DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

BULLETIN 537

THE CLASSIFICATION OF THE PUBLIC LANDS

BY

GEORGE OTIS SMITH AND OTHERS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1913

CONTENTS.

ILLUSTRATIONS.

THE CLASSIFICATION OF THE PUBLIC LANDS.

By George Otis Smith and others.

THE PURPOSE OF LAND CLASSIFICATION.

In the latter half of the nineteenth century the spirit of the public-land laws in the United States was settlement and development. With a public domain of one and a third billion acres, acquired in the preceding half century—1803–1853—by purchase, discovery, exploration, and cession, and with another third of a billion acres in Alaska constituting a later purchase, the Nation felt that it could be lavish with its lands. The wilderness called for pioneers of every type, and large premiums were held out to capital enterprise and individual initiative. Development was desired whatever the cost in lands that were intrinsically of little value without settlement. The same century that saw the creation of this national domain—an empire in itself—also witnessed the distribution of more than one-half of its acreage. This shrinkage of the national domain has naturally been coincident with national development in all lines of industry. Western prairies have become the world's granary, and western mountains, once wholly in public ownership, are now contributing to their private and corporate owners the profits on no small proportion of the world's output of metals and of mineral fuels.

With advancing years a wise nation, like a prudent man, learns to husband its resources. Land values are now recognized, the purpose in both legislation and administration has changed, and highest development alone is sought. With the most and the best of the Nation's land already alienated, the national duty is to put to its best use what remains.

Utilization of lands for their greatest value necessitates the determination of that value, which is, briefly, land classification; and, to be adequate, land classification must be based upon first-hand acquaintance with the particular land under consideration. With a national estate including country ranging from salt-incrusted deserts to valleys knee-deep with nutritious grasses or giant forests almost impenetrable because of luxuriant undergrowth, no general statutes that may be enacted can be made so definite as not to require the exercise of well-informed judgment in their execution. To this end examination and classification of the public lands constitute an initial step in their disposition for development and settlement. That a few decades ago settlement and development commonly outstripped classification and often far preceded even the legal disposition of the land itself is no good reason for failure to follow the more logical procedure now.

The principle of land classification is inherent in many of the public-land laws, and classification of lands has in late years been specifically recognized by Congress as a step indispensable to the administration of the national domain. This public estate is even now so extensive and valuable as to demand a business policy. Making allowance for the alienated lands included within the land units described in the various coal-land areas withdrawn by executive order for classification, and also estimating the expected reduction of these withdrawals by classification of parts of them as noncoal land, the people of the United States possess to-day 44,000,000 acres of coal lands, exclusive of the Alaskan coal fields. A large proportion of this acreage, however, is underlain by the lower-grade coals. In the almost equally important items of oil and phosphate rock the existing withdrawals indicate national ownership of over 2,000,000 acres of oil and gas lands and nearly 3,000,000 acres of lands which will furnish our agricultural regions their future supply of mineral phosphate. Nor have all the agricultural lands been alienated. Public and private irrigation projects will reclaim several millions of acres of arid land, and dry farming under the enlarged-homestead act will materially add to the area of farm lands.

To insure appropriate disposition and to secure highest use of the Nation's lands, scientific land classification by the United States Geological Survey has been made an integral part of public-land administration. Quantitative knowledge of the land and its resources is now made a preliminary, first, to disposition of lands under the various settlement and development laws; second, to reservation of lands from present acquisition pending the enactment of adequate legislation; and third, to valuation of lands under a statute which provides for their disposition at prices expressing known value.

The purpose of land classification, then, is highest utilization, and to attain this end it has been necessary to coordinate the work of scientific investigation with the administrative functions of the Department of the Interior. The large participation of the Geological Survey in the public-land administration has naturally presented problems involving changes both in office and field organization and in executive and scientific methods. For these changes there has been little or no precedent. Scientists and public men of older countries have been outspoken in their interest in this new application of science to governmental administration, and requests have been made for more detailed information on the subject than is available in the references appearing in administrative reports of the Secretary of the Interior and his subordinates.

A new application of any branch of science necessarily affects the science itself. New use involves added requirements and in turn may contribute in by-products even more than it demands. The general effect of this direct application of the Geological Survey's investigative work to large problems of public administration is believed to have been beneficial to science itself. It has broadened the outlook of the investigator, but especially it has demanded that results be sought which are quantitatively exact as well as qualitatively true.

A full statement of the policy of land classification and a detailed description of the procedure and methods so far found necessary to carry out that policy, in the stage of development already reached, are presented in this bulletin. This information is believed to be of value both to students of government and to geologists and engineers interested in the application of scientific investigation to practical business. The historical and legal phases of the discussion may be of greatest interest to the citizen concerned in his country's highest development, while the description of field methods should be of immediate value in indicating new requirements imposed upon scientific education, for details of this business policy of the Government are already being adopted in private and corporate land examinations.

This bulletin represents contributions by many authors—members of the land-classification board and of the field branches of the Survey. The description of the development of the Survey's organization for land classification, which immediately follows this introduction, was written by W. C. Mendenhall, who as chief of the land-classification board has been directly responsible for the preparation of the bulletin. The discussion of the history and legal basis of classification was prepared by M. W. Ball, a geologist who has been identified with the work of land classification from its beginning and is now chairman of the oil section of the board.

The chapter on the classification and valuation of coal land was written by G. H. Ashley, until recently State geologist of Tennessee and now the chairman of the coal section of the land-classification board. At the time of his earlier connection with the Survey Mr. Ashley, who has made a special study of coal problems in both the eastern and the western fields of the United States, wrote the chapter on "The value of coal land" which appears in Survey Bulletin 424. In the preparation of the present paper Mr. Ashley has been most efficiently assisted by C. E. Lesher, who is independently responsible for the short section on "The preparation of data for classification." Mr. Lesher should be credited with many of the office methods which facilitate the prompt and accurate handling of data contributed by the field men of the Survey.

Field methods are discussed by E. G. Woodruff, C. H. Wegemann, R. W. Richards, and F. R. Clark, all of whom are members of the geologic branch and have had wide experience in field work leading up to land classification. Under the topic "Oil and gas lands," J. D. Northrop, who has had experience in the California oil fields, and C. H. Wegemann, a geologist of broad experience in the Rocky Mountain fields, have collaborated in the discussion of the geologic occurrence of oil and gas, while Mr. Northrop has contributed the section on classification. In a similar way, under "Phosphate lands," A. R. Schultz and R. W. Richards, the former the chairman of the phosphate section in the land-classification board and the latter a geologist who has worked out with great thoroughness and detail the complicated structural problems of the phosphate fields in southeastern Idaho and adjacent parts of Wyoming, have collaborated in the general discussion of phosphate problems, Mr. Schultz being responsible for the section on classification. The description of potash-bearing lands and their classification is the joint contribution of A. R. Schultz and H. S. Gale, Mr. Gale being the geologist in charge of the section of nonmetalliferous deposits of the geologic branch. E. H. Finch, of the land-classification board, who has been closely identified with the cooperative work between the Survey and the General Land Office, has contributed the section on "Miscellaneous nonmetalliferous lands," and F. C. Calkins, one of the experienced economic geologists of the Survey, who has had much to do with the classification of the lands in the Northern Pacific grant, has written the discussion of metalliferous mineral lands and the problems involved in their classification. The section on "By-products of mineral-land classification" was written by G. S. Rogers, a geologist of the geologic branch, whose recent work has been done in the western coal fields.

The discussion of classification in relation to water resources has been prepared under the direction of N. C. Grover, chief engineer of the land-classification board, M. O. Leighton, Herman Stabler, E. C. La Rue, and W. B. Heroy collaborating. Messrs. Grover, Stabler, and Heroy have prepared the sections relating to classification and office procedure, while Mr. Leighton, as chief of the water-resources branch of the Survey, and Mr. La Rue, one of the experienced field engineers of that branch, have cooperated in preparing the discussion of field methods.

It is noteworthy that the authors of the sections of this publication describing the procedure employed in the work have themselves originated for the most part the methods that are so essential to successful and authoritative land classification. Mention should also be made here, however, of the important part played by A. C. Veatch, the chairman of the land-classification board at the time of its organization, by C. Willard Hayes and Waldemar Lindgren, former chief geologists of the Survey, and by M. R. Campbell, who has been in charge of the geologic work in the western coal fields continuously since 1906 and has supervised the preparation of the sections on geologic field methods in this bulletin.

DEVELOPMENT OF THE SURVEY'S ORGANIZATION FOR LAND CLASSIFICATION.

The report of the committee of the National Academy of Sciences on the surveys of the Territories, prepared in accordance with the terms of a clause in the sundry civil bill approved June 30, 1878 (20 Stat., 206, 230), contains these statements indicating the opinion of the committee as to the land-classification functions of the bureaus whose organization its members were recommending:

> The best interests of the public domain require, for the purposes of intelligent administration, a thorough knowledge of its geologic structure, natural resources, and products. The domain embraces a vast mineral wealth in its soils, metals, salines, stones, clays, etc. To meet the requirements of existing laws in the disposition of the agricultural, mineral, pastoral, timber, desert, and swamp lands, a thorough investigation and classification of the acreage of the public domain is imperatively demanded. * * *
>
> The Land Office shall also call upon the United States Geological Survey for all information as to the value and classification of lands. * * *
>
> The publications of the Geological Survey should consist of an annual report of operations, geological and economic maps illustrating the resources and classification of the lands, reports upon general and economic geology in all its branches, with the necessarily connected paleontology.

Maj. J. W. Powell, reporting to the Secretary of the Interior on November 1, 1878, in response to the request of the acting president of the National Academy of Sciences to transmit any information available in the Department of the Interior as to surveys then in existence, after listing the classes of lands recognized under the laws, adds the following comment:

> An examination of the laws * * * will show that the classes of lands mentioned above are therein recognized, and in the administration of the laws relating to these lands those belonging to each specific class must be determined; but no adequate provision is made for securing an accurate classification, and to a large extent the laws are inoperative or practically void; for example, coal lands should be sold at $10 or $20 per acre, but, the department having no means of determining what lands belong to this class, titles to coal lands are usually obtained under the provisions of statutes that relate to lands

of other classes—that is, by purchasing at $1.25 per acre, or by homestead or preemption entry. An examination of the laws will exhibit this fact—that for the classification contemplated therein a thorough survey is necessary, embracing the geological and physical characteristics of the entire public domain.

After extended hearings before the House and Senate committees and the publication of many documents bearing upon the questions involved, Congress, in March, 1879, agreed upon a law which embodied the recommendations of the Academy of Sciences for the abolition of the Territorial surveys and the establishment of the United States Geological Survey but made no provision for the mensuration survey also recommended by the Academy.

Under the law approved March 3, 1879 (20 Stat., 377, 394), establishing the office of Director of the Geological Survey, it is provided—

> That this officer shall have the direction of the geological survey and the classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain.

Clarence King, the first Director, who entered upon his duties May 24, 1879, discusses the functions of the then newly created organization in his first annual report to the Secretary of the Interior dated November 1, 1880. In this discussion he states that—

> Two special and distinct branches of duty are imposed upon the Director of the Geological Survey—(1) the classification of the public land and (2) the examination of the geological structure and mineral resources.
>
> As regards the classification of the public lands, the text of the law leaves an uncertainty whether this classification is intended to be a scientific exposition of the kinds of lands embraced in the national domain, such as arable, irrigable, timber, desert, mineral, coal, iron, showing the practical values and adaptabilities of the various classes or kinds of soil and surface, or whether, on the other hand, it was intended to furnish a basis of classification upon which the Government should part title to portions of the public domain. * * *
>
> Upon examination of the existing land system, I have assumed that Congress, in directing me to make a classification of the public lands, could not have intended to supersede the machinery of the Land Office and substitute a classification to be executed by another bureau of the Government without having distinctly provided for the necessary changes within the Land Office and adjustment of relations between the two bureaus. * * *
>
> I have therefore concluded that the intention of Congress was to begin a rigid scientific classification of the lands of the national domain, not for purposes of aiding the machinery of the General Land Office by furnishing a basis of sale, but for the general information of the people of the country, and to produce a series of land maps which should show all those features upon which intelligent agriculturists, miners, engineers, and timbermen might hereafter base their operations, and which would obviously be of the highest value for all students of the political economy and resources of the United States. Studies of this sort, entirely aside from the administration of the Land Office, can be made of the highest practical value; and to this end a careful beginning has been made.

This interpretation by Director King of the duties imposed upon the new bureau by that clause in the organic act charging him with responsibility for the classification of the public lands prevailed in part until about 1906, when the pressing need of the Department of the Interior for an adequate classification of mineral lands for purposes of administration led to a revival of this suspended function of the Geological Survey, not, as Director King seemed to think necessary, by superseding the machinery of the General Land Office, but by cooperation, financial and administrative, between that bureau and the Survey and by a series of orders from the Secretary of the Interior, to whom both bureaus report. These orders so define the part that each is to bear in public-land administration as to make the Survey chiefly responsible for the physical classifications.

At first the work was concentrated largely on the classification and valuation of coal land, and this phase continues to be quantitatively the most important. In the Twenty-eighth Annual Report of the Survey, for the fiscal year ended June 30, 1907, in discussing the work on the coal lands Director Smith makes this statement:

> Special investigations were conducted last year to determine the extent of the coal lands remaining in the possession of the Government and the quality and value of the coal deposits on these public lands. This work will be continued on a larger scale and under a more comprehensive plan. Special attention will be given to the classification and valuation of the coal lands and their prompt segregation from the noncoal lands. This work is to be provided for by a joint allotment from the appropriations for the geologic and topographic surveys and that for testing coals belonging to the Government, and the General Land Office is also cooperating.

The Twenty-ninth Annual Report of the Survey, for the fiscal year ended June 30, 1908, includes with some matter on the special features of the work of the Survey a discussion of land classification, which contains the following statement:

> In the last few years the Geological Survey has broadened the scope of its work in the classification of the mineral lands of the public domain. At the time of the organization of the Survey the classification intended by Congress was believed to be general in character and such as could be expressed on maps issued for the general information of the people. The present interpretation of the law is that the classification should be more definite, and therefore, during the last year, the Survey has continued its special field surveys of the coal lands belonging to the Government. * * *
>
> Increased demands have also been made on the mining geologists of the Survey for assistance in determining the mineral or nonmineral character of land for which title from the Government is sought.

This work, which has become an increasingly important feature of the Survey's activities, was definitely recognized by the organization, in December, 1908, of a land-classification board as a section of the geologic branch, and by the reorganization of the board on May 1, 1912, into a branch coordinate in rank with the other Survey branches.

The Geological Survey has been in existence as a distinct organization for about 34 years. The organizations which it succeeded and whose functions it continued to perform and gradually to enlarge upon as new duties were given it by Congress collected engineering material that was epitomized in topographic maps and geologic material that appeared either as geologic maps, as reports on geologic problems, or as data on the mineral resources of the Territories. Early in the Survey's history the necessities of its geologic work required the organization of a topographic branch for the preparation of base maps. Although these maps were intended to serve primarily as bases on which to delineate and present geologic material, they have proved to be of great value for other and wider uses. Not the least of these uses is that to which they are put in land classification. The thousands of maps issued are graphic engineering reports on the physical and cultural features of the areas they represent. They are essential to the study of drainage areas, irrigability of lands, possible power development, and rights of way, and supplemental sheets now prepared give additional data on the distribution of timber and of springs, of desert and of grass land, and of cultivated and irrigated areas.

On March 20, 1888, Congress, by joint resolution, directed the Secretary of the Interior, through the United States Geological Survey, to make a special investigation of the practicability of constructing reservoirs for the storage of water in the arid regions of the United States. This work was supported for a time by appropriations but was later discontinued by Congress after many reservoir sites had been examined and segregated and a number of reports valuable in the classification of the lands of the arid regions had been published.

After the irrigation survey was abolished the division of hydrography was organized within the Geological Survey, at first as a part of the topographic branch and later with special small appropriations, its purpose being to continue that part of the work of the irrigation survey that involved the study of the available water resources of the Western States and Territories. As the value of this work to reclamation became manifest, Congress responded by increasing the amount of the funds annually available for this purpose until in 1903 they reached the sum of $200,000 a year.

On June 17, 1902, the reclamation act (32 Stat., 388) was passed. This act represented the culmination toward which the work of the division of hydrography had up to that time been tending. That work gave definite information as to available supplies of water and the lands on which the water could be used. The reclamation act authorized the construction of works for the application of these waters and the reclamation of the tributary lands. But the reclamation fund is not available for general studies of water supplies; it can be used only for studies of water available for use on specific projects. The work of the division of hydrography therefore did not cease with the organization of the Reclamation Service but has been continued in the Geological Survey by the water-resources branch.

Developments within the geologic branch since its organization have likewise marked a steady evolution from its original type. The branch has grown, its appropriations and its force have increased, and its work has been more closely subdivided and specialized and has attained greater refinement in all departments; and while this evolution has been taking place it has steadily accumulated a great mass of facts bearing on the geology and mineral resources of the United States.

The material accumulated since their organization by the field branches of the Survey—the geologic branch, the topographic branch, the water-resources branch and its predecessors, the irrigation survey and the division of hydrography—constitutes a vast body of information concerning the public domain—its geology, its geography, and its water supplies and the engineering features that control the distribution of these supplies. This store of information is by no means complete, for many problems are still untouched and many areas are unexamined, but nevertheless the archives of the bureau contain a greater mass of material of the kind required for classifying the remaining lands of the public domain into types that accord with their various uses than exists anywhere else in the public records.

With the accumulation of the data indicated the Department of the Interior and its bureaus have become increasingly ready and willing to call on the Survey for assistance in that phase of public-land administration which requires as its basis a classification of the lands into the types recognized in the statutes.

The requests made by the department for information contained in the Survey's records were at first sporadic; later they became more frequent and numerous, so that it became necessary to create within the Survey itself an organization to assemble this information systematically and transmit it to the department and to other bureaus in the department in such form as would be most readily applicable to the solution of administrative problems. This organization was named the land-classification board and was first formed as a section of the geologic branch and finally made a branch of the Survey coordinate in functions and responsibility with the field branches whose evolution has been briefly outlined.

The Survey's organization for classifying the public lands consists, then, fundamentally and primarily, of three field branches—geologic, topographic, and water resources—and finally of the recently organized office branch known as the land-classification board, with its staff of geologists and engineers, who analyze and translate into terms of public-land administration the data collected by the geologists and engineers of the field branches.

In its organization the land-classification board is in a sense a replica in miniature of the bureau of which it is a part. It consists of two divisions—a division of mineral classification and a division of hydrographic classification. The first corresponds to the geologic branch and receives, digests, and issues as land-classification data the material collected by the field geologists; the second bears a corresponding relation to the topographic and water-resources branches and similarly utilizes the engineering data gathered by the field force of those branches. Again, the division of mineral classification contains a number of sections which correspond closely with similar sections in the geologic branch. These sections, in the organization as it exists at present, are the coal section, the oil section, the phosphate section, and the metalliferous section, corresponding roughly to similar sections in the geologic branch as well as to the principal of the natural resources with which the board deals.

The work of the coal section, described elsewhere in detail, is to define the principles that shall control coal-land classification, to determine the character of the data necessary for this purpose, to receive these data as collected by the field geologists of the geologic branch, and to make and promulgate the classifications and valuations by the use of these data—this in accordance with principles already carefully defined. The coal section consists of a chairman, who is a member of the land-classification board and one of the most experienced coal geologists of the Survey, and a number of additional members, who are familiar with coal problems and are chosen usually from the geologic branch, although some have been chosen from other sections of the board. The coal section thus organized holds frequent sessions, which are attended by coal geologists who have data to present for consideration. At these sessions the problems that have arisen in the field are discussed and solved in accordance with the established rules of the board. The form and the procedure for the submission of data, including data for classification and valuation, are prescribed, and after these data are received appropriate recommendations are made to the Director for withdrawals or restorations, and valuation plats are prepared for his approval and for promulgation by the Commissioner of the General Land Office.

Each step of these various processes is carefully recorded, in order that all evidence considered and all action taken may readily be reviewed at any future time should questions arise as to the correctness of the action or should new evidence be presented. Thereafter when reports on any subdivision classified are called for by any

Government department, by other bureaus, by public officials, or by citizens, prompt response can be made in the light of all action theretofore taken affecting that subdivision.

Because the laws applicable to coal lands, unlike those providing for the disposal of lands containing other minerals, authorize not merely the classification of the public domain as coal or noncoal land but the valuation and sale of the coal land at prices to be fixed in accordance with the quantity, quality, and accessibility of the coal, more complete action is possible in dealing with coal lands than with others, and the very completeness of action required involves correspondingly difficult problems.

Similar sections have been organized within the division of mineral classification for dealing with lands that may contain oil and gas, phosphate, and other nonmetalliferous minerals and for such limited and special classifications of metalliferous land as are required by law. The organization of each of these sections is similar to that of the coal section, and the action taken by them follows similar lines. Members of the land-classification board act as chairmen of the oil and gas section, the phosphate section, and the metalliferous section. Other members of the sections are selected from geologists who are engaged in field work on the particular resource which is the subject matter of the board's action.

A similar but less formal organization has been effected for the division of hydrographic classification. This division deals with those phases of land classification that depend on water supply and that involve the solution of engineering problems. The division's chief task is the classification of lands according to their irrigability and their power value, but it also reports on various complex problems which are involved in the consideration of miscellaneous rights of way. This division is administered by the chief engineer of the board. As occasion may demand, sections are organized within it for disposing of the various problems that arise. At present (1913) there are two such sections, one dealing with water powers and the other with irrigation. Each section consists of a chairman and two or more additional members, usually chosen from the engineers or hydrographic geologists of the water-resources branch. The section thus constitutes a committee which, like the sections in the division of mineral classification, may give preliminary consideration to a problem of classification (under the enlarged-homestead act, for example), or it may prepare instructions for the guidance of the field engineer or geologist and later give consideration to the data that he has obtained and prepare appropriate recommendations. The field branch with which these sections necessarily maintain closest relations is the water-resources branch, although their relation with the topographic branch is but little less close. The graphic data on drainage areas, stream grades, reservoir sites, and general topographic features which result from the work of the topographic branch, when combined with the data on water supply assembled by the water-resources branch, furnish the basis for determining most irrigation and power problems.

In addition to the work done by these technical divisions and sections, certain miscellaneous duties are performed by means of a less well-defined administrative division of the board, whose functions are closely interwoven with those of the technical divisions and are participated in by some of the same officers. A committee, of which the secretary of the board is chairman, has charge of the filing and docketing system. The chairman of the oil section is responsible for the records in the division of mineral classification and for the details of cooperation with the Land Office and the Indian Office; the chairman of the water-power section is chiefly responsible for the records in the division of hydrographic classification.

The more important elements in the organization are set forth in the following outline:

LAND-CLASSIFICATION BOARD.

Administration.

Chief of board.
Chief engineer.
Secretary.

Division of mineral classification.

A geologist in charge.
Coal section.
Oil section.
Phosphate section.
Metalliferous section.

Division of hydrographic classification.

A chief engineer in charge.
Water-power section.
Irrigation section.

HISTORY AND LEGAL BASIS FOR LAND CLASSIFICATION.

INTRODUCTION.

Ever since the policy of selling the lands of the public domain as a source of national revenue was abandoned and the contrary policy of so disposing of them as to promote settlement and development was adopted, the administration of the land laws passed by Congress has required a segregation of the lands into classes according with their character. It is apparent, although it has nowhere been expressly stated by Congress, that the fundamental principle guiding that body has been to dispose of each tract of the public domain for the use to which it is best adapted. Thus the laws have provided that agricultural entry should not be made upon valuable mineral lands, that lands containing deposits of coal should be sold only as coal lands, and so on for all other classes of lands. The underlying theory of devoting the public lands to their highest use and the consequent necessity for classification of uses may easily be recognized from a study of the brief outline of the more important existing land laws given on pages 20–32.

The same recognition by Congress of the necessity for land classification is shown by numerous acts calling for the classification of specific areas. Nearly every law providing for the opening of an Indian reservation has required the lands to be classified preliminary to their disposition. The act of February 26, 1895 (28 Stat., 683), provides and appropriates for a definite classification of lands within the limits of the Northern Pacific Railroad grant in portions of Montana and Idaho, and the sundry civil bill of June 25, 1910 (36 Stat., 739), makes further appropriation for the same purpose. The act of October 2, 1888 (25 Stat., 526), makes provision for a classification that was not necessary to the administration of the land laws then in force by appropriating $100,000 to the Geological Survey "for the purpose of investigating the extent to which the arid region of the United States can be redeemed by irrigation and the segregation of the irrigable lands in such arid region and for the selection of sites for reservoirs and other hydraulic works necessary for the storage and utilization of water for irrigation and the prevention of floods and overflows."

A relatively recent indication of Congressional belief in land classification is afforded by the two acts of June 25, 1910, providing for the withdrawal of lands from entry, the one of public lands, the other of lands in Indian reservations. As withdrawals constitute one step in the process of classifying the public domain, the passage of bills authorizing withdrawals clearly reaffirms the established policy of land classification. One of these acts (36 Stat., 847), in terms sanctions the classification of lands, providing—

That the President may at any time, in his discretion, temporarily withdraw from settlement, location, sale, or entry any of the public lands of the United States, including the District of Alaska, and reserve the same for water-power sites, irrigation, classification of lands, or other public purposes to be specified in the orders of withdrawals, and such withdrawals or reservations shall remain in force until revoked by him or by an act of Congress.

The other (36 Stat., 855) provides—

That the Secretary of the Interior be, and he is hereby, authorized, in his discretion, to reserve from location, entry, sale, allotment, or other appropriation any lands within any Indian reservation, valuable for power or reservoir sites, or which may be necessary for use in connection with any irrigation project heretofore or hereafter to be authorized by Congress.

Thus the plain intention of Congress that the public lands shall be classified and that they shall be disposed of in accordance with their classification is shown by definite provisions for the classification of certain areas, by the authorization of land withdrawals, and by the creation of an organization—the Geological Survey—among whose prescribed duties the classification of the public lands is specifically stated. But were there none of these evidences the fact that Congress has consistently recognized the necessity for the classification of public lands would be established beyond question by a study of the land laws, which, as the following brief outline will show, could not be administered without some sort of segregation into classes. This outline does not purport to set forth in detail all the laws under which disposition is made of the public lands; it only sketches the principal features of the more important laws.

LAND LAWS.

GENERAL DIVISIONS.

The land laws of the United States may be divided into two distinct classes—public-land laws and land grants. The first are general laws providing for the disposition of lands to any duly qualified person who may wish to avail himself of the prescribed conditions; the second are special laws granting certain areas to specified individuals, corporations, or State governments. The laws of each of these two classes may in turn be subdivided, the public-land laws falling loosely under the headings of agricultural, mineral, and coal land laws and laws relating to public and quasi-public uses, whereas land grants may be divided into grants made to States and grants made to railroads.

PUBLIC-LAND LAWS.

AGRICULTURAL-LAND LAWS.

Purpose.—In general, the purpose of the laws relating to agricultural land is to promote the settlement of the public domain. The principal acts are those providing for homesteads, forest homesteads, enlarged homesteads, desert-land entries, entries under the reclamation act, the sale of isolated tracts, and timber and stone entries. Every tract of land to which these laws are applied must be nonmineral in character.

Homesteads.—The homestead act was passed by Congress in 1862 and was approved by President Lincoln on May 20 of that year (Rev. Stat., 2289–2303). It marked the final abandonment of the policy of disposing of the national domain as a means of providing public revenue. Until 1912 the homesteader was required to establish a residence on his land and to reside thereupon for a period of five years. No definite amount of cultivation was required, but the building of houses and barns and the cultivation of a part or all of the area were regarded as evidence of the good faith of the entryman in entering the land for the purpose of building a home for himself, this being the fundamental object of the homestead act. On June 6, 1912 (37 Stat., 123), the law was amended by reducing the five years' residence theretofore required to a residence of three years. The requirement as to residence is modified by what is known as the "commutation clause" (Rev. Stat., 2301, as amended by the act of March 3, 1891, 26 Stat., 1098), which provides that after 14 months' residence and cultivation title may be obtained by paying a fixed price per acre, this price being either $2.50 or $1.25, the first if the land is within, the second if it is without the limits of a railroad grant. Homesteads reserving coal or oil and gas to the Government under the acts of June 22, 1910 (36 Stat., 583), and August 24, 1912 (37 Stat., 496), described later (p. 45), may not be commuted. The amendment of June 6, 1912, also provides that the entryman must cultivate "not less than one-sixteenth of the area of his entry beginning with the second year of the entry and not less than one-eighth beginning with the third year of the entry and until final proof." The homestead act contains the clause "nor shall any mineral lands be liable to entry and settlement." The area of the homestead is restricted to 160 acres.

Forest homesteads.—Lands in national forests are not in general open to agricultural entry, but under the act of June 11, 1906 (34 Stat., 233), forest-reserve lands which are chiefly valuable for agriculture, which are not needed for public purposes, and which, in the opinion of the Secretary of Agriculture, may be occupied without injury to the forest, may be entered under the homestead laws. Application for a particular tract desired, which must not exceed 160 acres in area nor 1 mile in length, must be made to the Secretary of Agriculture. The land is then examined by a field agent of the Forest Service, and if his report is favorable the land is listed to the Department of the Interior, where homestead entry is allowed. The entry thereafter proceeds as would any other entry under the homestead law, but no commutation is permitted. The law differs from all other agricultural-land laws in that the land must be chiefly valuable for agriculture and that the entry may be described by metes and bounds instead of by legal subdivisions of the public-land survey.

Enlarged homesteads.—An act known as the enlarged-homestead act, approved February 19, 1909 (35 Stat., 639), provides that in the States of Colorado, Montana, Nevada, Oregon, Utah, Washington, Wyoming, Arizona, and New Mexico a homestead entry may comprise 320 acres of nonmineral lands which have been designated by the Secretary of the Interior as not susceptible of successful irrigation at a reasonable cost from any known source of water supply. On June 17, 1910 (36 Stat., 531), a similar act was approved applying to Idaho, and on June 13, 1912 (37 Stat., 132), one applying to California and North Dakota. The requirements as to residence and cultivation on an "enlarged homestead" are, under the act of June 6, 1912 (37 Stat., 123), the same as those for other homesteads, but enlarged-homestead entries may not be commuted by cash payment. The enlarged-homestead acts further provide that tracts in the States of Utah and Idaho which have not upon them "such a sufficient supply of water suitable for domestic purposes as would make continuous residence upon the lands possible" may be subject to entry without the necessity of residence, but one-eighth of the area of the entry must be cultivated from the beginning of the second year and not less than one-fourth from the beginning of the third year until final proof has been submitted.

Desert land.—Under the desert-land acts entry may be made on lands which, by reason of lack of rainfall, will not produce native hay or other agricultural crops or trees without irrigation. Such lands may be entered by irrigating and producing crops on not less than one-eighth of the area. No residence is required. Any person duly qualified may enter an area not exceeding 320 acres of such lands. It should be noted, however, that this 320-acre area is limited by the fact that one person is not permitted to acquire more than 320 acres of land under the public-land laws, mineral entries not being taken into account. The entryman is given three years in which to reclaim his land, which must be nonmineral in character.

Reclamation act.—Under the act of June 17, 1902 (32 Stat., 388), the Government is building great irrigation projects for the reclamation of arid and semiarid lands in the West. Lands thus reclaimed, which must be nonmineral in character, may be entered by any person qualified to make a homestead entry. The enterable area is not more than 160 acres but is different in the different projects and in different parts of the same project. No charge is made for the land, but the entryman must pay his proportional part of the cost of the project in ten yearly installments. Three years' residence on the land is required, as under other homestead laws, and at least one-half the area of the entry must be cultivated before title can be obtained.

Isolated tracts.—Small tracts of public land surrounded by lands which have already been entered may be purchased as isolated tracts under section 2455 of the Revised Statutes as amended by the act of June 27, 1906 (34 Stat., 517). Under the act of March 28, 1912 (37 Stat., 77), mountainous tracts which are not isolated by entered land but which are unfit for cultivation may be purchased by the owner of adjoining land in the same manner as isolated tracts. A person desiring to purchase land in this manner files with the local land officers an application to purchase, whereupon, if the lands are nonmineral and are in fact isolated or mountainous, a public sale is advertised, at which the lands are sold to the highest bidder. No residence or cultivation is necessary, but the land must be nonmineral.

Timber and stone lands.—The foregoing five classes of laws constitute the principal types under which agricultural entry may be made. There remains a sixth class of considerable importance, which, while applying only to lands more valuable for other purposes than for agriculture, is nevertheless more nearly allied to the agricultural laws than to the laws relating to minerals, coal, or quasi-public uses. Under the act of June 3, 1878 (20 Stat., 89), and acts amendatory thereof nonmineral lands which are valuable chiefly for the timber and stone thereon and which are unfit for cultivation may be appraised and sold at not less than $2.50 per acre. Application to purchase is made in a manner similar to that required by the laws relating to isolated tracts, but there is no public sale. There is instead an appraisement of the value of the land by an appraiser designated by the Government, and the lands are purchased at the price so fixed.

MINERAL-LAND LAWS.

General provisions.—The mineral-land laws were in the main formulated in the 10 years between 1865 and 1875. They are based largely on local mining customs which had attained the force of law in the mining camps on the public domain. Their constant purpose has been to promote mineral development. The act of May 10, 1872 (Rev. Stat., 2319), provides that "all valuable mineral deposits in lands belonging to the United States, both surveyed and unsurveyed, are hereby declared to be free and open to exploration and purchase, * * * by citizens of the United States and those who have declared their intention to become such." No important amendment of the mining laws has been made since the date of this act. At that time the known deposits of importance on the public domain comprised only metalliferous minerals, and the laws were framed with such deposits in mind, provision being made for two classes of claims—lode and placer. From time to time since the adoption of the mining laws one and another nonmetalliferous mineral has become important, and its entry under the placer law has been authorized by Congress, which has thus specially provided for the entry of lands that are chiefly valuable for petroleum, salines, and building stone.

The general procedure under the mineral-land laws is the same for all classes of deposits. The person who desires to obtain mineral lands must first make a discovery of valuable mineral within the limits of the claim that he wishes to locate. This discovery, as interpreted by the Department of the Interior and the courts, must be such a showing of mineral as would warrant a man of ordinary prudence in expending his time and labor upon the claim in the reasonable hope and expectation of developing a paying mine thereon, or, as expressed in one of the latest decisions (40 L. D., 271) interpreting the lode law, "there must be actually physically exposed" within the limits of the claim "a vein or lode of mineral-bearing rock in place, possessing in and of itself a present or prospective value for mining purposes." The method of location, the posting of location notices, and other similar matters are determined by the local customs or miners' rules of the district in which the claim is situated. In order to hold a claim against possible adverse claimants—in other words, to prevent its being jumped—at least $100 worth of work, called "assessment work," must be performed on it each year. After $500 worth of assessment work has been done and certain requirements as to recording and surveys have been met, the applicant, on payment of a fixed price per acre, is entitled to patent.

