to a rock coarsely crystalline, the average of the quarry being finely crystalline to granular. Bodies of highly crystalline calcite are irregularly but profusely distributed through the upper third of the mass, and in their poverty of bitumen are in marked contrast to the general rock of the mine, which is highly impregnated. The upper half of the deposit is more generally crystalline than the lower. About 70 feet from the top of the limestone is a narrow zone, in which blue translucent chert also abounds; there is a trace of chert also at the base of the bed. The per cent of bitumen varies for different portions of the bed. Between 5 and 8 is said to be the average for a band of about 50 feet of finely crystalline to granular rock in the middle of the deposit. Below this horizon, including the limestone of muddy origin, it is reported somewhat lower. In the upper calcite-bearing beds a minimum amount is found, although narrow streaks of considerable richness are here threaded through the mass, and in addition there is an occasional body of irregular outline also of content higher than the average for this portion of the deposit. For the stock piles



PROFILES, BUCKHORN DISTRICT, INDIAN TERRITORY.

The letters A, B, C, D refer to cross-section lines similarly marked on the map (Pl. XXX). B, Bodine sandstone; D, Dixon sandstone; 3, No. 3 limestone. Numerals refer to numbers given in section on pages 275–278.

representing the product shipped, the average per cent in a sample obtained by the writer was between 5 and 6.

3. Limestone. Shaly; hard, with ringing sound when struck; homogeneous; fine grained; brown, weathering white; bituminous, but not highly so.
4. Calcareous shale or shaly limestone. Similar to 3, but here more shaly and disintegrated. This is the usual sequence of strata above No. 3 limestone.
5. Limestone. Fine, even grained, weathering gray, slightly bituminous.
6. Limestone. Bituminous.
7. Shale. Yellow.
8. Limestone. Crystalline; purplish, weathering gray; lower part slightly bituminous; fossiliferous. Probably the No. 3 of Section A, etc.

9 and 10. Quartzose sandstone. Cross bedded; grains round.

11. Sandstone. Quartzose; coarse grained; gray, to brown and black, locally mottled. Bituminous, the lower third the richer; believed to be the same as 4, Section A, and 1, Section D, etc.—the Bodine sandstone.
12. Limestone. Slightly resembling a quartzite; dark gray; bituminous, with maltha in some of its layers.
13. Limestone. Coarsely crystalline; hard; gray to black.
14. Limestone. Coarsely crystalline; gray.

The shales between 12, 13, and 14 are yellow and gray.

15. Sandstone (Dixon). Heavy bed; of large areal extent; bold outcrop; soft; white or gray to yellowish; quartzose. Here originally slightly bituminous, as evidenced by the flakes of dried bitumen adhering to the quartz grains. The top of the bed slightly resembles the cap to the bituminous stratum at the most easterly of the Kerby mines, i. e., mottled black and white, and hard. The lowest stratum of the bed here exposed is nodular by the hardening of portions of the general material. Same as 24 of Section D. The lower beds in this series are now depressed by a fault, with a repetition of a portion of the section given above.

The strata at both base and summit of Section E are overlain unconformably by the conglomerate, largely of limestone débris, that becomes such a prominent terrane to the north of the field under discussion, and which Mr. Taff has identified as the homologue of the Wapanucka limestone further east. The conglomerate is of Coal Measure age.

SECTION F.

1. Limestone. Crystalline; a purple band through it, but general color gray; fossiliferous—crinoids and molluscans. The No. 3 limestone.
2. Quartzite. A narrow but persistent bed, generally recognizable from numerous small sponges that occur in it. The succession 1–2 is again recognized in a repeated portion of these beds a short distance across the fault to the southeast.
3. Limestone. Crystalline.
4. Limestone. Coarsely crystalline.
5. Sandstone. Medium grained; gray to black; variably bituminous, but not here showing especially rich. Same as No. 4, Section A, etc., that is, the Bodine. This bed also is doubled in the section by faulting. It is recognized in outcrop in the segment to the southeast of the fracture, but is here obscured. The thickness as given is in excess of that indicated in the other sections, but it is based on the area of sandy outcrop and the most probable dip of the stratum.
6. Limestone. Coarsely crystalline; purplish to brown and yellow; crinoidal; solid. This stratum frequently outcrops in the eastern half of the field

and is the first of general recognition beneath the heavy bituminous Bodine sandstone, No. 4, of Section A. It is about 10 feet thick, and is underlain after an interval of 7 feet by a similarly colored quartzose limestone.

7. Quartzite.
8. Limestone. Crystalline; fossiliferous.
9. Limestone. Several thin layers in succession.
10. Limestone. Crystalline; also slightly pisolitic; brownish purple; somewhat ferruginous.
11. Limestone. Similar to 10, but quartzose, even changing locally to a calcitic quartzite.

12 and 13. Similar to 11.

14. Sandstone. Probably a portion of the Dixon, though still several hundred feet from the principal outcrop (D) on this line of section. The stratigraphy and structure are both greatly obscured at this horizon and locality. The position in the section is somewhat arbitrarily assumed from the general lay of the bed.

SECTION G.

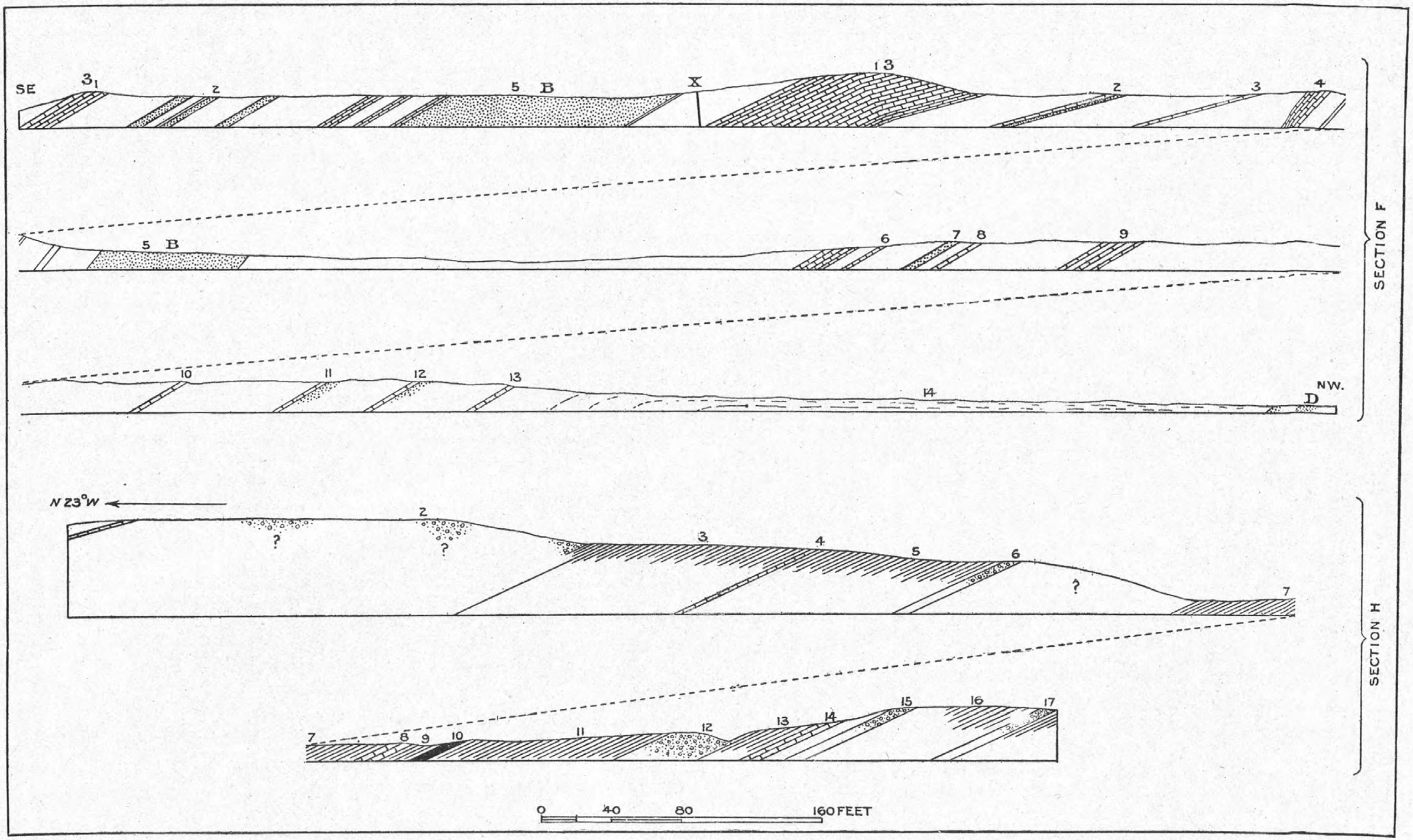
The strata in this section dip southward from 85 to 90 degrees. The figure gives, therefore, practically their relative positions in outcrop.

1. Shale. Chert-like; calcareous, argillaceous, or earthy; hard; bituminous. Approximately the base of the Mississippian of this region.
2. Limestone. Dark blue-gray; homogeneous to finely crystalline; a trace of bitumen in some layers. Fossiliferous. Lower Helderberg.
3. Limestone. The No. 3 with all its characteristics and fossils.

NOTE.—Much of this section is concealed. Compared with the upper half of Section E by reference to the No. 3 limestone, the blue-gray fossiliferous limestone described under 2 above, should correspond to a horizon 91 feet above the base of the great body of limestone quarried at the No. 4 mine of the Gilsonite Paving and Roofing Company, the top of which bed would fall about 18 feet below 1 of the present section. Careful search, however, in the vicinity of Section E failed to reveal a fossil horizon similar to that described above and the inference is either that the two horizons may be the same but with somewhat altered features, including an absence of fossils at the No. 4 mine, or that the strata belong to two entirely different members of the Silurian system—Ordovician and Lower Helderberg—which seems the more probable. Indeed, trilobites of Ordovician age were obtained from the horizons under discussion in the No. 4 mine.

SECTION H.

1. Limestone. Purple-gray, weathering yellow. Age, Coal Measures.
2. Conglomerate. A mass of waterworn, blue, drab, gray, and occasionally pink limestone pebbles 1 to 8 inches in diameter, an occasional quartzite, and an abundance of small angular chert fragments, the whole in a matrix chiefly of quartz sand. The chert is apparently of the same nature as that which enters so largely into the make-up of the Caney (Mississippian) and at the same time forms many of the intervening beds of the Coal Measures, and it is probably from these sources, especially the former, that it is derived. The source of the limestone pebbles is the Ordovician and other of the older terranes. The distance traversed by them in their deposition could hardly have been great. Among the quartzite pebbles, also, some of Ordovician age were recognized. The matrix or sandy portion of the rock, while prevailingly of quartz, carries also recognizable



PROFILES, BUCKHORN DISTRICT, INDIAN TERRITORY.

Corresponding to cross sections F and H on Pl. XXX. B, Bodine sandstone; D, Dixon sandstone; 3, No. 3 limestone; X, fault line. Numerals refer to numbers given in section on pages 279-283.

grains of limestone and chert. This fine material may so predominate as to locally convert a bed into grit or sandstone. In this case it may have become locally impregnated with bitumen. The conglomerate indicated at 6 in the section is also of the type described, except that it was not observed to have been impregnated with bitumen.

This conglomerate occurs, for the region of the section under discussion, about the summit and upper half of the hill in which is the No. 2 mine of the Gilsonite Paving and Roofing Company, and again to the west of this, on the crest of South Ridge, a half mile south of the mining settlement of Schley. In the former locality so scattered are the outcrops of the material, and so obscure are the dips, that it is impossible to say whether there are several beds, a confused outcrop of a single bed, or a reduplication by faulting, and the general structure of the locality is equally difficult of determination. There might, indeed, be doubt in a conservative mind as to the relations of some of the conglomerates to the adjacent strata, but the best evidence seems to point to their inclusion in the Coal Measures, and to their indefinite manner of occurrence as due to somewhat sharp folding and perhaps, also, to faulting. In the section under discussion, therefore, the conglomerate is drawn as in the Coal Measures, but the structure in which it is involved is left unrepresented. In the South Ridge, west of No. 2 Hill, the same indefinite relations exist, but here again all the conglomerates are believed to be members of the Coal Measures series, their outcrop suggesting their position in a broad, gentle synclinal flexure.

An equally conspicuous development of the conglomerates of the Coal Measures is in the bluffs of Rock Creek, about 3 miles northwest of the present section. Here it consists of a mass of pebbles, chiefly of a coarse, bluish-gray limestone, but including, also, pink and drab limestones, white chert, white quartzite or indurated sandstone, and along its lower line, arenaceous laminated clays. The size of the pebbles varies, 3 or 4 inches being a common diameter. The matrix is rolled quartz sand, which locally may form included beds, or at least greatly attenuated lenses. In the lower part of the bed the matrix is to some extent impregnated with bitumen which in instances has penetrated the more porous of the sandstone pebbles. The maximum thickness of the bed in this locality is approximately 100 feet; from this it decreases to a mere cover over the underlying formations. Its position is nearly horizontal, that of the Ordovician strata on which it rests being inclined. The conglomerate forms the surface terrane of the high, rolling, prairie-like country lying north of the Rock Creek drainage, and is believed to be of wide extent.

Of the conglomerates of the Buckhorn region, therefore, there at first sight appear to be two series, one undeniably included in the strata of the Coal Measures, with the Caney shale between these and the strata of Silurian age; the other in a measure independent of the first in its locality and structure, and directly and conspicuously unconformable with the Silurian terranes. Moreover, the two series display some differences in the proportions of their component materials, although the materials themselves are practically the same. Nowhere in the field did the writer see any direct connection between the conglomerates of the two localities, but remarked their resemblances as well as their differences, and in view of the attendant structure accepted the possibility, even probability, of their being of one and the same formation. Mr. Taff, who has wide experience in the stratigraphy of the territory, regards them as the same, and as the equivalent of the Wapanucka limestone of the Lower Coal Measures farther to the east.

3. Shale. The shales of the Coal Measures are at least several hundred feet thick. Their colors are white, blue, green, yellow, red, pink, gray, or drab, gray and drab prevailing. Their composition is argillaceous or calcareous, locally ferruginous, and occasionally finely quartzitic. In texture they are clayey and soft, earthy, or chert-like, and of extreme hardness. The harder layers often display jointing, are more or less fissile, and cleave somewhat after the manner of slates, though along stratification planes. A large proportion of the shales were evidently laid down as muds. Many of the harder, earthy, and calcareous layers throughout the series exposed emit a faint odor of bitumen, and some are distinctly charged with this material. This suggests a possible source for at least a portion of the bitumen now held in the limestones and sandstones of the region.

The shales, notwithstanding their inherent thinness of lamination, frequently form more or less massive outcrops along channels of erosion, while their presence beneath the general level of the country is marked by their chert-like fragments and the black gumbo earth that results from their disintegration and the absorption of water.

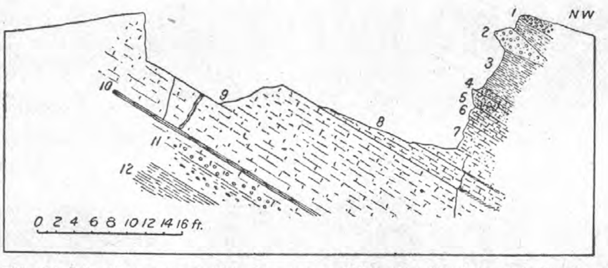


FIG. 21.—Section across No. 2 quarry, Gilsonite Paving and Roofing Company, showing bituminous limestone and associated strata. Numbers correspond to those in text.

The shales constitute the mass of the Coal Measures, not only in the Buckhorn district but throughout the region of the Arbuckle uplift. Conglomerates, sandstones, and limestones, however, are not wanting. The leading elements of the formation are strong and persistent.

4. Limestone. Drab; earthy, with occasional bodies of chert.
5. Shale. Similar to 3.
6. Conglomerate. Of the Coal Measures. Similar to 2, above.
7. Shale.
8. Limestone. Thin laminated; bituminous; 2 bands, each 4 or 5 feet thick.
9. Shale. Argillaceous; gray.
10. Limestone. In reality a combination of calcareous matter and quartz, infiltrated with bitumen. It bears a liberal amount of comminuted, nacreous shells, somewhat similar to those of the No. 2 mine, a few hundred yards to the northeast. Pebbles occur sparsely. Color, dark gray to brownish black. The amount of bitumen varies. The rock is the seat of No. 1 Prospect of the Gilsonite Paving and Roofing Company.
11. Shales. Argillaceous; chert fragments scattered over the outcrop, derived from strata through the terrane.
12. Conglomerate. The mass of the material rounded limestone pebbles; occasional quartzite pebbles; the chert especially angular and flint-like.
13. Clays. Red and yellow.

14. Limestone. The grain, even, except for calcite veins and bodies developed in it. It weathers, therefore, somewhat rough and irregular. The color is medium gray, locally mottled dark.
15. Conglomerate. Similar to 6, but chiefly of limestone pebbles.
16. Shale. Similar to 3.
17. Conglomerate. Similar to 15.

The latter portion of this section is typical of the succession to the Buckhorn bottoms, with, perhaps, a diminution in the proportion of conglomerate. The comparative frequency of pink in the coloring of the higher clays is also worthy of note, and characteristic Coal Measure fossils are found in some of the limestones.

A detail of this formation, belonging a little above the top of the present section, is shown in fig. 21. It represents the No. 2 quarry.

SECTION AT QUARRY OF GILSONITE PAVING AND ROOFING COMPANY.

1. Conglomerate, having the appearance of a superficial deposit, but probably one of the series of Coal Measures.
2. Conglomerate. Material comparatively fine; occurs in lenticles at about this horizon throughout the quarry. This and some other conglomerate bodies are irregularly and nonpersistently distributed in the shale.
3. Shales. Pink at top; drab, yellow, and gray in the middle; purple at bottom; all somewhat clayey.
4. Conglomerate. Top and bottom planes somewhat uneven.
5. Quartzite. Calcareous (perhaps a quartzose limestone); hard; often barren of bitumen.
6. Limestone. Dark; richer in bitumen than the rest of the layers over the quarried rock; nacreous shells.
7. Limestone. Appearance that of a dry bituminous rock; perhaps never especially rich; locally barren; the bed as a whole streaked light and dark; rejected as a product of the mine.
8. A layer showing wood fiber and coal; calcareous; the bottom 6 inches especially coal-like and conspicuous. The coaly material frequently occurs as a contorted friable mass, in appearance that of a coal bed crushed by local crumpling.
9. Limestone. Massive; hard; bitumen per cent high (14 the average) and uniform, except for the lower 1 foot, which is poorer. The upper 2 feet rich in nacreous shells, but these decrease in number below and in the lower half of the bed are almost wanting. At one point in this bed is an especially rich, brittle, bituminous material, which, though possibly a part of the general rock mass, may yet be the filling of an early fissure the walls of which have been somewhat obliterated by the blending of the bitumen of the vein with that of the rock on either side. Locally, also, the vein has the appearance of being composed of crushed bituminous limestone. In coloring the vein shows swirls of black and brown material. No displacement of the bed itself appears. The base of the bed is locally slightly conglomeratic.
10. Shale. A thin but persistent bed.
11. Conglomerate. An essentially calcareous matrix; gray limestone pebbles; black chert; wood tissue in great fragments lying in stratification planes, this also calcareous. Perfectly conformable with the overlying and underlying beds, differing in this respect—in appearance at least—from the conglomerates higher up.

12. A succession of shale and 4-inch bands of bituminous material; shales themselves may be bituminous.

With the exception of the present occurrence, this series, with its striking characteristics, was not recognized in any portion of the Indian Territory fields.

SECTION I.

This section, not drawn in detail, is exposed along the east and west forks of No. 2 Creek from opposite the No. 2 Hill to within a half mile of the head of the streams. It embraces strata of much similarity, essentially shaly, and is therefore one in which identification of horizons is difficult. The series represented is, according to Taff, entirely of the Caney division of the Mississippian. The shales include nearly every variety—soft and clayey, hard, earthy, calcareous, and chert-like. The harder layers occur in thin outcrops or in heavy massive beds. The colors are chiefly gray and drab, but among them are also browns, from the presence of small percentages of bitumen. The series is considerably contorted.

Summary.—Summarizing the facts as presented in the foregoing sections, the thickness of exposed strata in the Buckhorn district approximates 2,900 feet. Of this amount 1,500 feet are Ordovician or older; there is an undetermined but narrow zone of Lower Helderberg rocks; while about 1,300 feet may be classed as Carboniferous. Of the last, about 800 feet constitute the Mississippian (Caney) division; 500 feet the Coal Measures.

The Ordovician embraces limestones, sandstones, and shales—that is, if the entire succession of beds below the top of the No. 4 limestone be regarded of this age. The upper members of the series, however, the No. 4 and No. 3 limestones, are alone identified as Ordovician by fossil evidence. For comparison, the vertical sections have been adjusted to the top of the Bodine sandstone, a horizon of fair persistency and traceable with comparative certainty from point to point, though devoid of fossils and somewhat liable to confusion with similar beds lower in the series, especially in regions of faulting.

The No. 4 limestone, the uppermost member of the Ordovician, derives especial importance from the bitumen that it carries, being thus the source of a product of considerable economic value. Its greatest exposure is at the No. 4 mine, through which Section E passes; at this point it attains a total thickness of 340 feet. At the No. 8 mine, an eighth of a mile east of No. 4, it is still strongly developed, but farther to the east the outcrop becomes obscure, and on the line of Section G, near the eastern end of the Silurian terrane, it is not with certainty recognized.

The No. 3 limestone also is important from the presence of bitumen, having been mined at one point and prospected at several others. Its per cent of bitumen, however, falls somewhat below that of No. 4, and its thickness is usually between 20 and 50 feet. It is of especial interest from its remarkable persistency and the readiness with which it is everywhere recognized both lithologically and by its fossils, forming thus a horizon of identification of first importance. Even in isolated and limited outcrops, as at the No. 5 prospect, in the bluffs of Rock Creek, a mile north of the area represented in the sketch map, these features enable its immediate detection beneath an overlying body of Coal-Measure conglomerate between 50 and 100 feet in thickness.

The remainder of the series under discussion, that below the Bodine sandstone and provisionally assigned to the Ordovician, presents nothing for remark in a lithologic way until the heavy Dixon sand is reached, at least 250 feet below. This, 40 or 50 feet thick and of prominence in the type area, is believed to be the same as that mined at the Kerby quarries—in the latter locality, however, richly infiltrated with bitumen for a portion of its thickness.

The correlation of the foregoing principal members of the Ordovician series for their region of occurrence presents several difficulties, made apparent by reference to the vertical sections. Chief among these are the discrepancies in the distances between the beds mentioned. Section D, for instance, which has for its upper and lower beds the Bodine and Dixon sands, the same as represented in E, presents a marked contrast with the latter in the thickness of the intervening beds as well as in the fullness of their exposures. The excess of the one over the other is approximately 300 feet. It is impossible to detect any repetition by faulting in Section D, the beds presenting constant variety from base to summit, nor after careful study is it believed that the difference is attributable to a difference in the amount of material originally laid down in the two localities. An explanation is therefore to be sought along the line of Section E, which is coincident with the channel of Dixon Creek. This is, indeed, the more natural if the Sections D and F, which correspond in considerable degree, are to be regarded normal as to the distance between the Bodine and Dixon sands. In this event, the diminished distance between these horizons in Section E must be looked upon as abnormal and as the feature to be explained. The explanation sought is probably to be found in the irregularity shown in the sketch of Dixon Creek (fig. 20), where there is with little doubt a strike fault with relative elevation of the strata on the north side about 300 feet, bringing the Dixon sandstone in opposition with the considerably higher series of limestones and shale on the south. The trend of the fracture would carry its line across Section D, near horizons 7 and 8, but, if present at all here, it can hardly be more than in incipiency and would be difficult to detect in a series so little differentiated. West of Dixon Creek evidences of the fault would be quickly concealed by the mantle of conglomerate which there exists.

The position of No. 3 limestone with reference to the top of the Bodine sandstone varies but slightly except on the line of Section A, where the distance between the two beds is considerably diminished. In this instance the diminution is believed to be due to faulting or to a sharp flexure in the strata, so readjusting the beds as to show apparent decrease in the normal distance between the two horizons.

The No. 4 limestone, with perhaps some variation in its leading features and in its thickness, is probably present over the whole length of the Ordovician outcrop. It is included, however, in only two of the measured sections, C and E, distant from each other about 1¼ miles, but representing the extremes in its relations to the more uniform horizon of the No. 3 limestone. The greater distance between these two horizons is common to the region of the No. 4 and No. 8 quarries, and perhaps prevails as far east as the Bodine fault. Beyond this, however, this distance appears to be less until, in the vicinity of Section C, it is but 60 or 70 feet. As already noted, however, the outcrop of this limestone is illy defined in the eastern half of the field, and at no point can it be said that the upper line of No. 3 and the lower of No. 4 have been clearly determined. This may in part account for the discrepancies in the distance between horizons, but there may have been also an actual decrease in the amount of material originally laid down in the intervening spaces. It is worthy of note, too, that in the interval between the Bodine sandstone and No. 3 limestone and in that between the latter and No. 4 the composition of the beds shows considerable variation, indicating that there were many changes in sedimentation in the time of their deposition.

The Lower Helderberg appears to be a succession of limestones 4 or 5 feet thick, perhaps interbedded with shales; but nowhere can a satisfactory idea of the component members of the formation be obtained. It was recognized by its fossils at three points in the area under discussion, a half mile east of the No. 8 quarry, in a small hill just north of the No. 6 prospect, and to the west of the fault of that region; a few hundred feet southeast of the church at Schley; and in the northeastern part of the field, near the center of the south line of section 14. In the vertical sections it was recognized only in that designated G. West of the first position mentioned, the hill near the No. 6 prospect, the formation was not identified. It may still be present, however, as a narrow belt adjacent to the heavy limestones of the No. 8 and No. 4 quarries, notwithstanding the apparent immediate succession of these beds by the shales of the Mississippian. Comparing Sections E and G, although the massive limestone of the No. 4 quarry is not definitely recognized on the line of the latter section, the interval between the No. 3 limestone and the fossiliferous layer of the Lower Helderberg is there sufficient to encompass it, with still an allowance for the prevailing distance between the No. 3 and No. 4 beds in the eastern part of the field. The somewhat abnormal distance between No. 3 and No. 4 in Section E has already been referred to.

The Mississippian is represented in the present field by perhaps 800 feet of Caney shale. This formation has been studied in detail for 40 or 50 miles east of the Buckhorn district, especially by Mr. Taff, of the Survey, and it is on his authority that the series is assigned to the horizon referred to.

The Coal Measures are represented by about 500 feet of argillaceous shales, limestones, and limestone and chert conglomerates, and occasionally beds of a valueless, coal-like material. The shales are generally of a more clayey nature than those of the Caney, and their colors are gray, yellow, white, and pink. The relations of the Coal Measures and the Caney are probably those of unconformity.

STRUCTURE.

The central geologic structure of the Buckhorn field (Pl. XXX) is primarily that of a part of a broadly developed fold, or of an extended anticline with a major axis approaching east and west and passing through the heart of the region. Whichever it may be, but a small part of the total structure in the older formations is exposed, the remainder being concealed beneath the heavy conglomerates of the Coal Measures to the north. That portion of the fold visible indicates the anticlinal structure, especially in the eastern half of the area, where the northeasterly strike with southerly dip turns gradually through the north to northwest with dip to the northeast. A second suggestion of the anticlinal structure occurs in the northerly dip at the Kerby mines, and a third is to be found in the bluffs of Rock Creek, 1 to 2 miles northwest of the mapped area, in northeasterly dips of the No. 3 limestone. The greater part of the field, however, is occupied by beds of southerly dip.

Relations of the Coal Measures to older series of beds.—The entire northwestern portion of the Buckhorn district is underlain by the conglomerate of the Coal Measures as its surface terrane. The deposit at one time was doubtless of far greater extent than now, erosion having removed it from the region of the valleys and at the same time exposed the underlying beds in outcrops of varying ruggedness, according to the nature of their materials and the degree of folding to which they were earlier subjected. The position of the conglomerate is horizontal or gently tilted, while its line of union with the subjacent formations is evidence of its deposition on a surface of marked and sharp undulations. The southeastern edge of the conglomerate crosses the Buckhorn field at varying level and with waving trend. Beneath it at the west the Ordovician, Lower Helderberg, and the lower members of the Mississippian are observed to pass with high dips. On the north it rests upon the Dixon sandstone, appearing thus at Dixon Creek, the Kerby quarries, and the Moss pit, capping the ridges and continuing thence, with occasional interruption, to the prairie region north. Northeast and east from the Moss quarry erosion has removed the conglomerate over considerable areas, and it is not until between 2 and 3 miles from the center of the field that the formation again appears in strength. The deposit capping the Kerby Hill is an outlier, as is one of 2 or 3 acres just south of the No. 8 mine, three-fourths of a mile distant from the former. There is also a considerable area of the same conglomerate along the entire southern edge of the field, in places perhaps in contact with the Caney shale. The Buckhorn Valley, however, is occupied by shales of the Coal Measures.

Central area.—This portion of the field is divisible, as regards the older formations, into an east and west half by the Bodine fault. The same series of beds is recognized on either side of the fracture, but they are sharply interrupted at the line. The western half presents but one or two complications of structure, the shales of the Mississippian at the south being regularly followed by the Lower Helderberg, and this by the Ordovician with its many phases of limestone and sandstone. The strike of the beds varies between N. 60° and 80° E. The dip, with local exceptions, is south, the amount varying from 3° to 70°, the gentler dip, 3° to 15°, occurring in the north. The change from steep to shallow dip is sudden, and is locally marked by somewhat sharp crumpling, and on Dixon Creek by faulting. The gentler dips are modified by a greater or less amount of undulation. An instance of this occurs on Kerby Creek, a short distance below the Kerby mines, where, for a quarter of a mile along the channel, are exposed 25 or 30 feet of shale with a thin underlying limestone, the whole beneath the Dixon sandstone, which appears to arch around and over the outcrop of the older beds. The position of this gentle fold is close to the probable arch of the supposed anticline of the field, for a little to the north, at the Kerby mines, the dip has assumed a northerly direction.

Three faults have been identified in the western portion of the field. Two are visible on Dixon Branch (fig. 20), about 300 and 600 feet, respectively, below the edge of the Coal Measures. The trend of the northern fracture is N. 67° E.; the inclination of its plane 85° to 87° southeast; the amount of displacement about 70 feet; the beds to the north of the fault, depressed. Yellow and gray shales are found overlying the Dixon sandstone on either side, and at the break the shales on the north oppose the sandstone on the south (fig. 20). Attending the displacement, there has been some torsion, which is especially marked in the strata north of the break, the strike of these being N. 65° W., in contrast with N. 67° E., the regular strike of the beds south of the fracture. The dip is south on both sides.

The southern break has already been referred to in the discussion of the sections with reference to the correlation of their measures (p. 285 et seq.).

The third fault is a short fracture across the beds in the vicinity of the quarter corner on the west side of section 22. Its trend is N. 30° W., and the beds on the west are moved about 150 feet north relative to those on the east. The ends of the strata east of the line are pulled around to the north. The fault is of somewhat similar nature to the Bodine, but less extensive.

In the eastern half of the field the same formations are present as in the western. The Silurian terranes occupy the center, succeeded southward and southeastward by the Caney shales of Mississippian age and the Coal Measures, and to the north, in part, by the Coal Measures—the conglomerates already referred to. A short distance east of the Bodine fault the strata, for the most part with southerly dip, have a general strike of N. 60° E., which varies, however, between N. 40° and 80° E. This continues eastward for a mile, when, in the hills east of the settlement church, the strike gradually turns through the north to the northwest, the dip being maintained outward. Along the northern edge of the terrane, however, in the region of the Kerby and Moss pits, the dip is either flat, undulating, or to the north, indicating that the axis of the supposed anticline lies in the vicinity.

The several members of the Ordovician in the eastern part of the field present a number of problems of continuity, the chief of which relate to the Dixon and Bodine sandstones. The Dixon sandstone is traceable from the Kerby pits eastward through the Moss pit to a point half mile beyond, though the latter part of the distance a cover of disintegrated sand is the chief evidence of its presence. It is found also on the northern slopes of the Moss Ridge, where there is considerable seepage of bitumen from its enriched mass. Although outcrops are rare and indecisive, it is believed from the general relations of the various members of the Ordovician that the eastern end of the anticline in the Dixon sand is now reached, and that with northward dip the stratum passes beneath the prairies, perhaps in continuity, eventually, with the bituminous sand of the Ralston mine. In the absence of the anticline and its replacement by a succession of folds of greater or less magnitude, the Dixon sandstone may frequently be brought within short distances of the surface or, indeed, exposed.

The Bodine sandstone may be traced from the pit of this name eastward along the northern base of Middle Ridge to the point of the supposed anticline. Beyond this it is obscure. Over this portion of the field its outcrop has been reduplicated or broadened by faulting. Its per cent of bitumen is markedly variable.

The questionable continuity of the No. 4 limestone of this formation has been referred to in discussing the sections.

The Prindle fault presents a constantly increasing throw from west to east, until on the line of Section F it has attained a probable vertical displacement of about 250 feet. The strata on the north are depressed; the hade, however, is not distinguishable. The eastern end of the fracture probably lies in the valley of the western fork of No. 2 Creek. It was not observed cutting the upper limestones of the Ordovician in the hill beyond.

Other minor throws or crumples of a few feet only occur in the No. 3 limestone, notably a little east of the No. 3 sandstone quarry, and again about 75 yards west of the village church.

The same flattening of dip midway north and south in the field takes place in the eastern half as in the western. In the present area it occurs in the flat between the Middle and Moss ridges, but apparently somewhat nearer the former, where a decrease to 25° is attained. On the northern side of the valley it is still less, and at the Moss pit the Dixon sandstone lies in an approximately horizontal position. It is a noticeable feature of the exposures of the Dixon sand at the western of the Kerby pits and again in the Moss pit that the position of the bed as quarried is prominently higher than the flats in front of it. This suggests either a slight local displacement or a rather steep (7° to 15°) southward dip of the bed within a short distance of the outcrop. At the middle and eastern of the Kerby pits this elevation of the beds is not present, but its top is flush with the surface of the ground. Though but a trace of a southerly dip can be detected at the south edge of these pits, it is believed to exist and that the bed rapidly passes beneath the limestones and other strata beyond.

Several of the limestones observed in the lower half of Section F are traceable westward through the Prindle bottom to the vicinity of the Bodine fault, passing to the north of or beneath the Bodine sandstone. One of these, 50 or 60 feet below this sandstone, is comparatively readily recognized by its coarsely granular to crytalline texture, its red, brown, and rusty colors, and the presence of a considerable number of crinoid stems and other comminuted forms.

The Bodine fault is a fracture transverse to the general strike of the region, and is traceable from the vicinity of the south ridge to the Kerby quarries. It involves the Silurian and Mississippian, but disappears before the areas of the Coal Measure conglomerate are reached. It was doubtless developed prior to the deposition of this formation and coincidently with at least the early development of the central anticline. The relative displacement of the beds on the west of the fracture, at least along the southern half, is southward about 1,300 feet. Along the northern half the throw is considerably diminished and the displacement is not so well defined, but no conclusive evidence here appears for there having been a horizontal movement of the beds on the west to the north, and the fault will therefore be regarded as developed from a simple compressive crumpling of the strata, more or less in the direction of their strike, on the south of the axis of the supposed anticline. This idea is borne out also in the curvature of the strata on either side of the fracture plane, those on the west turning south, those on the east, north. This could hardly have happened had the fault been a cross fracture developed after the completion of the anticlinal folding, with the beds on the west raised vertically with reference to those on the east. The true character of the fault may be more easily comprehended if the lines of the break and adjacent beds be considered in the light of a vertical section drawn upon the ground. The line of the fracture now becomes, as it really is, a trace of its plane; the beds on the east appear as downthrown in a degree corresponding to their horizontal displacement in the surface plane; while the hade of the fault, as illustrated by the angle of its trend with the strike of the strata, is distinctly away from the downthrown side. The fault, therefore, is of the reverse type, resulting from compression forces acting along the strike of the beds.

Northwestern area.—In the bluffs of Rock Creek, 1¼ miles north of the Kerby quarries, and again at a point about 2 miles to the west of the quarries, are, respectively, exposures of the No. 3 bituminous limestone, and a sandstone also heavily impregnated with bitumen, perhaps the equivalent of the Dixon sandstone. The former has been but prospected, the opening made upon it being known as No. 5. The latter is the seat of the Ralston quarry, and has afforded a considerable amount of rock for purposes of paving or the extraction of its bitumen. The strike of the No. 3 limestone is N. 60° W., the dip NE. 40°. The strike, it is to be remarked, bears directly for the point of the anticline in the eastern part of the field. At the Ralston quarry the strike of the bituminous sandstone is N. 10° W., the dip 10° W. The beds of the No. 5 prospect and the Ralston quarry very likely belong to the same unit of structure, to the suggested anticline of the Buckhorn district. Nothing but deep boring, however, will reveal the structure of the rocks underlying the conglomerate in the area between Rock Creek and the main field.

Northeastern area.—The strata underlying the northeastern portion of the field are thrown into a series of more or less gentle undulations which, excepting in their time of development, are quite independent of the anticline that has been described. This is particularly evident in passing eastward across the southern half of section 14. The ridge between the East and Middle forks of No. 2 Creek carries a gentle anticline fold, with axis north and south along the crest. Between this and the central anticline the strata lie in a syncline. The axis of the syncline rises to the north; that of the anticline sinks to the south. Beyond the limits of the mapped area the structure was not followed.

The outcropping rocks in the anticlinal ridge just referred to bear a close resemblance to the series immediately below the Bodine sandstone, while this horizon itself is found, it is believed, in the bitumen-bearing stratum at the prospect at the base of the ridge, near the southeast corner of the section. This correlation is borne out by the structure of the area, for the dips and strikes on the south and east of the ridge are in harmony with the areal and stratigraphic succession of the beds referred to, while to the west of the ridge this harmony again exists in the westerly dip of the beds even to the axis of the syncline, which is in part occupied by strata of the Lower Helderberg on the hills to the northwest. The structure and stratigraphy thus suggested necessitate the passage of the Lower Helderberg, the No. 4 and No. 3 limestones, and the Bodine sandstone, together with their intervening associates, around the southern end of the ridge now under consideration, but no trace of them was observed, perhaps by reason of the broad mantle of material, washed from above, that covers the country in this vicinity. The first outcrops that occur below the exposures in the ridge mentioned above are of the Caney shales, several hundred feet below the forks of the Middle and Eastern branches of the No. 2 Creek.

Southeastern area.—The southeastern portion of the field is the seat of further folding that has been developed in a measure independently of the central anticline. The disturbance here has been more vigorous

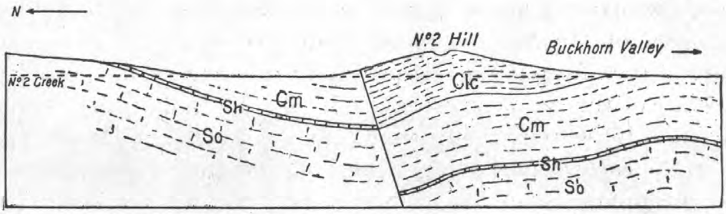


FIG. 22.—Profile through No. 2 Hill, Buckhorn district, Indian Territory. Clc, Lower Coal Measures; Cm, Mississippian; Sh, Lower Helderberg; So, Ordovician.

than in the northeastern part of the field, resulting in the development of the prominent No. 2 Hill and a geology of considerable complication, confined superficially to the Mississippian and the Coal Measures. Although the relations to several of the beds entering into this structure are very indistinct, particularly those of certain of the conglomerates, the general evidence points to a broad east and west syncline modified by a normal strike fault in the beds of its northern half. The adjacent diagram outlines the idea of the structure.

In passing southward from the low anticlinal ridge that lies between the Middle and Eastern forks of the No. 2 Creek, a general southerly dip is maintained nearly to the northern base of the No. 2 Hill. Along the upper portion of the western branch of this creek, however, a certain degree of crumpling has taken place, from the inclusion of the strata in the somewhat sharp synclinal trough lying between the anticline referred to and the greater one occupying the center of the district; but these crumplings disappear and the shales resume a regular southerly dip on the lower portion of the branch. Practical continuity of strike and dip is thus established for a broad and extended belt in the region of the south valley and that lying north of the No. 2 Hill, the region underlain with the Caney shale of Mississippian age. This southerly dip is that of the northern half of the syncline under description.

The northerly dip, that of the southern half of the syncline, is clearly demonstrated in the outcrops along the lower portion of No. 2 Creek and in the ridges on either side. The beds, however, of the southern half of the syncline are markedly different from those of the northern half. While the latter consist of an almost uninterrupted succession of shales, the former embrace shales, limestones, and conglomerates of a considerably higher horizon.

On approaching the center of the syncline, crumpling, with considerable variation in strike and dip and great confusion of detail, is encountered; in a broad way, however, the trough of the syncline is occupied by a prominent conglomerate, more conspicuous in the south ridge to the west of the creek than in the No. 2 Hill to the east.

Toward the eastern end of the latter elevation the sharpness of the crumpling seems to diminish.

The fault in the northern half of the syncline is, by reason of cover, difficult of detection excepting where cut by the eastern branch of No. 2 Creek. Here shales and conglomerate are found in abrupt contact, the dip of the former obscure, of the latter between 80° and 90° to the south or to the north, according to local structure, there having been considerable sharp crumpling in the beds on this, the southern side of the fracture.

The fault in the diagram (fig. 22) is sketched as normal on slight evidence, but from general conditions in the locality the figure is believed to be correct. The trend of the fault is approximately east and west, perhaps slightly north of east. The linear extent is undetermined. To the west its break was not detected beyond a distance of 200 or 300 yards, indicating in this direction a rapidly diminished throw, with the beds of the lower series of the Coal Measures in opposition. Eastward the fault may pass beyond the end of the No. 2 Hill, but here again to be lost in the shales of the lower series, with corresponding decrease in throw. The maximum throw opposite the No. 2 Hill can hardly be less than 600 feet.

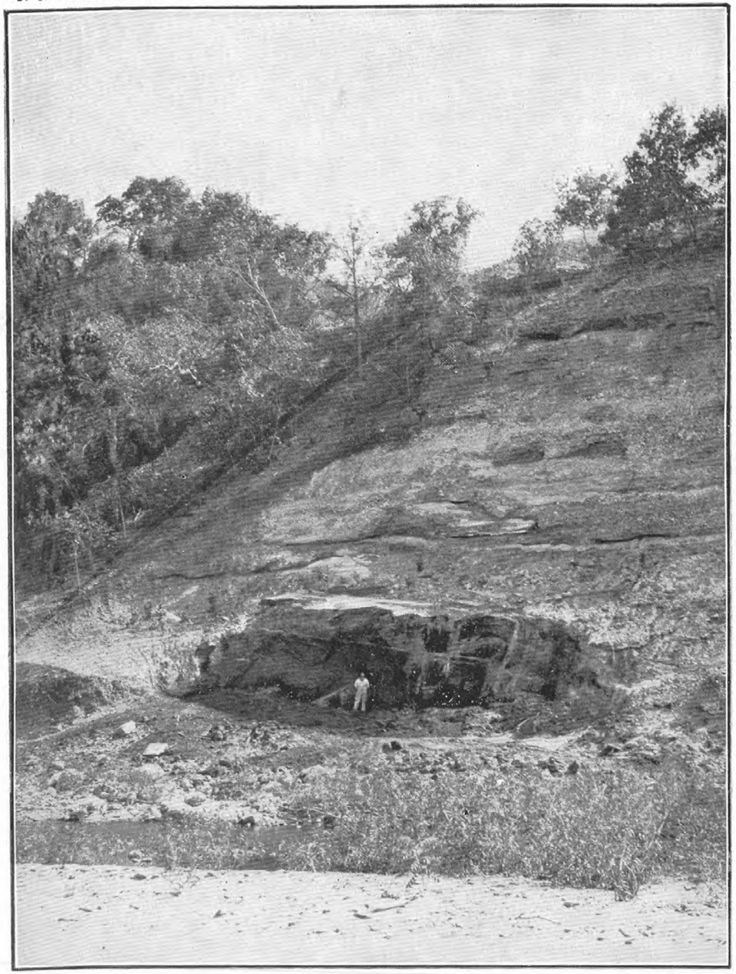
The effect of this fault in breaking the northward continuity of the rich bituminous limestone quarried at the summit of the No. 2 Hill is apparent.

The east and west trend of the axis of the No. 2 syncline is in sharp contrast with the north and south axis of the anticline in the ridge between the upper forks of the eastern branch. Indeed, the variety of trend in the folds and faults of the several portions of the field is significant of an area of general crumpling by forces acting from several directions.

Mr. Taff, who has studied the geology beyond the immediate area here discussed, reports a fault of considerable extent entering the field near the lake at its eastern edge and passing northwest toward the head of No. 2 Creek. It may be that the No. 2 fault passes into this.

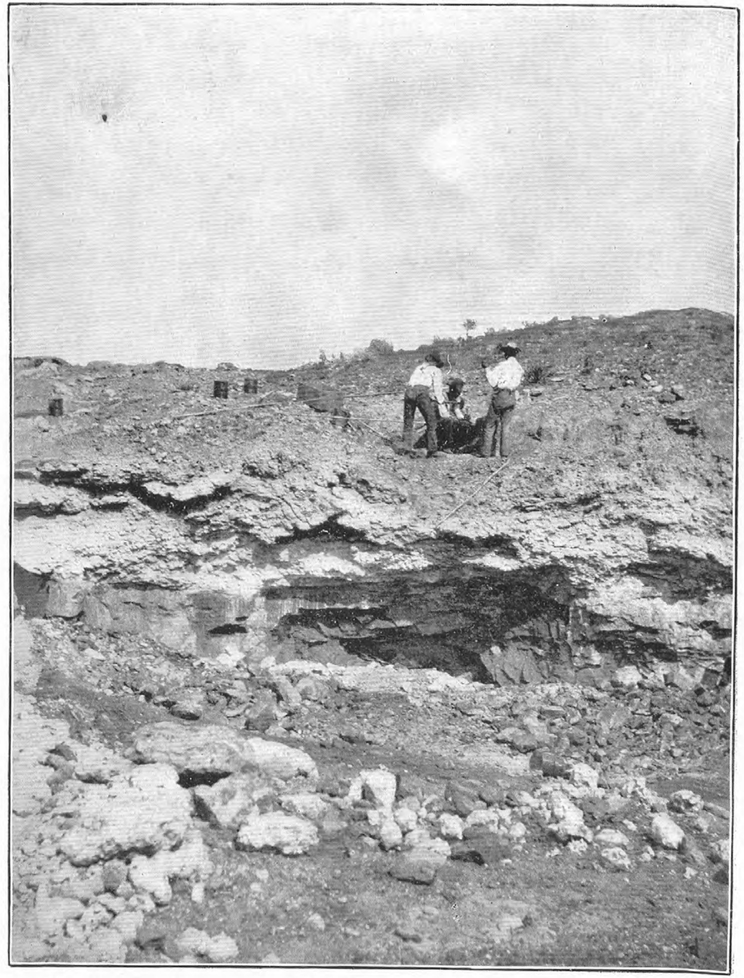
QUARRIES.

Ralston quarry.—This quarry (see Pl. XXXIV, *A*), under the control of Messrs. Ledbetter & Legrand, of Ardmore, Ind. T., is opened just above water level in the bluffs of Rock Creek, about 2 miles west-northwest of Schley, and about 8 miles northeast of Dougherty, the nearest station on the Gulf, Colorado and Santa Fe Railroad. The deposit where exploited is a richly impregnated, massive Ordovician sandstone, about 15 feet thick, lying beneath a cap of from 75 to 100 feet of Coal Measure conglomerate. The bitumen contents amount to between 10 and 12 per cent as the average of the present face. In hot weather the bitumen seeps from the rock in the form of maltha. The rock is black on fresh fracture, but weathers gray. It is tough, tenacious, and of gummy consistency when exposed to even a slight elevation of temperature, as by the sun or the warmth of the hand. Under the sun's rays great pieces slowly crack and fall from the quarry face—a common occurrence, however, in the case of all sandstones of like nature. The composition of the rock is of medium-sized, rounded, subangular and angular quartz grains, held together in bitumen. Upon the removal of the latter the residue falls to pieces—a mere mass of loose, white sand. The odor is strong. The age of the sandstone is believed to be Ordovician, but the time of its impregnation is uncertain. It may have been either prior or subsequent to the deposition of the overlying, unconformable conglomerate. The fact that the lower members of the latter formation are somewhat impregnated with bitumen is not conclusive evidence in either direction, for they might have been infiltrated with or from the sandstone itself. There are, however, occasional pebbles of bituminous sandstone sufficiently isolated from the enriched portion of the conglomerate bed to suggest their derivation from the Ordovician after impregnation. The extent of the enriched portion of the Ordovician sandstone can be satisfactorily determined only by boring. The exposure along the creek has a length of 150 feet. The strike of the bed appears to be N. 10° W., the dip, 10° westward, carrying the deposit rapidly below the creek level. With the frequent change in strike and dip, however, consequent upon the very considerable folding which the strata in the Buckhorn district have undergone, it is possible that the bed may occur in concealed outcrop at more than one point along the débris and timber-clad bluffs of Rock Creek. Equally, it may rise to within a few feet of the surface in the region above, covered, however, by a thin deposit of the conglomerate.



A. RALSTON QUARRY, BUCKHORN DISTRICT, INDIAN TERRITORY.

Bituminous sandstone of Ordovician age unconformably overlain by Coal Measures conglomerate.



B. WEST KERBY QUARRY, BUCKHORN DISTRICT, INDIAN TERRITORY.

No. 2 quarry.—This quarry, the property of the Gilsonite Paving and Roofing Company (fig. 21), is opened in the summit of the No. 2 Hill, at the eastern end of the Buckhorn district. The strike of the beds is here S. 62° W., the dip northward about 30°. The strata quarried are probably referable to the Lower Coal Measures, and have already been discussed as members of this series on page 292; but the details of the bituminous rock that constitutes, or is associated directly with, the product of the mine require somewhat further notice. The bed affording the product is 9 in the section, fig. 21. Although yielding a comparatively uniform product throughout, with an average bitumen content for the quarry of between 14 and 15 per cent, the bed presents a variety of rock phases that it is well to refer to as perhaps bearing upon the origin and development of the deposit, and at the same time that may serve as a record of the many conditions likely to be encountered in regions of bituminous limestone. The prevailing rock is brownish black on fresh surface, dark gray after exposure. It is fine-grained to granular, and in portions of the bed bears a high per cent of comminuted molluscan shells, together with many in a state of more or less complete preservation, all beautifully nacreous. The shell contents thus form a characteristic feature of the bed. A certain degree of porosity is also apparent throughout the rock. In occasional instances the bed is more or less minutely seamed with pure asphalt, apparently from the filling of fissures produced by cracking, or possibly by solution. The asphalt thus occurring is black, but gives a brownish streak and powder. A thin layer at the base of the bed presents a conglomerate phase of the foregoing, the pebbles being small and rounded, and consisting of black and white chert, sugary quartz, and perhaps other material; comminuted nacreous shell is also present. The matrix of this rock is fine-grained and is rich in bitumen, but the pebbles are barren, and the average bitumen contents of the layer is thus considerably lowered. This, with the texture imparted by the pebbles, renders the rock of diminished worth as an economic material.

In the breast of the quarry as exposed at the time of the examination there was observed a steeply inclined (62°) vein-like body of bitumino-calcareous material, about 18 inches wide. This could be traced N. 70° W. for 25 or 30 feet along the back of the stratum forming the breast, when it split into a number of veinlets, each of which quickly pinched to naught. The vein rock is mottled brown and black, indicating an uneven distribution of the component materials. The texture is exceedingly fine-grained to homogeneous; the fracture brittle, with tendency to conchoidal form, which is more strongly developed as the per cent of bitumen increases. The rock is dry and does not soil the hands. In this connection it may be observed that bituminous limestones generally are noticeably cleaner to the touch than the sandstones. In some instances in handling it has been found that they even absorb bitumen given out by a previous handling of the sandstones.

Comparing the brown and black portions of this vein material, the former effervesce briskly with HCl; the latter, more purely bituminous, not at all. The two varieties may be sharply defined or may pass into each other by gentle gradation, the latter condition being the more common. Through the brown may be seen occasional veinlets of pure black asphalt. Both brown and black are moderately hard, though yielding sectile shavings under the knife.

From the appearance of the material, the vein may have originated in either of two ways: First, a fissure having been formed, perhaps at the time of the general crumpling, it may have been subsequently filled with bitumen carrying a variable per cent of amorphous carbonate of lime acquired in its passage through the body of the limestone; or, second, a channel having been formed by solution, either complete or in a degree to render the rock on its course exceedingly porous, filling may then have been accomplished in the same manner as in the first instance. It is obvious that in the first case the fissure may have been formed either before the impregnation of the bed or after—in one instance being filled at the same time with the bed, in the other being filled after with bitumen derived from the adjoining rock mass. If the vein occupies a channel of solution, this presupposes the removal of the calcareous material prior to impregnation with bitumen. Of the foregoing, the origin in a fissure perhaps best meets the attendant conditions.

Other features of the general limestone bed are minute veins of pure asphaltum filling chance cracks, and imperfect coal, occurring either as the carbonized fragments of wood originally laid down in the calcareous débris, often mudlike in texture, that formed the limestone, or as coal seams in miniature, the material being bright, brittle, subconchoidal in fracture, and fibrous. But all such occurrences are very irregular. Overlying the main body of bituminous limestone are others of much lower grade, wholly excluded from the products of the mine.

The rock of the No. 2 mine is the richest mined by the Gilsonite Paving and Roofing Company. The amount that has been quarried is considerable, the open cut being nearly 400 feet long, the bed having been removed to a depth of between 20 and 30 feet. The extent of the bed beyond the present quarry lines is undeterminable except by a close succession of drill holes or a continuation of quarrying itself. The locality is one of great irregularity and ambiguity of outcrop, with strikes and dips most variable. It is believed that to the north, within 300 yards, the deposit is interrupted by the No. 2 fault; to the south it is possible that the bed may recur on a temporary south-

NO. 4 QUARRY, GILSONITE PAVING AND ROOFING COMPANY, BUCKHORN DISTRICT, INDIAN TERRITORY.

The quarry is in Ordovician limestone.

ward dip, but, again, the area in this direction is probably limited. Eastward the presence of the enriched limestone is questionable, for already at this end of the pit are encountered faults and foreign beds. The western extent of the stratum may prove to be several hundred feet, but the outcrop can be definitely traced only a short distance.

No. 4 quarry.—This is opened by the Gilsonite Paving and Roofing Company in the No. 4 Ordovician limestone at the western end of its outcrop in the Buckhorn district, about a mile west of Schley and 7 miles northeast of Dougherty (see Pl. XXXV). Immediately west of the quarry the limestone passes beneath the heavy Coal Measure conglomerate; eastward it forms a strong outcrop for nearly a half mile, another quarry, the No. 8 of the Rock Creek Natural Asphalt Company, lying about one-eighth of a mile east of the No. 4. Beyond the half mile the width of the limestone is obscure, and toward the eastern end of the field it was not identified with certainty. The indications are, however, that it is present and that it will be found in considerable width and continuity a short distance beneath the surface, beyond the more immediate influences of weathering.

The face proper of the No. 4 quarry embraces 128 of the total 342 feet of limestone, the lower 75 remaining unopened, the upper 139 feet having been opened, but the material being now rejected owing to the presence of a high per cent of barren calcite. The rock of the quarry is very massive, with a texture varying between earthy, granular, and crystalline. The crystalline texture is the most prevalent in the upper half of the deposit, the earthy and granular in the lower half. The average per cent of bitumen in the quarried rock is between 5 and 6, based on samples from the stock piles. Different portions of the bed, however, vary somewhat in richness, that quarried, which is the granular-crystalline, being regarded as the more satisfactory. The color is a deep chocolate brown in the more homogeneous, granular, and finely crystalline portions, varying to brownish gray in those more coarsely crystalline; the first described is the richer in bitumen. The rock is stratified, but the bedding is extremely heavy in the lower middle portion. Near the top and bottom the beds are from 2 to 10 feet thick, and the divisional planes are especially pronounced. Bodies of highly crystalline calcite are irregularly but profusely distributed through the upper third of the mass, and in their poverty in bitumen are in marked contrast to the general rock of the quarry. About 70 feet from the top of the limestone is a narrow belt in which blue translucent chert abounds, and there is a trace of chert also at the base of the bed. In the lower portion of the mass as quarried is a zone, about 20 feet in width, that presents the aspect of having originally been laid down as a calcareous mud. It is of a browner color than the crystalline granular rock and is regarded of slightly lower value. In this connection it may be noted that there are many instances of muddy texture in the limestones throughout the Buckhorn district, which, coupled with other features, are suggestive of a sedimentary origin for the greater number if not for all of them.

The effect of the calcite bodies in the upper portion of the limestone upon impregnation is noteworthy, the universally close union of their crystals preventing infiltration into their substance of more than the merest trace of bitumen, and often none whatever. In the portion of the limestone surrounding these bodies, however, infiltration has been free, or at least in proportion to the absence of the calcite structure.

The No. 4 quarry has the advantage of location over many of the quarries of the district with reference to transportation by rail, and its position in the hill, together with the steep inclination and great width of the bed, render the winning of its product peculiarly economical. The quarry is worked in a breast about 130 feet wide by 21 high, a depth of 8 feet the entire length and height of the face being removed at each blast, the material then being further broken by minor blasts or by wedge and hammer. The amount of stripping required is less than 10 feet. Steam drills are used. But little hand sorting is required.

No. 8 quarry.—The No. 8 quarry, the property of the Rock Creek Natural Asphalt Company, is newly opened on the No. 4 limestone near the summit of the same ridge as and about an eighth of a mile east of the No. 4 quarry. About 60 feet of the bed are included in the cut, which is as yet a little irregular. The product is derived chiefly from the same horizon as that of the No. 4 quarry, the granular to finely crystalline portion of the bed, but a certain amount of calcite is present either from the inclusion of rock from the upper zone or from occasional scattered calcite bodies through the general mass of the bed, an occurrence that happens both here and at the No. 4 quarry. The average per cent of bitumen in the product is said to be between 5 and 6. The same methods of quarrying are followed as at the No. 4.

No. 3 (limestone) mine.—This mine, the property of the Gilsonite Paving and Roofing Company, is located at Schley, on the crest of Middle Ridge, in the center of the Buckhorn district. It is opened by an incline on the No. 3 limestone, mining methods having been followed rather than quarrying, by reason of the dip, about 30°. The depth of the incline is said to be a little over 100 feet, but at the time of investigation the water prevented examination below 25 or 30 feet. The limestone has been fully described in discussing the geological sections, page 275 (Pl. XXXII, *A*), but for the purpose of comparison between mines and quarries it will be repeated here,

The upper 5 feet of limestone is coarsely crystalline; drab, weathering yellow-gray; distinctly fossiliferous; a trace of bitumen in the lower portion.

The 10 feet below is, in the main, fine grained. From 2 to 4 feet from the top, however, is a band carrying numerous small calcite bodies, round and elliptical, drab in color, and in general in marked contrast with the surrounding mass of rock. The rock is somewhat varyingly charged with bitumen up to a maximum of perhaps 6 per cent, a sample obtained from the upper portion of the mine yielding 5 per cent. The calcite bodies are, however, nearly or quite barren. It is obvious, therefore, that in proportion to their abundance the general average of the limestone in bitumen contents is lowered, this in addition to the variability in the per cent of the general rock mass itself. Veinlets of bitumen occur, passing alike through the general rock and the calcite bodies. The lower 2 feet of this zone is less rich and browner than the overlying portion.

The next 4 feet is fine to coarsely crystalline; light brown to black, more generally the former; fossiliferous and bituminous. In this rock the bitumen is held between the crystals rather than within their individual masses. The upper layer of this band is faintly pisolitic. The lower portion shows brecciation as though from the recementation of a fractured or disintegrated original. A bird's-eye appearance is locally imparted to the bed by the presence of numerous bodies of concentric structure, the origin of which is not definitely known.

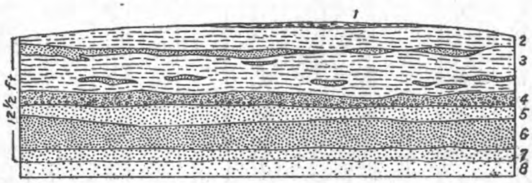


FIG. 23.—Face of West Kerby quarry, Buckhorn district, Indian Territory. Figures refer to numbers in section on p. 300.

The lower 5 to 10 feet of this bed are crystalline, drab, and nonbituminous.

The entire bed of limestone is more or less jointed, an impoverished chocolate-brown zone ¼ to 2 inches wide quite invariably lying on either side of the fracture planes.

The portion of the bed mined includes only the second and third layers from the top, the rich zone of 10 feet and that immediately underlying, 4 feet thick. The product thus far derived from these two beds probably amounts to several hundred tons. The mine is equipped with hoist and steam drills, and the company has at this point a small machine shop and store. Near by, also, is the factory at which mastic and street topping are made. The mine was closed at the time of the investigation.

Kerby quarries.—These, the property of the Rock Creek Natural Asphalt Company, are three in number and lie in close proximity to one another about two-thirds of a mile northwest of Schley. For convenience they may be designated the west, middle, and east quarries. All are opened in the Dixon sandstone. The west quarry lies in a low, flat knoll of small diameter, the other two in the rolling ground to the east. The west quarry presents the following section, representative of the face at the time of examination.

Section at westernmost of the Kerby quarries, near Schley, Indian Territory.