Lodes.—Claims for veins of quartz or other rock in place are known as lode claims (Rev. Stat., 2320). Their size is governed by the rules of the mining district in which they are situated but must not exceed 600 feet in width and 1,500 feet in length. Claims need not conform to the public-land system of surveys and may be in almost any shape, provided only that the end lines of each claim shall be parallel to one another. When patent is sought, a purchase price of $5 an acre must be paid.

All veins that come to the surface within a given claim are the property of the owner of that claim through their entire depth (Rev. Stat., 2322) but only for such portion of their extent as lies between the end lines of the claim. Thus the owner of the outcrop or apex of a lode may follow it downward indefinitely so long as he stays within his end lines and may mine it without regard to the ownership of the land under which it passes. This provision, which is known as the "law of the apex," has unquestionably been more provocative of litigation than any other provision of American land law.

The lode law provides also for the discovery in driving tunnels of veins not outcropping on the surface and not previously known to exist. It grants to the discoverers the right to 1,500 feet of extent of each vein so discovered within 3,000 feet of the face of the tunnel, with the same apex right as if the discovery were made at the surface. Failure for six months to prosecute work on a tunnel acts as an abandonment of the right to veins which may subsequently be encountered.

The number of claims which may be entered by one person under the lode law is unlimited, provided he does the necessary assessment work and otherwise complies with the law for each claim. Moreover, the owner of a group of claims may concentrate his assessment work on one claim of the group if such work tends to the development of every claim in the group.

Placers.—The placer law, which was approved July 9, 1870 (16 Stat., 217), was intended to apply to gold and silver distributed through deposits of sand and gravel. As at that date there were no known important mineral deposits except veins and placers, the law provides (Rev. Stat., 2329) that "placer" claims shall include "all forms of deposit, excepting veins of quartz or other rock in place." These placer claims are subject to entry and patent in a manner similar to lode claims, but where the lands have been surveyed the claim must conform to the legal subdivisions of the survey. The purchase price is $2.50 an acre. The maximum area that may be included in one claim by an individual is 20 acres, although, as in lode claims, there is no limit to the number of claims that may be entered. An association may enter in one claim an area equal to 20 acres for each member but not more than 160 acres. Only one discovery of mineral is required to support a placer location, whether it be of 20 acres by an individual or of 160 acres by an association. The applicant for a placer claim must make affidavit that there is not within the limits of the claim any valuable vein or lode and also that title is not sought in order to control watercourses or to obtain valuable timber. The assessment work on each claim, whether of 20 or 160 acres, must amount to $100 a year and to $500 before patent may be issued. On placer as on lode claims annual assessment work to the amount of $100 for each claim in a group may be done on any one of the claims in the group, provided it tends to the exploration or development of all.

Building stone.—By the act of August 4, 1892 (27 Stat., 348), the placer law was extended to apply to lands chiefly valuable for building stone. The requirements as to discovery, assessment work, area, and price are the same as for other placers. It is to be noted that in this act the factor of relative value was for the first time specifically introduced into mineral-land law. The earlier laws provide for mineral entry on lands which are valuable for their mineral deposits. It has been argued that only lands whose mineral value is greater than their agricultural value are properly enterable as mineral land, and the decisions of the department and the courts can not be said to have settled the matter conclusively. In the building-stone and subsequent extensions of the placer law, however, it is specifically stated that the lands must be chiefly valuable for the mineral upon whose discovery the claim is based.

This extension of the placer law to cover building stone neither repealed nor conflicts with the timber and stone act of June 3, 1878 (20 Stat., 89), already discussed. Thus lands chiefly valuable for building stone may be purchased at an appraised value not less than $2.50 per acre or may be entered under the placer law and patented after the completion of the required amount of assessment work, on payment of $2.50 per acre.

Oil.—About a quarter of a century after the passage of the placer law valuable deposits of petroleum were discovered on public lands. The discoverers, finding themselves without an appropriate law under which to apply for a patent, made application under the placer law—not because it was fitted to the needs of the situation but because of its general provision that all forms of deposit excepting veins of quartz or other rock in place should be entered thereunder. The Department of the Interior, recognizing the undesirability of applying the placer law to oil and gas, refused to allow the applications. On an appeal to Congress for relief, the act of February 11, 1897 (29 Stat., 526), was passed, providing that lands chiefly valuable for petroleum and other mineral oils should be enterable under the placer law. On February 12, 1903 (32 Stat., 825), specific authority was granted for doing assessment work on any one of a group of oil claims lying contiguous and owned by the same person or corporation, not exceeding five claims in all, provided that such assessment work tends to develop or determine the oil-bearing character of all the claims. The requirement of discovery of valuable minerals as a prerequisite to location—a requirement reasonable enough when applied to veins outcropping at the surface or to gold placers—is applied as rigidly to deposits of oil and gas, which, as a rule, can be discovered only after long and expensive exploration, as to other minerals. Lands included in petroleum placers, like those entered for building stone, must be chiefly valuable for the purpose for which they are claimed.

Salines.—The act of January 31, 1901 (31 Stat., 745), extends the placer law to cover lands that contain salt springs or deposits of salt in any form and that are chiefly valuable therefor. This has been interpreted as including only sodium chloride, no specific provision having been made for other soluble salts. The requirements as to area, assessment work, and price are those contained in the original placer law, except that the same person may not locate or enter more than one claim. The consideration of relative worth is again introduced.

COAL-LAND LAWS.

The law under which disposition is made of coal differs so radically from the laws regarding other minerals that it is not ordinarily classed with the mineral-land laws. It was approved March 3, 1873 (17 Stat., 607), and was incorporated into the Revised Statutes as sections 2347 to 2352. Any qualified person may purchase an area of coal land not exceeding 160 acres on payment of not less than $10 an acre if the land is more than 15 miles from a railroad and not less than $20 an acre if the land is within 15 miles of a railroad. An association of persons severally qualified may purchase 320 acres. An association of four or more persons who have opened and improved a coal mine upon the public lands and have expended not less than $5,000 in working and improving it may enter an area not exceeding 640 acres. No person may make more than one coal entry, either individually or as a member of an association, and no association any member of which has previously exhausted his coal right may purchase coal land. A person or association opening a mine on the public lands is entitled to a preference right of entry for the lands on which the mine is situated, provided that a "coal declaratory statement" is filed within 60 days from the initial date of actual possession and the commencement of improvements upon the land. This preference right is good for one year only. The operation of the law is restricted to surveyed lands, which must not be valuable for their content of gold, silver, or copper.

For over 30 years after the passage of this law all coal lands were sold at the minimum prices of $10 and $20 an acre prescribed by the statute. Since 1907 the selling prices have been fixed by the Geological Survey and have ranged from the minimum prices up to $600 an acre.

LAWS RELATING TO PUBLIC AND QUASI-PUBLIC USES.

The laws governing public and quasi-public uses of land differ from the other laws under discussion in that they provide for the use of rights of way for various specified purposes and do not contemplate the transfer to the beneficiaries thereunder of fee title to the land affected.

Railroads.—By the act of March 3, 1875 (18 Stat., 482), Congress granted to railroad companies right of way to the extent of 100 feet on each side of the center line of a proposed railroad through the public lands, under prescribed conditions. Upon the approval by the Secretary of the Interior of the location map filed by any railroad company, the road as located is noted on the plats in the General and local land offices, and thereafter all public land over which such right of way passes is disposed of subject to such right of way. By act of March 2, 1899 (30 Stat., 990), Congress provided for similar rights of way across Indian reservations, and by the act of March 3, 1899 (30 Stat., 1233), the Secretary of the Interior was authorized to approve rights of way for wagon road, railroad, or other highway across any forest reservation or reservoir site when in his judgment the public interest would not be injuriously affected thereby.

Irrigation.—By act of March 3, 1891 (26 Stat., 1095), Congress granted to canal and ditch companies formed for the purpose of irrigation the right of way for canals, ditches, and reservoirs to the extent of the ground occupied and 50 feet on each side of the marginal limits thereof, across public lands and reservations, provided that no such right of way shall be so located as to interfere with the proper occupation by the Government of any such reservation and that all maps of location shall be subject to the approval of the department of the Government having jurisdiction over such reservation. Upon the approval by the Secretary of the Interior of the location map the right of way is noted on the plats in the General and local land offices and thereafter all public land over which the right of way passes is disposed of subject to such right of way. By act of May 11, 1898 (30 Stat., 404), the use which may be made of the canals, ditches, and reservoirs for which right of way is secured under the act of 1891 was extended to include purposes of a public nature, water transportation, domestic purposes, and the development of power, as subsidiary to the main purpose of irrigation. The act of February 15, 1901 (31 Stat., 790), which provides for the issuance of revocable permits for the development of power, covers also canals, ditches, pipes and pipe lines, flumes, tunnels, or other water conduits and water plants, dams, and reservoirs used to promote irrigation.

Power.—Power development on the public lands and reservations can at this time (February, 1913) be accomplished only under the act of February 15, 1901 (31 Stat., 790), except that power development subsidiary to the main purpose of irrigation may be made under the irrigation acts and that power development on national forests for mining, milling, and municipal purposes may be made under the act of February 1, 1905 (33 Stat., 628). The act of February 15, 1901, authorizes the Secretary of the Interior to issue revocable permits, under general regulations to be fixed by him, for rights of way for electrical plants, poles, and lines for the generation and distribution of electrical power to the extent of the ground occupied by the works and not to exceed 50 feet on each side of the marginal limits thereof. The law provides that permits issued under this act shall not be held to confer any right, easement, or interest in, to, or over any public land, reservation, or park. The act of March 4, 1911 (36 Stat., 1253), authorizes the head of the department having jurisdiction over the lands to grant rights of way for a period not exceeding 50 years upon the public lands, national forests, and reservations for poles and lines for the transmission and distribution of electrical power, to the extent of 20 feet on each side of the center line.

Mining and milling.—The act of February 1, 1905 (33 Stat., 628), grants rights of way within or across national forests for dams, reservoirs, water plants, ditches, flumes, pipes, tunnels, and canals for mining purposes and for the purposes of the milling and reduction of ores. Outside of the national forests the use of similar rights of way for these purposes may be made only under revocable permit under the act of February 15, 1901.

Municipal uses.—Rights of way for municipal use for procuring water supply or for developing power may be obtained within a national forest under the act of February 1, 1905, and outside of the forests under the act of February 15, 1901.

LAND GRANTS.

GRANTS TO STATES.

In aid of schools and State institutions.—The Continental Congress, about the year 1785, declared that to each State created out of the public domain there should be given a certain portion of each township in the State, the proceeds derived therefrom to be used for public education. Accordingly, when the first State, Ohio, was admitted into the Union from the public domain, April 30, 1802 (2 Stat., 173), sec. 16 of each township was granted for the establishment of a school fund. As other States have been admitted this practice has been deviated from only in adding to the acreage granted. Sec. 16 has been a school section in every public-land State; to this sec. 36 has been added in many States, and in some States secs. 2, 32, and 36. The title of the State to these sections attaches immediately upon survey, unless the lands are at that date known to be mineral in character or are included in a valid settlement or other claim under the public-land laws or are within a forest, military, Indian, or other reservation. In any of these contingencies the State does not obtain title, but may select an equal area of nonmineral lands elsewhere. These are known as indemnity lands. As a rule they are not at once selected by the States but are selected only as the demand for specific lands arises.

In addition to granting school lands in place and their associated indemnity lands, Congress has made to certain States "quantity grants"—that is, grants of specified quantities of nonmineral lands wherever the State may choose to select them—in aid of State institutions, such, for example, as insane asylums. Selection rights under these grants, like those under the indemnity lists, are as a rule exercised by a State only when individuals or corporations purchase the right to select certain desired lands.

In aid of internal improvements.—In the early days of the country's history the right of Congress to grant public lands in aid of internal improvements was bitterly contested. The first legislation of this character was contained in the enabling act of the State of Ohio, already cited, and provided that one-twentieth of the proceeds of the sale of public lands within the State should be given to the State to be used in establishing public roads. The first grant of specific lands in aid of internal improvements was not made until February 28, 1823 (3 Stat., 727). This grant also was made to the State of Ohio to aid in the construction of a wagon road. Since that time there have been ten other wagon-road grants, eight canal grants, three river-improvement grants, and twenty railroad grants. The railroad grants to States alone approximate 40,000,000 acres. No grant to a State in aid of internal improvements has been made since the grant to Oregon for the Coos Bay wagon road on March 3, 1869 (15 Stat., 340). Although these grants were in terms made to the States, most or all of them were in fact made through the States to corporations that carried out the improvements contemplated.

Carey Act.—The act of August 18, 1894 (28 Stat., 372, 422), commonly known as the Carey Act, and amendments thereto, the purpose of which is to aid the public-land States in the reclamation of the desert lands therein and in the settlement, cultivation, and sale of such lands in small tracts to actual settlers, authorize—

(*a*) The temporary withdrawal of public lands from settlement or entry pending investigation and survey preliminary to the filing of an application for segregation, such withdrawn lands to be restored to settlement and entry at the end of one year from the date of withdrawal in case application for segregation is not theretofore made.

(*b*) The segregation of public lands by the Secretary of the Interior, contracts between the United States and any beneficiary State, and the reclamation of such lands by beneficiary States within 10 years from the approval of the State's application (subject to an extension of 5 years).

(*c*) The patenting to any beneficiary State of any tract of reclaimed land when satisfactory proof is made that an ample supply of water to reclaim it is actually furnished.

Other important provisions of the Carey Act are in brief as follows:

Prior to segregation of lands or execution of contract between the United States and any State, such State shall file a proper application and present satisfactory plans for the reclamation of the lands. Lands that are not desert, lands that are occupied by bona fide settlers or under the mining laws, unsurveyed lands occupied with a view to entry under the desert-land laws, and lands containing valuable deposits of minerals other than coal are not subject to segregation. Coal lands (in Utah oil and gas lands also) may be segregated, but when patent is issued it must contain a reservation of these minerals to the United States.

The usual procedure under the Carey Act is about as follows:

A corporation or individual applies to the State for the withdrawal of certain public lands proposed for irrigation. The State thereupon submits to the Interior Department an application for their withdrawal. On the approval of this application the State is allowed one year in which to investigate the project and prepare satisfactory plans for reclamation. The proposing company conducts the investigations and if a project that is considered feasible is developed makes application to the State for the segregation of the irrigable lands and offers to contract with the State for their reclamation. The State thereupon applies to the Interior Department for the segregation of the lands under the terms of the Carey Act and its amendments. If the plan of irrigation is found to be feasible, the irrigation company responsible, and the available water supply adequate, the lands are segregated and the contract for their reclamation is entered into between the United States and the State. When the irrigation works are completed to the satisfaction of the Government, patent is issued to the State or to its assigns. The State receives payment for the lands from the settler, and the irrigation company, either directly or through the State, receives payment from each settler for his proportionate share of the irrigation works and water rights involved.

RAILROAD GRANTS.

As already indicated, most grants of public lands in aid of internal improvements have been made through the States. Eight grants, however, have been made by Congress directly to corporations, to encourage the building of railroads. Four of these grants, aggregating approximately 109,000,000 acres, were made to Federal corporations created by Congress for the purpose of building the roads subsidized, and four were made to State corporations. Of the four grants to State corporations, two were declared forfeited by Congress in 1874, the two remaining aggregating approximately 6,000,000 acres. The first of the grants made directly to corporations was the Pacific railroads bill of July 1, 1862 (12 Stat., 489), which provided for the building of the Union Pacific-Central Pacific line from Missouri River to the Pacific coast. This act granted to the railroad every alternate section for 20 miles on either side of the right of way. The Northern Pacific grant of July 2, 1864 (13 Stat., 365), conveyed every alternate section for 40 miles on either side of the right of way. Neither of these grants contained restrictions as to the use to be made of the lands, but certain of the later grants required the lands to be sold only to actual settlers at prices not to exceed $2.50 an acre. The last of the railroad grants was made to the Texas Pacific Railroad Co. on March 3, 1871 (16 Stat., 573). Since that time Congress has consistently refused to grant lands, either to States or to corporations, in aid of internal improvements.

All the railroad grants were restricted to lands containing no minerals except coal and iron. These two were given to the railroads because of their use in the construction and operation of the roads. In certain cases the railroads were permitted to select other lands in lieu of those which, normally constituting a part of the grant, proved to be valuable for minerals other than coal and iron or to be included within Indian or military reservations or national forests or to have been covered by valid settlement. The right to make these lieu selections is usually sold by the railroads in the form of "scrip," which may be filed on any vacant unreserved nonmineral land.

NECESSITY FOR LAND CLASSIFICATION.

A study of the land laws shows the absolute necessity of some form of segregation of the lands into classes as a prerequisite to their disposition. Agricultural entry may not be made on lands containing valuable minerals, nor coal entry on lands containing gold, silver, or copper; lands included in desert entries or selected under the Carey Act must be desert lands; enlarged-homestead lands must not be susceptible of successful irrigation; placer claims must not be taken for their timber value or their control of watercourses; and lands included in building-stone, petroleum, or salt placers must be more valuable for those minerals than for any other purpose. So through the whole scheme of American land laws runs the necessity for determining the use for which each tract is best fitted.

No specific financial provision has ever been made for a systematic classification of the entire public domain into classes representing the highest use for each area. Such a scheme, with proper provision for revisions whenever necessitated by changing conditions or increased knowledge, would be of immense value in the administration of the public domain, and if it had been initiated when the major portion of the public-land laws were in process of formation it would have saved to the public natural resources of immense value. It can hardly be questioned that the National Academy of Sciences had in mind such a systematic classification of the entire public domain when it recommended the creation of the Geological Survey, but the new organization when created was not supplied with the funds to carry forward a work of such magnitude. The classification of coal lands and the segregation of lands valuable for oil, gas, phosphate, potash, water power, and reservoir sites constitute a tardy and very meager attempt to meet the need for a universal classification.

In default of a classification of the entire national domain the land department early adopted the expedient of requiring a classification of each tract of land at the time of its disposition. These classifications in general originated from four sources—first, from the applicant for the land; second, from deputy surveyors; third, from members of the Land Office field service; and fourth, from the Geological Survey. It is the present purpose to discuss the first three types of classification somewhat briefly and the last in considerable detail, and to show the weight given to each type and the results.

AGENCIES AND METHODS OF CLASSIFICATION.

CLASSIFICATION BY AFFIDAVIT OF APPLICANT.

Nearly every applicant for public land is required to submit an affidavit that the land desired is of a character properly subject to the proposed entry or selection. Every applicant under the agricultural laws must set forth by his own oath and that of two witnesses that the lands are nonmineral in character. The State in selecting indemnity or "quantity grant" lands must make affidavit to their nonmineral character. Mineral applicants must state under oath the discovery of valuable minerals, and similar affidavits are required of most if not all applicants.

Less and less weight has been given in recent years to classifications so made. It has been found that the affidavits of interested parties, whether furnished by individuals or submitted by sovereign States, do not furnish a reliable basis for the disposition of public lands. Furthermore, the determination of the mineral or nonmineral character of a particular tract may be too difficult and too complex a problem for solution by other than a special trained expert. At present all agricultural entries except homestead and desert-land entries on unwithdrawn lands are classified as to mineral character and power-site or reservoir value either by examination on the ground by the Land Office field service or by the Geological Survey from information contained in its records or procured by special examination. Thus, although the affidavit of the applicant has not been abandoned, it is of little importance. Similarly mineral claims in national forests are subjected to examination before the applicant's affidavit of discovery is accepted, and all along the line classification by the entryman or selector is being replaced by classifications made by the Government.

78894°—Bull. 537—13——3

CLASSIFICATION BY DEPUTY SURVEYORS.

The regulations for the survey of public lands require the deputy surveyor to note and report all occurrences of mineral. These requirements have varied from time to time. In certain periods the deputy surveyor has reported a somewhat detailed classification of the lands surveyed into first-class agricultural, second-class agricultural, grazing, mineral, timber, etc. At one time all lands reported by deputy surveyors to be mineral in character were withheld from agricultural entry, but the inaccuracy of the segregations and the magnitude of the areas involved led to a general order throwing all such lands open to all forms of entry. The only present result of a report by a deputy surveyor that land is mineral is to subject agricultural entries to a more careful scrutiny than would otherwise be made.

CLASSIFICATION BY LAND OFFICE FIELD SERVICE.

The General Land Office has a well-organized field service engaged in the examination of entries and selections of public lands. All agricultural entries or selections, including State selections and railroad lieu selections but excepting homestead and desert-land entries on unwithdrawn lands, are examined by this field service as to their mineral character and power-site or reservoir values, unless the Geological Survey is able from its records to make a classification of the lands. Formerly the reports of the members of the field service were accepted as final without review outside of the Land Office and the Secretary's office, and, as a result, some classifications by the Geological Survey were overruled by the Land Office. The resulting confusion led to the adoption of cooperative agreements between the two organizations, whereby the information gathered by each is made fully available to the other. The first of these agreements was entered into July 10, 1910. It has been replaced by a more comprehensive and more systematic agreement adopted March 5, 1912. Under this agreement all entries, selections, or applications except metalliferous mineral entries, coal applications, and homestead and desert entries on unwithdrawn lands are referred by the General Land Office to the Geological Survey. The Survey thereupon renders to the Land Office a report on each case, classifying the land involved. If the Survey classifies the land as having no mineral, power, or reservoir value, questions concerning these values are considered as settled and the case goes forward if it is otherwise regular. If in a given case the Survey reports that the lands are mineral or that they have power or reservoir value the applicant is given 60 days within which to prove that the land is not of the character claimed by the Geological Survey but that it is in fact of the character originally claimed by him. If he fails so to prove, his application is canceled.

If the Geological Survey reports that it has not sufficient information to make a definite classification it furnishes to the Land Office whatever data it may have, which are placed in the hands of a member of the field service for field investigation and report. The report rendered is forwarded to the Geological Survey for further consideration, and a classification based upon it and other facts at hand is reported to the General Land Office. Under this agreement the records of the Survey are enriched by the data gathered by the Land Office field service and, on the other hand, the great amount of valuable information regarding the public lands on file in the Survey is made available to the Land Office in its administration of the land laws.

CLASSIFICATION BY THE GEOLOGICAL SURVEY.

HISTORICAL SKETCH.

Although the act organizing the Geological Survey definitely imposed upon the Director the duty of classifying the public lands, it was many years before the records of the organization contained a sufficient fund of information to be of great use in public-land administration. During its first quarter of a century the Survey devoted its energies almost entirely to gathering scientific data regarding the whole of the United States, and only within the last six or seven years has the immense fund of information so gathered been applied in a systematic way to the solution of public-land problems. During the early period there were perhaps but two practical applications of the Survey's work to land classification. The result of the first application was the segregation of reservoir sites under the act of October 2, 1888 (25 Stat., 527), to which reference has already been made. Congress in 1891 restored all the lands that had been segregated under this act except the areas actually needed for the construction of reservoirs, which still remain segregated as reservoir sites and are not subject to entry. The second application was connected with the administration of the reclamation act by the Geological Survey. Many withdrawals of lands to be included in reclamation projects were made by the Survey prior to the separation from it of the Reclamation Service. With these two exceptions the Geological Survey devoted its energies to gathering data rather than to applying the data gathered to the classification of public lands until the year 1906. Since that date the Survey has been actively engaged in land-classification work. The cooperative agreement whereby certain types of information are made available to the Land Office in its administration of individual entries and selections has already been described. In addition coal lands are being classified and valued as rapidly as the funds at the disposal of the Survey will permit, and oil, gas, phosphate, and potash lands and lands valuable for water-power and reservoir sites are being withdrawn from entry as rapidly as information regarding them is obtained. It is proposed to explain here briefly the history of the classification undertaken with respect to each of these resources.

COAL LANDS.

In the years 1905 and 1906 the general public began to realize that large areas of valuable coal lands in the West had been obtained from the Government by means of agricultural entries. The frauds thus perpetrated were so great as to shock the public mind and to call for some immediate action to prevent further similar looting. Accordingly the President, on June 29, 1906, directed the Secretary of the Interior to withdraw from entry all valuable coal lands. The Survey had previously been making special studies of certain western coal fields and its geologists had assisted in unearthing some of the coal frauds. It was therefore prepared to submit a list of lands which should be withdrawn from entry, and on July 26, 1906, the Acting Secretary of the Interior withdrew from all forms of entry all the lands on the list submitted by the Survey. Other lists for withdrawal were prepared by the Survey during the summer and fall of 1906, and one very excellent list was prepared by the Forest Service. These withdrawals, being intended to prevent acquisition of coal lands under agricultural entry, were made in such terms as to prevent all forms of entry. However, on December 17, 1906, the form of all outstanding orders of withdrawal was modified to apply to coal entries only, so that the withdrawn lands became again subject to agricultural entries but were not subject to coal entry. Thus fraudulent acquisition again became possible and was prevented only by the activity of the field service of the General Land Office. On the other hand, purchase of withdrawn lands as coal land became impossible until after classification and valuation. From time to time other withdrawals from coal entry were made until the spring of 1909, when many of the outstanding withdrawals were restored to their original form and made effective against all forms of entry. Soon thereafter Congress passed the withdrawal act of June 25, 1910 (36 Stat., 847), and since that date coal withdrawals have prohibited all forms of entry except entries on certain classes of land which are exempted from withdrawal by that act and agricultural entries for surface rights only. The policy throughout has been to withdraw all lands on which there is a reasonable probability of the occurrence of coal, to examine these lands as rapidly as the funds available will permit, and on the information gathered to base classifications, the lands found to be noncoal land being restored to entry and those found to contain workable coal being appraised at prices not less than the minimum prices prescribed by the statute.

For a time the withdrawals worked great hardship. The greater part of the lands thus withheld were not good agricultural lands, but the total acreage suitable for agricultural development was large. The situation was finally relieved by the passage of three acts providing for agricultural entry upon lands withdrawn or classified as coal lands, the Government retaining title to the coal deposits and the right to prospect for and remove them. These three acts are more fully discussed below under the heading "Separation acts" (p. 45).

The first regulations prescribing criteria for the classification and valuation of coal lands were approved by Secretary of the Interior Garfield on April 8, 1907. They provided for a maximum workable depth of 1,500 feet and a minimum workable thickness of 2 feet, all lands underlain by coals of less thickness or at greater depth being classified as noncoal land. New regulations were adopted February 19, 1908, and these were in turn superseded by those of April 15, 1908, under which, although the minimum thickness remained unchanged, high-grade coals were classified as workable to a depth of 3,000 feet and certain thicknesses of low-grade bituminous and subbituminous coals to a depth of 2,000 feet. Under all these regulations valuations were based on an estimate in which the number of beds, the thickness of the beds, and the depth of the beds below the surface were taken into account; but the methods of computing prices were such that, for example, a 20-foot bed was valued at no higher price than an 8-foot bed. On April 10, 1909, Secretary Ballinger approved a new set of regulations, drawn on entirely different principles. The minimum thickness was fixed at 14 inches and—a more important change—computations of value were based on the tonnage of coal in the land rather than on the number of beds. The maximum depth was retained at 3,000 feet. These regulations, while far in advance of those preceding, were nevertheless open to criticism because they took little account of certain economic and mining engineering features, such, for example, as the relations between lift and haul, between thickness and mining cost, and between minimum thickness and workable depth. A new set of regulations has just been made effective in which these features have been taken into account and the maximum depth for the highest-grade coals has been increased to 5,000 feet. The prices are based on tonnage, heat value, depth, and thickness. These regulations are given in detail elsewhere in this bulletin (pp. 96–97).

OIL LANDS.

The earliest withdrawals of lands containing oil and gas were made in order to protect oil operators from agricultural entrymen. In 1900 certain lands in Wyoming and California were withdrawn from agricultural entry on representations made by citizens of those States that the lands contained valuable deposits of oil and gas and should be withheld from agricultural entry pending a determination as to their content of oil. These orders and others of similar character were from time to time issued by the General Land Office. The first withdrawal recommended by the Geological Survey was made in 1907. For years the Survey had been doing geologic work in the oil fields of California. Its geologists, studying the conditions of the oil industry as well as the geology and occurrence of oil, early became convinced that unless preventive steps were taken a great amount of fraud would be perpetrated and oil development would be seriously hindered by attempts to obtain oil lands through nonmineral entries. The withdrawal of certain lands was accordingly recommended, and on August 15, 1907, the Acting Secretary of the Interior approved the recommendation and the withdrawal became effective. In 1908 several withdrawals were made in California for the same purpose, and a withdrawal was also made in the Caddo field of Louisiana pending an investigation as to possible means of preventing the enormous waste of natural gas then taking place in that field.

Within a short time it became apparent that the situation was only partly covered by withdrawing oil lands from agricultural entry. The inadequacy of the placer law and its inapplicability to oil lands was clearly recognized. The law was framed to apply to solid minerals; when applied to fluids, such as oil and gas, it at once led to many abuses. Drilling along the boundaries of one claim in order to draw off oil or gas beneath a neighboring claim forced activity in drilling which resulted in production far greater than the demands of the market. The requirement of discovery as a prerequisite to title also forced development and overproduction. It became more and more apparent that oil and gas should be disposed of in terms of barrels or cubic feet rather than in terms of acres. These considerations, together with the advisability of retaining a supply of fuel oil for the use of the Navy, caused the Geological Survey to urge the suspension of all forms of entry on Government oil lands pending the enactment of new legislation by Congress. In consequence Secretary of the Interior Ballinger on September 27, 1909, withdrew from all forms of entry, location, or disposition all public lands believed to contain valuable deposits of oil or gas. As information has since been obtained indicating other public lands to be valuable for these minerals, they also have been withdrawn from all forms of disposition under the mineral or nonmineral land laws. Field examination has shown that certain lands so withdrawn are not valuable for their oil or gas deposits, and they have been promptly restored to public entry. In one State, Utah, the surface of the lands so withdrawn is open to agricultural entry.

A number of bills providing for the disposal of oil and gas deposits have been introduced in Congress, but none have yet been enacted into law, so that the petroleum withdrawals continue in force and new ones are being made as occasion arises. The need of the Navy for a supply of fuel oil has recently been more strongly recognized, the battleships last authorized being designed to burn oil exclusively. Fully to insure the Nation an adequate supply of fuel oil two naval petroleum reserves aggregating 68,249 acres and estimated to contain at least 250,000,000 barrels of oil have been created in the San Joaquin Valley fields of California, one under date of September 2, 1912, and the second under date of December 13, 1912.

PHOSPHATE LANDS.

Phosphate lands, like oil lands, are withdrawn because of the inadequacy of existing law to dispose of phosphate. Only within comparatively recent years has it been known that important phosphate deposits exist on the public domain, but as soon as such deposits were discovered conflicts arose between entrymen under the placer law and entrymen under the lode law. As a matter of fact neither lode law nor placer law is fitted to phosphate deposits, which occur as sedimentary beds interstratified with barren rocks in a manner identical with that in which coal occurs. The placer law provides for the disposition of all forms of deposit except rock in place. The western phosphate deposits are clearly rock in place. Moreover, some of them lie at great depth and are as difficult to mine as coal or any other solid mineral. It is clear that the placer law is not logically applicable to these deposits. Under the lode law a vein which outcrops within the limits of a claim may be followed to indefinite depths and distances so long as the end lines of the claim are not crossed. A phosphate deposit is essentially an interstratified bed, some deposits extending for many miles and being involved in great folds and undulations. The application of the apex law to such deposits would assuredly result in great confusion. For instance, if two sets or series of lode claims are located along the outcrop of a bed of phosphate that occupies a geologic basin and outcrops around its margin, one set of claimants on one side, the other on the opposite side, each set of claimants might be entitled to the bed throughout its extent from outcrop to outcrop. Thus the same property might be disposed of to two separate claimants, each of whom would have a good title. It is obvious that the lode law, under which such a condition is possible, is not suited to the disposition of phosphate deposits.

Still another consideration led to the withdrawal of phosphate lands. Agriculture in the United States is comparatively young, so that the exhaustion of lands from long-continued use has not yet begun to be generally felt. In a large part of Europe, however, phosphate fertilization has become an economic necessity, and as a result the greater part of the phosphate mined in this country is being exported. It has seemed to many students of the situation that the United States should not part with a deposit so vital to its agricultural future. Pending consideration of this question by Congress, as well as the enactment of laws more applicable than the lode and placer laws, the first phosphate withdrawal was made by the Department of the Interior on December 9, 1908. Other withdrawals have been made from time to time as additional valuable deposits of phosphate have been discovered. Since the first withdrawal the known area of phosphate lands has been greatly increased by the explorations of the Geological Survey, and the reserves now include lands in Wyoming, Idaho, Utah, Montana, and Florida.

POTASH LANDS.

The agricultural industry of the United States has begun to feel the need for the rejuvenation of lands by the application of potash. All of this mineral heretofore used, in manufacturing as well as in agriculture, has been imported from Germany. A threatened termination of the supply from that source by the German Government lent acute interest to the question whether or not potash deposits are to be found in the United States, and on March 4, 1911, Congress appropriated $20,000 for research and exploration for potash deposits by the Geological Survey. This appropriation was renewed the following year. Promising indications have been discovered, exploration work is being actively continued, and three areas have been found where the existence of potash salts warrants withdrawal of the lands. The first potash withdrawal covered one of these areas and was made on January 16, 1913. It is the present intention to recommend the withdrawal of all valuable deposits found and all lands in which there is a reasonable probability of the occurrence of valuable potash, these withdrawals to remain in force until Congress has provided more appropriate legislation than the existing placer law.

METALLIFEROUS MINERAL LANDS.

An unusual type of withdrawal, designated "Mineral-land withdrawal No. 1," was made in Arizona by the President on September 23, 1912. It covers an area in which investigations made by the Geological Survey show geologic conditions favorable to the occurrence of deep-seated deposits of copper. The deposits in this district are of such nature that no surface discovery, such as is required by the lode law, can be made. As a result valid locations can not be made upon the lands until valuable minerals have been discovered therein, either by deep drilling or deep shafting. There was danger that before either of these types of prospecting could be completed attempts would be made to obtain title to the lands by means of State selections or other nonmineral entries. Accordingly the President directed that the area be included in a withdrawal. By the terms of the withdrawal act the withdrawn lands are open to exploration and purchase under the mining laws, so far as they apply to metalliferous minerals. Thus the lands are reserved for exploration as to their metalliferous value but are not open to other forms of entry.

WATER-POWER SITES.

In messages to Congress during 1908 and 1909 President Roosevelt called attention to the danger of an uncontrolled monopoly of water-power development and to the desirability of preventing power sites on the public domain from falling into the hands of speculators and monopolists. As early as February 26, 1908, in a message transmitting a report of the Inland Waterways Commission, he advocated legislation providing for the leasing of such sites rather than their alienation. The report of the Inland Waterways Commission contains the following statement:

> Wherever water is now or will hereafter become the chief source of power, the monopolization of electricity from running streams involves monopoly of power for the transportation of freight and passengers, for manufacturing, and for supplying light, heat, and other domestic, agricultural, and municipal necessities to such an extent that unless regulated it will entail monopolistic control of the daily life of our people in an unprecedented degree.

Since that time President Taft, Senator Burton, Secretaries Garfield, Fisher, and Stimson, and many others have advocated a revision of the laws pertaining to lands valuable for water powers and have especially urged the retention of their control by the United States.

In the winter of 1908 and 1909, under the direction of President Roosevelt and Secretary Garfield, a number of withdrawals were made covering streams in the Rocky Mountain and Pacific coast States on recommendation of the Reclamation Service. These orders of withdrawal covered wide areas, and as the best agricultural lands in the West are in the vicinity of streams, a great deal of popular discontent and criticism followed. Secretary Ballinger, soon after his appointment, ordered the restoration of all the withdrawn lands, and many such restorations were made, mainly in the latter part of

March and the early part of April, 1909. On April 23, 1909, Secretary Ballinger directed the Geological Survey to make an investigation of water-power sites on the public domain and to recommend as early as possible any withdrawals necessary to protect them pending the enactment of legislation to be recommended by the President. The first withdrawal under this order was recommended by the Survey on May 3, 1909, and approved by Secretary Ballinger on the following day. Since then many such power-site withdrawals have been made, so that at the present time it is believed that the greater number of the valuable power sites on the public domain are withdrawn from entry pending legislation by Congress for their appropriate disposal. The available information does not indicate that there is now in existence any all-inclusive, nation-wide water-power trust such as has been feared by students of the situation. Certain powerful and far-sighted interests have, however, made very determined attempts to acquire control of valuable sites in advance of the possibility of developing a market for the power that might be produced. The passing of these strategic points from public ownership would seriously impair the control by public authority of water-power operations, which are inherently monopolistic. As soon as the Survey obtains knowledge of such sites their withdrawal is recommended. Field examinations have shown that certain areas withdrawn were not so valuable as had at first been supposed and these have been promptly restored.

RESERVOIR SITES.

Reference has already been made to the act of 1888 (25 Stat., 527) and to the fact that certain tracts specially valuable for the construction of reservoirs were segregated under that act and still remain withdrawn pending their restoration by Congress. In its study of the water resources of the public domain the Survey found that attempts were being made to obtain possession of advantageous reservoir sites, not for the purpose of development but for some inferior use or for speculation. Pending legislation by Congress which would make such acquisition impossible a number of reservoir-site withdrawals have been made, the first one having been recommended by the Survey on January 13, 1911, and approved by President Taft on January 17, 1911.

PUBLIC WATER RESERVES.

In the great semiarid grazing areas of the West watering places are few and the range is, in places, monopolized by control of the water holes. It has been common practice for a stock owner to file some form of land scrip or State selection upon all the springs in a district and thereby to exclude all other stock owners from the district as effectually as if he owned every acre of it. In most places the public range of the West is greatly overcrowded and the competition for possession of the water holes has been exceedingly bitter, with the advantage in favor of the large owner, on account of his greater ability to purchase land scrip. Exclusion from the watering places has ruined more than one stock grower and violence has not infrequently accompanied the struggle for their possession. This condition of affairs led members of the Land Office and of the Survey to urge that the watering places on the public range be retained in Government ownership and thrown open to the use of all comers. The possibility of the passage by Congress of a grazing law added to the advisability of such withdrawals. The present conditions on the public range are by no means satisfactory. They give undue advantage to the large stock raiser and are resulting in the deterioration and in many areas the ruin of the range. Several bills have been introduced in Congress providing for Government supervision of grazing under a leasing system. If such a law is passed it is highly important that a sufficient number of watering places to permit the administration of leases should remain in Government ownership. On March 29, 1912, public water reserve No. 1 was recommended by the Survey and approved by the President. Other public water reserves are being created as rapidly as field data can be considered.

WITHDRAWAL ACTS.

The early coal, oil, phosphate, and power-site withdrawals were made by the Secretary of the Interior in the exercise of his executive discretion and without specific authority granted by Congress. The right of the Executive Department to make land withdrawals has been established by numerous court decisions relating to withdrawals covering small areas, but as soon as general withdrawals of large areas were made interested parties began to question their validity. Many claimants asserted their belief in the department's lack of authority by proceeding in disregard and contravention of the withdrawals. This type of action was especially frequent in the oil fields of California and it early became apparent that, unless the validity of the withdrawals was clearly established, millions of barrels of oil would be taken from withdrawn lands while a decision was being obtained from the courts. Accordingly, Congress was urged to pass an act confirming the power of the Executive to withdraw public lands, and on June 25, 1910, a law was approved entitled "An act to authorize the President of the United States to make withdrawals of public lands in certain cases" (36 Stat., 847). That this act was merely confirmatory of powers already reposing in the President and his cabinet is shown by the report of the Senate Committee on Public Lands, from which the following is quoted:

> The power conferred upon the President by the proposed substitute is a power that he has possessed and exercised almost from the inception of our public-land system and is a power that he still possesses and exercises.
>
> The power of the President to reserve public lands from sale and entry rests upon various statutes, upon numerous decisions of the courts, and upon long-established and long-recognized usage.
>
> * * * * * * *
>
> It is only lately that this power has been doubted and questioned, and the object of the proposed substitute is to make it definite and clear beyond all dispute that the President possesses this power of withdrawal.

Immediately after the passage of the act of June 25, 1910, Executive orders were issued by the President ratifying, confirming, and continuing in full force and effect all outstanding orders of withdrawal. Since that date all new withdrawals have been made in accordance with the provisions of this act and have been approved by the President.

The act of June 25, 1910, contains several provisions modifying preexisting practice. In the first place, it provides that lands which are embraced in lawful homestead or desert-land entries made prior to the date of withdrawal or on which valid settlement has been made and maintained shall be excepted from the force and effect of the withdrawal order so long as the entryman or settler continues to comply with the law. Thus the effect of an order of withdrawal on a preexisting homestead or desert-land entry depends on the initial and continued good faith of the entryman, rather than on the value of his land for purposes other than that under which his entry was made. The second important provision is that the rights of any person who at the date of a withdrawal order is a bona fide occupant or claimant of oil or gas bearing lands and who at that date is in diligent prosecution of work leading to the discovery of oil or gas shall not be affected or impaired by the order so long as diligent prosecution of the work is continued. It is to be noted that this provision makes the critical date that of the withdrawal order, even though that order was made before the passage of the withdrawal act. The department has held that what constitutes diligent prosecution of work leading to the discovery of oil or gas must be decided upon the facts in each case. It is safe to assume, however, that many of the subterfuges that have been commonly practiced for the purpose of holding claims will not be considered effective against the withdrawal orders.

Section 2 of the act provided that withdrawn lands should " be open to exploration, discovery, occupation, and purchase under the mining laws of the United States so far as the same apply to minerals other than coal, oil, gas, and phosphates." There were two serious faults in this provision. For one thing, it did not permit the withdrawal of lands valuable for other minerals than the four enumerated. Thus, when interest in the potash situation became general and the desirability of reserving potash lands from entry was perceived it was not possible to make the desired withdrawals because of this provision in the withdrawal act. Furthermore, advantage was taken of this clause to locate valuable power sites as building-stone placers and to include oil lands of great value in placer claims located on comparatively worthless deposits of gypsum. These conditions led the President to urge upon Congress the amendment of the section by providing that withdrawn lands should be open to exploration and purchase under the mining laws for metalliferous minerals only, and on August 24, 1912, Congress so amended the original withdrawal act (37 Stat., 497). Public-land withdrawals now segregate lands from all forms of entry, location, or disposition except metalliferous mineral claims, preexisting homestead and desert-land entries and valid settlements, and oil placers on which work is being diligently prosecuted at the date of withdrawal.

SEPARATION ACTS.

The carrying out of the withdrawal policy for protecting the mineral and water resources of the public domain is in many cases rendered difficult and embarrassing by the agricultural value of the land withdrawn. If valuable water-power or reservoir sites were invariably valueless for farming, or if mineral and agricultural values could not coexist, no hardship would be imposed by and no retardation of development would result from the making of withdrawals. But some of the best farming lands in the West are underlain by coal or phosphate, and some are so situated as to be of strategic importance in power development. Any hindrance to bona fide home building or other agricultural development of the public domain is indeed unfortunate, but in order to protect the public's natural resources withdrawals resulting in such hindrance have been necessary. For certain lands the situation has been relieved by the passage of acts separating the surface right from the right to the underlying minerals. The first of these acts was that of March 3, 1909 (35 Stat., 644), which provides that persons who have entered or selected under the nonmineral laws lands subsequently classified, claimed, or reported as being valuable for coal may elect to receive patent to their lands by reserving to the United States the coal deposits and the right to prospect for and mine them. The act contains a provision for the indemnification of the surface owner for damages to his estate by prospecting or mining and a further provision that the owner of the surface patent shall have the right to mine coal for his own use prior to the disposal of the coal deposits by the United States. This act granted relief only for entries or selections antedating withdrawal. The act of June 22, 1910 (36 Stat., 583), goes a step further with regard to coal lands and provides that homestead entries, desert-land entries, and Carey Act selections may be made on lands withdrawn or classified as coal whenever it is stated in the application that the entry is made to obtain title containing a reservation of the coal to the United States. In this, as in the previous act, provision is made for damages to the surface estate by prospecting or mining. The act of April 30, 1912 (37 Stat., 105), extends the act of June 22, 1910, to include State selections and isolated tracts.

An act approved August 24, 1912 (37 Stat., 496), provides for the entry or selection of withdrawn or classified oil and gas lands in the State of Utah, with a reservation to the United States of the oil or gas. The provisions of the act are similar to those of the coal act of June 22, 1910, and the classes of entries and selections permitted are the same as those in that act as amended by the act of April 30, 1912.

DESIRABLE NEW LEGISLATION.

In carrying out its function of classifying the public lands and in making its fund of information available in the administration of the existing land laws the Geological Survey has become acutely cognizant of the need for certain new legislation. The laws desired are primarily of two types and embody two fundamental necessities—first, the extension of the principle of the separation of estates, and second, the application of the leasing principle to the disposition of natural resources.

As has already been pointed out, the public lands can not be divided into classes each of which is valuable for one purpose only. Instead, the same tract of land may be valuable for two or more resources. In one tract—for example, agricultural land that is underlain by coal—both resources may be utilized at the same time without interfering with each other. In another tract—for example, agricultural land within a reservoir site—the land may be valuable for one resource only until it is utilized for another. In the first case the problem is so to frame the laws that no resource will be forced to await the development of the other. In the second case the problem is to permit the use of the land for one purpose pending its use for another without losing public control of the development of the second. In both cases the answer is found in a separation of estates. The extension of this principle, now applied to coal, to withdrawn and classified minerals and to the uses of water resources would permit the retention of the mineral deposits and power and reservoir sites in public ownership pending appropriate legislation by Congress without in any way retarding agricultural development. Bills have already been introduced applying this principle to oil in other States than Utah and to phosphate in the State of Idaho. It is to be hoped that such bills will be passed and approved, or, better still, that a comprehensive act providing for the separation of the various estates will be introduced and enacted.

Nearly every student of the situation is agreed that the leasing system is far better than any other for disposing of natural resources. This conclusion is based partly on the logic of theoretical considerations, partly on the experience of other countries, such as the Australasian States, and partly on the fact that the leasing system is rapidly replacing all others in commercial practice in the United States. A single instance may be cited: Over 90 per cent of the oil production of the United States in 1911 came from leased lands. In the public interest leasing is to be preferred to sale for several reasons. In the first place, the sale of mineral lands at appraised values per acre presents problems of great difficulty and of uncertain solution, because of the number of factors involved. For example, in valuing coal lands under the present coal-land law or in valuing phosphate lands, should a similar law be enacted for that mineral, the items bearing on the value which should be fixed are so numerous, so difficult to estimate, and so variable that it is well-nigh impossible to arrive at conclusions which give the proper weight to all the factors involved. In valuing coal lands the end striven for has been to fix prices which shall be low enough to permit purchases for immediate development but which shall be high enough to prohibit speculative purchases or long-term investments. However, the proper consideration of transportation charges, market conditions, competing supply, and cost of labor is affected by so much uncertainty that it is difficult to fix a thoroughly satisfactory price for which lands should now be sold. When it is considered that the lands are to be sold in the indefinite future at the prices fixed now, the difficulties of the task become apparent. None of these difficulties would attend in the same degree the administration of a lease law under which the coal or phosphate would be paid for at a royalty per ton as mined. The fixing of the royalty would be very much simpler than the present task.

Attention has already been called to the inappropriateness of selling oil and gas by the acre. The distance within which oil and gas may be drawn off by a single well is not definitely known and is, of course, variable, but it is at least certain that a well drilled close to a property line will draw these minerals from immediately adjoining portions of neighboring tracts. Under a leasing law the person required to pay for deposits of these minerals would not be the person under whose land they originally occurred but the person from whose land they were produced, and the price would be fixed by unit of quantity. The fairness of this plan is obvious.

The uncertainties as to market value of potash and other nonmetals except coal, oil, gas, and phosphate make the payment of a sale price undesirable and the payment for the minerals as mined much more advantageous to the producer. In fact, one of the main arguments for the leasing as opposed to the sale system, not only for potash but for coal, oil, gas, and phosphate as well, is that instead of being required to advance the entire price of the land at the outset, the payments are made only as the mineral is produced, thus enabling the operator to begin operations with a much smaller initial investment. This is certainly advantageous to the small operator. Moreover, under a lease law the many uncertainties which enter into the fixing of sale prices would be eliminated, since only the quantity produced would be paid for.

Probably the present mineral laws are more satisfactory when applied to the metals than to the other minerals. Without doubt even here a lease law would effect a marked improvement on present practice, but if they were modified in three features the laws applicable to metalliferous lands would be reasonably satisfactory to the miner and to the public at large. In any event, the law of the apex should be abolished, the provisions regarding discovery should be modified, and the period for which a claim may be held without patenting should be limited. Regarding the first of these points there is little need for argument. Mining congresses and bar associations have alike recommended the repeal of the apex provision and shown conclusively the detriment which it is and has been to the mining industry. That it is possible to do away with it without resultant confusion is shown by the experience of British Columbia. One point, however, should not be overlooked—if the law of the apex is abolished the width of the claim should be increased in order to assure sufficient values to warrant the opening of a mine.

The requirement that mineral shall be discovered as a prerequisite to location is one that works undue hardship to those exploiting deep-seated deposits that do not crop out at the surface, such as those included in the mineral-land withdrawal in Arizona. Such deposits are by no means rare in certain mining districts of the West, and the law should be so modified as to provide either for some adequately safeguarded substitute for discovery or for the protection of the miner during the long and expensive prospecting which he must carry on before minerals can be discovered. Such protection would be best afforded by a provision for a prospecting permit of limited duration, to be granted only if the geologic conditions are at least moderately favorable for the occurrence of the mineral sought.

Under the law as it now stands a claim may be held indefinitely without an attempt to obtain patent, and so long as the annual assessment work is performed the claim is secure against adverse claimants. Until patent is issued no taxes are assessable by the State, and many producing mines refrain from patenting in order to avoid taxation. A limit to the number of years that a claim may be held pending the institution of patent proceedings would correct this abuse.

It is not only with relation to mineral deposits nor by comparison with a sale system that a leasing system is advocated. Leasing should replace the present permit system, under which rights of way across the public domain are granted for reservoir sites, power development and transmission, and irrigation works. Under the existing laws the right of way granted is either in perpetuity or is revocable in the discretion of the Secretary of the Interior. Both of these conditions are undesirable—the first because the resource passes forever beyond the direct control of the public, which thus becomes powerless to guard against misuse, disuse, or monopoly; the second because the capital which is required in the construction of such enterprises is not sufficiently protected. Between the grant in perpetuity, which inadequately protects the public, and the revocable permit, which inadequately protects the capital invested, lies the lease, which adequately protects both. By leasing rights of way for a fixed period of years absolute control would periodically return to the public, while the investor would be secure for a period long enough for his investment to return a profit.

If a lease law is to be adopted certain provisions should be incorporated in it, whether it is for a single resource or for all. In the first place the end to be attained is not revenue for the Government but is rather the retention of control in the public. It would be a long step backward to return to the early policy of using the public lands as a means of Federal revenue, and any lease law enacted should be so framed as to encourage development, prohibit speculation, and add nothing to the cost of the resource to the consumer. The States in which the lands are situated should be compensated for the loss of taxes which they would suffer from the permanent retention of the fee to natural resources in the National Government. Doubtless the simplest way to accomplish this is to provide that a certain percentage of net receipts from leasing shall go to the State in which the lands are situated. The term of a lease should be long enough to permit profitable investment and development. It should not be longer than is necessary to furnish an adequate return on the amount invested.

Whatever action Congress may decide to take regarding the natural resources now in public ownership should not be much longer delayed. The present withdrawals are a temporary expedient whose employment should be rendered unnecessary as soon as possible. It can not be economically advantageous to the country to have millions of acres of lands, valuable for petroleum, phosphate, or potash or for power or reservoir sites, absolutely segregated from all forms of disposal for an indefinite period. Some of the lands have already been so withdrawn for nearly four years. Congress should be fully informed concerning all the factors to be considered, but it should also act promptly.

CLASSIFICATION OF MINERAL LANDS.

FIELD METHODS.

DEVELOPMENT.

Since the United States Geological Survey was organized the methods it employs in its diverse field investigations have gradually become more refined and more precise. If a topographic map made by the Survey 20 years ago is compared with one of its recent maps the difference will be patent even to the untechnical critic, yet many of the important improvements adopted during that period do not appear on the map. The closer and more accurate triangulation net, the great increase in the numbers of intersected points and of level lines, and the general completeness of both vertical and horizontal control are not directly reproduced on the completed sheet, but they have been used in its preparation and give it far greater accuracy and expressiveness than the earlier maps. The methods employed by the engineers of the water-resources branch and by the geologists of the geologic branch have likewise undergone steady and consistent development.

Perhaps nothing in recent years has so directly stimulated the employment of more precise methods in field work than the requirements of land classification, and the development here is well exemplified in the work done by the coal geologists. The law under which coal land is classified, unlike the laws controlling the classification of lands containing other mineral resources, requires a valuation of the land. It is therefore especially necessary to trace the outcrops of coal beds with exactness and to fix their relations to the units of the public-land surveys by precise methods. This has led to the introduction of refinements that are not generally considered necessary in preparing a geologic folio or in determining the general relations of the formations in any region. It is perhaps worth while to trace a part of this development of the field methods employed in the classification of coal lands, as an example of a general improvement and as an introduction to a discussion of the methods now generally used by the geologist in the solution of problems of classification.

The acts separating the mineral and agricultural estates of coal lands were not passed until 1909 and 1910, so that the withdrawals of coal land promulgated prior to that time prevented the initiation of both homestead rights and coal entry on the same tract. In order that this interference with agricultural development might be reduced to a minimum, the first examinations were directed toward the correction of the withdrawals by the prompt elimination from them of the noncoal land. The methods first used, therefore, were planned with the idea of covering large areas quickly and did not involve a marked departure from reconnaissance methods already in vogue, except that it became necessary to tie the investigations as closely as possible to such cadastral surveys as existed. One of the first methods employed at the beginning of the work of coal-land classification in 1906 and 1907 was that of retracing land lines. In doing this work the field men rode along the section lines established by the General Land Office, using the pocket compass to determine direction and horse pacing to measure distance. Coal outcrops along the section lines were mapped, the geology was studied in a general way, and a sketch of the topography was made.

In areas in which the absence of satisfactory land corners made it necessary to construct a map independently of the Land Office surveys a different method was adopted. By the use of a 15-inch plane table and an open-sight alidade a main or control traverse was run, completing a circuit of the field, distances being measured by intersections from points previously located and altitudes determined with an aneroid barometer. The topography and geology were mapped by means of a network of secondary traverse lines tied to the primary traverse. As the work progressed a more or less complete system of triangulation was established which could be used in adjusting the main plane-table traverse, and in turn the plane-table traverse served to check meander traverse. In running these meander traverses a pocket compass was used for obtaining directions, distances were measured by pacing, and elevations were determined by aneroid. The meander-traverse lines were plotted in the field as the work advanced, a small celluloid protractor being used for laying off angles and a scale graduated to correspond to the scale of the township plats being used for measuring horizontal distances. During the field work especial care was taken to locate whatever land corners existed, in the hope that these corners would serve as a basis for later adjustment of the township and section lines on the map.

These two methods probably represent fairly the general field methods in use during 1906 and 1907, in connection with classification of coal land. Some idea as to the speed attained in this work may be formed from the statement that on an average a township (36 square miles) was completed by one man in four days. The following figures will also give some idea of the effectiveness of these methods for the purpose which they were designed to accomplish.

During the last six months of 1906 the total area withdrawn for examination was approximately 66,000,000 acres, and by the close of that year, as a result of the field examinations, approximately 2,000,000 acres had been restored to public entry. During 1907 there was an additional preliminary withdrawal of approximately 2,000,000 acres and by the end of the same year about 34,000,000 acres had been added to the restorations. Thus, of the 68,000,000 acres withdrawn during the first two years about 36,000,000 acres were restored as noncoal land as a result of the rapid methods then used. Had the Survey attempted a detailed study of these lands from the beginning, there would have been much undesirable delay in the restoration of large bodies of noncoal lands to entry. These early relatively inexact methods were therefore well adapted to the ends they were designed to accomplish.

The principal areas of coal land having been outlined by reconnaissance surveys, attention was next turned to more improved methods of field work to meet the constantly growing need for better and more detailed classification. The reconnaissance method was then replaced by that in which plane table and telescopic alidade are employed. The most satisfactory alidade, which was designed by one of the geologists engaged in the classification work, is a small instrument carrying a telescope fitted with cross wires for stadia work and a vertical arc for determining differences of altitude.

The details of method used in plane-table mapping are varied according to the topography and the forest conditions of the area mapped, as well as according to the condition of the land survey. In an area where there have been no land surveys or where those that have been made are very poor, the triangulation or station method is preferred, but stadia work only is practicable in certain areas—for example, heavily wooded districts or regions cut by deep, narrow canyons. Either method, however, gives excellent results, for by either the coal outcrop is actually traced in the field and the exact horizontal and vertical positions are determined for every observation. In connection with these precise locations full data are procured on the character of the coal. If the region is undeveloped and no coal mines or prospect pits are available for examination, openings are made and sections are measured wherever such work is necessary to give adequate data for classification.

Perhaps the most detailed work that is now being done in the coal areas is that carried on in those districts where the geologist works in conjunction with the topographer. This method results in a reduced cost of the work and a great degree of accuracy in location. In work of this kind the geologist usually examines the territory in advance of the topographer, prospecting the coal bed and carefully marking by means of flags all prospects and coal outcrops which he desires the topographer to locate. The topographer, in the course of his mapping, determines both the horizontal and the vertical positions of all points flagged by the geologist. This work is done instrumentally and with great accuracy, the probable limit of error in the horizontal location of any point being less than 20 feet and in the vertical location less than 5 feet. With many points on the outcrop thus accurately located, underground structure can be determined with a degree of accuracy that has seldom been attained in geologic work.

With this preliminary statement, it is proposed to set forth briefly some of the methods now in use under the various conditions that confront the geologist who is assigned to the task of making a mineral classification of a specific area.

A. If he is required to make a detailed survey, he will find one of the following conditions existing:

(*a*) A topographic base is available.

(*b*) A base map is not available but must be made.

(*c*) A topographic base is not available and is not essential, the land survey sufficing as a base map.

B. If he is making a preliminary survey only he will use reconnaissance methods.

DETAILED SURVEY.

METHODS USED WHEN A TOPOGRAPHIC BASE IS AVAILABLE.

It is desirable that the examination of the mineral deposits in regions of especial economic importance be based on an accurate topographic map prepared in advance of the geologic examination. Such a map, on which are shown the relief by contours of appropriate intervals, the position and character of the drainageways, and the location of land corners, roads, houses, and the bench marks and triangulation stations established by the topographers, enables the geologist to determine by surveyor's methods the location of the numerous points at which he makes observations, with a minimum expenditure of time and with a degree of precision adequate to the scale of the map and the work in hand. The scales which are generally used by the Geological Survey in work of this character are about 1½ or 2 inches to the mile, with contour intervals of 10, 20, or 50 feet. The degree of accuracy attained in work on such maps is represented by the width of a carefully drawn pencil line, or less than 20 feet for locations where refined plane-table methods are employed—for example, along the outcrop of the coal, oil sand, or phosphate bed—and by a somewhat variable larger figure for locations requiring a less degree of accuracy and made with less precise instruments. The actual elevation of observations along the outcrop of the valuable bed is determined with surveying instruments, so that the error is rarely in excess of 5 feet, an amount which is practically negligible in mountainous regions. In special cases, however, a higher degree of precision is attained.

The information collected by the geologist in the field relates to the quality and thickness of the economic deposit, the position of its outcrop relative to legal subdivisions, and its depth and accessibility where covered. He maps the actual position of the outcrop of the coal bed, oil sand, or phosphate bed by making careful locations at many points, as described above, and where possible determines the attitude of the bed by many careful dip readings with a clinometer or by computation from its elevation at several points. He also maps the position of the top and bottom of the overlying and underlying beds, so that the completed map shows the actual area covered by the outcrop of beds of sandstone, limestone, conglomerate, shale, or such other rocks as may be present in the region. He further determines the attitude of these rocks and collects typical samples and fossils which serve to determine their relative age. Part of this information is represented on the map by symbols whose significance is expressed in the accompanying legend, and part is recorded in suitable notebooks for use in the preparation of reports. This information is put together in a tabular form showing the normal arrangement of the beds, which is technically spoken of as a columnar section. Such a section shows the normal distance through the strata from the economic bed to the top or bottom of any one of the constantly related overlying or underlying beds, and it is used in combination with the data on the outcrop of the overlying rocks in working out the theoretical underground position of the bed. The methods of making the computation are explained in detail in the following discussion of the examination of areas for which a topographic base is not available.

The deposits of present economic importance or of promise for the future are sampled at many points where the natural exposures are favorable and in other places by means of pits, trenches, or drill holes. All the samples from any one deposit are taken by a uniform method designed for that kind of material.

METHODS USED WHEN A BASE MAP MUST BE PREPARED.

In the detailed geologic study of an area it is usually necessary to construct a map which shall place before the eye of the geologist all the available information concerning the area in such space that it can be viewed as a whole and the correct relations of details comprehended as they could not be on the ground. Such a map to be of the greatest value should show not only geology but surface relief and the positions of streams, roads, and houses, with the legal subdivisions of the public-land surveys, in order that the geology may appear in its true relation to surface features. The construction of a map giving such details is, strictly speaking, the work of the topographer rather than of the geologist, but the latter may be called upon to examine an area for which no adequate base map has been prepared and he is therefore obliged to construct a map, either contoured or plain, on which to record the geology. Such a map may be made by the use of various instruments, perhaps the most satisfactory in both accuracy and speed being the plane table and the telescopic alidade. These instruments used with a system of triangulation are particularly adapted to open country in which signals can be seen for considerable distances. In areas where, for various reasons, it is impossible to sight distant signals the method of stadia traverse is employed, the same instruments being used in conjunction with the stadia rod.

In constructing a map by a system of triangulation, the procedure is briefly as follows:

A base line is measured and the plane table is set up at one end of it and properly adjusted so that one edge of the table lies in a north-south line. The base line is then plotted on a selected scale, usually from 1 to 4 inches to the mile, and sights are taken and lines drawn in the direction of monuments on prominent hilltops. The plane table is then transferred to the other end of the base line and correctly oriented by back sight. Sights are then taken and lines drawn in the direction of the monuments sighted from the first station. The intersection of the two lines drawn in the direction of each monument establishes its location in relation to the base line as indicated on the map. After the various signals are located in a certain area the plane table may be set up at any point whose location is not known, and after it is approximately oriented by compass sights may be taken to the points already located and the position of the instrument determined by lines drawn from the locations of these signals on the map. These lines should exactly meet at a point. If they do not so meet there is some inaccuracy either in the previous work or in the orientation of the plane table. It is thus possible to keep a close check on the work and points may be located as accurately as the scale of the map allows.

On a scale of 2 inches to the mile a distance of 10 feet would be represented by the width of a fine pencil line, and it is not possible to plot a distance of, say, 5 feet. A distance of 10 or 15 feet, however, is perceptible, and locations may be accurately made within such distances. If the scale is increased to 4 inches to the mile the error in the location of a point should not exceed 10 feet. After the primary signals are established over the township the base map and the geologic map may be constructed simultaneously—that is, in tracing the exposures of some particular bed, such as a coal or phosphate bed or an oil sand, the geologist may sketch in the roads or streams or topographic features near which his instrument happens to be set.

In mapping a particular area geologically as many points are located as are necessary for the degree of accuracy desired on the map. In critical parts of an oil field, where all dip readings are located by the plane table, observations may be taken every 400 or 500 feet, but in parts of the area outside of the probable extent of the oil pool dip readings taken every mile may be amply sufficient if the dip is regular. Places at which fossils are collected are marked on the map and also places at which rock specimens and coal, phosphate, or oil samples are taken, as well as localities where sections of the beds or other geologic observations are made. In the construction of such a map any land corners that may be found are located from the signals previously established, just as rock outcrops and other features of interest are located. The land net is afterward drawn in from the corners which have been found, and any inaccuracies and irregularities in the old surveys will thus be detected. In land classification the tracts are always described with reference to these surveys, so it is very essential to locate as many of the corners as possible in order that the position of the land lines may be accurately known. The time required to construct a map of this kind varies greatly with the nature of the country and the character of the geology. One man can, as a rule, establish primary control over a township in one to three days, the time required being dependent entirely on the number of locations made and the nature of the country traversed.

The method of locating important rock outcrops by stadia traverse may be successfully employed in conjunction with location by triangulation, or it may be used alone without triangulation. In running a traverse with stadia the instrument man can not work alone but must employ the services of a rodman. The plane table is set at some known point, the stadia rod is held on the point whose location is desired, and the direction from the point occupied to the other point is drawn on the map by means of the alidade. The distance is read by means of the stadia and platted on the map by the use of a scale, in the direction already recorded; this locates the second point. The instrument is then transferred to a third point, the location of which is determined by a reversal of the method used in locating the second. The rod is then moved ahead and the process is repeated. Such a method is most useful when a coal or phosphate bed or an oil sand is to be outlined in great detail or when the work is done in deep valleys or canyons from which it is difficult to sight triangulation signals.

In the above description no mention has been made of the method of determining elevations, which in much of the work are of great importance. With a telescopic alidade the angle of elevation or depression from one point to another can be accurately determined. This angle being known and the distance between the two points being measured with a scale from the locations of the points on the map or by reading a stadia rod, the problem resolves itself into the solution of a right-angle triangle in which one side and one of the acute angles are known, the side to be determined representing the vertical distance between the two points, or, in other words, the difference of elevation between them. The altitude of a starting point being known or assumed, it is possible to calculate the altitude of any number of points in any direction from it. Elevations determined by this method are not absolutely exact but are of sufficient accuracy for most purposes of geologic mapping. In ordinary practice they are correct within 5 or 6 feet, but with certain refinements of work the error can be reduced to 1 foot or even less.

It is advantageous to represent on a map in some manner the form of the rock folds, which may or may not correspond to the surface relief. Ordinarily surface relief is represented on a contour map by lines drawn to indicate definite elevations above sea level, one line, for example, at 4,000 feet, the next at 4,100 feet, the next at 4,200 feet, and so on. These lines not only show the configuration of the surface but also give approximately the elevation of any point within the area thus mapped. It is possible to contour in the same way the surface of an oil-bearing sandstone or a coal or phosphate bed which has been bent into a fold. Such contours are known as structure contours. They bear no necessary relation to surface relief. In fact, a valley may occupy the axis of an anticline or a ridge the axis of a syncline.

Sedimentary beds deposited one above another during a period in which there has been no earth movement are parallel—that is, if one sandstone so deposited is 2,000 feet above another at one place it is probably 2,000 feet above the other 1 mile or 5 miles away. If since their deposition the beds have been tilted from the horizontal, the dip of a bed at the surface in general represents the dip of the beds below it. If a certain oil-bearing sandstone dips 5° E. where it appears at the surface and overlying beds of the same formation outcropping east of the exposure of the first bed also dip 5° in the same direction, it is probable that the first bed and all intermediate beds have the same dip in this area also. A dip of 1° is equivalent to about 92 feet in a mile, and a dip of 5° to about 460 feet in a mile.

Therefore a bed that dips 5° E. under a horizontal plain is 460 feet beneath the surface at a point 1 mile east of the outcrop.

If it appears from surface exposures of the overlying rocks that the dip is not constant, allowance must be made for the variations in the calculation. In areas in which drilling has been carried on the records of the wells are invaluable as giving accurately the depths of beds beneath the surface, thus checking the deductions from surface evidence.

The locations of structure contours are based on a variety of data. If a well whose altitude at the surface is 4,000 feet strikes an oil sand, for example, at a depth of 1,000 feet, it is evident that the 3,000-foot contour on the oil sand passes through the location of this well on the map. If the rocks dip toward the east and a sandstone known to be 2,000 feet above the oil sand outcrops half a mile east of the well at an altitude of 4,500 feet, the oil sand should be at this point 2,500 feet above the sea, or, in other words, the 2,500-foot contour should pass through the location of this sandstone outcrop on the map. If the dip of the rocks exposed at the surface is constant between the mouth of the well and the outcrop of the sandstone it indicates that probably the oil sand dips regularly to the east between these points, and the contours of 2,600, 2,700, 2,800, and 2,900 feet may be spaced evenly between the 2,500-foot contour at the sandstone outcrop and the 3,000-foot contour at the well. Should the dip, as indicated by the surface exposures, be irregular between the two points, the contours are spaced accordingly, being placed nearest together where the dip is greatest and farthest apart where the dip is least.

After a structure-contour map is completed it is possible to estimate from it the depth of a bed of economic importance at any required point, if the surface altitude of the point is known.

METHODS FOLLOWED WHEN THE LAND OFFICE SURVEY AFFORDS A BASE MAP.