1. Sandy shale, but over much of the hill 10 or 15 feet of a heavy bedded conglomerate of Coal Measures age prevails.
2. Clays, slightly sandy.
3. Sandstone lenses in a matrix of fine sandy clay, which also carries a considerable per cent of calcareous matter. The bed is spottedly bituminous.
4. Conglomerate, with lenticles of sandstone. The pebbles are chiefly limestone, with some quartzite; the matrix is of sand, largely quartzose. Matrix and sandstone bodies are somewhat impregnated with bitumen, but not richly so. The layer varies in thickness. Indeed the entire series 1 to 4 varies by the replacement of one bed with another in more or less irregular manner. Age, Lower Coal Measures.
5. Sandstone; delicately cross-bedded; brown, weathering gray; hard to soft. The bitumen once permeating it is now chiefly represented by its dried residue.
6. Sandstone, carrying an average of 7 per cent of bitumen and affording the product of the quarry. Color, black on fresh fracture; gray on exposed surfaces. Texture, tough, tenacious, gummy. Composition, medium to fine, rounded, clear quartz grains; no other minerals as primary constituents of rock appear. Cementing material, bitumen, which, extracted, allows the rock to crumble to sand.
7. Sandstone, similar to 5.
8. Sandstone; white; devoid of bitumen, but otherwise similar to that enriched (6). It is said to invariably succeed the enriched bed or zone wherever exploited on the line of outcrop.

This quarry is opened in the southern slope of the knoll; on the northern slope, less than 200 feet distant, the productive sandstone of the quarry shows but a trace of bitumen. The explanation probably lies in nonimpregnation of this portion. At the eastern end of the quarry the enriched zone of the bed (6 of the section) may be seen to feather out, although here as to the north the general width of the sandstone itself is maintained. The entire area of the bitumen-bearing sandstone is, therefore, even smaller than the diameter of the hill. It appears to be, in fact, the western end of a comparatively small body that has its eastern limit at some point perhaps a little beyond the eastern edge of the east quarry.

The view of the quarry face (Pl. XXXIV, *B*) is 30 or 40 feet west of the portion shown in the diagram (fig. 23). The bottom of the productive sandstone is obscured by débris, but the nature of the overburden, the Rock Creek conglomerate, though differing somewhat from that as sketched in the diagram, as was suggested it might, is clearly brought out. This overburden attains a maximum thickness over the quarry of between 10 and 15 feet. It is very hard and requires heavy blasts for its removal. The method of stripping, however, is simple, and after this has been accomplished to a sufficient distance and the quarry cleaned of the débris, the bitumen-bearing sandstone itself is removed, loaded on wagons, and shipped to the railway.

The middle quarry lies immediately east of the west, but at a level between 15 and 20 feet lower. The difference in level is, perhaps, primarily an effect of the Bodine fault; on the other hand, it may be ascribable to mere erosion from the summit of the bed, the protective cap of conglomerate having been first removed. In the latter event the lower level of the enriched rock in the middle quarry indicates an originally deeper impregnation of the bed and a consequent extraordinary unevenness in the separating plane between the rich and barren zones. An occurrence of this nature is quite possible, yet, in view of the proximity of the Bodine fault, the difference of level, it is believed, is best attributed to stratigraphic throw. But the irregularities in the details of impregnation are none the less well illustrated in the rapid succession, in the north wall, of highly enriched, black, oily sandstone; a brown, friable sandstone with the interstitial bitumen dried and lifeless, and barren rock with but scattered specks of bitumen amid the grains of quartz. These bodies of rock of differing composition and color are separated from one another in the face of the quarry by lines waving from vertical to horizontal and sharp or sharply transitional, indicating the irregular form assumed by the impregnated portion of the bed, and the manner of passage from barren to rich portions. The prevailing conditions suggest high enrichment for a part of the sandstone, none whatever for another, with a narrow intermediate zone, a few inches to 2 feet in thickness, in which infiltration may not have been as complete as in the richer portion, or from which, for some cause, the more volatile parts of the bitumen have now escaped and left only the dried residue in the interstices of the quartz grains. It is obvious, also, that both of these influences may have entered into the production of the present condition.

The texture, grain, and action of the enriched rock under heat is very similar to that described for the rock of the Ralston quarry, and like this upon removal of the bitumen the residue becomes a mere mass of noncoherent quartz sand. Occasionally in the bituminous portion of the sandstone occur balls of a calcareo-quartzitic nature, gray, and excessively hard, The barren portion of the sandstone is soft, friable, and variably ferruginous. Beneath the bitumen-bearing zone it is gray to white; overlying this, at the surface, it is white, brown, orange, or red, the iron, the source of the colors, seeming to have been as peculiarly and irregularly distributed, and with as sharply-defined bounding lines, as the bitumen in the other portions of the rock. This upper zone of variegated sandstone is apparently wanting at the west quarry, or it may be that a change in sediment took place, and in the lack of a protecting cap weathering has brought about the effect now prevailing.

The middle quarry appears to have been opened on the northern slope of the fold occupying the low northeast-southwest ridge between the Kerby and Bodine pits, the strike of the sandstone being about N. 40° E. with northerly dip of 5° to 7°. It is not clear from the outcrops whether the sandstone is continuous at this point to the southern slope of the fold just referred to, or is interrupted for a short distance.

The east quarry lies about 150 yards east of the middle. It is opened on the same bed as the latter, but continuity of the bituminous body is not established between the two. Like the middle, it is opened on the gentle northern slope of the same fold. The quarry has yielded the largest product of the three of this group, the pit being about 100 feet in diameter, the thickness of the bed worked, from 8 to 10 feet. The rock carries a comparatively high per cent of bitumen, perhaps 8 or 9, which, however, is said to contain a notable amount of volatile oil, an occurrence not met, according to statement, in the rock of the west and middle quarries.

A conspicuous feature of the bed is the presence in its upper 2 feet of many bodies of a white, quartzite-like rock, which impart to the layer, especially on its surface as stripped, a marked mottled white and black appearance, the mottling of various degrees of coarseness. The line of separation between the black and white is usually sharp. The two portions show quartz grains as their predominant constituent, but the white is found to carry in its interstices a heavy percentage of carbonate of lime, while the black shows either but a faint trace (with HCl) or none at all. The line of separation between the chemical constituents, as shown by reagents, is quite as distinct as that of color, and the two are coincident. If, too, there be a thin line of white threaded through the black, again the white shows the carbonate of lime reaction, the black, not. It can hardly be questioned that the sandstone held a calcareous cement unevenly distributed through its upper portion, and that when the bitumen came to be taken up it was received into all those interstices that were unoccupied, but was barred from those already filled with lime, including even the veinlets. The foregoing feature is not uncommon in the bituminous sandstones of the Buckhorn district.

Like many deposits of this nature, the body of impregnated sandstone embraced within the region of the three quarries just described appears in its entirety to be the modern representative in outcrop of an earlier and buried oil pool, and one of a number—at least two—horizons in the sandstones of the Ordovician in the Buckhorn district. In addition to these, there are the deposits in limestone which can hardly be regarded in any other than the same light—as early oil pools.

Moss quarry.—This quarry, controlled by the Rock Creek Natural Asphalt Company, is located in the southern face of Moss Ridge, a half mile north of Schley and an equal distance east of the Kerby pits. The Dixon sandstone is again the horizon quarried, the quarry face presenting an exposure of highly enriched rock between 300 and 400 feet long and about 10 feet high. From above the quarried portion for some distance back, 5 or 6 feet more of brown, impoverished, and weathered bituminous sandstone, have been removed, together with the overlying Coal Measure conglomerate, which capped the ridge to a depth of at least 20 or 25 feet. The rock quarried closely resembles in composition, texture, and richness that of the east quarry of the Kerby group. As at those pits, so here, the enriched bed is succeeded below by a soft, white sandstone, the line between the two being, as a rule, decisive and undulating. Locally, however, there may be a band of 2 or 3 inches, belonging rather to the enriched portion, that is brown, impoverished, and dried. Beyond the confines of the quarry occasional outcrops indicate the continued presence of bitumen, but the value of the rock and the actual amount still available in the ground can be determined only by prospecting. The quarry, idle at the time of the examination, has been one of the most productive of the district.

Bodine quarry.—The Bodine quarry, also controlled by the Rock Creek Natural Asphalt Company, is opened in the Bodine sandstone on the north side of Prindle Gulch, opposite the west end of Middle Ridge. It lies nearly with the strike of the bed, N. 40° E., and is about 400 feet long by 50 wide. The dip of the strata is here 25° southeast. Only a small tonnage of the rock has thus far been shipped, obtained chiefly from the southwest end of the pit, the remainder having been merely stripped. The sandstone lies beneath 5 or 6 feet of yellow clay which has the appearance of a local superficial deposit, although it may prove to be of the same age as the sandstone—Ordovician. The thickness of the sandstone is undetermined, but it is believed to be at least 9 or 10 feet. The rock consists of rounded quartz grains of medium fineness, with bitumen filling the interstices. The per cent of bitumen is said to average between 7 and 8. The rock carries the same calcareo-quartzitic bodies that occur so conspicuously at the East Kerby quarry, but they are not so large and the mottling is therefore on a smaller scale.

The continuity of the bed is interrupted to the west by the Bodine fault and the disturbance of the strata incident to this rupture. Across the fault the bed is found several hundred feet to the south. Eastward the sandstone passes up the valley of Prindle Gulch, but it is repeated by the Prindle fault and the superficial area is thereby considerably broadened. Concerning its bitumen contents in this direction, however, nothing is known except at the No. 3 sandstone quarry of the Gilsonite Paving and Roofing Company, near the factory at Schley. The western extent of the Prindle fault is not distinct; it may pass to a point opposite the quarry with diminished throw, and, taken in connection with the bended strata in the base of the Middle Ridge, this becomes quite possible. In this case, a short distance south of the quarry, the sandstone would be both crumpled and interrupted.

No. 3 (sandstone) quarry.—This quarry, belonging to the Gilsonite

Paving and Roofing Company, is located on an outcrop of the Bodine sandstone, just east of the factory at Schley, on the northern slope of the Middle Ridge. The opening is irregular and but a few hundred tons of rock have been removed. The beds exposed have been fully discussed under A of the general sections (p. 275), to which reference may be made; that portion, however, pertaining to the bituminous sandstone may be repeated. The sandstone is composed of medium-sized, sharp quartz grains, with bitumen filling the interstices. At the top is a layer of exceedingly hard quartzite, with probably a strong though somewhat uneven infiltration of carbonate of lime, similar to the occurrence at the easterly pit of the Kerby mines, three-fourths of a mile to the northwest. Its impregnation with bitumen is irregular, the rock being conspicuously mottled black and white. The total thickness of the sandstone is estimated to be about 10 or 12 feet, 9 feet being exposed at the quarry. The amount of bitumen contained in the main portion of the bed is variable, but an average of between 6 and 8 per cent is said to be maintained in the product. The continuity of the bed beyond the confines of the quarry is undetermined. As at other points, the extent and shape of an ancient and partially buried oil pool can be determined only by prospecting.

Other openings.—Other openings in the Buckhorn district are in the form of prospects. The chief of these are known as Nos. 7, 5, and 1, and in addition there is an unnamed pit near the eastern edge of the field, on the upper eastern branch of No. 2 Creek.

No. 7 is a small hole in the No. 3 limestone 500 or 600 feet northeast of the No. 8 quarry. About 10 feet of the limestone are here found varyingly impregnated with bitumen, but the opening is not sufficiently deep to afford an idea of the general enrichment of the body. A very considerable amount of calcite is distributed through the bed, which seriously militates against its value. The general petrographic features of the rock are the same as at the No. 3 mine, but the impregnated zone appears to be narrower and the component strata thinner. As at No. 3, the upper and lower layers of the limestone are practically unimpregnated, the upper being white to drab gray and bearing the characteristic fossils of the horizon.

The No. 5 prospect is opened in the bluffs of Rock Creek, about 1¾ miles northwest of Schley. This, again, is on the No. 3 limestone, which is here highly crystalline and conspicuously filled and marked with the calcite bodies, rendering the rock so far as exposed of little value. A variety of the rock is indistinctly mottled brown and white—the brown earthy to crystalline, the white pisolitic; it is also fossiliferous. The width of the exposure is about 10 feet. The strike of the limestone is N. 60° W.; the dip, NE. 40°. Forty or fifty feet above the channel of the stream the trend of the bed carries it southeastward beneath the Coal Measures conglomerate; to the northwest it probably crosses the valley beneath the wash of the creek, but no attempt has been made to trace it into the hills beyond.

The No. 1 prospect is a little pit on a bituminous, quartzose limestone of the Coal Measures, exposed in the southwestern slope of No. 2 Hill. Though bituminous, the rock is of no value, being variable in composition and impregnation, thin, and rapidly passing under cover. The strike is N. 62° 30′ E., the dip NW. 32°. The associated strata are given in profile H, Pl. XXXIII.

The prospect in the southeast corner of section 14 consists merely of one or two small pits sunk on the edge of the branch in what is probably the Bodine sandstone. The general strike for the locality is N. 50° E., the dip 20° SE., but in both pits the strata look horizontal. The thickness of the sandstone is said to be over 10 feet, but 2 feet only show above the water of the pits. The rock carries a moderate per cent of bitumen, is brownish black and tough. The bitumen is held in the interstices between the grains of rounded quartz which constitute its mass. A small per cent of lime may also be present. A peculiarity of this sandstone is a white venation that follows joint or fracture planes, of which there are many. Close examination shows the veinlets to be of rounded quartz grains in a white, earthy cement of undetermined composition. The veinlets are usually from a few inches to 3 or 4 feet long and from one thirty-second to one-half inch wide. On the face or plane of a joint, if the rock be there opened, they show as a thin film. In addition to the venations, mottling of black and white, similar to that seen in other localities, is also present. The bed is overlain by yellow quartzite and clay, this resembling the succession at the No. 3 sandstone quarry near the factory at Schley, and also that at the Bodine pit. The extent of the bed and its economic value can be learned only by prospecting.

Outlying deposits.—Six or seven miles northeast of the Buckhorn field and about 2 miles southeast of Hickory, in the SW. ¼ of sec. 21, T. 1 N., R. 4 E., on the Goodwin or Armfield farm, is an outcrop of bituminous sandstone lying in the flat a little west of the main fork of Mill Creek. The rock is of high grade, but neither depth nor area has ever been investigated, chiefly, perhaps, on account of distance from railway, which is about 15 miles. The bed is apparently horizontal, and from the nature of underlying shales, which outcrop in a neighboring gully, it is thought that it might be the lower portion of the Dixon sandstone, reappearing here after an extensive area of concealment to the northeast of the Buckhorn district. The composition of the sandstone is of rounded, medium-sized quartz grains, and probably bitumen alone forms their binding material.

About 2½ miles north of Schley and 1½ miles southeast of Sulphur Springs, a little to the east of the direct road between the two places, is a small opening on a body of bituminous sandstone, which, from its appearance and the general aspect of the overlying strata of shale, quartzites, and crystalline limestones, 10 to 15 feet in all, suggests the Bodine sandstone. No definite evidence, however, as to horizon was discovered. The bituminous sandstone occurs in two layers of about 4 feet each, both cross-bedded and carrying many bodies of the calcareo-quartzitic rock already described in the discussion of the sandstone quarries about Schley. Owing to the presence of these bodies, and also of a notable per cent of iron, the deposit as exposed is worthless. The strike of the bed is between S. 30° and 70° W., the dip 7° NW.

Still farther north, notably near Dolberg, other outcrops, unexploited, are reported, but an exhaustive examination of all such localities, with all the attendant questions, would have entailed a geological survey of many square miles, which was not contemplated in planning the present work.

BRUNSWICK DISTRICT.

The Brunswick district of bituminous rock, 1½ miles square, lies immediately north of Rock Creek, 4 miles northeast of Dougherty. The topography is rough, developed in strata highly crumpled and faulted. The structure is a part of that involved in the eastern end of the Arbuckle uplift.

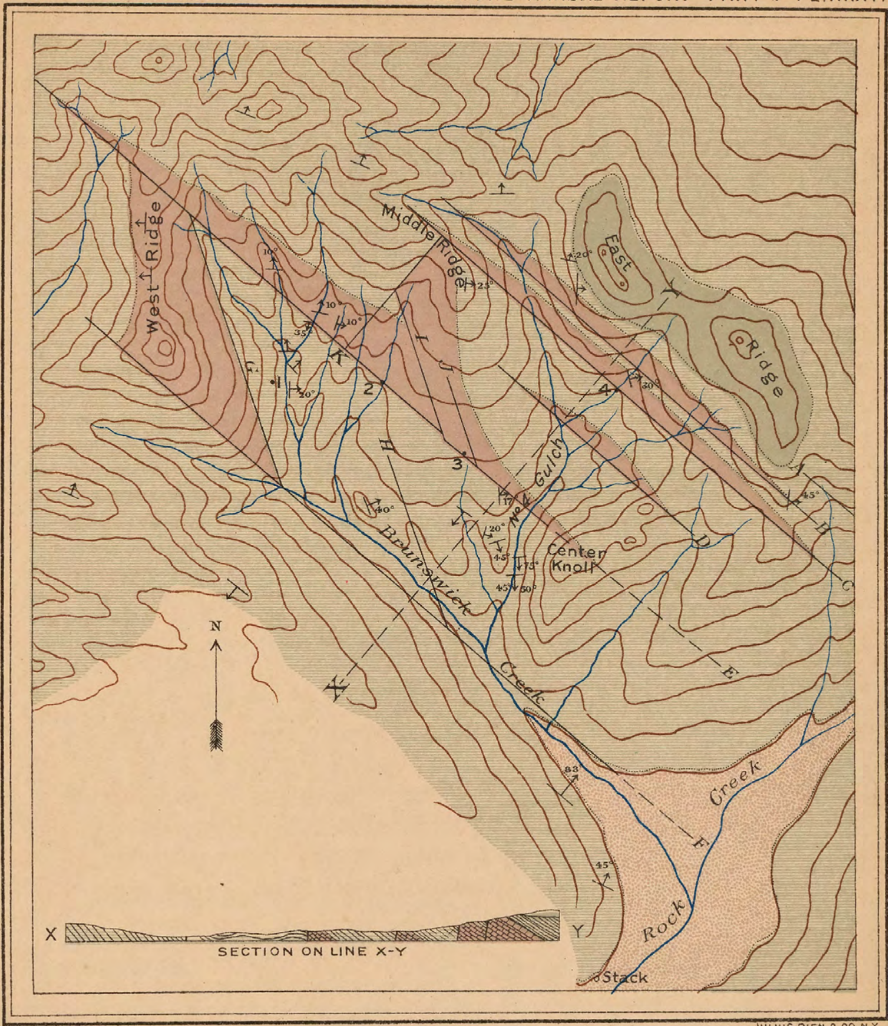
THE FORMATIONS.

The formations are the same as in the Buckhorn district—that is, the Coal Measures, with their conglomerates; the Mississippian, the Lower Helderberg, and the Ordovician (see Pl. XXXVI).

The conglomerate of the Coal Measures is identical in composition with that of the Buckhorn region, but here lies only in contact, unconformable, with the Mississippian or Caney shale. The thickness attained is about 60 feet, but the body is a mere remnant of that which doubtless once covered a large portion of the adjacent country. The position of the bed is nearly horizontal, perhaps with slight dip eastward.

The Mississippian is again recognized by its shaly nature, its fragmental chert, and the earthy and calcareous beds which enter so prominently into its make-up in the Buckhorn and other regions. The formation is prominent about the periphery of the Brunswick area, but from the center it has been largely removed by the erosion of the Brunswick gulch, the locus of which was doubtless determined by the severe fracturing which there took place in the strata.

The Lower Helderberg is recognized by its fossils, found, however, in but a single locality, the summit of West Ridge, in one of a series of thin limestones interlain with shales. The limestones and shales aggregate perhaps 50 to 100 feet, and but for the features mentioned might easily be confused with beds of closely similar appearance in



MAP OF
BRUNSWICK DISTRICT
INDIAN TERRITORY,
BY GEO. H. ELDRIDGE

Scale

¼ 0 ¼ ½ MILE

Contour interval 25 feet

LEGEND

RECENT | COAL MEASURES | MISSISSIPPIAN | SILURIAN

Lower Helderberg
Ordovician

A-K FAULTS 45° STRIKE AND DIP 1-4 OPENINGS the Coal Measures. Indeed, the members of the Lower Helderberg are more or less difficult to distinguish throughout the Brunswick area.

The Ordovician is represented in the Brunswick area only by its uppermost limestone, which is recognized from its heavy bedding, its homogeneous to crystalline texture, its calcite bodies, and its stratigraphic position, as the equivalent of the No. 4 limestone of the Buckhorn district. Here, as there, too, it is heavily impregnated with bitumen. Nowhere in the Brunswick field is it exposed in full thickness.

In this connection it may be observed that certain limestones—for example, those exposed at the No. 1 quarry, perhaps referable to the somewhat doubtful series provisionally regarded as Lower Helderberg, but here mapped as belonging in the Mississippian—have several features that are prevalent in the recognized Ordovician, notably calcite bodies, chert, and a comparatively high per cent of bitumen, these adding to the difficulty of the assignment of such strata.

STRUCTURE.

General features.—Structurally the Brunswick region includes a small portion of the northeastern slope of an anticlinal fold several miles in extent, which is one of the many that go to make up the eastern Arbuckle system. For nearly the entire area mapped the prevailing dip is about 30° to the northeast, but in the ridge in the southwestern portion the beds are sharply crumpled into minor folds that occupy the axial region of the anticline. The southwestern slope of the anticline is well exposed in a ridge south of Rock Creek, about a quarter of a mile below the Brunswick plant, where the dip is 35° SW.

Simplicity of structure in the northern arm of the anticline within the Brunswick area is completely lost in the extensive and complicated faulting that has taken place; but this very faulting, coupled with erosion, has been the means of exposing the rich bituminous limestone of the Ordovician and enabling the winning of a product of considerable industrial importance. There are two well-defined systems of fractures trending, respectively, N. 50° W. and N. 20° W., the former the more highly developed. In addition to these, there are others of minor value, but so numerous as to locally cause almost a comminution of the beds. This is especially the case in the region of the main forks of Brunswick Creek, where the effect has been even further heightened by sharp crushing of the shales that there exist. Such faulting has been not only the cause of repeated reduplication of the measures, but also the source of much confusion in the correlation of the beds involved. The delineation of the faults on the map (Pl. XXXVI) is in accord with the weight of the evidence, but their linear extent is generally obscured upon their passage into the Mississippian beds, and is, therefore, only approximately given.

Faults.—Fault A is to be seen in the face of the east ridge overlooking Rock Creek. It occurs in shales and limestones and is apparently a fracture of slight extent and throw.

Fault B is best exposed in No. 4 gulch, about 200 feet above the quarry there worked. The fault belongs to the N. 50° W. system of fractures. The No. 4 Ordovician limestone is exposed on the northeast; the shales of the Mississipian on the southwest. The stratigraphic throw is 132 feet. The hade is about 10° S. W.

Fault C is well defined in both the north and south walls of the No. 4 quarry. The general trend of the fracture is N. 50° W., although it wavers somewhat, locally. No. 4 limestone and the Mississipian shales are again opposed, the latter lying southwest of the plane. The hade, as in all the N. 50° W. faults, is southwest, here apparently between 20° and 30°, though elsewhere it may be less. The displacement of the beds is about 225 feet. To the southeast the fracture extends to the Rock Creek Valley; to the northwest it was thought to have been detected well toward the head of the gulch.

Fault D is exposed at the forks of the creek below the No. 4 quarry. The length of the fracture was not clearly determined; it may be much greater than indicated on the map, for the displacement of the strata amounts to about 325 feet, which is in excess of that of other faults whose linear extent is known to be considerably greater. The fault is a further occasion of a limited exposure of the No. 4 limestone of the Ordovician.

Fault E is traceable for practically the entire distance indicated, and to the southeast may continue to the Rock Creek Valley, the strata being more or less disturbed in this direction. In the region between the No. 3 quarry and the center knoll the position of the break is not so clear as to the northwest, for there is here great confusion of strike and dip and the strata have almost a comminuted appearance; it is possible in this locality that the main fracture may bear more to the east, a direction suggested in one or two of the strikes encountered in the vicinity of the No. 3 quarry. In the face of this quarry the direct trend of the E fault is slightly interrupted by the two diagonal faults there shown, the plane in the No. 4 limestone, to the east of each cross fracture, being moved about 50 feet southward. The hade of the E fault is 5° SW. The amount of displacement at this fault is unknown, but it is believed to be, at a maximum, less than 500 feet. Well toward the West Ridge the strata as identified on either side indicate a throw there of between 100 and 200 feet, decreasing toward the northwest. The fault is well exposed at the Nos. 3, 2, and 1 gullies, where, at each point, more or less prospecting has been done—at the No. 3, even quarrying.

Fault F is suggested by the relations of the strata in character and dip on either side of the Brunswick Gulch. The evidence of its presence, however, is not wholly satisfactory, chiefly because of the difficulty of distinguishing horizons in beds of such uniformity as occur in the shales of the Mississippian.

Fault G is somewhat in doubt, but there appears to be a break in the continuity of the beds in the locality indicated, the trend of which is in harmony also with the axis of a slight crumple that appears in the rocks of the ridge to the west. The strata on the west of the fault show Lower Helderberg fossils, but the amount of their relative displacement is undetermined.

Fault H is apparently of small extent and displacement and is confined entirely to the shales of the Mississippian.

Fault I is clearly defined in the vicinity of fault E, the plane of which has been thrown about 50 feet. To the south it passes into the shales of the Mississippian and is lost; to the north it extends at least as far as the cross fault K, where it is again lost in the shales of the Mississippian. Below the cross fault, Mississippian on the west opposes possible Lower Helderberg on the east. The amount of throw is probably less than 100 feet.

Fault J, parallel to I, is ill defined, but is doubtless of slight extent. Its effect upon the plane of E is similar to that of I.

Fault K is discernible only on close inspection of the adjacent beds. The northeastern end is in doubt; the southwestern may be recognized in the Ordovician limestone at the fault line E, beyond which it was not proved to extend.

QUARRIES.

The quarries of the Brunswick region are four, all under control of the Brunswick Asphalt Company. They are numbered 1 to 4, from west to east. No. 1 is opened on a limestone that has been somewhat provisionally assigned in the general discussion of the region to the Mississippian; Nos. 2, 3, and 4 are opened in the No. 4 Ordovician limestone, 2 and 3 in the plane of the fault E, No. 4 in that of fault C. No. 4 is the most recently developed, and at the time of the investigation was the only quarry worked.

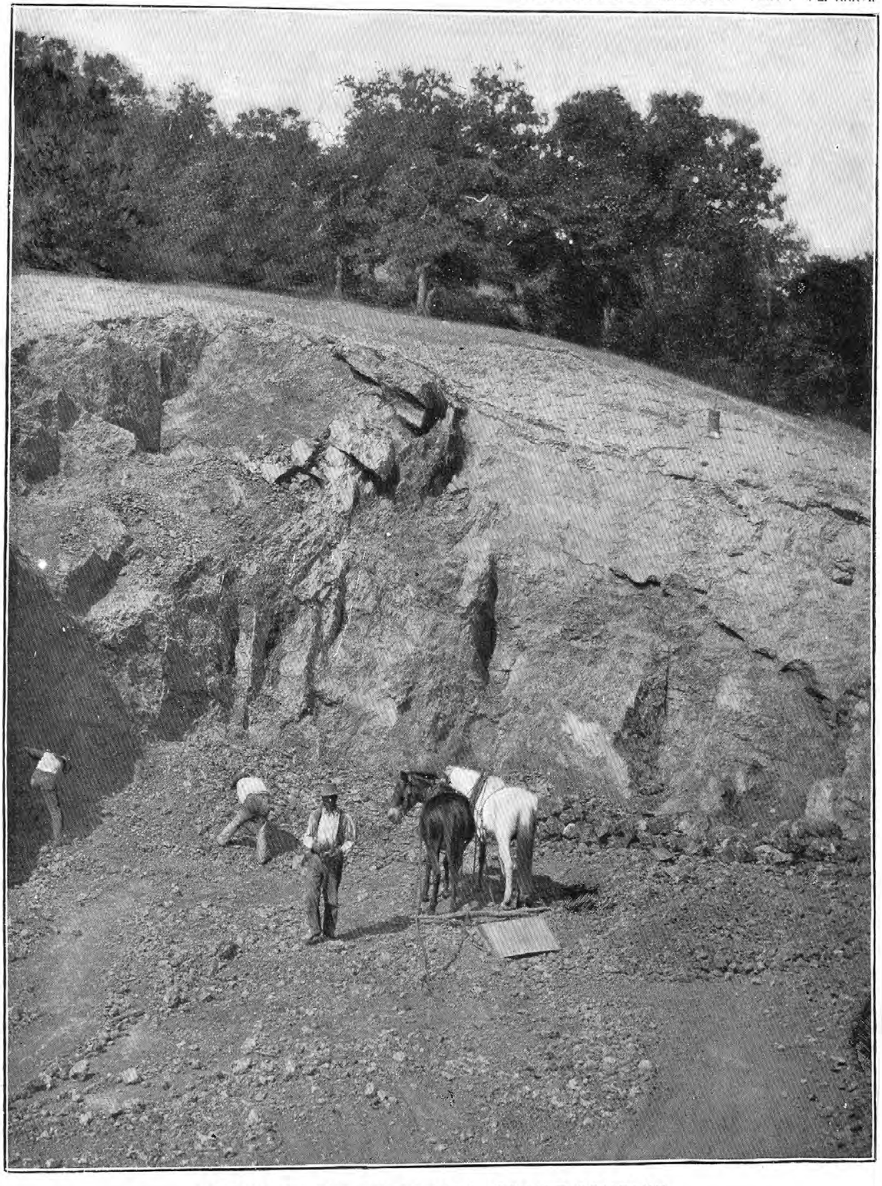
No. 1 quarry.—This is a mere prospect in a limestone outcropping in the banks of the dry channel at the eastern base of West Ridge. The strike is locally N–S; the dip, 20° E. Petrographically the limestone consist of (*a*) an ordinary granular to finely crystalline rock, impregnated with bitumen and looking at times as rich as the average No. 4 Ordovician limestone; (*b*) a calcitic variety, also impregnated with bitumen, but not always in sufficient amount to render the rock of value; (*c*) white chert, barren except for the seams into which the pure asphalt was forced at the time that, or after, the general deposit became impregnated. Stratigraphically the bed as exposed is divisible into two layers, an upper of 6 feet and a lower of 4 or 5 feet. The upper has the appearance of an ordinary bed; the lower is a bed composed entirely of lenticles of limestone, calcite, and chert, all dovetailing one with another. These lenticles average 2 feet in horizontal extent by 6 to 8 inches in vertical. The upper division of the bed is the more even in texture and in impregnation and, although calcitic, is wanting in chert. It is not to be counted a high-grade rock, although decidedly higher than the lower zone, which is in fact worthless. The lower half of the upper division is also the richer. The rock as exposed in the bluff has been greatly fractured, especially, it would seem, the chert, which in instances looks as though it had been shot through the limestone in angular fragments, imparting to it a brecciated appearance. Shales immediately overlie the bituminous limestone, carrying in their mass, especially just above this limestone, other thin, crystalline, yellow limestones. Greenish-gray clays underlie the bituminous limestone lower down the gulch.

It will be inferred from the foregoing that the rock of this quarry derives its sole interest from its composition and structure. From an economic standpoint it is practically valueless.

No. 2 and No. 3 quarries.—Of these the latter has yielded a considerable tonnage. No. 2 is hardly more than a prospect and barely larger than one or two other openings to the west on fault E not enumerated in the present list. Their rock is identical with that of No. 4, unless there should be, as is very likely, some variation in the bitumen percentage.

No. 4 quarry.—This is advantageously opened on what promises to be a productive body of rock in the block of No. 4 Ordovician limestone on the northeast side of fault C. The limestone has the same features of composition, texture, and impregnation as those described for it at the No. 4 quarry of the Buckhorn district. The earthy, granular, and crystalline texture are all repeated; the barren calcite bodies are present, in equal contrast with the general mass of the rock; the calcareous mud is as readily identified in one locality as in the other; and each variety of rock in texture shows the same difference in the degree of impregnation. If there be a difference in the rocks of the two localities it is in an apparently more general distribution of the calcite bodies through the rock of the Brunswick quarry, and a possible slight lowering in consequence, of an otherwise equally maintained average in the bitumen percentage. A feature, too, conspicuous in certain portions of the Brunswick pit, is the filling of fracture cracks with pure bitumen, derived, probably, by infiltration from the main body of the rock.

The same width of limestone is not exposed here as in the No. 4 quarry in the Buckhorn field, but at no point in the present area is the entire thickness of the bed brought to light. The possibilities in an economic way must therefore remain unknown unless the drill be resorted to.



QUARRY OF THE BRUNSWICK ASPHALT COMPANY.

The No. 4 Brunswick quarry is located about a mile north of the plant, to which the product is hauled, over an easy road, for conversion into mastic or other manufactured product, or is carried beyond to the railway at Dougherty, a total distance of between 4 and 5 miles.

WASHITA CANYON.

Geologic features.—The canyon here referred to lies about midway between the towns of Dougherty and Davis. In this region the heavy No. 4 limestone of the Ordovician is arched into a pronounced anticline that is well exposed in the lofty walls of the gorge. The axis of the fold lies in a N. 50° W. direction, diagonal to the course of the river. The limestone is here between 350 and 450 feet thick. Beneath it in the axis of the arch are 50 or 60 feet of shales and limestones highly crumpled and even faulted. The shales of the Mississippian overlie the No. 4 limestone on either arm of the fold, to the south occupying the syncline between this and the main fold of the Arbuckle Mountains across the river, to the north extending beneath the prairies and the conglomerates and shales of Coal Measure age forming their superficial terrane.

The section afforded by the Washita Canyon is toward the northern end of the anticline; the southern end, it is thought, is crossed on the Schley-Dougherty road, 5 miles south. The heart of the fold, with lower beds than those exposed along the Washita, and including a heavy sandstone with traces of bitumen, is laid bare in the first large gulch south of the canyon, about 1½ miles southeast of the region of the limestone arch described above. In the hills throughout the anticline there are many sharp crumples with corresponding local changes of strike and dip, but withal a general N. 50° W. strike is distinctly maintained. The No. 4 limestone occupies the higher points in the field, the underlying shales, sandstones, and other limestones being found only in the valleys. In the latter limestones were found, also, well-defined Ordovician fossils. The anticline here described is the first west of the Brunswick anticline, and it may be that at the north they pass into each other.

W. H. Hook prospect.—This is located near the center of Sec. 21, T. 1 S., R. 2 E., 4½ miles north-northwest of Dougherty, in a rugged gulch a quarter of a mile east of the Gulf, Colorado and Santa Fe Railroad. The opening is in the No. 4 limestone of the Ordovician on the northeastern slope of the anticline described above. The outcrop of the limestone is bold and of marked continuity, and impregnation has been general for a considerable area in the region of the prospect, indeed extending in a slight degree to the canyon of the river. The bitumen contents are variable, and the per cent is the question for the quarryman rather than the quantity of rock. The prospect at the time of examination was not opened sufficiently to permit a satisfactory estimate of its value. The color of the limestone is here mottled gray, the mottling from the uneven distribution of the bituminous matter. The rock is hard, though brittle; the texture, fine grained to crystalline from the development of calcite. The limestone, aside from its being in a highly folded region, also has the appearance of having once been crushed, with recementation of its somewhat slightly displaced fragments. There remained open, however, innumerable fine joints, which are now filled with bitumen, an occurrence in almost all jointed rocks of which the mass has been impregnated.

The location of the Hook prospect is advantageous from the point of transportation, lying as it does within a quarter of a mile of the railroad.

ARBUCKLE MOUNTAINS.

The region of the Arbuckle Mountains and the prairies to the west and south have many outcrops of bituminous sandstones, most of which have been prospected and one or two quarried. There is but one known to have been discovered in the mountains themselves, the others occurring in members of the Coal Measures or supposed Permian that occupy the prairie without.

THE INTERIOR.

Perry Russell prospect.—This lies well within the eastern end of the Arbuckle range, about 7 or 8 miles southwest of Davis. As exposed it is a thin limestone carrying a mere trace of bitumen, including a half-inch vein of the latter that has seeped from the body of the rock. With an underlying sandstone it occupies the axis of an anticline that includes a considerable portion of this end of the range and yet may be but one of a number of such folds that go to make up the mountains in their entirety. The trend of the anticlinal axis is here N. 10° W., but the beds at the center have undergone a considerable crumpling.

About a quarter of a mile southwest of the foregoing outcrop is a slightly impregnated sandstone in shales. Neither deposit is of any value.

The series of shales, sandstones, and limestones here exposed in the center of the anticline is probably Ordovician, corresponding to that of the lower half of this formation in the Buckhorn district, the counterpart of the limestones at the top being found in those occupying the high outer ridges of the range. The point of interest about the above occurrences is merely the additional evidence it contributes to the wide areal distribution of oil-bearing strata as represented in the exposed asphaltic limestones and sandstones of the present day.

AREA TO THE WEST.

At the western end of the Arbuckle Mountains, in the vicinity of Hennepin, Homer, and Elk, and even as far west as Robberson, a number of oil seepages in the water of wells, springs, or prospect pits were reported to the writer. These were accepted as evidence of the general distribution of oil in as yet undetermined quantities, but the only places visited were the Williams ranch, 3 miles southeast of Hennepin, where a seepage of oil occurs on the water in a small prospect pit in limestone, the only asphalt found being along thin seams in the fractured rock; a small pit exposing an inferior bituminous limestone on the Elk road, 2½ to 3 miles southwest of Hennepin, and the Nelson prospect, 2½ miles southeast of Elk. A specimen reported from the Robberson occurrence indicates it to be a surface deposit from an old maltha spring.

Nelson prospect.—This shows a nearly horizontal bed of bituminous sandstone and grit about 17 feet thick, underlain with greenish grey shale and overlain with a thin bed of shale followed by a limestone 2 to 3 feet thick, which forms the surface terrane of the prairies for a considerable region about. The series outcrops in a low bluff bordering one of the shallow washes of the upper drainage of Caddo Creek. The 17 feet of bitumen-bearing sandstone consists of the following, from above down:

Section at the Nelson prospect.

	Feet.
Sandstone, inclined to shaly structure	2
Sandstone, massive; of sharp quartz grains; brown; once comparatively rich, but now as though impoverished, and dried out and friable	4
Hard, shaly sandstone, richer than that overlying	1
Sandstone of sharp quartz grains, and somewhat cross bedded; a second grade rock of little value as exposed, although away from the outcrop, with sufficient cover it might improve; the lower 1½ feet conglomeratic	6
Greenish clay shale, nonpersistent, 2 to 4 inches.	
Conglomerate or grit; matrix of similar composition to the sandstones above; the pebbles fine, sharp to round, chiefly of quartz, but also some of limestone and black and red chert. This band is varyingly enriched with bitumen, of which there is considerable seepage; of little value, however, unless for the extraction of the bitumen at some future day	4

Twenty-five feet below this bed, the greenish shales intervening, there is another heavy conglomorate, about 4 feet of which shows above the bottom of the wash. This, also, is slightly impregnated. In a shallow gulch a few hundred feet south of the prospect thus described there has been a considerable seepage of maltha, now covering an area about 40 by 15 feet. The depth is, perhaps, 2 or 3 feet at some points. Whether this was derived from the sandstones and grits of the region or from some other source is doubtful.

The general strike of the beds for this region is about N. 30° to 50° W, with a southwesterly dip of 5° to 10°. At the prospect the former dip prevails. The horizon of this sandstone is believed to be in the Coal Measures. Tar seepages are reported between the Nelson quarry and Elk.

Oil Spring Prairie.—This region lies about 2 miles west of Wheeler, and is underlain with a heavy, horizontal, white to gray sandstone, which has been prospected for bitumen or oil to a depth of 12 feet, but with the only result of a small seepage of the latter, which rises to the surface of the pit water. Throughout this general region oil is encountered in many springs and wells. Somewhat similar indications are also to be found a half mile west of Graham, 5 miles north of Oil Spring Prairie. The strata of this region are, in part at least, of the supposed Permian.

Wheeler prospect.—At Wheeler is one of the largest oil seepages in the United States. The only parallel in size known to the writer is one still forming near Fort Washakie, Wyo. The Wheeler spring is long since extinct, as is shown by the appearance of the material and

FIG. 24.—Extinct petroleum spring, now a brea deposit, Wheeler, Ind. T. 1, Brea; 2, Bituminous sandstone and arenaceous shale; 3, Sandstone and shale, slightly impregnated. Height of face about 8 feet.

by the inclusion of fragmental asphalt derived from it deep in a deposit of 4 or 5 feet of alluvium along portions of an earlier channel, this being shown by the erosion, upon the same lines, of a modern channel which has cut alluvium, asphalt, and underlying beds. The conditions of occurrence are indicated in the accompanying illustration (fig. 24), where the asphalt of purer type is seen forming the superficial layer, succeeded below by sandstone alternately shaly and solid, and all varyingly impregnated with bitumen, the per cent diminishing with increasing depth. With the sandstone are associated red and gray argillaceous shales, and the whole series is probably of the Permian, which is prevalent in this region. The superficial asphalt rests upon a somewhat uneven surface of the approximately horizontal strata, and is from 6 inches to 3 feet thick—a hardened petroleum residue, resulting from the volatilization of the lighter oils, with perhaps a certain amount of oxidation, the common transformation in the case of all deposits of like nature. In the flow and in settling to its final state of rest the bitumen acquired a certain amount of sand (in the present instance subangular to rounded quartz) bark, twigs, and other substances with which it came in contact. It is, therefore, variable in purity of composition. This asphalt is primarily black; earthy, or clear and wax-like in texture; brittle yet tenacious, and under a slight rise in temperature becomes of gum-like consistency. In the face of the gully that is eroded in the deposit, the upper 1 foot maintains the richest, purest, and most unaltered appearance, the portions below becoming successively browner, more earthy, and easier to break. In places the line between the asphalt proper and the underlying sandstones and shaly layers is distinct, although the latter are impregnated with bitumen; in others this line is seemingly wanting, the asphalt shading from pure to less pure, to earthy, then becoming even shaly, and so uniting with the impregnated shaly layers, which, still lower, become impoverished, with increasing distinctness of stratification. It will be gathered from the foregoing that the impregnation of the sandstones and shaly layers, which latter also are arenaceous, took place both from above and laterally, the bitumen being derived from one or more vents or springs within the immediate region. The deposit is of interest in its bearing upon the presence of oil at depths and is another evidence of the possibilities of the region which have already been suggested in the references to oil-bearing waters of springs, wells, and prospects.

AREA TO THE SOUTH.

Sneider quarries.—Southeast of Woodford, in the broad, rolling prairie lands drained by Caddo Creek and its tributaries, are the two Sneider quarries, one, now abandoned, about 2 miles from town, the other, recently opened, 2 miles beyond, close to Henryhouse Creek. Both are in bituminous sandstones, but the identity of their horizons is not established; the sandstones differ in width, in their bitumen contents, in their dips, which are opposed, and in their strikes, which are N. 62° W. and N. 35° W. for the west and east quarries, respectively. All this signifies, however, but difference of structure, not essentially difference of horizon. It suggests the questions to be solved in detail if correlation be attempted. In any event, one or both horizons are high up in the Coal Measures, hardly less than 3,000 or 4,000 feet above the base of the formation, and it may be even 9,000. The series of the Coal Measures in this immediate region differs somewhat from that observed in the Buckhorn field, chiefly in the paucity of limestones, the absence of conglomerates, and the development of at least five more or less prominent sandstones, one of which, of quartzitic tendency, occurs but a short distance above the Silurian limestone and may be of Mississippian age; another at approximately two-thirds the distance from the base of the series to the Sneider sandstone as appearing at the western or abandoned quarry; a third, a little higher; the fourth in ascending order, the Sneider sandstone itself; and the fifth a sandstone overlying this by about 250 feet. In this series the sandstones at both the Sneider quarries, whether identical or distinct, are very likely included. They are the only ones, too, at present known, affording more than a trace of bitumen.

At the old Sneider quarry the sandstone has a N. 62° W. strike and a dip between 88° SW. and vertical. Four hundred feet to the south the dip is 35° SW., and it is probable, with the evidences of the sandstones lower in the series, that a southwesterly dip is normal for this immediate region from the foothills out; that is, that the sandstones and associated series of shales belong directly to the Arbuckle uplift without other than minor intervening crumples. Farther to the east it is quite possible that numerous folds of greater or less importance occur, or, on the other hand, that the syncline existing between the Arbuckle and Criner ranges becomes shallower, so accounting, in either way, for the constantly increasing divergence of the higher strata from those on the slopes of the Arbuckle Mountains.

The sandstone as exposed at the abandoned or west quarry shows a total thickness of between 150 and 200 feet. With the exception of the upper or southern 20 feet it is all more or less impregnated with bitumen. A belt of 45 feet in its center is especially so, and in the northern or lower 25 feet of this belt is the opening, a rectangular pit 25 feet by 30 feet in area, and said to be 40 feet deep though now filled with water to within 10 feet of the surface. From this depth, 10 feet, the sandstone in passing downward is said to have increased somewhat in its bitumen contents and to have averaged perhaps 7 or 8 per cent. The rock consists of fine to medium-sized angular quartz grains, with bitumen as the only cementing material. At the outcrop it is tough to brittle and friable, and black to brown, according to the amount of bitumen contained in it. Weathered surfaces, however, are gray. The richer portions afford considerable seepages of maltha.

The new Sneider quarry is in rock of the same nature as the old, but it is said to be somewhat richer in bitumen, and it is 2 miles nearer to rail transportation, being about 12 from Ardmore in a northwest direction. The general strike of the beds for the region is N. 35° W., but there is some waviness of trend, with a bearing especially toward the west. The dip is 65° to 75° NE., with gentle undulations. The total width of the sandstone quarried at the time of examination was about 40 feet, with shale showing on either side. This width is considerably less than that of the sandstone at the old quarry. The opening at the new quarry is with the trend of the bed, about 20 feet deep, and between 100 and 150 feet long. The rock appears to be of fair average grade, though somewhat variable.

In regard to the extent of the bitumen-bearing portions of steep pitching sandstones—the size of the ancient oil pool, in other words—the same uncertainty exists as in the horizontal beds.

M. Sneider has erected a considerable plant for the extraction of the bitumen at the new quarry.

ARDMORE DISTRICT.

Continental quarry.—This lies 5 miles west-northwest of Ardmore in open, rolling prairie. The stratum developed is a bituminous sandstone, between 25 and 30 feet wide, broken midway by a foot of yellow clays, and bordered on either side by clays that are both red and yellow. The horizon is high in the Coal Measures. The strike of the beds in the region of the quarry is N. 48° W., the dip 72° to 80° NE.; in structure the relation is perhaps with the Criner Ridge rather than with the Arbuckle Hills. The sandstone is of fine to coarse quartz, becoming even a grit locally; the grains are subangular to round. The prevailing color is brown, in varying intensity, the rock at the surface being now dried out, lifeless, and friable. In depth it is said to have been found sufficiently rich in bitumen to have warranted working, but the pit, 60 by 30 by 40 feet—the last the reported depth—was flooded at the time of visiting, limiting inspection to the outcrop only.

The company has the third most expensive extraction plant in the United States. It has been idle most of the time since its erection.

Hickory Creek.—On Hickory Creek, about 8 miles southwest of Ardmore, is an outcrop of a bituminous sandstone about 12 feet thick striking N. 25° W., and diping 85° NE. The rock is of small, subangular to round quartz grains, and is brown and dry. In an opening near by, however, the bitumen appears to have retained some of its normal features, and the rock is of better grade, but from the surface one can not estimate its actual value. The sandstone is accompanied by two others of a width of 5 feet each, 10 and 35 feet below—to the southwest—shales separating them. These are barren. This series is included in the Coal Measures, which for the general locality show their type features and carry two or more prominent conglomerate beds between which, though at a considerable distance, the sandstones described lie. By the course taken by the outcrops of the conglomerate, which are most conspicuous for miles, the present sandstones would underlie by several hundred feet the sandstone of the Continental quarry, both being considered to belong to the Criner uplift.

REGION OF THE CRETACEOUS PRAIRIES.

GEOLOGIC FEATURES.

The area of Permian, Carboniferous, Silurian, and Archean rocks, as exposed in the Ouachita, Arbuckle, and allied folds, is bordered on the south by the formations of the Lower Cretaceous, which lie nearly horizontal and rest unconformably on the older series of beds. Of the Cretaceous, the Trinity sands and Goodland limestone are especially conspicuous, immediately underlying a large portion of the prairies along the southern portion of the Territory and in northern Texas. In the bluffs of nearly all of the stream channels within this belt both of these formations are well exposed, and occasionally, also, one or more of the overlying divisions of the Lower Cretaceous. The line of union between the Cretaceous and older strata is very irregular in its course east and west, in the region of the Missouri, Kansas and Texas Railroad extending northward to within a mile or two of Atoka; in that of the Gulf, Colorado and Santa Fe, only to Overbrook, about 7 miles south of Ardmore. A short distance east of the western border of Indian Territory, the line as at present known turns abruptly south and passes into Texas, in this part of its course marking the union of the Trinity and Coal Measures, although at other points the formations in contact may vary considerably.

Deposits of bitumen in the region of the Cretaceous prairies are reported at a number of localities, but none have been worked—hardly, indeed, prospected. Those near Emet and Marietta were visited, the others being attended with more or less uncertainty of occurrence.

DEPOSITS BETWEEN EMET AND CADDO.

A. C. Harkins prospect.—This deposit of bitumen, in practically horizontal Trinity (Lower Cretaceous) sandstone, occurs on the A. C. Harkins farm, 3 miles southeast of Emet, within a short distance of the line between the Choctaw and Chickasaw nations. The locality is between 15 and 20 miles from railroad, and has received little attention. One or two small prospect pits within an area of a half mile have been sunk into the sandstone that here lies immediately beneath the surface, but the extent, continuity, and thickness of the impregnated rock are unknown. The rock consists of sharp quartz grains of medium size with occasional bodies of small, subangular to angular pebbles of this and other material scattered in layers through the mass of the bed. The pebbles are not impregnated either in their material or in cracks across them. The color of the rock is brown, weathering brownish gray. Bitumen, although in varying quantity, is probably the chief cementing substance, but a small amount of oxide of iron is visible in the unimpregnated portions of the bed. The richer portions of the rock are soft and gummy. Six per cent of bitumen is perhaps the maximum.

Matubby Springs.—At Matubby Springs, about 5 miles northwest of Caddo, and also at a point a mile west of these, the Trinity sandstone yields a small amount of maltha, in the former instance in connection with a spring of water, in the latter directly from the rock itself.

Oakland.—A deposit similar to that on the Harkins farm is also reported near Oakland, 16 miles southwest of Emet.

DEPOSITS NEAR MARIETTA.

The southernmost known occurrences of bituminous rock in Indian Territory are about 5 miles northeast of Marietta. Here, in the southern bluffs of Hickory Creek Valley, the nearly horizontal Trinity sands of the Lower Cretaceous are found to be varyingly impregnated with bitumen for 3 or 4 miles along their outcrop.

Love and Washington prospects.—Two localities are of especial prominence, one on the Jerry Washington place, a mile east of the Gulf, Colorado and Santa Fe Railroad, the other a mile and a quarter farther east, on the Tom Love farm. About 30 feet of the Trinity sands here outcrop 40 or 50 feet below the general level of the table-land to the south. They are associated with red and gray clays and just beneath the surface of the table-land the Goodland limestone generally prevails. Of the 30 feet of Trinity sands exposed, only the lower 10 feet show impregnation with bitumen. Of these the lower 4 feet are especially rich, black, oily-looking, and tough, the upper 6 feet being brown, now but slightly oily and friable. The upper portion is thin laminated, the lower massive. The amount of bitumen in the lower is perhaps 6 or 7 per cent. Subangular to rounded quartz is the mineral with which the bitumen is associated.

The Love deposit shows only in outcrop. From the Jerry Washington place about 20 tons have been shipped for trial, but the results were not learned. A mile east of the Love outcrop an oil spring is reported at about the same horizon. Beyond the region thus defined the occurrence of enriched sand is not reported, though inquiry was carefully made. The richer rock of this region, obtained from outcrops, in appearance compares favorably with that of the better class from other localities in Indian Territory, but the deposit is comparatively thin and in some portions of the area the very considerable cover would require for it exploitation by mining methods.

At the Jerry Washington pit, 12 feet deep, the 4 feet of enriched rock at the top is said to be succeeded below by a white sandstone, which would indicate that the base of the bituminous layer was not necessarily the base of the formation. The beds, not only for the immediate region but for a large surrounding area, have a general dip of 5° to the south or southwest, which is in harmony with the lay of the Cretaceous series over the entire southern portion of the Indian Territory.

OKLAHOMA.

But a single occurrence of a bitumen has been reported from Oklahoma. This is about 3 miles southeast of Fort Sill, and according to the statement of the Rev. B. C. Hammond,[1] chaplain, United States Army, stationed at this post, is in the nature of a maltha seepage, of about the consistency of thick tar except where dried by the sun. Capt. W. C. Brown, of the First Cavalry, makes a similar statement and indicates for the deposit a considerable size. No bituminous limestones or sandstones are known to him in the country about.

Mr. Robert T. Hill[2] states that "west of Duncan, Ind. T., the limestone hills [of the Arbuckle uplift] are buried beneath the red beds (Permian) for 20 miles, but again appear in the neighborhood of Fort Sill, forming a low ridge north of and parallel to the Wichita Mountains." The recurrence of the Arbuckle series of strata and of a petroleum product in their vicinity is significant of conditions allied to those of the region of bitumen east of the Arbuckle Mountains.

Of the Wichita Monntains, which extend from near Fort Sill westward to the one hundredth meridian, 120 miles, Mr. Hill observes that they are essentially of igneous rocks, hard, firm, rugged, and barren, and although differing materially from the Ouachita and Arbuckle mountains he considers all three ranges as the result of one and the same general uplift.

TEXAS.

Bituminous rock deposits occur in Texas in Montague, Burnet, and Uvalde counties, in the northern, central, and southern parts of the State, respectively.

MONTAGUE COUNTY DEPOSITS.

The deposits in Montague County occur in the Trinity sands, at or near the same horizon, and are opened at two points about 3 miles north and northeast of St. Jo, in the bluffs overlooking the Red River Valley, and at a third point an equal distance southeast of the town, at the head of one of the higher tributaries of Trinity River. The last was not visited, the deposit being described by the owner as resembling those to the north.

Owen deposit.—The deposit north of St. Jo is on the farm of Mr. T. J. Owen, in a narrow mesa-like ridge, forming one of the minor headlands extending into the Red River Valley. The following section is here presented.

At the top of the ridge, 20 feet of thin-bedded, fossiliferous limestones of the Goodland formation; beneath this, about 20 feet of gray clays and marls, the latter bearing numerous molluscan forms; 6 feet of bituminous sandstone; 25 feet covered; and at the base a massive bed of soft white sandstone, 10 feet thick, with pink and yellow sandy

[1] Personal letter to the writer.

[2] Reconnoissance of the Ouachita Mountain system in Indian Territory: Am. Jour. Sci., 4th ser. Vol. XLII, Aug., 1891, p. 119.

clays underlying. This section resembles in its lithologic features that northeast of Marietta, Ind. T., and belongs to the same formation.

The upper 2 feet of the bituminous sandstone are poor; below this, however, the amount of bitumen increases, until in the lower 1½ feet it has reached the maximum of perhaps 7 per cent. All but the upper 2 feet of the bed, however, are regarded as available. The bed dips from 2° to 5° southward. The areal extent of the sandstone is considerable, but through how much of it the infiltration of bitumen has taken place is a question for the prospector. It can not be determined from the outcrop, well defined as this is.

The position of the deposit beneath so heavy an overburden would require for its development mining methods, in connection with which the comparative thinness of the bed would also have to be considered. For local use, however, it should prove of value.

Sampson deposit.—This deposit, 3½ miles northeast of St. Jo, also lies somewhat below the top of the mesa-like headland in which it occurs, the section of which presents practically the same features as the locality already described. The strata underlying the bituminous bed are, however, better shown here, consisting of thin-bedded, yellow, arenaceous clays for 2 or 3 feet, rapidly changing to heavy-bedded white sandstone, locally ferruginous, in all 20 feet. Below are more bright-yellow clays, tinged red in layers, while succeeding these are still other alternating sandstones and shales of like nature. The general appearance of the series, as exhibited in the headlands and their outlying buttes, indicates a sandy rather than clayey composition.

At the small quarry opened upon this deposit there is but 2½ feet of bituminous sand of the richer variety, although it is said to run somewhat thicker than this beneath the débris that has fallen from the face of the overlying portion. Immediately overlying the sandstone is the same series of beds as at the Owen quarry.

Laterally the bituminous sandstone may be traced for a considerable distance on either side of this headland, but, as in the case of the Owen deposit, prospecting will be necessary to determine the precise extent of the enriched portion.

BURNET COUNTY DEPOSITS.

Post Mountain deposit.—This deposit occurs in one of the Cretaceous limestones at Post Mountain near the town of Burnet, Burnet County, Tex. The locality was not visited by the writer, but from notes that have been kindly furnished by Mr. R. A. F. Penrose, jr., who is familiar with the occurrence, the deposit is in the form of a number of local impregnations of the limestone with the asphalt, the intervening spaces being barren, although the limestone itself is continuous. The impression gained by Mr. Penrose at the time of his visit was that the quantity of the asphalt-bearing rock was very limited:

Analyses of several samples taken by Mr. Penrose follow.

Analyses of bituminous limestone from Burnet County, Tex.

	1.	3.	5.
	Per cent.	*Per cent.*	*Per cent.*
Insoluble matter	1.26	1.49	3.66
Oxides of iron and alumina	.36	.75	.57
Lime	52.19	51.35	50.68
Magnesia	.605	.818	.844
Asphalt	3.78	3.98	3.64
Lime and magnesia above equivalent to—			
Carbonate of lime	93.16	91.64	90.44
Carbonate of magnesia	1.26	1.71	1.76

UVALDE COUNTY DEPOSITS.

The deposits of asphalt that have been found in southern Texas are in limestone. They occur in the region of the Anacacho Mountains,

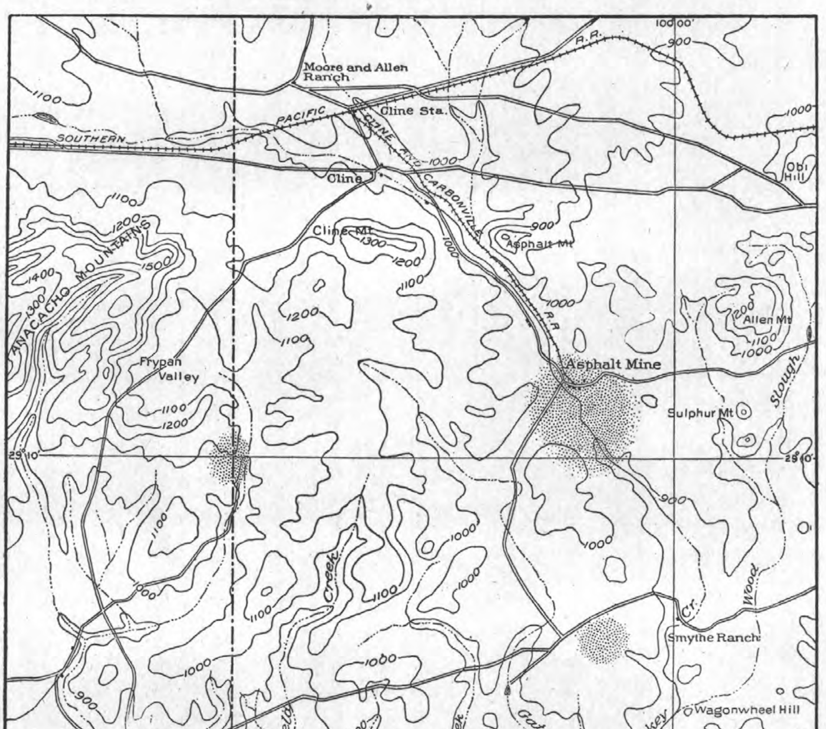


FIG. 25.—Uvalde County (in part), Tex. Shaded areas, localities of bituminous limestone outcrops.

18 to 25 miles west of Uvalde, in the southwestern portion of the county of this name.

Topographic and geologic features.—The region is gently rolling, but is relieved here and there by hills 400 to 600 feet in height and of considerable variation in type. The drainage is southeastward to the Nueces River. The water courses for long distances, however, afford but intermittent streams, according to the character of the rocks forming the beds. The supply of water is therefore limited, and by the single company in operation is held by well-constructed dams in natural reservoirs and is used again and again.

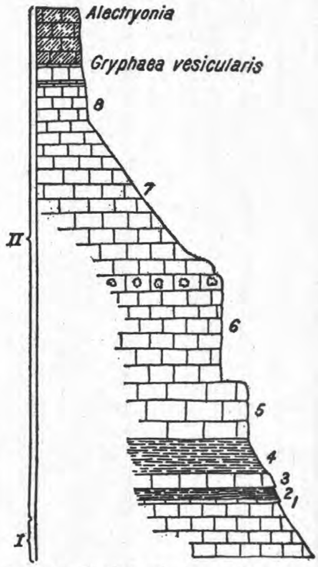


FIG. 26.—Section of Anacacho formation, Anacacho Mountains, Kinney County, Tex.

The geology of the region is a part of that of the Rio Grande Plain, and for a full description reference may be had to a recent report[1] made by Messrs. Robert T. Hill and T. Wayland Vaughan, and to the folios of the Geologic Atlas of the United States, prepared by Mr. Vaughan,[2] and more recently published, showing the geology of the Nueces and Uvalde quadrangles.