More than half of the coal land still owned by the Government lies in the rather sparsely settled plains region which has not been mapped topographically but has been covered by the cadastral surveys of the General Land Office. For such land, a topographic map not being essential, a method of survey different in some ways from those described above has been adopted. Plane table, telescopic alidade, and stadia rod are used as in the other work, but the results of the surveys made by the General Land Office are used as a base for the work, and the township forms a unit, the results being sufficiently detailed and accurate to permit classification by legal subdivisions. As previously stated, some of these surveys are not accurate, but they are official and in general they provide a suitable base for the survey. Locations and measurements are therefore accepted as recorded on the Land Office plats unless the field work proves them to be in error.

If a preliminary examination of the township to be surveyed shows that it contains only a few isolated outcrops of coal beds and no continuous exposures, the geologist locates the outcrops by triangulation and sketches their inferred locations. For the triangulation two convenient land corners are selected from which to begin work, and for a base line the distance given on the land plats is used, it being assumed that this distance has been correctly determined in the land surveys. The corners thus selected are located on a plane-table sheet, and from them other triangulation stations are established over the field and their elevations determined by vertical angles, as already described. After enough points to control the work in the township have been established the geologist makes a detailed examination of the coal. He goes to each outcrop and digs or bores through the bed to learn the thickness of each bench of coal and of each parting and to obtain samples of the coal for study or analysis.

After the bed has been examined and the dip of the strata has been measured the position of the outcrop is located on the plane-table sheet and the elevation determined.

The examination of the coal bed is most important. It must be made carefully and accurately. Each geologist who surveys coal land is told that "every inch of the bed must be critically examined." If the inspection shows that the coal may contain more than the normal percentage of impurities a representative sample is selected and taken to camp, where an ash test is made with a small portable chemical outfit. If there are mines in the area a sample is procured according to the prescribed method (see p. 106) and is sent to the chemical laboratory for analysis. The strata in which the coal is found are also carefully examined to obtain any additional information they may give concerning the depth and continuity of the coal beds where they are covered.

The triangulation method of location described above suffices in areas where there are only a few small outcrops of coal beds, but in townships which contain more than a few outcrops or in which the beds can be traced the outcrops must be accurately located by stadia traverse in addition to the triangulation. If the triangulation and stadia work are done properly, locations should be correct within 20 feet and elevations within 5 feet.

In work of this kind the surveyor traverses the outcrop of the coal bed and with the aid of an assistant and instruments he locates points at short intervals along the line of outcrop and sketches its position between these points. All such locations are tied to land corners accurately with instruments, and the elevation of each point is ascertained, so that the underground relations of the bed can be determined.

The number of sections measured along the outcrop of the bed depends on the local conditions. If the bed is variable it must be examined at short intervals, but if it is regular the measurements may be made farther apart. Some records show measurements only 50 feet apart, whereas others are half a mile or more, though a shorter distance is recommended. There is no definite number of measurements to the township. In some townships few are made, whereas in others there are as many as a hundred.

At the same time that the geologist is examining the field he procures any information which may have been obtained by miners, prospectors, well drillers, or others making excavations. Such information ordinarily consists of records of wells, drill holes, and mine shafts, mine maps, both exterior and interior, records of production and use, etc., and is of great value in the proper classification of the land.

This method may be applied equally well to materials other than coal if they occur in or in a definite relation to stratified beds, and with modifications it may be and is adapted to less regular deposits of metalliferous minerals. Its chief application, however, in actual Survey practice is in the coal fields of the plains region, where the recent and more accurate Land Office plats are available as bases.

RECONNAISSANCE SURVEY.

Reconnaissance surveys are ordinarily only preliminary and those made for purposes of classification are intended to determine the general distribution of the mineral deposits in areas which have not been described by geologists or which may have been examined only casually or with some other problem in mind than that of discovering minerals of economic value. If no reliable information is at hand concerning an area containing public land, a geologist makes a reconnaissance to determine the best method of work to be followed if minerals are found.

The method of reconnaissance varies with the character of the country to be examined. If the country is suitable for the use of the plane-table method of surveying, the geologist uses that method. He proceeds in the manner already described but on a smaller scale and with less detail. If the country can be readily crossed and little accuracy is required, the geologist starts with an assistant and travels by buggy to the points to be examined. He determines his location from traverses based on hand-compass readings to give direction and on counted revolutions of the buggy wheel to give distance. These traverses are tied to known points wherever possible, and the intermediate locations are adjusted from them. If the country can not be crossed in a vehicle, the geologist goes on horseback or on foot and determines direction as before and distance by counting the number of paces taken by horse or man. This method gives considerable accuracy in location and provides an adequate basis for determining the general mineral or nonmineral character of an area.

State or county maps furnish locations for the geologist on some reconnaissance trips. When working with such a map he starts from a town, post office, or some point shown on the map and proceeds toward some other point also shown. To obtain his location at intermediate points he estimates distance and direction and records his observations with regard to the estimated locations. This method is seldom used, because of its inaccuracy, and it is never used to procure final data for land classification. It was found applicable to conditions in one of the Western States where large areas were withdrawn on the basis of a report that later proved to be erroneous. In this State the general reconnaissance proved the area to contain no coal of value; hence no careful examination was required.

PUBLIC-LAND SURVEYS.

Public-land surveys made by the General Land Office result in the official township maps which are the basis of all land titles and to which, therefore, all data on land classification must finally be adjusted. The system now in use was adopted in essentially its present form in 1785. Under this system a certain initial point is first selected through which a north-south line, called a principal meridian, and an east-west line, called a base line, are run. At successive intervals, usually 24 miles, north and south of the base line standard parallels or correction lines are established parallel to the base, and similarly at intervals east and west of the principal meridian guide meridians are established. Because of the convergence of meridians toward the poles these guide meridians are not parallel to the principal meridian but approach it toward the north. In order to correct this narrowing the guide meridians are offset at each standard parallel and started anew northward at their original distance apart. The quadrilateral thus defined is subdivided into townships, each approximately 6 miles square, and each township in turn is divided into 36 sections 1 mile square. Each section is further subdivided into quarters, and each of these is held to contain four 40-acre tracts, or quarter-quarters, the smallest commonly recognized legal subdivision of the public-land system. Appropriately marked monuments are set at all township and section corners and at the middle points of the side lines of sections, thus indicating the limits of the quarter sections. Posts indicating the quarter-quarters are not set, but this unit, and indeed in special cases smaller units of

10-acre or even 2½-acre tracts, may be recognized in land classification.

This general plan, where properly carried out, is simple and effective and has furnished a satisfactory basis for land records and titles for more than a century and a quarter. Its execution, however, has not in all localities been satisfactory. For a great many years the work was done by contract under State surveyors general, despite the repeated and urgent requests of many Commissioners of the General Land Office for authority to do the work directly. In earlier years the contracts were sometimes distributed as rewards for political services, and the inspections were not always of a character to guard against the acceptance of inadequate surveys. Some of the contracts were obtained by honest men who did their work well, but others fell to inefficient or dishonest contractors who made poor surveys or none at all, although they prepared township plats which were submitted under oath as to their accuracy and which were accepted. In the older fraudulent surveys of this type all sorts of errors and omissions are encountered. In certain localities no monuments can be found and there is every reason to believe that the lines were never run. In other localities the work was done so carelessly that the corner posts are found far from the proper locations. The General Land Office, under the contract system, required that monuments were to be made of stone wherever it could be procured, but the use of wooden posts was permitted in other places. In some localities where advantage was taken of this permission the stakes set were so small or so poorly fixed in position as to constitute merely a nominal observance of the requirements, and many of the stakes thus set have disappeared.

Within recent years the Land Office has adopted the plan of marking corners permanently by deep-set iron posts and has been authorized by Congress to make surveys directly instead of by contract. These modern surveys provide a highly satisfactory basis for land titles, and some of the special surveys made on the Indian reservations by a combination of cadastral and topographic methods are models of complete and satisfactory base mapping.

For purposes of land classification it is imperative that the data procured by the geologist shall be tied to the land net because his classifications must be expressed in terms of the public-land surveys. Furthermore, these identifications must be exact, because it may occasionally be necessary to estimate values of the public lands in tracts of 40 acres, 10 acres, or even 2½ acres. It is obvious that in such cases the land lines must have been accurately run and the corners sufficiently well established to permit undoubted identification. In a few places classification has been impossible because the land lines could not be found and the official surveys could therefore not be identified.

PREPARATION OF DATA FOR CLASSIFICATION.

The geologist, on returning to the office from a field examination of land for the purpose of classification, informally presents to the appropriate section of the board a general outline of his work, the area covered, and the problems met. Thereupon the section decides the particular form of map and report desired. The essential factor in determining in just what form the data shall be submitted is the requirement that all pertinent facts determined by the field investigator shall be recorded and that the finished report shall be as accurate as the field work in location and interpretation. The importance of accuracy and completeness becomes apparent when it is realized that the record once submitted must form the basis not

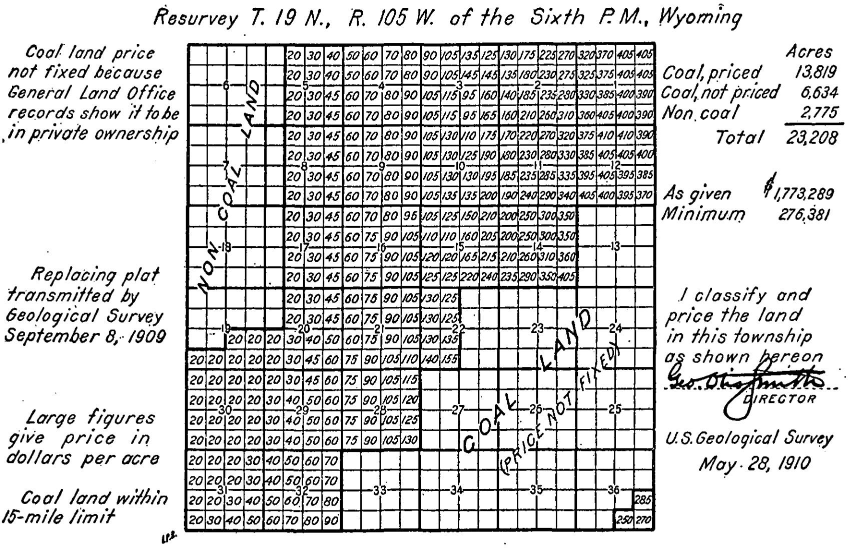

FIGURE 1.—Township map showing classification and valuation of coal lands.

only for the classification of the land as mineral or nonmineral, a classification which may affect the interests of a large number of people, but also, in the case of coal land, for valuations aggregating millions of dollars. As an example, a copy of a township classification and valuation plat as transmitted to the General Land Office is given in figure 1. In June, 1912, private individuals purchased from the Government sec. 12 of this township, for which they paid the classified price as shown, amounting to over a quarter of a million dollars.

In general the data are compiled by the field geologist from his original maps and notes in two forms. The first consists of a small-scale map with an accompanying general report presenting the results of a study of the whole field. In this report the geologist discusses the stratigraphy and structure of the field as well as the occurrence of economically important minerals. On the map accompanying this report most of the finer details are omitted and only geologic formations and the outcrops of coal, phosphate, or oil sands are shown. The general report on a field contains a description of all that is known of the physical and chemical properties of the minerals occurring in that field. This report then serves as a basis for a set of general minutes, in which the appropriate section of the board outlines the application of the regulations governing the classification of lands containing those minerals to that particular field. After the general report has been considered by the proper section and the general minutes have been written, the field geologist prepares the classification data and in the case of coal land makes the valuation, under the immediate supervision and with the assistance of some member of the coal section of the board. Later the record is reviewed and passed on in detail by the entire section. Each 40-acre tract, and sometimes even each 2½-acre tract, is considered individually and all facts affecting its classification as mineral or nonmineral are weighed. A report of the proceedings of the section for each township is prepared, giving in detail the result of the classification and the reasons therefor. This report becomes part of the permanent records of the land-classification board.

Detailed reports on each township examined, with accompanying large-scale maps, constitute the second form of data. These are prepared in addition to the general report for all areas on which the smaller-scale map will not suffice for classification. On these large-scale township maps every feature that is possible of cartographic portrayal is represented—the outcrops, dips, and measured thicknesses of all coal or phosphate beds or oil sands, all mines, prospects, or lodes, the location of these features with respect to established land lines, and, if essential, the topography of the surface. Each map is supplemented by a description which gives the dates and methods of field work, the condition of land surveys, the proximity to railroads, and a discussion of the geology. In the valuation of coal land all calculations by which the price per acre for each tract has been derived are given in detail.

These reports and maps are all permanently mounted, arranged in order of State, range, and township in loose-leaf locking binders, and filed in fireproof steel cases. As new information is acquired, from whatever source, with regard to the mineral character of any township, it is added in its proper place in the binder. Such information consists of reports from field agents of the General Land Office, data obtained by members of the Geological Survey on subsequent examinations, affidavits of public-land claimants, and other matter. The original field sheets and notebooks are likewise deposited in the files of the land-classification board and are always readily available for use. Card indexes are maintained covering both sets of files.

COAL LANDS.

PURPOSE OF CLASSIFICATION.

By act of March 3, 1873, Congress provided for the sale of coal lands belonging to the United States, specifying the conditions of sale and the minimum prices. To carry out the act it is necessary to determine, first, what lands are coal lands (classification), and second, at what price they shall be sold (valuation). To give uniformity to Executive action in this work certain rules have been prepared by the Geological Survey and approved by the Secretary of the Interior under the title "Regulations for the classification and valuation of coal lands." These regulations provide exclusively for the classification and valuation of coal lands and are not to be confused with the regulations providing for the disposition of coal lands issued by the Land Office under the title "Coal-land laws and regulations thereunder." It is the province of the Geological Survey to determine what lands are underlain by coal within the limits set by the classification regulations, and to it has also been assigned the work of valuing the lands classified as coal land. Classification and valuation must follow three antecedent steps—(1) the adoption of regulations formulating the principles and practice which are to govern classification and valuation; (2) the field examination to determine the presence, position, quality, and other features of the coal in the land; (3) the assembling of the field data in such form as to facilitate the work of classification and valuation by making possible the simultaneous consideration of all the facts. Finally, classification and valuation involve a consideration of all the known facts to determine what legal subdivisions of land are coal lands under the regulations and at what price they shall be sold.

Preliminary to the detailed consideration either in the field or office of any area believed to contain valuable coals the lands are withdrawn from entry under the authority of the act of June 25, 1910 (36 Stat., 847), as amended by the act of August 24, 1912 (37 Stat., 497). A typical coal-land withdrawal order is appended with the accompanying letter of transmittal:

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, January 21, 1913.

The honorable the SECRETARY OF THE INTERIOR.

SIR: Information on file in the Survey indicates that the land listed below contains valuable deposits of coal, and I therefore recommend the submission to the President for appropriate action of the following order of withdrawal, involving 1,600 acres.

Very respectfully,

GEO. OTIS SMITH,
Director.

JANUARY 28, 1913.

Respectfully referred to the President with favorable recommendation.

SAMUEL ADAMS,
Acting Secretary.

ORDER OF WITHDRAWAL.

Coal-land withdrawal—Montana No. 10.

Under and pursuant to the provisions of the act of Congress approved June 25, 1910 (36 Stat., 847), entitled "An act to authorize the President of the United States to make withdrawals of public lands in certain cases," as amended by act of Congress approved August 24, 1912 (Public No. 316), and subject to the provisions of the act of Congress approved June 22, 1910, entitled "An act to provide for agricultural entries on coal lands," as amended by the act of Congress approved April 30, 1912 (Public No. 141), it is hereby ordered that the following-described lands be, and the same are hereby, withdrawn from settlement, location, sale, or entry and reserved for classification with respect to coal values:

Montana meridian.

T. 3 N., R. 3 E., sec. 25, NE. ¼, S½;
sec. 26, SE. ¼;
sec. 35, E. ½;
sec. 36, all.

WM. H. TAFT,
President.

JANUARY 29, 1913.

METHODS OF CLASSIFICATION.

PRINCIPLES INVOLVED.

In preparing the regulations for classification three principles are paramount: (1) The regulations must be based on demonstrated facts or on well-founded and generally accepted inferences; (2) they must be based on all the stable, permanent factors involved; (3) they must be as definite yet withal as simple as possible. Ideally the regulations should be so simple that anyone at all acquainted with the subject could correctly apply them, and they should be so definite as to admit of little or no disagreement in interpretation. Neither of these ideal requirements can be realized.

The workability of coal at a given point to-day depends on factors of two types. Those of the first type—such as quality, thickness, and depth—are intrinsic; those of the second type—such as railroad transportation and markets—are extrinsic. To-day the extrinsic factors may determine absolutely the commercial workability of a bed of coal at any locality. A coal bed 75 miles from a railroad and 50 miles from the nearest town, no matter how valuable it may be some day, has to-day a value that is purely prospective, depending on an unknown factor—the time when transportation shall reach it. A new railroad may "make" a coal-mining district by opening new markets or may "break" it by bringing in competition that it can not meet. To be stable, therefore, the regulations must be based directly on the intrinsic factors involved. Tracts classified as noncoal land are disposed of as such without further question as to their content of coal. Classification should therefore anticipate and assume the ultimate coming of conditions favorable for mining and marketing any coal if the coal is otherwise workable.

If an 18-inch coal of a certain grade occurring under certain conditions is workable in Missouri to-day, hundreds of thousands of tons being mined yearly, it would appear to be a reasonable assumption that a coal of like thickness and quality occurring under similar conditions elsewhere will be workable some day and should therefore be classed as a workable coal; especially does this assumption appear reasonable when it is considered that everywhere the tendency is to extend the limits of workability. Coal mining has nearly always been conducted on a very close margin. In any new field—and most of the coal fields of the West to-day are new—only the most accessible, thickest, and best of the coal beds can be worked at a profit. Twenty years hence the most accessible coal will have been largely mined out and mining will be done on coal that is a little less accessible and that costs a little more to mine and that necessarily will sell at a little higher price. This higher price will permit the mining of other coal—a little thinner and a little poorer—which could not be mined profitably to-day, and the process will continue until all coal within minable limits is exhausted. The regulations attempt to define what these minable limits are, not in view of the conditions that may exist as the coal supply approaches absolute exhaustion, but in view of actual practice to-day under favorable conditions of transportation and of market.

FACTORS INVOLVED.

ESSENTIALS OF WORKABILITY.

The workability of any coal will ultimately be determined by two offsetting factors—(1) its character and heat-giving quality, whence comes its value, and (2) its accessibility, quantity, thickness, depth, and other conditions that affect the cost of its extraction. It must be considered a workable coal if its value, as determined by its character and heat-giving quality, exceeds the cost of extraction, either as judged by actual experience at the point where it is found or as judged by actual experience on similar coals similarly situated elsewhere. There are no absolute limits to any of the factors. The mining of 1 inch of coal that may involve the mining of 3 feet of rock is physically possible but would not pay. Most unworkable coal beds lack one or more of three things—quality, thickness, accessibility—that is, they are too poor, too thin, or too deep. Other things—such as poor roof, gas, water, faults, pitch, and lack of timber—may render mining difficult and temporarily unprofitable, but most or all of them are subject to engineering control. They may depreciate the value of the coal and defer its mining but may not make it unworkable.

QUALITY.

Coal is essentially a fuel. The heat afforded by burning coal is derived mainly from its carbon and the hydrogen that is free to burn. Associated with these are oxygen, nitrogen, water, and ash. A pound of the best coal, which contains about 90 per cent of carbon and "available" hydrogen and 10 per cent of the other ingredients, will yield from 14,000 to 15,500 British thermal units. A British thermal unit ("B. t. u.") is the amount of heat required to raise the temperature of 1 pound of water 1° F. under certain standard conditions. Poorer coals contain larger percentages of noncombustible constituents and correspondingly less carbon and available hydrogen, and their heating value (in British thermal units or other units of measurement) is reduced in much the same ratio. On analysis some coals show a content of all impurities that is in excess of the average; others show an excess of ash or water only; but whether the increase is in ash or water, or both, its effect is to decrease the heating value of the coal as expressed in B. t. u. Instead, therefore, of specifying the maximum quantity of ash or water allowable in a commercial or salable coal the regulations fix a minimum value in B. t. u. which will cover either one or any combination of these two or any other impurities. The limit of allowable impurity in a salable coal is affected by the facts that very wet coals may be improved by air drying and that coals which are very high in ash may usually be improved by washing or may, perhaps, be used in a producer-gas plant. The possibility that improvements may be devised in the utilization of coal—such as its entire utilization at the mine for producing electric power—makes the determination of the powest limit of usable quality of coal difficult and very uncertain. Again, in a study of the B. t. u. value of low-grade coals that are now worked, difficulty is encountered in the fact that many of the earlier samples taken were weathered coal. On account of the possible improvement of the quality of the coal by drying or by washing, the lowest limit of usable quality is fixed by analysis of an air-dried sample, and if the coal as obtained in the mine contains a very high percentage of ash the possibility of its being washed is considered. Analyses of samples of coal cut in the mine from unweathered coal, according to the practice of the Geological Survey and the Bureau of Mines, indicate that any coal mined commercially in the United States to-day will yield, after being washed or air dried, at least 8,000 B. t. u. This figure has therefore been fixed as the minimum B. t. u. value of any coal that shall be considered workable. In practice the washed product of any coal subject to washing must have at least 50 per cent of the weight of the unwashed coal. The washability of any coal is determined on a sample of one-quarter inch size by a float and sink test, the liquid used having a specific gravity of 1.5. Even if its workability is thus indicated in the laboratory it can not be considered workable unless there is sufficient water in the field for washing it.

THICKNESS.

More coal is unworkable because it is too thin than for any other reason. The result of a study of the relative cost of mining in relation to the thickness of beds is given on pages 83–86.

For the purpose of classification a careful study was made of the thicknesses of coals that are actually mined in a large commercial way. Many of the facts disclosed by this study have been published.[1] By platting these with reference to the B. t. u. content of the coal it became evident that in actual practice coals yielding 10,000 B. t. u. are worked with profit down to a thickness of 18 or 19 inches, that coals yielding 12,000 B. t. u. are worked down to 14 or 15 inches, and that better coals are mined from beds still thinner. Some coals of the qualities mentioned are mined from beds that are thinner than those noted above, but under very exceptional conditions. In considering the low-grade coals three special factors must be noted: (1) Most of them occur in rocks of more recent age than the others, which have been less affected by mountain-making forces and are therefore less indurated. On this account it is thought that future extensive mining may show the frequent necessity of leaving some of the coal for roof and of leaving larger pillars. (2) Owing to the air-drying loss in very wet coals they are likely to shrink considerably before they are marketed. (3) If the low B. t. u. value of these coals is due to their high content of ash an allowance should be made for loss in washing. For these reasons the minimum thickness for beds of the low-grade coals is set much higher in proportion to B. t. u. value than for beds of coals of higher grade.

The minimum minable thickness of bed is fixed at 14 inches for all coals having more than 12,000 B. t. u. For coals having less than 12,000 B. t. u. the minimum minable thickness increases at the rate of one-tenth inch for each decrease of 100 B. t. u. down to 11,000, then at the rate of one-tenth inch for each 50 B. t. u. down to 10,500, then at the rate of one-tenth inch for each 25 B. t. u. from 10,500

[1] Fisher, C. A., Depth and minimum thickness of coal beds as limiting factors in valuation of coal lands: Bull. U. S. Geol. Survey No. 424, 1910, pp. 56–62.

down to 10,000. The increase for coals yielding less than 10,000 B t. u. is at the rate of one-tenth inch for each decrease of 10 B. t. u. in the coal. The following table gives the thicknesses for B. t. u. of even five hundreds:

Minimum thicknesses for even five hundreds B. t. u.

B. t. u.	Inches.	B. t. u.	Inches.	B. t. u.	Inches.
15,000	14	12,500	14	10,000	18
14,500	14	12,000	14	9,500	23
14,000	14	11,500	14½	9,000	28
13,500	14	11,000	15	8,500	33
13,000	14	10,500	16	8,000	38

An important question that frequently arises is, What value, in relation to thickness, shall be given to split or broken beds? The general practice of the United States Geological Survey in classifying coals has been to give a split bed the value of an unbroken bed with which it can fairly be compared. It is evident that a solid 3-foot bed is worth more than two 18-inch benches separated by 6 inches of clay or shale. After careful study the Survey adopted the simple expedient of prescribing that any parting or bench of bone or impure coal included in a bed injured the value of the coal of the bed in amount equal to the thickness of the parting. Thus the split bed just cited, with its 6-inch parting, is regarded as equivalent to a solid bed 30 inches thick (36 inches of coal minus 6 inches of parting equals 30 inches). If the benches on either side of the parting are not of the same thickness the thickness of the parting is deducted from the thickness of the thinner bench. It is not necessary to consider the whole thickness of a coal bed. It is the practice of the Survey to start with the best bench, if in itself not of workable thickness, and to add the thickness of the next bench above or below after deducting the thickness of the intermediate parting. If the whole bed thus included is still not of workable thickness and more benches exist above or below, the thickness of these benches is added, after subtracting the thickness of the parting between them and the principal bench. If a parting is thicker than the thinner adjoining coal bench, that bench is considered as having no value. This practice is best illustrated by a group of concrete examples. (See fig. 2.)

As a matter of practice two coal layers, each workable, are treated as parts of a single bed if the two layers both exceed in thickness the parting between them and the parting does not exceed 3½ feet. In general two layers of coal are treated as two beds if the parting between them exceeds either one in thickness, and their workability is determined on that basis.

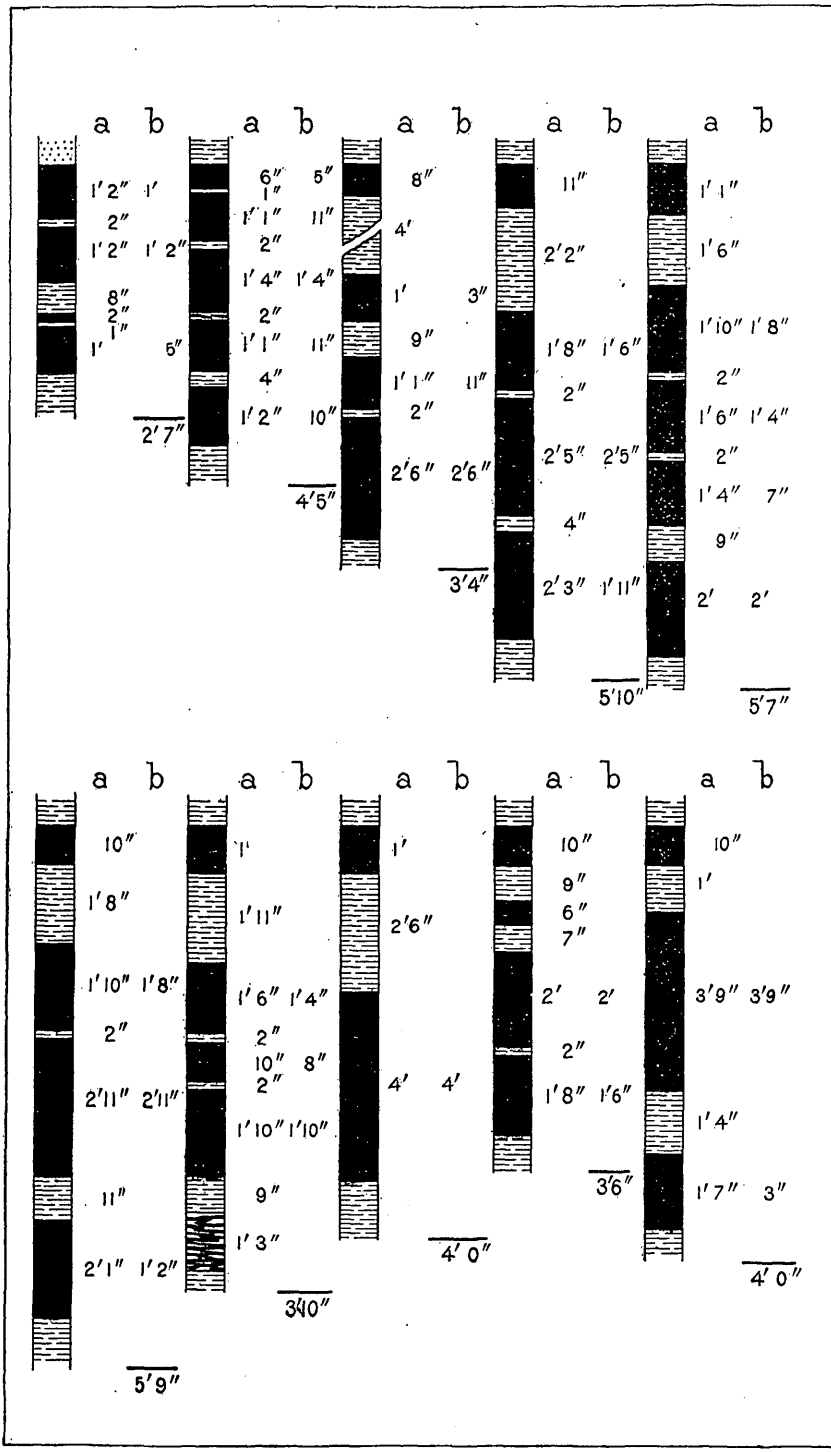

FIGURE 2.—Diagram showing split or broken beds and their value for classification: a, measured thickness; b, equivalent thickness used in classification and valuation.

The criteria given in the preceding paragraphs are intended to determine the workability or nonworkability of a coal measured at any given point. The most difficult problem in classification is the determination of the probable limits of workability of an irregular coal. Coal occurs in beds ranging in thickness from a fraction of an inch to 100 feet or more and in areal extent from a few square feet to thousands of square miles. Some beds maintain a nearly uniform thickness over hundreds of square miles. Others may be traced at the same geologic horizon over hundreds or thousands of square miles but vary greatly in thickness, ranging from a few inches to several feet or back again within a quarter of a mile. Every grade of regularity or irregularity between these extremes is found, and it is possible to determine the "habit" of some beds as regards regularity.

The simplest problem is that in which two unequal measurements on a single bed, taken at different places, are available. All such beds are assumed to grade uniformly in thickness from the thicker measurement to or through the thinner measurement, and a limit to the workable coal is thus fixed that, while it may or may not agree with the unknown facts, is the most probable limit. In general, a coal bed that can be traced continuously along the face of a cliff, as can many beds in the West, has usually been assumed to extend under the land back from the cliff at least one-half the length of the cliff outcrop, the lens or bed having the shape of a half-circle, the length of the cliff outcrop being the diameter of the circle. Obviously, if the outcrop runs along the cliff for many miles, the extension of the coal back from the outcrop may be modified by many other factors, such as limit of depth, or outcrop on the opposite side of the hill. If the bed outcrops along the cliff with irregular thickness, only a moderate extension of the bed behind the cliff is assumed, the estimate being based on the character of the irregularities shown by measurements made along the cliff, or by a general knowledge of the extent of the lenses of that particular coal or of coals of that group, and depending on the general "habit" of the bed, if known, and also taking into account all local features. If the exposed outcrop does not extend in a straight line, but, as is more common, runs in and out of ravines, careful note is made of the thickening or thinning of the coal between one point of measurement and another in order to detect, if possible, any general tendency of the bed to thicken or thin in any direction, and all these measurements and tendencies are taken into account in determining the probable extent of the lens in any direction.

Many beds studied are known to be of less than workable thickness in larger or smaller part, and any measurement showing a workable thickness on such a bed must usually be considered as a measure taken at the center of a small lens of workable coal. A discovery or measurement of a coal bed by a well, or by drilling, will have the same value as an isolated measurement on the outcrop. The content and shape to be assigned to any lens must depend on conditions and are largely matters of judgment, and such assignments or determinations especially require a wide knowledge of coals and of the particular group of coals to which the bed under consideration may belong. To insure uniformity in treating the thousands of questions of this kind that may arise—for nearly every field involves some, and many fields involve a great number—the Geological Survey has gradually established a series of precedents, and in every question the attempt is made to reach conclusions by means of mathematical calculation. The limits of this bulletin will not allow the consideration of these methods here.

DEPTH.

Some of the facts about the deep mining of coal in this country and abroad have been presented and discussed in an earlier bulletin of the Survey.[1] Not many years ago it was the common opinion and practice in parts of the West to consider as coal land only land on which coal actually cropped out, and requests are still occasionally sent to the Geological Survey asking the reclassification of certain land that had been previously classified as coal land, the writers contending, and supporting their contention by abundant affidavits, that the land is noncoal, because no coal shows at the surface and none has been found on it in wells. If such land should be considered noncoal land, however, most of the coal now mined in Illinois, Indiana, western Kentucky, Michigan, Kansas, and some other States comes from noncoal land, for most of the mines in those States are on lands where the coal mined does not crop out but is reached by shafts. The actual outcrop of most of the coal mined in these States is from 5 to 75 miles away from the shafts.

Two questions are here involved: (1) How deep can coal be mined? (2) Can all coals be mined to the same depth? Coal is now being mined to a depth of practically 4,000 feet (3,937 feet), and many shafts in England, Belgium, France, and Germany go deeper than 3,000 feet. Moreover, a consideration of the still greater depths to which substances other than coal are being successfully mined and a study of the deepest coal mines have convinced many of the best engineers of England and Europe that coal mining will be extended to 5,000 feet.[2] The fact also that some of the largest coal companies of this country have purchased as coal land certain tracts under which the coal is believed to lie at depths of 5,000 to 6,000 feet

[1] Fisher, C. A., Depth and minimum thickness of beds as limiting factors in valuation of coal lands: Bull. U. S. Geol. Survey No. 424, 1910, pp. 48 et seq.

[2] Idem, p. 51.

shows that some American engineers believe that coal mining will be carried to those depths.

Although, without regard to profit, there may be a physical limit to the depth that coal can ultimately be mined, in general the depth of mining must be determined by its cost. Given a steady market the depth to which coal can be mined is a question that involves diminishing profits; every added foot of depth adds to the time required to lift the coal, thus reducing the possible output of the mine, to the cost of the lift, to the initial capital required and the interest on that capital, to the size of pillars, and to other factors. Where coal is mined at a certain depth with a narrow margin of profit, obviously mining at a much greater depth will extinguish that margin and render that coal unworkable until markets are better. Of two coals at the same depth, of the same thickness, and in other ways equal but of different quality, one, the better coal, may yield a profit and the other may not. A similar inequality of profit may exist between two coals of the same quality but of different thickness. The thicker coal, which can be mined at a less cost, may be minable at a profit, while the thinner may not. In brief, the depth to which any coal can be worked depends, on the one hand, on its quality, which determines the profits where the cost of working is the same, and, on the other hand, on the cost of mining, which, omitting differences due to depth, is in general proportional to the thickness of the coal. Therefore, given a certain grade of coal which sells on the market at a certain price the profit will be in inverse ratio to the cost of mining, and hence, other things being equal, the depth to which that coal can be mined will differ for different thicknesses of coal and is assumed to vary in direct proportion to the value of the coal as computed from the cost of mining.

The depth to which any coal can be mined is therefore assumed to be directly proportional to the B. t. u. value of the coal and inversely proportional to the cost of mining for different thicknesses. Thus below the adopted minimum depth of 500 feet, a 10,000 B. t. u. coal can be mined to only two-thirds the depth of a 15,000 B. t. u. coal, and an 8,000 B. t. u. coal to two-thirds the depth of a 12,000 B. t. u. coal of the same thickness. If 5,000 feet is assumed as the maximum possible depth at which any coal can be mined, it is also assumed to apply only to coal of the highest grade and to the thickness costing the least to mine—in other words, to a 15,000 B. t. u. coal 6 feet or more thick. By this assumption a 6-foot coal of 12,000 B. t. u. is considered as workable to only 4,000 feet or a 6-foot coal of 10,000 B. t. u. to only 3,333 feet.

Elsewhere in this bulletin it is pointed out that the cost of mining a ton of coal is much higher for thin beds than for thick beds. There is no great difference in the cost of mining coals between 6 and 10 feet thick, but, especially in the West, the cost of mining coals less than 6 feet thick increases as the thickness decreases. It has therefore been assumed that a coal of the minimum thickness for its grade is workable to a depth of not more than 500 feet; that a coal 6 feet or more thick is workable to a depth of 100 feet for each 300 B. t. u. it contains; and that a coal between its minimum thickness and 6 feet is workable to a depth between 500 feet and the maximum depth limit for that coal proportional to the thickness above the minimum. Thus, a 12,000 B. t. u. coal 6 feet or more thick has a maximum depth limit of 4,000 feet and an assumed minimum thickness of 14 inches; a bed of 12,000 B. t. u. coal 4 feet thick is workable to a depth determined by the rule above given as follows: $72-14:48-14::4{,}000-500:x; x=2{,}050$, which added to 500, the depth limit for a bed of the minimum thickness, gives 2,550 as the depth limit for the bed under consideration.

The accompanying chart (fig. 3) is copied from part of a large-scale diagram used by the Geological Survey in classifying coal land. It is arranged to show the depth limit fixed for a coal of any B. t. u. value of any thickness under 6 feet.

For convenience the readings for the even feet and for the even thousand B. t. u. are given in the following table:

Limits of minable depth of coal of various thicknesses and various heating values in B. t. u.

British thermal units	15,000	14,000	13,000	12,000	11,000	10,000	9,000	8,000
Thickness, in feet:								
1½	811	787	764	751	665	500		
2	1,275	1,217	1,160	1,100	1,000	825		
3	2,200	2,075	1,950	1,830	1,665	1,440	950	
4	3,140	2,940	2,740	2,550	2,340	2,075	1,650	1,140
5	4,070	3,800	3,540	3,270	3,000	2,700	2,330	1,920
6	5,000	4,666	4,330	4,000	3,660	3,330	3,000	2,660

In general the limit of depth at which a coal bed may be profitably mined depends entirely upon the thickness of the bed and the quality of the coal. If, however, a thin but workable bed that lies below its ordinary minable depth is overlain by a thicker bed that lies within its own minable depth, the lower thin bed may, perhaps, be profitably worked by extending downward the shaft sunk to the higher, thicker coal, whereas the thinner bed could not have been profitably mined alone. A single shaft may also give access to all the coals of a group, and, though the cost of raising all the coal will be the same as if the coal were taken from a single bed, the cost of the shaft and the interest on that cost will be borne by the proceeds of a larger product. In some places the whole cost of a shaft may be borne by the coal of a thick bed that underlies several thinner beds or that lies in the middle of a group of thinner beds. It is clear that no two shafts that penetrate groups of coal beds will present

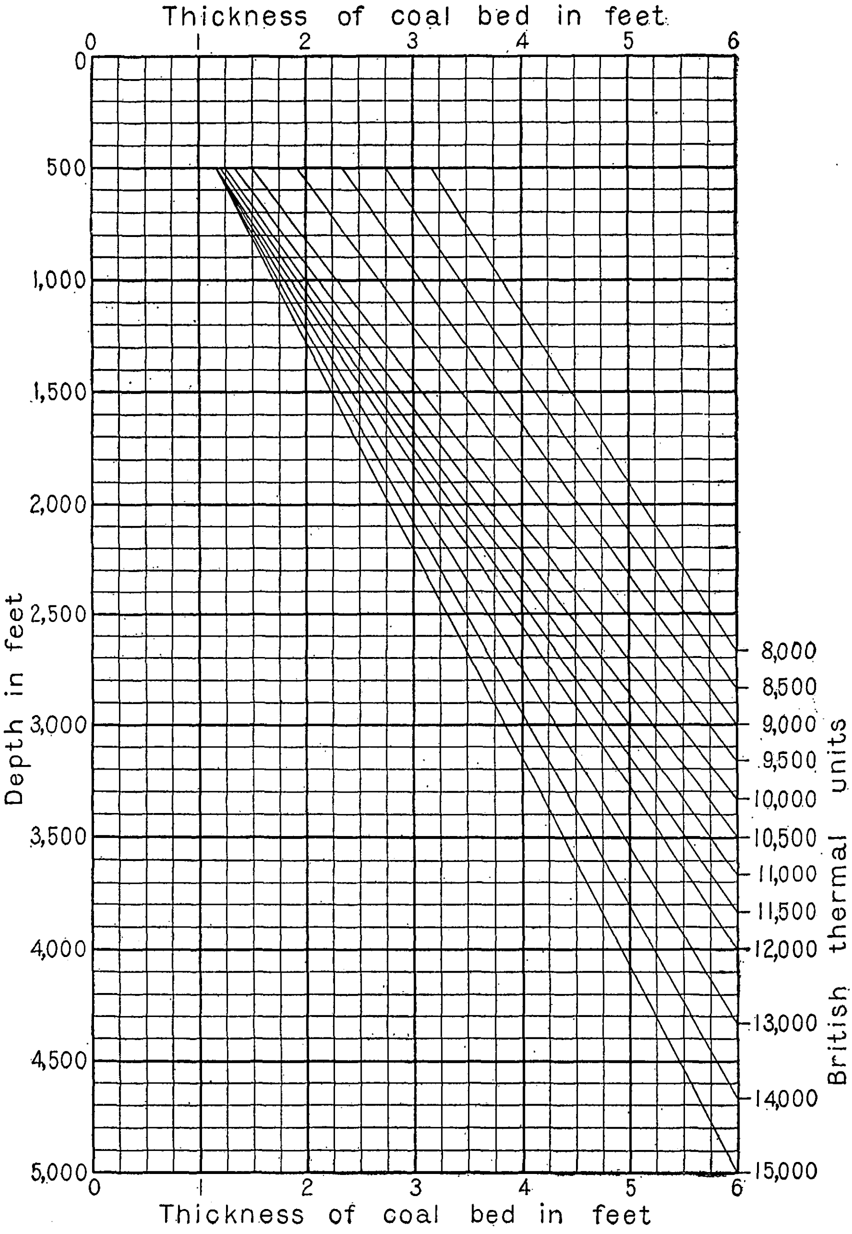

FIGURE 3.—Diagram showing depth limits of coals of different B. t. u. and of different thicknesses under 6 feet.

similar conditions. The coals of such groups will vary in number from two to twenty or more and may be included in an interval of 50 to 500 feet or more. Every case involving such conditions must be considered on its merits, and here again the Geological Survey has found it necessary to establish a series of general precedents in order to make its treatment of such cases reasonably uniform. In some places it has been found possible to treat a group of coal beds as if they were all gathered at a "center of weight"—that is, at a point determined by multiplying the computed thickness of each bed by its depth from the surface and dividing the sum of the products by the sum of the compensated thicknesses, the thicknesses of the various beds being reduced for partings in the manner already described.

The determination of the limit in depth at which a coal bed can be mined may be complicated by the fact that in a region of very rugged topography the coal gets below minable limit in passing under some high ridge or peak but is within the minable limit under a valley on the other side. Again, in some places the coal outcrops near the foot of a great cliff, such as commonly flanks a high plateau in the West, and it goes below minable depth within a short distance from its outcrop. In order to cover all the different occurrences of this kind the regulations provide that tracts underlain by horizontal beds of coal that lie at depths below the minable limit may under certain conditions be classified as coal land. Horizontal beds of coal may be mined to a distance back from their outcrop equal to 10 times the depth limit for coal of that particular grade and thickness. It is evident that, to be commercially minable at a certain depth, a coal bed must be minable for a reasonable distance from the foot of a shaft sunk to it, in order to pay the cost of the shaft. It is also evident that if it is profitable to sink a shaft to the depth limit for a given coal and then mine out horizontally by drift a certain distance from the foot of the shaft, it would be profitable to mine farther from the foot of the shaft if it were not so deep. The relative values involved in shaft and drift can be easily calculated if unit values are fixed for the horizontal and vertical components. For purposes of classification and valuation it has been assumed that 1 foot of vertical shaft in rock involves as much expense in its construction and maintenance and in the removal of the coal as 7.5 feet of horizontal drift in coal. For this reason the horizontal distance to which the drift can be carried will be no more than the prescribed limit for mining from the outcrop (in this case set at 10 times the vertical limit) minus 7.5 times the depth of the shaft. Thus if the minable depth of a certain coal bed is 2,000 feet, but that bed is horizontal and crops out in a cliff, the area underlain by it is classified as coal land for a distance of 10 times 2,000, or 20,000 feet, back from the outcrop. If the bed is horizontal but lies at a depth of 700 feet, it is assumed that the coal can be mined back 20,000 minus $(700\times7.5) = 14{,}750$ feet from the foot of a shaft of that depth, even if, away from the foot of the shaft, the coal is more than 2,000 feet below the surface. If the shaft is 1,200 feet deep the coal can be mined back 20,000 minus $(1{,}200\times7.5)=11{,}000$ feet. If the coal is at the depth limit at the foot of the shaft it can be mined back 20,000 minus $(2{,}000\times7.5)=5{,}000$ feet, or approximately 1 mile in any direction.

CLASSIFICATION BY 40-ACRE TRACTS OR LOTS.

In ordinary practice coal land is disposed of by parcels composed of "smallest legal subdivisions," which are ordinarily quarter-quarter sections, or 40 acres, except along the north and west sides of townships and in areas bordering meandered rivers or lakes, where the tracts are usually irregular in size and shape and are called lots.

The price of a tract that is wholly underlain by coal is the price per acre multiplied by the number of acres. The price of a tract that is only in part underlain by coal is the price of the coal per acre multiplied by the number of acres it underlies. To obtain the sale price per acre of the 40-acre tract or lot, the amount obtained by the above computation is divided by 40 or by a figure representing the actual acreage, but no land must be appraised at a price below the minimum fixed by law. Thus if 24 acres of a 40-acre tract is underlain by coal valued at \$50 an acre the price of the "forty" is 24 times \$50=\$1,200, or \$30 an acre (\$1,200÷40=\$30). The value of the coal in some lands, however, is so small that to charge even the minimum price for them would make the price of the coal abnormally high. For example, to take an actual case: Five acres of a 40-acre tract is underlain by coal 2 feet thick, the total value of which under the regulations is about \$100. The tract is within 15 miles of a railroad, and therefore if it is all sold as coal land it must be sold at the rate of \$20 an acre—that is, the whole tract must be sold for \$800. The coal land in the forty is therefore segregated from the agricultural land, the line of division following the 10 or 2½ acre subdivision. The two portions of the forty thus segregated are treated as separate lots. The 5 acres of coal land is sold for \$100, its value, and the noncoal tract is subject to disposal as nonmineral land. Such a division of the forty into two lots, one coal and the other noncoal, is made only along the outcrop of the coal and only within so short a distance from known corners that little doubt can arise as to the exact position of the outcrop.

OUTCROP COAL AND BURNED COAL.

In coal-mining practice it has been found that the coal along the outcrop and for a distance back of it ranging from 30 to 100 feet or more, the distance depending on the amount of cover, is more or less influenced by weathering, which materially decreases its value. Difficulty due to the thin and weak roof is also encountered in mining on the outcrop. If only a thin edge or corner of coal extends into a forty it may be neglected, as it will give the tract no value as coal land. If the coal outcrops in bluffs or steep hillsides or has a high dip weathering may be neglected. If the coal outcrops at the top of a mesa or on the face of a long, gentle slope an allowance is made for thinness of cover. The possibility of mining outcrop coal by stripping with steam shovel or otherwise is generally considered, as such a method of coal mining has in many places proved highly successful.

In many areas of the West the coal beds have been burned along the outcrop. In some places one or more or all of the beds have been burned not only along an outcrop over a whole field but under the flat tops of mesas where the coal is close to the surface. In a few places mining has shown that this burning extends back 1,000 feet or more and lies many hundred feet under cover. In general, however, the coal does not appear to have burned back more than a few rods. All places where coal has been burned are indicated on the field maps. In classifying the land in these places the edge of the coal is fixed along a line drawn back of the outcrop, only slightly back of it where the line crosses ravines, but to a considerable distance back of it where it crosses projecting divides, especially if the coal is under light cover.

METHODS OF VALUATION.[1]

COST OF COAL IN THE GROUND.

The total cost of coal in the ground consists of the original purchase price, interest on investment, amortization charges, taxes, and, if the coal is leased, the cost of inspection and of collecting royalties. The following table shows the amortization and ultimate cost of coal in the ground per dollar of investment for periods ranging from 20 to 40 years, at 5 and 6 per cent interest.

Ultimate cost of coal per dollar of purchase price.

Amortization period in years.	Rate of interest.	Annual interest.	Annual taxes at 1 per cent.	Annual amortization charge.	Total annual cost.	Total cost per dollar of purchase price at end of amortization period.
	Per cent.					
20	5	$0.05	$0.01	$0.03	$0.09	$1.80
	6	.06	.01	.027	.097	1.94
30	5	.05	.01	.015	.075	2.25
	6	.06	.01	.0125	.0825	2.475
40	5	.05	.01	.008	.068	2.88
	6	.06	.01	.006	.076	3.04

[1] For a more detailed account of the principles of valuation of public coal land see Survey Bulletin 424, on the valuation of public coal lands.

It is generally agreed that the price paid for coal in the ground should be recovered by the investor during the early years of the mining, when the cost is lowest. Otherwise it must be recovered when the inevitable increase in the cost of working the mine has reduced the profits and the business has reached a condition that is the bane of the eastern coal-mining industry to-day. The initial investment should invariably be refunded within the first 20 years of the life of the mine. The above table shows that if the mine is opened and operated immediately and continuously after purchase the total cost of the coal in the ground will be about two dollars for each dollar of the purchase price. The value of coal in the ground at the time of its extraction is measured by the current royalty rate in the region where the coal is situated. Its value at the time the mine is opened is, then, approximately one-half the royalty rate, as has been indicated. Were it possible to know in advance the exact number of tons that would be recovered from any acre of land, the value of that acre at the beginning of mining would be one-half the royalty rate per ton multiplied by the tonnage recovered. If the royalty rate is 10 cents a ton, the value of coal per ton in the ground when a mine is opened is at least 5 cents. To insure profit and safety, however, the purchaser of coal land, as a rule, in buying demands a margin on the estimated tonnage value (1) as a consideration for the risk of the investment, (2) to offset possible delays in the mining of the coal, and (3) as a contingent against an overestimate of the recoverable tonnage. If this margin is fixed at one-half the estimated value, the coal should have a sale value of 2½ cents a ton if the royalty is 10 cents a ton. Royalties on bituminous coals in the United States range from about 3 to the equivalent of 35 cents a ton. A comparison of royalties paid in the United States, some of which are given in Survey Bulletin 424 (p. 10) shows that 10 cents a ton is not far from the average royalty paid under private leases—somewhat less in the East, somewhat more in the West. Therefore 2½ cents a ton is a fair sale price for unmined coal that is to be mined immediately, where 10 cents a ton is the prevailing royalty. As a matter of fact, where the character and tonnage of the coal are well known to both buyer and seller prices often range from one-quarter the royalty rate almost or quite to the royalty rate. For example, the Pittsburgh coal, in southwestern Pennsylvania, is worked to a thickness of about 7 feet. On an estimate of 1,200 tons recovery per acre-foot this bed should yield 8,400 tons an acre; yet it is reported that 99 separate transfers were made in Westmoreland County between 1901 and 1910 at an average price of $1,102.70 an acre—over 13 cents a ton—and many of these sales were made at a price much higher than this average. Occasionally the sale price for small tracts adjacent to operating mines may reach the royalty rate.

The general impression that coal lands are sold at low prices is due largely to the fact that in the past most of the sellers had bought their land as farm land, knowing little or nothing of its coal content or value, and had regarded the coal as a little overmeasure on the part of nature for which they were willing to take anything that was offered or that looked good to them. As a result a large number of the recorded sales of coal land have been made at prices that have had little relation to the value of the coal, and in the past a large percentage of the total acreage has been sold at such prices. A recent review of coal-land sales for one year, as recorded in one of the most reliable of the coal journals, excluding all sales of tracts containing over 10,000 acres, which were obviously bought for holding or speculation, showed 40 sales, representing a total of 95,218 acres, at an average price of $209 per acre. This average price for a year's sales shows the great extent to which coal lands have passed out of their original farmer ownership. Grouped according to prices, it is found that that year's sales as thus recorded ran as follows:

Prices of coal lands sold in one year.

Price per acre.	Sales.	Acres.
$800 or more	3	10,198
$600 to $800	2	1,633
$400 to $600	3	417
$200 to $400	8	14,046
$100 to $200	10	26,097
Less than $100	14	32,817

In other words, 65 per cent of the sales and the acreage were at $100 an acre or more and 40 per cent of the sales were at $200 an acre or more.

It is evident that a large share of these were sales of lands not purchased for immediate development. Sixteen of these sales, conveying 74,633 acres, covered tracts containing more than 1,500 acres, an area generally admitted to be as large as can be economically mined from one plant in present-day practice.

In order to give the prospective buyer an ample margin of safety, the basing prices of the Government coal lands are fixed at only 40 per cent of the value ($2\frac{1}{2}$ cents per ton) named in a preceding paragraph, or at 1 cent per ton for a coal of good average quality—say 12,500 B. t. u.—equivalent to one-tenth of a cent for each 1,250 B. t. u. of the coal. This price is one-tenth the assumed average royalty rate.

FACTORS INVOLVED.

The valuation indicated, however—1 cent per ton for coal in the ground—is not put on all coals indiscriminately. Though the value of any coal is most readily obtained by taking the royalty rate, the royalty rate itself is based on the average difference between the cost price of the coal ready for sale and the sale price—that is, on the profit. If competition is keen and the profit is low, these facts are reflected in a low royalty rate. Whatever affects the profits affects the royalty rate and correspondingly the value. Other things being equal, the lower the grade of coal the less readily it sells and the less the profit, the royalty, and the value. On the other hand, the more expensive the coal is to mine the less the profit, the royalty, and the value. The Government valuations can not take account of changes in competition, markets, transportation facilities, or freight rates, or other factors that affect the profit, but it can and does take account of the quality and character of the coal, both chemically and physically, which affect the sale price and so the profit and value, and of those natural factors that affect the mining cost. The most important of these factors are thickness and accessibility.

EFFECT OF QUALITY ON PRICE.

One cent per ton is therefore the price put on a good average coal—a noncoking bituminous coal of 12,500 B. t. u. heat value, 6 to 10 feet thick, and at the surface. For coals of other B. t. u. value the same rate of one-tenth cent for each 1,250 B. t. u. is applied, and provision is made for increasing this value (not to exceed 100 per cent) for coking coal or coal that has special qualities which enhance its value in the market, the percentage of increase depending on the quality of the coke it yields or the extent to which its special qualities enhance its value; and on the other hand provision is made for reducing the appraised value because of special impurities, such as sulphur, or because of physical defects that obviously detract from the market value.

EFFECT OF MINING COST ON PRICE.

The cost of mining coal is affected by many factors—such as cost of prospecting, shaft sinking, or other mine opening, surface and underground plant, perhaps community plant, water, supplies, timber, feed, and insurance—all of which vary from place to place or in accordance with the method of working the mine. Within the mine the main factors are mining rate, thickness, depth, and dip or pitch of bed, variations or irreguarity in thickness, partings, "sulphur" or other impurities that must be removed, kind of roof or floor, presence of gas or water, provision for drainage and ventilation, haulage and hoisting, faults, and igneous intrusions. Many of these factors give rise to problems for the engineer; others definitely affect the value of the land for coal mining. One of the factors of the latter class—thickness—has so definite and constant a relation to the cost of mining that it must be taken into account in determining the value of all coal land.

VALUE OF THIN COALS.

The cost of mining thin coals increases rapidly with the decrease in their thickness, for the following reasons: The rate paid for mining the coal increases with the thinning of the bed, as do the amount of dead work per unit of output, the cost of trackage, ties, rails, haulage, and ventilation, and, for the very thin coals, the cost of taking up floor or brushing down roof to obtain height.

H. M. Chance[1] has prepared curves expressing the relations between mining cost and thickness for anthracite coal. The figures showing Chance's determinations are given in column 2 of the table on page 84. Similar figures (column 3) were obtained by the Survey for bituminous coals. Detailed cost sheets of mines working coals of different thicknesses were taken and the costs were separated into four items—(*a*) capital cost (interest, etc.); (*b*) mining rate; (*c*) tonnage cost (proportional to output, tipple, office, etc.); (*d*) acreage cost (proportional to acreage mined out, dead work, hauling, etc.). Obviously, if the recovery per acre-foot is the same, the last item would be double for a 5-foot coal bed what it would be for a 10-foot bed yielding the same output and would be inversely proportional to the thickness of the bed. Though the tonnage recovered is greater per acre-foot from thin than from thick beds, yet the recovery varies so greatly from mine to mine and from time to time that an absolutely invariable recovery from a bed of a given thickness can not be assumed. Therefore, in reaching the results now to be stated, differences in recovery from beds of different thickness have not been considered. As in all studies of coal mining made by the Geological Survey the obtainable figures relating to any particular factor were, if possible, gathered together and platted graphically on a chart, by which it has usually been practicable to show certain definite averages or curves expressing the relation sought. Whenever possible, these curves have been reduced to mathematical formulas. A concrete example is a curve showing the relation between the mining rate and thickness of bed, a relation which it was necessary to determine in working out the total cost of mining beds of different thicknesses. In making this diagram the mining rates at different places in the United States were platted on cross-section paper as shown in figure 4 (p. 85), on which the curve A–B was drawn to express the average relation between these two factors, a relation which was used in later computations.

[1] Chance, H. M., The cost of mining coal: Eng. and Min. Jour., May 29, 1909, pp. 1099–1101.

The following table gives the derivation of the formula showing the relation of the thickness to value of bed, uniform recovery being assumed:

Table showing derivation of formula for relation of thickness to value of bed.

Thickness of bed in feet (t).	Average cost.		Approximate combination cost.	Value by inversion.	Difference= 10 minus thickness in feet.	Square of amount in column 6.	100 minus amount in column 7.
	Anthracite (Chance).	Bituminous.					
1	2	3	4	5	6	7	8
10	1.00	1.00	1.00	1.00	0	0	100
9	1.01	1.03	1.02	.97	1	1	99
8	1.045	1.075	1.05	.95	2	4	96
7	1.10	1.126	1.10	.91	3	9	91
6	1.18	1.20	1.20	.83	4	16	84
5	1.35	1.30	1.33	.75	5	25	75
4	1.65	1.45-1.55	1.50	.66	6	36	64
3	2.13	2.00	2.00	.50	7	49	51
2	3.36	3.00	3.00	.33	8	64	36

The first column in the table gives the thickness of the bed in feet; the second the average cost of mining anthracite at these thicknesses, according to Chance (not including breakerage charges); the third column, the computed relative cost for bituminous coal; the fourth column, the approximate combination of the two; the fifth column, the relative values of beds of the same quality of coal of different thickness, obtained by dividing 100 by the cost, given in column 4; the sixth column, the difference in feet between 10 and the particular thickness given; the seventh column, the square of the numbers in column 6; the eighth column, the result of subtracting from 100 the square of the difference between 10 and the thickness in feet. By comparing columns 5 and 8, column 8 is seen to give a close approximation to the computed figures in column 5, and as the figures in column 5 are by no means absolute and fixed the figures in column 8 have been taken as fairly expressing the relative value of different thicknesses of the same coal; but this is found by subtracting from 100 per cent a percentage equal to the square of the difference between 10 and the thickness, or $\frac{100}{100}-\frac{(10-t)^2}{100}=1-\left(\frac{10-t}{10}\right)^2$. The value per ton of a bed less than 10 feet thick of a given grade of coal may therefore be found by multiplying the normal value per ton for a 10-foot bed of coal of that grade by $(1-\left(\frac{10-t}{10}\right)^2)$.

In valuing land by the acre-foot, however, an additional factor must be considered, namely, that a larger recovery of coal per acre-foot is possible from thin beds than from thick beds. This difference offsets in a measure the rapid increase in mining cost with thinning of beds. Thus 1,000 tons an acre-foot for a 10-foot bed and 1,200 tons an acre-foot for a 6-foot bed are considered fair recoveries. But 1,000 tons of coal at 1 cent a ton is $10, and 1,200 tons at 0.84 cent a ton (84 per cent being the corresponding value of a 6-foot bed) is $10.08. It is then practically immaterial whether land containing a 6-foot bed is valued at 84 per cent of the normal value of land containing a 10-foot bed of coal of a certain grade and an assumed recovery of 1,200 tons an acre-foot or whether the same value per ton and the same recovery per acre-foot are assumed as with the 10-foot bed. As the latter treatment is the simpler it has therefore

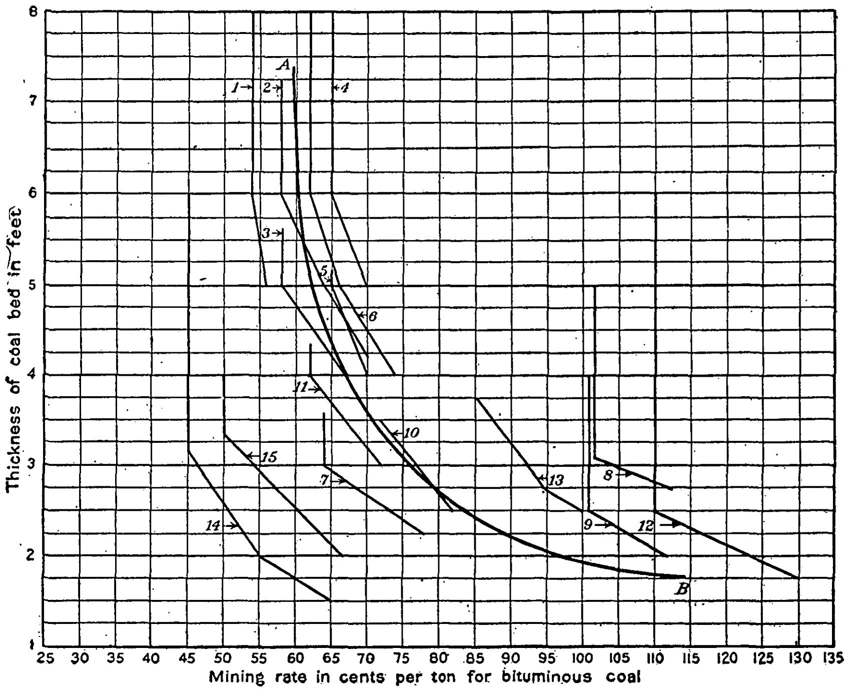

FIGURE 4.—Rates paid in the United States for mining coal of specified thicknesses and curve (*A–B*) showing average relation between mining rate and thickness. 1, 2, 3, Wyoming, southern fields, run of mine, agreements of 1912. 4, 5, Colorado, northeastern coal fields, run of mine, agreements of 1912. 6, Montana, Red Lodge field, run of mine. 7, Indiana, miscellaneous agreements, run of mine. 8, Indiana, block coal agreements, screened. 9, Michigan, summary of agreements of 1910. 10, Missouri, summary of agreements, run of mine. 11, Missouri, Bates and Vernon counties, run of mine, agreements of 1908. 12, West Virginia, summary of agreements, screened. 13, Kentucky-Tennessee, Jellico mining district, screened. 14, Tennessee, Durham Coal & Iron Co., run of mine. 15, Tennessee, summary of agreements, run of mine.

been adopted and the value of a ton of any coal in the ground is taken as constant for thicknesses between 6 and 10 feet.

The rate of increase in cost of mining a bed less than 6 feet thick, however, is too great to be compensated for by the greater recovery per acre-foot. After making various assumptions as to fair average acre-foot recovery for thin coals—assumptions based on known recoveries—and after computing the value of the coal in thin beds, according to the formula given on page 84, it was decided to avoid a sliding scale both in value and recovery by reducing the value of beds less than 6 feet thick 10 per cent for each foot below 6 until the minimum for that coal is reached. Thus the coal in a 5-foot bed is computed at 90 per cent of the value per ton of the coal in a 6-foot bed, the coal in a 3-foot bed at 70 per cent of the value per ton of the coal in a 6-foot bed, and so on. This reduction for the value of the coal in beds less than 6 feet thick is readily computed by multiplying the normal value per ton by $\frac{4+t}{10}$, where t is the thickness in feet. Figures showing the results obtained by multiplying the relative value of coal in thin beds, given in column 8 of the preceding table, by various assumed rates of recovery were plotted on cross-section paper and an arbitrary line was drawn through the middle of the group of lines so obtained. This line is practically a straight line, giving a reduction in value of 10 per cent for each 1-foot reduction in thickness, and was accepted as representing fair average relative values.

Sufficient data were not at hand on the relative cost of mining coals more than 10 feet thick to lead to definite figures, or figures having more than approximately authoritative value. It is, however, generally recognized that the cost of working coals does not continue to decrease indefinitely as the beds increase in thickness, for the increased cost of timbering and increases due to other practical difficulties gradually overcome the gain due to smaller acreage, and increases for the thick coals in general probably entirely offset that gain. From beds more than 10 feet thick, other things being equal, the recovery per acre-foot decreases with increase in thickness, owing to the necessity of leaving larger pillars and the difficulty of reaching all the coal. It has therefore been assumed that the recovery diminishes on each additional foot above 10. Thus a 16-foot bed takes first the normal value on 10 feet; next the eleventh foot is valued at only 99 per cent of the value fixed for the tenth foot, the twelfth foot at 98 per cent, and so on, the sixteenth foot having a value of only 94 per cent of the value fixed for the tenth foot.

In computing acre values on beds over 10 feet thick it has been found best to use the normal basing value in cents per ton of a 10-foot bed and assume the same recovery per acre-foot and then compute the thickness (t') of a bed that without deduction will yield the same acreage recovery as the bed in question. Where the thickness in feet (t) is more than 10 the equivalent thickness (t') is expressed by the following formula: $t'=9+\frac{t-9}{2}\left(2-\frac{t-10}{100}\right)$.

Summarizing the above: The Government price per ton for a bed 6 to 10 feet thick will range from 6.4 mills (0.64 cent) for an 8,000 B. t. u. coal to 1.2 cents for a 15,000 B. t. u. coal, but if a coal is of coking quality its price may be increased to a maximum of 2.4 cents, or if its quality is low it may be decreased to one-tenth cent or less.

In computing the thickness of a split or broken bed for valuation the same allowance is made as in considering classification.

The following table gives the computed value per acre of ordinary coal beds of different B. t. u. and different thickness:

Normal price per acre of coal land containing one bed of coal with heat values from 10,000 to 15,000 B. t. u. and thickness from 1 foot 6 inches to 50 feet.

Actual thickness.	Equivalent computed thickness.	Price per acre.						Tons per acre at 1,750 tons per acre-foot.
		10,000 B. t. u.; 0.8 cent per ton.	11,000 B. t. u.; 0.88 cent per ton.	12,000 B. t. u.; 0.96 cent per ton.	13,000 B. t. u.; 1.04 cents per ton.	14,000 B. t. u.; 1.12 cents per ton.	15,000 B. t. u.; 1.20 cents per ton.	
Ft. in.	*Ft. in.*							
1 6	8	[a] $6.60	[a] $7.25	[a] $7.93	[a] $8.58	[a] $9.25	[a] $9.90	2,625
2	1 2	[a] 9.60	[a] 10.56	[a] 11.52	[a] 12.48	[a] 13.44	[a] 14.40	3,500
3	2 1	[a] 16.80	[a] 18.50	20.15	21.85	23.50	25.20	5,250
4	3 2	25.60	28.16	30.75	33.30	35.80	38.40	7,000
5	4 6	36.00	39.60	43.20	46.75	50.40	54.00	8,750
6	6	48.00	52.80	57.60	62.40	67.20	72.00	10,500
7	7	56.00	61.60	67.20	72.80	78.40	84.00	12,250
8	8	64.00	70.40	76.80	83.20	89.60	96.00	14,000
9	9	72.00	79.20	86.40	93.60	100.80	108.00	15,750
10	10	80.00	88.00	96.00	104.00	112.00	120.00	17,500
20	19 5	155.60	171.20	186.72	201.94	218.00	233.30	35,000
30	27 10	223.40	245.60	268.00	290.00	312.50	334.80	52,500
40	35 4	282.70	311.00	338.30	367.50	395.00	423.00	70,000
50	46 9	374.80	412.00	449.00	486.50	525.00	562.00	87,500

[a] Where the computed value is less than $20 the minimum prescribed by law is placed on the land—$20 if the lands lie within 15 miles of a railroad and $10 if more than 15 miles from a railroad.

VALUE OF IRREGULAR BEDS.

If the calculated thickness of any coal bed or group of beds shows a considerable variation in thickness and shows that this variation is not regular, it must be recognized that on any 40 acres concerning which no data are available the coal may be as thick or as thin as the maximum or minimum measured in adjacent areas. Because of the limited acreage that one purchaser may now legally buy and because he may not exchange his land for other land if it proves not to be underlain by as much coal as had been estimated in determining its price, an allowance should in fairness be made to him for possible local thinning.

If any regularity is shown in the changing thickness of the coal, the practice is adopted of drawing lines of equal thickness, a feature best illustrated by giving a concrete case, such as is represented in figure 5.