The formation carrying the bituminous limestones is the Anacacho of the Upper Cretaceous. It is well displayed in the mountains of that name, from which the following section was obtained by Mr. Hill:

Section of Anacacho formation, Anacacho Mountains, Texas.

	Feet.
8. Scarp-making rock, forming the top of the hill. It is a hard, yellow subcrystalline limestone. In the top a species of *Alectryonia* was found. About 30 feet below the top great numbers of *Gryphæa vesicularis* occur, firmly embedded	60
7. Softer limestone: *b*, Soft, yellow, marly limestone, containing a large species of *Cardium*, 50 feet; *a*, soft, white, chalky limestone, containing a species of *Turritella* with three prominent revolving striæ on each whorl (*T. trilira* Con.?), 30 feet; total	80
6. Hard limestone ledges. The upper 30 feet is brownish and contains great numbers of *Exogyra ponderosa* firmly embedded near the top. The next lower 20 feet is a yellowish granular limestone with glauconitic specks. This bed forms a platform on the east end of the Anacacho Mountains	70
5. Ledges of yellow, ferruginous, not very hard, crystalline limestone, forming the lower scarp on the east end of the hill	30
4. Slope composed of marly limestone in the upper part, the lower portion yellow marls with fragments of a very large and coarsely corrugated *Inoceramus*	20

[1] Geology of the Edwards Plateau and Rio Grande Plain adjacent to Austin and San Antonio, Tex., with reference to the occurrence of underground waters: Eighteenth Ann. Rept. U. S. Geol. Survey, Part II, p. 193 et seq.

[2] Geologic Atlas U. S., folios 42 and 64.

3. Yellowish limestone, weathering into nodular chunks, iron-stained along the weathering cracks. Contains some poorly preserved fossils—*Tri gonia* (?), *Mactra*, and a finely ribbed *Lima*	10
2. Soft material containing fragments of a very large *Inoceramus*	5
1. Thin, very hard, brown, siliceous ledge	3 or 4
Total Anacacho beds	279
Austin chalk, at base of above:	
3. Hard brownish limestone, containing many *Gryphæa*, *Aucella*, etc	5
2. Hard chalky limestone	10
1. Unexposed—to bottom of arroyo	20
Total Austin chalk exposed	35
Total Anacacho beds	279
Total here exposed	314

The bituminous limestone worked by the Uvalde Asphalt Company is, according to Mr. Hill, the upper part of the No. 6 in the above section, and it is probable that this horizon is the one more generally impregnated throughout this field.

The structure of the region is primarily a portion of the Anacacho monocline which lies to the south of the Edwards Plateau, the rocks having a general southward dip of from 10° to 20°. For great portions of the area, however, the amount of dip diminishes very considerably, and the strata take on broad, gentle undulations of subordinate value. Such, for instance, is the nature of the folds in the vicinity of the Uvalde Asphalt Company's quarry, yet with the maintenance of a gentle southerly dip withal.

Deposit of the Uvalde Asphalt Company.—The only deposit worked in this somewhat extensive field is that by the Uvalde Asphalt Company, 18 miles west of Uvalde and 8 miles southeast of Cline, a station on the Southern Pacific Railroad, with which it is connected by rail. The limestone quarried primarily consists of what seems to be an assemblage of minute organisms together with a conspicuous proportion of crystalline calcite. Molluscan remains, often of large size, are also present. Through the mass of the rock there is a high per cent of interstitial space, which in some instances may even exceed the solid portions. In addition to the interstitial space, properly so called, are cavities produced by the removal of the molluscan remains, and others of vug-like character. These spaces, interstitial and other, are occupied by bitumen, but it is evident by the many examples throughout the bed that the supply was inadequate to completely fill the intervals provided, or that the channels to the same were blocked before the filling was accomplished. An interesting feature in connection with the larger cavities of the rock is the presence of white, well-crystallized calcite, which has replaced the shells of the molluscan forms originally present, and has also been deposited in secondary form on the walls of the cavities whether of animal origin or vugs. The bitumen, in passing into these cavities, has filled, in instances, every angle made by the crystalline lining of the walls, and fractures of the rock now yield most beautiful cross sections.

The asphalt itself has a brilliant luster when fractured, but when, in the broken rock, that portion which formerly was in contact with the walls of the cavities it filled is exposed, the brilliant luster is wanting, a surface of dead black replacing it. The material is brittle and in hardening apparently suffered no shrinkage. The asphaltic limestone itself is tough and unyielding.

Throughout the rock occasional particles of pyrite are observed, and there are instances in which both these and calcite have been caught up and carried on in the flow of the infiltrating asphalt. The molluscan cavities are varied in form and size, and embrace those of both bivalves and univalves. Among the former is one resembling a *Gryphæa;* among the latter, a long tubular form showing delicate striations on its surface. This especially abounds.

A feature of the bed is the presence of small gray to white bodies of calcite of such close texture that they remained unimpregnated by the bitumen. Such bodies are excessively hard, are lacking in interstitial spaces, and even have the tubes which they, too, carry filled with secondary, earthy, and crystalline calcite. In the northern part of the quarry, rock of this composition and texture may equal the more porous, bitumen-bearing portion, imparting to the bed a marbleized and mottled effect.

In this portion of the quarry there is also a transverse or vertical joint plane, which is of interest chiefly because of the impoverishment that has taken place in the bed on its either side—on the north to a distance of 8 inches to 1 foot, on the south less. The line between the impoverished and rich portions, as exhibited by their brown and black colors, respectively, is, too, quite as distinct as the joint plane and practically parallel with it throughout.

The amount of bitumen in the rock of this quarry is said to vary between 10 and 20 per cent, 14 or 15 being common, while 20 occurred in one locality in a body of considerable proportions. The sample of the quarry face obtained by the writer gave 14½ per cent. The structure of the rock has naturally had a most material influence upon the distribution of the bitumen.

The extent of the enriched body of limestone at the Uvalde Company's quarry had not been determined either laterally or in depth, but it could be easily and economically ascertained with a drill, for the position of the bed is at most but a short distance from the surface. The outcrop of the limestone shows it, however, to have been more or less impregnated, and doubtless with important interruptions, throughout an area of several miles.

The area of rock removed at this quarry, though somewhat irregular, is between 300 and 400 feet in diameter, while the depth quarried averages perhaps 15 feet, the enriched rock below this passing beneath water level. The section of limestone exposed is: At the top, 3 or 4 feet of barren, drab, or buff rock of the composition described as general for the unimpregnated portions of the bed, this everywhere forming the cap; beneath this, a zone 1 or 2 feet thick of impoverished brown rock, breaking more easily than the richer portions below; finally, the bitumen-bearing bed of high per cent, 18 feet in full depth to the floor of the pit. This company is finely equipped both for mining and for the extraction of its product, the only parallel to the plant being that of one of the California companies.

Other deposits.—Eight miles southwest of Cline and 10 west of the quarry of the Uvalde Asphalt Company, in the summit of the Anacacho Mountains, is the broad areal outcrop of a gently dipping limestone of a facies similar in all ways to that of Uvalde Company, and of a percentage in bitumen probably closely approximating this. The thickness of the enriched portion of the bed could not be determined. The position of the deposit on the summit of the mountain, the absence of water, and the distance from rail will prevent it from being as economically worked as it otherwise would be. The deposit is located on the James ranch, and it may be just across the line in Kinney County.

On the Smythe ranch, about 20 miles a little south of west from Uvalde and 4 or 5 miles south of the quarry of the Uvalde Asphalt Company, is a deposit of bituminous limestone that outcrops in a small water hole. The extent of the bed and its thickness are not shown. The rock is fine grained, black to brownish black, and hard. Minute, short, filamentous bodies, perhaps of organic origin, are conspicuous in portions of the bed, but otherwise its material resembles a compact, fine-grained sand, calcareous in the main, but with traces of quartz. Bitumen fills the interstices. The deposit differs thus from that of the Uvalde Company, and may be of a different bed. Its value can not be determined except by prospecting, which has not yet been undertaken.

At the Black Wax Falls of the Nueces, 15 or 16 miles southeast of Uvalde, another outcrop of bituminous limestone is reported, but, being merely an outcrop and undeveloped, it was not visited.

On the Allen ranch, 2 miles north of Cline station, is a well in which it is said a bed of bituminous limestone was struck at a depth of 100 feet, the thickness of which is in doubt.

Six miles farther west, on Turkey Creek, another well, on the Reid place, is also said to have passed through a body of bituminous limestone, the thickness of which is also in doubt.

On the Blanco, 5 miles west of Sabinal and one-half mile south of the Southern Pacific Railroad, an outcrop of 12 feet of an asphaltic limestone is reported in the bluffs of the creek. It has not been exploited, however, and its value is undetermined.

COLORADO.

DEPOSIT IN MIDDLE PARK.

Locality.—The asphalt of Middle Park, Colorado, occurs in vein form, and in appearance resembles gilsonite, having the same bright luster, an equal brittleness, and a brown streak. Chemical investigation, however, may show differences that will ally it with others of the asphaltite series or establish it as an entirely new hydrocarbon compound. The locality of the vein is the region of Upper Willow Creek, a stream rising in the divide between Middle and North parks and, after a course of 25 miles southward, entering the Grand River at a point about 10 miles above Hot Sulphur Springs. The route into the region is by rail to Georgetown, stage to Hot Sulphur Springs, and thence by private conveyance, about 35 miles, to the deposit. The position of the property has also been established by land surveys and is found to be in sec. 24, T. 4 N., R. 77 W. The region lies well within the high ranges on the northern rim of Middle Park, but is easily accessible by the canyon of Willow Creek, which affords an excellent roadway. The altitude at the prospect, which is on a small fork known as Sherman Creek, is about 10,000 feet. Gravel Mountain, a conspicuous landmark, lies immediately south, Willow Creek curving around its northern base from east to west.

Geologic formation.—The region on either side of the route, from near the Sulphur Springs to the head of Willow Creek, is occupied by the Middle Park formation, the equivalent of the Denver beds of the plains. The formation throughout presents all the distinctive lithologic features of composition, color, and succession of this well-known post-Laramie horizon. The thickness of the series is here estimated at between 3,000 and 5,000 feet. A new and special interest attaches to it in the present instance by reason of its carrying the veins of asphalt to be described; this, too, apparently well up in the series, in the midst of rapidly alternating clays, sandstones, and conglomerates.

Occurrence.—The accompanying sketch (fig. 28), from a memorandum made in the main tunnel, illustrates the immediate succession of beds at this prospect.

The points to be emphasized in the facts brought out in the above section are the rapid alternation of clays, conglomerates, and sandstones; the predominance of the clays and the semiclayey nature of the matrix of the conglomerates; the instability of the strata thus composed and their tendency, when included in a folded area, to crumple, fracture, crush, and shift their relative positions, often in large blocks, and the always irregular form assumed by fissures that chance to open in such strata thus folded. It is under these conditions that the asphalt veins of this region have been formed, the fissure having opened and become filled with liquid or viscous bitumen, derived, it must be, from adjacent or near-by strata.

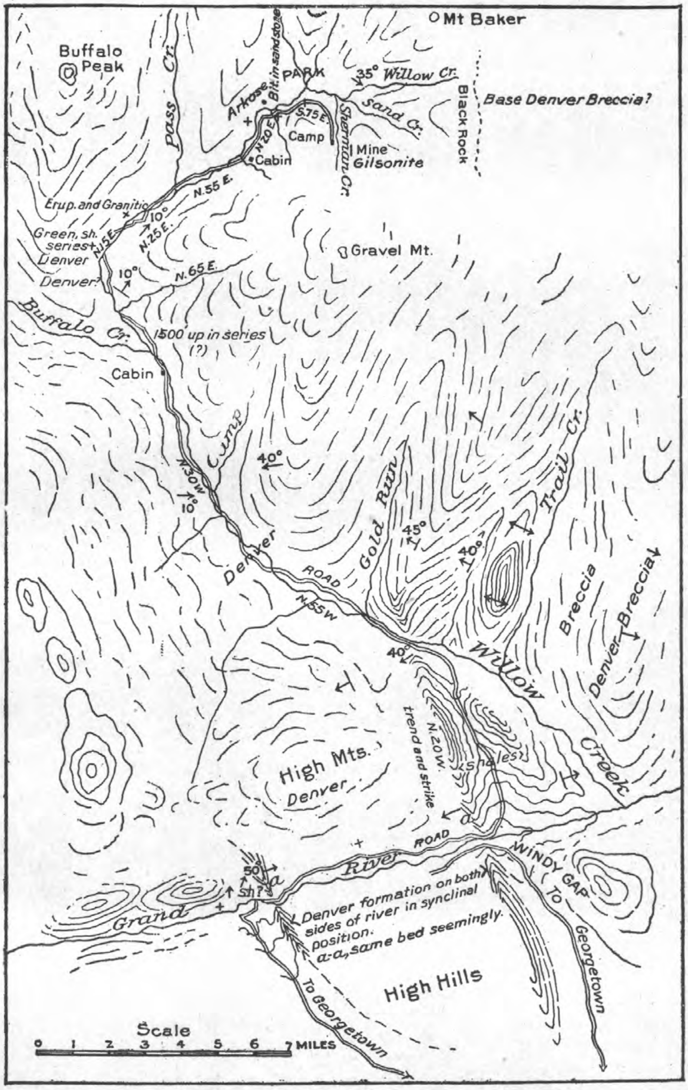


FIG. 27.—Region of Willow Creek, Middle Park, Colorado.

Not only is the irregularity of the veins shown in the plan of the tunnel above figured, but at a near-by shaft on the same fissure an important lateral vein springs from the greater vein, extending diagonally down across the beds, it is thought, from developments, for fully 50 feet below the point of its departure, but with a constantly diminishing thickness. At yet another point in the same hill and on the general trend of the fissure, but quite independent of the other openings, is a crack in the strata, from which the asphalt, amounting to

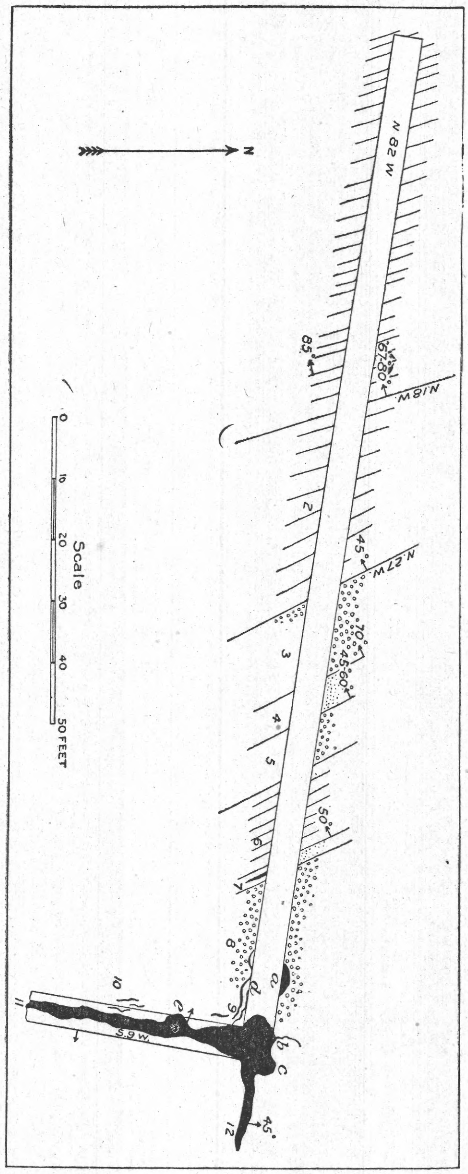


FIG. 28.—Vein of asphaltite (uintaite?), Willow Creek, Middle Park, Colorado.

Section in tunnel, etc.—1. Clay shale, with thin, hard lenses of the same material; cracks present, highly inclined, 85° W., showing vertical slickensides. 2. Shales, massive, harder than foregoing. 3. Conglomerate: pebbles small to 4 inches. 4. Sandstone, hard. 5. Conglomerate, showing irregularity in lines of dip and in its relations to the sandstone. 6. Clays. 7. Sandstone; thin and minute lens of asphalt in this. 8. Conglomerate; heavy body; much crushed, and carrying irregular bodies of asphalt. 9. Sandstone and conglomerate, crushed; asphalt streaks through the mass. 10. Clays, brecciated, with asphalt. 11. The end of the drift; in very hard rock, a conglomerate in which rounded bowlders 8 inches in diameter occur; forms both walls of vein here. 12. Cross vein, pinched to 1 inch; walls clean, slightly rolling.

a, b, c, e, Offshoots of asphalt from main vein, irregular in outline and trend. *d*, Two asphalt seams, one in top, one in bottom of drift, running into pocket. *e*, Small pocket from vein. Shaded area is pocket vein of asphalt.

only a few tons, has been entirely removed—an irregular pocket in clays. Still other fractures with their filling of asphalt have been encountered, as though portions of a general fissure or as laterals from it.

At the time of the examination 2 or 3 feet of snow covered the ground, making all attempts at detailed surface geology futile. From the position, however, of the several openings, covering a linear distance of 600 to 700 feet, and the evidence these afford, there appears to be a general line of fracturing, extending in a N. 8° to 20° W. direction, along which was produced a fissure that in part remained open for the reception of the asphalt, although varying greatly in width. The pitch of the fracture is 65° to 70° W., more or less with the general dip of the strata, although for both fracture and beds there are doubtless many variations in the amount of inclination. Of the cross fractures there are also many different strikes and dips.

The main vein of asphalt has been cut at several points within a vertical range of 100 to 125 feet, showing a width of from a few inches up to a maximum of 6 feet. The continuity of the vein, however, both in depth and on the strike, can be solved only in the course of exploitation. The evidence is that in all formations into the make-up of which clays or shales enter largely the fissures and their contained veins are of extreme irregularity. Moreover, in regard to the identity of the veins of this locality at their several points of exposure, there is the possibility that instead of a single fracture there may be several of an individual nature within a general fractured zone. Indeed, a number of minor cracks with asphalt fillings have been detected. These points have a direct bearing upon the value of the property and its economic working.

DEPOSITS ALONG THE COLORADO-UTAH LINE.

The veins of gilsonite on the western border of the Colorado will be referred to under the section pertaining to Utah, they being directly related to the great veins of the Uncompahgre Ute Indian Reservation, just across the line.

UTAH.

INTRODUCTORY.

The materials of an asphaltic nature within the confines of Utah are wurtzilite, uintaite (trade name gilsonite), ozocerite, nigrite, bituminous limestone, shales and sandstone, and maltha. Petroleum also seeps from the ground in scattered localities, the chief value of which thus far consists in its being indicative of a general distribution of the hydrocarbon series in the rocks that underlie a very large area in northeastern Utah and the adjoining portion of Colorado. Of the materials enumerated gilsonite has readily assumed the first importance from an economic standpoint, while the second place is divided between wurtzilite and the bituminous limestone. Ozocerite has been mined to some extent, but the deposits appear to be restricted; nigrite is a comparatively recent find (1895), and the bituminous sandstones are still untouched. Maltha and petroleum springs are mere occurrences.

The class relations of these minerals have been given in the table of classifications of hydrocarbons and allied substances, p. 220.

The area in which uintaite (gilsonite) and its associates of the hydrocarbon series, wurtzilite, nigrite, ozocerite, and maltha, the asphaltic limestones and sandstones, and a great series of bituminous shales are found lies in eastern Utah and just beyond in the western edge of Colorado. It is included between the meridians 108° 45′ and 111° 30′ W. and the parallels 39° and 40° 30′ N., in all perhaps 10,000 square miles, and is in the main coincident with the western half of the topographic depression known as the Uinta Basin, together with its southern rim.

Within this area uintaite (gilsonite) is, so far as at present discovered, confined to the eastern portion of the area. The wurtzilite deposits lie in the southwest, chiefly in the southern portion of the Uinta Indian Reservation, only one or two localities being reported beyond its border. The ozocerite occurs in the vicinity of Soldier Summit, a station of the Rio Grande Western Railway, on the divide between the waters of Green River and those of the Utah and Salt Lake Valley. Nigrite is exploited 5 miles north of east from this station. Maltha is reported at a number of isolated points within the area, notably in the divide between Spanish Fork and Strawberry Creek, 10 to 15 miles north of Soldier Summit, and in the region of Emma Park, northeast of Castle Gate. The asphaltic limestones thus far exploited occur in the southern spurs of the divide between Strawberry and Soldier creeks, about 7 miles northwest of Clear Creek station (Tucker P. O.). They are of importance, however, north of the divide, in the canyons of Indian, Lake, and adjacent streams, tributaries of Strawberry Creek. The asphaltic sandstones outcrop in many of the valleys, notably the Ashley and Nine Mile, and the bituminous shales are broadly distributed.

GEOLOGY OF THE UINTA BASIN.

TOPOGRAPHIC FEATURES.

The Uinta Basin (Pls. XXXVIII and XL) has a general altitude of 5,000 to 6,000 feet and an entire length from east to west of about 170 miles, extending from the Wasatch Mountains to the White River Plateau, 60 miles east of the Colorado-Utah line. The maximum distance across the basin, north and south, is a little over 100 miles, and is practically coincident with the 110th meridian. On the north the basin is confined by the anticline of the Uinta Mountains, the peaks of which rise to nearly 13,700 feet; by the eastward continuation of this range, the Yampa Plateau, between 8,000 and 9,000 feet in altitude; and by the

Danforth Hills, which form the divide between the headwaters of the White and Yampa rivers. On the south the basin is limited by the summit of the Roan or Book Plateau, a monoclinal ridge which overlooks the valleys of the Price, Green, and Grand rivers, tributaries of the Colorado, and presents to them for nearly 200 miles a bold and almost continuous cliff having a general height ranging from 2,000 to 3,000 feet. Locally the cliff may be broken along formation lines by benches a mile or more in width, the result of differences in material and texture between the several series of rocks. Such benches may become the sites of grassy parks, always with more or less timber.

The interior of the Uinta Basin is a comparatively shallow depression, the axis of which lies nearer the northern side. The several Eocene formations involved in its constitution, consisting of soft sandstones, argillaceous shales, and thin-bedded limestones, have been irregularly eroded into lofty tables, mesas, ridges, buttes, and spires, presenting in general a scene of much desolation and decay.

Green River divides the basin into east and west halves, and has cut for itself, except for 15 to 20 miles across the center of the depression, canyons from 1,000 to 3,000 feet deep, wholly impassable except by boat at great risk. In the center of the basin this stream receives from the east and west, respectively, the White and Duchesne rivers. The former, the larger, enters the open valley about 12 miles above its confluence with the Green, after a tortuous course through 70 or 80 miles of continuous canyon in the shales and sandstones of the Green River and Bridger formations. Along this portion of the stream the bottom lands are reduced to a few short, narrow strips at long intervals. The valley of the Duchesne River is open for 50 miles above its mouth, the bluffs being low and the channel bordered for most of the distance with rich bottom lands from 1 to 2 miles wide. North of this stream the uplands, particularly in the vicinity of the Uinta River and Lake Fork, afford extensive areas that are both arable and irrigable, and under ditch have already given evidence of great productive capacity. Both streams flow comparatively full, the water derived from the Uinta Range being of great purity. The same conditions prevail in regard to Ashley Creek, the valley of which is one of the most fertile of Utah. East of the Green River, however, but little water is received from the mountains, and the center of the basin becomes almost arid, in a few localities only there being grass sufficient even for light grazing.

The southern half of the basin, and especially that portion east of the Green River, presents a scene of great desolation and decay. Canyons with labyrinthine intricacy have been cut to depths of between 1,000 and 2,000 feet in the backs of the strata forming the Roan or Book Plateau, while the intervening ridges are sharp and crumbling, developing spires and buttes and castellated forms in greatest profusion, all

GEOLOGY OF THE UINTA BASIN, UTAH-COLORADO

Compiled by G. H. Eldridge.

Topographic Authorities: Powell, King, Hayden

Pleistocene — Tertiary — Cretaceous — Paleozoic — Eruptive

Asphaltic limestone

Uintaite (gilsonite) veins: (Over 2 feet wide) (Under 2 feet wide)

Wurtzilite veins

Scale of miles: 10 9 8 7 6 5 4 3 2 1 0 10 20 30 40 50

Contour interval 1000 feet

Geologic Authorities: King, Hayden, Wheeler, Eldridge

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seemingly ready to topple to pieces at the first heavy storm. Little water is carried in any of these gorges, and this, except at their heads, through the sands of their channels instead of as surface flows. It is, moreover, frequently impregnated with alkali, which abounds in all the formations of the locality. In Indian Canyon, a tributary of Strawberry Valley, there are numerous warm springs, which are said to remain open all winter. Parks, well grassed and timbered, and with more or less water, may be found at the heads of many of the canyons, features that relieve the general barrenness found in other localities. Of such canyons as the foregoing the White and Duchesne valleys receive a number, while one of the most rugged in the basin is that of the Minnie Maud, which enters directly into Green River from the west, 15 or 20 miles below the Duchesne.

THE FORMATIONS.

DESCRIPTION.

For simplicity the essential characteristics of the formations entering into the structure of the Uinta Basin have been placed in tabular form:

TABLE IV.—*Formations of the Uinta Basin.*

Period.	Formation name.	Maximum thickness, in feet. (*a*)	Description.
Pleistocene	....	25	Gravel, sand, and clay, according to formations from which derived. From the Uinta Mountains, a coarse gravel of quartzite; from the Roan or Book Plateau, sand, argillaceous shale, and clay. Some of the gravel is secondary, having first been a constituent of the Eocene.
Eocene	Uinta	500 to 1,000.	Conglomerates, sandstone, and shale, the first two predominating, especially toward top. Material derived chiefly from Paleozoic quartzites of Uinta Range and Yampa Plateau. Prevailing color, red to pink, though many of the sandstones are a rusty yellow to brown. (*b*)
	Washakie	200	Sandstones and shales. Difficultly recognizable. (*c*)

a Largely estimated.
b According to J. B. Hatcher the Uinta of this region is the equivalent of Osborn's Diplacodon elatus beds.
c Equivalent to the top of the Bridger, according to some authorities.

TABLE IV.—*Formations of the Uinta Basin*—Continued.

Period.	Formation name.	Maximum thickness, in feet.	Description.
Eocene	Bridger	600 to 1,000.	Conglomerates, sandstones, shales, and an occasional 1 to 2 foot layer of white limestone. Sandstones prevail; they are heavy bedded, somewhat ferruginous, and of gray to rusty yellow and chocolate-brown color. Conglomerate fine. Formation identified by vertebrate remains, according to investigators.
	Green River	2,000	Calcareous shales and thin limestones. Shales and limestones bituminous, locally in a degree to be of economic value. Prevailing color gray, weathering light. Occasional thin sandstone layers, becoming more prominent toward top. Country deeply eroded.
	Wasatch	1,000 to 1,500.	Conglomerates and sandstones in heavy beds. Red color.
Cretaceous	Laramie	1,000	Sandstones and shales. Sandstones largely predominate. They occur in heavy beds; color yellowish-gray. Shales gray. Near base of formation workable coal beds; coal, locally, coking; general quality excellent.
	Montana	2,000 ?	Shales. Argillaceous, leaden gray. Occasional limestone concretions. Upper 200 to 300 feet of beds more sandy and firmer in outcrop. In general of the same appearance as elsewhere in the West.
	Colorado	300?	Shales. Argillaceous, black. Few thin limestones. Ironstones. General appearance same as elsewhere in West.
	Dakota	500	Sandstones. Heavy bedded, gray; separated by thin shaly layers. Of usual appearance in the West.

TABLE IV.—*Formations of the Uinta Basin*—Continued.

Period.	Formation name.	Maximum thickness, in feet.	Description.
Juratrias	Jura	500 to 700.	Shales and thin limestones. Former brilliantly variegated; latter drab. Gypsum in heavy local beds.
	Trias (Red Beds)	2,000	Conglomerates, grits, and sandstones. Last prevail. Color, lower half red; middle buff; top white. Few thin limestones.
Carboniferous.*a*	Permo-Carboniferous.	200 to 500.	Calcareous shales and argillaceous rocks and clays intervening between the Coal Measures and Trias, conformable to both, and carrying Permo-Carboniferous fossils.
	Upper Carboniferous.	2,000 to 2,500.	Limestones—some layers cherty—and calciferous sandstones variable in thickness. The series prevailingly of heavy limestone at base, with varying thin-bedded intercalations of lime and sand near top, always capped with a zone of highly cherty Bellerophon-bearing limestone. Rich in Upper Coal Measures fossils.
	Weber quartzite	12,000	A series of siliceous beds—impure sandstones at east end of Uinta uplift, gradually compacted to quartzite in western portion of range. These beds are intercalated with groups of clay shales and occasional conglomerate sheets, which contain round, rolled Archean pebbles.
Archean *b*			Pure white quartzites, hornblendic schists, and hydromica (paragonite) schists, richly charged with garnet, staurolite, and minute crystals of cyanite.

a U. S. Geol. Expl. Fortieth Par., Clarence King, Vol. I, pp. 153-154.
b U. S. Geol. Expl. Fortieth Par., Clarence King, Vol. I, p. 43.

The formations below the Laramie are, so far as at present known, of minor importance in their relations to the occurrence of the hard asphalts, and will be mentioned only incidentally in what follows.

INTERRELATIONS OF THE TERTIARY AND CRETACEOUS SERIES.

The Tertiary series, embracing the Wasatch, Green River, Bridger, Washakie, and Uinta formations, is wholly Eocene in age. In the relationship of the several members one with another they have been found in uncomformity in many localities, particularly in the Green River, Washakie, and Vermilion Creek basins, to the north; in the Uinta Basin, however, the evidence of unconformities at the different horizons is not so pronounced, and, indeed, except in the case of the Uinta along its northern border, the only suggestion of interruption to continuity of deposition from base to summit of the series that was observed by the writer is a sharp change in sedimentation between the several members. But it is to be remarked that the writer's investigations in this direction were far from exhaustive.

Between the Cretaceous and Tertiary series, also, along the face of the Roan or Book Cliffs, there is no apparent break except in character of sediments. Along the base of the Uinta Range, however, evidences of unconformity between the two series and within the Tertiary exist in force. Here there is a most marked overlap of the Uinta upon the older formations, ranging from Laramie to Carboniferous, the youngest Tertiary resting in turn against the Upper Coal Measures, the Permo-Carboniferous, the Juratrias, and the several members of the Cretaceous. In the ridge forming the western rim of the Ashley Valley it rests unconformably upon different layers of the Laramie, with a somewhat indistinct divergence in dip, but southward the difference in dip appparently diminishes and the formations are upturned to nearly the same degree, 5° to 20°, the dip being west. In Raven Ridge, 30 miles east of Green River and south of the Yampa Plateau, according to the observations of the Hayden Survey, which were in greater detail than the writer's, the Laramie, at first overlain by the Uinta, is, in passing eastward, separated from it by the Wasatch formation. A little farther on the Green River formation appears between the Wasatch and the Uinta, and finally is itself separated from the youngest Tertiary by the beds of the Bridger formation. The interrelationship of the Laramie and Tertiaries is shown on the special map of the region, Pl. XL, p. 342.

AREAL DISTRIBUTION OF THE FORMATIONS.

The Paleozoic series of strata, in uplifted position, form the northern rim of the Uinta Basin—the Uinta Range and Yampa Plateau. In some instances the Paleozic is overlain to great altitudes by the Juratrias, and in one or two localities even by the Dakota and shaly members of the Cretaceous. At all points along the base of the ranges, except where overlapped by the Tertiaries, the Mesozoic beds form more or less prominent fringing reefs, and in the divide between Ashley and Uinta creeks, and in Raven Ridge, 20 miles east of Green

River, the Tertiaries also are inclined at considerable angles—20° to 30°—shallowing rapidly, however, to the south and west. At the eastern end of the Uinta Basin, in the White River Plateau, the same general conditions prevail. At the western end of the basin the geology is more complex, the surface distribution of the formations which here enter into the structure of the eastern side of the great Wasatch fault monocline having been considerably modified by the presence of eruptives and by erosion. The southern rim of the Uinta Basin—the Roan or Book Plateau—is formed of the Green River, Wasatch, and Laramie strata, which to the south overlook the valleys of the Grand and Price rivers, a broad belt of Montana shales lying at the base of the cliffs. The Green River series forms the summit of the greater portion of the plateau, although occasionally the Wasatch constitutes the divide. From here northward to the vicinity of White River and Minnie Maud Creek the Green River beds, with dip somewhat steeper than the topographic slope, form the floor of the Uinta Basin.

No line of demarcation between the Green River and Bridger formations has ever been well established, at least in the Uinta Basin, and it is here uncertain just where one series ends and the other begins. Between the well-pronounced shales of the Green River, interbedded with a few sandstones, and the heavy, shale-divided sandstones referred by the paleontologist to the Bridger, there is a zone in which both shale and sandstone occur, the shale largely predominating. The old lines employed by Dr. Hayden have been provisionally accepted by the writer for the map of the White River uintaite region, but it is suggested as quite possible that the southern line of the Bridger (Pl. XL) will be found to lie, for that portion of the basin east of Green River, at or a little south of White River, appearing also for a considerable distance in the canyon walls of the latter stream, and to the east, in the vicinity of the Colorado-Utah line, rising somewhat above them, while west of Green River it may be placed at the summit of the divide between Minnie Maud and Argyle creeks on the south and the Duchesne and Strawberry valleys on the north. Too little is known of the Washakie formation, considered, indeed, by many as the upper member of the Bridger, to distinguish it from the main body of this formation below, and their line of demarcation is undefined.[1]

The southern line of the Uinta formation, where crossed by the Price and Fort Duchesne stage road, lies about 5 miles south of the Duchesne River, and pursues a nearly east-and-west direction for its entire length. The westward extension of this line, as of the others between the Eocene

[1] Between the description here given and the outline of the Bridger formation on the special map, Pl. XL, a wide discrepancy exists. The map gives the results and conclusions of the Hayden Survey. In this text the delimitation of the Bridger is based upon the statements of Mr. J. B. Hatcher, of Princeton College, who has, with others, made a somewhat careful examination of the Eocene fauna of the Uinta Basin. In both cases the stratigraphy is the same, the only questions being the horizon at which to place the line between the Green River and Bridger series and its consequent delineation.

formations, was not traced by the writer, nor has it ever been defined, so far as he can learn. It is probable, however, that it continues well toward the head of the Strawberry Valley. The eastward extension is that determined by the Hayden Survey, and is shown on the map forming Pl. XL. The northern boundary of the Uinta formation in the western half of the field follows closely the base of the Uinta Mountains, but in the eastern half, where involved in the uplift of the Yampa Plateau, its line of outcrop has been carried by erosion well to the southward, away from the base of the range. In the region of Ashley Valley and Green River its outcrop and the outcrops of the Laramie and Montana pass in a sweeping curve around the ends of the older and harder Paleozoic and Mesozoic measures constituting the mountain proper and its immediate foothills. Farther to the east, in the region of Raven Park, by still another fold in the southern face of the Yampa Plateau, now combined with a supplemental flexure in the Cretaceous and Tertiary beds immediately south of it, the outcrop of uplifted, southward-dipping Tertiaries is carried in the high Raven Ridge a distance of 15 or 20 miles to the south, to be regained in a northerly direction in the angle between the Yampa and White River plateaus. In the supplemental fold referred to the Laramie has a sharp, quaquaversal dip about a center of Montana, and possibly even of Colorado, shales.

Another quaquaversal, on the East Fork of Evacuation Creek, 5 or 10 miles above its confluence with the West Fork, presents a center of Wasatch, the Green River beds encircling it with lofty cliffs of the same general character as the Book Cliffs.

STRUCTURE.

The geological structure of the Uinta Basin has been quite fully set forth in what has already been said, but it is desirable to bring together under a single section the chief features. The basin is a syncline, with a major east-and-west axis about 170 miles in length, and a transverse north-and-south axis 75 to 100 miles long. The depression, except at the very rim on the northern and eastern sides, is gentle, with only

FIG. 29.—Diagrammatic section N.-S. through Uinta Basin.

occasional local crumples, the most important observed by the writer being the Split Mountain fold, the quaquaversal on the East Fork of Evacuation Creek, and the Raven Park fold. The fact that the entire Eocene series has been brought under the action of the forces causing the formation of the basin is evidence that the generation of the Uinta and Wasatch ranges and of the Yampa and White River plateaus was not complete till after the close of Eocene time.

Faulting of great importance occurred on the flanks of the high ranges bordering the basin on the north, east, and west, but in the development of the central portion of the basin no displacements greater than 8 or 10 feet seem to have occurred. On the southern slope of the Roan or Book plateau, beyond the confines of the basin proper, a throw of 75 or 100 feet was observed by the writer in the vicinity of the mines of the Wasatch Asphaltum Company, northwest of Clear Creek station. This was the maximum displacement found in the Tertiary area. Of the fractures in the center of the basin, it is a noticeable fact that all discovered have a lateral rather than a vertical displacement. In one or two localities slight displacement along a stratification plane has also been observed.

But if faulting with displacement is at a minimum, the basin is nevertheless the seat of a large number of most remarkable vertical cracks, now filled with the various asphaltites, from one-sixteenth of an inch to 18 feet across, and in length from a few hundred yards to 8 or 10 miles. Their walls are smooth and regular, they show but the slightest undulation, and between the strata on opposite sides not even the slightest displacement can be detected. The cracks have a direction varying between N. 35° W. and N. 55° W., and except for an occasional short, sharp, transverse throw are peculiarly straight in trend. In some localities they appear to be approximately parallel with the strike of the strata and the trend of the main flexures in the ranges and their foothills; in others, they cut the strata diagonally to the strike. On this account there is not everywhere suggested a connection in their genesis with the broader structural folds. Again, none of the cracks show the irregularities of fissures formed by the tearing asunder of strata along the axis of an anticline, nor are there the slickensides occasioned by the rubbing together of the walls in displacement. The termination of a crack, either in outcrop or vertically, may occur by the gradual approach of its two walls, but, as will appear subsequently, may also take place from other causes. An instance of the first was observed in the Black Dragon vein on the West Fork of Evacuation Creek (fig. 36). Of the second, illustrations will be found in the disappearance of the Cowboy and Bonanza mines of gilsonite near the eastern border of the State (fig. 34). From the nature of these cracks, however, the surface extent of a vein does not necessarily indicate its extent below the surface, for at a depth the fissure may continue far beyond its length of outcrop, or, on the contrary, may fall considerably short of this.

Figs. 32 and 35 also present another feature of common occurrence in veins of uintaite, namely, included fragments of country rock. These vary in size from a piece 2 inches across to one which might be regarded as locally splitting the vein in two. Occasionally separation from a wall is not complete, the fragment lying at an angle with it still attached—perhaps even to both walls (*d*, fig. 31). All the fragments observed by the writer were of the same material as the undisturbed stratum opposite which they were found, indicating that the distance traversed by them was slight.

Not uncommonly there spring from a fissure one or more lateral cracks (*cc*, fig. 31), making with it a very acute angle, and being at their points of departure from one-fourth of an inch to 1 foot in width. They usually run to a point within a few feet, though the wider are somewhat the longer. These minor cracks show the same clean sides as do the main large fissures, the narrow portion of the rock between also being sharp of outline.

The origin of the cracks now filled with uintaite is, so far as our present knowledge avails us, still in doubt. They may have been produced by the gentle folding that took place in the formation of the Uinta Basin syncline, the strata being torn asunder from below upward instead of, as in an anticline, from above downward.[1] It has been suggested by Mr. Henry Wurtz[2] that a very similar crack, filled with grahamite, in West Virginia, may possibly be a shrinkage fissure. But in the Uinta Basin, with the exception of an occasional warm spring, there are no conspicuous evidences of former heat which, followed by cooling, might have served to produce shrinkage.

Of these two theories, therefore, the writer is inclined to the first, the theory that the cracks had their origin in the gentle folding that produced, on a broader scale, the syncline itself, the strata not being sufficiently yielding to withstand even this comparatively small strain. If this is correct, the cracks may extend to a considerable depth, perhaps several thousand feet, and would have a tendency to widen in their descent, at least for a distance, unless occupied by rock masses squeezed in from the side.

UINTAITE (GILSONITE).

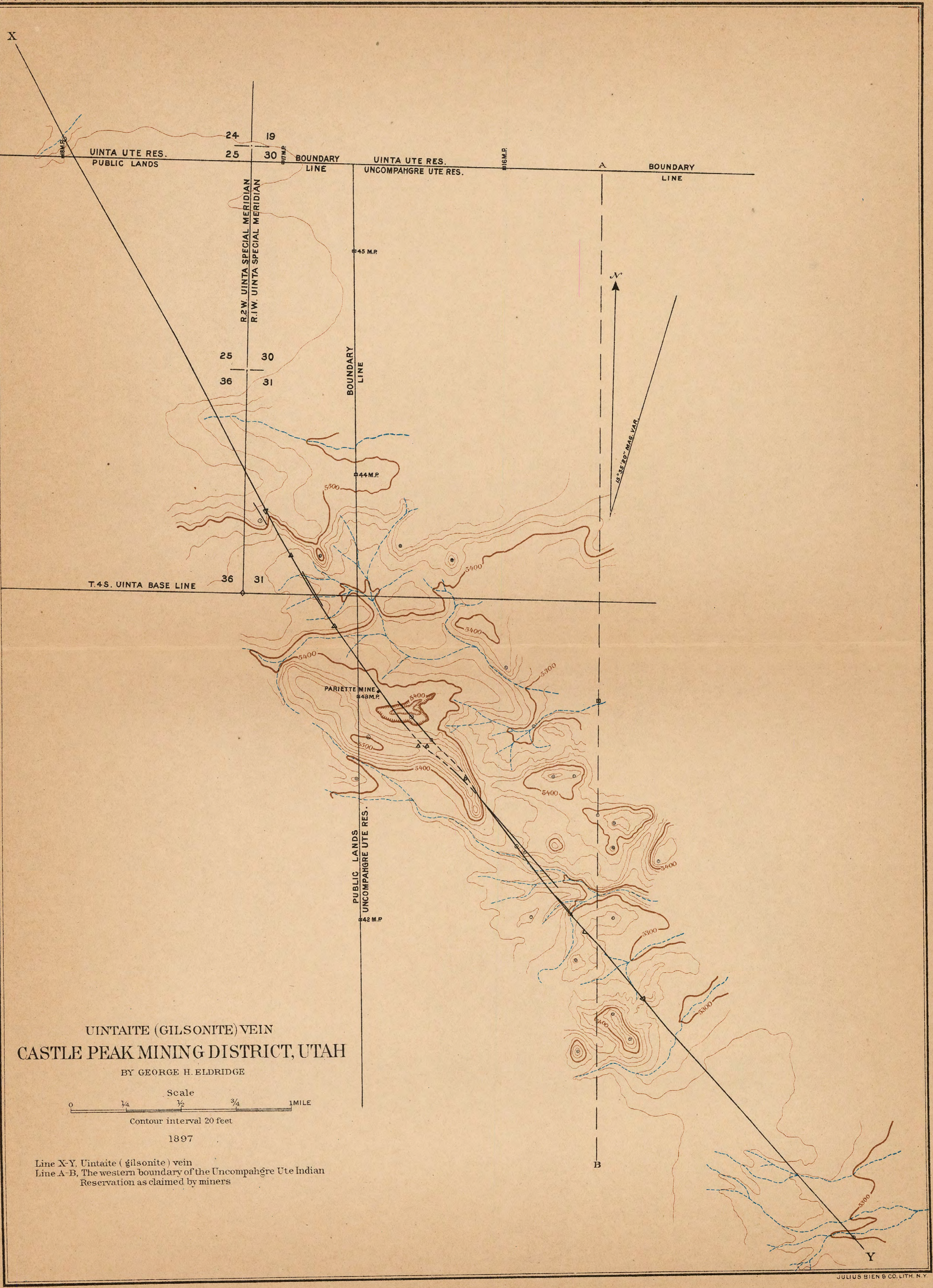
THE VEINS.

APPEARANCE OF UINTAITE IN THE VEIN.

Uintaite (gilsonite) is a black, tarry-looking substance of most brilliant luster, normally of absolutely homogeneous texture, and exceedingly brittle. Its fracture is coarsely conchoidal. In mining, it gives off a fine, chocolate-brown dust, most penetrating to skin and lungs. Sufficiently near the outcrop of the vein to be influenced by atmospheric agencies, it loses its brilliant luster for a dead-black surface. ' ut

[1] For an instance of asphalt filling a crack along the axis of a gentle anticlinal fold (dip 4° and 14° on either side), see account of grahamite in the Huasteca, Mexico, by J. P. Kimball: Am. Jour. Sci. 3d series, Vol. XII, 1876, p. 282.

[2] On the grahamite of West Virginia and the new Colorado resinoid, by Henry Wurtz: Proc. Am. Assoc. Adv. Sci., Vol. XVIII, 1869, p. 125.



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a fresh fracture, no matter in how small a particle, shows its brilliancy still present, indicating a change to an inconsiderable depth only. Under atmospheric influences, also, uintaite shows a fine columnar structure at right angles to the walls of the vein and to a distance of about 6 inches from them. This structure has been recognized by Wurtz, Lesley, and others in grahamite, and by Lesley is called "pencillate." In addition to the columnar, there may be developed a cuboidal structure, in some instances by a further transverse separation of the penicillate rays; in others independent of these. In the upper 10 or 15 feet of a vein the latter structure not infrequently prevails through a large proportion of the uintaite, shading laterally into the two penicillate zones at the sides. It would seem quite probable that this structure, penicillate and cuboidal, is inherent in the material, having originated perhaps immediately after its injection into the fissure from cooling or from pressure.

The walls of the uintaite veins are usually impregnated with the mineral to depths of from 6 inches to 2 feet, though the shales, on account of their close texture, do not permit this to such a degree as the sandstones. The line between the impregnated and nonimpregnated portions of the wall rock is usually somewhat indefinite, but instances are not wanting of the sharpest demarcation.

LOCALITIES OF THE VEINS.

The region in which the uintaite (gilsonite) veins are found extends between the parallels of 39° 30′ and 40° 30′ and the meridians of 109° and 110° 10′, or from a point 4 or 5 miles within the Colorado line, westward for 60 miles into Utah. The larger veins are somewhat scattered, one lying about 3½ miles due east of Fort Duchesne, a second in the region of Upper Evacuation Creek, and the two or three others of chief importance in the vicinity of White River and the Colorado-Utah line. Besides these, there is a 14-inch vein near the western edge of the area in the vicinity of the fortieth parallel; another of equal size about 6 miles southeast of the junction of the Green and White rivers; a third in a gulch 4 or 5 miles northwest of Ouray Agency, west of the Duchesne River, and a number from one-sixteenth of an inch to 1 foot in thickness in an area about 10 miles wide, extending from Willow Creek eastward for 25 miles along both sides of the Green and White rivers. The locations of these veins are all shown on the general map of the Uinta Basin. Float gilsonite was also reported to the writer by Mr. McAndrews of the Ouray Agency, on Asphalt Creek, next west of Evacuation Creek, but at the time of the present investigation no actual discoveries of veins could be learned of, and the locality was not visited. Since then, however, two veins of importance are reported on reliable authority as having been prospected, one crossing the creek a mile or two above its mouth, the other lying a mile to the west.

DUCHESNE VEIN.

For convenience, the vein lying 3 miles east of Fort Duchesne may be designated by the same name as the post. This vein has been worked for several years and is opened to a depth of 105 feet, but at the time of the writer's visit was accessible only to a level 65 feet beneath the surface. The superficial strata are of the Uinta formation, and consist of heavy bedded sandstones and shales having a gentle northward dip of 5° to 10°. The manner in which the uintaite occurs and its appearance in the fissure are the same as given above for the veins in general.

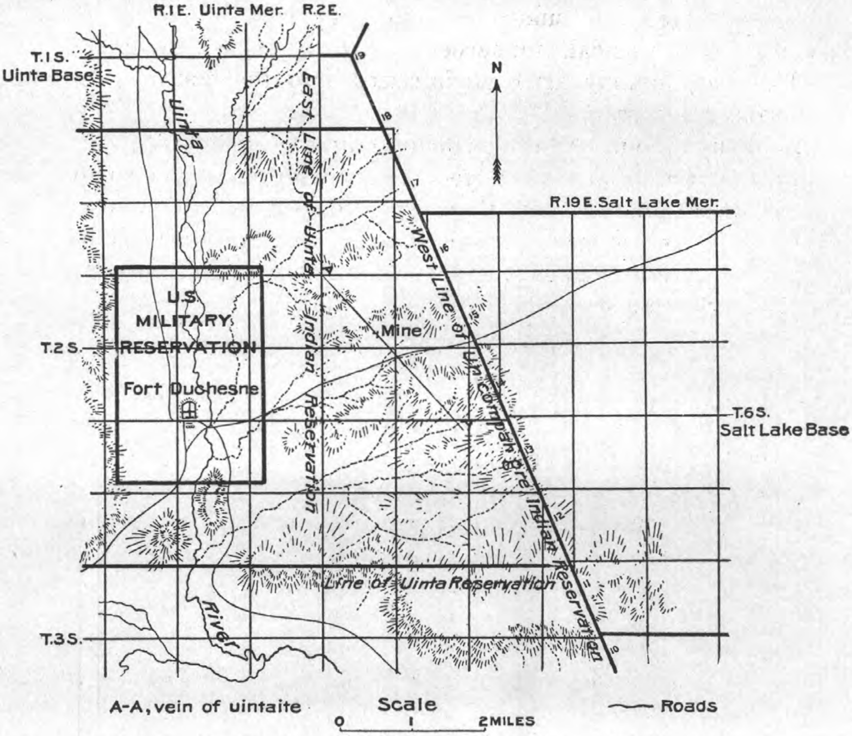
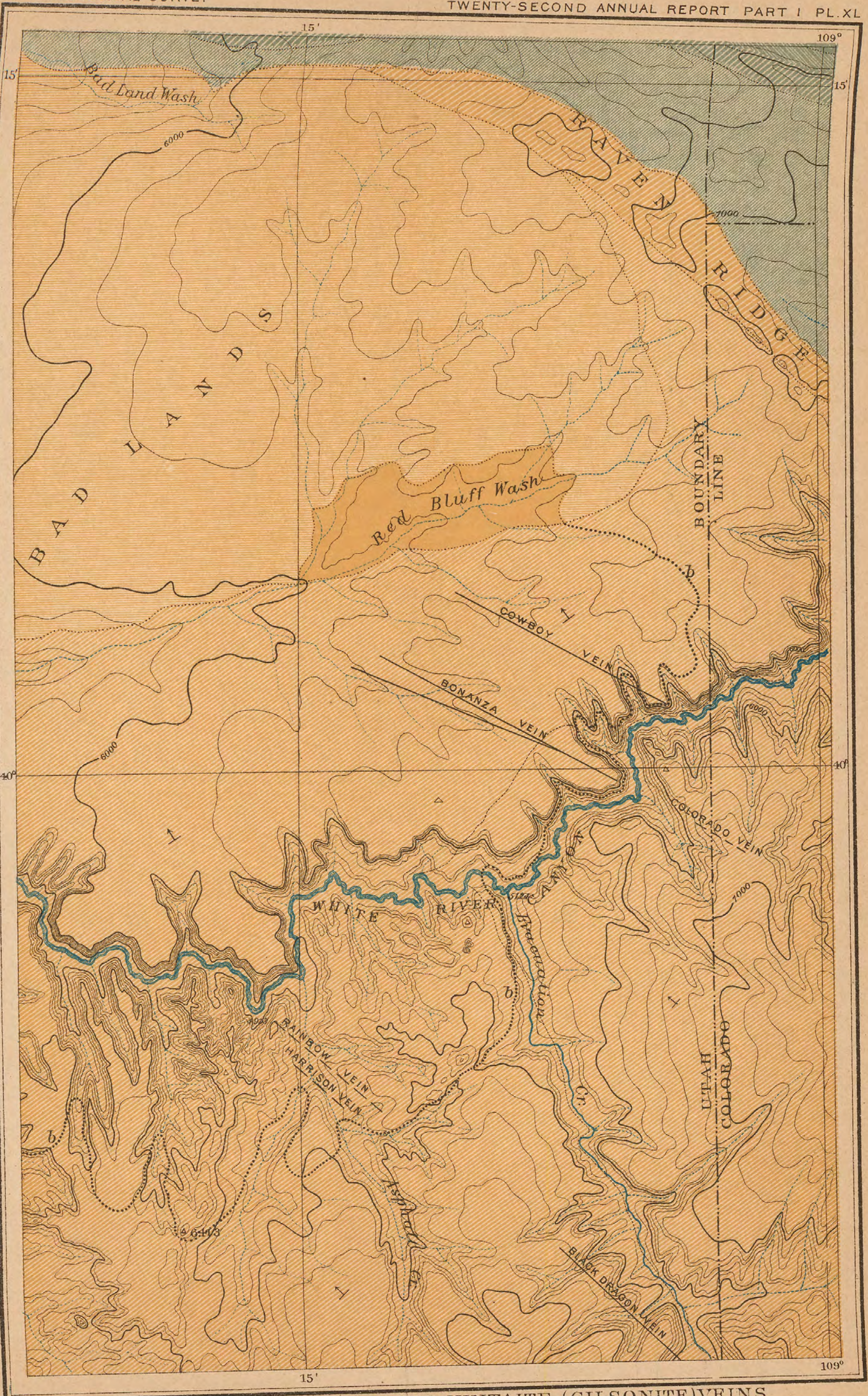


FIG. 30.—Sketch of region about Fort Duchesne, Utah.[1]

The vein is vertical and has a N. 40° W. trend. It is traceable for about 3 miles. A width of from 3 to 4 feet is maintained for a length of about 1½ miles along the middle of the outcrop, but beyond this, in either direction, it gradually diminishes to complete disappearance. The Duchesne vein shows an occasional short transverse fault (*bb*, fig. 31), the planes of which may differ in trend and dip, but in the two or three instances observed by the writer were inclined to the eastward 75° or 80° with the horizon. The throws, none over 8 inches, cause

[1] Since the preparation of this figure the Uncompahgre Reservation has been opened to settlement, but with the reservation to the United States of the mineral rights.



REGION OF THE WHITE RIVER UINTAITE (GILSONITE) VEINS

TERTIARY: UINTA, BRIDGER, GREEN RIVER, WASATCH

CRETACEOUS: LARAMIE, FOX HILLS, COLORADO, DAKOTA

Scale of miles

5 0 5 10

Contour interval 200 feet

(Base, Hayden map Colorado Atlas)

Dotted line *b* is possible southern limit of Bridger.

Location of Rainbow, Harrison, and Colorado veins, by report only.

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little disturbance to the vein other than a direct crack across the filling. Near the northern end of the present workings, in a surface trench, the vein displays several included fragments of wall rock completely surrounded by asphaltic material (*bb*, fig. 32). Another feature, perhaps of especial significance in the origin of these veins, is the diagonal course of country rock (*d*, fig. 31), dividing the vein in two at a level near the present surface of the ground. It is quite probable that this diagonal course of sandstone will disappear in depth and the vein then become continuous. This is apparently an instance of a rent in which the crack was interrupted by a body of rock which was not wholly severed from either wall in the rending. The walls of the Duchesne vein are well defined, though their planes wave slightly both on the trend and in depth. Several openings, surface cuts and shafts, have been made, which show the character of the deposit for nearly its entire length.

The St. Louis Gilson Asphaltum Company controls the greater part of the vein, and has shipped a comparatively large amount of gilsonite in the nine or ten years in which it has been operating. The product, according to its even, homogeneous texture and massive character, or its cuboidal or penicillate structure and crumbling tendency, indicative of alteration from atmospheric influences and confined to the upper portions of the mine, is divided into first and second grades, used in the trade for different purposes or for the manufacture of different qualities of the same article.

FIG. 31.—Diagram showing the several features of the Duchesne vein in plan; not drawn to scale. *a*, Included fragment of sandstone; *bb*, fault; *cc*, lateral cracks; *d*, cross course of sandstone; *e*, country rock.

CULMER VEIN.

The Culmer vein, which is the principal one of the Castle Peak mining district, crosses the fortieth parallel immediately west of the one hundred and tenth meridian. Its trend varies between N. 35° W. and N. 41° W., and its outcrop can be traced across the desert, with slight interruptions, for 7 miles. In this distance its width varies from a knife edge to 30 inches, a common width being 8 or 10 to 16 inches. The vein has a westward dip of 85° to 88°. In the main there appears to be one principal fracture, with, however, laterals of greater or less extent, one or two traceable for over half a mile, with the clearest definition and a width of 12 to 16 inches. While in general the laterals diverge in their surface plan from the main fracture, and at very acute angles, in one or two instances they outcrop as distinct fissures, yet are doubtless connected with the leading crack in depth. The width of the zone thus fractured is about 250 feet, but there are long intervals where but the single break exists. In the majority of instances the branches from the main fissure are given off to the east, but north of the fortieth parallel is one, at least, of considerable importance on the west.

The superficial rock of the region is gray, green, and purple sandstone and shale, in part, perhaps, of the Uinta formation, in part of the Washakie or Bridger formations. The strata strike WNW. and dip about 5° NNE.

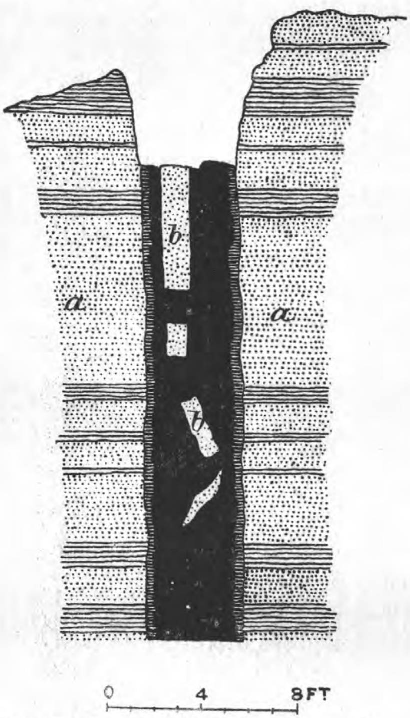


FIG. 32.—Cross section Duchesne vein. *aa*, Country rock; *bb*, fragments of wall rock.

In its general character the Culmer vein resembles the Duchesne. The uintaite shows the same homogeneity of texture remote from atmospheric influences, and near the outcrop the columnar, penicillate, and cuboidal structure. Fragments of the country rock are found in it, and in places the vein may be divided along its length for a considerable distance by one or more slices split from the wall. Indeed, in this instance the fissure itself may sometimes be said to have been divided. At one point delicate venations of calcite were found in the uintaite, the material derived, evidently, from the country rock.

The Culmer vein shows a number of nearly vertical, transverse faults, often at short intervals, with offsets from 1 to 10 feet each, the portion of the vein south of the fracture almost always being carried west. Neither vein nor adjoining country rocks seem to have suffered especially marked fracturing in these displacements. Besides the vertical faults there are many of the type shown in fig. 33, at intervals along the vein, of which the plane has a gentle dip of from 2° to 8° to the northeast or southwest. The strata above the fracture have been moved in both directions along the fault plane from 6 to 12 or even 24 inches, and up the plane as well as down it. Several such displacements have also been observed within a vertical distance of 10 to 30 feet, giving the appearance of a succession of a number of small step faults, always of limited extent. In addition to faulting, the uintaite itself shows at one or two points diagonal jointing, as though from a tendency to a horizontal movement of the walls with the length of the vein.

The Culmer vein and its laterals have been prospected at intervals for their entire lengths, and the main fissure about midway has been mined to a depth of 200 feet, with stopes 150 feet each way from the shaft. Nearer the surface the vein has been removed, with interruptions, to depths of 40 to 75 feet for nearly half a mile. Within this distance its width has varied from 3 to 30 inches, in the present lower levels being but 6 inches. This, however, signifies little for the general behavior of the vein but indicates constant and rapid variation at all points. From the foregoing it will be seen that the action of the vein is that peculiar to all deposits of asphalt of like nature occupying fissures cutting clays, shales, and thin sandstones. The exploitation along this portion of the vein is known as the Pariette mine and has been conducted by the Messrs. Culmer, of Salt Lake City. The total product of the vein, including the Pariette mine and two or three extensive prospects north and south of it, has, perhaps, amounted to 1,000 tons.

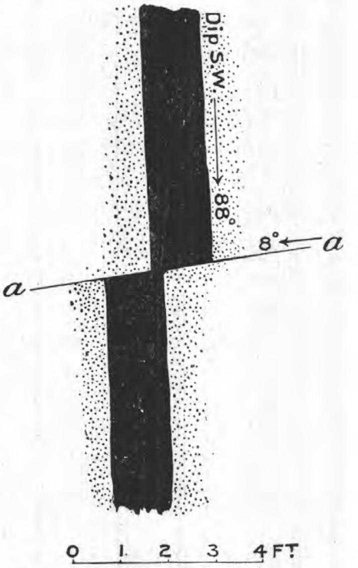


FIG. 33.—Cross section Culmer vein; *a—a*, fault.

The product of the Pariette mine is separated into first and second grade, on the same basis as at the Duchesne. On account of the narrowness of the vein especial care is used in mining not to deteriorate the higher-class material by sand from the walls or by admixture with it of the more weathered portion of the gilsonite. The second-grade material is sometimes thrown over a coarse sieve or screen, by which some of the dirt is removed and the quality thus improved.

The water from the mine is strongly mineralized, rendering it highly unpalatable.

Parallel with and opposite the southern portion of the mined segment of the Culmer vein as above described, at a distance of 255 feet, is a second vein, 8 to 12 inches in width, that has been worked to a depth of 18 or 20 feet, here and there, for a distance of 700 feet, the total length of the vein outcrop being about 1,200 feet. It is unimportant.

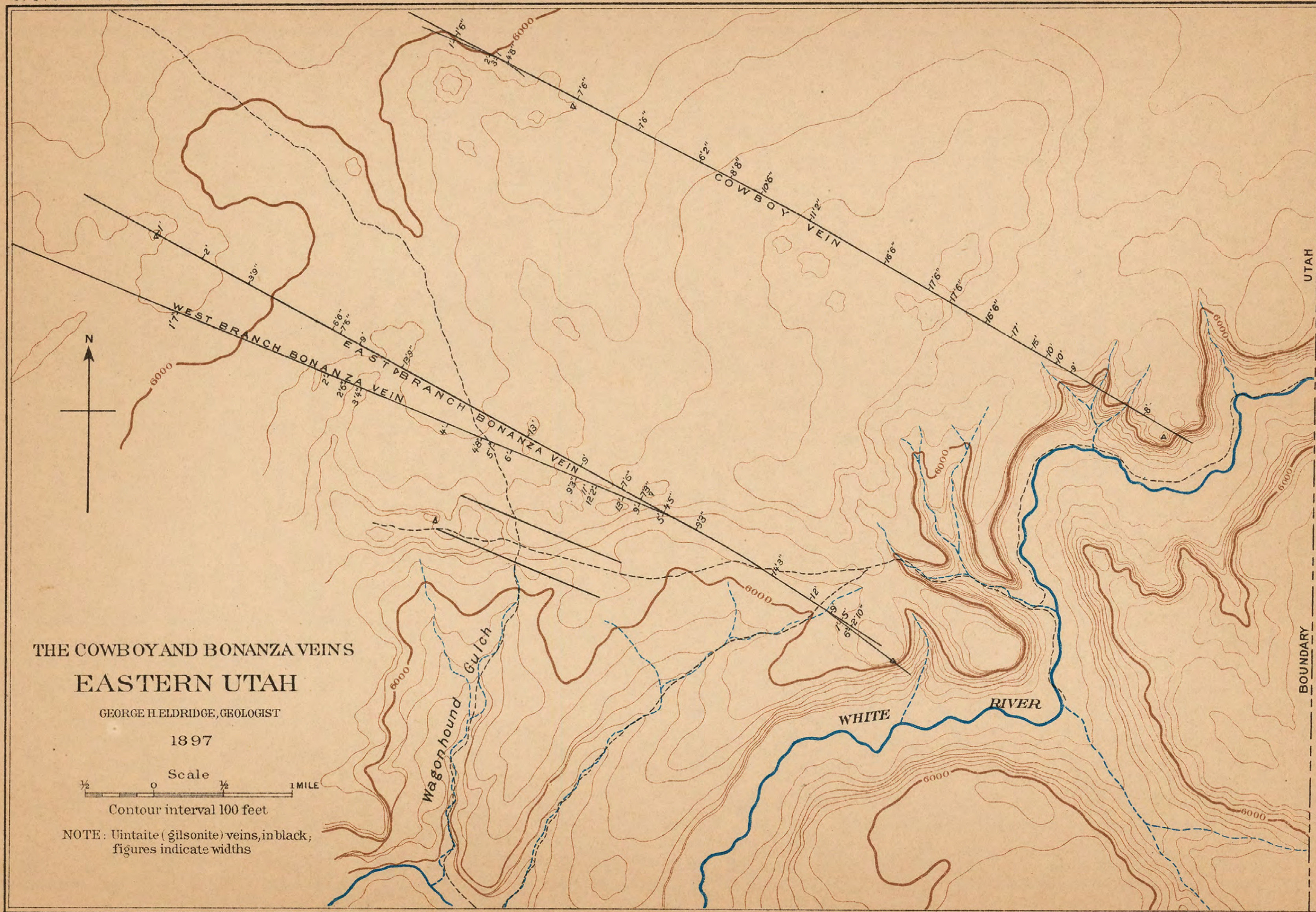
BONANZA AND COWBOY VEINS.

The most important locality of uintaite (gilsonite) is the region immediately north of White River, near the eastern edge of Utah. Here are three nearly parallel, vertical veins, of almost constant N. 60° W. trend, cutting the heavy sandstones of the Bridger formation, and extending slightly into the shales of the Green River below. The strata dip to the northwest, the fissures having a direction somewhat diagonal to the dip, which is about N. 55° W. The veins are known as the East and West Bonanzas and the Cowboy, the two Bonanzas uniting to the southeast. The two Bonanzas are at varying distance from each other, while from the East Bonanza the Cowboy is distant about 2½ miles. None of these veins are exploited, only a shallow prospect appearing here and there. In general features and in character of filling they are like the Duchesne and Culmer veins; the cracks are doubtless of similar origin, and the material occupying them is unquestionably derived from the same ultimate source as that in the others. The structure of the uintaite is also the same—that is, it is primarily massive, but in the outcrop is penicillate, next to the walls and cuboidal elsewhere; the brilliant luster, too, is replaced in the outcrop, except on a fresh fracture, by the dull black of a surface long exposed.

The West and East Bonanzas may be traced from the slopes of the White River Canyon northwestward a distance of fully 7 miles. The greatest widths of the veins are attained in the region of the summit north of the river. Their variation in this respect is indicated on the special map of the locality (Pl. XLI). Their outcrops are everywhere pronounced, the broad swath of scant vegetation which marks the presence of such veins being a conspicuous feature of the scene. South of White River it is questionable if the Bonanza vein is continued, unless in the higher land. Mr. McAndrews, of the Ouray Agency, states, however, that he has traced veins of minor importance at intervals in this direction quite to the Colorado line.

In Colorado the single vein discovered near the Utah line is said by Mr. Joseph Luxon, of Vernal, Utah, who is familiar with the locality, to be about on the trend of the Bonanza, and it may be that this is its continuation; on the other hand it may represent another vein originating in an independent crack belonging to the same fissure system. The vein is reported to have a length of nearly 2 miles east of the interstate line, to have been prospected for this distance, and at one or two points to have been worked in a small way to a depth of 100 feet. Its general width is said to be about 30 inches. The openings are located on the crest and eastern slope of the ridge dividing Evacuation Creek from the waters running directly into White River and the streams farther east.

The Cowboy is the largest of the three veins in the White River region, a maximum width of 18 feet having been observed at the crest of the ridge 2 miles north of the river. In either direction from this point it thins considerably, but maintains a width of 8 to 12 feet for a distance of at least 3 or 4 miles, and above 4 feet for nearly 6 miles. The total length is between 7 and 8 miles. The northwest end of the



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vein is about a half mile north of a prominent hat-shaped butte in the Coyote Basin and between 4 and 5 miles northwest of the point where the vein crosses the ridge north of White River. The southeast end is at the bluffs of White River. As in the case of the Bonanza, the vein is easily traced by the swath its outcrop makes in the vegetation, being especially conspicuous on account of its width and continuity. South of White River it is said not to have been discovered, passing perhaps above the formations on that side.

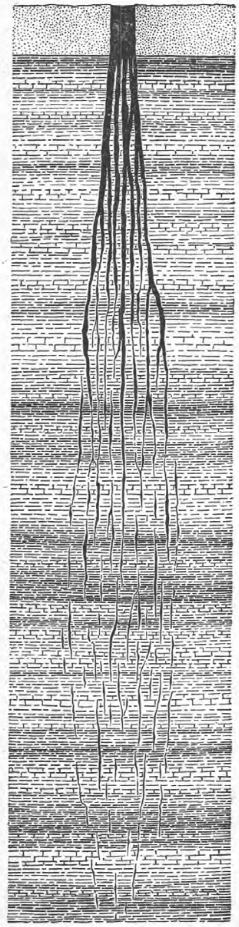


FIG. 34.—Cross section southeast end Cowboy vein, showing passage from sandstone to shale.

The general occurrence of the Cowboy and Bonanza veins is extremely simple, yet remarkable when the proportion of their width to their length is considered, approximately 1:4000, yet a proportion that is exceeded in the case of the Culmer vein, where width to length is as 1:37000. Such proportions render the continuity of the fissure, the evenness of its walls, the maintenance of a straight open crack, truly marvelous. But this is an occurrence where the veins are held in a series of beds in which sandstones not only largely predominate but occur in rapid succession and are individually of considerable thickness. In a heavy series of shales the case is quite different, as has already been shown in occurrences in Colorado, Indian Territory, and West Virginia. The fissile character of shales enables a distribution of rupturing effect over extended areas, while their nonresistance to compression and yielding nature readily permit readjustment of disturbed portions, with consequent closing of any fissures that may have at first been opened.

It is in a succession of strata similar to the foregoing in their entirety, that the Cowboy and Bonanza veins have been formed and found their limitations. They are maintained in the heavy sandstones of the Bridger and the softer and more arenaceous shales immediately below; they disappear in the great body of hard, calcareous shales that underlie these and in those which succeed the sandstones above. Their disappearance in length, within the Bridger sandstones, may have occurred by the gradual diminution in the width of the crack—a pinching out. In depth and height, however, in their passage to other series of strata their disappearance depends, aside from the inherent size of the crack, upon the texture of the strata. This is manifest in the conditions that prevail at the southeast ends of both Cowboy and Bonanza veins. In the case of the former especially, its fissure, upon passing from the massive sandstones of Bridger age and the underlying brown and gray shales of doubtful assignment into the heavy series of hard calcareous shales of Green River time, splits into a score of minor cracks extending from 50 to 300 feet into the lower horizon. From the width of the unbroken fissure above, the minor cracks spread, in passing downward, till they occupy a lateral space of 40 or 50 feet; contracting, however, before closing, to less than half this. The cracks in their upper portion remained open in a greater or less degree to the inflow of the asphalt, but, assuming considerable irregularity of shape and undergoing further division below, finally closed completely. Below this horizon joint planes alone are visible. All this is clearly pictured in the lofty walls of the White River Canyon. Of the Cowboy and Bonanza veins, the splits of the former extend farthest into the gray, calcareous Green River shales; those of the Bonanza, which at the cliffs is itself divided and considerably reduced, barely reach this lower horizon, but disappear for the most part in the shale zone of questionable assignment between recognized Green River and Bridger.

The disappearance of the Bonanza and Cowboy veins to the northwest is also in shales, soft and clayey, but in which open fissures of a foot to 18 inches were maintained and filled with asphalt for a distance of a half mile before finally feathering out. The veins here split at the ends, but the ultimate branches disappear by ordinary diminution in their width. A vertical section illustrating the disappearance of the fissure above the massive Bridger sandstones could not be found.

The great body of hard, calcareous shales of the Green River formation, constituting the walls of the White River Canyon and delimiting the Cowboy and Bonanza veins below, and which extends the length of the Uinta Basin, generally forms, it is found, a barrier to the passage of important, if, indeed, not to all, asphalt veins, whether from below or above—this notwithstanding cracks of limited vertical extent, filled with wurtzilite, that occur in a middle zone of limestones in the western half of the Uinta Basin.

The topography of the region under discussion is that of a high body of land cut to a depth of 1,000 to 1,500 feet by the narrow gorge of White River. The elevated region south of the stream is deeply indented with lateral canyons and is excessively rugged; that north is but slightly indented, and presents at its top a broad area of rolling hills upon an otherwise flat table. The region north of White River is therefore of a nature to render the veins easy of access and readily worked, except for water, which would have to be raised from the river, and for fuel, which in a short time at furthest could be obtained only at a distance of 15 to 50 miles.

OTHER VEINS IN THE COWBOY-BONANZA REGION.

About 3 miles southwest of the Bonanza veins and a little east of the summit of the grade leading out of the White River Canyon is a uintaite vein traceable for a mile or more across the ridge in a direction about N. 67° W. The maximum width found was $3\frac{1}{2}$ feet, in the region of the ridge crest. South of this it quickly diminishes to 14 inches, varying between this and 24 inches for a half mile, when a still further decrease takes place and the vein disappears toward the bluffs of the river canyon. Northwest of the summit also the outcrop indicates a gradual but somewhat rapid decrease, but the vein is outlined for fully a half mile by float and the swath in the herbage—a feature characterizing the outcrop of all gilsonite veins.

Seventy-five yards northeast of the foregoing are traces of another small vein, and a third of a mile southwest yet another, the latter a foot wide and traceable for one-third to one-half mile.

The veins referred to on page 341 as having been discovered on Asphalt Creek since the writer's visit to the field are said to have a general northwest trend, are vertical, and display in the main the same features as the Cowboy, Bonanza, and Black Dragon veins. The eastern vein, known as the Rainbow, has been traced, it is said, for at least 2 miles, the greater portion of it lying east of Asphalt Creek. The other, the Harrison, is considerably shorter. The eastern has a maximum reported width of 9 feet, tapering from this to either end; the western, it is said, is only about 4 feet at its widest.

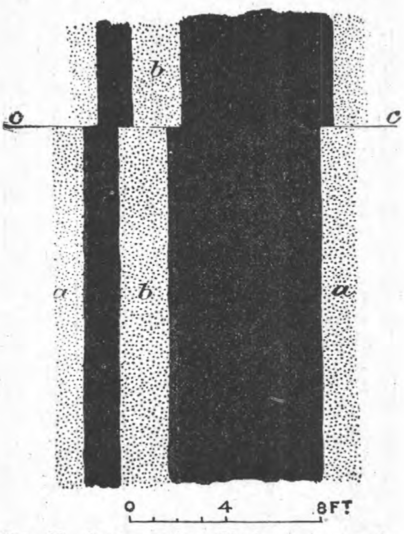


FIG. 35.—Cross section Black Dragon vein, Evacuation Creek, Upper Prospect. *aa*, Country rock; *bb*, horse; *cc*, fault.

BLACK DRAGON VEIN.

The Black Dragon vein (Pl. XL) is located in the region of Upper Evacuation Creek. The southern end of its outcrop is in a canyon tributary to that of the West Fork of the creek, the first of importance above the confluence of the latter with the East Fork, a distance of about a mile. From this point, which is within a half mile of the Colorado line, the vein is traceable 4 miles, the trend being N. 46° 30′ W., the pitch from 85° NE. to vertical. The variation in thickness is given in the longitudinal section, Pl. XLII. Along the line of fracturing the vein shows frequent parallel fissuring, the cracks being sometimes three or four in number. In most instances they are separated from one another by but 2 or 3 feet of the country rock, though at one point a maximum of 30 feet was found between two veins. Excepting in the southern mile, the separate veins rarely exceed 3 feet in width, 2 and 2½ feet being the more common. Near the southern end of the vein a large prospect shows a clean breast of uintaite 8 feet 6 inches across. The walls are vertical, and, whether of sandstone, limestone, or shale, are impregnated with the asphalt from 1 to 3 feet from the vein. The columnar, or penicillate, structure is developed in the asphalt to a depth of 6 inches from either side; the center, the remaining 7 feet, except at the very surface, shows the usual structureless, homogeneous mass, of coarsely conchoidal fracture and brilliant black luster. At a prospect a few hundred feet above the main opening on the vein the conditions shown in fig. 35 were found. The included 2 feet of sandstone (*bb*), evidently separated from the main wall opposite, was, like it, completely impregnated with uintaite, which showed on a minute scale the same physical properties, fractures, etc., as the material in mass. The vein here also shows a sharp horizontal displacement (*cc*) of 8 inches, the portion above having moved to the northeast. Although somewhat concealed from view at the line of fracture, the vein seemed to afford in the more exposed portions but little evidence of actual crushing. On the southern side of the gulch in which the foregoing observations were made, within 150 or 200 yards of the openings referred to above, the very southern end of the vein, at least at the outcrop, shows in a low cliff of sandstone precisely as sketched in fig. 36. From its appearance it gives evidence of continuing in depth beyond this point, the apex of the vein sinking to the southeast.

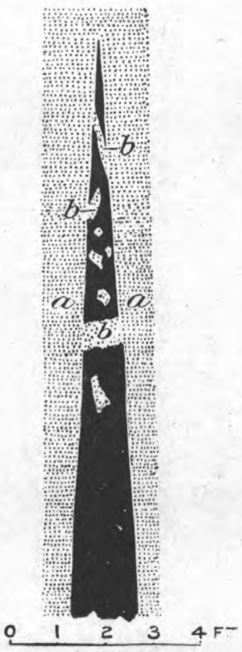
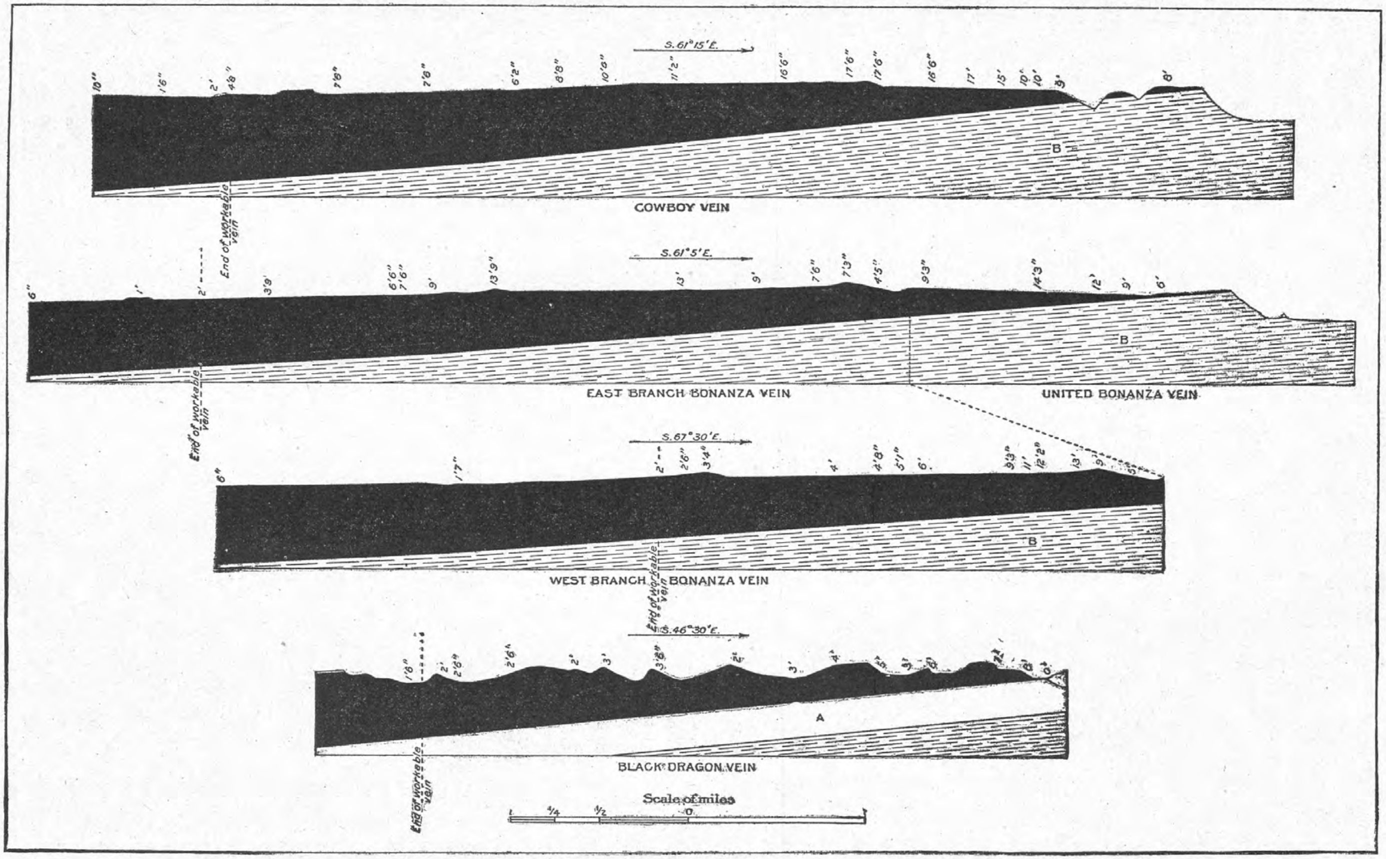


FIG. 36.—Terminal cross section at outcrop of Black Dragon vein, Evacuation Creek. *aa*, Country rock; *bb*, fragments of wall rock.

The vein cuts the lower portion of Green River beds, sandstones, shales, and limestones, among the latter being some fine types of oolitic structure, so characteristic of the lower part of this formation. In passing through these several beds, different as they are in texture, the walls of the crack seem to have been but little disturbed in their regularity, presenting everywhere an almost perfect plane. The strike of the beds is here approximately northeast-southwest, the dip 5° NW. The position of the vein is advantageous to economical working, in that a drift from the bottom of the valley where exposed would pass at least 500 feet below its highest point of outcrop. Timber is more



LONGITUDINAL SECTIONS OF COWBOY, BONANZA, AND BLACK DRAGON VEINS.

convenient here than at points on White River, but water is in minimum quantity.

In the same cliff in which is exposed the section of the southern end of the Black Dragon vein, and parallel with the latter in strike and dip, are two bodies of dark-gray sandstone that would at first sight be taken for vertical dikes in the lighter gray sandstone of the cliff. Fig. 37 represents one of these bodies. They prove, however, on close examination, to be simple zones of the ordinary sandstone, impregnated with uintaite to a remarkably uniform distance on either side of a median crack now tightly closed, but with a thin film of the asphaltic mineral here and there along it. The total width of each zone is 18 inches, one-half on each side of the median crack. The distance between the zones is 9 feet, and the eastern one is also 9 feet from the uintaite vein. These impregnated bodies pass upward beyond the end of the vein of uintaite, but they were not traced out. The precise manner in which their impregnation took place is difficult to surmise. The median crack would seem to indicate at least a possibility of its having once been opened, furnishing a channel for the asphaltic material, and then closed, the uintaite passing into the walls to a surprisingly regular depth. Evidence that such is the case exists in the lateral continuation of the laminæ composing the heavy bed of sandstone from the unimpregnated portion to the impregnated, even plant impressions, which occur in quantities between the layers, being found half in the impregnated and half in the unimpregnated part without interruption in continuity.

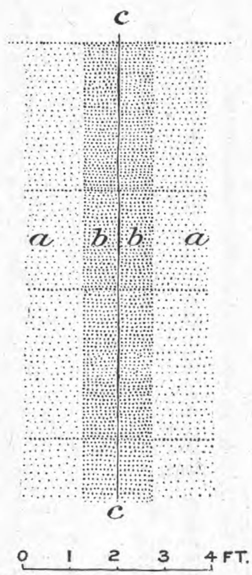


Fig. 37.—Cross section of a uintaite-filled sandstone having the appearance of a dike. *aa*, Country rock; *bb*, zone impregnated with uintaite; *cc*, median crack.

CONDITIONS OF IMPREGNATION.

The condition in which the gilsonite found its way into the veins seems most probably to have been that of a plastic mass, coming from below under pressure, and, although of high viscosity, sufficiently fluid to be pressed between the grains constituting the wall rocks, whether of sandstone, shale, or limestone. As to the fragments of country rock in the veins, it is to be remarked that they are often entirely free from the walls, surrounded with uintaite. They are heavy, and, but for a supporting medium, when torn from the walls must have fallen to the bottom of the crack, or at least lodged at points far below their original position. They would hardly have been carried to the very apex of the fissure, as seen in the section of the southern end of the

Black Dragon vein. It would seem, therefore, that in the formation of a fissure it must have been almost instantly filled with the plastic asphalt, and that the pieces of wall rock, more or less separated from the sides, hanging by mere threads, as it were, were caught in the rising current of uintaite and so carried a short distance from their original places. The larger fragments, the horses, which also occupy positions isolated from the walls, it is difficult to conceive as acquiring their position in any other way than that suggested, and it must be due to the rapidity with which the asphalt hardened, as well as to its viscosity, that they did not sink to the bottom in a medium which is so different in specific gravity.

The writer frankly confesses his lack of ability to suggest the conditions under which the uintaite (gilsonite) existed prior to its flow into the cracks.

ESTIMATED TONNAGE OF THE UINTAITE VEINS OF UTAH.

Following is an estimate of the amount of uintaite (gilsonite) in the five veins of workable thickness that have been described in the foregoing pages. The figures must be taken with allowance, for in the unexploited condition of the veins it is impossible to deduce exact laws of occurrence in depth or in width. The tables setting forth the contents are preceded by a table giving a general estimate for veins of uintaite of definite dimensions and the figures which have been employed in computing the contents of the veins for the tables that follow.

Tonnage contents of gilsonite veins for a depth of 1,000 feet, but of varying widths and lengths.[1]

Width of vein.	Length of 1 mile.	Length of 2 miles.	Length of 3 miles.	Length of 4 miles.	Length of 5 miles.
Feet.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
1	176,000	352,000	528,000	704,000	880,000
2	352,000	704,000	1,056,000	1,408,000	1,760,000
3	528,000	1,056,000	1,584,000	2,112,000	2,640,000
4	704,000	1,408,000	2,112,000	2,816,000	3,520,000
5	880,000	1,760,000	2,640,000	3,520,000	4,400,000
6	1,056,000	2,112,000	3,168,000	4,224,000	5,280,000
7	1,232,000	2,464,000	3,696,000	4,928,000	6,160,000
8	1,408,000	2,816,000	4,224,000	5,632,000	7,040,000
9	1,584,000	3,168,000	4,752,000	6,336,000	7,920,000
10	1,760,000	3,520,000	5,280,000	7,040,000	8,800,000

In the case of the Cowboy, Bonanza, and Black Dragon veins, the basis upon which their contents have been estimated is, first, the dip

[1] Specific gravity of gilsonite, average of several authorities, 1.07. Weight of cubic foot of gilsonite, 66.875 pounds. Number of cubic feet in 1 ton, 29.9 (taken at 30 in table).

of the inclosing strata, from 3° to 7°, in the same direction as the trend of the veins—that is, northwest; second, the disappearance of the veins in the underlying shales by splitting into scores of minute fissures; third, the maintenance of the veins along the surface through the many changes in the lithological character of the inclosing strata, suggesting that they may very probably extend through the same beds in depth, and with about the widths attained at the surface, until the underlying shales are encountered in their dip; fourth, the disappearance of the veins in the overlying shales to the northwest. These conditions give the triangular, vertical, longitudinal sections represented in the profiles along the planes of the veins (Pl. XLII), and, with the thickness indicated by the numbers along the veins on the map, have afforded the estimates about to be given. In the case of the Black Dragon it is impossible to suggest the total depth attained by the fissure, for nowhere is its bottom visible. The estimate in the tables is based upon that portion which lies above the line of dip of the lowest stratum appearing at the southeasternmost exposure of the vein, and is probably considerably below the actual content.

Estimated tonnage of the Cowboy, Bonanza, and Black Dragon veins.

Cowboy	14,069,250
Bonanza:	
East Branch	10,434,387
West Branch	4,084,497
Black Dragon	2,086,479
Total	30,674,613

A rough estimate of the contents of the Duchesne vein—including the product already mined—based on observations along the outcrop, and for a depth ot 500 feet, shows the amount of uintaite (gilsonite) to be a little less than 500,000 tons. The details of the measurement, with the tonnage, are:

Contents of the Duchesne vein.

	Average width of vein.	Yield in 1,000 feet depth.
	Feet.	*Tons.*
For about 660 feet from the northwest end of the vein	$1\frac{2}{3}$	18,333
For next 300 feet southeast, about	$2\frac{1}{4}$	11,250
For next 2,970 feet southeast, about	$3\frac{1}{3}$	165,000
For next 3,960 feet southeast, about	3	198,000
For next 2,970 feet southeast, about	$1\frac{7}{12}$	78,375
		470,958

The outcrop then shows a width less than will allow profitable working.

The Culmer vein, by the selection of such portions as are of the more advantageous widths, may be found equal to a fissure of 15 inches 2 miles long. Such a vein for a depth of 200 feet would yield about 90,000 tons. It is questionable, however, whether a quarter part of this tonnage will ever be mined, for upon the larger veins becoming available for mining purposes, the value of the Culmer vein will be practically wiped out.

The vein in Colorado would afford a product of 44,000 tons in a depth of 500 feet if the reported width of 30 inches for 2 miles be taken.

The total yield of the five uintaite veins of Utah and the Colorado vein would, upon the basis of estimates, amount to nearly 32,000,000 tons. To this must be added the tonnage of the still undeveloped and but little known veins reported on Asphalt Creek.

EXPLOITATION OF THE UINTAITE VEINS.

Mining for uintaite will be conducted after the ordinary methods, by means of shafts and tunnels. With the establishment of hoists and conveying machinery, of especial necessity will be the installation of a ventilating plant, for the dust derived from the gilsonite in mining is exceedingly annoying, penetrating both skin and lungs and there remaining, except under the action of a solvent, impossible, of course, in the latter case. This peculiarity of the mineral is due to its insolubility in water and to its softening under the temperature of the body. It is therefore very different in behavior from coal dust, which readily succumbs to water, and can in a measure be thrown off by the lungs. From the skin of the miner gilsonite dust is commonly removed by the application of kerosene oil, but any of the solvents given in Table III (p. 222) may be used. Besides the harmful results in breathing it, the dust has proved a dangerous element in mining, being highly explosive when its mixture with atmospheric air acquires a certain ratio and it is then disturbed by the accidental fall of a lighted candle through it. Safety lamps can be used only with difficulty on account of the heat melting the substance, which then forms a film over glass or gauze.

Thus far ventilation has not been attempted, the men using aspirators, sponges, or other methods, the dust of the mines being laid every few days by spraying the walls with water, which finds its way to a sump and is raised in buckets. Any of the methods of ventilation adopted in coal mines, mills, etc., would in great degree remedy the inconvenience and danger attending the winning of this product.

Timber suitable for mining purposes is in most instances from 10 to 50 miles distant, and for fuel but little less. For the mines comparatively little will be required, the veins being vertical, the strata nearly horizontal, and the sandstones and shales likely to stand well with the minimum support. For fuel much more timber will be needed, unless coal be employed, transported from points 25 to 75 miles away.

Water is rarely to be found in position advantageous for utilization. From experience at the Culmer mine, the mine water can be used neither for domestic nor for steam purposes. White River will supply mines located in its vicinity, but will require comparatively expensive pumping plants capable of heavy lifts of 1,000 to 2,000 feet.

Electric power may, perhaps, be obtained from the White, Duchesne, and Uinta rivers.

The mining of gilsonite can best be accomplished with the pick alone, as the material is very brittle and readily yields. It also strips clear of the walls, and little or no separation or sorting is required after once getting below the superficial zone affected by atmospheric influences. Blasting is not required. One man can mine and sack and send to the surface by horse whim 2 tons per day of ten hours, the present wage cost being about $1.75 per ton. The items of expense other than wages will be fuel, ventilation, pumping, and water supply.

COMMERCIAL CONSIDERATIONS.

TRANSPORTATION ROUTES.

The region within which the uintaite (gilsonite) veins occur is deficient in transportation routes. From the north it is inaccessible except by very indirect roads. To the south it is separated from the valleys of Grand and Price rivers by the rugged Roan or Book Plateau and its canyons, though the travel of to-day is in this direction, the product of the Culmer and Duchesne mines being taken by wagon to Price, on the Rio Grande Western Railway. Up Strawberry Valley and across the Wasatch Range the route is somewhat more difficult than the last, and the distance to railroad is considerably greater. The mines in the edge of Colorado now ship their product by wagon over a circuitous and hilly road via Meeker to Rifle, on the Denver and Rio Grande Railroad, 125 miles. It is thought possible, however, by those familiar with the country, to find a feasible route 50 to 70 miles shorter than this directly southward along the State line. The Bonanza and Cowboy group of veins is a little more remote from Rifle than are the Colorado openings, though perhaps attended with no greater difficulties of transportation. By the way of Fort Duchesne to Price the route from these veins is about 180 miles. The vein of uintaite (gilsonite) on Upper Evacuation Creek is more inaccessible than any of the others unless it should be proved possible to establish a route directly south across the Roan or Book Plateau, when it would become the nearest of all the deposits to railroad communication.

The cost of freighting the product of the Duchesne and Culmer mines to rail is now $10 to $15 per ton. Railway freight to St. Louis is said to be about $8 per ton. The total cost of mining and placing the material in Chicago or St. Louis is therefore not far from $25 per ton. Office and management expenses may increase this to $30. The present price per ton in Chicago and St. Louis for the best grade is $40 to $50, leaving a net profit of $10 to $20. The factors in a reduction of the price to the trade will be railroad transportation direct from the Uinta Basin, which seems probable at a future day, and competition, which will arise should any equable distribution of mining claims be made among the numerous companies that will doubtless be inclined to work these great deposits.

USES OF UINTAITE IN COMMERCE.

Uintaite (gilsonite) is employed chiefly in the manufacture of black, low-grade brush and dipping varnishes, such, for instance, as are used on the various kinds of iron work, and as baking japans. For a high-grade rubbing varnish for coaches, and for ebonizing and similar uses, it is said to be altogether unadapted. By one company it is also employed for mixing with an asphaltic limestone in the manufacture of paving material.

Other uses, according to the statement of Mr. E. W. Parker in Mineral Resources of the United States for 1893, are:

For preventing electrolytic action on iron plates of ship bottoms.
For coating barbed-wire fencing, etc.
For coating sea walls of brick or masonry.
For covering paving brick.
For acid-proof lining for chemical tanks.
For roofing pitch.
For insulating electric wires.
For smokestack paint.
For lubricants for heavy machinery.
For preserving iron pipes from corrosion and acids.
For coating poles, posts, and ties.
For toredo-proof pile coating.
For covering wood-block paving.
As a substitute for rubber in the manufacture of cotton garden hose.
As a binder pitch for culm in making brickette and eggette coal.

It is probable, however, that many of the uses of gilsonite enumerated by Mr. Parker are still in the experimental stage.

Prior to the use of gilsonite in manufactures the raw material is crushed to a half or three-fourths inch size and screened, an operation by which any chance foreign matter is removed. The screened material is usually designated "first grade," the screenings "second grade." The latter are said to be about the quality of the second-grade mine product.

In the manufacture of varnish, gilsonite of the higher grade is heated with linseed oil to a temperature of about 400° F., in a tank built for the purpose and fitted with a device for stirring. After thorough liquefaction and mixing, the resulting product is run into a second receptacle and thinned with either turpentine or naphtha, according to the ultimate product desired, the turpentine being employed in all the better grades, naphtha making an inferior quality and being used only on account of cheapness. After thinning it goes to a receiving or storage tank, from which it is drawn into cans and sealed ready for the trade. This is the general practice, devoid of details, which vary widely according to the quality of varnish desired, the purpose for which it is to be employed, and the personal experience of the manufacturers in their study to produce results the most satisfactory to the consumers. It is an occasional practice to dilute the gilsonite with resin, an operation which, carried too far, renders the varnish product made from it comparatively worthless, and in all cases counteracts in greater or less degree the very properties for which the gilsonite compound is so valued, namely, elasticity. This property of elasticity is considered one of the most essential qualities of a varnish, and in imparting it, together with a black of peculiar richness, gilsonite is said to be unapproached by other asphalts. The writer has seen sheet tin coated with the varnish subjected to the severe test of repeated bending back and forth, followed by hammering the bent edge with a piece of steel, without the slightest detriment to the japanned surface either by cracking or loss of luster. In this respect it shows a marked similarity of result to an enamel made from wurtzilite, a mineral preeminent for its elasticity.

The color of varnish made from gilsonite has a brownish tint in thin coats, but this is completely remedied by a heavier, yet still thin, application. In this connection it is suggested by the writer that it may be possible to employ the nearly related mineral albertite, which, unlike gilsonite, has a jet black powder and streak. But it is not yet established, so far as can be learned from the literature on the subject, whether albertite possesses the same elastic properties as gilsonite. If it does not, the problem is still unsolved, except, of course, by a direct admixture of a foreign matter of decided black color.

By some manufacturers the use of gilsonite in preference to other asphalts is considered advantageous from the standpoint of economy, as it is said to require less linseed oil to obtain equally satisfactory results, to have a greater capacity for the thinning medium with correspondingly less deterioration from its use, and to maintain an equal bulk of product with employment of a smaller percentage than of other asphalts.

The present cost of varnishes of the first quality made from gilsonite is about $1.25 per gallon, and somewhat lower for lower grades. From the evidence gathered by the writer, the opening of the gilsonite veins and competition among mining companies would tend to lower the price of the raw material to manufacturers, but many of the latter do not believe an increased supply of this would materially lower the price of the varnish, as competition has already brought this to a limit. There would result, however, an improvement in quality among those who are now inclined to adulterate with resin, and the foreign asphalts used for the same purpose would be driven almost entirely from the markets of the United States. The quantity of gilsonite used by varnish manufacturers would also doubtless be considerably increased, but the total consumption for this purpose would always be comparatively small, for among even the larger concerns a carload often lasts six months.

In the manufacture of paving cement, gilsonite of the second grade is melted with petroleum residue in a tank similar to that used for its liquefaction with linseed oil for use in varnish making. To the heated mixture is added ground asphaltic limestone carrying perhaps an average of 10 to 15 per cent asphalt. After thorough mixing and heating, the material is drawn from the tank into barrels and stored ready for shipment. For paving it is remelted, the requisite amount of sand is added, and the mixture is then spread like the ordinary asphaltic paving material in such wide use in the larger cities.

WURTZILITE.

GEOLOGIC FEATURES.

The area in which wurtzilite is found embraces about 100 square miles in the region of Indian, Lake, and Sams canyons, a little northeast of Grey Head and about 50 miles southwest of Fort Duchesne (see Pl. XLIII). The mineral occurs in vertical veins from 1 to 22 inches wide, 20 to 200 feet high, and of a maximum length of 3¼ miles. The trend of the veins varies according to locality, the chief directions being N. 66° E. and N. 80° W. The veins are confined to a horizon of about 200 feet midway in a cliff-forming series of shaly limestones or calcareous shales, which, in this locality, constitute the middle zone of the Green River formation, underlain by several hundred feet of a dark greenish gray, soft mud shale, and overlain by a series of yellow, gray calcareo-arenaceous shales, thin-bedded limestones, and occasional sandstones. From this also it will be inferred that the areal distribution of the wurtzilite is governed by that of the sediments mentioned, in so far at least as the region in which this type of asphaltite has been developed is concerned. In the immediate vicinity of the wurtzilite veins, the cliff-forming shaly limestones, often bitumen-bearing, are conspicuously developed; in the amphitheater of Avenequin Creek only the lower, mud shales are present in outcrops; to the east, in the region of Antelope Creek, the higher series is perhaps the most broadly distributed. Why it is, however, that one form of an asphalt has resulted in one locality, another in another, and this practically without their commingling, is a question unsolved.

The structure of the wurtzilite region is simple—a uniform N. 35° E. dip of 5° to 10°, consistent with the portion of the Uinta syncline to which the strata belong. Joints and the gash-like fissures, now filled with the asphalt, are the only other results of the forces that were once in action, attended, it is true, in some instances by a limited amount of crushing.

THE VEINS.

GENERAL FEATURES.

In the region under discussion perhaps thirty different veins of wurtzilite were observed, but the number might easily be doubled, for they are adventitious in the extreme. Although their width and height are clearly visible, it is in nearly every instance impossible to estimate the length of the fissures because of the confinement of their outcrops to a vertical range of 200 feet in the faces of the cliffs, and their rare extension to the summits of the ridges. An exception of especial importance in this respect is a vein on the southeast side of the

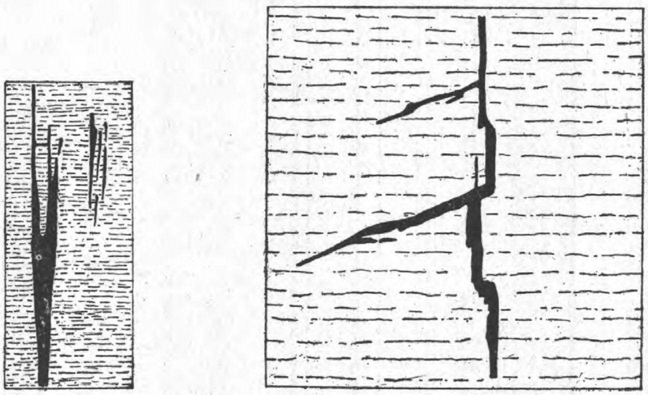


FIG. 38.—Features of wurtzilite veins. Veins 6 to 28 inches wide; height proportional.

Left Hand Fork of Indian Canyon, which, from having been cut at numerous points by side gulches, can be traced for a distance of 3¼ miles. A vein, also, on the northwest side of Lake Canyon, about 4½ miles above the upper lake, can be traced for a few hundred feet, though in width it is of slight importance. A vein in Jones Hollow, an upper tributary of the Right Hand Fork of Indian Canyon, can be traced for barely 100 feet, though it may extend into the hill a considerable distance. Veins of narrower widths, from 2 to 6 inches, prevail; the maximum widths, 15 to 20 inches, are rare. The wurtzilite veins end in length and depth by the gradual closing of the cracks; at the top, however, they are as frequently truncated as wedge-shaped. Locally, both at top and bottom they split into a number of small cracks, which quickly become mere joint planes.

In the details of their appearance, aside from the physical differences of the mineral itself, the veins of wurtzilite display many of the features of those of gilsonite. They carry inclusions of country rock, in one or two instances even to brecciation, with asphaltic cement. They send off numerous laterals, vertical or horizontal, extending between the thinly bedded strata or diagonally across them (fig. 38). They also exhibit a certain unevenness of wall due to the shaly nature of the limestones crossed by the fissures. In weathering the mineral takes on a dead black surface and cracks. Locally, a larger vein may be paralleled by two or more smaller ones at distances of 5 to 10 feet. The material resulting in the wurtzilite is believed to have been derived from the adjacent or nearby limestones.

TONNAGE.

Of the wurtzilite veins it is questionable if any are of workable size, but this will depend upon the value of the material to possible consumers after the processes for rendering it available in manufacturing have been perfected. The following is a tonnage estimate of the three or four most promising veins, the one on the Left Hand Fork of Indian Canyon, that in Jones's Hollow, and two in Lake Canyon—one about 4½ miles above the upper lake, the other about 3 miles below. No evidences of veins of a thickness of more than 5 or 6 inches were found in Sam's Canyon.

Estimated tonnage of wurtzilite veins.[1]

Vein in Left Hand Fork of Indian Canyon[2]	5,150
Vein in Jones's Hollow[3]	150
Vein in Upper Lake Canyon[3]	100
Vein in Lower Lake Canyon[3]	100
Total	5,500

The region of wurtzilite veins can be made accessible by wagon either from the Strawberry Valley or directly from the south.

NIGRITE.

The deposit of this material occurs in the same general locality as the other asphalts described in this chapter. More definitely, it is located about 5 miles north of east from Soldier Summit. It occurs as the filling of a fissure, suggested by Mr. Peterson,[4] from whom this present information was derived, as a shrinkage crack.

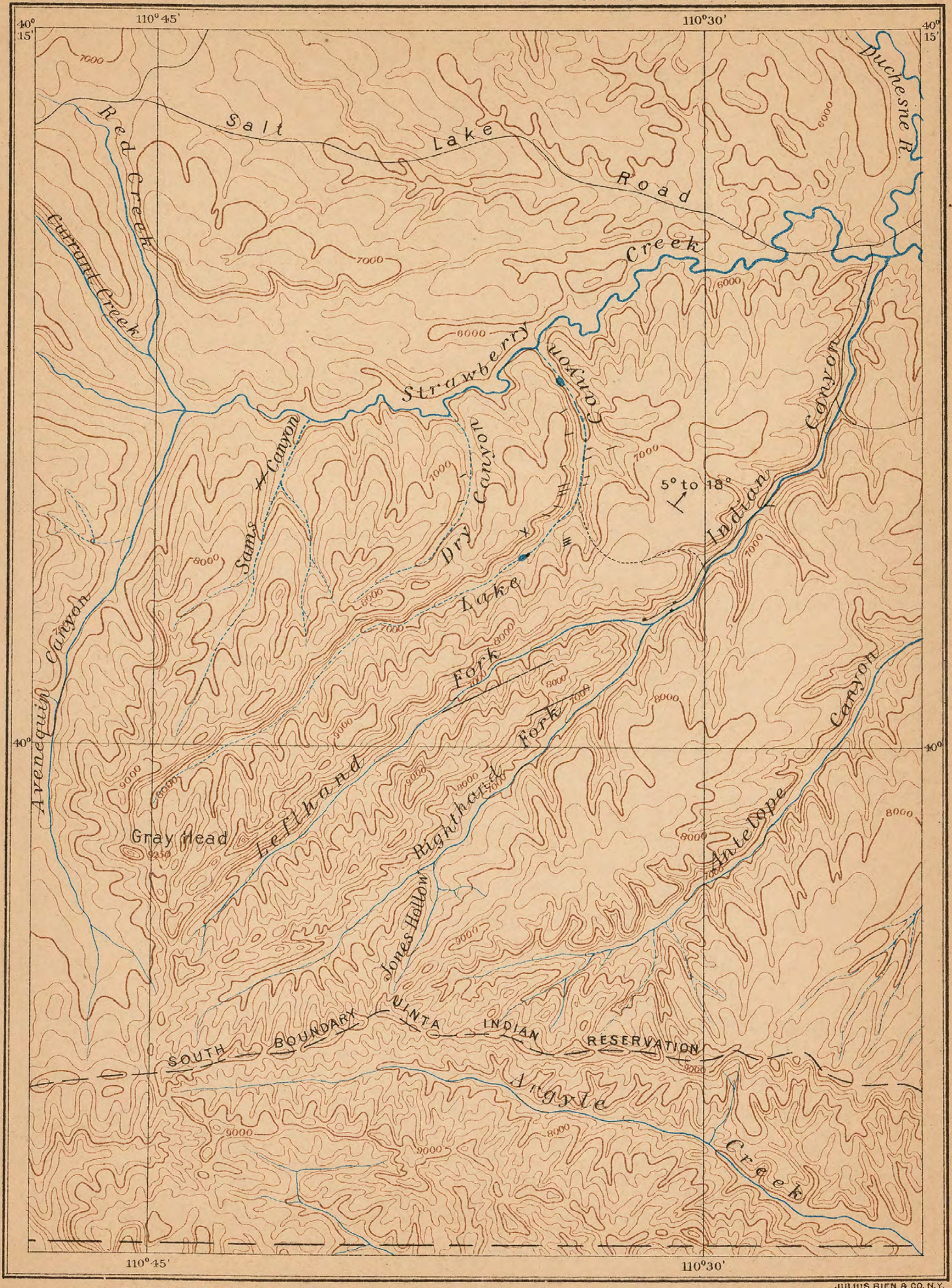
The trend of the fissure is northeast-southwest and is traceable on the surface about 3,000 feet. It is opened at probably the broadest place, about midway, where it measured 20 inches, but at a depth of 120 feet it diminished to a mere seam. It is doubtless another instance

[1] Specific gravity wurtzilite, 1.0227; 31.3 cubic feet equals 1 ton.

[2] Possible workable length, 3,229 feet; possible average width, 0.5 foot; possible average depth, 100 feet.

[3] May prove more extensive on development.

[4] Mr. C. A. Peterson, in letter dated December 24, 1898, addressed to the Director of the United States Geological Survey.



REGION OF WURTZILITE AND ASPHALTIC LIMESTONE

UINTA INDIAN RESERVATION, UTAH

Locally revised by George H. Eldridge

WURTZILITE VEINS

Scale

0 5 10 MILES

Contour interval 250 feet

1898

of a gash vein. Other similar deposits are reported in the region of Soldier Summit.

The opening on the vein is but a prospect, a carload only having been mined and shipped.

OZOCERITE.

The deposit of this material that has been opened is located at Soldier Summit, immediately north of the track of the Rio Grande Western Railway. It was inaccessible at the time of the present investigation, but the material is said to occur as a thin vein crossing the stratification, and in small pockets lying with the strata. The vein itself is of irregular thickness, the widest portion being reported as 18 inches, closing in from this to a mere crack within 50 feet either way the length. The trend of the vein is said to be northeast-southwest. Outcrops of this mineral are also reported for a mile or two either side of Soldier Summit, but none indicating deposits of importance.

ASPHALTIC LIMESTONES.

The asphaltic limestones of Utah occupy an area in the northeastern portion of the State but little more extended than that of the asphaltites. Their chief occurrence is in the same locality as the wurtzilite veins and to the southwest of this, along portions of the outer face of the Roan Plateau, or, rather, its westward extension, across Soldier Summit.

DEPOSITS IN INDIAN AND LAKE CANYONS.

The horizon of the asphaltic limestones is here the same as that of the wurtzilite veins, the middle, cliff-forming but shaly limestones of the Green River series. Several bands are distributed up and down the height of the canyon walls, but all but two or three are inaccessible. These, however, are representative, and are especially indicated as 4, 8, and 11 in the following section, which presents the general succession of beds in the region in question.

Section in Indian and Lake canyons, Utah.

		Feet.
1.	At the summit of the series and of the ridges, yellow to gray, calcareo-arenaceous shales; thin bedded, brown to bluish limestones, and occasional sandstones	300 +
2.	Limestones or calcareous shales; pink, gray, yellow, the pink bituminous, and locally the others also; cliff-forming	150
3.	Shale; muddy but hard; pinkish-gray; often cliff-forming	20
4.	*Limestone; locally richly asphaltic;* often cliff-forming	4
5.	Shale; yellow; hard; often cliff-forming	20
6.	Shale; brown and ochery; sandy; locally conspicuous; often cliff-forming	4
7.	Shale; hard; often cliff-forming	15
8.	*Limestone;* pink and blue; *bituminous;* conspicuous concretions, calcareous, but impregnated with a hard, bright asphalt resembling wurtzilite	10

		Feet.
9.	Limestone; gray and yellow; shaly; hard; cliff-forming	10
10.	Shale; mud texture; brown, olive green, or gray; nowhere forming cliffs, always slopes, separating cliffs above and below	80
11.	*Limestone; asphaltic, but poorer than those above;* brown; irregular, though prominent and continuous	4
12.	Shale; green, yellow-green; jointed; arenaceous and calcareous	30
13.	Shale; brown to light gray; bands of limestone; cliffs locally	200
14.	Limestone or calcareous mud; prominent and persistent	1
15.	Clay; mud-like; dull gray; occurs at heads of Indian and Lake canyons and in Avenequin amphitheater	300 +

The asphaltic limestones are generally 2 to 6 feet thick; brown on fresh fracture, but weathering pink, blue, and white; emit a strong odor of bitumen, but show varying per cents, and they are generally delicately laminated, with a shaly tendency in many layers. Occasionally a streak of wurtzilite is distinguishable, either vertical or lying between the layers. Locally, especially in the Right-Hand Fork of Indian Canyon, the series carries a few more or less extensive lenticles of sandstone, also somewhat bituminous.

The stratum numbered 4 in the section in its locally enriched portions varies in thickness from 1 to 5 feet, in length of outcrop from 50 to 500 feet, and in bitumen contents commonly between 10 and 20 per cent, with a maximum of from 50 to 70. It may persist as a solid bed, or split into two or three layers with shales between. A breccia structure is also sometimes present. Besides the horizontal band, there occurs in Lake Canyon a short vertical gash vein, 60 or 70 feet in height by 6 inches to a foot in width, cutting the stratified deposit and passing into both the underlying and overlying shales. From the similarity in composition of the vertical and horizontal bodies, at least in the region of their intersection, and from their equality in richness, it might be inferred that they were of the same origin—that the horizontal deposit as well as the vertical occupied a rift in the shales, but along instead of across the lamination planes. Yet, at a distance from the intersection, the calcareous and laminated nature of the normal bed reasserts itself. It is more particularly in the vertical vein, and in the horizontal deposit near the point of intersection with the former, that the highest per cents of bitumen are attained, often so great as to impart to the mass a waxy texture, considerable tenacity, and occasionally even a degree of viscosity at the higher summer temperatures. Vesicularity was also recognized in the richest parts. At this horizon the enrichment generally is very high, imparting to considerable bodies of the rock a marked asphaltic appearance.

Stratum No. 8 of the section is possibly a more uniformly persistent band than the one just described, and is subject to less variation in width and otherwise. It is not, however, generally of the richness of the No. 4, being, rather, one of the ordinary moderately saturated limestones of the region. Still, there are portions which attain a considerable per cent of bitumen, even 10 or 15 in some instances, probably. It is a particularly noteworthy layer, however, through the presence of many bodies of most peculiar nature. These bodies, from 1 to 2½ feet in diameter, grade from a rich, asphaltic, brown limestone, with delicate mottling, to a variety conspicuously spangled with fine to coarse, brilliant particles of purer asphalt—wurtzilitic in appearance—which, especially toward the exterior of the mass, arrange themselves in rays radiating from the center outward. The heart of the mass is generally of great purity, but asphaltic or waxy in texture and appearance, rather than of the nature of wurtzilite. While usually distinct in outline and conspicuous in the faces of the cliffs in their concretion-like weathering, these bodies in instances seem to grade into the surrounding limestone, even though this, a little beyond, has a tendency to shaly structure. If there be in the body a band of fine homogeneous material, it weathers as a blue-white streak at the surface, in sharp contrast to the balance of the rock. This appearance is frequently encountered. It is worthy of note also, in this connection, that the laminations of the including limestone show a tendency to arch around the concretion-like mass, both above and below. The origin of these bodies and of the ray-like arrangement of their constituent materials is difficult to explain, though various suggestions will at once occur to the reader.

The lower band of limestone, No. 11 of the section, shows a somewhat similar constitution to that of the others, but has no developed concretionary structures. It is varyingly impregnated with bitumen. When very rich, its laminations disappear and it becomes a brown, homogeneous, asphaltic rock. Though but 1 to 4 feet thick, it constitutes a conspicuous member of the series.

TIE FORK DEPOSITS.

Asphaltic limestones of the same nature and of probably the same stratigraphic horizon in the Green River formation as those on the southern slopes of the Uinta Basin are mined by the Wasatch Asphalt Company on Tie Fork of Soldier Creek, 7 miles northwest of Clear Creek station (Tucker post-office), on the Rio Grande Western Railway. The general aspect of the formation is here the same as in the Uinta Basin, even to the occurrence of the deposits themselves. Being opened, however, a better opportunity is afforded for observing the normal conditions of the asphaltic material than in a mere outcrop that has for years been exposed to weathering influences. But a single horizon of limestone is worked, which, well within the mine, gives the following section, characteristic of the deposit as a whole.

Section on Tie Fork of Soldier Creek.

	Feet.
1. Overlying the body of rich bituminous limestone is a series of gray, calcareous shales, also slightly bituminous. Into this veins of very pure asphalt, one-fourth inch to 6 inches wide, here and there extend from the main bed of asphaltic rock below. The bitumen contents of these veins is said to be 70 per cent. The asphalt is brownish black	50+
2. A light gray calcareous rock; but slightly impregnated; thin laminated, the lines wavy. Veins pass from main bed upward through this	1
3. A rock, of which the base is calcareous matter, but which is said to contain 40 per cent of bitumen. In this, irregular bodies of the 70 per cent material occur. Brecciation present here and there, giving the appearance of a rock impregnated to the lower per cent, fractured, and the spaces thus produced filled with the higher grade. The higher grade is also that of the veins, which appear to cut this bed also and may have been formed at the time that brecciation was effected. This layer, from 18 inches to 2 feet thick, shows no lamination, but on the contrary is of considerable irregularity of form, both under and upper surfaces being wavy, though not always with a distinct line of separation from the adjoining layers. The stratum, in mining, breaks in irregular fragments. The rock weathers blue, but is deep brown to brownish black on fresh fractures	2
4. Limestone; also richly impregnated, but to less degree than No. 3; it is said to carry 20 to 25 per cent bitumen and constitutes the second-grade product of the mine, the No. 3 being the first; lamination, more or less clear; portions, mottled. Shades at bottom to a still less rich rock. The two, 1½ to 2 feet thick. A vein of the 70 per cent material cuts it	2
5. Shale; slightly bituminous. Similar to cap rock	8
6. Limestone; bituminous. Similar to No. 3; not quarried	½
7. Shale; slightly bituminous. Similar to 1 and 5	20+

This rock is mined like coal, the undercut being in the No. 5 shale. Some faulting has occurred in the vicinity of the mine, one throw of 75 feet having been observed. Some of the planes shows films of asphalt.

The general dip of the strata in the locality is 5° to the northeast.

BITUMINOUS SANDSTONES.

The deposits of bituminous sandstone in Utah have received little or no attention. None have been exploited. In the present investigation, casual observation was made of an outcrop on the crest of Cedar Ridge between the Uinta and Ashley valleys and another at the eastern base of the ridge, the former 3 to 16 feet thick, the latter approximately 20 feet, both varyingly impregnated with bitumen to a maximum, perhaps, of 6 or 7 per cent. The sandstones are quartzose, oily, brown on fresh surfaces, dark gray on weathered. The extent of the deposits could not be determined from the outcrop. The horizon of the sandstones was not determined.

Other localities of bituminous sandstone are reported, notably in the Laramie sandstones running east from near Jensen on the Green River, and in the higher portions of the Roan or Book Plateau near the head of Willow Creek, these localities on the authority of Mr. McAndrews, of the Ouray Agency.

WYOMING.

The only deposit of asphalt in Wyoming that has come to the writer's attention is one in process of formation 2 or 3 miles northeast of Fort Washakie. Its locus is that of a large spring that bears on its waters a considerable amount of oil. On coming in contact with the atmosphere this loses its more volatile matters, becomes, perhaps, somewhat oxidized, and finally cakes from the periphery toward the center of the pool, or wherever an unsubmerged bit of land has afforded a grounding place. The diameter of the deposit is about 150 feet, but the center is still occupied by the living spring. It occurs in a general region which has developed some excellent oil prospects. The superficial strata of the region are of Juratrias age, surrounded by the Dakota and other Cretaceous formations, the whole in an anticline, the oil spring near the axis. The asphalt has been used for walks at the nearby army post.

CALIFORNIA.

INTRODUCTORY.

In presenting the following review of the asphalt and bituminous rock deposits of California, only so much of the general geology will be presented as bears directly on the deposits themselves or will be of advantage to one engaged in their study, search, and development. All that is demanded, therefore, is a résumé of the formations that are to be encountered and the structure of the ranges in which the deposits occur. A map showing the areal distribution of the formations would be of great service, but neither the topographic base nor the requisite knowledge exists for such, and to forego the inevitable harm that always results from attempts of this nature it has been deemed better to do away with it entirely and rely only on local sketches and the text to afford the desired insight into the occurrence of the bituminous materials. Details of geology may be found by those who wish them in the various publications of the geological survey of California, of the State bureau of mines and mining, the bulletins of the University of California and of the Leland Stanford Junior University, the Journal of Geology, and the reports of the United States Geological Survey.

The deposits of asphalt and bituminous sandstones of California are found in the immediate region of the Coast Range, and are distributed from Point Arena in the north to Los Angeles in the south (see Pl. XLIV). They occur on both the east and the west slope of the general range and at several points within. As at present known, they are confined chiefly to that portion of the range lying south of the Bay of San Francisco. The purer variety of asphalt has been found in the vicinity of McKittrick, in Kern County, at the eastern base of the mountains; near Santa Maria, in the Graciosa and Azufre hills; and again 6 or 7 miles west of Santa Barbara on the coast. Bituminous sandstones occur at Point Arena, in the north, and at several localities in the south, notably near Santa Cruz, San Luis Obispo, Los Alamos, and Carpinteria.

TOPOGRAPHIC FEATURES OF THE COAST RANGE.

The topography of California consists essentially of a great central valley, extending for nearly two-thirds the length of the State, lying between the Sierra Nevada on the east and the Coast Range on the west, the latter separating it from the Pacific Ocean. This great valley is drained from the north by the Sacramento River, from the south by the San Joaquin, the two uniting opposite the Bay of San Pablo, into which their waters discharge, thence finding outlet through the Golden Gate to the sea. Both rivers receive their chief branches from the Sierras, the eastern side of the Coast Range supplying but a minimum of their waters. The southern half of the valley is the larger and the dryer, and for large areas presents the aspect of a desert.

The Coast Range, considered as a topographic province, includes all the mountains lying between the great central valley of California and the Pacific Ocean. It has no well-defined central axis, either topographic or geologic, but consists rather of a number of parallel ridges of a general elevation of between 3,000 and 4,000 feet, with occasional peaks extending to somewhat greater heights. The range is of very recent origin, and is the combined result of structure and erosion. At the south it unites with the Sierra Nevada in a sweeping arch about the head of the San Joaquin Valley; at the north it also blends with the Sierra Nevada in the vicinity of Mount Shasta, but this region is one of considerable topographic and geologic confusion.

The Coast Range is of impressive ruggedness, although many of its longitudinal valleys are of considerable area and marked fertility. The coastal slopes also are extremely fertile wherever sufficiently gentle to permit a foothold for the soil, and owing to the excessive moisture from fogs and rains they are richly grassed and chiefly given over to dairying.

Although the topographic features of the Coast Range north of San Francisco in themselves merit as detailed a description as the portion to the south, yet as the deposits of asphalt are confined to their ocean front, they will be dismissed for the present without further comment.

South of San Francisco the Coast Range is for the first 100 miles broadly divisible into four minor ranges, separated from one another by the valleys of the Carmelo, the Salinas, and the San Benito rivers. The westernmost of these ranges is known as the Santa Lucia and it extends practically to the region of San Luis Obispo. The range east of this, between the Carmelo and Salinas rivers, has received the name of the Palo Escrito Hills. That between the Salinas and the San Benito

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is the Gavilan Range, which has a northward extension in the Santa Cruz Mountains and the high ridges of the San Franciscan Peninsula. The easternmost range is known as the Monte Diablo. This unites with the last mentioned at the head of the San Benito River and continues southward to the head of the Salinas, where it joins the Santa Lucia Range.

The general topographic trend of the Coast Range from the region of San Luis Obispo north is approximately N. 30° W.; southward and eastward, however, there is a distinct turn to N. 50° W., and this trend is maintained, with occasional local exceptions, nearly to the southeastern corner of the State.