On this map lines were drawn from the position of one measurement to the position of each adjacent measurement and the thickness was assumed to grade uniformly from one to each of the other points. Valuation is then based on the average thickness thus found for each forty that is being valued. If the measurements do not show any regularity in the change of thickness, the Survey has adopted a method of computing thickness that permits the thickness of the coal under any tract of land to be considered as less than the average of the measurements, in order to favor the buyer, for the reasons already stated. For while the coal is as likely to be above the average as below and, mathematically, is more likely to be just the average thickness than any other, yet a cautious buyer bargaining for coal would always want to discount the probability a little, as a matter of safety. If all the measurements on a bed indicate the same thickness, that thickness may be safely taken as the thickness of the coal under any land included by the measurements. If the measurements vary but slightly from the average, the thickness under the land where no measurements are obtained is not likely to be much below the average. If, however, the variation is large, the coal in some places may be even thinner than the smallest measurement; yet to assume that the coal under all the land where no actual measurements were made is as thin as the thinnest measurements obtained would be overcautious. A more probable thickness is obtained by multiplying the average of the measurements by $(1-\frac{SD}{S})$, in which S is the sum of all the measurements and SD is the sum of the numbers obtained by subtracting from the average each measurement below it or subtracting the average from each measurement above it. For example, if the measurements on a given bed in a certain area are 4 feet, 5 feet, 7 feet, 3 feet, 4 feet, 8 feet, 5 feet, 2 feet, 4 feet, 2 feet, 6 feet, and 10 feet, the average of all the measurements is 5 feet; the sum of the measurements is 60 feet; the difference between the several measurements and the average 5 feet is 1 foot, 0, 2 feet, 2 feet, 1 foot, 3 feet, 0, 3 feet, 1 foot, 3 feet, 1 foot, 5 feet, which added together give 21 feet; so 21 feet divided by 60 has been called the "modulus of irregularity" and has been adopted as a factor of safety; $1-\frac{21}{60}$ or 100 per cent $-$ 35 per cent $=$ 65 per cent; 65 per cent of 5 feet $= 3\frac{1}{4}$ feet; therefore $3\frac{1}{4}$ feet is taken as a safe average thickness on which to sell the coal—in other words, the thickness which it is highly probable will be reached or exceeded by the coal under any of the land within the area of the measure-

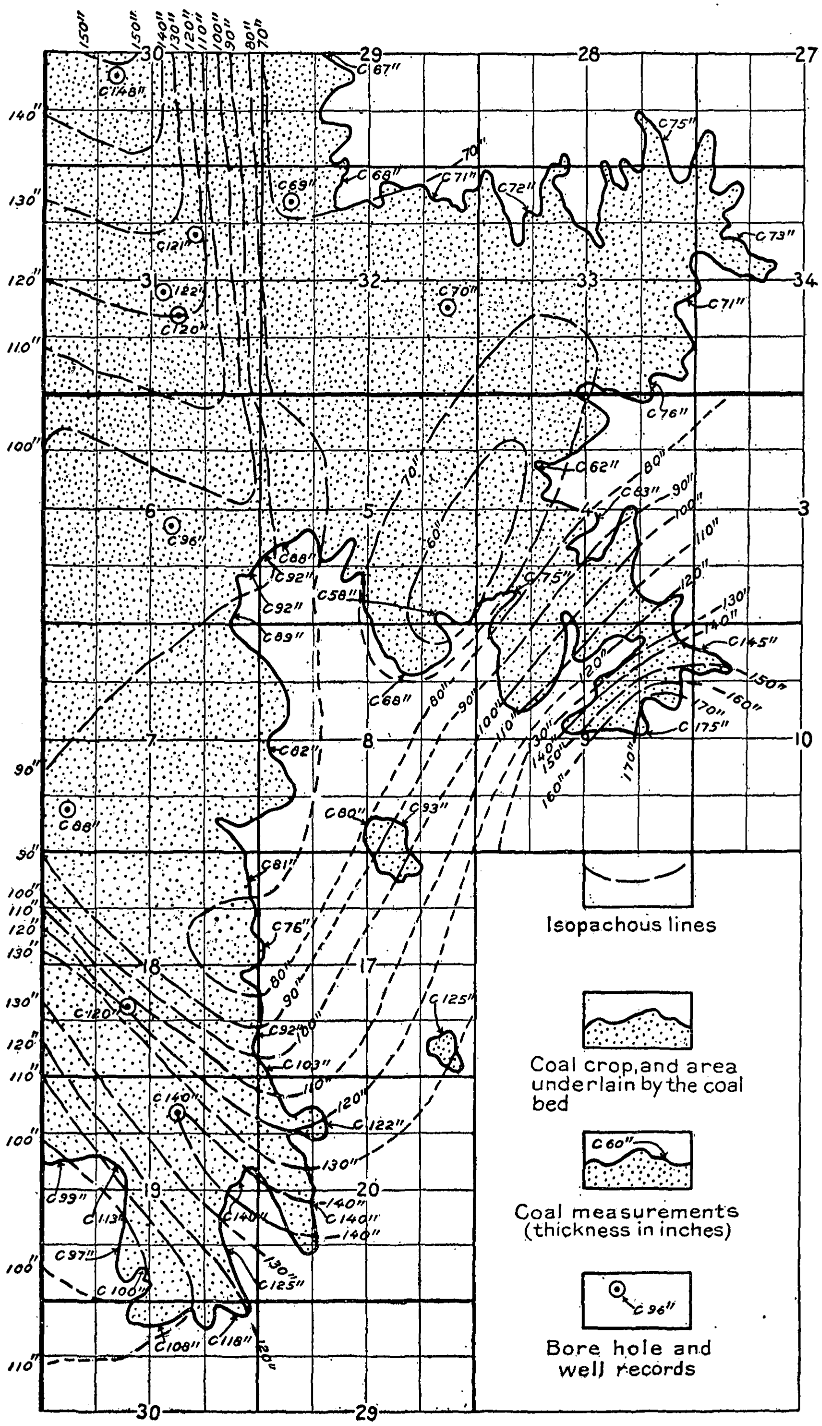

FIGURE 5.—Sketch map showing lines along which a coal bed is of equal thickness (isopachous lines), drawn for use in the valuation of coal land.

ments given. In this, of course, the Government is favoring the buyer to the extent that the computed safe average is below the actual average of measurement; but, on the other hand, it is believed that this is no more than would properly be demanded by the average purchaser of private coal lands who, knowing the measurements of thickness on the land to be purchased, wishes to safeguard himself against the possibility that the measurements will prove to be above the average of all of the coal. This safeguard is, of course, in addition to the allowance for such a possibility in the purchase price.

VALUE PER ACRE.

The Government prices for coal land are based on an assumed possible recovery of 1,000 tons per acre-foot. As an acre of coal a foot thick contains 1,750 to 1,800 tons, this recovery represents about 60 per cent of the coal in the ground. This percentage was long used in commercial estimates, though at present it is usually much exceeded by the percentage actually recovered in all good coal mining, especially in the bituminous fields of western Pennsylvania and in many regions in the Central West where the longwall method of mining has been practiced, by which the recovery in many places is estimated at 90 per cent or more.

Although a recovery of 1,000 tons per acre-foot is fixed in the regulations and is used in all computations, the value per ton assumed for coals thinner than 6 feet or thicker than 10 feet recognizes the recovery of more than 1,000 tons per acre-foot for coal in thin beds and of less than 1,000 tons per acre-foot for coal in very thick beds, thus avoiding the use of a variable recovery factor in making individual computations.

If more than one bed underlies a tract of land the early rule in valuing was to take the normal value of the bed likely to be worked first, 60 per cent of the value of the bed next worked, 40 per cent of the value of the next, and 30 per cent of the value of any others, the reduction being made on the beds not worked at first to allow for interest on the investment for the long period during which they remained in the ground. Fuller consideration of this subject, however, and closer study of the operation of many mines that work several beds simultaneously or one immediately after the other and of the practical advantages of using the same plant for working beds either simultaneously or successively have led to the belief that these advantages more than outweigh the added interest that accrues during the longer period of holding.

Accordingly, under the regulations now in force, consideration is had only of the total quantity of coal in the ground, no reduction being made for interest on the investment if, after allowance for the reduced value of the thin beds, the sum of the thicknesses of the beds does not exceed 10 feet. If the total thickness of the coal under a tract of land, after reduction for thin beds and for partings, is more than 10 feet, the total value of the coal is computed by the formula previously given for computing the value of thick beds.

REDUCTION FOR DEPTH.

It has been pointed out that the determination of the depth to which a coal may be profitably mined is a problem involving the consideration of diminishing profits. If a coal that is being mined near the surface is yielding a net profit of 25 cents a ton and if the cost of mining it increases 1 cent a ton for every 100 feet of increase in depth (purely an assumption), it is evident that the profits will disappear when the mine has reached a depth of 2,500 feet, so that the coal becomes unminable at a reasonable profit at some point of less depth, say 2,000 feet. Obviously anything that increases the profits—such as a gain in quality—will increase the depth of profitable mining, and anything that decreases the profits—such as an increase in the cost of mining—will decrease the depth of profitable mining.

If depth limits are assumed for coals of different grades and different thicknesses, it may also be assumed that the cost of mining increases uniformly with increase of depth, though it is strongly suspected that the cost of mining increases at an accelerating rate as the depth increases, but as sufficient data to prove this are not available a uniform rate of increase has been assumed.

If a certain coal has a normal value at any depth within 500 feet of the surface its value has been assumed to reach zero at its depth limit, and its price has been decreased uniformly from a point where it goes below the 500-foot depth down to its depth limit. If, for example, a bed has a value of $60 an acre at the depth of 500 feet and its depth limit is 2,500 feet, and if it reaches its depth limit 3 miles beyond the point where it lies at a depth of 500 feet, its dip remaining constant, it loses a value of $60 in crossing twelve 40-acre tracts, or $5 for each forty. The successive forties underlain by this coal would therefore be valued at $55, $50, $45, $40, $35, $30, $25, and thence to the depth limit at $20.

Ordinarily the depth of a bed does not increase uniformly to its limit, but its steepest pitch or dip is at its outcrop and its dip gradually lessens toward the center of the basin in which it lies. Its depth at all places is indicated on the field sheets by contour lines representing uniform elevations above sea level. From these contour lines it is possible to compute the average depth of the bed under any 40-acre tract, and, the rate of diminishing value having been established by dividing the difference between the depth limit and 500 feet by the normal value at the surface, each 40 acres can be

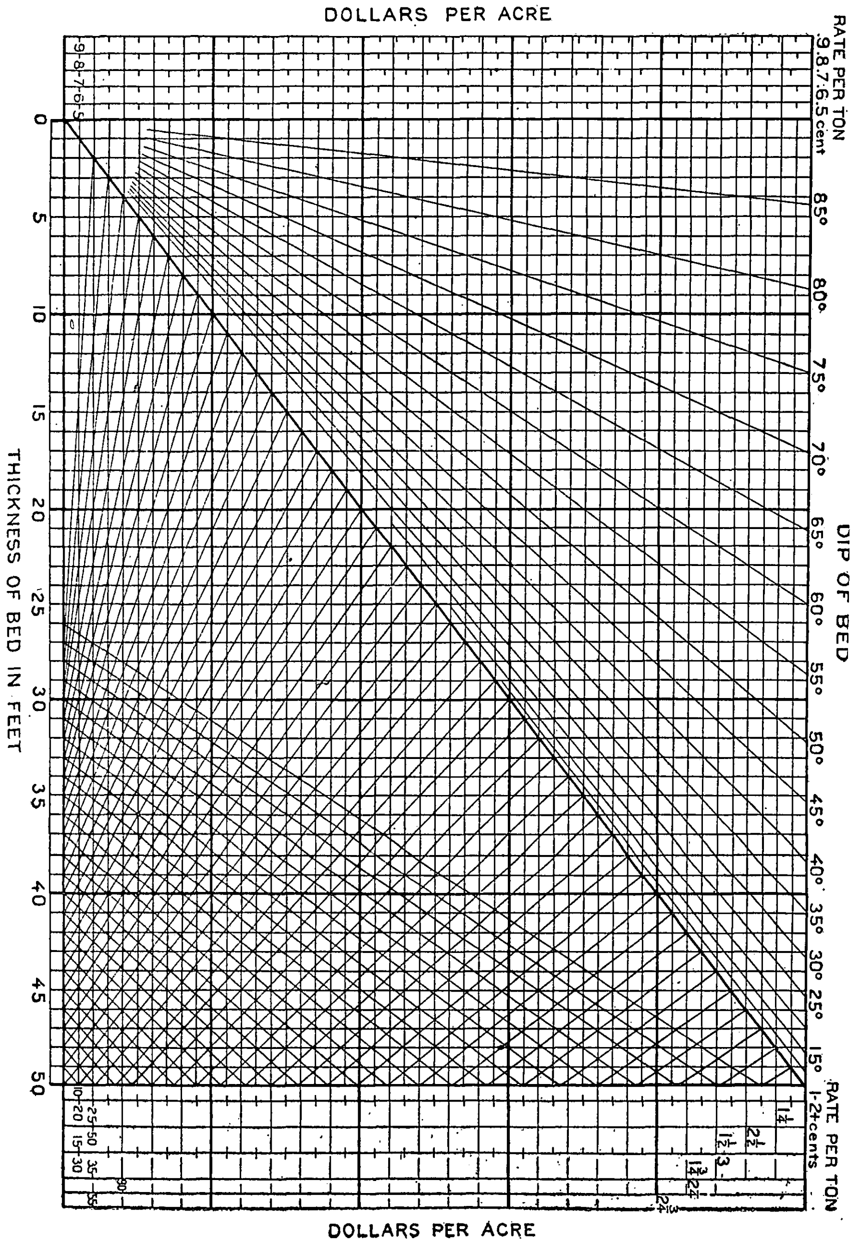

FIGURE 6.—Reduced copy of diagram used by the United States Geological Survey in computing value of coal lands; one-fifth size. From tracing that omits much of the detail on the edges of the chart.

valued accordingly. The average depth of coal in a forty that is crossed at an angle by the outcrop or the depth-contour lines is the depth at the geometrical center of the area underlain.

If the dip of the coal bed whose value is given above had not been regular the rate of its diminishing value would have been $\frac{2500-500}{60}=\$1$ for each $33\frac{1}{3}$ feet, so that if the depth under a given forty averaged 1,600 feet, the value of the forty would be

$$\$60-\frac{1600-500}{33\frac{1}{3}}=\$27.$$

If more than one bed of coal underlies a 40-acre tract and the beds are not close together each one is valued independently and the value of the forty is taken as the sum of the value of the independent beds. If several beds occur in a group a normal value is figured out for the group and this value is reduced according to the depth. In fixing the value of a group of dipping beds allowance is made for the change in the value of the group due to the lower beds passing below the 500-foot line before the higher beds and reaching the depth limit before they do.

Formulas have been worked out to facilitate the calculation of the value of beds involved in some of the more common types of computations in these cases are read directly from large diagrams. These diagrams contain so much matter that a reproduction of one of them (fig. 6) on the reduced scale necessary for publication in this bulletin does little more than give a general idea of their character, particularly as they are too involved to permit their description in a bulletin that is not intended to set forth details of classification.

ALLOWANCE FOR FAULTS.

Faults—that is, breaks in the rocks involving a movement of beds on either side of the break—occurring in a coal field depreciate the value of the coal for mining and in places may render it entirely unworkable. Small faults may be disregarded unless they are so numerous as to render the coal expensive or difficult to mine. If, however, the throw of the fault is large—that is, if the edges of the beds that are broken have been so far separated by movement at an angle to the bedding that entries can not handily be driven from the coal on one side of the fault to the coal on the other—the value of the land is clearly less than that in which there is no fault, its smaller value being due both to the extra cost of recovery and to possible crushing of the coal along the fault planes. The price of coal in such places is determined by considering the two parts of any forty traversed by the fault separately, and giving the normal price to the part having the higher value and 40 to 95 per cent of the normal price to the part having the lower value. From the total thus obtained 5 to 15 per cent may be deducted to allow for crushing along the fault plane.

EFFECT OF INTRUSIONS.

Intrusions of igneous rock may affect a coal bed favorably, as where they occur in sheets close above or below the coal and have had the effect of changing it from a bituminous or lower grade of coal to an anthracite. The physical character and B. t. u. value of such coals reflect amply the favorable results of the intrusion. More often the intruded masses of igneous rock are in the form of more or less vertical dikes that cut the bed in various directions. Obviously these dikes detract from the value of the bed by increasing the cost of mining, and an allowance is made in the final price in accordance with their character and extent.

ALLOWANCE FOR OTHER FACTORS.

In addition to the factors that have been specifically considered, many other factors are taken into account in valuing the land in any field. Of these the one for which the largest allowance is likely to be made is that of uncertainty. In some fields it has been possible to obtain measurements on the coal along its outcrop at points a quarter of a mile or less apart, and some of these measurements are supplemented by others made in drillings at points "back" from the outcrop, so that in such places it is possible to determine the "habit" of the bed with some degree of certainty. In other places, especially in coal fields covered with a blanket of glacial deposits, or in broad valleys where the coals are under an alluvial cover, or in other fields where, owing to almost continuous burning along the outcrops, it is difficult to get accurate information as to the thickness of the beds, an allowance is made for uncertainty—an allowance that may take the form of a greatly reduced estimated thickness of the bed or, as is more common, of a restriction of the assumed area of workable coal. It has been found that the coal of certain fields was originally deposited with more regularity in some belts and areas than in others, and in many places the coal was deposited with great regularity around the edge of a basin but not in its center. Allowance is made for the possible thinning of the coal in all such places if exact data are not at hand, and the tract is classed either as noncoal land or as coal land of the minimum value. Many other factors are taken into account, such as known poor roof or floor, which may seriously affect the cost of mining and the value of the coal in place. Allowance is made for the extra cost of mining beds that include partings by making deductions for partings, it being assumed that the extra cost due to the partings eats up the profits on an equal thickness of coal.

REDUCTION FOR DISTANCE FROM RAILROAD.

Distance from railroads very largely affects the value of coal land. In fixing the value of Government coal land, however, distance from railroads is not taken into account, their value being based on that of the coal itself, but, in accordance with the law, the price so fixed is automatically reduced one-half for all lands lying more than 15 miles from a railroad in operation. Some land that contains coal beds, though within 15 miles of a railroad, can not be reached by a railroad switch without going either around or over a high mountain, so that by either route its distance from the railroad practically exceeds the 15-mile limit. Such land is treated as if it were beyond the 15-mile limit and its price is reduced one-half, though not below the legal minimum—$20 an acre.

MAXIMUM PRICE.

In view of the uncertainty that may exist concerning many features of an undeveloped coal field, even if the evidence seems conclusive that it contains a large volume of coal, the maximum price of coal land is fixed by the regulations at $300 a nacre, except that if the field in which the land is situated contains very large mines, and if the coal is well known in the market and its adaptability to different uses has been demonstrated, the price of the land is computed from the value of the coal it contains, whether it exceeds $300 an acre or not.

REVIEW OF CLASSIFICATION.

According to the regulations the classification of any land as coal land is subject to review by the Secretary of the Interior, but the person making the application for review must present facts that show clearly and specifically that the land is not coal bearing in the sense of that term as it is defined in the regulations. The facts set forth in nearly all applications for review and reclassification of coal land simply show that no coal can be seen outcropping on or close to the land and that no coal has been found in drilling wells for water on or near the land. Before such applications are filed request should be made of the Geological Survey to state the basis of the classification, for a large percentage of the coal land has been classified as such because it is underlain by coal at depths of 500 feet or more, whereas the rocks at the surface contain no coal and may be of entirely different age from the underlying coal-bearing rocks. Data presented in a request for reclassification have determinative value only if they differ from data already in the records of the Geological Survey.

REGULATIONS FOR THE CLASSIFICATION AND VALUATION OF PUBLIC COAL LANDS.

The following regulations were approved February 20, 1913, by Secretary of the Interior Fisher:

II. CLASSIFICATION.

1. Land shall be classified as coal land if it contains coal having—

(*a*) A heat value of not less than 8,000 B. t. u. on an air-dried, unwashed or washed, unweathered mine sample.

(*b*) A thickness of or equivalent to 14 inches for coals having a heat value of 12,000 B. t. u. or more, increasing 1 inch for a decrease from 12,000 to 11,000 B. t. u., 1 inch for a decrease from 11,000 to 10,500 B. t. u., 1 inch for each decrease of 250 B. t. u. from 10,500 to 10,000, and 1 inch for each decrease of 100 B. t. u. below 10,000.

(*c*) A depth below the surface for a bed of coal 6 feet or more thick of not more than 100 feet for each 300 B. t. u. or major fraction thereof, and for a bed of minimum thickness for that coal a depth of not more than 500 feet, and for beds of any thickness between the minimum and 6 feet a depth directly proportional to that thickness within these limits, provided that, if the coal lies below the depth limit but within a horizontal distance from the surface not exceeding 10 times the depth limit, or if its horizontal distance from the foot of a possible shaft (not deeper than the depth limit) plus 7.5 times the depth of such shaft does not exceed 10 times the depth limit, the land shall be classified as coal land; provided, further, that the depth limit shall be computed for each individual bed, except that where two or more beds occur in such relations that they may be mined from the same opening the depth limit may be determined on the group as a unit, being fixed at the center of weight of the group, no coal that is below the depth limit thus determined to be considered.

2. Classification shall be made by quarter-quarter sections or surveyed lots, except that for good reason classification may be made by 2½-acre tracts or multiples thereof described as minor subdivisions of quarter-quarter sections or rectangular lotted tracts.

II. VALUATION.

3. For purposes of valuation the price per ton for a noncoking, nonanthracite coal 6 to 10 feet thick shall be one-tenth of a cent for each 1,250 B. t. u.:

(*a*) Provided that the price per ton may be increased by not more than 100 per cent if the coal is coking, smokeless, or anthracitic or has other enhancing qualities; or it may be decreased for high sulphur or ash, friability, or nonstocking or other qualities that reduce the value; and

(*b*) Provided, further, that if the coal in one bed is over 10 feet thick the price on each foot above 10 feet shall be reduced 1 per cent for each such foot (thus the reduction will be 1 per cent on the eleventh foot, 2 per cent on the twelfth foot, and so on); or if the coal is less than 6 feet thick the price shall be reduced by multiplying the normal value by $\frac{4+t}{10}$, where t equals thickness in feet; and

(c) Provided that where the thickness of any bed varies irregularly its computed thickness (CT) over any area shall be equal to the average of the measurements (AM) less the sum of the differences between each measurement and the average of the measurements (SD) divided by the sum of the measurements (S):

$$CT=AM-\frac{SD}{S}$$

4. The value of any acre within 15 miles of a railroad in operation shall be determined at the rate per ton prescribed above on an estimated recoverable tonnage of 1,000 tons to the acre-foot:

Provided that if the coal is in several beds having an aggregate thickness of more than 10 feet if beds less than 6 feet thick are considered at the reduced thickness as prescribed above, the value due to each foot above 10 feet shall be reduced 1 per cent for each such foot (as in computing the price per ton on a single thick bed) up to a thickness of 80 feet, above which any additional thickness shall be valued at 30 per cent of the normal value.

5. This price shall be decreased one-half if the land is more than 15 miles from a railroad in operation, or if it is within that limit but inaccessible owing to topographic conditions; but no land shall be valued at less than the legal minimum price, nor shall the price of any land exceed $300 an acre except in districts which contain large coal mines and where the character and extent of the coal are well known.

6. Within the above restrictions a graded allowance shall be made for increasing depth, and allowance may be made for any special conditions enhancing or diminishing the value of the land for coal mining.

7. If only a part of a smallest legal subdivision is underlain by coal the price per acre shall be fixed by dividing the total estimated coal values by the number of acres in the subdivision, but this price shall not be less than the minimum provided by law.

8. When lands which were at the time of classification more than 15 miles from a railroad are brought within the 15-mile limit by the beginning of operation of a new road, all values given in the original classification shall be doubled by the register and receiver.

9. Review of classification or valuation may be had only on application therefor to the Secretary, accompanied by a clear and specific statement of conditions not existing or not known to exist at the time of examination.

RESTORATION.

After the classifications and valuations are completed the lands are restored to entry. Those that contain no coal resume the status that they had prior to the withdrawal. The coal lands, after restoration, may be acquired under the coal-land laws at the valuation prices, surface entry under the agricultural-land laws and the State selection acts being permitted at any time prior to their alienation under the coal-land laws. A typical order of restoration is given below.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, February 12, 1913.

The honorable the SECRETARY OF THE INTERIOR.

SIR: The classification of the lands listed below, which are included in an existing withdrawal, has been completed and reported to the Land Office, and I therefore recommend the submission to the President, for appropriate action, of the following order of restoration, involving 264,009 acres, all noncoal. These lands are not included in petroleum or phosphate reserves or in national forests, but part are within a power-site reserve.

Very respectfully,
GEO. OTIS SMITH,
Director.

FEBRUARY 18, 1913.

Respectfully referred to the President with favorable recommendation.

WALTER L. FISHER,
Secretary.

ORDER OF RESTORATION.

Coal-land restoration—Idaho No. 10.

So much of the order of withdrawal made heretofore for the purpose of coal-land classification, namely, Idaho No. 1, as affects the lands hereinafter described is hereby revoked for the reason that the Director of the Geological Survey has classified these lands. This revocation does not affect withdrawals or reservations other than as above set forth.

Boise meridian.

T. 35 N., R. 1 E., all of township.

[Here follows the remainder of the land description.]

WM. H. TAFT,
President.

FEBRUARY 18, 1913.

FIELD WORK ON COAL LANDS.

GENERAL NATURE OF THE WORK.

The second general step in the process of classification is to obtain in the field the information there available that is necessary for the classification. Field work that is done expressly for the classification of coal land involves all research that is made in general geologic field work but gives special weight to certain factors. The information needed for classifying coal land relates to (1) location, (2) stratigraphy, (3) horizontal extent and thickness of coal beds, (4) vertical position, and (5) quality of the coal. These may be taken up in turn.

LOCATION.

In work done for classification all the points or features concerning which information is obtained in the field must be accurately located with reference to the land lines, for if locations are not exactly specified the information is of little value. For example, a geologist may study an outcrop of a 30-foot bed of coal, measure its sections, photograph it, and sample and analyze the coal to determine its quality or test it in any other way, but if, when he has done all these things, he can not tell whether the outcrop is in sec. 31 or sec. 32 of a given township, the information he has gathered is entirely valueless for purposes of classification. It is therefore necessary that all the features to which his information relates be accurately located on his field maps, with special reference to township and range lines, section lines, and quarter-section lines, and even accurately within the 40-acre tracts, as it is desirable to know exactly how many acres of the forty are underlain by coal in order to determine the value of that particular forty. The methods of survey by which the geology is tied as accurately as possible to the public-land net have been described in a preceding chapter.

STRATIGRAPHY.

The first purpose of gaining a thorough knowledge of the stratigraphy is to be able to recognize groups of rocks that are coal bearing elsewhere or to recognize other rocks that the wide experience and knowledge now available concerning the geology of the Western States have shown not to be coal bearing. The second purpose is to determine, from such data as may be obtained on the surface, the "lay" or structure of the coal-bearing formation and the groups of coal beds it contains.

Just as in the Eastern States it has been found that workable coal beds are confined to a particular part of one large group of rocks, which has long been designated the "coal measures," so in the West it has been found that workable coal beds are confined to relatively few groups of rocks, which are separated usually by great thicknesses of other rocks that are nowhere known to contain workable coal beds. As the sedimentary rocks of the West consist mainly of sandstones, shales, and limestones, those of like lithologic character being similar to one another in general appearance, the particular sandstones and shales with which the coal beds are associated can as a rule be distinguished only by means of the fossil plants or animals that are associated with them. Thus it has been found necessary to employ the services of several experienced paleontologists to examine the fossils associated with the rocks and from these fossils to determine the age of coal-bearing formations.

The first step of the geologist who has been sent into a field or area that is known or has been reported to contain workable coals is usually to determine what groups of rocks occur in that region and then, knowing the groups of rocks that contain workable coal beds in other places, to concentrate his attention on those groups, hunting for coals in them. Having found the coals his next work is to determine the number of groups of coals, as the same territory may contain two or three or even more coal-bearing formations, though usually they occur in different parts of the same field. His next step is to examine the several coal-bearing formations in order to determine, if possible, the number of coal beds in each. This work naturally leads to the determination of the areal extent and thickness of the beds.

EXTENT AND THICKNESS OF COAL BEDS.

Coal is a rock that has been formed from vegetal matter. The vegetation may have grown where the coal bed is now found, much as it grows in the great peat bogs of Europe or some of the large swamp areas of this country, or it may have been washed or drifted from the place where it grew to the place where it now occurs as coal. In changing from a mass of decaying vegetal matter to a bed of coal its volume has decreased and its weight per cubic foot has greatly increased. It has also lost many of the elements of the plants, especially the moisture they contained, and if during its formation the coal bed was inundated by muddy waters its vegetal matter may have been overlain or intermingled with sand or mud. This material may have been added in small quantities at frequent intervals, simply rendering the coal "dirty," or it may have come in at long intervals and then in large quantity so as to form a blanket of mud or sand, which, being covered by renewed accumulations of vegetal matter, becomes a parting of clay or sandstone in the coal bed. In a few places a single coal bed has been deposited in a formation, and thousands of feet of other rocks have been laid down beneath and above it, no other coals having been formed. More frequently, however, where coal-forming conditions have existed they seem to have recurred in such a way that a succession or series of coal beds are laid down in the same area. In one region most of the coals in a group deposited in that way may be thicker in the same general area, and all the beds may tend to thin away from that area. In another region one bed of a group may be thicker in one locality and a higher bed of the same group may be thicker in another locality.

Coal beds vary greatly in extent, ranging from pothole fillings having about the shape though not the size of a kettle to flat-lying beds thousands of square miles in extent. In Missouri a number of coal beds have a thickness in places of 90 feet or more and an areal extent of only a few hundred feet or less, being simply fillings of deep holes in the rock, similar in shape to the "potholes" that are so abundant around some waterfalls. In other places, as in the Sharon field of Ohio, the coal bed has the shape of a valley, with branches where side streams have come in, and a single mine may follow one of these valleys for some distance, the coal being confined to a width of perhaps a few hundred yards but extending indefinitely up and down the valley, which in some places winds tortuously. In still other places, as in the Block coal field of Indiana, the coal occurs in a succession of shallow basins, the beds having a thickness of 3 to 5 feet in each basin and thinning out to a few inches between the basins. The bottoms of the basins lie 20 to 30 feet below their rims. Some of these basins are so small and so close together that the coal from several of them is extracted by a single mine, the entries being cut through the rock from the lower level of one basin to the lower level of the next basin. Other basins have a length of 2 or 3 miles in a northwest-southeast direction and a width of one-half mile or more. Some of the individual beds can be traced from basin to basin and clearly recognized by peculiarities in the coal. In other fields the coal appears to have been deposited unevenly in little depressions that are scattered irregularly over a large territory and lie at various levels, so that it is not possible to trace a bed from one point to another, and each little basin must be considered as a unit. From these types of irregular and narrowly limited coal beds every gradation may be found to some of the relatively even and continuous beds of the West, the extensive beds of the central interior coal fields, or the Pittsburgh and other beds of the East, which have an outcrop line hundreds or even thousands of miles in extent and were laid down in a more or less continuous sheet, many of them covering thousands of square miles. Thus the Pittsburgh bed has a known extent of over 6,000 square miles and is found in isolated areas beyond the limits of the main bed. Other Appalachian coal beds are of much greater extent, some of them, as the Lower Kittanning, having many times the areal extent of the Pittsburgh bed, though not its regularity.

Certain coal beds in the Illinois fields have been traced without question as to their identification over a large part of that State, through a portion of western Kentucky, and through the entire length of the Indiana coal field. It is believed that many of the coal beds of the Western States are also traceable over large areas. Most of these widely extended coal beds have certain slight but definite features or peculiarities or are associated with other rocks of distinctive character, so that it is possible to recognize them at any point. The peculiarity of a bed may consist of some particular type of parting or arrangement of partings which may hold for long distances, or it may consist of the presence just above or below the bed of a stratum that has easily recognizable characteristics. In order to trace and identify some coal beds it is necessary to study their relations to one another. One of the main reasons for studying the stratigraphy is to identify if possible at the outset the group of coals studied, and in this work note should be taken of the determinations reached by the wide study of the same formations in previous seasons. For example, in the great coal field that covers much of western North Dakota and part of South Dakota, all of southeastern Montana and the great Powder River field of Wyoming, there are two coal-bearing formations—the Fort Union above, named from its early recognition at Fort Union in North Dakota, and the Lance formation below, named from the occurrence of those rocks on Lance Creek in Wyoming. The Fort Union coals are as a rule persistent; they have local thicknesses of 10 to 30 feet or more, and some of them can be traced for hundreds of miles along their outcrop, and individual beds can be recognized from point to point. On the other hand, the Lance coals occur as a rule in small lenses, most of them a fraction of a mile or a very few miles in extent. The coal in these lenses ordinarily is but little above the minimum workable limit and thins rapidly to nonworkable thickness in all directions. If the geologist knows that the coals in any particular area are in the Fort Union or Lance formation he knows what to expect concerning them, for if he finds that they are of Lance age and he is studying at the moment the coal at a point where it is workable, he is careful to trace it if possible in order to see how far it may extend before it becomes unworkable, so as to determine as closely as practicable the extent of that particular lens. If, on the other hand, he knows that the coal before him is of Fort Union age he attempts to determine, if possible, what particular coal bed in the Fort Union it is, and, assuming that he will find that same bed in a large part of the country ahead of him and that he will judge of its thickness by combining a great number of measurements made over a large territory, he does not with the same attention attempt to discover whether the coal pinches out a short distance on either side of the point where he is standing. In all of this work it is, of course, not safe to assume too much, for toward the south end of the Powder River field the beds of coal in the Lance formation increase in extent and thickness, so that they more nearly resemble those of the Fort Union formation, farther north.