Between San Luis Obispo and Ventura the Coast Range is still composed of at least three distinct ridges, each attaining an altitude of between 3,000 and 5,000 feet, with one or two peaks of 9,000 feet. The southernmost of these is the Santa Ynez Range, bordering the Santa Barbara Channel and extending from Point Concepcion into Ventura County. North of this is the Sierra San Rafael, which divides the valley of the Santa Ynez from those of the Sisquoc and Santa Maria. Indeed, by some the San Rafael Range is regarded as embracing the entire region of elevation between the Santa Ynez and the interior valley of California. Southeastward the Coast Range is further continued in the San Gabriel, the San Fernando, and the Santa Monica mountains. These in turn give way to the Santa Ana, San Jacinto, and San Bernardino ranges, with still others farther to the southeast.

GENERAL GEOLOGY OF THE COAST RANGE.

The geology of the Coast Range has as yet been but superficially studied except in local areas. The conditions therefore are but little known when compared with those of eastern regions, or even of many Rocky Mountain fields. That the geology is complex will be gathered from the assemblage of subordinate ranges that constitute the general range; from the variety of formations and the marked lithologic peculiarities of some of them; from the presence of metamorphic and eruptive rock masses; and from the rapid and successive changes in structure apparent in traversing the range either with its length or transverse to this.

The asphalt and bituminous rock deposits are confined to the formations of the Neocene and more particularly to the Monterey shale and the sands and sandstones that occur immediately below and above. Before discussing their geology, however, a brief review of the general geology of the Coast Range will be given. In presenting this the writer has culled from the published researches of Fairbanks, Lawson, Diller, and others, for his own investigations were of necessity limited to the immediate regions of asphalt and bituminous rock deposits, and a general study of the Coast Ranges was in no wise attempted.

FORMATIONS.

By those who have made a more extended and general study of the geology of the Coast Ranges than was permitted the writer, the series of strata entering into their make-up are reported as embracing, in the main, a wholly crystalline basement complex, consisting of granite, schists, and limestone; a younger series of sandstones, limestones, and cherts, known as the Franciscan series; a third, a body of dark shales, in the main of Lower Cretaceous age; a series of sandstones, in part Cretaceous and in part Eocene, known as the Chico-Tejon series; a fifth, consisting of heavy sandstones at the base, with characteristic shales above, these of Miocene age; semiindurated sandstones with Pliocene fossils; the whole followed by valley and coast deposits of the Pleistocene, conspicuous among which are the terrace formations along the ocean front.

The distribution of the foregoing horizons is as yet but incompletely determined, for it must be remembered that the study of the geology of the western coast has been undertaken only in comparatively recent times. In portions of northern California especially is this the case; in southern California somewhat more is known by reason, perhaps, of accessibility, but also from the discovery of petroleum, which has exerted an important influence on the industrial progress of this part of the State.

The basement complex.—Of the granite, schists, and limestone making up the basement complex the first has been described somewhat at length by Professor Lawson in his Geology of Carmelo Bay.[1] Professor Lawson has referred to it as the Santa Lucia granite because of the extent to which it enters into the structure of the range of this name. He regards it as a rock that solidified under deep-seated conditions and whose plutonic facies has been exposed only by the removal of a large volume of superincumbent rock. The eroded surface of the granite, where it passes beneath the sedimentary rocks, is well seen in cliff sections, particularly at Carmelo Point. The surface of the granite here passes beneath a basal conglomerate of the Carmelo (Tejon) series. The surface is smooth and fresh, but not even; there are low, rounded, lumpy portions, and the surface has in places a domed aspect.

"There is no shadow of doubt," adds Professor Lawson, "as to the intervention of a long period of erosion between the solidification of the granite and the deposition of the conglomerates and sandstones of the Carmelo series. The notions which have become current of the intrusion of the granite into the Miocene are utterly erroneous. * * * The granite is the oldest rock on this part of the coast, and its age is at the latest pre-Cretaceous."

[1] Bull. Dept. Geology, Univ. California, Vol. I, 1893, p. 17.

In the Santa Cruz Range, north of the Bay of Monterey, granite probably of similar age to that in the Santa Lucia Range again appears, here as the basement upon which the Franciscan series was laid down. Associated and in contact with the granite is a limestone which, although fossiliferous, has thus far yielded no recognizable forms. It is believed, however, to be at least as old as the Carboniferous, and by Lawson, who, in 1895, published the results of his special studies of the Santa Cruz and Peninsula ranges,[1] the granite is regarded as a batholite intrusive in this possible Carboniferous terrane. The bodies of limestone are of greater or less extent, but all are of disconnected and uncertain occurrence.

A granite, probably the same as that in the Santa Cruz and Santa Lucia ranges, is also observed in the Gavilan Range, opposite the Santa Lucia Range, across the Salinas River. It is here of considerable although undetermined extent.

Granite has also been observed farther to the south by Fairbanks and other geologists, and is referred to by Whitney as forming the central mass of the Santa Monica Range northwest of Los Angeles.

The age of this granite is dwelt upon with emphasis, for at one or two points in the Gavilan Range, northeast of King City, a body of arkose material derived by disintegration from the granite, yet overlain by the shales of the Miocene, forms a reservoir for the storage of bitumen—another evidence of the early age of the rock.

Of the schists and associated limestones of the Coast Ranges making up the balance of the basement complex but little has been written. The schists are frequently mentioned as rich in mica, while the limestones, especially in the Santa Cruz Range, are generally crystalline and of the nature of marble. Both schists and limestones have, according to Mr. Fairbanks,[2] received their greatest development in the Santa Lucia Range, the schists here being even more extensively developed than the granites. The crest of the range, however, is for many miles of its length, Mr. Fairbanks says, formed of limestone remarkable for the extreme degree of metamorphism which it has undergone. Mr. Fairbanks also speaks of the rock as occurring in irregular lenticular forms, the different outcrops varying from a few feet to several thousand feet in thickness, and as being found both in the granite and the schists, in the latter case conformable to stratification. The schists themselves are of the quartzite, hornblende, and mica varieties, and "undoubtedly represent sedimentary terranes, but by far the greater part of the rock is gneissoid." The same limestone is recognized also in connection with the granite and gneiss of the Gavilan Range.

Franciscan series.—This series of rocks has been studied by Professor

[1] Geology of the San Francisco Peninsula: Fifteenth Ann. Rept. U. S. Geol. Survey.

[2] Review of our knowledge of the geology of the California Coast Ranges: Bull. Geol. Soc. America, Vol. VI, p. 79.

Lawson in great detail in the San Francisco Peninsula, and the following résumé is quoted, in substance, from his published account[1] as being preferable to any statement that the writer could make from his more limited study of the formation:

The Franciscan series is a voluminous assemblage of petrographically diverse formations. * * * The petrographical elements of the series may be broadly and conveniently classified as follows:

(1) A basal formation of conglomerates, coarse grits, sandstones, shaly sandstones, shales, and argillaceous limestones.

(2) The San Francisco sandstone, the dominant sedimentary formation of the series [in the San Francisco Peninsula], consisting of a moderately fine-grained sandstone, fairly uniform in character over large areas, with subordinate beds of shale and conglomerate. The sandstone is uniform not only in its lateral extension, but vertically for great thicknesses. In the old writings it has commonly been referred to as the San Francisco sandstone, and the term is here adopted from that usage. It is interbedded with the formations 3–5 which are named below.

(3) Foraminiferal limestones.

(4) Radiolarian cherts.

(5) Volcanic rocks, including basaltic lavas, diabases, pyroclastic accumulations, etc. Besides these there are intrusive rocks of a corresponding character, some of which are probably connected with these extravasations, and also intrusive peridotites and pyroxenites, now serpentinized.

In addition, there are certain metamorphic schists, which are the products of the local alteration of the sedimentary or volcanic formations of the series, and, according to the writer's interpretation of them, do not constitute a separate formation. There are also a few patches of a peculiar vein-like rock associated with the San Francisco sandstone, but of rather uncertain generic relations. * * *

[The San Francisco sandstone has in some instances undergone secondary action, which, however, does not generally mask its clastic structure.] Veining is local and exceptional. Occasionally secondary calcite, chlorite, or iron oxide are present. * * * A more important alteration is the development of the interstitial paste which serves as the cementing and indurating material. * * *

The foraminiferal limestone of the Franciscan series has a fairly constant petrographical character throughout the terrane, although it is found at more than one horizon. It is, in general, a very compact, dense rock, resembling a lithographic limestone. Its color varies from light-drab gray to dark gray, and in either case its weathered surface is usually a very light gray. The rock is generally traversed by veins. These are of two kinds: (1) Minute slender veins of calcite, cutting the rock in all directions, generally without evidence of faulting; (2) larger veins of dark-colored silica, usually an inch or two thick, traversing the rock in parallel attitude, with only an occasional transverse vein of the same kind. These veins have sometimes the nature of lenses. They are traversed by a system of minute veins similar to that affecting the body of the limestone. The larger veins are not so common as the minute veins, and appear to be local developments occurring in a sufficient number of localities to indicate that they are characteristic of the formation. They seem, where best developed, to be parallel to the bedding of the limestone, and it is doubtful whether they are true veins filling fissures, or siliceous deposits contemporaneous with the formation of the limestone. * * *

When examined closely, the limestone is seen to contain a great number of clear hyaline spots, of varying size, with sometimes a diameter of half a millimeter. These spots have usually indefinite and blurred outlines, but in favorable cases they may

[1] Sketch of the geology of the San Francisco Peninsula, by Andrew C. Lawson: Fifteenth Ann. Rept. U. S. Geol. Survey, 1893-94, p. 416 et seq.

be observed with a lens to have the form of minute shells. A microscopic study of them shows that they are the remains of Foraminifera. * * *

[The radiolarian cherts are the most salient and remarkable of the formations which constitute the Franciscan series.] Their excessive hardness and their resistance to weathering and decay make them the best exposed formation in the series, and the most rugged topographic features of the terrane are due to their presence. * * * They are prevailingly of a dull brownish-red color, particularly in the thicker and more evenly bedded portions of the formations. Yellow and green colors are, however, fairly abundant. White, colorless, blue, purplish, gray, brown, and black cherts are also seen, but the coloring is usually local and is not characteristic of extensive masses of the rock. Where the cherts have been subjected to heat, as at the contact with eruptive rocks, they are of a brilliant vermilion-red color.

The bedding of these cherts is one of their most remarkable features. [Essentially it is an alternation of thin sheets of chert with partings of shale.] In the most representative sections the sheets of chert range, generally, from about 1 to 3 or 4 inches in thickness, with an average of perhaps 2 or 3 inches. Occasionally there are much thicker beds of chert, but their presence scarcely detracts from the general thinly and evenly bedded aspect of the sections. The shaly partings between these sheets of chert range usually from about one-eighth to one-half an inch in thickness, but they are frequently also mere films. As the formation is frequently exposed in sections many hundred feet in thickness, we have the remarkable phenomenon of an alternation of thousands of these sheets of chert with the corresponding layers of shale. In the common red phase of the formation, which is by far the most abundant, the regularity of these thinly sheeted stratifications is amazing. * * * In the less ferruginous varieties the chert beds have their maximum thickness and the shaly partings their minimum, and the formation also here frequently presents sections to which the description above given for the most representative sections would not apply. The parting planes have little or no shale, and the beds or lenses of chert exhibit a thickness ranging from several inches to several feet. In these places the formation is very massive in aspect. There are all possible gradations, from the massive to the thinly bedded variety.

Petrographically the radiolarian cherts are not uniform. In many cases they are true jaspers. In other cases the silica of which they are composed is chiefly amorphous, and the rocks are of a flinty or hornstone character. In still other cases the proportion of iron oxide and other pigment present is so large that the cherty character disappears, and the beds locally become so soft as to be easily scratched with a knife. In a few cases, notably in those phases devoid of coloring matter, they have been observed to pass into a quartz rock, in which the flinty or jaspery character is absent and the mass does not differ essentially from vein quartz. This quartz-like condition is, however, exceptional, and is probably due to special local causes. * * *

In almost any specimen of these cherts that may be examined critically with a lens, minute, round or oval, dark hyaline or whitish dots may be observed scattered throughout the base of the rock. These are the residual casts of radiolaria, the characteristic fossils of the formation.

Professor Lawson in discussing the origin of the cherts says:

The silica seems to have been an amorphous chemical precipitate, forming in the bottom of the ocean in which the radiolaria thrived. The dead radiolaria dropped into this precipitate, became embedded in it, and were so preserved. * * * The hypothesis of the derivation of the silica from siliceous springs and its precipitation in the bed of the ocean in local accumulations, in which radiolarian remains became embedded as they dropped to the bottom, seems the most adequate to explain the facts. * * *

There is abundant evidence of contemporaneous volcanic activity during the deposition of the sedimentary rocks of the Franciscan series. Sheets of amygdaloidal lava and of volcanic tuff interstratified with the sandstones and limestones are a salient characteristic of the series. Although the greater portion of the volcanic material is interstratified, yet it is evident in some cases, and probable in others, that the igenous rocks are intrusive in the sedimentary strata. There seems to be no good ground for sharply separating such intrusive masses from those which have been extravasated as flows. The rocks are petrographically similar, and it seems reasonable to regard both the extrusive and the intrusive occurrences as not radically different manifestations of the same volcanic activity. Both may be properly said to be contemporaneous with the sedimentary rocks in the sense that the activity which produced them began and ceased within the time occupied in the accumulation of the series. * * *

These rocks fall into at least four general classes, which, although petrographically distinct, are probably genetically allied, viz, olivine diabase, diabase, olivine-free basalt (with perhaps augite-andesite), and volcanic tuffs. * * *

The [metamorphic] schists have a very wide range of petrographic character as well as of distribution, and appear to represent various stages of the alteration of rocks originally very diverse. Among the least altered forms may be recognized: (1) Rocks not essentially different from the San Francisco sandstone, save for a rudely schistose structure with the appearance of having been sheared. These grade, often in the same mass, into micaceous schists with glossy sheen surfaces and less commonly into bluish schists whose color is due to the presence of needles of blue amphibole. (2) Bluish shales, being apparently the common shale occurring as subordinate beds in the San Francisco sandstone, in which needles of bluish amphibole have been developed. (3) Volcanic tuff, such as is common in the Franciscan series, save that it has acquired a bluish appearance, due to the development of blue amphibole needles, and has assumed a rude and irregular, often scarcely perceptible, schistosity. (4) Massive basic rocks, probably referable to the basalts and diabases of the Franciscan series, but with a rather abundant development of blue amphibole. The schistosity in these is often very feebly developed.

From these less-altered forms of the common rocks of the Franciscan series, gradations may be traced into schists in which all trace of the original rock is lost. These highly altered forms are of two general classes: (1) The light blue, fissile schist which is commonly called "glaucophane schist," although it is doubtful whether all the blue amphibole is really glaucophane. (2) Various micaceous, hornblende, and chloritic schists with or without a subordinate proportion of blue amphibole.

Lawson attributes the metamorphism to the intrusion of peridotites.

Cretaceous.—Strata of this age are reported in or adjacent to the Coast Range for quite its entire length. Along the eastern slope, in the great interior valley of the Sacramento and San Joaquin, the series forms an important terrane, though varying somewhat in the divisions that are present and in the more general features of its sediments. In its full development, in northern California, the series comprises beds that have been designated by the names Knoxville, Horsetown, and Chico; in southern California the Horsetown bed may prove wanting, but the Knoxville and Chico have been recognized at several points.

The Knoxville of the south has been especially studied by Mr. Fairbanks in the vicinity of San Luis Obispo, where it is reported by him to consist of dark shales with small lenticular bodies of limestone and thin-bedded sandstones, suggesting thus the Montana beds of the Rocky Mountain region. At the base of the series are local layers of conglomerate containing pebbles of jasper and other siliceous rocks. The total thickness of the series in the San Luis Obispo region is estimated at 3,000 feet. It is unconformable, says Fairbanks, with the underlying Franciscan series, evidenced by discordance of dip, less distortion of the younger beds, and absence of intrusives characteristic of the older terrane.

The upper division of the Cretaceous in southern California, the Chico, is also displayed in considerable force in the region of San Luis Obispo, and occurs, besides, at other points both north and south in the general range. The terrane is chiefly one of sandstone with local development of conglomerate at the base sometimes 50 to 100 feet thick. It rests in unconformable contact both with the Franciscan series and the Knoxville shales. The latter relation Mr. Fairbanks now regards as positively determined, even to the discordance in dip. The unconformity is also indicated in both northern and southern California by the serpentine having cut the Lower Cretaceous without intrusion into the Chico, the Chico resting upon it. It is suggested that the Knoxville was intruded by the peridotite, upturned, and eroded before the deposition of the Chico.[1]

Eocene.—The strata of this age, according to the later writers, appear to consist almost wholly of sandstones and conglomerates, which are developed in considerable force at intervals along the Coast Ranges. The Eocene is a prominent factor in the geology about Carmelo Bay, and has been found extensively developed in Ventura and Santa Barbara counties. In northern California also it is well known. The conglomerate at the base apparently varies in composition with the rocks from which it has been derived in the regions of its occurrence. In the vicinity of Carmelo Bay the Eocene is unconformable with both the underlying and overlying series of rocks, i. e., with the Santa Lucia granite and the Monterey shales. In the southern portion of the Coast Ranges Mr. Fairbanks[2] also reports a marked unconformity with the Miocene. It was observed "in the high ranges in northern Ventura County, along the Sespe, in the valley of the Sisquoc, canyon of the Cuyamas River, south of the old mission of Santa Luiz, in the upper valley of the Salinas, and many other places."

Lower Neocene (*Monterey*).—The rocks of this age usually embrace a heavy body of sandstones, conglomerates, and shales at the base, in which the form *Ostrea titan* is often found; overlying these in some places is a body of gypsiferous clays that, in the region of Point Sal, for example, attains a thickness of nearly 2,000 feet; above all is the

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[1] The above reference to the Cretaceous is largely from Geology of the Southern Coast Ranges, by H. W. Fairbanks: Jour. Geol., Vol. VI, No. 6, 1898, p. 559

[2] Geology California Coast Ranges: Bull. Geol. Soc. America, Vol. VI, p. 99.

salient feature of the series, a great body of more or less siliceous shales, everywhere of considerable thickness and locally embracing at least 2,000 or 3,000 feet. This succession is not, however, strictly adhered to at all points. The formation is distributed the entire length of the Coast Range from Cape Mendocino to beyond Los Angeles. It borders the coast and occurs in the interior, forming a conspicuous terrane along the great valley of California drained by the San Joaquin and the Sacramento rivers. It enters largely into the composition of the several members of the Coast Range and occupies positions varying from horizontal to vertical.

Concerning the make-up of the lower portion of the Monterey, Mr. Fairbanks[1] remarks that in the region in question it is composed of limestones, clays, volcanic ash, sandstones, and conglomerates. The sandstones and conglomerates are locally developed to a thickness of between 6,000 and 8,000 feet, notably in the region lying east of the Rinconada Valley, between it and the main granite range. The volcanic ash referred to is said to form a fairly constant horizon over a very considerable area, attaining in the mountains south of San Luis Obispo a thickness of 800 feet, while near the western end of the San Luis Range it has an areal extent along the southern slope for a distance of over 30 miles. Locally, as on Old Creek in the San Luis Obispo district, a small flow of banded rhyolite is reported as associated with the fragmental material.

Two classes of rock constitute the mass of the shales that form the upper division of the series, one white, soft, porous, and chalk-like; the other hard, often excessively so, and brownish drab, though weathering yellow from iron contained in small amounts. These shales are generally bituminous, but often the eye can detect only the merest trace of bitumen. Both hard and soft varieties resist weathering influences, and preserve their fragments sharp and clear of edge. The softer rock in mass, however, forms rounded hills; the harder, bluffs and cliffs, and locally a range of greatest ruggedness. The harder shales are varyingly siliceous, sometimes highly so, becoming even opal-like; they are, however, readily distinguishable from the cherts of the Franciscan series.

Throughout the Monterey shale may be found evidences of former life in remains of minute foraminifera, radiolaria, and diatoms. In instances the casts of the forms are clearly discernible; in others there is left merely the space once occupied by the fossil. In the writer's experience these organic remains have been more frequently met in the white, chalk-like shale than in the hard siliceous rock, but they have been found locally profuse in both. It is believed that they will prove a characteristic of the formation in all localities of its occurrence.

[1] Geology of the Southern Coast Ranges: Jour. Geol., Vol. VI, No. 6, September-October, 1898, p. 561. See also Geology of Point Sal; Bull. Dept. Geology, Univ. California, Vol. II, No. 1, 1896, pp. 1-8.

Regarding these shales and their siliceous aspect, the studies and suggestions of Professor Lawson are of interest. He remarks:[1] "The silica [in the shales silicified in limited degree] is apparently chalcedonic, and has [locally] replaced the shale without obliterating the shaly layers, though quite frequently veins of the chalcedony cut the latter transversely." He continues, however:

> Apart from these local and secondary silicifications there are thin beds of a dense, compact, light gray, opal-like rock. These contain, like the chalky shale, numerous hollow molds of minute univalves and occasional impressions of a bivalve of the genus Macoma. The pores formed by these molds in the opaline rock are not so numerous as in the chalky facies; they are also more sporadic and are not arranged in bedding planes.
>
> The rock is entirely unaffected by boiling in hydrochloric acid, has a conchoidal fracture, yields water in the closed tube, and may be scratched with a knife like opal. The tongue adheres strongly to the broken surface of the rock. Fragments of this opaline rock, or, indeed, of any portion of the shaly series, whether chalky or opaline, turn black when heated on a piece of platinum foil, and then, on continued heating, burn white again. This, together with the bituminous odor yielded in the closed tube, indicates the presence of a carbon compound, distributed through the rock, and is suggestive of the source of the asphaltum which is elsewhere found in heavy deposits in these rocks. The density of the rock is 2.018. The ultimate source of the carbon compound, the presence of which is revealed by these simple tests, was doubtless the bodies of the minute animals whose shells have been removed by leaching.
>
> The fact that the molds of the minute univalves are very sharply defined and quite empty of mineral matter indicates that these opaline beds are original formations and not secondary silicifications. There are gradations from the distinctly opaline varieties to the chalky.

In regard to the origin of these shales, Professor Lawson observes also that the discovery of infusorial beds in certain portions of the series, taken together with the soft chalky character of the formation, has led to the belief that—

> the entire series is of organic origin and is made up of the siliceous remains of diatoms, radiolaria, sponges, etc. Such a conception of the origin of the series, taken with its great thickness, would of course imply an enormous time for its accumulation. This conception is, however, probably only partially true. * * *
>
> It becomes probable from a microscopic examination that the mass of the white chalky shale, in part at least, is the fine ash of a very acid volcanic eruption. The bulk of the rock is a finely granular, seemingly homogeneous, cloudy, isotropic substance, which in some cases shows an irregular, angular, reticulated aspect, as if composed of fragments of glass cemented by an isotropic paste. Through this, as a groundmass, are scattered broken (never waterworn) crystals of quartz, orthoclase, plagioclase, and biotite, together with a small proportion of fragments of hornblende. There are also some minute crystal fragments of intermediate minerals. In some cases there may be observed a little secondary chalcedony. The opaline beds differ microscopically from the prevalent chalky rock only in that the groundmass is less granular in aspect. The fragments of crystals of quartz, feldspar, etc., which are scattered through it are fewer in number than in the chalky rock. The suggestion of the volcanic origin of the shale of the Monterey series yielded by the microscope

[1] Geology of Carmelo Bay, p. 23.

is strengthened by a chemical analysis of a representative specimen of the chalky rock. The results of the analysis are as follows:

SiO_2	86.89
Al_2O_3	2.32
Fe_2O_3	1.28
CaO	.43
MgO	Trace.
K_2O	1.26
Na_2O	2.32
Ignition	4.89
	99.39
Sp. gr.	1.8 to 2.1

Regarding the relations of the Monterey shales and their underlying sandstones to other formations with which they are in contact in various portions of the Coast Ranges, there seems to be comparatively little doubt that with the overlying beds they are, at least, generally unconformable, while with those beneath they are said to be unconformable by some observers, by others conformable. It is possible that these discrepancies are due to the localities in which the several observers have worked. The observations of the writer have been too limited, except in special instances, to give an expression of his own. Assuredly some unconformities were observed by him.

Middle Neocene (*San Pablo formation*).—Overlying the Monterey series unconformably, according to Mr. Fairbanks[1]—

is a series of soft sandstones, diatomaceous beds, and some flinty shales. It forms the eastern extension of the San Luis Range between San Luis Obispo and the ocean, as well as a considerable area in the Upper Salinas Valley. In the latter region it is filled with fossils which indicate the Middle Neocene, but to be more exact, whether the uppermost Miocene or the lowest Pliocene is as yet undetermined. Dr. Merriam has, in a recent publication,[2] described a series of strata on the southern shore of San Pablo Bay containing a similar fauna, which he believes represents a distinct and hitherto unrecognized paleontologic group. These strata, it appears, overlie those of the Contra Costa County Miocene, with indications of a nonconformity, but the fossils collected from them by earlier paleontologists have in some cases been referred to the Miocene, in others to the Pliocene. To this series of rocks Dr. Merriam has given the name San Pablo formation. As the group of rocks in the southern Coast Ranges is undoubtedly the equivalent of those on San Pablo Bay, the latter name will be extended to it. In the San Luis Obispo region the nonconformity of this series of rocks with the Monterey series is distinctly shown in many places. Good examples appear along the coast north of Pismo, as well as in the vicinity of Santa Margarita in the Upper Salinas Valley. The basal conglomerates of the San Pablo formation, often but little disturbed, lap over on the more highly tilted and disturbed shales and contain many fragments of the latter, often filled with mollusk borings. A great interval of time must have separated the deposition of the San Pablo formation from that of the bituminous shales, for the former formation extends over the shales in places and rests directly on the Golden Gate series. This time must have been sufficient for the erosion of at least 5,000 feet of the Monterey

[1] Geology of the Southern Coast Ranges: Jour. Geol., Vol. VI, No. 6, p. 563.
[2] Bull. Dept. of Geology, University of California, Vol. II, No. 4.

series. During this time also the chief chemical change was wrought in the bituminous shales, for pebbles of the flinty, altered shales occur at the base of the San Pablo formation in exactly the same conditions as the shales on which this formation rests.

The discovery by Dr. Merriam of the marked palæontologic differentiation of the fauna of this group of rocks is an important addition to our knowledge of the younger formations of the coast ranges. That it is not a local condition is shown by the results reached by the writer along different lines and wholly independently. The pronounced nonconformity so clearly apparent in the San Luis Obispo region is confirmatory of the palæontologic investigations, and firmly establishes the validity of the new formation. Its fauna is certainly older than that of the Merced beds, and if it should prove to be the uppermost Miocene the rocks of that age in California can no longer be looked upon as forming a unit, but separated into two divisions by an extended period of elevation and erosion. This point established, other and puzzling questions relating to the Miocene and Pliocene are in a fair way to be cleared up.

Upper Neocene (*Paso Robles formation*).[1]—Mr. Fairbanks continues:

The later Neocene in this portion of the coast ranges consists of a very extensive series of beds having apparently a freshwater origin. They fill the Salinas Valley as far up as Atascadero, lapping over uncomformably upon the upturned and sharply folded San Pablo formation. They are characteristically exposed about the town of Paso Robles, hence the designation. From Paso Robles the beds extend westward toward the Santa Lucia Mountains, and for many miles north and east of that place, filling the valley of the Estrella and its tributaries, and may reach into the Great Valley. The formation consists of conglomerates, sandy and marly clays, as a general thing, but slightly consolidated. The great extent of this formation in the drainage area of the Upper Salinas River, its peculiar character, and total absence of marine organisms, or organisms of any kind, as far as observed, make it appear probable that it is of fresh-water origin, and for these reasons, though it is possibly contemporaneous with the marine formation known as the Merced beds, it should be given a distinct name. The strata are generally almost horizontal, but along the Salinas River in particular they are tilted and faulted. Beds of the same character overlie the San Pablo formation in the vicinity of Arroyo Grande.

Fresh-water beds of Pliocene age are widely distributed through the Coast Ranges.[2] Those in the valleys of the Upper Benito and Salinas have been referred to by Lawson as Pliocene delta deposits,[3] and considered the equivalent of the Merced beds. While the latter view is probably correct, there is no reason to consider them delta deposits; on the contrary, they have decidedly the character of fresh-water lake beds, and there is no reason to believe that they were ever connected with the Merced beds.

The Merced series, with which Mr. Fairbanks is inclined to correlate the Paso Robles formation, according to Professor Lawson, consists—

chiefly of soft sandstones of varying degrees of coherence. In some cases they are quite firm and compact, but for the most part they may be easily broken with the fingers, and many beds are little more than compact sand. There is for a considerable portion of the entire volume a large admixture of clayey material, and the rocks would be classed as sandy shales. Beds of pure clay shale are practically absent, although there are occasional beds of dark, clayey mud in which fossils abound.

[1] Bull. Dept. of Geol., University of California, Vol. II, No. 4, p. 565.

[2] Mon. U. S. Geol. Survey, Vol. XIII, p. 238; Bull. Dept. of Geology, Univ. of Cal., Vol I, pp. 152, 363.

[3] Bull. Dept. of Geol., Univ. of Cal., Vol. I, p. 153.

Hard shell beds firmly cemented, generally with an abundant admixture of gravel, and hard, thin beds of cemented gravel, practically free from shells, occur at intervals. There are also soft and uncemented shell beds, and occasional beds of hard, bluish-gray, sandy limestones. Thin, lignitic layers are occasionally observed, and volcanic agency has contributed a thin bed of white volcanic ash in the upper portion of the series. The most remarkable features of the Merced series are (1) the great volume of its strata, 5,834 feet at Lake Merced, its type locality, and (2) the deformation to which it has been subjected at so recent a period in geological history.

The rocks are highly tilted, generally at high angles. The fossils of the formation embrace many Pliocene forms, and there are besides trees and other forms of plant life embedded in its sands.

In the La Graciosa Hills, 6 or 7 miles south of Santa Maria, and also in the Azufre Hills, an equal distance southwest of the town, is a great body of loose sands or soft sandstones which caps their summits and overlies the Monterey shales in marked unconformity. The formation is notable because of its being cut by veins of very pure native asphalt, which carry an abundance of Pliocene fossils that have apparently been derived from the associated sandstones and brought into their present position by the asphalt which flowed in to fill the open fissures. While this formation was observed by the writer especially in the region mentioned, it is believed to occur in other localities both to the north and to the south. In the vicinity of the coast northeast of Lompoc, for example, is a great body of sandstones which may possibly be of the same age.

Terrace and other formations.—Along the coast at intervals, and at varying horizons above the sea level up to 800 or 900 feet, are the remnants of old beach deposits, chiefly shingle and sands. These formations, though interesting from a scientific standpoint, do not enter into the geology of the asphalt, and therefore need no further reference in the present report.

Eruptives.—Rocks of this nature occur at many points through the Coast Range, but they have no especial connection with the geology of the asphalts and therefore will not be discussed.

STRUCTURE.

Structurally the Coast Range consists of numerous parallel anticlines and their corresponding synclines. There is no dominant axial fold, the crust having been crumpled into a close succession of ridges or waves of varying amplitude and height of arch it is true, yet devoid of either sharp or extreme differentiation. This structure is vividly suggested in the topographic lines, and especially so by reason of the comparatively late period in which the range received its final development. Erosion, though somewhat extensive, leaves still uneffaced to any great degree the lines of early folds. As to the age of the Coast Range, it was not till the close of the Merced period in late Pliocene times that it received practically the structural appearance of to-day.

The topographic trend of the general range from San Luis Obispo north is about N. 30° W., veering to westward south of this. The structural trend of the folds composing it, however, is between N. 20° and 40° W. from the thirty-sixth parallel north; N. 50° or 60° W. in the region of San Luis Obispo, and from Point Concepcion east, N. 80° to 90° W. Throughout the entire range it is distinctly diagonal to the coast line, except, perhaps, along the Santa Barbara Channel.

Faults will doubtless be encountered throughout the Coast Range; they have been delineated in the geology of the San Franciscan Peninsula, and on the maps of the San Luis Obispo region, and have been observed at many points both by the writer and others.

A discussion in detail of the structure of the Coast Range as a whole would contribute little to an understanding of the occurrence of the asphalts and bituminous sandstones; as the local geology of all deposits of economic value will be given in detail, it is unnecessary here to consider further the general subject.

POINT ARENA DISTRICT.

GENERAL FEATURES.

This district embraces a small area of Monterey shale lying along the coast about 110 miles north of San Francisco. The shales form a low, rolling bench between ocean and Coast Range, 2 or 3 miles wide, and from 100 or 200 feet above the sea at the shore to 300 or 400 at the base of the range proper. The bench is cut transversely by streams from the mountains, and along them the shales are well exposed, displaying several folds with axes trending N. 50° W. The most prominent fold is an anticline whose crest lies close to the shore, indeed is cut by the waves at many points, and of which, coupled with the syncline immediately east of it, there is a fine transverse section in the hills just south of the port of Point Arena. It is along the eastern side of this syncline that the asphalt deposits of the region are found.

The shales of the Monterey in this locality are interlaminated with sandstones varying in thickness from a foot or two up to 30 or 40. These are exposed both in the gulches and along the coast. The shales are brown on fresh fracture, weathering a greenish-grey; they are also clearly bituminous, not only for the locality in question but along the whole of this portion of the coast. The sandstones, as is often the case in the Monterey, have become the reservoirs of oils derived from the shales, and now in their exposed condition constitute the bodies of asphaltic rock.

THE O'NEIL DEPOSITS.

These consist of the sandstones just referred to, and have been slightly prospected in the face of a gulch about 2 miles north of

Point Arena town, a half mile back from the sea. There are here two horizons, about 70 feet apart, the beds striking N. 50° W. with a dip of 60° to the southwest. The lower or eastern bed is composed of about 4 feet of enriched sandstone separated into two layers by a foot of shale; this constitutes the lower half; the upper half consists of like sandstone, but through it pass numerous thin and irregularly persistent streaks of shale rendering it valueless; above this are 10 or 15 feet of shale with thin streaks of sandstone, the reverse of the last. The two lower bands of the sandstone carry, perhaps, an average of 6 or 7 per cent of bitumen, although the amount undoubtedly varies considerably. Along the outcrop of the bed there is some confusion of shale and sandstone, as though in the folding of the strata there had been a crushing together of the two kinds of rock; it is not impossible, however, that the appearance may be due to irregularity of sedimentation.

The western of the two deposits under discussion is for the greater part of the exposure more irregular from crushing than the eastern, but as the bed passes below the bottom of the pit it recovers its probable normal steadiness and presents a width of bituminous sandstone of about 6 feet, of which the central 2 feet are the richer, the remainder being more or less spotted. The shales on either side of the sandstone carry other thin streaks of sandstone, also slightly bituminous, and there are numerous joints which are filled with bitumen that has seeped from their walls. This bitumen is hard and brittle, but probably softens under the sun's rays.

PORT DEPOSITS.

Immediately north of Port Gulch, in the lofty cliffs at this point, is another succession of shales and sandstones, the former predominating, yet the sands attain a thickness of 1 to 30 feet. A section at this point is the following:

Section in cliffs north of Port Gulch, near Point Arena.

	Feet.
At the top of the cliff, hard, brown to gray, shale, somewhat bituminous, with two 8-inch bands of sandstone	40 to 50
Bituminous sandstone, the upper 10 feet dry; the middle richer, fresher, and more oily, this constituting the prospect; the lower 10 feet unopened but resembling the middle zone	30
Sandstone in attenuated lenticular form, with contained lenticles of shale, the sand slightly impregnated with bitumen	4 to 6
Shale, here and there arenaceous and bituminous	100
Enriched sandstone	2
Shale	25
Sand, bituminous	1
Shale	40
Sandstone, somewhat shaly and less rich than the beds above, this at sea level	10

The foregoing section is given, not so much for its value in connection with the deposits under consideration as to indicate the possible general composition of the Monterey formation. While there is doubtless great variation, even to all shale or all sand, it shows what may be its constitution at any point and so its capacity for the storage of oil in its reservoirs of sand, and, from the general presence of bitumen in its mass of shale, the possibility of a recurrence of this condition at other localities.

The bituminous sandstone of the above section is apparently of the same nature as that 2 miles to the north. It is quartzose and of a sharp and varying fine grain. With the quartz is a small amount of a feldspathic looking mineral, a few grains of a dark greenish chert, an occasional clay pebble and a little iron. Bitumen is the cementing material, the average content being perhaps 6 or 7 per cent. The rock thus falls far below the very rich product of the Santa Cruz and San Luis Obispo districts, but may prove of value locally, and especially at a depth below the outcrop. The color is a brownish black; the texture tough, but not very tenacious.

The structure of the portion of the Point Arena field carrying the deposits of bituminous sandstone is that of a syncline, showing well, however, only at the southern end, in the vicinity of the port. Here the outcrop of the enriched bed is seen to bend around the end of the trough, the dip changing from the northeast through the north to the southwest. From this point the sandstone of southwest dip passes in outcrop northwestward directly for the prospects 2 miles distant. In the vicinity of Seal Rock the equivalent of the bituminous horizon may be the heavy sandstone in the sea cliff, but owing to its inaccessibility this was not determined.

MARIN COUNTY.

Seams of asphalt are reported in the cliffs of Monterey shale at Bolinas Bay, a short distance north of San Francisco, in Marin County. As they were said to be unprospected and of minor importance so far as exposed, no visit was made to the locality.

SANTA CRUZ DISTRICT.

The Santa Cruz district of bituminous sandstone lies about 60 miles south of San Francisco. The deposits occur from 4 to 6 miles northwest of the city of Santa Cruz, the more remote being the most extensively quarried. The properties are controlled by a number of private individuals and by the City Street Improvement Company of San Francisco. Most of the quarries are opened near the summit of the Empire Ridge, which here parallels the sea and which is in reality a spur of the Santa Cruz Mountains.

TOPOGRAPHY.

The ridge referred to has an altitude of about 800 or 900 feet in the vicinity of the quarries, although rising higher to the north. The width of the ridge must be approximately 5 or 6 miles, and its general trend is N. 50° to 60° W. The core of the ridge consists of granite, to which has been given the name Montara by Professor Lawson. The western slope of this ridge—that on which the deposits of bituminous sandstone are found—is composed of the Monterey shales and underlying sands, which abut against or rest upon the granite. Associated with the granite are scattered bodies of the earlier crystal-

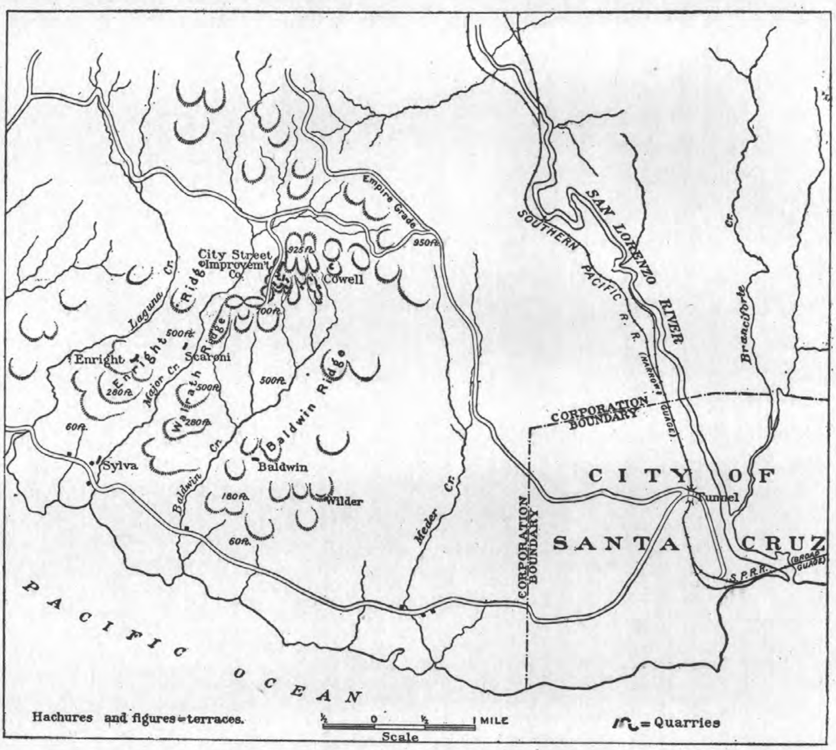


FIG. 39.—Map of Santa Cruz district, California.

line limestone of limited extent. The position of the Monterey series is almost horizontal in the higher parts of the ridge, but the beds dip somewhat in one direction or another along the coast. From the crest of the ridge to the sea is about 3½ miles. The summit of the ridge has almost the appearance of an early table-land, into which channels of erosion have been cut to depths of 300, 400, and 500 feet, the waters flowing directly to the ocean. The result of this topography is a number of subordinate, flat-topped ridges at right angles to the coast. The profiles of these ridges indicate for the original slope, of which they are now but the remnants, a clearly terraced structure—a feature that is prominent along this portion of the coast for a distance of 15 miles westward from Santa Cruz, and again to the south, across the Bay of Monterey, along the northern portion of the Santa Lucia Range. In the region of the quarries the terraces are most conspicuous at intervals above the sea of 60, 180, 280, 500, 700, and 950 feet, the last being the summit of the main ridge. Standing on any of these terraces one may trace it in continuity from ridge to ridge nearly as far as the eye can see. There are, however, occasionally what appear to be remnants of minor terraces, at intervals between those enumerated above, which perhaps have disappeared from the areas in which they are not found. The general features of these terraces are as follows: The slopes from step to step comparatively steep; the benches flat or sloping gently backward, and of widths varying from a few hundred feet to half a mile. All are beautifully grassed and dotted with clumps of live oak and other timber, the gulches carrying also numerous varieties of conifers. The region to the north and northwest of the immediate area under consideration becomes somewhat more rugged, owing partially to a slight change in structure, partially to a change in sediment. Moreover, the granite itself in this direction becomes more prominent, an additional cause for ruggedness.

STRATIGRAPHY AND STRUCTURE.

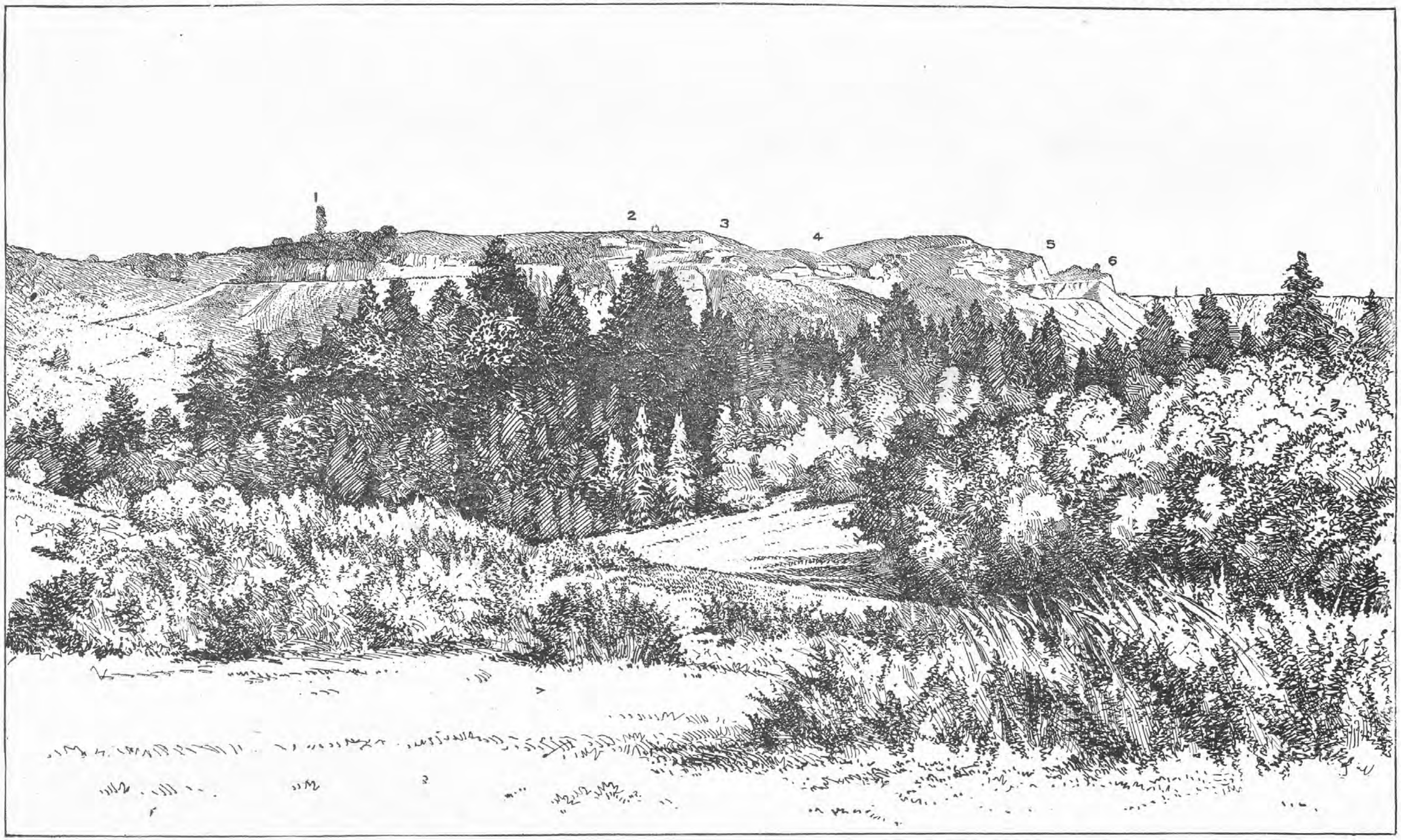
The geology of the region is, withal, of great simplicity, embracing a persistent mass of Monterey shale; underlying this, or, in some instances, apparently at the same level, but not covered by it, a heavy body of sands, locally loose, or hardened to a sandstone of the softer variety; the granite already referred to; and a superficial terrace gravel. Although the shales and sandstones together form a thickness of perhaps 500 or 600 feet they are, nevertheless, more in the form of a blanket covering the granite. That this is so is evidenced by the outcrops of the latter rock not only in the main portion of the ridge at a distance from the sea, but nearer the latter in the walls of some of the gulches. Of the latter occurrence a notable instance may be seen in the eastern wall of Major Creek, a little below the Scaroni quarry. At this point the sands seem to be wanting, the Monterey shale coming directly in contact with the granite. From this and observations at other points the question at once arises as to the real character of these sands and their relations to the shales. For the Coast Range, in general, it has been already stated that the lower portion of the Monterey frequently consists of sandstones. The sands here referred to may be the equivalent of these; or, on the other hand, it may be that they are simply a shore deposit of uncertain age laid down prior to the deposit of the Monterey shale, and derived in large measure from the adjoining granite or brought to their position by coastwise currents. The composition of the sand leads one rather to the latter idea, for it is generally a quartzose material with but a slight admixture of feldspar or granite. Its derivation, however, was not looked into in detail; the fact of its existence is all that is necessary in the consideration of the deposits of asphalt which it contains. As to structure, the sands show distinct stratification at most points, yet, as on the upper portion of Major Creek, they are often so loose as to give the appearance of a mere offshore deposit. In addition to the formations thus referred to there are on the several terraces, and markedly so on that at 700 feet, thin deposits of gravel and sand, even shells, which mark the level of the beach at the time the terrace formed.

The structure of the terraced front of the ridge under discussion is in reality that of a gentle anticlinal fold, the axis at right angles to the coast and lying approximately in the Walrath Ridge, to the west of this the dip of the beds being southwest, to the east of this southeast. The structure is therefore really like the nose of an anticline plunging beneath the sea. On approaching Santa Cruz it is possible that the strata become horizontal or nearly so; to the west the same. From the position of the axis of the gentle fold here described it is clear that it can be nothing more than the merest crumple in the general fold of the range itself, which has a trend northwest and southeast, somewhat diagonal to the coast line between here and the Golden Gate.

From the foregoing it is evident that the geology of the deposit of bituminous sandstone, which is really embraced within an area of 5 or 6 square miles, is complete in itself, and for the full understanding of its occurrence one need not go beyond the confines here indicated.

THE PROPERTY OF THE CITY STREET IMPROVEMENT COMPANY.

General description.—The property of the City Street Improvement Company is shown on the sketch of the Santa Cruz region (fig. 39), but the distribution of its quarries, their relations to each other, and the immediate topography of the tract can best be gathered from fig. 40. The quarries lie at the head of the Walrath Ridge and are opened in the uppermost terrace of the country, that of which the base is at 700 feet, the summit at 925 feet. The general features of this terrace may be gathered from Pl. XLV. The top of the terrace, as there shown, is the general level of the present summit of the Empire Ridge. The quarries are opened chiefly on the seaward slope of a headland of this ridge. The lower terrace in the view is that at 700 feet, and is a portion of the Walrath Ridge. The gulch in the foreground is that occupied by Major Creek. The view is taken from a point on the Enright Ridge a mile southwest of the quarries. The cap of the ridge over the quarries consists of the Monterey shales; the quarries



GENERAL VIEW OF QUARRIES OF CITY STREET IMPROVEMENT COMPANY, SANTA CRUZ DISTRICT, CALIFORNIA.

1, Last Chance; 2, Thurber; 3, The Hole; 4, Old; 5, Point; 6, Rattlesnake. Seen from the southwest.

themselves are opened in the upper portion of the sandstone underlying the shale. The remainder of the sandstone, which is barren, extends generally to a level lower than the present gulch erosion.

The quarries of the City Street Improvement Company are the Last Chance, Thurber, the Hole, New, Old, Side Hill, Point, and Rattlesnake. As will be observed from the sketch, fig. 40, they are opened at two different topographic horizons, the Thurber, Hole, and New quarries having their floors about a hundred feet above those of the others. These two topographic horizons correspond to a difference in the geologic occurrence of the deposits of the two series of quarries. The deposits opened at the Last Chance, Old, Point, Side Hill, and Rattlesnake are in one and the same bed. The geologic horizon of the deposits of the Thurber, Hole, and New quarries is somewhat in doubt, notwithstanding the most careful work and the time that were put upon their study.

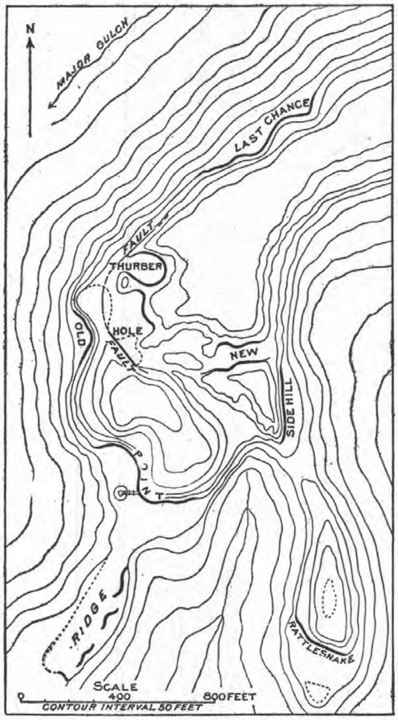


FIG. 40.—Quarries, City Street Improvement Company, Santa Cruz district, California.

The general succession of beds for the region is most completely shown at the Point mine, Pls. XLVI, *A* and XLVII, *A*, where the bituminous sandstone is observed in two benches, separated by an intermediate zone of sandstone of inferior grade; overlying this is a heavy body of Monterey shale; underlying it, for the most part covered by the quarry dump, is a great mass of bedded, horizontal, yellow and white, somewhat argillaceous, but in the main quartzose, sands.

The Monterey shale is of the type described in the general discussion of this formation. All of the features there mentioned recur in force in the present region. They are of excessive hardness, silicification in greater or less degree, a brown to white color, a slight per cent of bitumen, and an abundance of the minute fossil forms of foraminifera and radiolaria; jointing, vertical or highly inclined, in directions varying between northeast and northwest is conspicuous. At times so great has been the disturbance concomitant, perhaps, with this jointing that cracks of no inconsiderable size have been opened and filled with sand, doubtless derived from the main sandstone below. Whether, however, this occurred prior to the infiltration of the bitumen or after is unknown. A certain similarity is recognized between the occurrence of these sandstone dikes and those which have been observed at other points in the Coast Ranges, and which Mr. Diller in his discussion of them has referred to an origin in earthquake phenomena. The dikes are from minute size up to 6 or 8 feet, possibly even 25 or 30 in thickness, and extend at all angles with the stratification of the shale (fig. 41). In some of the thinner ones, which may be traced for several hundred feet, it is remarkable how the sandy filling could have so effectually occupied their every space. The dikes branch, anastomose, and again pass into single channels almost as prominent as that portion leaving the main bed of bituminous sandstone. They have often been found guides to the main bed beneath their point of occurrence, at least in the region about Santa Cruz. The joints of the shales, which have not been filled with sand but have remained comparatively tight, have, however, almost everywhere a thin film of pure bitumen that either has seeped from their walls or has made its way upward along the narrow channel from the main reservoir of sandstone below.

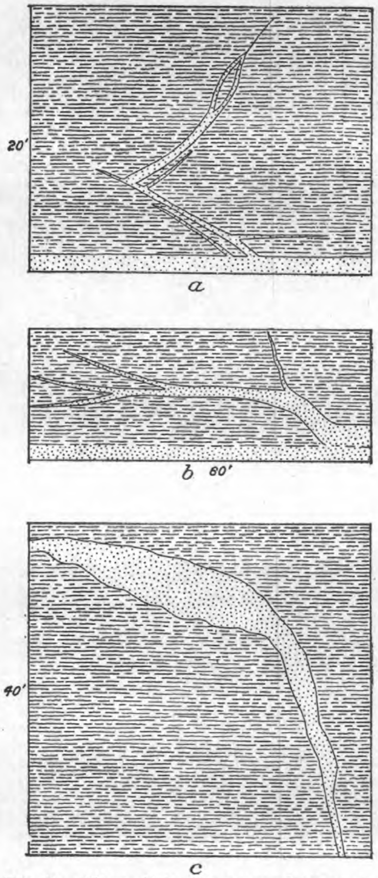
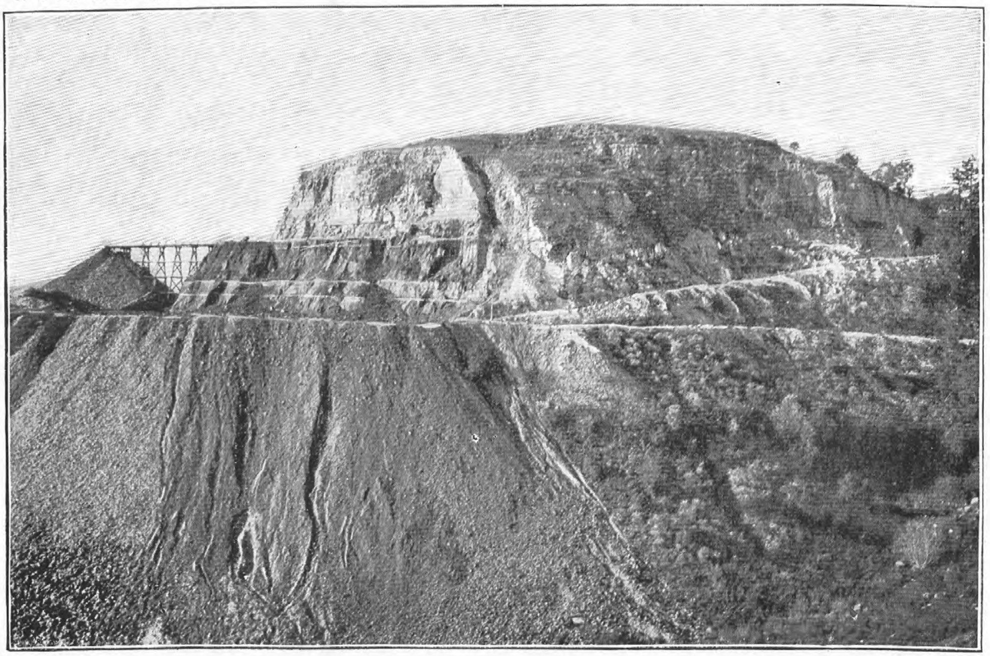


FIG. 41.—Dikes of bituminous sandstone cutting Monterey shale. In *a* and *b* top of main bed of bituminous sandstone showing.

The bituminous sandstones which constitute the product of the quarries of the City Street Improvement Company are essentially an aggregate of minute to medium-sized quartz grains. In addition to these, there is a slight admixture of a feldspar-like material suggestive of the derivation of the sediment from the adjacent granite area. There is also present at times a slight amount of iron and a clayey-looking material in fine grains. Only the quartz, however, is conspicuous. This is subangular to rounded. It is in the interstices of this rock that the bitumen is held to an extent of between 14 and 16 per cent in the average specimen. The rock varies somewhat in hardness, but on the whole is soft, crumbling under the sun's heat, very



A. POINT QUARRY, CITY STREET IMPROVEMENT COMPANY.

Viewed from the southeast.

B. RATTLESNAKE QUARRY, CITY STREET IMPROVEMENT COMPANY.

Viewed from the northwest.

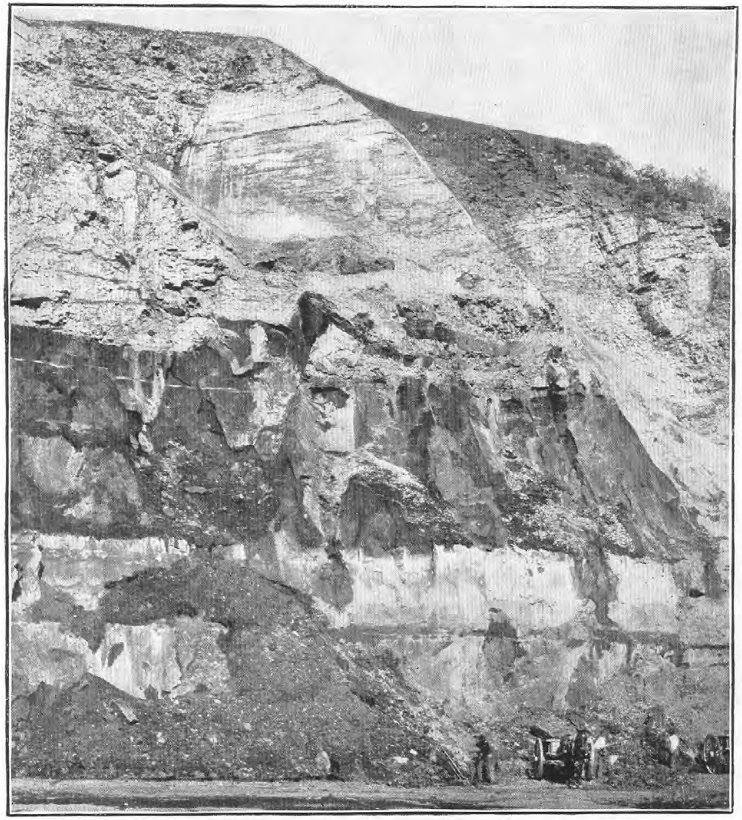
tenacious, and gummy to the touch. Its color is normally black to brownish-black, weathering to a gray on exposure to the atmosphere. As to the coarseness of the material constituting the bed, while the mass of it is of a medium grain, there are bodies of small extent of coarser stuff, imparting a gritty and at times even a fine conglomerate appearance, the pebbles also being of quartz, though occasionally one of clay is found. The temperature of the atmosphere, according as it is cold or hot, renders the rock either brittle or soft. There is but little variation from the above features for the quarries that are opened on the main bed at the lower horizon. Moreover, the members of this bed themselves varied but little from each other.

Point quarry.—The full series of bituminous sandstones is best shown at the Point quarry (Pl. XLVII, *A*), where there are four distinct divisions. The uppermost, which may be regarded as the upper layer of the bituminous sandstone, has the general features that are mentioned above, but it is of rather finer grain than that of the remainder of the beds, is somewhat harder, and crumbles a little less readily under the sun's rays. The layer immediately beneath this, about 26 feet thick, and the basal member, from 6 to 14 feet, in reality afforded the description for the rock in general. In the lower one the feldspathic mineral is, perhaps, rather more in evidence than in the upper. Separating the foregoing sandstones about midway and showing in the view of the quarry as a lighter band half way the height of the face, is a body of sandstone somewhat impregnated with bitumen, but not sufficiently rich to permit its inclusion in the product. Its color is light gray, slightly tinged with yellow. This refers, however, to its weathered surface; on fresh fractures it is distinctly brown. The grain is finer than that of the richer rock, and there seems to be in it a considerable percentage of what may prove to be feldspar, yet differing in a measure from the grains of this mineral contained in the product. The rock is rather soft and friable, but it does not crumble as the rock of the remaining portions of the beds, owing, probably, to its poverty in bitumen. It is, of course, a drier rock to the feel. The thickness of this intermediate sandstone is between 6 and 12 feet.

The position of this great bed of bituminous sandstone is practically horizontal. The features of chief interest concerning it, aside from the actual contents in bitumen, are its extent and certain peculiarities having principally geological interest. The extent of the bed is practically that of the ground embraced within the property and lying above the horizon of the bed (fig. 40). It is therefore confined to the ridges, the gulches having been cut to depths considerably below this. The thickness of the bed varies greatly. The maximum occurs at the Point mine. At the Old quarry, on the western side of the same ridge, it is reduced to less than 6 feet, divided into an upper and under zone, with a narrow band of low grade between. At the Last Chance mine, overlooking Major Gulch, the thickness is somewhat increased over the foregoing, but is still generally under 8 feet. The division, however, observed in the Old mine is wanting, and the bed is one continuous body of comparatively rich rock. Even in the Point mine this diminution is presaged, for along the western face the upper bed within a distance of 200 feet from the point of the quarry is reduced to but 12 feet, the lower to but 2 feet, while the middle, more barren band, somewhat increases over its thickness of 6 feet at the turn of the face. This thinning of the beds, together with that shown at the Old and Last Chance quarries, indicates for the deposit in general a diminution to the northwest, although a certain thickness is found to have been maintained even across Major Gulch on the head of Enright Ridge. The thinning, of the lower bed at least, appears to be chiefly from below; regarding the upper division there is doubt.

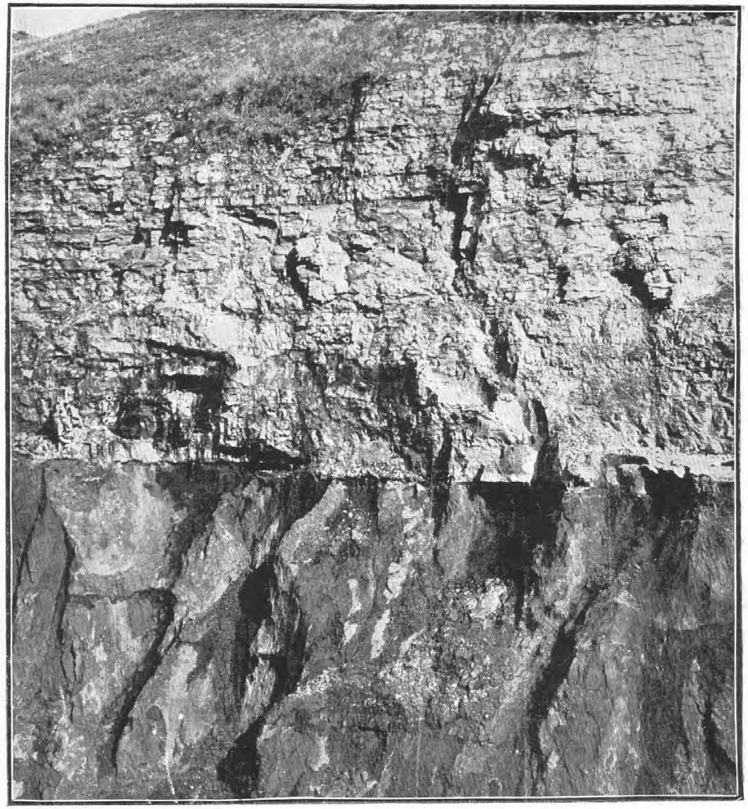
The feature of greatest geological interest is in the relationship of the upper member of the bituminous sandstones to the overlying Monterey shale. The upper 4 feet of the sandstone, rich as it is in bitumen, is most erratic in certain localities. In the western face of the Point quarry and near the point, after steadily maintaining itself as a portion of the bed proper and in perfect horizontality with it, it passes diagonally upward into the overlying shale, preserving its thickness for a certain distance, then splitting into three attenuated forks, also diagonally crossing the strata of shale. In addition to these a vertical crack receives a shoot from this vein-like portion of the upper bed (*a* fig. 41, and Pl. XLVII, *B*). In this face, also, there are other similar occurrences.

In the south face of the quarry, toward its eastern end, this same upper 4 feet of rich bituminous sandstone again takes on the utmost irregularity. Here, instead of constituting a vein, the appearance is as though this upper member and the adjoining shale had been broken into each other, so that the appearance at this point is that expressed in Pl. XLVII, *A*, i. e., a number of practically isolated masses of shale, in which the horizontality of their stratification planes is maintained, surrounded by bituminous sandstone, the same as that of the upper bed—in fact, probably derived from it. The angles of fracture in the shale are always sharp, and a dike-like vein of sandstone given off from the main mass will zigzag through the overlying rock in most remarkable fashion. Were it not for the persistent regularity and apparent nondisturbance of the underlying bed of bituminous sandstone, it could not otherwise be regarded than that the appearance thus described was brought about by a local fracturing, crushing, and mixing of the upper 4 feet with the adjoining shale. These are the facts. It is left for those who speculate on geological problems to explain them. Economically, in this instance at least, it is of no importance.



A. POINT QUARRY, CITY STREET IMPROVEMENT COMPANY.

South face, showing details of stratigraphy.



B. POINT QUARRY, CITY STREET IMPROVEMENT COMPANY.

Showing the structure of the Monterey shale, a dike of bituminous sandstone passing from the main beds upward, and the upper layer of the main bed of bituminous sandstone. Compare *b*, fig. 41.

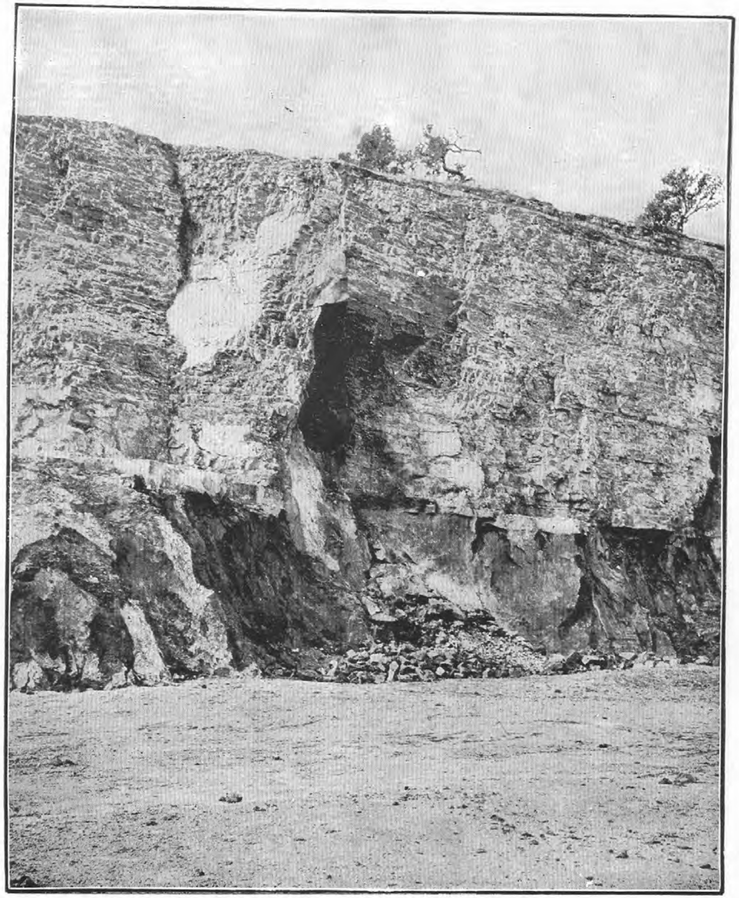
The southern face of the Point quarry presents one further feature of note, namely, the faulting that has occurred along some of the joint planes. These planes are found to pass from the shales into the bituminous sandstones, and in one instance the stripped surface of the quarried rock shows a drop of 12 to 16 inches. The direction of these joint planes and faults varies from N. 18° E. to N. 18° W.; the dip of the planes is in either direction. In the fault just referred to, the throw is normal.

In the west face of the Point quarry, near the base of the upper member (not the 4-foot cap which has here passed as a dike into the shale), is a horizontal series of sandstone concretions. They have no concentric structure, so far as could be observed, but consist merely of a mass of soft, white sand, with the barest trace of bitumen.

Of the relations between the bituminous sandstone of this quarry and the overlying shales it may be said that there are only traces of what might be interpreted as an unconformity between the two series of rocks. The two formations, here at least, are practically conformable.

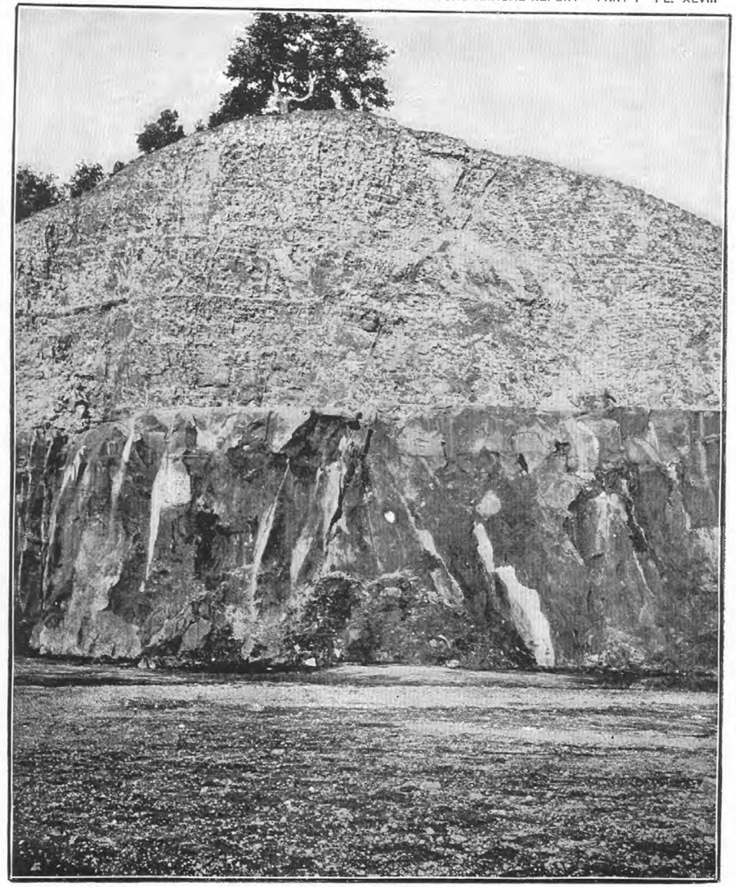
Side Hill quarry.—This is one of the important openings on the property of the City Street Improvement Company. It is developed in the same bed as the Point quarry, but only in its upper member—that above the intermediate, nearly barren, body of sandstone. The lower member here appears at but one point, near and a little below the eastern end of the quarry. It is apparently reduced to a minimum, at least the enriched portion, for it passes downward into a loose, brown, quartzose sand, succeeded in turn by one yellower and still freer from all traces of bitumen. The thickness of the middle and lower members would here seem to be between 20 and 30 feet, but they are difficult to observe, being for the most part covered by the dump of the quarry. The upper member is about 18 or 20 feet thick, showing the same general features as at the Point mine, even to the line of sandstone concretions 6 to 8 feet above the bottom, and to the upper division of 4 feet separated from the lower only by what appears to be a line of stratification. The features of especial interest along the face of the Side Hill quarry are the dikes and the joints. Both are shown in the accompanying view (Pl. XLVIII, *A*). The dike in the center is one of the most prominent in the region. Its nature is clearly shown—a rapidly narrowing vertical fissure, broad at the base, wedging to a film at the surface 40 feet above the bituminous sandstone bed. The material of which the dike is composed is almost the same as that of the main bed, only perhaps a little finer. The per cent of bitumen is about equal in the two. There is really no evidence of a flow or pressing of the material of the main bed upward into this broadly open fissure, yet there is no division separating the two bodies from each other. The upper stratum of 4 feet capping the bituminous sandstone was unfortunately covered at the juncture of the dike and the main bed, and the condition of the face above did not permit examination. The joints of this quarry have commonly a southwesterly trend. Their planes all lie in curves, as shown in the illustration, but with a general dip of 60° SE. They pass from the shale to the bituminous sandstone, but no displacements were discovered. Some of the joints are observed to pass from the shales through the dike described above, indicating a difference in their periods of development. Indeed, it is quite probable, in view of the frequency of earth movements along the Pacific coast, that each has developed a new set of joints. The bitumen that has infiltrated along the joints of the shales at this quarry is often in the form of minute veins and is brittle and bright on fresh fracture, but after exposure to the atmosphere becomes dead black or brown.

Rattlesnake quarry.—The Rattlesnake quarry (Pl. XLVI, *B*) is opened on the same bed as the Side Hill, i. e., on the upper member of the series as described at the Point mine. This is here approximately 26 feet thick, showing the upper 4-foot divisi n the same as at the other localities. The rock is practically the same in composition and bitumen contents as at other points, a possible slight increase in feldspar being the only difference. Only the top of the intermediate bed was observed, appearing just above the floor of the quarry. The lower member, at least along the slope opposite the face, was covered by the dump. Beyond this, however, there were traces of its outcrop, unenriched, in the hillside. Many of the features already described for the other quarries reappear here—joints, small thread-like dikes, gentle faulting, and minor disturbances in the relations between the shales and sandstones. Chief among these are the joints, which are especially conspicuous in the face of the bituminous sandstone (Pl. XLVIII, *B*), and more so here than at any other point observed by the writer. Their trend is roughly northeast to southwest. Their dip is in either direction, rather more frequently westward in the western half of the face, eastward in the eastern half. They pass from the sandstone into the shale, but are of interest chiefly in the former. In this rock the joints are comparatively tight, although occasionally opened for a width of an eighth to a quarter of an inch and filled with the hardened bitumen derived from the walls. Their chief feature, however, is the impoverished zone of dry, brown, sandstone, 2 to 4 inches wide, on either side. In this zone the bitumen now appears merely as a dead-brown coating of the quartz grains. On exposure these zones exhibit a marked tendency, under the influences of weathering, to crack off from the main body of richer rock, and if the quarry face is left so as to make it possible, great sheets will peel and drop to the floor of the mine. Their line of separation from the enriched portion is distinct and comparatively smooth, yet



A. SIDE HILL QUARRY, CITY STREET IMPROVEMENT COMPANY.

Showing the main bed of bituminous sandstone and a dike of the same extending from bed upward into the Monterey shale.



B. RATTLESNAKE QUARRY, CITY STREET IMPROVEMENT COMPANY.

Showing joint planes in the bituminous sandstone.

showing a granular texture on the walls, from the constituent quartz grains. On the joints proper greater smoothness prevails, yet no slickensides were actually observed. Occasionally a penicillate structure will be developed in the impoverished zone, the rays at right angles to the original joint and fracture planes. This structure is most marked in the half next the joint proper, diminishing to the right and left on approaching the richer parts of the bed. It is quite possible that this structure differs from the penicillate rays so commonly developed in gilsonite seams, in that it may be here merely the weathering out of planes of sedimentation.

The line of union between the bituminous sandstone and the underlying barren portion of the bed (fig. 42) is wavy, as though crumpled laterally, and is marked by a zone of brown sand from 4 to 12 inches thick. The brown color is, however, not solid, but is distributed in concentric lines following the curvature as described above—that is to say, were a vertical section given, one would find beneath the enriched sand 2 or 3 inches of brown, dark, and somewhat richer sand than the balance below, perhaps, even, slightly oily; next to this an almost barren white ribbon of sand an inch or so in thickness; following this another brown zone, then a white, and so on until there remains practically no trace of bitumen.

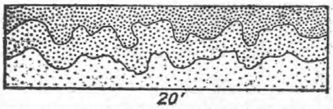


FIG. 42.—Zone of transition from the enriched bituminous sandstone to the barren sands below.

The concretions of sandstones appearing in this quarry show an outer ring of bitumen, an interior ring, also bitumenized, separated from the former by a barren zone with a barren center of white sand. This structure, however, is not usual in the Santa Cruz district.

Another feature particularly well displayed at this quarry is the heavy cross bedding which the bituminous sandstone displays. Another, showing at the northwestern end of the face and from here northward to the end of the Rattlesnake Hill, is the disturbed relation of sandstone and shale, suggesting a considerable degree of fracturing, possibly even faulting. This is particularly noticeable in a small cut at the north end of the hill.

Last Chance quarry.—This quarry lies a few hundred yards north of the quarries already described and overlooks Major Gulch at a height three-fourths the distance from the general level of the valley to the top of the ridge in which it is opened. The quarry has a face of 600 feet along the hill, but has not been cut back from the outcrop over 40 or 50 feet. The bed here exposed is about 8 feet thick midway the length, thinning to 4 at the eastern end, at the western passing beneath talus.

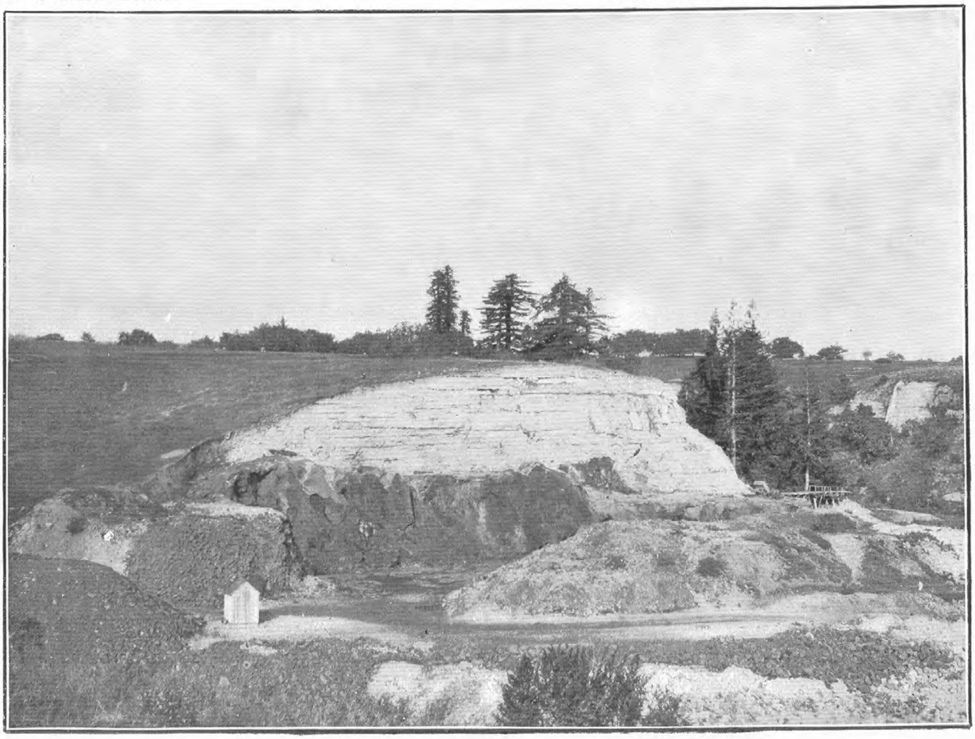
The sandstone is composed chiefly of quartz grains, the interstices filled with bitumen. The quartz is angular, and on the whole somewhat coarser than that found at the quarries already described. Locally it even takes on the appearance of a fine grit. There is but a trace of any other mineral in the bituminous sandstone itself, a few scattered particles of the same feldspathic-like material observed elsewhere at this horizon perhaps being present. Occasionally a fine pebble of greenish color and clay-like consistency is also found. The per cent of bitumen in this rock is probably the average for the property in general, i. e., 15 or 16.

The shales overlying the sandstone are of the usual Monterey type and bear the customary joints trending in either a northwest or northeast direction and dipping both ways. The joints have in places remained open for a time and have been filled with sand, with bitumen in the interstices. These minute sand dikes, never over 4 or 5 inches in width and usually much thinner, display a jointing diagonal to the plane on either side, evidences of movements in times posterior to the formation of the vein itself. Even in the shales, where there may be a narrow interjoint zone, this structure is again taken on. As elsewhere, the dikes branch, anastomose, and in instances are faulted. Many of the joint planes are curved.

The sandstone underlying the bitumen-bearing bed is apparently of the same composition as the latter, but is devoid of bitumen. It appears to be more or less ferruginous, is soft and friable, and, in general, resembles that underlying the productive bed at the Point and other quarries described above.

The upper portion of the bituminous sandstone of the Last Chance quarry is clearly defined from the overlying beds, yet there is the appearance, if not of transition, of at least a very material increase in the sandy constituents of the layers for from 5 to 6 feet at the bottom of the shale series. This zone resembles somewhat the middle zone of the Point mine. It is dull gray or, occasionally, slightly yellowish; it is fairly solid and massive at some points, while at others it has the shaly lamination—this suggestive of its relation with the shale rather than with the bituminous sandstone itself. The interstices of the rock seem to have had washed into them a certain amount of clay, which coats the quartz particles, or which may prevail to an extent sufficient to impart to the bed a thin lamination and a shaly character. Traces of the minute organisms found in the shales are also found here. This sandy zone has a pronounced concretionary tendency. Throughout the zone is more or less disseminated pyrite, which by decomposition is probably the source of the iron that has imparted the coloring to the rock.

Whether the bituminous sandstone is the homologue of the upper or the lower band of like rock at the Point quarry is not satisfactorily determined; the conditions of its occurrence suggest the lower, in which case, also, it is not to be correlated with the beds of the Rattlesnake



A. NEW QUARRY, CITY STREET IMPROVEMENT COMPANY.

Showing features similar to those of the Thurber.

B. THURBER QUARRY, CITY STREET IMPROVEMENT COMPANY.

Showing the bituminous sandstone overlain unconformably by Monterey shale.

and Side Hill mines, which correspond to the upper band at the Point mine. It is possible, too, that the greenish-gray sandy shale just described at the base of the Monterey, although it rests with distinct dividing line upon the enriched sand at the Last Chance, is the homologue of the middle zone at the Point quarry, only here practically unimpregnated. In either case, unconformity is suggested between the shales and the sandstone bearing the bitumen. It can not be regarded, however, as proved. The suggestion is interesting in view of the conditions to be described at the Thurber, New, and Hole mines.

Old quarry.—This quarry has long since been abandoned, but merits a brief description because of its position with reference to the Hole mine, lying but a few feet from the latter, but at a considerably lower topographic level. The quarry displays a body of horizontal sandstone in two or three layers; an upper, 2½ feet thick, narrowing to 1 at the north end of the quarry; an under, also 2½ feet thick; both comparatively rich in bitumen. Between these is a foot or two of sandstone appreciably lower in its percent of asphaltic matter, and instead of consisting almost wholly of quartz, as the zones above and below, carries considerable material feldspar-like in nature, some mica, and a much finer-grained quartz, the whole at times showing also the accession of clay. This rock bears a certain resemblance to that overlying the bituminous sandstone at the Last Chance quarry, i. e., the gray arenaceous band at the base of the shales. It may be that the upper zone of bituminous sandstone which has here diminished in such degree has there entirely disappeared. It has already been remarked that this diminution of the bitumen-bearing bed as a whole was suggested even at the northern end of the Point quarry.

At the Old quarry also there is a certain degree of transition from the upper layer of bituminous sandstone to the overlying shales, or at least a somewhat less distinct division line than usually prevails. It comes about by the passage upward of the layers of the sandy material, diminishing in number until replaced entirely by shale, all within 2 or 3 feet. The sands in this position are slightly bituminous.

The underlying sands at this quarry are conspicuously a loose agglomerate of quartz grains, with pebbles of quartz, bluish granite, and an unknown greenish mineral. This coarse, pebbly feature was also noticed in the corresponding sands beneath the base of the bituminous sandstone at the western end of the Last Chance quarry.

Thurber quarry.—This quarry is opened in a mass of bituminous sandstone that lies at an altitude somewhat over a hundred feet higher than that of the Point, Side Hill, and Rattlesnake mines, although, owing to a rise in the strata in this direction, at a somewhat less distance above the Last Chance (fig. 40). The quarry is about 200 feet in diameter, but the sandstone extends beyond this for an undetermined distance, being perhaps continuous with that of the New quarry as well as with that of the Hole. The height of the sandstone in the quarry face is variable, but a maximum of 40 feet is attained on the eastern side. The upper surface of the sandstone is uneven, the Monterey shale resting upon it as though unconformable. Beneath the bed as exposed there are traces of a white sand, with the usual 4 to 6 inch ribbon of brown, dried out, bituminous sand between.

The bituminous sandstone forming the product of this quarry is black, weathering bluish-gray, fine-grained, distinctly finer than that of the Point or the Side Hill quarries for instance; its texture is even and the rock is tough, tenacious, and harder than that of the quarries at a lower topographic horizon. The composition of the rock is of quartz, a conspicuous fine mineral of reddish color which may be a feldspar, numerous grains of a black mineral, nature undetermined, and a mica—the quartz in excess of the others in a considerable degree. The grains, on the whole, are angular. The bitumen fills the interstices of the rock to an extent of 14 per cent. The rock is considered and known as a harder rock than that of the Point quarry, and is desired for admixture with the latter for certain conditions under which paving is to be done. Mr. Dow, to whom the Geological Survey is indebted for the determinations of the bitumen contents of the samples collected by the writer, asserts that there is also a marked difference in the bitumen itself derived from the two sandstones. The Thurber rock apparently contains also, at least in some portions, a small but not injurious amount of iron. Throughout the mass of the rock are occasional concretions or other like irregular bodies of sandstone, devoid of bitumen, and appearing in the face of the quarry like cannon balls shot there. These concretions, on examination, are found extremely hard and their pores infiltrated with carbonate of lime, affording the usual effervescence with HCl.

Three features of especial interest are to be found in the walls of this quarry:

The first of these is what appears to be a fault (fig. 40), which is at present visible only in the point immediately north of the entrance to the quarry. Here the Monterey shale is found opposing the bituminous sandstone. The shales are horizontal; the sandstone has the appearance near the fault of a bending downward, as though its mass had been uplifted and in the friction against the fault plane this portion had dragged. The trend of the fault and its position carry it practically along the face of this portion of the ridge, and it is said by the foreman of the quarries that in opening the Thurber there was cleared away from the front of the sandstone a body of horizontally lying shale which, but for prospecting, would have given no clue to the rock that lay behind. This fault doubtless passes into the valley just north of the end of the Old quarry, and it may be that there is a certain amount of interruption to the passage of the lower bed of sandstone from this point to the Last Chance quarry. Indeed, this seems highly probable. The amount of throw of this fault is probably less than 50 feet, the strata on the north being carried down.

A second feature of this quarry is the apparent unconformity between the mass of bituminous sandrock and the overlying shale. This is clearly illustrated in the view of the east face of the quarry, Pl. XLIX, *A*, where the layers of shale are seen to pass successively farther and farther over the sandstone, the lower ones abutting against the slope, the higher passing completely across the bed. The upper surface of the sandstone is smooth, although uneven. Next to the shale there is locally a somewhat impoverished zone resembling a rock dried of its bitumen contents. This unevenness of line between the two formations prevails, not only about this quarry, but at the New mine and the Hole as well. In the view given of the Thurber quarry there will be observed, 10 or 15 feet above the main body of sandstone, a second thin bed (2 or 3 feet) of sandstone also bituminous, forking at

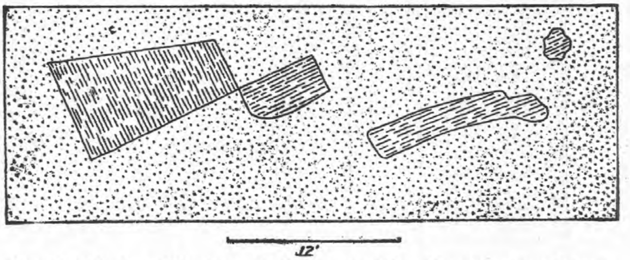


FIG. 43.—Blocks of Monterey shale in underlying bituminous sandstone.

the southern or right-hand end, as though filling a nearly horizontal split in the shale.

The third feature of interest and the most peculiar and unaccountable of all is the inclusion deep within this bituminous sandstone of great bodies of shale, none other than the Monterey, even to the fossil contents, and of necessity derived from this terrane in the immediate locality.

Fig. 43 illustrates this. There is a body of shale in which the stratification lines are perfectly maintained, with a pitch, as indicated in the sketch, of 50° or 60°. It is an angular body that has been caught in the sandstone in a position that indicates it as having either been carried with it, tumbled into it from some overlying cliff, or sunk into it when the consistency of the sandstone was possibly that of quicksand. Adjoining this at one of its corners is a second body of shale precisely similar, of which the lines of stratification are at right angles to those in the body just described. A little removed from these are two others, again at variance. This is but one of dozens of similar occurrences in the immediate vicinity of this quarry, either in its western face or on the opposite side of the ridge which separates it from the cut of the Hole. How such conditions were brought about is a question. The jumbling of sandstone and shales suggests that in the vicinity there was, perhaps, with the faulting a breaking of the adjoining strata and a mingling of the one rock with the other, with the inclusion of shale bodies in the more pliable and plastic sandstone. There are nevertheless two considerations to be given in any such theory, namely, that the sandstone itself shows little disturbance unless it be the obliteration of its stratification lines; second, it is to be borne in mind that the rock of this quarry differs in its mineral constituents materially from that of the bed which is opened either at the Point, Side Hill, or Rattlesnake mine. These statements are made with a view of the possibility that the Thurber deposit might have been a portion of the bed which occurs, at the Point, for instance, pushed upward—indeed, dike-like in a measure.

New quarry.—This quarry (Pl. XLIX, *B*) is located about 500 feet southeast of the Thurber and at a slightly lower elevation. With reference to the Side Hill mine it lies about 100 feet higher and a little to the north and west. In the face of the quarry is exposed a bituminous sandstone bed of a thickness of from 18 to 30 feet, the lesser thickness being at the eastern end. The sandstone is underlain by the usual white sands separated from the former by the brown, dry, once more or less bituminized rock commonly present in all the quarries. The bituminous sandstone is overlain by the Monterey shale, which is continuous with that overlying both the Thurber and the Last Chance quarries, with perhaps both joints and faults intervening. The line of union between the bituminous sandstone and the shale is, broadly, most irregular, indicating as the relation between the two formations an unconformity as pronounced as that already described for the Thurber quarry. In this connection it may be again observed that the unconformity here suggested is by no means an established fact; this irregularity of line between the two formations may have been brought about by the intrusion, if the term may be so used, of the sandstone into the shales as already suggested as possible at the Thurber. At the New quarry the irregularities of surface are much sharper and less broad than at the Thurber, the bituminous sandstone rising in places to a height of 7 or 8 feet above the adjoining portions within a lateral distance of 10 or 15 feet. In such cases the shales abut against the sandstone. Toward the western end of the quarry the upper 2 feet of the sandstone has become from some cause more or less impoverished, and has taken on the brown aspect of such rock. At one point in the face of the quarry a fault is to be seen, the trend of the plane being N. 27° W., the hade to the east, the downthrow on this side 2 feet in amount. At the very eastern end of the quarry is another fault of a trend S. 70° W., the hade to the north, the downthrow 2 feet on the south side—a reversed fault. The foregoing faults are illustrative of what may be met with at many points throughout the region under discussion.

The bituminous sandstone of this quarry is practically of the same composition as that of the Thurber—that is, primarily of sharp grains of quartz, a feldspar-like mineral, particles of comminuted shale (?), a small amount of iridescent mica, and an equal quantity of a bright red or green mineral, the latter the more abundant. While the accessory minerals form but a small per cent of the rock in comparison with the quartz, they nevertheless impart to it a character that is prevalent through all of the quarries of the upper horizon, and is at times, it is thought, recognizable in the filling of the ordinary fissures of the locality. Bitumen occupies the interstices of this rock, and is apparently its chief binding material. It is somewhat variable in amount, yet the entire bed is of high grade, containing a per cent as high as 15 or 16.

The concretions that have been described in the rock of the Thurber quarry are also found in that of the New. Their composition in the latter quarry is so clearly that of the rock mass in general that there can be no question as to the origin of the one from the other. Occasionally the concretions show in the interior a concentric structure, the same as that described for a similar rock in the Rattlesnake quarry; that is, two or three layers of sand which may carry a small amount of bitumen, separated from one another by absolutely barren layers. The concretions are all more or less calcareous. Near the eastern end of the quarry face there is a small bituminous sandstone body in the shale about 15 feet above the main bed.

The face of the bituminous sandstone as exposed in the quarry displays certain lines which resemble those of stratification, this especially toward the eastern end of the quarry, where they are also more nearly horizontal. In the western half of the quarry face these lines arch upward quite sharply, following an equivalent upward arching of the surface of the sandstone bed itself. The appearance here is as though a result from lateral compression.

The New quarry has been cut through the summit of a minor ridge, embracing the lower portion of a slope that extends from a table of lesser altitude to that forming the crest of the main ridge, the upper terrace of the region. There has been left, therefore, a small body of rock on the south side of the quarry reaching 15 or 20 feet above the floor. This body of rock is, in the main, shale, but the wall in reality lies almost along a fault plane, only an occasional mass of the bituminous sandstone of the quarry adhering to the shale across the break. The sandstone thus showing is very broken and is more or less concretionary. Toward the eastern end bodies of shale of various forms are included. The trend of this fault is a little north of east.

"*The Hole*" *quarry*.—This quarry, now practically worked out, forms a small opening somewhat nearer the Thurber than the New, but on the same general level as the others. The rock of this quarry is identical in composition with that of the Thurber and New, and all are unquestionably of one general rock mass. The original outline of the deposit has been lost in the development of the quarry, but sufficient material has been left at the sides to indicate, at least for the upper surface, the same irregularities as exist at the two other quarries. The leading feature of this quarry is a fault plane that is exposed along the western side (fig. 40), the shales forming the wall, the bituminous sandstone having been stripped from the fracture plane to a depth of 25 or 30 feet. The trend of the fault is about N. 50° W., the hade being to the northeast from 5° to 10°. Toward the southern end of the opening, judging from the irregularity of the now vertical surface, there were apparently one or two fractures of minor importance branching from the main one here described. The result of the proximity of these two or three planes is considerable confusion of strata for the immediate region. At the northwestern corner of the quarry the bituminous sandstone which has been left along the fault plane is conspicuously marked with cleavage lines and cracks parallel to the fracture. At this point, also, there is a cross fracture extending in a S. 55° W. direction, slight displacement only having taken place. The main fault here described as forming the western wall of the Hole gives evidences in passing from the northern end of the quarry of bending more to the northward, and it has the appearance of either passing into the northeast-southwest fracture described as forming the outer border of the Thurber mine, or, indeed, becoming that fracture itself, the fault in this case arching from one quarry to the other. At the southern end of the Hole there is also an evident tendency of the same fault to turn toward the east, possibly here passing into that which has been described along the south side of the New quarry. If this be the case, the form of a plug is suggested for the deposit which is opened in the Thurber, Hole, and New quarries. How the peculiar form was induced and the space made for the sand which filled it, is a question that must remain unanswered.

At the northern end of the Hole, and in the point between this and the Thurber quarry, there is great admixture of shale bodies with the bituminous sandstone, as though—so far as the shale is concerned—a brecciated mass of large fragments held in a matrix of the bituminous material. The shales are of the Monterey type and nearly everywhere show the minute organisms characteristic of this formation.

THE COWELL PROPERTY.

General description.—This property adjoins that of the City Street Improvement Company on the east with practically a continuous deposit of bituminous sandstone from the one to the other. While the property of the City Street Improvement Company faces the sea, that of Mr. Cowell lies a little within the hills, on gulches that drain to the south of the former property. The altitude of the deposits on

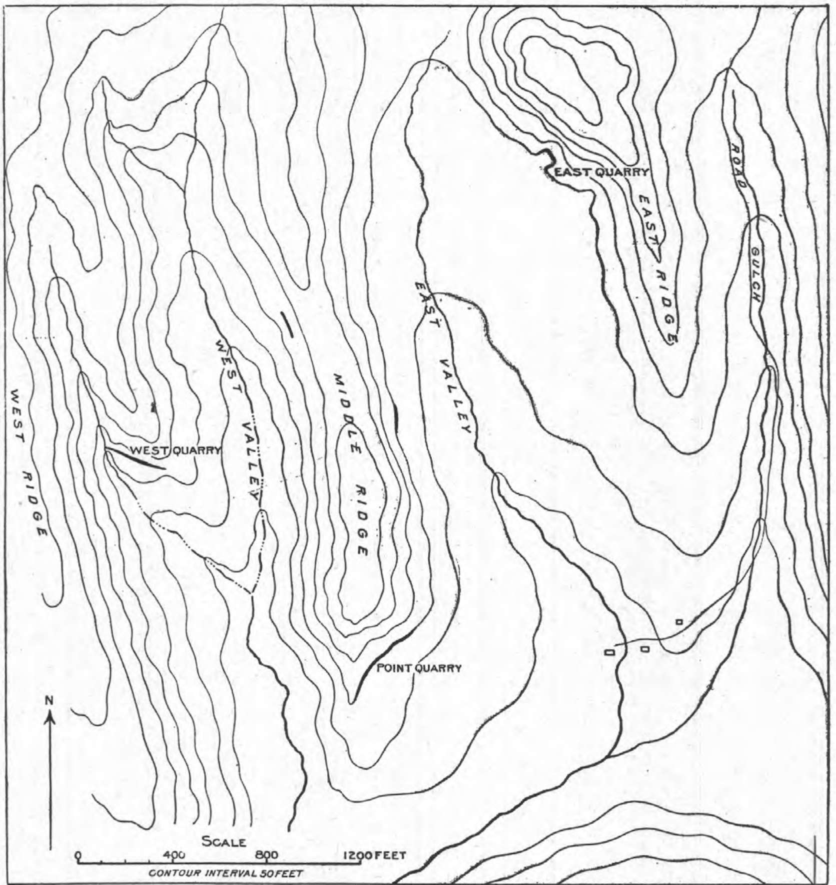


FIG. 44.—Quarries of a bituminous sandstone, Cowell property, Santa Cruz district, California.

both properties is about the same, that is, in the upper bench of the several that here border the ocean front. The accompanying sketch affords an idea of the distribution of the openings made by Mr. Cowell. Although several thousand tons have been shipped from them the business has not received especial attention, and the development has been far less than that at the quarries of the City Street Improvement Company.

The Cowell quarries lie in the slopes of the higher spurs given off at the head of the Walrath Ridge, from 100 to 200 feet below their summits. The same series of sediments occur as in the area to the west, that is, a heavy body of sands and sandstone, partially impregnated with bitumen, overlain with Monterey shale of the usual pronounced type. The latter constitutes the highest terrane of the region; the former, the sands and sandstone, constitute the lowest, except at the eastern edge of the property, where they are found resting upon and against Montara granite, it may be, forming the coastal feature of the lower portion of the Lower Neocene series. Whether or not these sands correspond to those of general occurrence at the base of the Monterey in other portions of southern California is a question; it is a possibility. What underlies the sandstones of the City Street Improvement Company's quarries it was impossible to determine, erosion having been insufficient. About halfway between the latter property and the sea, in the eastern wall of Majors gulch, well toward the bottom, granite again outcrops. This, with the foregoing outcrop, suggests a comparatively thin coating of sediments over the granite, now shales being in contact with it, now sands.

In connection with the occurrence of the bituminous sands in contact with the granite on the Cowell property, it is of interest to note that the area immediately to the north, on either side of Majors gulch, shows a heavy body of sands of generally similar composition, though but little impregnated; these, again, traceable to contact either with granite or with a crystalline limestone that is believed to be of the terrane of possible Paleozoic age referred to in the section on the "General geology of the Coast Range" (p. 367). The position of the strata, both on the Cowell and the adjoining property, is practically horizontal, although on the Cowell, if there be a dip, it is gently to the north.

The bituminous sandstone of the Cowell property is a portion of a general bed which, except for erosion, extends through its entire area, and westward, beneath the lands of the City Street Improvement Company. On the Cowell property it is essentially a mass of semicompacted sand or soft sandstone, 50 to 75 feet thick at least, but probably variable in this respect from its resting upon the uneven surface of the granite. It is apparently the upper half that has been impregnated with bitumen, the lower half being completely barren, more or less argillaceous as with disseminated clay, and of bright yellow, gray, and white colors. The usual 2 to 4 inch zone of brown sand lies between the enriched and barren portions. On the Cowell property the enriched portion of the sandstone does not appear to be as thick as farther to the west, and, moreover, has a tendency to develop a lenticular form or, at least for its southern and eastern edges, a wedge shape. A section at the West quarry of this property gives the following:

Section at the face of the West quarry.

	Feet.
Shale, Monterey type, with one or two bands of sandstone	50 to 100
Bituminous sandstone, in outcrop only	8
White sand, quartzose; resembles sea sand	3
Yellowish-white sand, at this point freer of clay than the sands immediately over the main bed of bituminous sandstone at the Point mine of this property	10
Bituminous sandstone, quartzose; upper 1 foot brown	10

Floor of quarry, barren yellow sand, 2 to 4 inches, separating it from the main enriched bed overlying.

The salient points of the above section are the two beds of bituminous sandstone; the barren sand between; the wavy line of union between the lower enriched bed and the yellow sands beneath, marked by the 2 inches of brown earthy sand; the sea sand beneath the upper enriched zone and a semishading of the one into the other; and concretions of bituminous sand and narrow, horizontal, slightly inclined, or vertical seams of the same material through the overlying shales. Joints occur in the face of the quarry, with trend about N. 20° W., apparently of two systems, one pitching 70° eastward, the other 47° westward.

In addition to the foregoing features, most of which may be seen at any point in the field, is the presence, more marked at the Point quarry than elsewhere, of minute white filaments, single or forked, of what is evidently mineral matter, but may represent the casts or skeletons of some low organism. They occur both in the lower bituminous sandstone and in the yellow sandy zone overlying the latter—the intermediate sandstone at the West quarry. In this sandstone they are particularly prominent. Upon their removal, by solution or otherwise, the sandstone is filled with minute holes.

The composition of the bituminous sandstone of the Cowell property is essentially a fine-grained and angular quartz, but there is also a trace of a feldspar-like mineral, similar to that in the rock of the Rattlesnake mine, one-half mile to the west. This applies to the beds opened at the quarries. On the western edge of the property, however, near the summit of the West Ridge, there is a body of bituminous sandstone of the dike type, which is pronouncedly a combination of quartz and a pinkish feldspar-like (?) mineral—this the same as occurs at the Thurber and New mines, and, in fact, in all of those bodies of a dike-like nature so common in the upper shaly horizons of the high benches of the region.

Point quarry.—This is the extreme southern opening on the Cowell property, and is located at the end of the middle ridge. The succession of beds showing in the face embraces the lower horizon of bituminous sandstone, the intermediate yellow sands, and a trace of the upper sandstone succeeded by the typical Monterey shale. The general lithologic features of the strata are the same as described in the last paragraph, but the quarry presents one point worthy of especial notice, namely, the rapid thinning of the main or lower bed of bituminous sandstone from 17 feet at the western end of the face to less than 6 feet at the eastern, all in a distance of approximately 300 feet. This condition indicates a wedge shape for at least the edge of the deposit, and either the actual edge of an extensive deposit covering possibly the two properties of the region or else a lenticle of several hundred feet opened at the Point quarry, although undetermined as to actual size. This feature is repeated at the quarry at the eastern base of the middle ridge, about 700 or 800 feet north of the Point quarry. In both localities the surface of the ground, by reason of its cover, did not permit an examination of the conditions of the rock underlying the bituminous sandstone, but it is believed that the enriched portion alone wedges out, that the sandstone itself, unenriched, continues, perhaps with the same general thickness except as modified by the uneven surface of granite upon which it may be found to have been deposited.

The rock quarried at this opening carries approximately 16.15 per cent of bitumen, and has been found satisfactory for paving purposes. It is, perhaps, the richer rock of the property, and has been shipped to the extent of 1,000 or 2,000 tons.

Another feature of the deposit at the Point quarry is the contained bodies of quartzite-like rock, the same in kind that have been encountered at quarries of the City Street Improvement Company at other points in California, and, indeed, more or less generally throughout the sandstone deposits of the United States. These bodies are excessively hard, and are primarily a clear gray, but if impregnated to any degree with bitumen are correspondingly turned black, the line of distinction between enriched and barren portions being either sharp or graded. The composition of the rock is quartz, with the interstices infiltrated with carbonate of lime. This infiltration took place prior to the inflow of bitumen, and filling the interstices prevented impregnation by bitumen. In addition to the grains of quartz there are others of what appears to be chert, and, perhaps, of feldspar, also. The per cent of this last mineral is not, however, as high as in the main rock mass of the quarry. The per cent of carbonate of lime in the quartzite bodies is variable, evidenced by the briskness of effervescence with HCl, marked diminution occurring in the areas of black. Traces of pyrite also occur in the rock. The slender, tubular spicules are also present, but these are seemingly local features. This rock projects nodule-like from the face of the quarry.

West quarry.—The face of this quarry afforded the general description of the measures of the region given at the beginning of this section. It need only be added that the continuity of this deposit with the Point and with the beds of approximately the same altitude across the West Ridge, along the eastern edge of the property of the City Street Improvement Company, is very probable. The measures at the West quarry are more regularly developed than at the Point, the lower bed maintaining an average thickness of about 10 feet, the upper, of 6 to 8. The quantity of rock that has been produced at this quarry is nearly the same as at the Point.

A quarter of a mile above the West quarry, in the West Valley, is a small prospect in what is probably the upper seam of the two showing at the West quarry. But 2 or 3 feet of the bed show, overlain by the Monterey shale. Between this and the West quarry the bed has been bored for at intervals and found from 5 to 7 feet thick beneath the talus of the hill slope. The intermediate sandstone shows just east of the prospect here referred to, forming a low 10 to 12 foot cliff.

Quarry on west side of Middle Ridge.—A small quarry has been opened on the west side of and near the summit of the Middle Ridge, in the upper bituminous sandstone. The lower bed is found to the south of the quarry at its proper altitude and along the grade leading up to the upper quarry the middle, barren sandstone horizon is passed in heavy outcrop, at this point appearing somewhat thicker than ordinarily on this property. The bituminous sandstone as opened is divisible by a mere parting into two layers, an upper of 5 feet, a lower of 4. The white sand of the middle bed underlies, a narrow, wavy, zone of brown sand separating. For the greater length of the face, 75 feet, the deposit displays no especial irregularity, but at the western end the upper division of the bed apparently turns sharply upward, and although somewhat fractured has from this point the appearance of a dike extending from the main bed into the Monterey shales, with barely the slightest disturbance to the shales themselves. This feature has already been referred to as forming one of the most puzzling problems of the Santa Cruz district. In the present instance it is quite inexplicable.

The bituminous sandstone of this quarry is also conspicuously jointed, the planes running N. 40° W., parallel with the quarry face, and standing vertical. On either side of a plane is an impoverished zone of 2 to 4 inches, remarkably persistent, and although originally an integral part of the general rock mass, now scaling from it with readiness after exposure to the atmosphere. This, however, is a feature of common occurrence throughout the United States.

The rock of the quarry as now exposed can hardly be regarded desirable owing to the extreme jointing it has undergone and its consequent impoverished condition.

Quarry on east side of Middle Ridge.—The full series of strata is exhibited at this opening without perceptible variation from the general conditions prevailing in the region. Shales, the two bituminous sandstones, the intermediate sands with the white layer at the top, and the underlying yellow, semi-argillaceous sands are all strongly developed and well exposed. The lower bituminous sandstone presents the only peculiarity, a wedging out of the bed from below in the same manner as described for the Point quarry. The quarry is small, a hundred tons, perhaps, having been shipped from a bed averaging 6 feet exposed for a length of 100 feet.

East quarry.—This small opening at the west base of the East Ridge shows about 10 feet of the lower bituminous sandstone, here of a brownish tint weathering gray, somewhat dry, and with concretions of orange sand projecting from the quarry face. Sand of this nature also overlies and underlies the enriched bed, and is separated from it by wavy lines. Traces of the upper bed appear in the hill above the quarry, with the usual shales still higher. The feature of interest in this locality is the occurrence of granite 300 or 400 feet east of the opening, this forming the mass of the hill between the East Valley and the Road Gulch, and extending eastward to the crest of the Empire Ridge.

The enrichment of compacted sands that bear the relations described above to overlying shales of the Monterey type and to a heavy body of underlying granite upon and against which they rest, is noteworthy; the occurrence is repeated in the Gavilan Range, northeast of King City. It substantiates the fact that the sandstone is very probably but the storage reservoir of oil derived from shale, and that it may come from above as well as below the receiving stratum. The age of the sandstone is undetermined.

OTHER DEPOSITS IN THE SANTA CRUZ DISTRICT.

Scaroni quarry.—This quarry lies about 1¼ miles southwest of the property of the City Street Improvement Company. It is opened near the summit of the Enright Ridge and overlooks Major Creek. It can hardly be considered more than a prospect. The series of rocks exposed includes a thin cover of Monterey shale at the summit; underlying this about 30 feet of bituminous, quartzose sandstone, locally a grit, the interstices filled in varying degree with bitumen; and below this, again, a series of calcareous quartzites and grits, 70 feet thick, slightly bituminous, carrying layers in which there appears considerable débris of comminuted fossils of undeterminable nature. Much calcite is developed through this zone. Beneath this, all is covered, but it is believed that granite is not far distant, for directly across the gulch, and a little below, it was found in outcrop.

The bituminous sandstone of the Scaroni quarry is of the same general composition as that of the City Street Improvement Company, and displays many of the same features of jointing, bedding, etc. It is, however, somewhat more brittle and possibly of somewhat lower grade as exposed in the bluff.

It is impossible to correlate the Scaroni deposit with any of those of the region of the City Street Improvement Company's quarries. The Scaroni is opened just beneath the 500-foot terrace, while the mines at the head of the Walrath Ridge are opened in the terrace above this. If the deposits are practically the same, the Scaroni must be in a sandstone that was deposited at a lower level on the granitic slope of the earlier range; or there must be a concealed fault between the two localities, the Scaroni deposit being depressed some 150 feet. The writer inclines to the first explanation.

Enright quarry.—This quarry lies less than half a mile a little south of west from the Scaroni, on the opposite or western side of the same ridge. The sandstone which constitutes the product is the same as that of the Scaroni prospect and has the same general features of composition and structure. Seventeen feet is exposed, but the deposit as barren sand extends somewhat below this. There are occasional clay inclusions in the bituminous sand, in one of which was found the cast of a bivalve. A bivalve was also found in the shale of the region overlying the sandstone. On the west side of the quarry are several clay inclusions of considerable size, as though rolled from an adjoining terrace into the sand. As at the Scaroni prospect, the overlying shales form but the merest coating; this is, in fact, the condition for this entire terrace. Remnants of a fine pebble beach occupy the summit of the ridge in the locality of the quarry.

Immediately west of the Enright quarry shale comes in at the same elevation as the bituminous sandstone, and in localities shale and sandstone have the appearance of dovetailing. Traces of shale also appear on the east side of the sandstone.

West of the mine there has been considerable fissuring with corresponding venation of minute sandy dikes through the shales.

Six feet of bituminous sandstone are exposed in the seaward bluff of the same terrace as the foregoing; one or two minor beds appear below. These are, perhaps, the equivalents of the Enright and Scaroni deposits.

Regarding the geology of Major Gulch below the quarries of the City Street Improvement Company, it may be added that the bituminous sandstone horizon, in which is opened the Scaroni and Enright mines, is traceable for a considerable portion of its length. It is also found in some of the tributaries of the stream north of the Enright ridge. Throughout this area, while impregnation has been extensive, there are localities in which the bitumen appears to be entirely wanting. In such instances the sandstone may be either soft and friable, or of excessive hardness and thoroughly infiltrated with carbonate of lime, weathering like limestone and frequently outcropping in the form of spires that stand prominently up from the hill slope, or yet remaining in contact with the shale, particularly at the higher levels.

Sylva quarry.—This quarry is opened immediately west of Major Creek, just above the Coast road. Although in a terrace considerably lower than the Scaroni prospect, and with perhaps a strike fault between, it is opened in what is apparently the same bed, with much the same succession of strata. Thirty feet of bituminous sandstone are exposed, and the same general composition and structure are met with that were found at the Scaroni opening. Shales overlie the sandstone; beneath this the slopes are covered. The strata at the Sylva quarry have a seaward dip of 10° to 20°.

Along the sea cliff between the Enright and Walrath ridges the Monterey shales which there outcrop show evidence of bitumen seepages, as though possibly from a sandstone underlying at no great distance.

Baldwin quarry.—This quarry lies about 2 miles south of those of the City Street Improvement Company, in a short canyon tributary to Baldwin Creek. Ten thousand tons have perhaps been shipped from the opening. The quarry is at about the same altitude as the Scaroni and Enright, but there is in this locality a little irregularity in the terrace levels, rendering correlation of the beds uncertain. The Baldwin quarry is, however, opened at an assuredly lower altitude than the property of the City Street Improvement Company.

The series of strata at this point include the usual sandstone and shale, the latter of the type variety and with the minute fossil organisms, structure, joints, and dikes characterizing the terrane at other points. The sandstone is varyingly rich, in part, doubtless, from proximity to the surface. Twenty-five feet are exposed at the western end of the quarry; 16 at the eastern, 150 feet distant. The upper 10 feet at the western end is outcrop. The 10 feet below this was apparently once rich in bitumen, but is now somewhat dried. In this layer there are numerous small bodies, one-half inch to 1 inch in diameter, of white to yellow sand, in cross section showing a white ring with black center, the ring barren, the center bituminous. This feature renders much of the bed undesirable. Beneath the foregoing is 5 feet of first-quality rock, chiefly quartzose, moderately hard and tenacious. Underlying all is 6 feet of impoverished sand passing to cover immediately below. While the foregoing is the nature of the rock as appearing in the face of the quarry at the present time, it is not to be taken as precluding a better condition of the bed within.

Wilder prospect.—This lies about a mile east-southeast of the Baldwin quarry, in the terrace next below. The prospect is in a quartzose, medium-grained to gritty sandstone, with shales above, the base not exposed but probably near. At a little distance up the slope is a mass of orange sand overlying a bituminous portion, the latter gritty and even conglomeratic. One or two hundred feet north of the prospect is a small mass of granite protruding from the creek bed up into the bituminous sandstone, or more correctly, a granite mass around and upon which the sandstone was deposited. This is another evidence of the early and perhaps independent deposition of the sands which have been impregnated with bitumen in this region; they may not be, in fact, of the Monterey.

BITUMINOUS SANDSTONE DIKES OF THE SANTA CRUZ DISTRICT.

Throughout the region of the quarries of both the City Street Improvement Company and the Cowell property are numerous bodies of sandstone, which partake somewhat of the nature of dikes. Fig. 41 suggests the variety encountered. The dikes are of sand impregnated with bitumen, and occupy fissures that have been opened to greater or less widths and in greater or less irregularity through the Lower Neocene shale. The general features of the dikes have already been referred to in the description of the foregoing quarries, but it is desired here to especially call attention to their variability in size. They are recognized of 7 or 8 feet in thickness and as passing upward through the shale for 50, 75, or even 100 feet. They may rise directly, or may break from this to a curved, diagonal, or zigzag course across the stratification. They may ascend for a distance of a foot or two in width, broadening to 6 or 8, thinning again to nothing. All this is but what might be expected of a crack in such material as the Lower Neocene shale, and of a filling of sand rendered more or less plastic by the presence of a thick bitumen. There are, however, still greater bodies of sandstone about which the writer confesses he has been unable to come to a definite decision as to their origin and geologic relations. These are the bodies of rock that have been quarried at the Thurber, New, and Hole mines. In places they have the appearance of beds; at other points they resemble, it is thought, enormous dikes, or at least masses of sand that have been squeezed into openings in the shales.

SALINAS VALLEY DISTRICT.

Bituminous sandstone is scattered along the length of the Salinas Valley and its tributaries for a distance of 50 miles midway its length. The localities best known and visited by the writer include one reached from Metz, one from King City, several prospects from San Ardo, and still others near Bradley. That reached from King City is perhaps the most extensive opening, and at the same time affords an especially good insight into certain relations which the bituminous sandstones are found to bear to the underlying and overlying rocks.

DEPOSITS NORTHEAST OF KING CITY.

Mylar quarry.—This quarry is located about 10 miles N. 60° E. of King City. It is opened on a short tributary of San Lorenzo Creek in an interior, park-like region within the hills that border the Salinas River on this side. It is reached by what is known as the Priest Valley road from King City, a road of easy grade with a single divide of between 600 and 700 feet.

The topography of the region under discussion is suggested in the accompanying sketch—a basin, the rim from 1,000 to 1,500 feet higher than the floor. San Lorenzo Creek cuts it with irregular course from east to west.

The geology of the region consists of a central granite dome, indicated in the sketch by the broken line. On the southern side of this

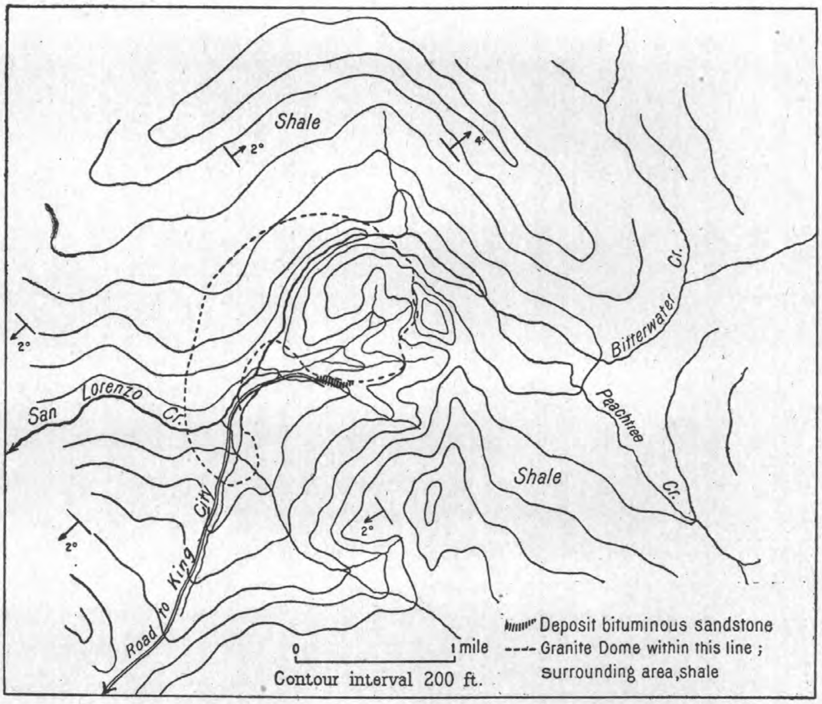


FIG. 45.—Region of San Lorenzo Creek, Monterey County, Cal. Shaded area, deposit of bituminous sandstone. Dotted line incloses a granite dome.

dome of granite is an old talus slope, the materials of which were derived from the granite, the fragments varying in size up to 4 or 5 inches in diameter. This has since been impregnated with bitumen. Resting upon both talus and granite, are Monterey shales attaining a thickness in the locality of perhaps 400 or 500 feet. The shales are prevailingly of the softer, chalky variety, and show minute foraminifera and other forms peculiar to the series. This formation is overlain by shales of the San Pablo or Middle Neocene, with characteristic mollusca at several horizons. The thickness of the Middle Neocene beds is approximately 150 feet. Above the Middle Neocene is a thin layer of conglomerate belonging to the upper division of the Neocene, the Paso Robles formation, followed on the higher points by a few feet of clays. The conglomerate carries pebbles of siliceous shale derived from the Monterey and a small amount of granitic débris, the matrix being quartz sand. The rock is hard, pebbles and matrix breaking across alike. The horizon is a conspicuous one over a comparatively wide region, by reason of its hardness frequently forming a shoulder in the ridge profiles, or a protecting sheet over greater areas. The San Pablo is apparently conformable with the Monterey in the locality in question. Between the Paso Robles and its older associates there is a general unconformity although not always observable in the dips.

The bituminous sandstone consists, aside from the bitumen, of rather coarse, sharp grains of quartz, feldspar, and some mica. It is frequently of the nature of grit or a fine conglomerate. The percentage of bitumen is variable, some portions being of considerable richness, others poor, and still others barren. The entire deposit is evidently but a local enrichment of a talus slope, which, were it uncovered, could perhaps be traced about the periphery of the granite. The color of the bituminous sandstone is black to brown, according to its richness or the degree of impoverishment, and it is correspondingly tough and gummy, or friable and crumbling. The mass of the rock is very porous, as is usually the case where the material is coarse; the interstices are but partially filled with the bitumen, as though the supply were insufficient for their complete occupation. As to the relations of the bituminous sandstone to granite or overlying shale there is no question of their uncomformity one with another.

Matthews quarry.—This quarry is located on the head of Chelone Creek, about 7 miles in a direct line east-southeast of Metz and perhaps an equal distance northwest of the Mylar quarry. The deposit here is practically a repetition of the Mylar deposit, an impregnated mass of arkose material derived from an extended body of granite lying to the west of it and overlain by heavy beds of Monterey shale. The talus consists of about 10 feet of coarse broken granite resting directly on the nondisintegrated portion of the latter. A finer sand of the same composition fills the interstices of this layer. Overlying this is a 2-foot pebble layer with the same interstitial bodies of sand. Above this is sand, increasing in fineness from base to summit. The whole series has been impregnated with bitumen, excepting, of course, the fragments of granite themselves. The layer of broken granite, the pebble layer, and 10 feet of sand immediately overlying, carry a high percentage of bitumen in their interstitial space; the upper 15 feet of the sand, however, perhaps because near the surface, is of an impoverished nature, brown and friable.

The main opening at this point is hardly more than a comparatively large prospect. Near by, however, are one or two other openings probably on a continuation of the bed just described. At all of the openings the lines of sedimentation dip toward the east, i. e. down the slope of the underlying granite terrane.

From the foregoing it will be inferred that there may occur at many points within the general region like deposits of bituminous sandstone, for the conditions must have been repeated many times. While none others were found in outcrop, granite itself was seen at a number of points even in the lower hills of the main Salinas Valley.

SAN ARDO DEPOSITS.

The deposits of this region lie along the uplands bordering the Salinas River on the west. They have been prospected in a slight degree opposite the town of San Ardo, a station on the coast division of the Southern Pacific. They occur as impregnated sandstones in the Middle Neocene series. The measures are here upturned in conformity with the structure of the Palo Escrito Hills. The strike of the beds in the region of the deposits is generally about N. 12° to 20° W., the dip E. 40° to 85°. Locally, however, a westward dip of 10° to 15° may be found, a crumple in the strata. The structure of the country was not determined, but at a distance both topography and the lines of outcrop suggested an anticlinal axis, either secondary or primary, at no great distance in the mountains to the west.

The terrane of bituminous sandstone is reported for a distance along the strike of 5 or 6 miles, although the observations of the writer were confined to a length of about 3. The series consists of shales overlain by 125 feet of sandstone varyingly impregnated with bitumen; this is followed by about 400 feet of shale, which is in turn overlain by a succession of shale and sandstone, a half dozen beds each, the sandstones here again enriched. While the foregoing comprise all of the beds of this nature that are known in the region, it is evident that others may occur both above and below, depending simply upon the material which was laid down locally in Middle Neocene time. Within a short distance east of this series beds of later gravel and sands occur, resting unconformably upon the older formation.