It is not advisable to assume absolutely that, because in some area already examined a coal bed is very extensive and keeps the same thickness with great regularity, it will continue to be extensive and regular in territory that may be studied later. For example, the Pittsburgh bed, which maintains a very uniform thickness over a large area in western Pennsylvania, becomes very irregular in southern Ohio, so much so that it has been wrongly identified, and it is only within a few years that the bed there identified as the Pittsburgh has been shown to be another coal higher in the series. Likewise, in the Illinois-Indiana field coal V, which is probably the most persistent bed in that field and can be traced along its outcrop for thousands of miles with great regularity, pinches out in parts of Greene County, Ind., close to other localities where it shows its greatest thickness; and, again, in Warrick County it loses its usual characteristic roof and is split into two distinct beds. In the same way many of the coals in the West that on casual scrutiny appear to be persistent prove, when studied in detail, especially in connection with mining operations or where close prospecting has been done with a drill, to vary considerably both in thickness and in distance apart. For example, at Castlegate, Utah, four beds are at one point separated by 50 feet, 20 feet, and 14 feet of strata, whereas a short distance away these intervening rocks pinch out and the four beds, which separately are on the average only about 3 feet thick, come together to make a single bed 12 feet thick. Drilling in that field has shown that all the beds tend to be very irregular, splitting and combining again and changing in thickness, so that in tracing them from drilling to drilling it may be found that though each core shows certain workable beds, yet a bed that is thick at one point is thin at the next. Detailed work in many of the eastern fields where extensive mining operations have afforded minute data in regard to the coal, or where thousands of dollars have been expended in drilling, has shown that even the most persistent of the beds are subject to variations, so that a bed which can be traced from one mine to another over a whole county and which may show a variation of only a few inches from mine to mine may suddenly, in mining parlance, "go to pieces." It is therefore the special work of the field geologist not only to locate the coal on the ground but to make as detailed a study as possible of its thickness and extent in order to learn just how far it maintains a workable thickness, how persistently it maintains a given thickness, and whether it is likely to vary greatly from point to point and also to determine, so far as he can, any or all of its features. Space does not permit the detailed description here of all the possible irregularities that may occur in a coal bed, for which the field geologist must be on the lookout.

In some fields the coal beds are exposed in cliffs or steep slopes in such a way that the coal may be seen almost continuously for many miles. In such places the geologist takes the opportunity to make a careful study of the regularity or irregularity of the coal beds with reference both to their thickness and to the variability or regularity in thickness and in character of the intervening rocks and of the spaces between the beds. In regions in which the beds are not well exposed it may be possible, from a knowledge of the position of a bed with reference to other rocks which show on the surface, to determine exactly the position of the particular coal under consideration and, by means of a very small amount of digging, to expose the bed so that its thickness and partings can be measured. In some coal fields hundreds of such openings have been made in the study of the bed. In other fields the beds occur in rocks that weather down to soils rapidly, and it may be only where a coal bed crosses a stream or is otherwise exposed that it can be located or seen. It may be difficult to trace such a bed from point to point, and in some places where exposures are several miles apart it may be difficult or impossible to determine exactly its position. In other places beds may be traced readily, but the fact that they have been burned continuously along their outcrops makes it difficult to get accurate information concerning their character and thickness. It is of course possible to map the position of the coal bed in such places and it is then necessary, from such information as can be obtained concerning the thickness and character of the coal, to infer its character at points between these places. It is especially in such areas that a general knowledge of the "habits" of the bed or group of beds assists in their classification, for if it is known that a particular bed, whose burned outcrop has been traced with detailed measurements perhaps at only one or two places in a township, occurs at a certain horizon in a certain formation, it is possible to surmise whether it is regular or irregular in the broad area between these exposures, where no information on the bed itself can be obtained. Again, it may be possible, by making a careful study of a coal in a mining region, to apply the information to a wide area where but scanty information on the coal itself can be obtained. Wherever the coal is exposed the field man makes careful examination and measurement of every possible section, measuring down to the fraction of an inch, even though, where the bed is irregular, it is recognized that another measurement made a short distance away may be quite different. Where a bed is irregular special effort is made to obtain as many measurements as possible, in order to obtain average figures for use in the classification and valuation of the land underlain by that bed. In some places where the data are very meager, as in regions where the rocks crumble to soil and the land is largely meadow land, considerable time has been given to making openings on the coal because of the necessity of having actual information and measurements as a basis for classification.

ATTITUDE AND DEPTH OF THE COAL.

As already stated, the coal throughout wide areas lies entirely below the level of drainage—in places hundreds or even thousands of feet below—and the outcrops of the particular coal beds on which land is classified as coal land may be scores of miles away. It therefore becomes necessary for the field man to determine as accurately as possible not only the position of the coal outcrop with reference to the land lines and the thickness of the coal as exposed along the outcrop or the extent of the lenses, but also the depth of the bed beneath the surface and its attitude as it dips into the basin. He does this, first, by studying the inclination of the coal beds where they dip into the ground and, next, by studying the inclination and thickness of the other rocks that overlie them. As coal beds lie more or less nearly parallel with layers of sandstone, shale, and limestone, one of his duties is to determine how nearly the coal beds are parallel with these other rock layers. If he finds by observation at many points that there is very little variation in the interval, say 300 feet, between a limestone bed above and the coal bed that he is studying, he may assume that the dip of that limestone bed measured possibly at a point a mile back from the outcrop of the coal indicates the dip of the coal beneath that point at a level 300 feet below the surface. If, again, he finds that some other rock bed a thousand feet above the coal bed is parallel to it, he may assume that a measurement of the dip of that bed taken 5 or 10 miles back from the coal outcrop may indicate rather closely the dip of the coal bed itself 1,000 feet below. Hence the field geologist must not only study the details of the coal bed along its outcrop, but must also study the geology of the area back of that outcrop, especially with reference to the dip of the rocks. If, as sometimes happens, he finds that the space between a coal bed and the overlying rocks is variable, he can not compute the depth of the coal bed so closely. In some places all the rocks associated with certain coal beds, having the same great folds and basins, have been overspread by a blanket of other rocks that do not have the same structure. Such a blanket may completely hide not only the coal-bearing formation but the other formations that are associated with it and that have been folded in the same way. In such places it is only possible to infer from broad general knowledge of the field how deep the coals may lie below the surface.

QUALITY OF THE COAL.

The character and quality of a coal can be determined in part by a simple examination of the coal bed. Thus it is possible in most examinations to determine whether a coal is a lignite, a subbituminous coal, a bituminous, a cannel, or an anthracite coal. It may also be possible to estimate rather closely whether or not a coal contains a large amount of ash. Where small mines or prospects have been opened it may be possible, by studying the coal on the dump, to determine whether the coal can be shipped or stocked, or the extent to which it tends to crumble under the action of the atmosphere.

The final tests, however, are the chemical test, consisting of an analysis of the coal, which shows fully its percentage of the various heat-giving elements and of the ash and other elements that do not yield heat but detract from its value, and the test of its heat-giving value in the calorimeter. Experience has shown that coal of certain kinds—especially low-grade coal—changes in chemical composition very rapidly when exposed to the weather, so that in getting samples for analysis it has been found necessary, in order that the samples may be fairly compared and may form the basis of a uniform system of classification and valuation, that they be taken with great care in a uniform manner and that the treatment of each sample from the time it is taken until it is analyzed shall follow certain standards. To this end certain regulations have been prepared in regard to the method of obtaining coal samples for analysis and are consistently enforced. These regulations in brief are as follows:

1. Select a fresh face of unweathered coal at the point where the sample is to be obtained and clean it of all powder stains and other impurities.

2. Spread a piece of oilcloth or rubber cloth on the floor so as to catch the particles of coal as they are cut and to keep out impurities and excessive moisture where the floor is wet. Such a cloth should be about 1½ by 2 yards in size and should be so spread as to catch all the material composing the sample.

3. Cut a channel perpendicularly across the face of the coal bed from roof to floor, with the exceptions noted in paragraph 4, of such size as to yield at least 6 pounds of coal per foot of thickness of coal bed; that is, 6 pounds for a bed 1 foot thick, 12 pounds for a bed 2 feet thick, 24 pounds for a bed 4 feet thick, etc.

4. All material encountered in such a cut should be included in the sample, except partings or binders more than three-eighths inch in thickness and lenses or concretions of "sulphur" or other impurities greater than 2 inches in maximum diameter and one-half inch in thickness.

5. If the sample is wet, it should be taken out of the mine and dried until all sensible moisture has been driven off.

6. If the coal is not visibly moist, it should be pulverized and quartered down inside the mine to avoid changes in moisture, which take place rapidly when fine coal is exposed to different atmospheric conditions. The coal should be pulverized until it will pass through a sieve with one-half inch mesh, and then, after thorough mixing, it should be divided into quarters and opposite quarters rejected. The operation of mixing and quartering should be repeated until a sample of the desired size is obtained. When the work has been properly done a quart sample is sufficient to send for chemical analysis. This sample should be sealed in either a glass jar or a screw-top can with adhesive tape over the joint and sent to the chemical laboratory for analysis.

Since the value of the land varies with the quality of the coal as determined by the chemist, his methods are briefly described here.[1] Immediately after the sample is received at the laboratory it is weighed and placed in a shallow tin pan in a large drying oven, in which a temperature of 30° to 35° C. is maintained. The sample remains exposed to currents of warm air in the oven until the loss between two successive weighings made six to eight hours apart does not vary more than 0.2 per cent. The loss of weight in the oven is called air-drying loss.

After being air dried the sample is crushed to a fine powder and thoroughly mixed. To determine the amount of moisture remaining in the coal after air drying, a 1-gram sample is heated for an hour at 105° C. and then cooled in a desiccator over sulphuric acid. The moisture in the sample is thus driven off, hence the percentage of loss represents the percentage of moisture in the coal. The remaining part of the sample is next used to determine the amount of ash in the coal. This determination is made by slowly heating the sample in a muffle furnace until all of the combustible matter is burned off. The remainder is ash. The volatile matter is determined from a fresh 1-gram sample in a 30-gram platinum crucible, with a close-fitting cover, heated for seven minutes over a Bunsen flame 20 centimeters high. The loss in weight minus the moisture at 105° C. is the weight of the volatile combustible matter. The sulphur is determined on a separate example by what is known as the Eschka method. The percentage of fixed carbon given in the analysis is the difference between 100 per cent and the sum of moisture, volatile combustible matter, and ash.

The calorific value of a coal, or the amount of heat that can be obtained from it, is the most important factor in classification and valuation.

The calorific value of coal is determined with a bomb calorimeter. The following is a brief description of the details of operation:

A 1-gram sample of coal (60-mesh) in a platinum tray is placed in the bomb and the lid is screwed down tightly against a lead gasket. Oxygen is forced into the bomb until the pressure is 18 to 20 atmospheres. The bomb, filled with oxygen, is placed in a brass bucket containing distilled water, the bucket having been previously placed in an insulated jacket.

The coal is ignited by electric current and is burned at once. The heat of combustion is transmitted through the walls of the bomb and is manifested in a rise in the temperature of the water. This rise in temperature is measured by a very delicate thermometer. The

[1] The methods of analyzing coal and coke are fully described in Technical Paper No. 8, Bureau of Mines, by Frederick M. Stanton and Arno C. Fieldner. The method outlined here is summarized from that paper.

quantity of heat given off by the burning of the coal is determined by multiplying the product of the weights of the metal and water in the apparatus and their respective specific heats by the rise in temperature. The result thus obtained is calculated into terms of calories and British thermal units.

PREPARATION OF MATERIAL.

The preparation of material by the field man, so that it may be considered to the best advantage in the work of classification and valuation, has already been considered in the chapter entitled "Preparation of data for classification," immediately preceding the discussion of the classification of coal lands.

PROCEDURE IN CLASSIFICATION AND VALUATION.

In the actual work of classification of coal lands each area under consideration must be treated individually, yet in general a definite line of procedure is followed.

The first step is to assemble all the available data, including not only the maps and reports of the geologists who may have made a special examination of the field, but the reports of any special agents of the Land Office who have been in that field, as well as all reports of geologists who may have visited the field at some earlier time (probably for some other purpose) and all other available information concerning the land or the coal it may contain. The land-classification board has a system of graphic records which show at once the existence of any reports on the field and give references to them, so that when the case is taken up all the data available are at hand. As a matter of fact the field man will usually have familiarized himself with all these earlier data and will be prepared to present them as may be necessary.

The second step is to scrutinize carefully all these data, and by their aid to take the action or to obtain the information listed under the following heads:

1. The number, names, character, and other features of the coal-bearing formations are determined. As most of these formations extend over large areas, some of them crossing several States, a general knowledge of the formations at once suggests the probable conditions to be found in the field studied, and that general knowledge may strongly affect the action to be taken in classification and valuation.

2. The number of coal horizons or groups of horizons is ascertained.

3. The thickness of each coal bed over the field is determined, if it can be traced. If each bed can not be traced the group of coals

is studied as a whole to determine from point to point the number of beds and their aggregate thickness and value.

4. The basing value per ton of the coal is computed by comparing its analyses and its obvious character with the standard scale. An average B. t. u. value having been fixed for the coals of the field or for the different groups of coals, the other qualities of the coal—such as its adaptability to coking or to stocking—are studied to determine whether they enhance that value or detract from it, and the price is raised or lowered accordingly.

5. If the field is small and the data are scattered the field may be studied as a unit. If the data are abundant in any township the coals in that township are studied by themselves, and, exceptionally, the variation in thickness may make it necessary to divide a township into belts or areas, in each of which a basing value of the groups is determined.

6. All sections of the coal are examined, and if the coal beds are split the equivalent thickness of a solid bed is computed and a memorandum of the results is placed beside the drawn section. Then further reduction is made for the reduced value of the bed, if it is less than 6 or more than 10 feet thick. If a bed is variable in thickness but varies so regularly that lines of equal thickness can be drawn on a map of the field these lines are so redrawn as to indicate the reduced thickness determined by allowance for their reduced value if the thickness is less than 6 or more than 10 feet. If the beds are of irregular thickness the average of the measurements taken is obtained, and by the use of the "modulus of irregularity" a computed average thickness is obtained for use in valuation.

7. The outcrops of the coals are examined to determine which are workable coals and especially to make note of the outcrop of the lowest bed or the bed covering the largest area. Where the coal lies in one or more lenses a computation of its gradation in thickness is made between points at one of which the coal is below the minimum thickness and at the other is above, to determine the position of the minimum. The limits of workable coal having been determined for certain points, the limits of the lenses of the coal are drawn on the maps. For isolated measurements at points where the bed is above the minimum limit the extent and character of the several lenses measured are determined, special formulas being applied where possible.

8. If the coal passes below the depth limit of workable coal the position of that limit is determined and indicated on the map.

9. The limit of workable coal having now been determined, a line is drawn on a plat along the 40-acre lines, or, where necessary, along the 10, 5, or 2½ acre lines in the forty, to separate the area that con-

tains workable coal from the area that does not contain workable coal. The latter area is then plainly marked "noncoal," and if the land is only to be classified and not valued a copy of the plat is made on a blank township sheet to show accurately the coal land and the noncoal land. This copy, after checking and proper designation, is dated and signed by the members of the coal section of the board. Its later history is the same as if valuation had been made.

10. The tract or township may now be valued. The particular steps at this point may vary greatly, depending on the complications involved in the valuation. It may be that the coals are of a grade so low that, like the low-grade lignites, regardless of their thickness, they will be valued only at the minimum. Or it may be that the tract contains only one thin bed that lies flat and at slight depth, so that the land may be valued at the minimum or perhaps at a uniform price. From these simple conditions there will be conditions grading in complexity all the way to those found in such fields as, for example, the Rock Springs field of Wyoming, where there are three groups of beds of coal of different age, character, and quality, each group containing from six to eighteen coal beds, and where each coal bed has been accurately traced by means of hundreds of measurements made on the coal in each township, both along the outcrop and in mines and drillings. Owing to differences in quality and thickness coals have different depth limits. They may also vary in dip and may be locally broken by faulting or by igneous intrusions. The value of the land that is involved in these complications is computed by using printed blanks that contain columns arranged to show not only the observed data on each bed in each 40-acre tract, but also the computed values of each bed, ending with the computed value of the 40 acres. This completed blank becomes part of the permanent record, so that, if additional data are obtained or if for any reason the valuation should be reviewed, it shows not only the field data but the steps that have led to the final result. As values are determined they are recorded on a blank township sheet and if the data are abundant and complicated the coal boundaries may be drawn on transparent oversheets, on which the computed valuation prices are placed. This sheet is properly labeled, dated, and signed by the members of the coal section.

11. As the land in a township is classified and valued memoranda are prepared to show the basis for any criteria used, and all these memoranda, with blank forms showing the computations and allowances, are retained as "minutes" and, when reviewed and signed by the members of the coal section, form a part of the permanent record.

PROGRESS IN CLASSIFICATION AND VALUATION.

The following statement shows the status of the work of classification on January 1, 1913:

Progress of coal-land classification to January 1, 1913.

Total withdrawals	acres	128, 147, 312
Area classified and valued as coal land	do	16, 433, 817
Area classified as coal land, price not fixed	do	841, 706
Area classified as noncoal land	do	42, 244, 682
Restored without classification	do	2, 717, 395
Total restorations	do	62, 237,600
Total withdrawals less total restorations (total outstanding withdrawals)	acres	65, 909, 712
Value of coal land at classified price		$702, 157, 268
Value at minimum price		$279, 122, 661

OIL AND GAS LANDS.

OCCURRENCE OF OIL AND GAS.

To the minds of many people who find little difficulty in comprehending a classification of lands containing deposits of coal or phosphate the possibility of applying a similar classification to lands containing oil and gas, especially in advance of actual drilling, appears uncertain, to say the least, and, according to the nature and experience of the individual critic, such a classification is looked upon either as a more or less scientific guess or as evidence of the possession of supernatural powers by the classifier. The classification of oil and gas lands, however, calls for the use of no mysterious or haphazard methods but is based on detailed field examinations, followed by careful consideration of all the available facts, geologic and economic, in their relation to one another and to the known principles of the occurrence of oil, which have been proved again and again in the development of oil fields throughout the world. Although the ultimate test of the presence of oil in commercial quantities is made with the drill, it is nevertheless a fact that the intelligent application of the principles of oil accumulation to the geologic facts observed will indicate at least the areas where no oil will be found and will go far toward delimiting the areas where production is reasonably certain. To the classifier of oil lands, as to the oil-well driller, the theories proposed to account for the origin of oil and gas are of only incidental interest; the problem of prime importance to him comprises the assignment of proper values to the many factors which influence accumulation and the determination therefrom of the present position and extent of the deposits.

Oil and gas are composed for the most part of carbon and hydrogen, but they vary greatly in the proportions of these elements and in the way in which they are combined. The petroleum oils range from low-grade heavy oils containing much asphalt to high-grade light oils which contain a large percentage of paraffin and volatile constituents and little or no asphalt. The heaviest oil is chiefly valuable as fuel, for which it is used in its crude state. Progressively lighter oils are used less and less for fuel and more and more for the other products that are obtained from them. There is a general opinion that weight for weight the fuel value of light and heavy oils is about equal, but because of the value of the distillates from the lighter oils it may be stated in general that the lighter the oil the greater its value.

In classifying lands as to their probable content of oil and gas it must be borne in mind that oil and gas are mobile substances and that, owing to their mobility and to the resulting increased importance of gravitation, temperature, hydrostatic pressure, and capillarity, it is necessary to make certain variations from the type of procedure employed in classifying lands containing coal, phosphate, or other stable minerals. The mobility of oil and gas has, in many regions, permitted their migration through varying thicknesses of pervious strata to their present places of accumulation, so that the problem is not to discover where the hydrocarbons originated but rather where they have accumulated.

The present position of these accumulations depends mainly on the character of the strata, the attitude of the strata (commonly spoken of as the rock structure), the presence or absence of water, and the character and specific gravity of the oil. The fluid hydrocarbons do not, as is supposed by some, occupy underground lakes or reservoirs surrounded by walls of rock. Instead they saturate porous rocks in places where the geologic structure, the conditions with regard to underground water, and the succession of strata are such that the accumulations are sealed by relatively impervious beds. Thus, although the accumulations of oil or gas are called "pools," they are not to be confused with such pools as are formed by the collection of liquids upon the surface of the ground. The porous stratum in which the hydrocarbon collects is often spoken of as an oil or gas "sand," although it may in reality be sandstone, gravel, limestone, or a zone of fractured rock. Into this "sand" the hydrocarbon comes from one or another source, but if there is to be an accumulation of importance the migration of the oil or gas along this pervious bed must be stopped by a change in dip or by some other obstacle to continued progress, and, in addition, the reservoir thus formed must be sealed by strata that are relatively impervious, such as compact shales, clays, or fine-grained sandy beds saturated with water.

The accumulations within the United States may be divided roughly into three classes, as indicated below.

1. Those occurring in strata of sandstone or limestone bounded above and below by rocks comparatively impervious to oil. The sandstone or limestone may be of broad or of very narrow extent, in some places comprising merely small lenses of porous material embedded in relatively impervious rocks, in others underlying hundreds of square miles of territory in comparatively regular beds. To this class belong the greater number of oil accumulations of this country.

2. Those occurring in porous strata, apparently lenticular, associated with the "salt domes" of the Gulf Coastal Plain.

3. Those occurring in fissures in shale, as in the Florence field of Colorado. The fracturing of other rocks, such as limestone and sandstone, affords favorable conditions for the accumulation of oil; but sandstone and, under certain conditions, limestone are capable of storing oil without fracturing, the fracturing merely increasing their capacity. A fine-grained shale, on the contrary, although capable of containing oil, does not permit its migration through the rock mass with sufficient rapidity for collection in wells unless the shale is broken by fissures, which serve as channels or reservoirs for the slowly migrating oil.

It may be stated as a fundamental principle that important accumulations of petroleum and natural gas are to be found only in stratified or sedimentary rocks. Regions in which the strata have been greatly disturbed or altered by intrusions of igneous rock are, as a rule, unfavorable to the accumulation of petroleum, because the attendant heat and fracturing would as a rule have had disastrous effects on volatile substances of this character. An interesting apparent exception has been noted in Ventura County, Cal., where oil to the extent of 5 or 6 barrels a day has been obtained from wells drilled in close-textured crystalline schist. Although the schist is underlain by granite, it is overlain at a distance of only a few hundred feet from the wells by Tertiary rocks which in the same general region are petroleum bearing. These relations suggest that the presence of the oil in the schist is due to infiltration from the Tertiary sediments through fractured zones rather than to origin in the sediments that were metamorphosed to form the schist.

In general, then, oil is found in sedimentary strata of greater or less extent and regularity. These strata were originally deposited by water in the ocean, in fresh-water lakes, or on great deltas practically at sea level. The beds were therefore horizontal, or nearly horizontal, as first laid down, and where a series of beds was deposited one above another, there being no earth movement during the deposition, the several beds were parallel. After the beds of sand, mud, and marl were deposited and hardened into the resulting sandstone, shale, and limestone, they were in certain areas bent by earth movements into folds of various shapes, and it is about these folds that the accumulations of oil are found. The attitude in which the rocks lie, the shape of the folds, and the presence of faults or breaks in the strata constitute the rock structure.

In any consideration of the factors which control the accumulation of oil or gas the importance of the part played by the structure can hardly be overestimated. The fluid contents of porous beds obey the laws of gravitation and capillarity, separating and distributing themselves in the main in accordance with their specific gravities. If water, petroleum, and gas are, as is usual, present in petroliferous beds, the gas would as much as possible disengage itself from the fluid and rise to the highest point in the fold, while the water would endeavor to displace the petroleum and find a resting place as low down as possible. If the bed of rock is inclined and the water is under artesian pressure, it will be forced upward along the bed, the oil remaining above the water because of the difference in specific gravity. If the porous bed is continuous in dip to the outcrop, the gas and oil are likely to exhaust themselves at the outcrop in the form of seeps. If, however, the progress of the hydrocarbons up the dip is stopped by a fold in the bed, or by a fault which seals instead of opening the stratum, or by saturation of the bed with water, an accumulation takes place, the oil and gas remaining between the water down the dip and whatever has impeded their progress up the dip. This theory, which is known as the anticlinal theory, is in some form now accepted by practically all geologists, not as indicating absolutely the limitations of the occurrence of oil and gas but as expressing the general relations of their occurrence to geologic structure, subject to various modifying conditions. Other factors less well understood enter into the problem, such as the difference in the capillary attraction exerted between water and the rock particles and between oil and the rock particles and the differences in friction experienced by the two fluids in passing through the rock. There is much to be learned concerning the whole problem, but enough is known to make the study of any oil field of economic as well as scientific value.

If the rock containing the oil does not also carry water there is no force to impel the oil into the upfold or anticline. On the contrary, gravity tends to pull it downward and it collects in the adjoining downfold or syncline. This condition is found in some of the Pennsylvania fields.

Where the migration of oil is due to the pressure of dissolved or occluded gas in the absence of water saturation the oil will move in all directions until it is stopped by some impervious stratum, where accumulation takes place in apparent disregard of structure.

The simplest structure favorable to the accumulation of oil and gas is that of a symmetrical anticline having little or no pitch of the axis and moderately dipping flanks. If the requisite condition of porous oil-bearing rock adequately sealed by impervious beds is fulfilled and the strata are impregnated with water under moderate hydrostatic pressure, the hydrocarbons will, under ideal conditions, segregate in the axis of the fold and extend down the flanks a distance dependent on the quantity present. Farther down the flanks and in the troughs of the corresponding synclines water will as a rule be found. It is evident that, other things being equal, the extent of the productive area controlled by anticlinal structure is greater where the fold is broad and the dip of the strata on the flanks relatively low than where the fold is narrow and has steep flanks, for in the former case the gathering ground for oil and gas is much greater than in the latter. From the simple symmetrical anticline there are gradations on the one hand into domes pitching away from a central point and on the other hand through unsymmetrical folds to an extreme type in which one flank is vertical or overturned. In every symmetrical fold the boundary between an oil pool lying at the top of a fold and extending part way down the sides of the fold and the water saturating the rocks farther down is an approximately horizontal line, because as long as the fold is regular the water tends to rise to the same level all along it. If, however, there are minor irregularities on the sides of the fold these have their effect on the distribution of the oil, making the margin of the pool irregular or causing small pools to collect along the slope.

Structural features of other types are under certain conditions favorable for the accumulation of petroleum and natural gas. Among these may be mentioned monoclines, which present conditions favorable for the concentration of oil wherever there is a change in the rate of dip or an abrupt change in the strike of the rocks, shallow synclines where water is absent from the oil-bearing zone, and synclines where the oil and water are of nearly the same gravity. Unconformities where steeply dipping petroliferous strata are overlain by relatively impervious horizontal or nearly horizontal beds are also favorable. Faults are usually considered wholly unfavorable to the accumulation of oil and gas, and for areas where the dislocations are many and extensive this view is undoubtedly correct. However, in many places faults have quite the contrary effect. For instance, strike faults may cause a greater concentration of petroleum toward the crest of a fold, and dip faults in a series where there are many oil sands may bring about communication between the different sands and have a notable effect on local production. In a series of uniformly dipping beds an oil sand which would normally crop out at the surface may be cut off by a strike fault and sealed beneath impervious beds and thus retain oil which would otherwise migrate to the surface and be dispelled. Moreover, faulting may produce fractured zones along which the oil or gas can migrate and in which it may collect. In a number of localities, as in some of the fields in Mexico, where intrusive dikes have pierced oil-bearing strata and consequently arrested the movement of the oil in certain directions, the petroleum has accumulated in apparent disregard of the structural features of the sedimentary series.

In many fields there is little or nothing at the surface to indicate the presence of valuable hydrocarbons below, but in many other fields there is ample indication of oil at the surface. The oil-bearing stratum itself may crop out and the oil ooze from it, giving to the rock a dark, greasy appearance and the odor of petroleum, or the oil may find its way to the surface from the oil pool below through some fracture of the overlying rock. Water charged with various salts or with sulphur may rise with the oil, so that a spring is formed, the oil floating as a brown scum on the surface of the water or in smaller quantity producing the brilliant iridescent sheen characteristic of petroleum. Gas may find its way to the surface and appear in "gas springs" or under certain conditions may produce the phenomenon of mud volcanoes. The place at which oil has come to the surface and evaporated through long periods of time may be marked by a deposit of asphaltum. In certain localities oil-bearing shales have been burnt to a pink or deep brick-red color or altered to a hard vesicular rock resembling scoriaceous lava. This metamorphism is due to the burning of the hydrocarbons that have impregnated the rock, and the presence of such rock therefore becomes an important surface indication of petroleum.

The stratigraphic occurrence of hydrocarbon minerals in the United States is by no means limited; on the contrary, petroleum in the solid, liquid, or gaseous form is found in greater or less quantity throughout the range of strata from the Cambrian to the younger members of the Tertiary series.

In general the commercially important accumulations of oil throughout the central and eastern portions of the United States are found in strata belonging to the Paleozoic era. In the great Appalachian field, which extends from the southern portion of New York along the western slope of the Allegheny Mountains to northern Tennessee, the accumulations of oil occur in strata ranging in age from early Devonian to late Carboniferous. In Ohio and Indiana petroleum is derived chiefly from rocks of Ordovician age, and in Indiana mainly from Carboniferous strata. In the Mid-Continent field, which embraces Missouri, Kansas, and Oklahoma, the petroleum has accumulated in rocks of the Pennsylvanian and Permian series. In the Gulf field, which includes the Coastal Plain of Louisiana and Texas, the petroleum-yielding rocks are Mesozoic and Cenozoic in age, being assigned in part to Cretaceous and in part to Tertiary formations.

In the Rocky Mountain fields the productive formations range in age from late Paleozoic to late Mesozoic. The Wyoming fields present perhaps the greatest range of occurrence, yielding oil from strata belonging to the Carboniferous, Triassic, Jurassic, and Cretaceous systems. The Colorado and New Mexico fields thus far developed obtain their oil from strata included entirely within the Cretaceous, and the small quantity of oil produced in Utah is derived from rocks assigned to the Carboniferous system, although indications of oil are found at certain localities in the Jurassic and Cretaceous rocks.

In the Pacific coast region the important accumulations of oil are found chiefly in Cenozoic rocks, although in certain fields an output of local importance is obtained from late Mesozoic rocks. In Ventura County, Cal., the principal oil-yielding formations are classed as Tertiary and range in age from Miocene to Pliocene. Along the west side of the San Joaquin Valley the range is greater, the oil extending downward into the upper members of the Cretaceous system. In the Kern River field, on the east side of the San Joaquin Valley in Kern County, oil is obtained from rocks of late Miocene or Pliocene age. In Santa Barbara County the oil is derived chiefly from early Miocene rocks. In portions of Oregon and Washington small amounts of oil and gas have been obtained from rocks assigned to the Eocene and Miocene series.

Despite this wide distribution of fluid hydrocarbons the conclusion does not necessarily follow that accumulations of asphaltum, oil, or natural gas may be found in any area of sedimentary rocks, for such accumulations take place only where all the essential conditions governing origin, adequate storage facilities, and favorable structure are fulfilled.

CLASSIFICATION OF OIL AND GAS LANDS.

The immediate purpose of the classification of oil and gas land is to withhold from entry all lands containing valuable deposits of fluid hydrocarbons pending the enactment of adequate legislation providing for their disposition. The ultimate purpose of the classification is to determine the position and extent of the areas whose value for their deposits of oil or gas, whether proved by actual drilling or indicated by favorable geologic conditions, is greater than their value for agriculture or other purposes and to provide for a disposition of the deposits in accordance with this greater value.

Classifications are made by the oil section of the land-classification board. This section consists of three geologists, in addition to the chief of the board. Each classification is based on data submitted by a field geologist, who is called into consultation at the meeting at which his data are considered. Other geologists having special knowledge of the area under consideration may also be consulted. The factors observed by the field geologist are reviewed in detail, and his inferences and conclusions are subjected to the severest tests of experience and theory. Each factor which can be conceived as having a bearing on the accumulation and present distribution of oil within the area under discussion is carefully considered in all its relations before an attempt at classification is made.

The record data submitted by the field geologists consist primarily of a map or maps showing the facts observed in the field. On these maps surface contours and drainage are indicated and the details of the areal geology of the region are clearly shown. The position of all petroleum seepages and indications is recorded, as well as the location, by appropriate legend showing the results obtained, of each well drilled within the area examined. All determinations of dip and strike are shown, also the axial lines of all anticlines and synclines, with the direction and amount of pitch of each fold. The location of all land corners found is likewise noted, in order that the classification may conform to the established system of land surveys. Structure sections are necessary to explain complicated structural conditions and indicate the relative thicknesses of the formations and the position of the productive zones. Underground structure contours must be drawn to show the relative position of the principal oil-yielding zones above or below sea level, in order that the approximate depth of the oil zone beneath any desired point in the field may be readily determined when the elevation of the point above sea level is known. In a field where considerable development work has been done the preparation of the data should include the plotting of all available well records and the correlation, if possible, of the several oil-yielding zones.

The principal factors considered by the board in determining the classification of an area are the stratigraphy, the structure, the continuity and character of the oil sands, the quality of the oil, and the presence or absence of water. In many fields the productive sands are confined to a single geologic unit, the formations above and below being uniformly barren. It is therefore necessary to know not only the number and relation of the productive zones in a particular succession of strata but also the geologic system or series and, if possible, the formation or group to which these zones belong. The assignment of productive zones to a definite formation or group outside of which the strata are known to be barren constitutes an important step in the classification, the productive portions of the field being thus limited to the areas underlain by the petroliferous units and the areas not so underlain being at once disregarded as having no prospective value for oil.

As it is the structure of the petroliferous strata which largely determines the place of accumulation of oil and gas, it is apparent that a detailed knowledge of the structural conditions is absolutely essential to classification. In the classification of areas whose structure is anticlinal all lands are classified as oil bearing which lie along the axes of the anticlines or which are so located on the flanks that the oil sand underlies them within an arbitrarily chosen limit of depth. This limit may be the depth below which it is estimated that drilling can not be profitably carried because of mechanical difficulties, or it may represent the distance from the axis beyond which it is considered improbable that oil or gas in valuable quantities have accumulated. In monoclines similar considerations limit the distance down the dip to which classifications as oil land are carried. In the rarer synclinal accumulations the width of the zone classified as oil bearing depends mainly on what is known regarding the quantity of oil present.

The thickness and porosity of the reservoir rock are important factors to be considered with regard to the production and life of the wells, but their bearing on classification is subordinate, for classification is concerned with the boundaries of productive areas rather than with estimates of probable production. The continuity of the oil-bearing zone is, however, an important factor in classification, though, unfortunately, it is one whose exact value can rarely be determined, because of the difficulty of obtaining adequate data on the subject. In many areas of Tertiary rocks, where lateral variations in lithologic character within short distances are to be considered the rule and not the exception, changes in the thickness and extent of the oil-bearing zones must be expected, and although field examination may show the general trend of the variations in a certain region, local variations can seldom be predicted in advance of drilling. A factor of uncertainty is thus introduced, which may now and then result in an erroneous conclusion and give rise not only to adverse criticism of a particular classification but even to sweeping and unjust condemnation of the entire method of procedure.

The quality of the oil obtained in a given field is considered in classification mainly with regard to its bearing on distribution. In general the greater the specific gravity of the oil the slower will be its migration, the less complete its separation from the associated water, and the lower down on the flanks of the folds its resting place; and, conversely, the less the specific gravity the more rapid the rate of migration, the more complete the segregation, and the higher in the folds the ultimate place of accumulation. Experience has shown that only under exceptional conditions may considerable accumulations of light paraffin-base oils be expected in monoclines, although in many places the monoclinal structure lends itself to the accumulation of heavy asphaltum-base oils.