The bituminous sandstone forming the 125-foot bed consists chiefly of rather coarse quartz grains, together with a little feldspar, the whole infiltrated with the bitumen. The exposures were practically in outcrop, and it was difficult to judge as to actual percentages. It is believed that originally the amount of bitumen was high, and in depth it may be found so even at the present day.

The upper series of bituminous sandstones, that in which these rocks alternate with shale, is of fine-grained material, and while in the main typical sandstones, in some instances have the appearance of modified shales, with but indistinct definition from those of actual shaly structure. The amount of bitumen carried by these sandstones was comparatively small, perhaps owing to their occurring in outcrop.

The separating shales are of the softer, chalky variety, as seems to be more commonly the case in the Salinas Valley, in distinction from those of clayey texture in many other localities. They were also observed to carry both the minute organisms, together with traces of molluscan remains, in this respect, as well as in their texture, resembling the series in the mountains east of King City and Metz.

Of incidental interest is the appearance in the shales of this region of local bodies of calcareous quartzite, which may be continuations of the purer sandstones, of which portions are impregnated with bitumen. None of the quartzites was found impregnated, and the correlation of the beds for the general locality is somewhat in doubt.

Again, it is worthy of note that wherever a true, noncalcareous sandstone is found in the San Ardo region included in the shales of the Middle Neocene, it generally shows at least a trace of bitumen.

DEPOSITS NEAR BRADLEY.

The deposit of this locality is of the nature of a bituminous sandstone and conglomerate, and is found upon either side of the San Antonio River, 5 or 6 miles west of the town of Bradley. The strata have a general strike of N. 40° W., and a dip of 40° to 85° eastward. The deposit is perhaps of a formation younger than the Monterey series, for the coarser materials are derived from shales resembling the underlying, and there is some evidence of unconformity between the conglomerate or sandstone and the shales. Moreover, with the shaly constituents are incorporated also others of granite, and in some instances what appear to be eruptives. This bed is impregnated with bitumen in varying degree, in some portions rather richly, but it has thus far been prospected by the merest pits. Aside from the actual variation in the amount of bitumen that filtered into the bed there is also a variation dependent upon the composition, the more pebbly layers being naturally much poorer than those of finer grain, for nowhere were the pebbles observed to be in the least degree infiltrated. The bed can doubtless be traced for several miles through the foothills of the range, although it is questionable if it is at all points enriched, even in a slight degree.

The shales of the Monterey are here decidedly cherty in many of their layers, but intervening are many bands of the soft, chalky variety. The series has apparently a thickness of several thousand feet, but it may be that a portion of it is the result of duplication by faulting. This is suggested, although in nowise proved, by a bed of conglomerate and sandstone similar to that described above, devoid of bitumen. If the series is in succession the distance between the two conglomerates is something like 2,000 feet.

From the foregoing descriptions of the deposits in the Salinas Valley it is evident that the nature of the Middle Neocene series is somewhat at variance with that in many regions of California, perhaps because of its greater development. The Salinas Valley series carries a far greater proportion of chalk rock.

SAN LUIS OBISPO DISTRICT.

The San Luis Obispo district of bitumen-bearing rocks embraces an area of about 80 square miles south and southwest of the town of San Luis Obispo; it is coincident with the ridge of moderate height that separates the San Luis Valley from the sea, and which is the southeastern end of the San Luis Range. This range to the northwest attains a much greater general height, with peaks of 1,500 to 2,000 feet elevation. It is of varied formation, of intricate plication of strata, and has undergone extensive modification by erosion. The northwestern half is especially rugged. The portion involved in the present report is cut transversely by the three creeks, San Luis Obispo, Pismo, and Arroyo Grande. All afford excellent geologic sections. The details of topography may be gathered from the map (Pl. L).

The geology of the region has been worked out by Mr. H. W. Fairbanks, under the auspices of the Survey, and will doubtless have been published by the time the present report is in press. The accompanying map has been condensed from Mr. Fairbanks's manuscript sheets, by his permission and by the authority of the Director.

THE FORMATIONS.

The formations delineated embrace: The Franciscan series, described in the opening section of this chapter; the Monterey[1] shale, in its full development and characteristic features; the San Pablo formation, which is that of especial interest in the discussion of the asphaltic sandstone deposits; the Paso Robles formation; and the deposits of Pleistocene times. In addition to these are numerous eruptives, which on the original map are all delineated, but which, for the sake of clearness in the exposition of the features of immediate importance in this discussion, have been omitted from the accompanying excerpt, or at least combined with the formations with which they are associated.

Mr. Fairbanks's description of the Monterey, San Pablo, and Paso Robles formations is of such excellence that it is deemed desirable to give here a brief of his text. Of the Monterey, he remarks:

The succession of strata in the Monterey formation in the region of San Luis Obispo may be generalized as follows: Beginning at the bottom, conglomerate and sandstone beds varying greatly in thickness at different points, clay shale, rhyolite tuffs and ash, limestone and bituminous shales. [The sandstones and conglomerates, which have their greatest development beyond the region under discussion, have a thick-

[1] The Monterey formation is designated simply "Lower Neocene" in the legend of Pl. L. This is due to the fact that the Survey recognizes the priority of the application of the name Monterey to the Silurian formation of Virginia, and when Pl. L was at proof stage it had been determined to use the general term Lower Neocene in this paper for the California formation; but later, when proof of the text was in hand, it was concluded that it would be better to adhere to the familiar name in this economic paper. Then, however, the plate had been printed.—EDITOR.

JULIUS BIEN & CO. LITH. N.Y.

ness, according to Mr. Fairbanks, of 5,000 to 6,000 feet.] Clay shales come next above the sandstones. In the region of San Luis Obispo they have a considerable thickness in some places, but in others are absent. Farther to the southeast in the Coast Ranges they attain a great thickness and are richly impregnated with gypsum and the alkalies.

The shales are followed in ascending order by volcanic beds, mainly of ash and pumice. At several places in the San Luis quadrangle these beds are several hundred feet thick, not continuous but divided into several distinct portions by beds of clay shale which may reach a thickness of 100 feet or more. This condition is well illustrated upon the coast near Pismo. [Numerous other occurrences have also been observed both by Mr. Fairbanks and the writer. Molluscan remains have been found in the ash by Mr. Fairbanks.]

The limestone beds of the Monterey formation have a somewhat irregular thickness. They are chiefly confined to the horizon between the volcanic ash and the siliceous shales which come still higher in the formation. The limestone attains a thickness of about 300 feet along the southern slope of the Santa Lucia Range east of the town of San Luis Obispo. As a general thing, however, the thickness is much less. A microscopic study of the limestone shows it to consist in large measure of nearly obliterated skeletons of calcareous organisms, chiefly foraminifera.

Within the area under discussion the siliceous shales, or bituminous shales, as they were called by the older geologists, constitute the greater part of the Monterey formation. Eastward from San Luis Obispo Creek they pass beneath the San Pablo formation, although still outcropping as a narrow fringe upon either side of the San Luis Range.

These shales have been so frequently referred to by the writer that a further description is here unnecessary. It may be remarked, however, that in the intercalations of white, chalky material that are a feature of the series, Mr. Fairbanks has detected not only their diatomaceous nature but has found commingled a very considerable per cent of matter of volcanic origin.

Mr. Fairbanks offers some valuable suggestions as to the origin of the shaly members of the Monterey just referred to, but it is unnecessary to state them at this time.

The San Pablo formation has been referred to in the earlier portion of this chapter. Mr. Fairbanks, who has studied it in all its variations in southern California, describes it as a series of soft, white sandstones, conglomerates, diatomaceous beds, and flinty shales. "Abundant fossils show it to be of Middle Neocene age, but whether it should be placed in the Miocene or Pliocene has not been determined." It is conspicuously unconformable with the Monterey, both in dip and in the materials constituting it. In the San Luis Obispo region, where it is impregnated with bitumen, it is mainly a sandstone of quartzose material, the grains fine to medium coarse, and both angular and round. Occasionally other minerals are present—feldspar (?), particles of shale derived from the Monterey, and traces of eruptives from adjoining localities. With the quartz these latter materials may be of pebble size, forming thus a conglomerate. This is the case at the eastern of the quarries near the railroad a mile southeast of Edna; the bituminous sandstone here carries two layers of such conglomerate, one 15 feet thick, the other but 1 foot. The thicker is the coarser, and is apparently the higher layer by between 20 and 30 feet. It may be that this is of the conglomerate referred to by Fairbanks as lying at the base of the San Pablo. The sandstones of the region under discussion are impregnated with bitumen to per cents ranging from 0 to 14. This variability seems to depend on the fineness of rock grain and the amount supplied, instances of both being thought to have been observed.

The Paso Robles formation occupies the southeastern portion of the San Luis Valley and a considerable area about the town of Arroyo Grande. Mr. Fairbanks remarks that the two bodies were probably once connected. He adds:

> The greatest thickness shown by these beds is about 200 feet, a little south of Arroyo Grande. About Arroyo Grande the beds show no disturbance, for the stratification dips no more than usual for shore deposits. The formation is made up in great measure of fragments of Monterey shale which are often considerably cemented. In addition there are some sandy and clayey strata.

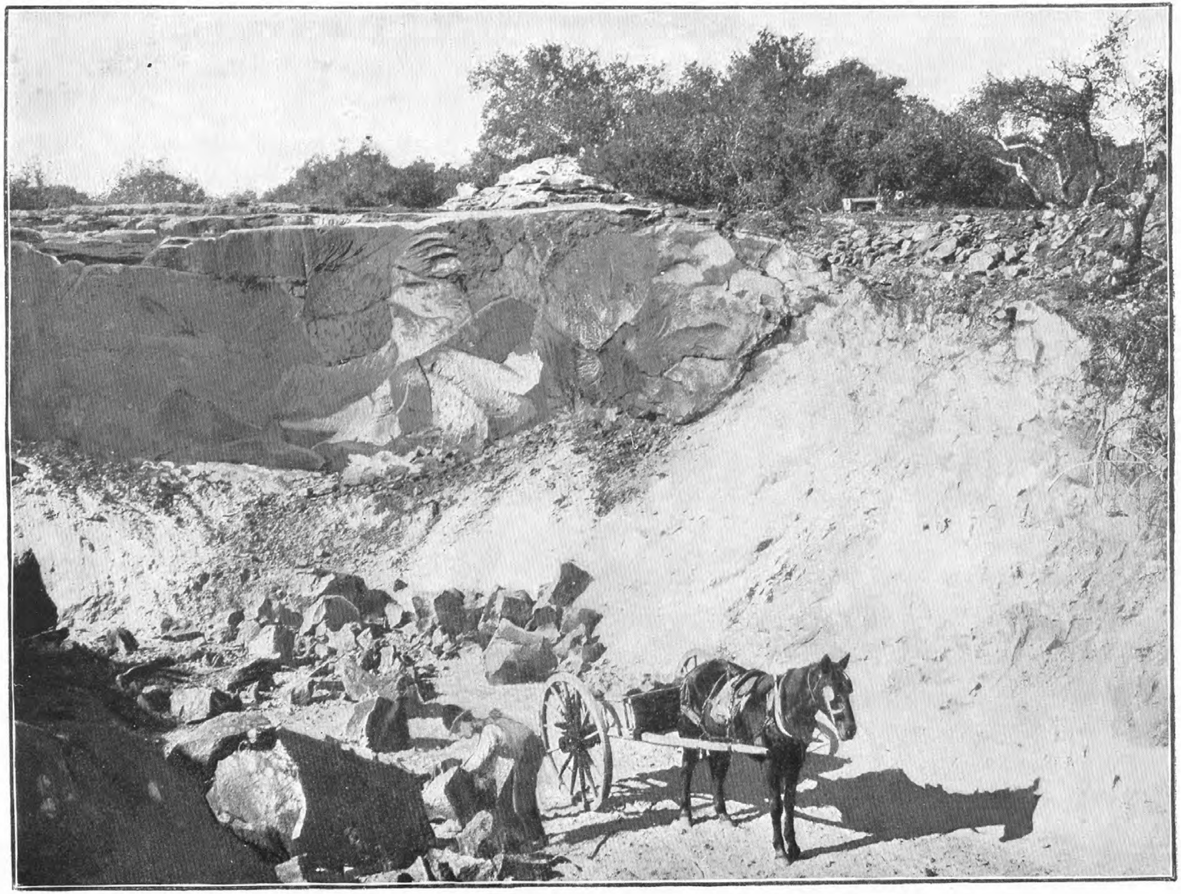
The Paso Robles is unconformable with the formations below.

STRUCTURE.

The structure of the San Pablo formation in the region under discussion is broadly that of a gentle syncline, with minor folds of local importance. The gentleness of the folding in the formation mentioned is replaced by the sharpest crumpling in the region of the Monterey to the north, and, indeed, in that to the south as well. The San Pablo beds rarely display dips greater than 40°, but the older formations have been tilted even to the vertical position. Fractures and faults, also, are more general in the Monterey strata; and it is in these, too, that eruptives abound, having cut their way up through the mass of the beds at frequent intervals.

The axis of the general syncline in the San Pablo trends about N. 60° or 70° W. and lies in the middle of the trough. The latter with its gentle curvature, is well shown in the crests of the hills between Pismo and San Luis Obispo creeks. The border of the terrane shows a somewhat greater crumpling of the strata than the center, and the beds usually have a steeper dip. The folds in the Monterey have the same general trend as in the San Pablo, showing the continuity of the movements begun in earlier times, although with a gradual diminution in the forces that affected the folding.

Of the minor folds within the gentle depression of the San Pablo is an anticline whose axis lies along the Pacific Coast Railroad from the vicinity of Pismo Creek eastward. The axis is practically coincident with the valley occupied by the road. The southern half of the fold is conspicuously exposed in the heavy cliff-forming sandstone overlooking the valley on this side (Pl. LII); the northern half appears in the San Pablo that occupies the summit of the hill north of the valley, this itself carrying a slight syncline of limited area; the crest of the



THE WEST QUARRY, SAN LUIS OBISPO BITUMINOUS ROCK COMPANY.

Showing contact of enriched and barren portions.

arch has suffered extensive erosion. While the foregoing statement suggests a simple fold in the region referred to, by reason of the difference in elevation of the beds on either side of the axis, faulting, also, is suspected of having taken place. Moreover, Mr. Fairbanks, while delineating no faults on the map, indicates in his text the possibility of their presence in this region. The eastern extent of the fold just described was not determined, but it may continue for several miles.

Another area of minor folding is that about Indian Knob, a sharp anticline passing through this eminence in a N. 70° W. direction, an equally sharp syncline lying immediately north, the north side of which is, finally, a portion of the southern slope of the rim of the general syncline. South of the Indian Knob anticline the strata pass into the gentle central depression of the broad syncline, of which the axis passes up the open park in that vicinity. South of this the northerly dip prevails, a gentle swerving of strike or dip in one direction or another being alone perceptible. The valley of the San Luis Obispo Creek is crossed by the synclinal axis a little north of Sycamore Springs. West of the valley the syncline is generally preserved with all clearness to the end of the San Pablo terrane, only occasional traces of the variable dip being found. On passing into the Monterey, however, the crumpling, and the irregularity of structure so common in this formation, at once manifests itself in force.

In the region of the mouth of Price Canyon, and showing partiularly on the east side of the entrance, is a small anticline accompanied by one or two even smaller crumplings. The axis of the anticline trends N. 70° W., the dip on its either side is gentle, and the affected area is perhaps a half mile wide by 2 miles long. West of the creek is a small body of the San Pablo, almost an outlier in an area of Monterey. The details of the relations of the two formations are somewhat confused, for the folding is exhibited at the line of union of the two formations which are, moreover, unconformable with each other. Even the shales themselves display considerable variety of composition, while beds of a rhyolite tuff are also present. The arch of the anticline described is well exposed in a quarry of bituminous sandstone that has been opened in the San Pablo at this point.

The region between Pismo and Arroyo Grande creeks presents a clearly defined synclinal structure for the San Pablo terrane, but there are within its confines, especially in the higher ground in the vicinity of canyons No. 1 and No. 2 and of Carpenter Canyon, many changes in strike and dip, all gentle, and representing the merest undulations of the strata induced at the time of the general uplifting of the San Luis Range.

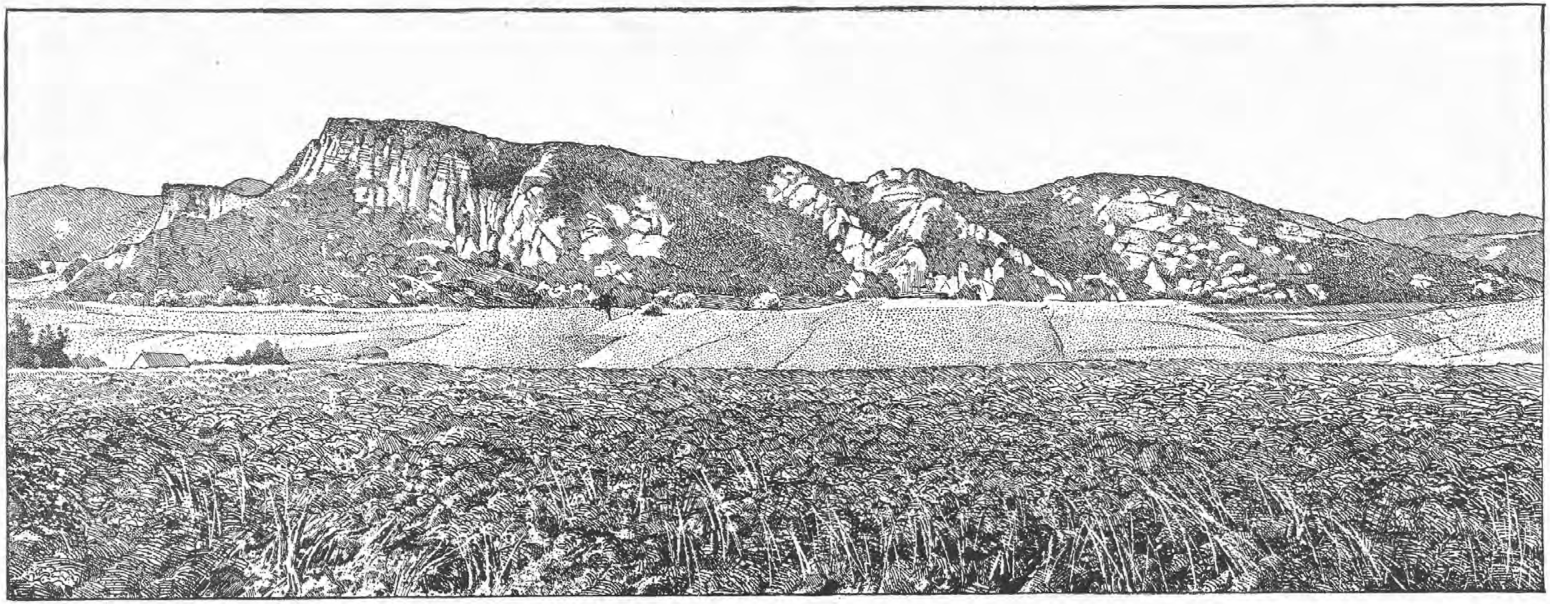
The small portion of the San Pablo east of the Arroyo Grande belongs apparently to the northern half of the general syncline under description.

In the map of the region it has not been deemed desirable to plat the dips of the minor folds because of the confusion that would have resulted to the clear delineation of the general broad syncline.

THE QUARRIES.

The quarries of the region here discussed are chiefly distributed about the periphery of the San Pablo terrane, but not a few have been opened well within its border. Unopened deposits also are exposed at many localities throughout the area. Indeed, it would seem that the San Pablo formation has been impregnated with bitumen for its whole extent in the present field, but with marked variation from point to point. Some localities show barren rock alone; others a bed with only traces of bitumen; still others a rock enriched sufficiently to afford a product of first grade. Many of the quarries, however, have been long abandoned, and it is impossible to judge unerringly of their actual contents. At the faces as now exposed the rock has an inferior appearance, not so much on account of general poverty in bitumen as because of the variation of the bitumen from stratum to stratum; indeed, even in the same stratum. This is due to differences in the coarseness and porosity of the rock, which affect both the space offered for the reception of the bitumen and the ability of the rock to afford an easy channel for the flow of the bitumen to its final resting place. The entire appearance of the field is a repetition of the occurrences observed in other portions of the United States, and suggests the deposits of the present day as but the remnants of ancient oil pools, the oil dried and perhaps oxygenated by exposure to the atmosphere through the folding and erosion which the beds have undergone. The San Pablo has acted as a conspicuous storage reservoir for the oil that was probably derived from the Monterey.

The quarries of the San Luis Obispo region embrace a score or more of openings of various sizes, many of which have long been idle. That most important at the present time, though but recently opened, is the West quarry, lying near the crest of the ridge, a mile west of the railroad as it enters the San Luis Range from Edna. It is the No. 1 of the map. The opening is in a body of impregnated sandstone, of which Pl. LI affords an idea. The rock itself is fine grained and even textured, and in the main consists of quartz, but with traces of the same feldspar-like mineral found in the rock of the Santa Cruz deposits. The grains are both sharp and round, and are apparently cemented by the bitumen alone. The per cent of bitumen is nearly 15, and the rock is one of the best in appearance to be found in California. It is black on fresh fracture, weathering gray to brown. It is tough and tenacious, and its use as a paving material is said to be satisfactory. The area occupied by the deposit and the local variations



RIDGE OF SAN PABLO SANDSTONE, SAN LUIS OBISPO DISTRICT, CALIFORNIA.

Numerous old quarries of bituminous sandstone at base of ledge.

in its bitumen per cent are undetermined, but are matters of easy definition. The sandstone itself is continuous over a region of many miles, of which this is a local enrichment.

A point of much interest at this quarry is the sharp and irregular line that defines the impregnated from the unimpregnated portion of the stratum. This, but for débris, would appear quite across the lower edge of the face, sloping downward to the south; it is only partially shown in the illustration. The portion of the line which underlies the bituminous rock is marked by the usual zone of brown and white banded sandstone, here from 1 to 2 feet thick. Laterally, however, the passage from rich to barren rock is more abrupt, and without the banding just described. The appearance here is as though a flow of oil, having penetrated the bed, had extended in the direction of the stratification as far as the supply permitted when further impregnation ceased. There is for a foot or two from the richer rock a diminishing degree of impregnation, but being with the stratification rather than across it, the banding is wanting. The features of occurrence here again suggest an ancient oil pool as the original of the deposit.

The position of the enriched body of sandstone is north of the axis of the general syncline, the dip being toward the S. 15° to 20°, the strike about N. 70° W.; there is, however, in the region about the quarry more or less undulation of the strata.

Four quarries of bituminous sandstone have also been opened on the same property within a quarter of a mile west of the railroad. Three of these are in the southern face of the outer or northernmost ridge of the general uplift, and one is in the northern face of the next ridge south, just across the valley from the first. The sandstones at these points have a strike of N. 60° to 70° W., with a dip of 45° to 50° toward the south. The stratification lines are distinct, though the bed itself is massive. In composition this rock resembles that of the ridge quarry just described, though it is distinctly coarser and at times even gritty or pebble bearing, with quartzose, granitic, and serpentine débris. The grade, also, of the rock available as a product, appears to be somewhat lower, which may be due to texture and grain, or to the original supply of the bitumen. It is, however, sufficiently high to be of economic value.

At the opening farthest west the bed as exposed consists of an upper layer of brown, nearly lifeless, rock, 6 or 7 feet thick (2 of fig. 46); underlying this (3 of the cut) a zone particularly rich, 15 feet, but narrowing somewhat toward the western end of the cut; below this a second brown rock, 18 feet (5 of the figure), separated from the richer zone above by 2 feet of a deep brown, semiimpoverished band, and from the underlying barren sands by a zone of still further diminished bitumen contents, of the utmost irregularity, a foot or two wide, and cutting the strata diagonally (6 of fig. 46). The lower brown zone (5) is even poorer than the upper, but it carries occasional irregular bodies of enriched sand, which, however, add nothing to the value of the bed. The variability in the thickness of the sediments and in their

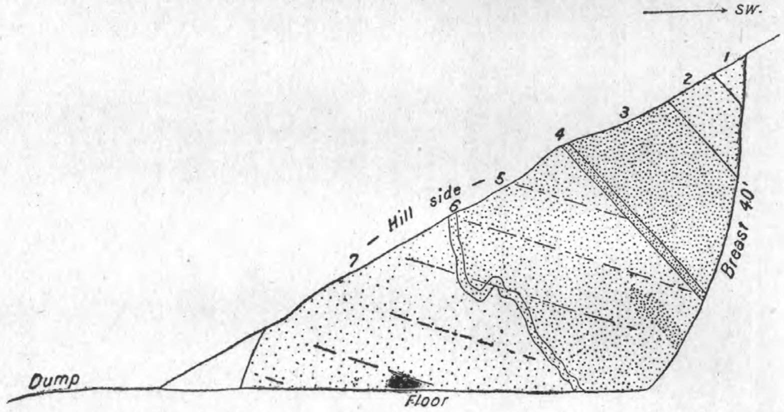


FIG. 46.—Quarry features: 1, lightly impregnated; 2, impoverished, dead brown; 3, rich zone; 4 deep brown; 5, less bitumen than in 2; 6, transition band; 7 white sandstone.

coarseness of grain and texture are noticeable features throughout the quarry. This has doubtless had its influence on the product.

The three openings in the south face of the north ridge, immediately west of the railway, are practically on the same bed, although the horizons of at least two of them differ somewhat. The western two are

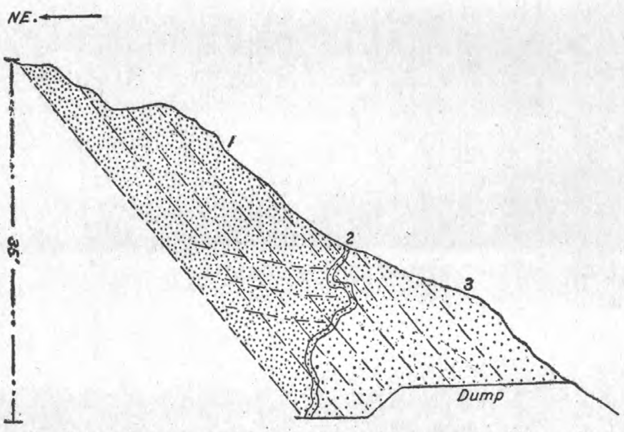


FIG. 47.—Quarry features: 1, rich rock; 2, transition zone; 3, white sandstone.

separated by a short interval of unexploited hill slope. The interval to the eastern is a little greater. Stratification is clearly defined in all, as are also the lines between the impregnated and barren portions of the beds. The latter deserve especial mention. They cross the bedding planes diagonally, but with irregular trace (fig. 47), and are usually marked by a narrow streak of brown sand, often without the banding, however, which such lines have when coming beneath an impregnated body of rock The bedding planes pass uninterruptedly from the white, barren, to the black, bituminous portion. There are, also, indications of a white sand beneath or back of the exposed bituminous strata of the quarry figured above, though perhaps only locally.

The quarry adjoining the foregoing on the east is opened in a horizon that appears to be a little higher, the barren sand, shown in the lower portion of the face of the former, underlying, perhaps, the impregnated body of the latter. The relations, however, are not quite definite.

At the third quarry on this side of the gulch (4 of the map, Pl. L) there is apparently a bituminous zone, 20 or 30 feet wide, crossing the beds irregularly and separated both above and below from white, barren, friable sandstone, the materials of which are, excepting for the lack of bitumen, the same as of the impregnated portion. Both upper and lower lines of the impregnated zone are clearly defined. Within the underlying white sand, which is particularly exposed in the higher portion of the quarry, is an irregularly shaped mass of sand that has also been impregnated with bitumen. It is not far distant from the main enriched zone, and it may have been a chance deposit from the latter.

In considering the possible explanations of the relations between barren and impregnated bodies in the four quarries just described the possibility of the leaching of the sandstone in the parts now barren, owing to their contiguity to the surface, presents itself. But it is believed, rather, that these portions were never impregnated; that the bituminous zone is merely the locus of a flow from below, after the beds had been lifted practically into their present position; and that the irregularities in the forms assumed by the deposits, and the lines defining them, are due to variety of texture coupled with steepness of pitch; in other words, that the infiltrating oil followed the general horizon of the bed in its inflow, but spread from one layer to another according as a channel was presented it. In the folding to which the strata were subjected, as suggested, before the influx, the arrangement of the constituent minerals may have been somewhat disturbed, thus allowing an easier passage across the planes of bedding than would have been permitted had the beds remained in an undisturbed or, at least, uncrumpled position.

The extent of the deposition in the more steeply dipping beds of sandstone has never been ascertained so far as could be learned. In a more or less enriched form the outcrops may be traced from a half mile to a mile west, while eastward they are continued in the quarries across the creek, another half mile distant. In depth, boring alone will determine their extent.

In the hill to the east, across the creek from the quarries just described, are two openings (6 and 7 of map, Pl. L) in the same bituminous sandstone, one at the end of the spur indicated on the map, the other east of this, across the hill and road nearby. The general features and composition of the rock are here the same as to the west. The conglomerate phase, however, is particularly developed at the easternmost quarry, where there are two layers separated by 20 to 30 feet of enriched sandstone, the upper layer 10 to 15 feet thick. These conglomerates are, of course, worthless as paving material, but both openings show heavy bodies of available sandstone, the western having afforded a large yield in the past. A sample from the long-exposed face of this quarry contained 11 per cent of bitumen. The remaining material is chiefly quartz, fine to coarse, and both angular and round. The customary uneven and steeply pitching line of division between the rich and barren portions in the beds of high dip is again in evidence, and shows the same independence of stratification lines as already described in the quarries to the west. At the western of the two openings under discussion this line is most irregular in its course, passing beneath a part of the bituminous zone at a steep but wavy pitch. There is usually a brownish zone between the two kinds of rock.

The dip of the bed at the west quarry is obscure, due to its position in a region of crumpling. At the east quarry there is the same obscurity, with suggestions of a pitch to the north, changing to the south within a few hundred feet north. The strike of the strata at both quarries is N. 65° to 70° W. Monterey shales occur to the south of the quarries, and it may be that the valley in this direction is entirely occupied by them, coming as they do beneath the arch of the anticline in the San Pablo sandstone of this locality. The shales also outcrop in the northern slope of the hill in which the quarries are opened, bordering the broad valley that extends to the base of the Santa Lucia Range. This is in keeping with the general structure of the locality, the bituminous sandstone of the present hill, in its suggested syncline, uniting with that clearly developed in the sandstone in the summit of the ridge next east, while to the west it joins the sandstone across Pismo Creek, and, in the sweep around the western end of the Monterey to the south, that of the lofty cliffs in the high ridge in this direction. There is, however, more or less doubt as to the details of structure for this entire region.

The high ridge south of the Pacific Coast Railroad (see the map, Pl. L) east of Pismo Creek is conspicuous for the great development of the San Pablo sandstone and the lofty cliffs which it forms on the northern face. The sandstone has a thickness that can be but little short of 300 feet, with still other members added, perhaps, in the high land to the south. Of this great thickness about 80 feet in the lower half has been in varying degree impregnated with bitumen. Of the 80 feet, the lower 40 feet alone is especially enriched. Whether this lies at the very base of the formation is uncertain, but it is not far above it.

The impregnated zone, as, indeed, the entire sandstone, consists of varyingly coarse and angular quartz grains, with a local distribution at certain horizons, chiefly the lower, of pebbles of quartz, granite, and eruptives, all derived from comparatively nearby terranes. The coarseness of the material affords interstices of considerable size. Cross bedding is pronounced. The composition, coarseness, interstitial space, and cross bedding have all influenced the degree of impregnation with bitumen which the rock has undergone. The bed is, in fact, of a spotted nature, with comparatively little regularity in the distribution of the flow or the course which the latter pursued. From the relations of the enriched to the more barren portions, and of the latter to parts free from bitumen, the appearance is as though infiltration, after the accession of the bitumen, proceeded laterally along stratification planes, the upper and under lines undulating, the mass of the flow seeking the channels which were freest.

The above ledge is again opened at several points along the ridge. At some the rock has a far richer appearance than at others, and it is also more solid and tenacious, while the portions of low grade or entirely barren are reduced to a minimum. Again, the reverse is the case. The thickness enriched and the general features of the rock thus vary considerably. Apparently, too, the horizons worked are not everywhere precisely the same.

The largest quarry in this ridge is that nearest Pismo Creek. The location is well toward the crest in a heavy sandstone that is quite similar to that of the other quarries in the ledge. The horizons however, may, or may not be the same, for faulting has possibly taken place along the front of this hill. The bitumen at this quarry is more completely disseminated through the mass of the rock than at the associated openings, but there are lines of clayey matter interlaminated with the sandstone, which, though very thin, form a conspicuous feature of the face.

The rock of the quarries just described is apparently of lower grade and more variable in composition than that opened nearer the railway and at the present quarry of the San Luis Obispo Bituminous Rock Company. This may be attributed to the difference in the original material of the rock, and to the texture and the fineness of grain, rather than to any marked variation in the amount of the inflow of bitumen.

West of Pismo Creek a quarter of a mile, and about a half mile within the San Pablo terrane, is an old quarry (see the map, Pl. L) in the same sandstone as that of the quarries in the ridge just described.

As in the latter, so here, the dip is southward from 20° to 25°, the strike being about N. 70° W. The quarry is opened in the back of the strata but shows little difference from the openings in their face. The thickness of bituminous sandstone exposed is about 25 feet. Unevenness of impregnation again prevails, rich and poor spots showing at intervals across the breast. The upper portion of the rock has been considerably dried, the dividing line between rich and dried being irrespective of dip, and on the contrary, practically parallel with the hill surface. This is a feature of beds of steep dip.

Within the confines of the San Pablo terrane there are several other openings in bituminous sandstones, either of the same or different horizons as those of the quarries already described. Of these, one is located immediately east of the mouth of Price Canyon, a half mile from Pismo. The rock is a coarse-grained sandstone of considerable thickness and moderate richness. The face of the quarry suggests a per cent of bitumen about equal to that in the heavy sandstone of the cliffs south of the Pacific Coast road.

At the western end of the San Pablo terrane, also, in the region about Harford Canyon, there are several outcrops of sandstone more or less impregnated with bitumen, but which have been hardly prospected. At the opposite extremity of the terrane, in the region of canyons Nos. 1 and 2, Carpenter, Bee, and Corbett, indeed extending to and beyond the Arroyo Grande Valley, are many outcrops of the sandstone showing bitumen, but they remain unprospected. The single exception to this is a quarry just above the town of Arroyo Grande, where a cut in the Paso Robles formation, a short distance below the crest of the hill, has exposed a bed some 7 or 8 feet thick that is available for local use. The bed is strongly conglomeratic and in the quarrying has required separation of the finer sandstone from the pebbly mass. It is hardly of broad economic value when compared with the higher grade rocks of the State, or when the limited extent of the deposit is considered.

The San Pablo formation, it will be seen from the foregoing, is one in which bitumen has been broadly distributed in varyingly rich proportions. The terrane suggests in the spotted character of the enrichment the accumulation within it of numerous oil pools, irregular and indeterminate in shape, some connected, some distinct. The oil which has been converted into an asphaltic material was probably derived from the Monterey shales which underlie. Perhaps the crumpling which the strata of this series have undergone has been conducive to the yielding up of its bitumen to the overlying sandstone. As regards the extent of the deposits of bituminous sandstone, it is useless to speculate; the outcrop gives only a single dimension. There are, however, deposits of unquestioned value in the region; for example, the present quarry in the ridge west of Pismo Creek opened by the San

Luis Obispo Bituminous Rock Company. As compared with the Santa Cruz field, the region of distributed bitumen is more extensive, but the rock appears, with exceptions, to be of a lower grade and more variable in its bitumen contents.

THE CARPENTER OIL WELL.

The Carpenter oil well (see the map, Pl. L) is located in the canyon of Pismo Creek, opposite the lofty ridge of bituminous sandstone of the San Pablo terrane bordering the Pacific Coast road on the south. The well starts in the bituminous sandstone at the level of the valley bottom, and its bore afforded the following section, which is taken from the account in the Tenth Annual Report of the California State Mineralogist, 1890, page 576:

Section of Carpenter well.

128 feet. The sandstone; "indications" of petroleum at base.

260 feet. The sandstone continued to this depth, when a flow of black maltha came in.

295 feet. Sandstone here replaced by bituminous shale.

376 feet. Shale of the bituminous variety continued from the 295-foot point to here, with one or two thin beds of sandstone; the shale produced oil.

422 feet. Bituminous shale from 376 to 422 feet, with a 3- and 5-foot band of sandstone, the latter oily; also one or two thin layers of white slate.

486 feet. From the above to here bituminous shale, producing water and gas in small quantities; bottom of well in a sandstone.

The maltha of this well continues to stand within 10 or 15 feet of the surface. It has not been considered of sufficient quantity to be of value. There is especial interest attaching to the occurrence of this oil at this point, for that it is found to exist in the shale is doubtless the explanation of its presence in the overlying sandstone.

TAR SPRINGS.

On Tar Spring Creek, a tributary of the Arroyo Grande, about 20 miles southeast of San Luis Obispo, is a considerable surface deposit of asphalt, derived by seepage of a thick, black petroleum or maltha from the underlying Monterey shales. The main deposit covers an area 200 feet in diameter and occupies the bed of the valley. On a hillside at the north, 30 to 40 feet above the valley, is a second deposit, independent of the first but probably derived from the same source. The valley deposit is on the increase from springs which at present flow perhaps a half gallon to a gallon a day. The maltha rises to the surface in connection with sulphur water, as is commonly the case. About the springs the material remains soft and treacherous to the foot. At a distance and where shielded from the sun's heat, it has hardened and become brittle. The thickness of the valley deposit is variable, conforming to the floor upon which it was deposited. In general, however, there seems to be 3 or 4 feet, increasing to 10 or 15 feet in places. The hill deposit is of minor importance.

The asphalt shows an appreciable, though small, percentage of fine sand, and such débris as may have become engulfed in the flow over the surface. Stratification lines are present, and certain layers are more impure than others.

The hill deposit is an asphalt of practically the same composition as that in the valley, but the inclusions are derived from the shales, not from the valley débris.

SANTA MARIA DISTRICT.

TOPOGRAPHY, STRATIGRAPHY, AND STRUCTURE.

This district embraces the region of La Graciosa and Azufre hills, which border the broad valley of the Santa Maria River on the south and southwest. The altitude of the hills is 500 or 600 feet above sea level, and their general trend is NW.-SE. Casmalia Creek rises on the edge of the Santa Maria Valley, but instead of flowing northward into the river of this name turns almost at once to the southwest and passes through the hilly region dividing the territory of La Graciosa Hills from that of the Azufre. La Graciosa Hills themselves are cut in two by La Graciosa Creek, which also heads within the general valley of the Santa Maria, but flows south through the elevated country referred to. Topographically, the Azufre Hills are the more rugged. La Graciosa Hills, although of the same order of structure as the Azufre, are capped with a heavy deposit of what are probably Pliocene sands, which have softened their contours and modified their summits. The Azufre Hills are more ridge-like in their form, while La Graciosa consist of many irregularly placed knobs and ridges.

The geology of the region embraces an underlying series of folded Monterey shale of both the soft and more organic material and that which is hard and siliceous, but the former predominates. So far as observed by the writer, this series of beds was not exposed at any point in its entirety. Overlying the Monterey unconformably, and especially developed in La Graciosa Hills, is the heavy and extensive deposit of Pliocene sands, grits, and conglomerates already referred to. The composition of the later deposit is chiefly quartzose, although there is a mingling of other débris derived from the underlying shales and from the granite and eruptives of more or less distant localities. Of still later age are the valley deposits of the Santa Maria and, most recent of all, the great body of drift sands at the mouth of this river.

The structure of the district is developed out of a number of folds in the Monterey shale their axial trend in the Azufre Hills being about N. 55° W., in La Graciosa Hills, for the region under discussion at least, somewhat north of east. In the area between La Graciosa and Casmalia creeks the strike is a little north of west, this region connecting the structure of the other two. No attempt was made to work out the details of the many folds and their relationships; but in the Azufre Hills, along the road from Waldorf south, there was

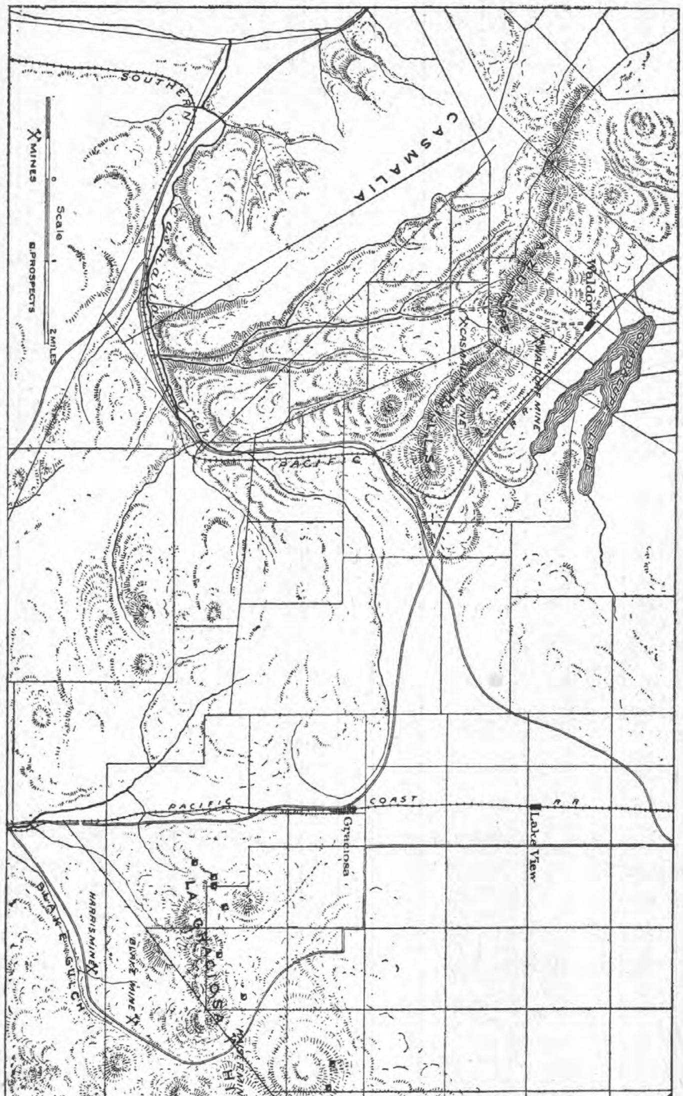


FIG. 48.—Sketch map of Santa Maria district, California.

observed a prevailing central fold somewhat to the north of the topographic axis of the ridge. It is probable that in La Graciosa Hills there is also a predominating central ridge, indications of which were seen, but the cover of Pliocene prevented observations in detail.

The Pliocene of La Graciosa Hills and of the Azufre Hills where found shows a less degree of folding than the underlying Monterey, yet the movement that produced the pre-Pliocene ridge has apparently been continued subsequent to the deposition of the materials of this age, for gentle dips of from 2° to 10° are to be observed in the later formation.

THE DEPOSITS.

The asphalt of the Santa Maria district embraces two varieties; one a high-grade black material found in veins, the other an impregnated shale, from all appearances. The two varieties may be found in the same locality, but the veins are especially developed in La Graciosa Hills in the region indicated on the map as the Kaiser, Blake, and Harris properties.

Veins.—The Kaiser property has been especially well developed and shows veins of the purer asphalt in both the shale of the Monterey and in the overlying sandstone of the Pliocene. It is quite prob-

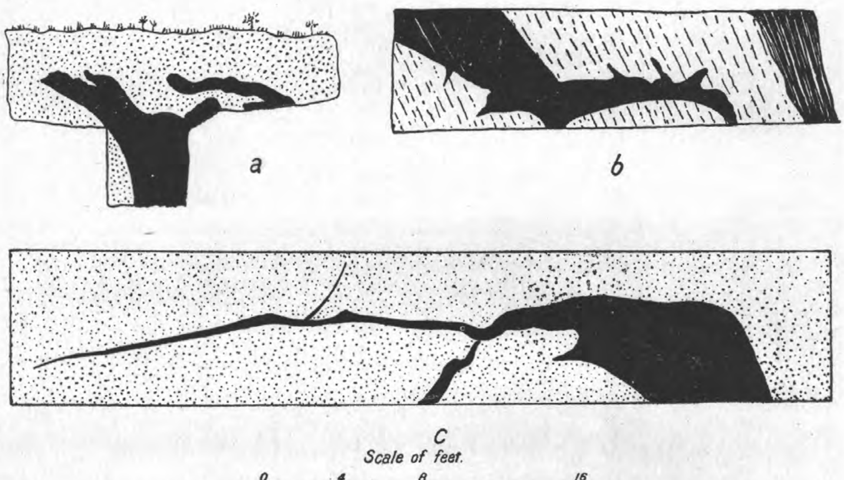


FIG. 49.—Vein features, Santa Maria district, California.

able that such veins pass from the one to the other of the formations. In the sandstone they are particularly clearly developed and have the appearance of originating in cracks irregularly disposed through a mass of fairly coherent sand or sandstone. The shape assumed by the veins is of infinite variety, at one point being a mere thread, less than an inch in width and of unknown length; at another point, a few inches to 1 or 2 feet in width by a considerable length; and in still a third instance having the form of a great irregular mass that filled an equally irregular chance cavity. The outlines of the veins in the sandstone are perceptibly less jagged than in the shale. There is an occasional infiltration of the sandy walls by the bitumen which flowed into the fissure, and there is generally a border to the veins, an inch or two in width, of brown altered asphalt that has evidently been derived from the general body by the weathering to which the mass has been subjected owing to the porosity of the sandstone. The asphalt also shows inclusions of clay, themselves more or less enriched. These do not, as a rule, form a high percentage of the vein variety, at least in the sandstone, although there are instances when they occur in such numbers as to impart a brecciated appearance to the material.

The veins of purer type occurring in the shales bear a close resemblance to those in the overlying sands, and have practically the same features, but they are somewhat more irregular of outline and show the displacements that are so often present in the shale and are wanting in the sandstones. They are also somewhat more inclined to the brecciated structure.

Impregnated shale.—The second variety of asphalt in the district under discussion has more the appearance of a shale which has been highly impregnated with bitumen, and that occurs as zones in the general formation. These zones have, in the main, the inclination of the strata, but there are at times irregularities of outline that suggest an inflow through the general mass by way of the channels which were most feasible by reason of variation in texture. In other words, there is a slight resemblance between the channels of this nature in the shales and those in the steeply dipping sandstones of the San Luis Obispo region. These interbedded bodies of bituminous shale were observed at a number of localities, the most conspicuous of the occurrences being at the Casmalia mine, on the western slope of the Azufre Hills. Here, within a distance of 200 feet, several such layers were found. They were also observed on the Hobbs place, a half mile west of the Kaiser openings (lower sketch, fig. 49, *c*). In some instances veins of the purer asphalt are found in their immediate locality, or even cutting them.

In some localities, as though derived from the more highly enriched bituminous shale, are bodies of asphalt which are apparently of comparatively high grade and yet have a brecciated structure to such a degree that from their association with the actual beds described above they may be regarded as having been derived from the latter. This is but natural, since everywhere the shales of the Monterey give evidences of greater or less crushing and rearrangement of their fragments.

THE PROPERTIES.

Kaiser.—On the Kaiser property there must be in the neighborhood of 30 or 40 openings, some showing the veins in the sandstone of the Pliocene, others those in the shale, and still others the impregnated zones described above. While there is not a well-defined regularity in the occurrence of the veins, the prevailing strike seems to be rather with the strata, i. e., northeast-southwest. Their inclination is high, sometimes to the northwest, at others to the southeast. They are distributed over an area of a mile or two (on the strike) by a half mile across the measures. They have been opened by tunnels and shafts, the latter inaccessible at the time of the writer's visit. Considerable material has been taken from the openings and rendered into mastic at a small refinery built by the company formed to operate the property. These openings are on the north side of La Graciosa Hills.

Blake and Harris.—The Blake and Harris mines are located on the south side of La Graciosa Hills, from 1 to 2 miles distant from the Kaiser openings. Both properties were in the main developed by shafts, which are now inaccessible and do not therefore permit an estimate of the size of the deposits. From the Blake a considerable amount of material was apparently derived and refined at the company's kettles near by. A few tunnels and surface cuts show the nature of these deposits—veins and zones—to be the same as of those to the north of the ridge. On the Blake property there is an additional point of interest in the occurrence of a band of shale, 100 feet or more across, which was originally impregnated with a varying per cent of bitumen, and which for some reason, either of spontaneous combustion or prairie fires, has been burned. The fuel was the contained petroleum. The shale now appears red, ash-like to hard and clinker-like, glazed or silicified; bodies of bitumen contained within this have the appearance of a coke, as though derived from the solid fixed carbon of the petroleum. Nor is this the only place in which this phenomenon was observed. A second locality is in the region of the Telford prospects—to be described later—in the ridge south of Los Alamos or north of the Santa Ynez River. In both regions the area affected is considerable—in the Telford several acres, in La Graciosa Hills reaching along the outcrop of the horizon for at least a mile.

In regard to the impregnation of the shales of this region it may be observed that they are of the porous, soft, white, chalky variety, which is far more susceptible to infiltration by bitumen, or of its development within their mass, than the hard, siliceous variety that occurs at many other points in the State, and perhaps here at a depth beneath the surface.

FOSSILS.

One of the features of the deposits of this region, including both the La Graciosa and Azufre hills, is the abundance of fossils that are found in the vein asphalt—well-preserved bivalves and gasteropods. The age of these has been determined by Dr. W. H. Dall as Pliocene. The bed from which they were derived has not been found. Their only observance has been in the veins or in a mass of sand-cemented shell by the side of a vein. The occurrence is peculiar, although not of especial economic importance. Among the forms identified by Dr. Dall are *Parapholas californica*, *Nassa californiana*, *Macoma inquinata*, *Cerithiopsis* sp. (also found in the Pleistocene at Santa Barbara), *Turritella*, *Natica cancellaria* and *Crepidula princeps* Conrad.

It is hardly necessary to enter into a detailed description of each opening that was examined in this great district, for statements regarding them would be but repetitions, and of little service beyond the discussion herewith given.

COMPOSITION OF THE ASPHALTS.

The composition of the asphalts of this district is that of a sandy shale impregnated with bitumen, or of a bitumen carrying a large per cent of clastic material derived from the shale. Two samples of first and second grade varieties from veins, obtained by the writer for the purpose of study rather than for the determination of their economic value, yielded 41.74 and 29.15 per cent of bitumen respectively, with some bituminous organic matter. Sixty-eight per cent of bitumen is said to have been obtained from occasional samples by others. It is quite possible, for throughout the entire field the greatest variation in bitumen percentages was clearly observed. The different grades are not confined to different localities, high and low rock being observed at almost every opening visited by the writer, whether in the La Graciosa or the Azufre hills.

LOS ALAMOS DISTRICT.

TOPOGRAPHY, STRATIGRAPHY, AND STRUCTURE.

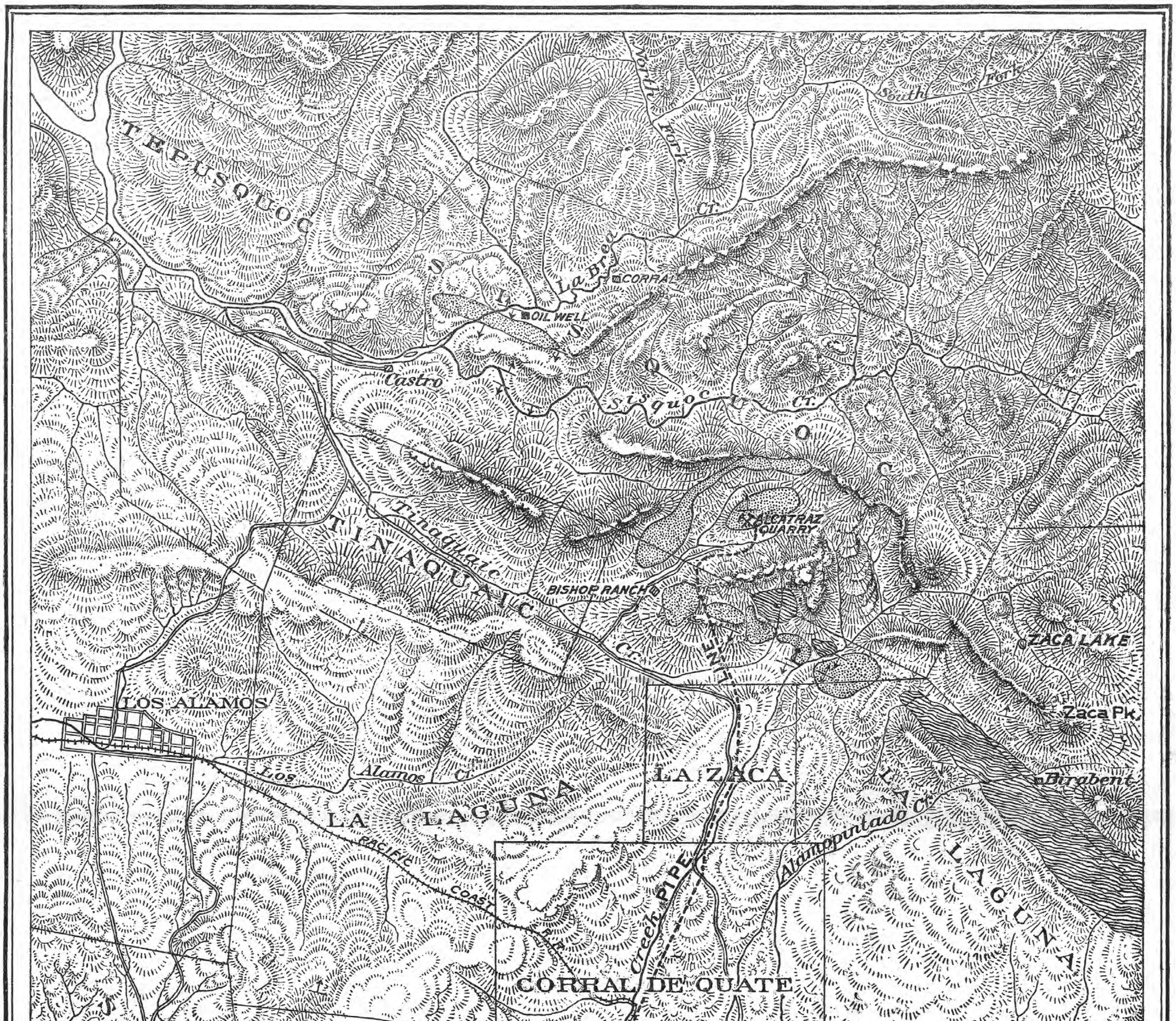
The region about to be discussed may be designated by the name Los Alamos, which is that of a town centrally located with reference to the numerous deposits of bituminous sandstone and purer asphalt that occur in its vicinity. The area embraced is about 15 by 20 miles and lies in the western portion of Santa Barbara County. The San Rafael Range borders it on the north, the Santa Ynez Range on the south. The principal streams are La Brea, Sisquoc, and Tinaquaic creeks, tributaries of the Santa Maria River, and the Santa Ynez River, with its tributaries Alamopintado, Zaca, and Santa Rosa creeks (Pl. LIII). The country can hardly be called rugged, for except in the San Rafael Range, the elevations are less than a thousand feet above sea level; the hills are fairly well rounded, and the valleys often open and well cultivated. The San Rafael Range, however, is sharp of topographic outline, for it consists of heavy sandstones, hardened shales of the Monterey series, and the resistant jaspers and cherts of still older periods. The country is reached by the Pacific

Coast Railroad of the Southern Pacific system. Although Los Alamos is the more central town, Santa Ynez is considerably the larger and more important, while Los Olivos is the terminal of the railway. The region is divided into numerous ranches, of which the Sisquoc, Tinaquaic, La Zaca, La Laguna, San Carlos de Jonata, and Santa Rosa are of especial interest in the present discussion. Of the bituminous sandstones the principal deposits occur on the Sisquoc and La Laguna ranches. The deposits of purer asphalt lie in the ridge separating Los Alamos Creek from the Santa Ynez River.

The formations of the region embrace a series of jaspers, cherts, and serpentines, probably referable to the Franciscan series; a great series of typical Monterey shale with some sandstones; a younger deposit of heavy bedded sandstones, perhaps Middle Neocene, with still others of the Pleistocene. The jaspers and serpentines were encountered in the lower portion of the southern slope of the San Rafael Range, their position being indicated on the map. They are highly contorted, and altogether have the general features of the Franciscan series in the region of San Francisco. An occurrence of interest in connection with the Franciscan series was observed in a high bluff just north of Alamopintado Creek, where, as a lens included in the serpentine, was found a limestone consisting very largely of Pliocene shells, as determined by Dr. Dall. In view of the supposed age of the serpentines, it is thought that the deposit was formed by the accumulation of sediment and shells in a crevice of the older rocks at the time they perhaps formed the sea bluffs. It is assuredly difficult to account for the occurrence on any other ground. In his report to the writer Dr. Dall remarks the similarity of these fossils to others collected in the asphalt and associated rocks of La Graciosa district.

The earlier Neocene of the present region consists in the main of the usual soft, white, chalky shale and the harder, drab, siliceous beds; both show the customary minute organisms, foraminiferal and radiolarian. Intercalations of sandstones and of rhyolitic tuffs also occur. This series forms nearly the entire northeastern portion of the region mapped, the hills between Tinaquaic and Los Alamos creeks, and again those between the latter creek and the Santa Ynez River. The strata lie in folds, with average dips of 30° to 50°.

The later Neocene includes a conspicuous body of sandstones at the base of the San Rafael Range, which is again met with in the Santa Ynez Range south of the river of this name. In the vicinity of La Zaca and Alamopintado creeks the Pleistocene sands and gravels occupy the valley between the two ranges just mentioned, and are also seen in the Tinaquaic and Los Alamos valleys. The map delineation of these formations has not been undertaken for lack of data, which it was not necessary to collect for the discussion in hand. All are unconformable with one another.



SKETCH MAP OF LOS ALAMOS DISTRICT, CALIFORNIA.

In structure the Los Alamos region presents a series of folds, which are in general coincident with the topographic ridges and valleys. The northernmost are of those that go to make up the San Rafael Range, and embrace Monterey and Franciscan strata. That between Tinaquaic and Los Alamos creeks is also a gentle uplift of the Monterey, which in the vicinity of the Alamopintado Creek disappears, but to the west passes into La Graciosa Hills. Another fold is the anticline between the Los Alamos and Santa Ynez streams, likewise appearing to rise from the valley in the vicinity of Los Olivos and Santa Ynez; it extends westward to the sea with but little complication. The Santa Ynez Range, which divides the valley of this name from the Pacific to the south, is a further anticline, of most pronounced character. Opposite the area under discussion it attains a height above sea level but little over a thousand feet. This increases to the east until, in the vicinity of Santa Barbara, it has an elevation of from 3,000 to 4,000 feet, with a few of the peaks of even greater height. It is worthy of note that the valleys of the region under consideration for the most part occupy the synclinal troughs. It is possible that some of them also occupy fault lines, but no attempt was made to acquire details of structure except in so far as they bore upon the occurrence of the asphalt. The general trend of the folds for the Los Alamos district, and, indeed, for a great stretch of country beyond, is N. 70° to 80° W., the dips being north and south. Excepting in their trend, however, there is but little regularity in the disposition of the folds, and their axes, both longitudinal and transverse, vary greatly in length. In addition to the main and conspicuous folding that has been described there are frequent crumples of minor importance.

SISQUOC-LA LAGUNA REGION.

In the Los Alamos district the deposits of bituminous sandstone that are best known lie at the foot of or just within the San Rafael Range (Pls. LIII, LIV, *B*, and fig. 50). Of these, one of lesser repute crosses La Brea Creek, a mile above the Sisquoc. The others, more or less related to one another and having a considerable extent in the foothills of the range, occur in the southeastern portion of the Sisquoc ranch and just across its line, in La Laguna. The latter region will be first described.[1]

Stratigraphy.—The bituminous sandstones of the Sisquoc-La Laguna area are so disposed stratigraphically and topographically

[1] In explanation of the brevity of the following statement regarding the geology of this most interesting and noteworthy region, it is to be remarked that the Geological Survey was refused admission to the properties leased by the Alcatraz Company, including a large part of the Sisquoc ranch, on the ground that in the opinion of its directors no benefit was to be derived by the company from such investigation by the Survey. The general facts, however, are in the main as presented. In correlating the sandstones, the writer has severely felt the disadvantage under which he has labored, and he regards it as most desirable that someone more fortunate shall in the future revise the tentative conclusions of stratigraphy and structure that are expressed in the accompanying text.

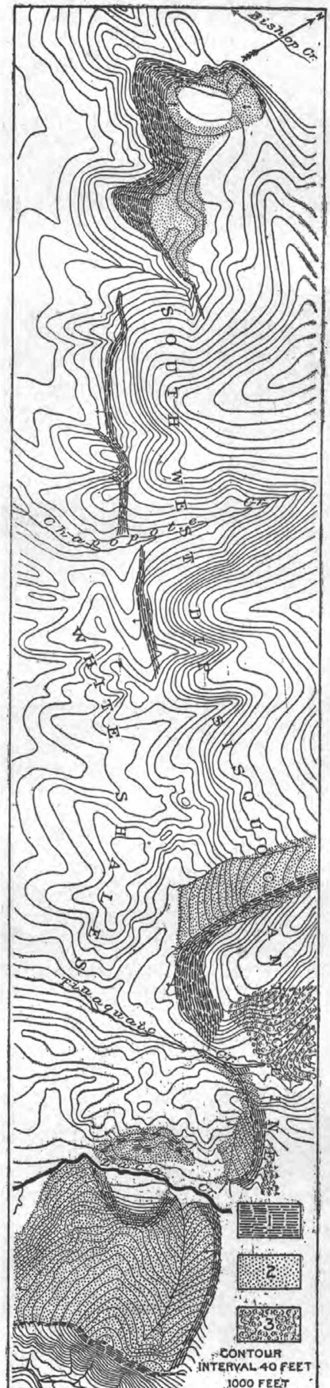


FIG. 50.—Foothills ot San Rafael Range, showing deposits of bituminous sandstone. (By permission of A. S. Cooper, State mineralogist of California.) 1, exposed strata of bituminous rock; 2, surface of bituminous rock; 3, serpentine.

that their proper correlation is attended with some doubt. Some of them appear to be members of the Monterey by inclusion in its shales; others, both along the base of the range and on its slopes, are so disposed to the shales as to appear of later age, of the Middle Neocene, at least. The latter sandstone is the more extensively met with, and is, perhaps, of greater economic value, although both are more or less heavily charged with bitumen. This sandstone outcrops at intervals for a distance of 3 or 4 miles along the base of the San Rafael Range. It is a formation of variable thickness, 0 to 125 feet, and in the intervals in which it is wanting in outcrop it is possible that its sedimentation was entirely absent. This does not preclude, however, its presence in depth at such points. The conditions of occurrence suggest merely an uneven surface of the shale upon which the sandstones, afterward bituminized, were laid down. Pebbles from older formations occur in it here and there. While the foregoing suggests the conditions of deposition, there is no doubt, also, that the sandstones formerly occupied a considerably greater area over the slopes of the range than they now show, for there are still remnants that reach to heights of 300 or 400 feet, notably immediately east of Zaca Creek, just west of Tinaquaic, and at the western end of the field.

The sandstones that occur as a part of the Monterey by their inclusion in its shales appear in the slope of the hills immediately east of Bishop Creek. These sandstones, although conspicuously divergent in dip from the shales of Monterey type, are nevertheless wedged between them, the two classes of rock dovetailing with each other in a manner most marked. This condition is illustrated in the accompanying view (Pl. LIV, *A*). Striking examples also present themselves a little west of this point, where the following section was observed:

A. SISQUOC REGION OF BITUMINOUS SANDSTONE, IN PART.

View from front ridge (3, fig. 51) northeast, looking into the interior. Alcatraz quarries in 125 feet of sandstone just above and to left of buildings. The sandstone also outcrops near the summit of the ridge beyond this. Between the ridges is a fault or sharp fold. (See profile, fig. 51.)

B. MONTEREY SHALES, WITH INCLUDED SANDSTONES, SISQUOC-LA LAGUNA REGION.

Here is an apparent unconformity between the two series of beds.

At the base of the series, the shales.

Resting upon these, the sandstone, with divergence of dip of fully 10° or 15°. This is the main sandstone figured in the view. There is one still lower in the shale, it will be observed, which a short distance beyond the point unites with the main bed above.

Overlying the main bed of sandstone on our line of section is a second mass of shale 20 feet thick, also disappearing a few hundred yards east, thinning by loss of layers at the top, and followed by a second bituminous sandstone 30 feet thick which unites with the lower. This sandstone is also unconformable by dip with the shales below.

Shales again succeed the second sandstone, with still other sandstones intercalated. The entire thickness of bituminous sandstone in this series is between 100 and 125 feet.

From the foregoing descriptions it will be gathered that the difficulty in correlating the sandstones is considerable.

A feature of interest at a horizon a little lower than the section just given is the presence in the shales of a band of material closely resembling in general appearance the rhyolitic tuffs that are found in the series at Pismo, in the San Luis Obispo region. The stratum was not followed, however, and the proportion of this rock to the series as a whole is unknown.

The bituminous sandstone of the Sisquoc–La Laguna region, whether of one or the other of the doubtful horizons, is almost wholly quartzose, the grains subangular to rounded, and generally medium in size. There are, however, in both terranes pebbles derived from older beds, especially the shales. The rock has been impregnated with bitumen, often to a high degree, a surface sample taken at random on the Bishop Ranch carrying between 14 and 15 per cent. At a depth from the outcrop this amount should increase materially.

Structure.—The structure of the southeasterly Sisquoc region, that over which the bituminous sandstones especially prevail and with which we are immediately concerned, is primarily an anticline, accompanied by a succession of minor crumples, with perhaps some faulting. The axis of the anticline lies well to the front of the range, along the face of the slope overlooking the Tinaquaic and adjacent valleys, the prevailing dips in the higher portions of the elevation being to the north, a southerly dip only appearing in the strata along the base or lower part of the mountain. To the anticline thus described Mr. Cooper, of the State mineralogical bureau, has given the name Sisquoc. The longitudinal extent of this fold and its immediate associates is great. At the west it rises from the valley of the Sisquoc near its confluence with the Tinaquaic. To the east it may be traced far beyond the limits of our area of exploration, its axis seeming to rise to the crest of the frontal ridge of the San Rafael Range, perhaps 10 miles east of Zaca Peak and Alamopintado Creek. From Zaca Creek east the heart of the anticline, as exposed, consists of the Franciscan jaspers, serpentines, etc. These rocks are also found at one or two other localities to the west, where denudation has been sufficient to lay them bare. The Monterey generally borders the Franciscan, although in the region of Alamopintado Creek the younger formations rest upon or against the jaspers and serpentines.

The crumpling and possible faulting that has accompanied the greater fold is not confined to the shales of the Monterey, but is a conspicuous feature of the bituminous sands as well. This is shown in a section across the ridges in the region of Bishop Creek, near the western end of the field (fig. 51), and again near the eastern end, in the knoll just east of Zaca Creek (fig. 52). In the latter locality the knoll in question is in the main occupied by an anticlinal crumple, but

FIG. 51.—Profile of bituminous sandstone beds, Bishop's Gulch. Light line, hill profiles; Heavy line, bituminous sandstone; Broken line, trace of latter in air; F?, fault or fold. 1, Alcatraz quarry; 2, Tinaquaic Valley; 3, Front Ridge.

in its northern slope the beds turn sharply up, forming an accompanying syncline. The folding is particularly well shown in the bituminous sandstone which caps the hill. The entire crumple is smoothed out immediately west of the creek, and the sandstones take on a general southerly dip beneath the later deposits of the valley, which holds nearly to Bishop Creek. The amount of dip is between 60° and 80°.

West of Tinaquaic Creek an arm of the sandstone extends up the slope of the range 300 or 400 feet, the upper portion dipping at a much lower angle than that at the base of the hill. West of this there is an interval of 2,000 or 3,000 feet in which the sandstone does not appear. As suggested above, it may not have been deposited at this particular point, the Pleistocene (?) beds overlapping. The sandstone reappears about 1,500 feet east of Chapopote Creek, continuing thence without interruption to a point nearly a mile west. Over this distance the thickness of the bed appears to be considerably less than the average for the region as a whole.

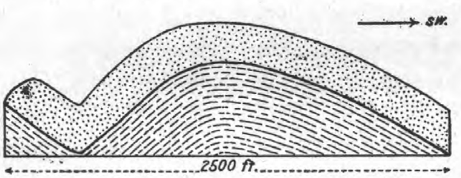


FIG. 52.—Fold in bituminous sandstone east of Zaca Creek. Monterey shales underlie.

In the region of Bishop Creek the crumpling is on a broad scale, and is effectively shown in the bituminous sandstone that occurs in the successive ridges for a mile or two into the interior of the range. Fig. 51 affords a key to the structure, the heavy line indicating the folds in the bitumen-bearing sandstone and their relation to the ridge profiles. The structure in the Monterey shale is not attempted. The quarry of the Alcatraz Company is opened in the middle one of the three ridges showing in the figure. Between the bituminous terrane in this and the north ridge the geological connection was difficult to observe at the distance permitted the writer, but to account for the apparent difference in elevation of the bed between the two sides of the intervening gulch there may be a fault in place of a simple fold. North of the northern ridge the geology is in doubt.

The folds just described were not followed eastward, and it is impossible to say what is the lay of the bituminous sandstone in that direction, at least within the outer ridge. In the front of this ridge, too, there is much doubt as to the ultimate action of the bituminous sandstone in this direction. Within a half mile of Bishop Creek the higher terrane disappears in a most remarkable way, apparently abutting the Monterey shales. It is wholly separated from the sandstone to the east along the base of the hills, as well as from that just below it in the neighborhood of Bishop Creek. Here, again, it may be that a fault, of which indeed there is some evidence, is the explanation of the irregularity. If so, the trend of the fracture is about that of the folds of the locality. On the upper portion of Chapopote Creek the Monterey shales show some folding, which to the north may have developed in a fault.

West of Bishop Creek the asphaltic sandstone is traceable for a half or three-quarters of a mile when, except doubtless for the part beneath the valley, it disappears by erosion. In this portion of the field the hills are capped by the sandstone, which shows still considerable folding, but markedly less than east of the creek. Well within the range there are sandstones that appear from a distance to be intercalated with the shales of the Monterey.

The eastern limit of the bituminous sandstone is found in a long, narrow tongue that extends for at least half a mile along the crest of the ridge, passing eastward from the knoll immediately east of Zaca Creek.

Quarries.—It is on one of the richer portions of the sandstones described in the early portion of this section that the Alcatraz Company has opened its quarry, in the ridge next north of that forming the front of the range. The position, topographic and geologic, is shown in Pl. LIV, *B*. The opening is in the southern face of the ridge, extending along its length several hundred feet. The rock exposed and quarried has a thickness of something over 100 feet, most of which is of good grade. The strike at the quarry is about N. 70° W., the dip north. The bitumen is said to be removed from the sandstone at the quarry by means of naphtha, in which it is carried by a pipe line to a landing owned by the company on the ocean front near Gaviota. It is then, according to account, separated by distillation, the naphtha recovered being pumped back to the quarry for further use as solvent and conveyer. The distance between the quarry and the refinery is about 35 miles.

While the foregoing is the only development of importance within the limits of the region of the Sisquoc, the evidence is that there are other deposits of perhaps equal value, especially along the line of the Sisquoc–La Laguna ranches. Prospecting just without the southern boundary of the Sisquoc has been light, but several small pits and tunnels show a rock of excellent quality.

LA BREA CREEK REGION.

The bituminous sandstone that has been described for the region covering the southeastern portion of the Sisquoc ranch and the immediately adjacent territory possibly again outcrops at the mouth of La Brea Canyon, 4 or 5 miles northwest of the first locality. Certain it is that a very similar sandstone here forms the outer slope of the foothills, striking about N. 70° W. and dipping 40° or 50° S. The sandstone outcrops in a heavy bed at the entrance of the canyon and may be seen ascending the hills on either side for a quarter to a half mile away. The sandstone, at the outcrop at least, is of the brown, dried variety, inferior to those outcropping in the region to the southeast. It is possible, however, that at a depth the weathering influence may have lost effect and that the grade of rock may prove satisfactory. The sandstone occurs in beds from 20 to 60 feet thick, forming a total series of hardly less than 250 or 300 feet. The composition of the sandstone is quartzose, with the more barren layers occasionally having a slightly clayey cement. The presence of such clay may account for the decrease in the amount of bitumen present. Siliceous shale and chert of Monterey type immediately underlie the sandstone, here apparently conformable.

The extent of this undeveloped bituminous sandstone along the front of this portion of the range is undetermined, nor was its connection with the great bodies to the southeast traced. In general, however, it may be said that it belongs structurally to an anticline developed, as it were, en échelon with that to which the Alcatraz deposits belong. The latter anticline may be traced northward from the region of Bishop Creek to the forks of the Sisquoc and Tinaquaic, where it passes beneath the general level of the valley, the axis dropping in this direction. The strata passing thus beneath the valley of the Sisquoc may be those that reappear with southerly dip at the mouth of La Brea Canyon. Throughout this field erosion has removed much of the original deposit of bituminous sandstone, giving to the terrane at the present day the appearance of isolated outcrops.

The region of La Brea Canyon, with its bituminous sandstone and the underlying typical Monterey shales, derives especial interest from the occurrence in the latter of petroleum. At the point indicated on the map, about 2 miles above the mouth of the canyon, a well said to be 1,000 feet deep has been bored, the sulphur water from it bringing up a heavy black petroleum of the general appearance and consistency of maltha. The flow, however, is not sufficient to give an economic value to the well. The boring was based on seepages of oil from the shales in the immediate vicinity. Indeed, for a half mile on either side of the well such seepages are to be found, many of them coming to the surface in springs of sulphur water. Occasionally the seepage seems to be of oil alone.

The structure of La Brea region is that of an anticline sufficiently prominent to warrant its being classed as one of the primary folds of the country, though secondary to the general uplift of the San Rafael Range. The axis of the anticline has a N. 70° W. trend, and crosses La Brea Canyon in the vicinity of the oil well and the nearby seepages. The strata here show more or less crumpling, and, indeed, some faulting of minor importance. The position and the concomitant fracturing are doubtless the occasion of the seepages at this point. The bituminous sandstones that occur at the mouth of La Brea Canyon on the southward dip of the anticline may prove the homologues of other but barren sandstones that outcrop in heavy beds about an equal distance above the axis of the fold, well within the range. Beyond this the stratigraphy and structure of the formations was not attempted, but Mr. Castro, long a resident of the neighborhood, reports seepages of petroleum here and there to the head of La Brea Canyon.

Evidences of minor folding exist in the Sisquoc Valley about the mouth of La Brea Creek, and it is also in this region that the anticline from the region to the southeast disappears.

The valley of the Sisquoc above La Brea Creek presents many irregularities of structure. Anticlines of importance occur from the mouth of the canyon up; heavy beds of sandstone appear a mile above the entrance, here barren of bitumen and uncorrelated; bitumen-bearing shales, also, are conspicuous at several points, while faulting has undoubtedly played its part in the general confusion. In the vicinity of an anticline just without the mouth of the canyon a prospect well was sometime since sunk in the mesa west of the stream, without results, however. In the bluffs near by the siliceous shales of the Monterey show slight seepages, while there also occur layers of slightly bituminous sandstone 3 or 4 feet thick, which have the appearance of intercalations in the Monterey shale, though at times seeming to cut across the strata, dike-like. The region is one of much fracturing, sandstones and shales alike showing its effects. No attempt was made to correlate the folds along the Sisquoc with those of La Brea Creek.

LOS ALAMOS RIDGE.

In the region between Los Alamos Creek and the valley of Los Olivos, on the one hand, and the Santa Ynez Valley on the other, there are a number of asphalt and bituminous rock deposits, the latter of shale or a fine sandy variety of this that has become impregnated

The ridge occupying the area in question consists in the main of the siliceous and chalky shales of the Monterey, which are crumpled into a number of irregularly developed folds, yet with one predominating anticlinal flexure of a N. 70° W. trend, the dips on either side averaging about 40°, though varying locally. Towards the western end of the ridge heavy deposits of a younger sandstone overlie the shales and form conspicuous outcrops over a greater part of the crest; although said to be locally impregnated with bitumen, no important deposits of the material are reported.

Zaca Creek.—The easternmost deposit of bituminous material is an asphalt of the purer type that occurs in a vein in the Monterey shale crossing Zaca Creek a half mile below the Pacific Coast Railway. The vein is unprospected, and shows but a few feet in length of outcrop, with a width of from 3 to 13 feet. Its trend is N. 25° W.; its dip vertical to 85° SW. The shales strike N. 70° W. and dip towards the north gently. The asphalt resembles that of other veins found in shales in California, at least in physical appearance. It is black, carries fine clastic material through its mass, and shows traces of the brecciation common to this variety. The asphalt is not, however, evenly enriched, judging from the play of the blacks and dark browns. The fracture is conchoidal; the odor strong.

Botija Creek.—The deposit next west of the above is one of a bituminous sandy shale and chalk rock in the Botija Valley, about 2 miles from its mouth. This occurrence seems to be an impregnated zone in the Monterey series, not a vein. The richer portion has a thickness of 10 feet, although 15 or 20 are more or less impregnated. There is considerable irregularity in the distribution of the bitumen as indicated by the lines between richer and poorer rock. The strike of the measures at the prospect is N. 70° W., the dip 40° S. The dip, however, changes to the opposite direction a short distance on either side, the strata showing several folds in the immediate vicinity. To the north about a quarter of a mile of outcrop may be traced, varying in richness. South, the bed almost at once turns up and in a strong exposure passes westward over the hills. It was followed for only a short distance and in a general way. It is one of several similar occurrences in the ridge under discussion, the chief value of which is, perhaps, the evidence it affords of the general presence of bituminous matter in the shales of the region. Boring for oil in the immediate vicinity of the outcrop of bituminous shale has been started, but was without results at the time of the writer's visit.

Telford ranch.—The Telford property, on Santa Rosa Creek, presents for inspection a few tunnels, shafts, and prospect pits well towards the heart of the ridge dividing the Santa Ynez and the Los Alamos valleys. The openings are about 3 miles west of that on Botija Creek. The Telford asphalt is in part of the purer variety that occurs in the form of veins, and in part appears to be an impregnated shale resembling that on Botija Creek. This latter rock, however, is somewhat obscured as to its exact nature by the fracturing which the beds of the locality have undergone; still, a bedded form is thought to be discernible. The vein-like bodies are more clearly defined and display many of the features of those in the La Graciosa district, including the border of brown, altered, material on the sides. All of the openings are small, permitting no insight as to the extent or continuity of their veins, or as to how many fissures there be that may have been filled with the asphalt. It is reasonable to suppose, however, that the same features of occurrence will be encountered here as at other points where like deposits have been opened in shales that have been extensively folded and fractured. The vein asphalt is of a very high quality. The position of the Telford veins is in the southern slope of the anticlinal fold that occupies the ridge of the locality, the axis of which is a little north of the ridge crest.

The ridge in question is capped by a heavy bedded sandstone that rests unconformably on the shales of the Monterey and carries in its lower layers some of the débris of these. This sandstone increases in importance to the west and is thought to be of Pliocene age. It is here and there bituminous, the bitumen doubtless having been derived from the shales.

The shales of the Telford region also show evidences of having been afire, with all the phenomena described for the La Graciosa district.

La Purissima ranch.—Ten miles west of the Telford exposures is a small tunnel showing a diminutive vein, also in shale; other prospects are said to occur in the same region, notably on the Wise ranch, a few miles west. While in the great stretch covered by the La Purissima and adjoining ranches there have not thus far been found deposits of asphalt that can be considered of especial value, the occurrences are of interest in the evidence they afford of the continued wide distribution of bitumen through the Monterey series.

SOUTHERN COAST REGION.

GENERAL FEATURES.

Stretching along the coast from near Point Conception to the region of the San Buenventura River is a narrow strip of terrace land, rarely over a mile or two in width, and from 100 feet in height at the ocean front to 200 or 300 feet at the base of the Santa Ynez Range. The terrace is cut transversely by numerous streams. Between these there may be heavy deposits of talus, or the original bench level may have been maintained, affording the areas now occupied by farms and orchards. The basal rock of the terrace for the greater portion of the distance is the Monterey shale, bordered along the mountain front by a heavy series of underlying sandstones that are by some believed to form the base of the Miocene. The strike of the beds is in the main that of the Santa Ynez Range, from N. 80° W. to W. Within the terrace portion the dip is prevailingly to the south, although with local minor variations rather of inclination than of direction. So also is the dip of the heavy sandstones that constitute so large a portion of the front of the Santa Ynez Range; but the structure of the range as a whole is anticlinal. On approaching the region of Santa Barbara the structure becomes complicated with a number of folds of a secondary nature, which are well shown in the crest of the range along the line of the Santa Barbara–Los Olivos stage road. To these folds and their en échelon arrangement is due the width of the terrace—from 3 to 4 miles between mountain and sea—in this locality. East of Santa Barbara simplicity of structure is again resumed, with a corresponding narrowing of the terrace.

Opposite the broader portion of the terrace the bench is underlain by heavy sands and gravels of Pliocene and post-Pliocene age, compacted to a considerable degree. The extent of these deposits along the ocean front is perhaps 3 or 4 miles, their width between 1 and 2 miles. The beds of post-Pliocene age[1] are especially prominently developed in the vicinity of More's Landing, about 6 miles west of Santa Barbara. It is here a gray, quartzose sandstone, 80 to 100 feet thick, and lies in an approximately horizontal position, or, possibly, with a slight synclinal flexure, the underlying Miocene shales steeply pitching and locally sharply crumpled. The two formations are unconformable with each other.

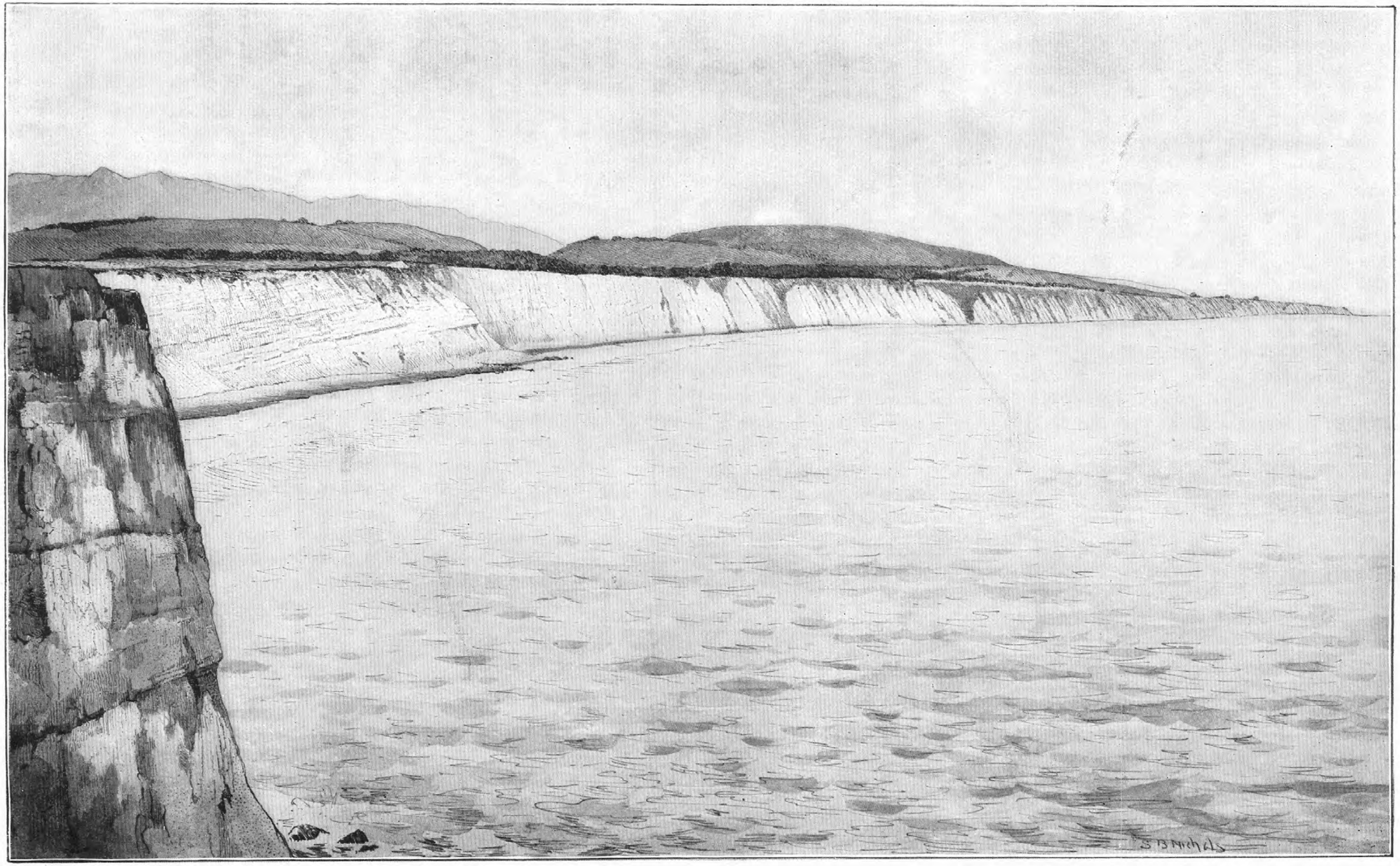
The heavy beds of gravel and sand in the low hills nearer Santa Barbara were regarded by Whitney as Pliocene. Recent sands also occur along the coast, of which, especially interesting and once valuable, is the mass that has been so heavily impregnated with bitumen near Carpinteria.

Within the coastal region here described are several occurrences of asphalt or bituminous sandstone, and also of petroleum. They occur in sandstones or conglomerates that are included within the Monterey itself, in the post-Pliocene referred to above, and in the sands of later age, as at Carpinteria.

VICINITY OF GAVIOTA.

The westernmost deposits that have been prospected outcrop at intervals for a mile along the beach west of Gaviota. Here the bitumen-bearing rock is sandstone and conglomerate. While in the main the composition is of quartz in coarse grains, there are distributed through this, as though by eddies originally, irregular masses of gravel which consists of serpentine, quartzite, limestone, chert, and shale

[1] Whitney, Geol. Survey California, Vol. I, p. 132.



OCEAN BLUFFS, MORES LANDING TO SANTA BARBARA.

fragments, the last two derived from the harder layers of the Monterey. The cherts are by far the most important in point of numbers, and are also especially conspicuous from their black color; although many of them are homogeneous in texture and of uniform color, there are, nevertheless, banded types, black and white. Of the finer material of the bed, quartz is the most important, but there is an appreciable percentage of other constituents, particularly feldspar and serpentine. From the nature of the rock, therefore, so variable in its material, in its coarseness, and in its texture, other than a marked variation in its bitumen content is not to be expected. It is for this reason, probably, coupled with the narrowness and uncertainty of the bed itself, that prospecting has not been pushed in greater degree; furthermore, a portion of the outcrop is beneath the sea at high tide. The bitumen in the rock is probably never above 7 or 8 per cent. The maximum thickness of the bed is, possibly, 25 feet.

Besides the foregoing deposit, the shales carry several thin streaks of interbedded sandstones, many of them but an inch or two thick and irregularly persistent. The per cent of bitumen in these is, perhaps, somewhat less than in the larger bed.

The Monterey of this locality, it is evident, includes bands of sandstone worthy of attention. The infiltration of this material with bitumen has doubtless been from the shale, for traces of it are found throughout the terrane. The occurrence of the sandstones can hardly be regarded as more than adventitious, yet they give an insight into the possible make-up of the general formation that will doubtless be of service in the consideration of the presence of petroleum in different localities.

VICINITY OF MORE'S LANDING.

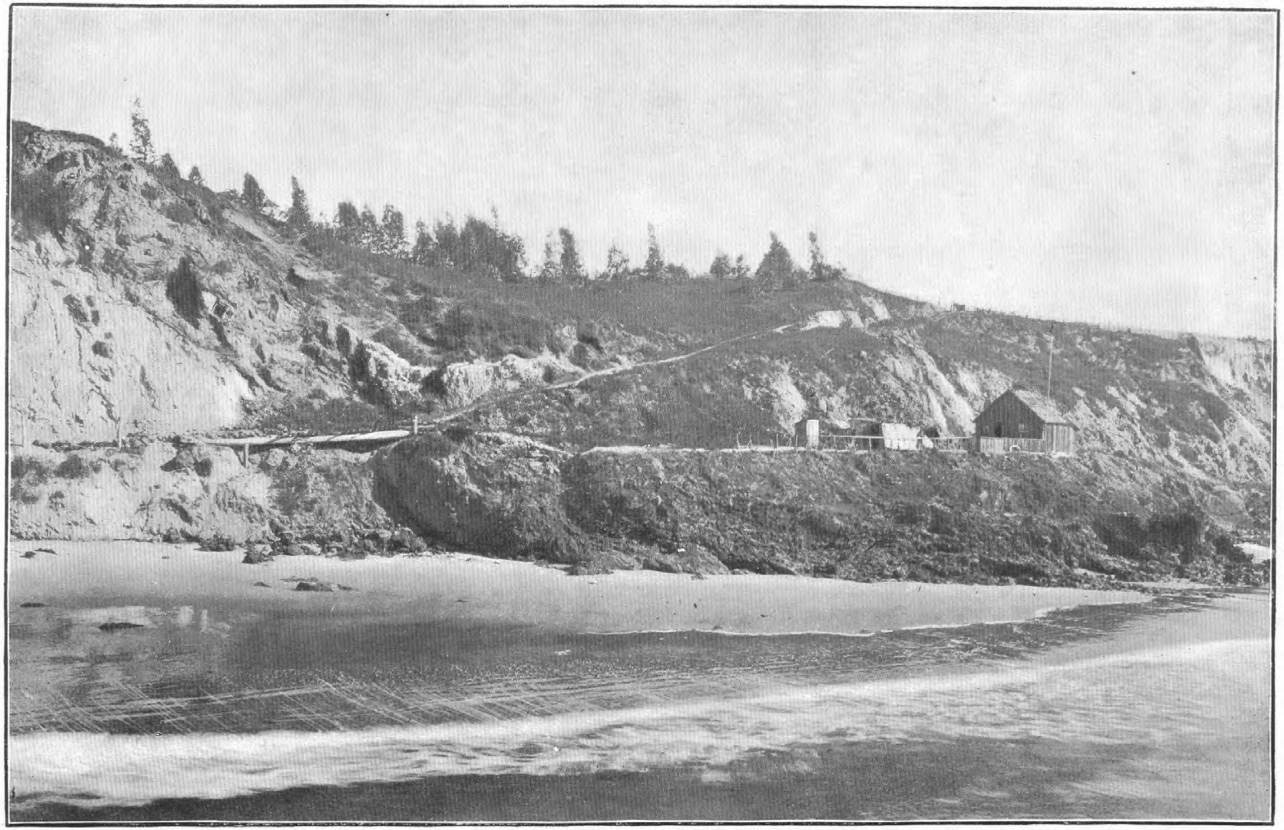
General occurrence.—The asphalt at More's Landing, 7 miles west of Santa Barbara, occurs under three conditions; one deposit as a massive body of high-grade material; a second, as a material of even greater purity than the first, forming veins in the sandstones of the region; the third, of extreme purity and resembling gilsonites, in small pockets in the sandstones. Of the first, the color is black; the fracture, conchoidal; the texture and grain, if it may be so referred to, even; the odor, strong. The constituents are the asphalt itself and a minor portion of clastic matter, of which, perhaps, the chief is quartz, with feldspar and serpentine as minor accessories. Occasionally small (one-sixteenth inch) clay inclusions are also to be seen. The vein asphalt resembles the foregoing, except that it seems to be of still higher purity, i. e., freer from the clastic material. It softens readily under the sun's rays, with a flow structure developed from its position in the face of the cliffs. The third variety of asphalt, that developed in small pockets, consists of the purest of all the local phases, bearing a strong resemblance in structure, brilliancy, and fracture to gilsonite or to one of its close allies.

The more massive body of asphalt (Pl. LVI) occurs close to the line of union of the shales of the Monterey with the sands of the post-Pliocene. The relations of this bed to either terrane is difficult to determine. That the bitumen was derived from the shale by seepage is highly probable. That it has involved the sandstone, passing upward into it not only by infiltration through its pores, but also in veins, is equally evident. But the great body of asphalt to-day lies in a dome above the beach level, now uncovered of sand, and as though, in part at least, a flow of comparatively recent times. Yet it is possible that the body formed at the line of the sandstone and shale by the yielding up from the latter the heavy petroleum or maltha, which thus made its way along their line of union, impregnating the sandstone with variable richness and marked unevenness of outline, and, perhaps, when exposed by the erosion of the sea, becoming again semifluid under the sun's heat, and so producing the effects as they are shown to-day.

The veins of asphalt (Pl. LVII) are of marked variety of form. They appear at any altitude in the ocean cliffs from beach to crest. At no point were they observed in direct passage from the shales; on the contrary, the face of the sandstones show veins that are apparently independent, as though derived by flow from the sides into a crevice developed perhaps by slight disturbance of the strata, perhaps by contraction. It can not be said, however, that there is not some connection between these apparently isolated veins and the mass of underlying shale.

Concerning the sandstone in which these veins occur, it may be remarked that the body is at least a hundred feet thick, semiindurated only, of a composition chiefly of quartz grains, and in color light greenish gray to yellowish white, and occasionally buff. The sandstone, while massive, shows nonpersistent bedding planes at intervals of 20 to 30 feet. The bluffs formed of it are from 60 to 100 feet high, and vertical. The mass lies unconformably on the shales. If flexed at all in the vicinity of More's Landing, the bed is in the form of a gentle syncline, the axis of which is somewhat east of the landing and has a trend of about N. 60° W. It is worthy of note that the position of the sandstone is opposite the mouth of a valley coming from the northeast; it may have been derived, therefore, from the mountains in this direction, a comparatively local deposit.

La Patera mine.—The La Patera mine is one of the well-known asphalt properties of California. It lies close to the sea, about 10 miles west of Santa Barbara. It was apparently abandoned at the time of the writer's visit and was inaccessible. From the twelfth and other annual reports of the State mineralogist and from information given



DEPOSIT OF MASSIVE ASPHALT, MORES LANDING, SANTA BARBARA COUNTY, CAL.

the writer by miners of the product, the following seem to be the facts in the case: The deposit is of the vein type, and it is said that there are three or four important fissures of a more or less intermittent character that have been filled with asphalt, the maximum width of any one pocket being 12 feet. The trend of the main veins is about N. 30° E., while their dip is nearly vertical, an inclination to the west being reported in one instance. Lateral cracks are given off in all directions. The country rock is of typical Monterey shales, which lie in some confusion at the mine, but along the neighboring beach strike N. 60° W., with a dip of 20° to 25° NE., the latter changing to southwest a half mile east of the mine. The veins are opened by three or four shafts of depths from 20 to 500 feet, it is said, the latter figure being given with reservation. The several veins of the property, judging from the openings, are distributed over a distance, more or less transverse to the measures, of 600 feet.

A feature of the La Patera mine, particularly below the 100-foot level, is the tendency of the asphalt to swell in the floors of the tunnels or drifts, requiring its constant removal and the resetting of the timbers, as well as watchfulness for the general condition of the mine. It is even stated that the equivalent of a body of asphalt of the width and length of the drift and 20 feet in height has been removed in the course of a year, all thus derived. Notwithstanding this feature the asphalt is said to maintain a reasonable degree of hardness. Concomitant with the swelling, also, is an escape of gas, which, though marked, is not sufficient to interfere with the working of the mine. The presence of the gas has brought about a conspicuously porous condition of the asphalt involved. Many of the cavities are a half inch in diameter, and some are lined with a secondary deposit of bitumen, brilliant, brittle, and black.

The La Patera asphalt is of great purity, there being, probably, but about 30 per cent of fine clastic material disseminated through it. It thus resembles the highest grade in the veins at More's Landing, 2 or 3 miles east. The asphalt is jet black, solid to porous, and rather soft by comparison with many of the purer varieties. The more or less enriched clay inclusions, common in almost all asphalts of this type, are present. Here, perhaps more than elsewhere, they have the appearance of having welled up with the asphalt from below in the filling of the fissure. Moreover, their proportion seems to increase in depth, deteriorating thus the product of this portion of the mine.

An occurrence of interest a half mile east of La Patera mine is the deposition upon a point of limestone extending into the sea of a heavy film of petroleum, derived from ocean springs and washed there by the waves and currents. Oil on the waters of the Pacific between Point Conception and Santa Monica has long been observed from steamers, and it is frequently found impregnating the beach sands or caught in the crevices of the ocean bluffs.

VICINITY OF CARPINTERIA.

The deposit at Carpinteria is a rich bituminous sand of recent origin, lying along the ocean's shore. A maximum thickness of 15 feet was observed in the face of the Las Conchas quarry, but the average is more nearly 12 feet; from this it diminishes laterally on passing beyond the quarry. The position of the bed is horizontal; it rests upon Monterey shale of the typical variety, which, at the quarry, shows a vertical or steep dip to the south, with a strike of N. 70° W. A half mile east of the quarry, marked and intricate crumpling sets in. The quarry opening is about 700 by 200 feet, and is protected from the sea by a narrow dike of the bituminous sand that has been left.

The face of the quarry exposes the following section, somewhat variable from point to point:

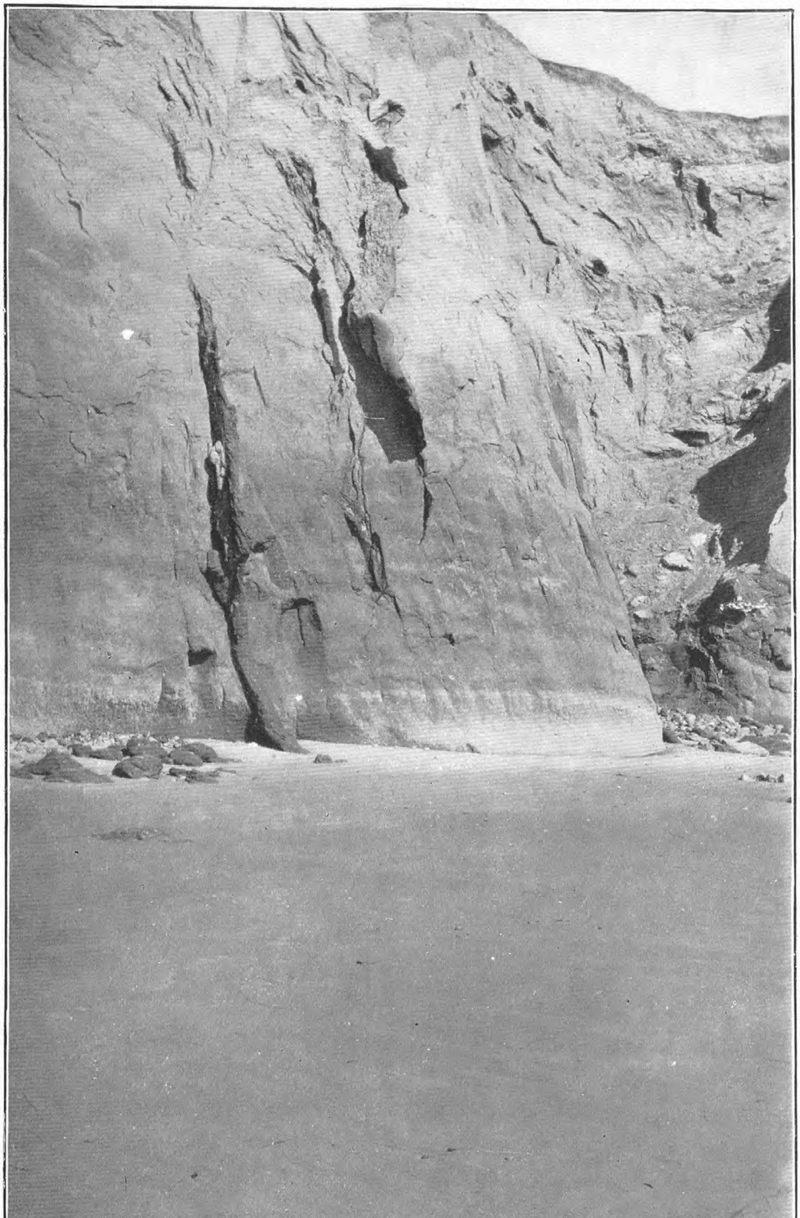
Section at face of Las Conchas quarry.

	Feet.
Earth	4 to 6
Orange sand	4 to 6
Bituminous sand (carrying 18 to 20 per cent bitumen)	10
Monterey shale.	

The layer of earth presents but a single feature of note, namely, an occasional oil seepage from the beds below or from an included body of sandstone that appears to have been derived from the underlying layers, although separated from them.

The orange sand is quartzose and generally free from bitumen, although here and there a small mass of it may show itself impregnated. A few pebbles and an occasional shell are also to be found in it.

The bituminous sand is also quartzose, sharp, and medium to coarse in grain; it differs from the orange sand only in its enrichment with bitumen. The upper surface of the sand is roughened by the presence of a great many knobs, which, on being uncovered of the overlying sand, present the appearance shown in Pl. LVIII, *B*. The roughened surface is doubtless owing to the cohesion of the sand due to the presence of the bitumen, the latter having risen through the mass of the layer to heights represented by the unevenness. Between this layer and the orange sand there is locally a tendency to shade from the one to the other in bitumen contents. The base of the enriched bed carries here and there pebbles and shells doubtless derived from the sea prior to the deposition of the sands. The pebbles are Monterey. In this connection it is also of interest to note the bore holes made by marine animals in the upper surface of shale before the sands were deposited upon it. These present all the features of present-day borings so commonly observed along the adjacent ocean bluffs.



VEINS OF ASPHALT IN SANDSTONE, MORES LANDING, SANTA BARBARA COUNTY, CAL.

The shales in the floor of the quarry are still giving forth the thick maltha wherever exits are afforded, this forming small pools a few inches to a few feet in diameter. The occurrence is repeated at numerous points along the terrane east of the quarry, where, also, even an oil well is flowing about two barrels a week.

The whole history of this deposit is written in the foregoing lines. The shales of the Monterey were at this point rich in petroleum. They became intricately and sharply folded, with the resulting and inevitable fracturing. An exit was thus afforded for the oil, which found a storage reservoir in the recent sands deposited in the locality. One might go so far as to say that were the excavation of the quarry refilled with fresh sand it would be but a comparatively short time when this, too, would be saturated. That the orange sand referred to in the section of the quarry face was not infiltrated may be due to the inability of the petroleum to rise generally to a greater height, or to an unobserved difference of texture from the sand underlying, or it may be that the orange sand is a more recent deposit, subsequent to the infiltration of that underlying and to its hardening.

From this, from the seepages at Carpinteria, from the oil wells at Summerland, and from the occurrences at More's Landing and La Patera, this general region can not but be regarded as one preeminent in the oil-bearing nature of its rocks, in the structure which has permitted its liberation, and, perhaps, in the actual proximity of the source to the surface of the country.

The extent of the Carpinteria deposit is limited on the west by a region of lowlands, over which the sandstone carrying the bitumen was either not deposited, or if deposited was removed prior to bitumenization. To the east the thickness of the deposit diminishes by a thinning in the thickness of the zone impregnated, apparently from the top, but the sands themselves continue for a distance farther. Landward the extent of the deposit was not learned, although doubtless it was known to the company which worked it. The property was apparently abandoned a little before the writer's visit.

VICINITY OF PUNTA GORDA.

Near Punta Gorda, and 5 or 6 miles east of the Carpinteria deposit, the Monterey shale, again highly contorted, carries an occasional pocket-like vein of the purer variety of asphalt that has been indifferently prospected. The principal tunnel shows an irregular lenticle of asphalt at the mouth and a vein 4 inches wide 80 feet in. At this latter point is a shaft, said to be 100 feet deep. In this a maximum width of 4 feet is reported to be attained by the asphalt. The general trend of the vein is northeast-southwest, and at the point cut by the tunnel the position was vertical. The strike of the shales is approximately, though perhaps locally, in conformity with the trend of the vein, their dip being northwest and steep. The material carries about 28 per cent pure asphaltum, the remainder being ash, silica, lime, etc.[1]

About a mile and a half northeast of the Punta Gorda mine, at an altitude of approximately 900 feet, is a body of bituminous sandstone 4 feet thick, of Pliocene age, resting unconformably on shales, probably of the Monterey. The deposit has been but slightly prospected. This is known as the Rincon prospect.[1]

OJAI VALLEY AND VICINITY.

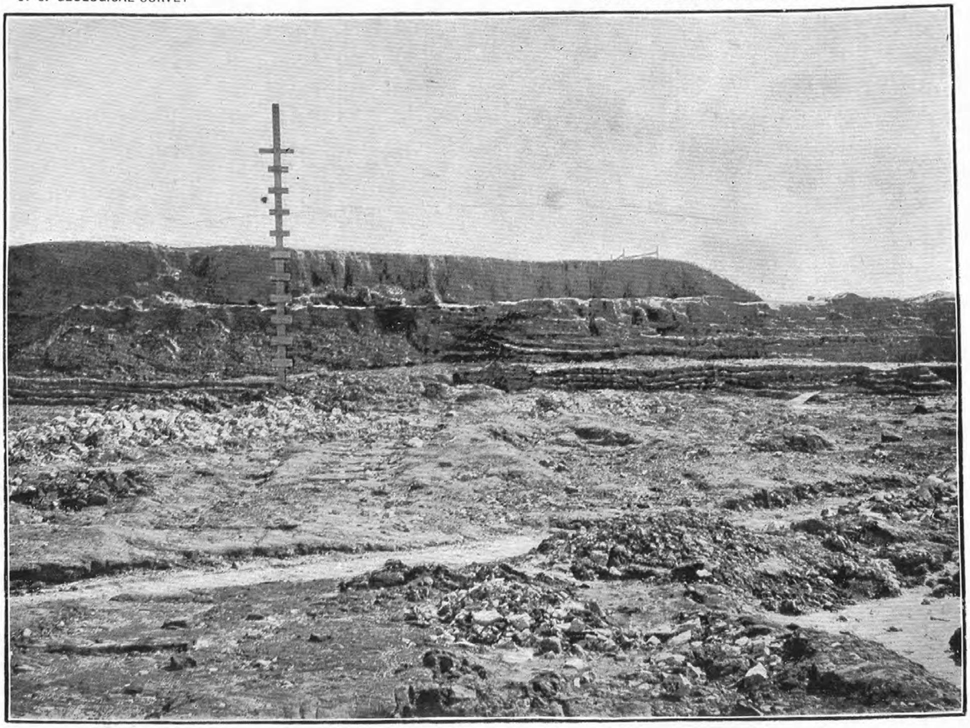
In the Ojai Valley, 4 miles east of Nordhoff, well upon the hill slope to the south, is another strong seepage of maltha which has bound together a mass of talus extending over an area 100 feet square. The maltha still flows at many points, the springs being opened through the talus. The deposit can hardly be regarded of value except in so far as it might afford a small amount of refined asphalt, or as an indication of the further occurrence of petroleum in the general region under discussion. Indeed, numerous seepages are reported throughout the San Buenaventura region. They, like this, are all said to be in the Monterey shale.

Veins of asphalt are opened on the Weldon ranch, 6¼ miles north of Ventura, in a canyon that enters the San Buenaventura from the east. There are three or four such, of the usual type found in the Monterey shales. Their thickness varies widely and rapidly, a maximum of 4 feet being reported by the foreman in charge of development. Two feet was the maximum observed by the writer. The deposits are distinctly the fillings of irregular cracks in the shale, the infiltration having probably taken place from the surrounding country. The strike and dip, both of shales and veins, in the immediate locality of the tunnels, is obscure; the shales appear to strike about east and west with dip irregular but steep. A mile southeast of the above another opening is reported, where the vein is said to dip about 20° S. It is regarded by the foreman as a "blanket" vein, but from his description it is merely a lens 2 feet thick and 45 feet across. The asphalt of these veins is of high grade.

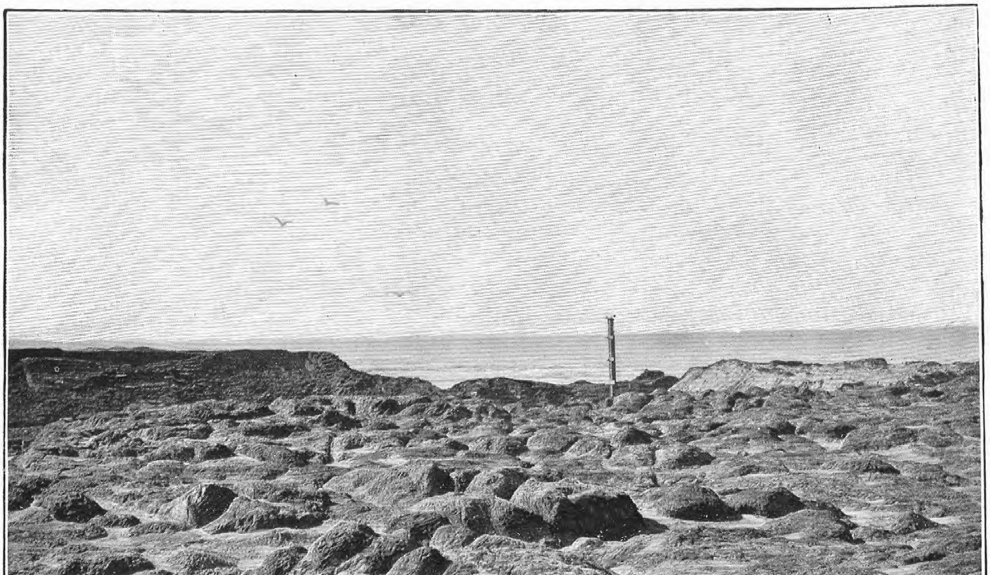
In the Tenth Annual Report of the State Mineralogist of California, page 763, Prof. E. W. Hilgard, of the University of California, gives an account of a mine of this region which was not visited by the writer because reported as having been long idle and so not in a condition to afford a satisfactory insight into the occurrence of the asphalt. Following is a résumé of Professor Hilgard's statement:

The mine is located in the Cañon del Diablo, a tributary of the San Buenaventura River from the west. Its distance from the town of

[1] Thirteenth Ann. Rept. State Mineralogist of California, p. 45.



A. BITUMINOUS SAND OF RECENT TIME, LAS CONCHAS QUARRY, CARPINTERIA, CAL.



B. TOP OF BITUMINOUS SAND OF RECENT TIME, CARPINTERIA, CAL.

San Buenaventura is 5 miles. The topography is hilly and comparatively rough. The geology presents a steeply dipping series of "bituminous shale," 600 feet of siliceous "clay," and a succession of "sandstones, sand, and gravel," the first on the "upper or northern edge" of the clay, the last on the "southern edge." The clays and shales are "Miocene Tertiary." They strike N. 75° W., with a dip nearly vertical. The strike of the veins, of which there appear to be two, is, according to Hilgard, N. 45° W., the dip 65° to 70° SW.

The "main vein" is an asphalt-filled fissure, pockety, and with at least one important spur. The vein varies in thickness, some of the pockets expanding to between 7 and 16 feet. The asphalt improved in depth. In the development a horse of the country clay was found at one point, entirely inclosed in the asphalt.

The asphalt is described as a brownish-black uniform mass, of conchoidal fracture, and with brown streak. The percent of "asphaltum" ranges between 15 and 22, the remainder of the material being a fine siliceous clay similar to that of the inclosing country. Fossil shells are occasionally found in the asphalt, as at the mines in La Graciosa district. Clay inclusions are also a feature of the veins. Hilgard determined the per cent of fixed carbon in the bitumen at about 30.

The region of the foregoing veins and of the Ojai springs is about 30 miles northwest of the Santa Paula oil field.

CHINO DISTRICT.

Four miles west-southwest of Chino and about 35 miles southeast of Los Angeles is a limited area of bituminous sandstone which has the appearance of being a member of the Monterey series. The actual horizon it is impossible to judge without work of considerable detail. The composition of the bed is in the main quartzose, but with a heavy per cent of mica; the bitumen is variable, but rather below the average of the best California asphaltic sandstones. Moreover, the bed is threaded with minute seams of shale parallel with the stratification lines and it also carries small clay inclusions. The sandstone has a north-and-south strike at the principal prospect, with a dip of 15° to the east, but both strike and dip vary in conformity with local folding. The thickness of the bed attains a maximum of 20 feet, although it is doubtless variable. The exposure shows 4 feet of yellow argillaceous sand at the top; 6 feet of bituminous sandstone underlying this, which is marked with "cannon-ball" concretions; then 12 feet of bituminons sandstone, similar to that overlying, but with more frequent partings of clay and with clay inclusions.

The deposit lies near the summit of the mass of hills in the locality mentioned. Its intercalation in the shale series is almost without question. It is, however, difficult to trace beyond a limited area, and it may be that the sandstone is but a lenticle. The deposit is, perhaps, of some value locally, but could hardly compete with the great deposits of the State.

The Puente oil wells occur about 10 or 12 miles southwest.

ASPHALTO DISTRICT.

This district lies in a desert-like country at the eastern base of the Coast Range, about 50 miles west of Bakersfield. The deposits of asphalt occur both as superficial flows, now well dried, and as veins in the folded Middle Neocene shales of the region.

GEOLOGY.

The Coast Range is a succession of anticlines of varying strength, more pronounced in their development, perhaps, in the interior than along the border of the range. Of the border crumples is that which extends through the district under discussion. The trend of this fold is about N. 60° W., the axis lying close to the settlement of McKittrick. It is along this axis for a distance of 3½ miles that the oil wells of the region have been bored. It is toward the southern end of the oil field and, perhaps, toward the southern end of the anticline that the deposits of asphalt have formed.

The strata involved in the anticline are Lower and Middle Neocene. The composition of the older terrane is practically the same as in the coastal region of California; it is a succession of highly siliceous shales, with earthy layers and occasional concretionary limestones. The general aspect of the formation is well maintained and in many of the shaly layers the minute forms of organic life may be clearly seen. The Middle Neocene is equally developed with the Lower, and consists of conglomerates, sandstones, and shaly clays, with a thickness of over one thousand feet. Conspicuous in the materials of the conglomerate are pebbles of siliceous shale. The beds of conglomerate and sandstone are numerous, and several of them, from the presence of petroleum, have come to be known as oil sands. The details of their disposition, and the location of the wells with reference to the structure of the region, were not attempted by the writer, for the matter was not immediately relative to the work in hand.

The condition of the openings both in the superficial deposits of asphalt and in the veins at the time of the writer's visit was in general such as to preclude their satisfactory examination, the property having lain idle for several months. The following excerpt of a description by Mr. W. L. Watts, of the California State mining bureau,[1] is therefore inserted, Mr. Watts having had special opportunities for study at the time the Standard Asphalt Company, the operator of the property, was actively at work. Mr. Watts says, in substance, that the asphalt deposits occur as superficial beds and as veins.

[1] Bull. No. 3, August, 1894.

SUPERFICIAL DEPOSITS.

The superficial beds lie south of the railway a mile. One covers an area of probably 7 acres. The asphalt rests partly on sandy and clayey drift and partly on a white, calcareous sand. This deposit constitutes the northern portion of a much larger one, from which, in May, 1893, large quantities of crude asphalt had already been removed. The asphalt varies in quality from a dull black, compact material of pitch-like luster, here and there rendered viscous by fluid petroleum, to a brown, pulverulent mass, more or less mixed with earthy matter. The better material lies near the surface, in some places forming a stratum from a few inches to 2 feet thick. Beneath this the bed is impure and fissile, with frequent intercalations of wash from the adjacent mountain. In some places small veins of purer asphaltum show, penetrating the earthy material. At the time of Mr. Watts's visit he reports as stacked in the vicinity of the superficial deposits 100 or more tons of fairly good asphalt. The holes made in mining were then filled with heavy oil, or with water the surface of which was covered with oil.

South of the foregoing area the continuation of the deposit, in May, 1893, remained intact, excepting for occasional pits, where a maximum thickness of about 4 feet of fairly good asphalt was shown. Beneath the asphalt is sand, impregnated with heavy oil. A trench across this deposit for a distance of 250 feet penetrates the asphalt and the sand soaked with oil from 3 to 12 feet. Oil accumulates in the bottom of the cut, from which it is collected into a tank. This latter body of asphalt covers an area of about 6 acres.

Similar beds also occur west of the bodies just described. These, according to Mr. Watts, are more ancient than those farther down the hill, and much of the asphalt is of poor quality. Their general trend is northwest-southeast, and they appear to extend along the contact of a sandstone with light-colored shale. The shale has a general strike west-northwest and stands at a high angle. Mr. Watts observes that this deposit of asphalt has been afire, with the formation of "masses of clinker," locally called coked asphaltum, a sample of which showed 39.1 per cent of carbonaceous matter. About 10 acres are covered with this ancient asphalt, all of which is situated on the hills overlooking Asphalto.

VEINS.

The principal working from which the vein asphalt was being mined at the time of Mr. Watts's visit in 1893 was a shaft about 40 feet deep, with drifts. He observes that a vein near the surface showed a thickness of 8 feet. It was found in depth, however, to vary greatly and rapidly in strike, dip, and thickness, frequently pinching completely, only to reappear on following the indefinite line of fissuring.

At the bottom of the shaft a lower vein, 2½ feet thick, was also observed, dipping about 45° in a N. 5° W. direction. The foot wall was a light-colored clay, with streaks of gypsum; the hanging wall, a sandy clay. The drift from the foot of the shaft terminated in a light-colored friable sandstone. This lower vein was also mined from another shaft, known as No. 2. Here the vein dipped between 45° and 55° N., 15° to 25° E. The average width of the vein was found to be from 3 to 4 feet, much of it good, bright, black asphalt.

Other openings, mainly tunnels, are scattered over the adjoining region and show varying widths, strikes, and dips of the vein. An outcrop of a vein about 60 feet west of the second of the shafts described above shows a strike of N. 68 W., with a dip to the northeast of 70°. Near the end of one of the tunnels a seepage of heavy oil occurred. An open cut in the region showed a disturbed vein of asphalt 3 feet wide, with irregular masses of asphalt spreading therefrom. The inclosing rocks were light-colored sandy clays, dipping about 40° southeast. Seams of gypsum are frequent in the clays.

After citing many outcrops, prospects, and tunnels, with their occurrences of asphalt, Mr. Watts remarks:

> The asphalt veins herein described may be divided into two orders—those having a strike and dip dissimilar to that of the rocks inclosing them, and those having a strike and dip similar to that of the inclosing rocks. The asphaltum veins of the first order are no doubt dikes of asphaltum, which occupy fissures in what appear to be rocks of late Tertiary formation. The genesis of the asphaltum veins of the second order is more dubious; some of the veins may be dikes filling fissures formed between the contact planes of upheaved strata, or they may have been formed as subaqueous exudations. The asphaltum has a specific gravity of about 1.10, and even if it were less, assuming that it exuded beneath water, its viscosity would tend to keep it submerged. An interesting feature of this locality is the diversity in the direction of the dip of asphaltum-bearing strata within comparatively small areas, although the prevailing dip appears to be northeasterly. * * *
>
> This recent discovery of veins of asphaltum appears the more important when we remember that formations of similar geologic age to those at Asphalto can be traced along the foothills on the western side of the San Joaquin Valley, and it is hardly likely, therefore, that such veins are confined to the vicinity of Asphalto. The heavy mantle of alluvium covering the western foothills of the San Joaquin renders prospecting in the underlying formations difficult, but the rapid erosion which takes place during the rainy season will probably, from time to time, expose other veins, which it will be well to investigate.

The limited observations of the writer confirm the statement of Mr. Watts. As to the deposits of brea or surface asphalt their origin is clear. Even at the present day the thick petroleum seeps from cracks and fissures in the strata of the region and involves fragments of shale that rest upon the surface, carrying them onward in increasing number until hardening stops the progress. Successive flows cover the earlier, and from the cleaner surface over which they pass are less contaminated with foreign matter. So the deposit accumulates. This process has been going on for many years, the older bodies being cut at the present day by channels of erosion which have exposed their entire thickness and structure.

The veins were found by the writer to have all the characteristics of structure and composition of those in the shales of the Monterey in other parts of California, and indeed many of the features of veins of purer asphalt throughout the United States. Of especial interest in the Asphalto district is the softness of the bitumen that forms the veins. This is, perhaps, attributable to their close proximity to deposits of petroleum, the nearest of the latter being less than a half mile distant. Indeed, the idea at once forms upon visiting the locality that the veins are but hardened bodies of petroleum that have escaped from the adjoining country rock, or from some other source which is common with that of the oil of the present day, the fissures that it filled resulting from the sharp folding to which the strata of the region have been subjected.

The asphalt itself is divisible into two or three grades or varieties, known among the miners as the "regular," the "dry black," and the "dry brown." For "regular," "first-grade" might have been substituted. This rock is of a rich black color, waxy texture, softer than any observed at other points in the United States, and remarkably free from visible impurities, even the earthy, clastic material so commonly present being here inconspicuous. Occasionally a greenish clay inclusion, noncalcareous, somewhat micaceous, and to a degree impregnated with bitumen, appears, picked up, doubtless, in the ascent of the petroleum. The fracture of the asphalt is brittle, notwithstanding the naturally tough, tenacious character of the substance, the material first yielding and then snapping. The fracture varies from conchoidal to coarsely hackly, the latter, it is believed, induced from the former by movement of the body after deposition and hardening. Indeed, this movement is evidenced by slickensides in the asphalt itself. The material on exposure to the atmosphere readily yields up more or less of its volatile constituents, with the development of cracks without system. A penicillate structure is also occasionally present along the walls of a vein.

The amount of bitumen in the regular grade is said to be between 60 and 70 per cent. A sample by the writer showed but 31, indicating a wide variation. The regular and dry-black grades were alone shipped.

From the foregoing high-grade material there is every variation to a mass that consists almost entirely of clay fragments, these held together by the bitumen that has filled their interspaces. The appearance is that of an asphaltic clay breccia. These clay fragments are earthy in composition, but generally have the appearance of a hardened, slightly enriched bituminous mud. They thus differ somewhat from the included masses in other localities, as, for instance, in the Santa

Maria district; and yet, as in the latter, they are doubtless derived from the inclosing rocks. In the present occurrence, if from any cause the clays have suffered cracking, the fissures so opened have been refilled with purer asphalt.

The pocket nature of the veins, notwithstanding the fact that they have now been followed to a reported depth of 300 or 400 feet in the shafts of the company, is clearly established. The history of the mining has been the following of a succession of such pockets through their narrow connecting cracks, both in depth and in length, along the drifts. Of the number of veins present in this locality it is difficult to speak. There are at least two or three, perhaps more, that have been opened, and it is but reasonable to expect that there may be others. At the same time, some of those well established and apparently independent may at intermediate points unite.

SUNSET DISTRICT.

Superficial deposits of asphalt also occur at Sunset, 30 miles southeast of Asphalto, but they are generally similar to those at Asphalto and therefore need not be described.

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