The presence or absence of water in the formations of an oil-bearing region is a factor in the classification only as it affects the accumulation of the hydrocarbons, determining very largely their relation to the structure, as already explained. Whether or not it is present in the petroliferous strata must be known before a satisfactory classification can be made.

The maximum depth at which accumulations of oil or gas will warrant the classification of an area as oil land is a matter that demands careful consideration for each field. The factors that determine this depth limit are primarily the richness and the continuity of the oil-bearing zones, secondary consideration being given to the quality of the oil, present market conditions, and transportation facilities. Thus in certain areas where production is large and the oil-yielding zones are believed to continue productive to considerable depth, lands beneath which the productive zone lies at a computed depth of 5,500 feet have been classified as oil lands. On the other hand, in areas where the geologic conditions preclude a large accumulation of oil and indicate a doubtful continuity of the oil-bearing zones, depth limits as low as 3,000 feet have been fixed. That quality, market, and transportation facilities should receive only incidental consideration becomes evident when it is realized that deposits of low-grade oils that can not now be commercially exploited may, in the not distant future, as a result of improvements in methods of drilling and refining, become important contributors to the Nation's fuel supply; that the use of oil is practically just beginning, and it appears certain to build for itself a market far greater than it at present commands; and that with the advance of settlement or the beginning of production transportation facilities will be provided for fields now remote and essentially undeveloped. To many persons a maximum depth limit of 5,500 feet appears excessive, but to one who has acquainted himself with the rapid progress in well-drilling methods and machinery during the last decade this limit is far from unreasonable. In many of the California fields wells drilled to depths of 3,500 or 4,000 feet are by no means uncommon, and in foreign countries and at a few localities in the United States wells more than 5,000 feet deep have been drilled. In the Kern River oil field, California, one well has a depth of 5,135 feet; in the Midway field of the same State a well whose depth is slightly more than 5,000 feet is reported; and in the vicinity of Los Angeles a well was recently completed at a depth of approximately 5,200 feet. In western Pennsylvania one well more than 5,500 feet in depth has been drilled, and another, not yet completed, has been sunk to a depth of more than 6,000 feet. The effect of a few more years of improvement in drilling methods on the development of deep-lying oil deposits can be inferred only from the history of the past, but in land classification, which seeks in a measure to foresee and provide for future conditions, this progress can not be ignored.

When a conclusion has been reached by the board as to the portions of the field presenting conditions favorable for oil and gas accumulation, when a depth limit of profitable extraction has been fixed, and when the boundaries of the favorable and unfavorable areas have been determined and translated into terms of legal subdivisions of the land surveys, withdrawal or restoration orders are prepared and forwarded by the Director through the Secretary of the Interior to the President for final action. Two general types of withdrawals are made—first, preliminary withdrawals, based on more or less meager information, and, second, withdrawals made after field examination.

The usual type of oil-land withdrawal order, based on field examination, closely resembles that used in the withdrawal from public entry of lands valuable for their phosphate content. An example of an order of withdrawal of phosphate lands is given on page 133. Two special petroleum reserves have been created in the State of California in order to retain in Government control bodies of oil-bearing lands containing what are believed to be sufficently large reserves of fuel oil to provide for the future needs of the United States Navy. An example of an order creating a naval petroleum reserve is appended

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, August 8, 1912.

The honorable the SECRETARY OF THE INTERIOR.

SIR: In accordance with your instructions to recommend for inclusion in a special reserve a compact body of public lands containing an ample supply of fuel oil for the use of the United States Navy, I have prepared and recommend for submission to the President the following order of withdrawal, involving approximately 38,068 acres in the Elk Hills, Kern County, Cal.

Very respectfully,

GEO. OTIS SMITH,
Director.

AUGUST 10, 1912.

Respectfully referred to the President with favorable recommendation.

WALTER L. FISHER,
Secretary.

ORDER OF WITHDRAWAL.

Naval petroleum reserve No. 1.

It is hereby ordered that all lands included in the following list and heretofore forming a part of petroleum reserve No. 2, California No. 1, withdrawn on July 2, 1910, from settlement, location, sale, or entry, and reserved for classification and in aid of legislation under the authority of the act of Congress entitled "An act to authorize the President of the United States to make withdrawals of public lands in certain cases" (36 Stat., 847), shall hereafter, subject to valid existing rights, constitute naval petroleum reserve No. 1, and shall be held for the exclusive use or benefit of the United States Navy until this order is revoked by the President or by act of Congress. To this end and for this public purpose the order of July 2, 1910, is modified and the withdrawal of that date is continued and extended in so far as it affects these lands.

Mount Diablo meridian.

T. 30 S., R. 22 E., sec. 24, all.
[Here follows the remainder of land description.]

WM. H. TAFT,
President.

SEPTEMBER 2, 1912.

The preliminary withdrawals are made as a first step in classification and are based on recommendations of Survey geologists or of field agents of the General Land Office. A few such withdrawals have been based on petitions filed by residents of the community in which the occurrence of oil is suspected. The purpose of the withdrawals is primarily to withhold the lands from disposition pending their examination and classification. Because of the lack of definite geologic data most of the preliminary withdrawals of necessity embrace areas larger than those ultimately found to be valuable.

As soon as practicable after preliminary withdrawal the lands are examined geologically, and from the data obtained in this examination, presented and considered as already described, decisions as to the probable productive and nonproductive portions of the area are made. The areas classified as nonoil land are promptly restored and become subject to entry and disposition as if no withdrawal had been made.

The following order illustrates the form in which such restorations are made:

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, September 9, 1912.

The honorable the SECRETARY OF THE INTERIOR.

SIR: Field investigation by the Geological Survey indicates that the lands listed below do not contain deposits of oil or gas. The following order of restoration, which involves 133,626 acres, is therefore recommended for submission to the President for appropriate action. A small part of these lands is within national forests, but none are included in public water reserves, coal, phosphate, or power-site withdrawals.

Very respectfully,

GEO. H. ASHLEY,
Acting Director.

SEPTEMBER 21, 1912.

Respectfully referred to the President, with favorable recommendation.

SAMUEL ADAMS,
Acting Secretary.

ORDER OF RESTORATION.

Petroleum restoration No. 12—California No. 7.

So much of the orders of withdrawal made heretofore for classification and in aid of legislation affecting the use and disposition of petroleum lands, namely, reserves No. 2, No. 18, and No. 20, as affects the lands hereinafter described is hereby revoked, for the reason that the Director of the Geological Survey reports that the lands are not valuable for the purpose for which withdrawn.

And it is further ordered that all such lands not otherwise reserved or withdrawn are hereby restored to the public domain and shall become subject to disposition under the laws applicable thereto upon such date and after such notice as may be determined upon by the Secretary of the Interior.

Mount Diablo meridian.

T. 16 S., R. 11 E., sec. 21, N. ½ of SW. ¼, SE. ¼ of SW. ¼, S. ½ of SE. ¼.
[Here follows the remainder of the land description.]

WM. H. TAFT,
President.

SEPTEMBER 23, 1912.

The areas classified as oil land remain withdrawn pending the enactment by Congress of appropriate legislation for the disposition of oil and gas deposits.

PHOSPHATE LANDS.

USE OF PHOSPHATE.

Phosphorus is one of the mineral elements that are essential to plant growth and therefore necessary to make soils productive, and it is one of the three most likely to become exhausted by continued removal in crops taken from the soil. Work at the agricultural experiment stations in Illinois, Ohio, and Wisconsin has shown that lands under cultivation in these States during the last half century have been depleted of one-third of their original content of phosphoric acid. This depletion per acre annually is equivalent to the phosphoric acid contained in 60 pounds of high-grade phosphate rock. At this rate 12,000,000 tons of high-grade phosphate rock, approximately four times the production in 1911, or one-third the total marketed production in the United States from 1867 to 1911, would be required each year simply to offset the depletion of the 400,000,000 acres of cultivated land in the United States, the question of increasing the present agricultural yield not being considered.

Phosphate or rock phosphate is a mineral substance made up of lime and phosphoric acid and is the principal source of the phosphate of commerce. Its value is becoming more apparent and more clearly recognized in the United States, not only through the decreasing yield per acre of cultivated lands but also through the discovery of the fact that some virgin lands are deficient in this essential to plant growth. The marketed production of phosphate rock in the United States increased from 448,567 long tons in 1888 to 11,900,693 long tons in 1911. The rock phosphate is used as raw rock flour (or "floats") or in the form of a superphosphate, which is made by treating the rock with sulphuric acid.

LANDS CONTAINING PHOSPHATE.

The commercially available phosphate deposits of the public domain are those in Florida and those of the western fields, which, so far as investigated at present, are confined to the States of Idaho, Montana, Wyoming, and Utah.

Deposits of phosphate in the Rocky Mountain States were first discovered in northeastern Utah and southeastern Idaho, in the vicinity of the Idaho-Utah-Wyoming line. From this locality the deposits have been traced south, east, and west halfway across the States of Idaho, Utah, and Wyoming and northward to the vicinity of Helena, in west-central Montana, so that the phosphate beds now known cover an area extending about 220 miles from east to west and 420 miles from north to south. Of course only a small part of this territory is underlain by deposits that are commercially valuable.

Deposits of phosphate rock exist also in Tennessee, South Carolina, and Arkansas, but these deposits are on lands that have passed into private ownership. The production of Tennessee is increasing, that of Florida appears to have about reached its maximum, the South Carolina output is diminishing, and the Arkansas deposits are of low grade. For these reasons the largest future production must come from the western fields, where the deposits are chiefly on the public lands, although Florida will remain an important factor in production for many years to come.

PHOSPHATE RESERVES.

In order to prevent the alienation of the phosphate deposits on the public lands until Congress shall provide a law for their disposition that will encourage development under conditions favorable to the public interests, the known phosphate lands remaining in Government ownership have been temporarily withdrawn from entry. The reserves thus created embrace lands in the phosphate belt of Florida and in Utah, Idaho, Wyoming, and Montana.

FLORIDA RESERVES.

The deposits in the Florida reserves include two important kinds of phosphate—the hard rock and the land pebble; the latter doubtless was derived from the former. Deposits of both these types are found near the surface and are mined after removal of the soil cover or overburden. The pebble deposits are fairly regular in thickness, but the hard rock occurs in irregular pockets in the limestone of which it is supposed to be a residual product. The pebble deposits cover a large area, mainly in southwest-central Florida; the hard-rock deposits are distributed through the northwestern part of the State.

The hard-rock phosphate is sold on a guaranty of 77 per cent of tricalcium phosphate (the bone phosphate of commerce) and the pebble phosphate on guaranties of 60 to 75 per cent.

The prospecting or geologic mapping of these practically flat deposits in a region of slight relief is in most places complicated by the presence of overburden, so that any investigation of undeveloped portions is conducted principally by systematic drilling.

WESTERN RESERVES.

The phosphate deposits in the western reserves consist of rock phosphate occurring in beds interstratified with other rocks, in much the same way as coal occurs. The beds over 4 feet thick containing 70 per cent of tricalcium phosphate are from one to three in number in different places. These are interbedded with yellowish to brown phosphatic sandstone and shale and here and there with thin beds of dark limestone. The shale contains from 25 to 60 per cent of tricalcium phosphate and is doubtless of future economic importance. The phosphatic series ranges from less than 6 feet to about 180 feet in thickness and usually lies between a light-colored sandy limestone of variable thickness and a white, brown, yellow, or dull-black cherty limestone averaging 225 feet in thickness. The chert overlies the phosphatic beds where the strata are in normal order, but in places the beds have been turned completely over in the intense folding that has occurred. The phosphate deposits therefore not only lie flat but stand at various inclinations, and they lie at great depth except where the long-continued action of the elements has worn away parts of the rock folds. These folds are of two principal types—upfolds, or anticlines, and downfolds, or synclines. In some places the folding has been moderate in amount and the folds are long, regular wrinkles. In other places the folding was so intense and the wrinkles were so sharp and extensive that the beds are broken or "faulted" and come together in irregular order. Faults may and in many places do sharply separate phosphate from nonphosphate land, and where such faults are concealed by later deposits, such as gravels, they may lead to an apparently unwarranted difference in the classification of adjoining and seemingly similar tracts. Two 40-acre tracts in a section may in reality be underlain by phosphate and the remaining tracts may be barren, although the surface character of all may be exactly similar, so that it is necessary that the field examinations, the nature of which is more fully explained elsewhere, should involve more than a study of specific tracts.

The phosphatic series is composed of rocks which wear away easily under the action of the elements, and its outcrop is therefore inconspicuous; but the rocks immediately above and below it are resistant and in many places stand out in ledges that are easily traced. The field surveys on which the classification of the lands is based are made with sufficient detail and accuracy to determine the distribution of phosphatic beds relative to 40-acre tracts or other legal subdivisions, the thickness and character of cover, and the quality and thickness of rock phosphate. The determination of the factors last named has in places involved the actual prospecting of the deposits by deep trenches, the longest of which was over 400 feet long. Certain other preliminary surveys of a reconnaissance nature have been made in order to acquire data for withdrawals and preliminary modifications of the reserve boundaries.

The estimated quantity of high-grade rock (containing 70 per cent or more of tricalcium phosphate) included in the area surveyed in detail to date is more than 3,000,000,000 long tons, yet it is possible that such an estimate, based solely on information collected along the outcrop of the beds, may be excessive. Below the surface the brown phosphate of Tennessee rapidly becomes lean and grades into the phosphatic limestone from which the phosphate is supposed to have been concentrated by weathering. The phosphate deposits of the western reserves may ultimately be found to show a similar change, although they do not exhibit clear evidence of such concentration but in the main have the characteristics of original bedded deposits, probably in part of purely chemical and in part of organic origin. They have therefore been inferred to have practically the same richness underground that they show at the outcrop. However, in view of the unproved value of the deeper portions of the phosphate beds it is advisable that they be sampled by deep prospecting before any plan for the final disposal of the lands is adopted. If such prospecting shows that the greater part of the rock included in the estimates is relatively of low grade it will be self-evident that the exhaustion of the phosphate resources is not so distant as it now appears and that the value of the outcropping portions that are now known to include high-grade phosphate rock is much greater than is at present suspected.

SUMMARY OF PHOSPHATE SITUATION.

The question of the future adequacy of our phosphate resources for our own needs had been mentioned by several authorities prior to the conference of the governors in 1908, in which the discussion of this and kindred topics drew public attention to the situation. At this conference the possibility that foreign investors might acquire the better-known and supposedly richer portions of our deposits was suggested, the wisdom of permitting the exportation of so essential a quasi-public commodity was questioned, and the desirability of an early examination of the available supplies was emphasized. In part as a result of these indications of public interest, in part as a continuation of the policy already adopted in reference to coal lands, and in part because of the legal dilemma existing in the western fields through the inadequacy of the laws governing the disposal of mineral land the Secretary of the Interior, on December 10, 1908, withdrew from entry about 7,000 square miles of public land in Idaho, Utah, and Wyoming, pending an examination of their phosphate resources. In the following summer the United States Geological Survey began the examination of these lands and the investigation has been continued up to the present time, some 4,000 square miles having been examined in a preliminary way and about 2,500 square miles surveyed in detail.

The first withdrawal was based partly on information collected by the Hayden Survey in 1877 and partly on later detailed and reconnaissance examinations made by the United States Geological Survey. Field work done subsequent to this withdrawal revealed the regularity and the character of the phosphate deposits, so that it has been possible not only to revise the estimates of the reserves in the area actually examined since the first withdrawal but also to make a closer interpretation of the information gathered by the earlier surveys. These facts and relations are brought out in the following table:

Approximate area of phosphate lands, in square miles.

Year.	Reconnaissance surveys.	Detail surveys.	Total.	Withdrawn.	Restored.
1908				7,000	75
1909	1,000	800	1,800	600	3,600
1910	1,400	500	1,900	65	90
1911	1,200	800	2,000	55	237
1912	400	400	800	1,890	495
	4,000	2,500	6,500	9,610	4,497

CLASSIFICATION OF PHOSPHATE LANDS.

FACTORS INVOLVED.

As the phosphate deposits on the public domain exist as stratiform sedimentary beds or as residual deposits of the placer type, they are, as a rule, readily found and their extent may be determined by the ordinary methods of areal geologic mapping. In examining deposits of this type the geologic problems involved are chiefly structural. The purely economic considerations of accessibility, means of transportation, and nearness to market are highly important in the problem of establishing a commercial mine but are not involved in the classification of the land as phosphate or nonphosphate land.

The classification of a given tract as phosphate land is governed by the facts observed in the course of a field examination. A knowledge of the general geology of the region tells the examiner in what geologic environment the deposits may be expected, and a knowledge of the local succession of the beds tells him at what horizons and at what depths such deposits may be found in the tract examined. Before making a mineral or nonmineral classification of withdrawn phosphate lands it is essential to know exactly the distribution of the valuable deposits and to ascertain their relation to the legal subdivisions, so that the lands may be correctly described and classified. In making a classification it is also necessary to know the thickness and the number of the phosphate beds; the proportion of phosphoric acid (P_2O_5), or its equivalent expressed as tricalcium phosphate, that they contain; and the depths below the surface at which they occur.

The facts determined and recorded in the course of a field examination are shown on the township maps submitted by the field geologists to the land-classification board. If any of the data collected can not be represented on the maps they are supplied in the form of descriptive notes. One of the most essential factors to consider in the classification of any tract is the relation of the bed and its outcrop to that tract. If the rocks are in normal position—that is, if they have not been overturned or greatly disturbed by faulting—all the area underlain by rocks stratigraphically below the outcropping bed and therefore not underlain by the phosphate bed—may at once be classified as nonphosphate. In order to determine what lands are underlain by phosphate deposits it is necessary to work out from the recorded dips and strikes the structure of the field and to ascertain in what position and at what depth the phosphate beds lie. When these factors have been duly considered and the position of the phosphatic layer has been determined, it is necessary to know the regularity of the phosphate content of the bed, its variation in thickness, and the uniformity of its chemical composition from point to point in order to determine whether or not the tract contains a sufficient amount of phosphate to justify its classification as phosphate land.

Frequently in considering these factors it is desirable to make use of data of a confidential character which may have been procured in the course of the field examination. Such data, although used in determining the classification of the land, never appear on the map that is filed, but for all confidential sections, drill records, or other data only the location is indicated on the map and the material itself is kept separate from the general description and is not open to public inspection.

PRINCIPLES CONTROLLING THE CLASSIFICATION OF PHOSPHATE LAND.

Lands that have been included within phosphate reserves because preliminary examinations indicated that parts of them at least contain valuable deposits of phosphate whose exact distribution could not at that time be ascertained are further examined as soon as practicable and all lands barren of phosphate are recommended for restoration. In order to determine what lands should be so recommended and what lands should be retained in the phosphate reserve pending legislation providing for the disposition of phosphate deposits, it is necessary to determine what is and what is not to be regarded as phosphate land. It is very evident that lands which contain phosphate beds only an inch or two in thickness or with a content of tricalcium phosphate that is only 2 or 3 per cent of the entire mass or lands beneath which the phosphate beds lie at depths so great that they can not be commercially mined should be considered nonphosphate land.

REGULATIONS FOR THE CLASSIFICATION OF PHOSPHATE LANDS.

In order that the restorations and withdrawals may conform as nearly as possible to the factors that are involved in determining whether a given bed of phosphate possesses any actual or prospective value as a source of commercial phosphate, the following regulations were framed and have been applied in the classification of phosphate lands.

The principles incorporated in these regulations are to be used primarily for guidance in determining what lands will be recommended for reservation and what lands will be restored or excluded from future reserves. These principles, however, are based on a careful consideration of the factors which affect phosphate values and which may be involved when provision has been made for the disposition of the phosphate lands or of the deposits themselves. Furthermore, due regard has been given to such future developments as can be anticipated from present conditions.

Phosphate deposits shall be classified according to their thickness, their depth below the surface, and their calculated tricalcium phosphate determined from phosphoric acid content.

Lands underlain by beds of phosphate less than 1 foot in thickness or containing less than 30 per cent tricalcium phosphate or lying at a depth greater than 5,000 feet below the surface shall be considered nonphosphate lands, except as hereinafter provided.

A. Lands underlain by beds of phosphate 6 feet or more in thickness and containing 70 per cent or more of calculated tricalcium phosphate shall be considered phosphate lands if the beds do not lie more than 5,000 feet below the surface. The depth limit for beds containing 70 per cent of calculated tricalcium phosphate shall vary from 0 to 5,000 feet in direct ratio to the variation of thickness of bed from 1 foot to 6 feet. For beds containing less than 70 per cent tricalcium phosphate the depth limit shall vary from zero to the depth of a 70 per cent bed of any given thickness in direct ratio to the variation in tricalcium phosphate content from 30 to 70 per cent.

B. Lands underlain at depths greater than the depth limit given in "A" by horizontal beds of phosphate 6 feet or more in thickness and containing 70 per cent or more of calculated tricalcium phosphate shall be considered phosphate lands to a distance of 10 miles from the outcrop or point of accessibility from which they can be reached by a horizontal tunnel, which distance shall be decreased to 0 in direct ratio as the thickness decreases to 1 foot. For beds containing less than 70 per cent calculated tricalcium phosphate the maximum distance for any given thickness of phosphate bed shall be decreased to zero in direct ratio as the percentage of tricalcium phosphate decreases from 70 to 30 per cent. If the phosphate beds dip toward the outcrop or lie above the point of accessibility, they shall be included under this paragraph.

C. The maximum horizontal distance for any given thickness of phosphate bed shall be decreased from that given in "B" to one-fourth that distance in direct ratio as the depth below the outcrop or point of accessibility increases from zero to the limiting value given in "A." This limiting horizontal distance applies both to horizontal and to dipping beds, but in no case shall land be classified as phosphate land where the bed lies at a depth below the point of accessibility greater than that given in "A" or where the amount of barren tunnel and shaft work required to reach the phosphate bed would be more than three-fourths of the total tunnel and shaft work required to mine the bed, 1 foot of lift being considered equivalent to 7.92 feet of haul.

D. Where the phosphate bed occurs at or near the surface so that the deposits may be readily mined by open-cut or stripping methods, the minimum thickness of a phosphate bed containing 70 per cent or more of tricalcium phosphate shall be 3 inches. For beds containing less than 70 per cent tricalcium phosphate the minimum thickness shall increase to 1 foot as the percentage of tricalcium phosphate decreases from 70 to 30 per cent.

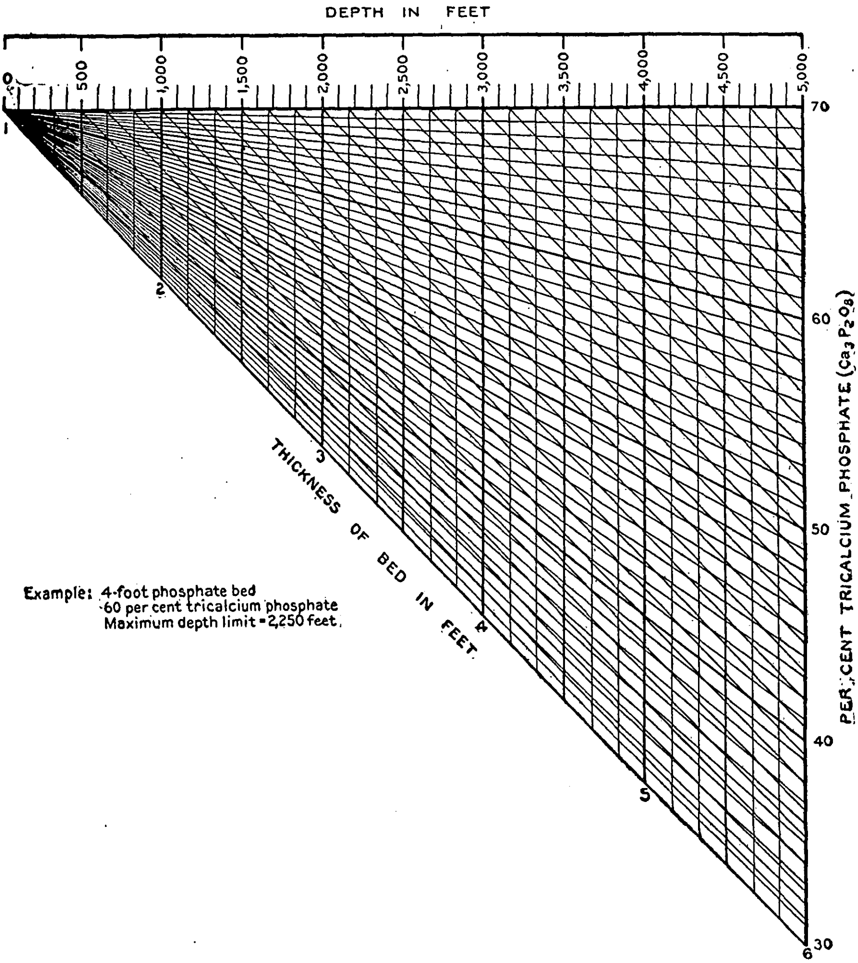

FIGURE 7.—Diagram showing depth to which phosphate deposits are classified under article A of the regulations.

PROGRESS IN CLASSIFICATION.

Classifications of the phosphate lands that have been examined are made according to articles A and D of the regulations. Recent field work in the closely folded phosphate region in the Western States and in the comparatively shallow deposits of Florida has shown that the attitude of the beds in these localities is such that it is not necessary to make use of articles B and C in classifying the lands. The classifications that are made according to the regulations outlined in article D are comparatively simple, but those made under article A are much more complex and require considerable computation. In order to reduce to a minimum the computations involved in determining the maximum depth a given phosphate bed of known thickness and content of tricalcium phosphate may attain for the land to be classified as phosphate land, the accompanying diagram (fig. 7) has been constructed, by which each individual problem falling under article A can be readily solved.

All beds 6 feet or more in thickness are computed as 6-foot beds, and all beds having a content of tricalcium phosphate greater than 70 per cent are computed as 70 per cent beds. In order to determine from the diagram to what depth any phosphate bed whose thickness and content of tricalcium phosphate are known should be considered workable, the vertical line in the diagram that represents the thickness of the bed is selected and followed to its intersection with the diagonal line representing the percentage of tricalcium phosphate the bed contains. From this point of intersection the actual or constructed diagonal line is followed to the top of the diagram, where the maximum depth limit is given. Every 40-acre tract between the outcrop of the phosphate bed and the line where the bed reaches this depth limit should be classified as phosphate land.

Where the phosphate rock occurs in several thin beds or groups of beds sufficiently close together to be mined as a unit but with different percentages of phosphoric acid, all the material that can be mined as one bed should be taken, or in case part of it consists of barren rock that portion of the group that can be mined as a unit and will give the greatest amount of phosphate rock should be considered. Where more than one bed exists that can be mined separately without destroying the value of the other beds the land should be classified on the basis of each bed separately, all the lands being classified as phosphate land that can be so classified with reference to any one of the beds. This method of calculation gives the maximum amount of phosphate that can be obtained from the bed or group of beds and is the method used in determining what lands should be classified as phosphate land.

As a result of action of this type, based on field examinations made by the geologists of the geologic branch, withdrawals and restorations have been recommended from time to time.

Examples of withdrawal and restoration orders are given below:

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, January 25, 1913.

The honorable the SECRETARY OF THE INTERIOR.

SIR: Investigations by the Geological Survey in the Florida phosphate region indicate that the lands listed below lie within the phosphate area and probably contain valuable deposits of phosphate. These lands were reported by the General Land Office in a letter, dated January 15, 1913, as vacant Government lands, or as unapproved State or railroad selections. Their withdrawal is in accordance with the procedure outlined and advocated in my letter of August 16, 1912. I therefore recommend the submission to the President of the following order of withdrawal, involving 75,851 acres.

Very respectfully,

GEO. OTIS SMITH,
Director.

FEBRUARY 3, 1913.

Respectfully referred to the President with favorable recommendation.

WALTER L. FISHER,
Secretary.

ORDER OF WITHDRAWAL.

Phosphate reserve No. 16—Florida No. 5.

Under and pursuant to the provisions of the act of Congress approved June 25, 1910 (36 Stat., 847), entitled "An act to authorize the President of the United States to make withdrawals of public lands in certain cases," as amended by act of Congress approved August 24, 1912 (Public No. 316), it is hereby ordered that the following described lands be, and the same are hereby, withdrawn from settlement, location, sale, or entry and reserved for public use.

Tallahassee meridian.

T. 2 N., R. 1 E., sec. 6, E. ½ of SW. ¼.
[Here follows the remainder of the land description.]

WM. H. TAFT,
President.

FEBRUARY 3, 1913.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, August 8, 1912.

The honorable the SECRETARY OF THE INTERIOR.

SIR: Field investigation by the Geological Survey indicates that the lands listed below do not contain deposits of phosphate. The following order of restoration, which involves 67,557 acres, is therefore recommended for submission to the President for appropriate action. Part of these lands are within coal withdrawals, but none are included in national forests, power-site or petroleum reserves.

Very respectfully,

GEO. OTIS SMITH,
Director.

AUGUST 17, 1912.

Respectfully referred to the President with favorable recommendation.

WALTER L. FISHER,
Secretary.

ORDER OF RESTORATION.

Phosphate restoration No. 6—Wyoming No. 2.

So much of the order of withdrawal made heretofore for classification and in aid of legislation affecting the use and disposition of phosphate lands, namely, reserve No. 4, as affects the lands hereinafter described is hereby revoked, for the reason that the Director of the Geological Survey reports that the lands are not valuable for the purpose for which withdrawn.

And it is further ordered that all such lands not otherwise reserved or withdrawn are hereby restored to the public domain and shall become subject to disposition under the laws applicable thereto upon such date and after such notice as may be determined upon by the Secretary of the Interior.

Sixth principal meridian.

T. 23 N., R. 119 W., secs. 5 to 7, inclusive;
sec. 18, all;
sec. 19, all;
sec. 30, all;
sec. 31, all.

[Here follows the remainder of the land description.]

WM. H. TAFT,
President.

AUGUST 17, 1912.

As a result of these orders, 3,291,527 acres of lands were included in phosphate reserves on January 1, 1913. The areas involved in these recommendations are indicated in the following table:

Phosphate land withdrawn, restored, and outstanding on January 1, 1913.

State.	Total withdrawals.	Restorations.	Outstanding withdrawals.
	Acres.	*Acres.*	*Acres.*
Florida	45,979	2,199	43,780
Idaho	2,215,834	1,157,778	1,058,056
Montana	274,861	....	274,861
Utah	581,039	473,294	107,745
Wyoming	3,060,098	1,253,013	1,807,085
	6,177,811	2,886,284	3,291,527

LANDS BEARING POTASH AND RELATED SALINES.

GEOLOGIC OCCURRENCE OF THE DEPOSITS.

No potash deposits of proved commercial value are yet known in the United States. Indeed, large deposits of potash salts are rare anywhere. Much the greater part of the world's supply is obtained from deposits in central Germany, first known from their discovery near Stassfurt. The only other noteworthy deposit in the world is said to be that at Kalusz, Galicia, in northern Austria. Deposits of the Stassfurt type may eventually be found in the United States, but the chances are perhaps greater that potassium-rich saline deposits in this country will vary widely from the German type in the character of the salts and in their mutual associations. It appears, therefore, that a discussion of the geologic occurrence of potash based on the Stassfurt type alone would be inadequate if intended to apply to possible deposits in the United States.

Potash in its soluble or most useful forms is almost universally associated with other soluble salts. Therefore it is to the natural saline residues and natural or artificial brines and bitterns that attention is directed in an exploration for soluble potash.

Great deposits of salines, especially those composed of sodium chloride or common salt, occur in many parts of the United States, but so far as known none of the important deposits now worked for salt contain an important percentage of potash salts. Saline beds occur at the surface in the arid regions of the West more abundantly than elsewhere. These occurrences include at least two types of deposits—the bedded salines included in stratified formations, which have commonly been tilted and otherwise displaced since their deposition, and the more recent saline deposits, which are to be found in the undrained playas and salt marshes of the Great Basin region.

The manner of formation of these more recent saline deposits is clearly revealed by the geologic record of the events that led to their accumulation and deposition. These events are so recent that the changes which are constantly taking place on the earth's surface have not yet obliterated or seriously obscured the evidence. This clearness and completeness of the geologic record justifies confidence in the correctness of the hypotheses concerning the manner of origin of saline deposits of this form.

Saline deposits in the Great Basin region, as elsewhere, are formed by the accumulation of the water-soluble constituents of the surface rocks of the earth's crust set free by that form of dissolution generally referred to as weathering. These salts thus freed are taken into solution by the rainfall and the ground waters and are gradually removed by the streams from the soils where they originate. Where these streams flow into inclosed basins with no outlet to the ocean, as is the rule in the Great Basin region, the dissolved salts are carried to the lowest part of the drainage area, where they accumulate. In the past, presumably because of greater precipitation than at present, these waters formed large lakes, which have since wholly or in part disappeared, and in the evaporation of these lake waters the salts have been deposited. Examples of saline deposits that have originated in this way in the low parts or so-called sinks of the inclosed drainage areas are common.

Saline deposits derived from the wash of continental areas normally contain among other constituents a certain proportion of potash salts. As a whole, the quantity of potash associated with the sodium and other bases is so small—only 2 or 3 per cent of the whole—that the potash can not be recovered profitably for commercial use. However, as the potassium salts are somewhat more soluble than most of the other constituents of natural saline solutions, it is believed that they are generally among the last to be deposited when those solutions are evaporated. Owing to this selective action of evaporation it is probable that somewhere in the saline residues of completely desiccated lakes the potassium compounds will be segregated in much richer concentrations than elsewhere. This condition might not exist in natural saline deposits if the deposition of the salines were interrupted by some event which permitted the escape of the residual brines before all their constituents or final products were deposited. But apparently in the playas of the Great Basin no such event has interposed; hence all the constituents of the accumulated brines must still remain, and it is believed that in certain favorable places rich potassium-bearing salts exist.

Most of the lakes that formerly existed in the Great Basin have completely disappeared by evaporation. Vast quantities of saline residues must have been deposited by the final drying up of these lakes, but for the most part such deposits are not now seen at the surface. It is believed that the greater part of the salines deposited simultaneously with the disappearance of the lakes has since been buried by sediments carried into these basins by streams and deposited as alluvial wash or in later lakes that have occupied the original depressions. Older saline deposits elsewhere have been formed in a similar way.

If this hypothesis is sound, it follows that the probability of encountering saline deposits by drilling in the bottom of the desiccated lake basins is very great and that under favorable conditions potassium-rich salines will be among those encountered. It is hoped that such buried salines may not in all places be so deep as to be inaccessible.

Field work undertaken by the Government in the search for potash has heretofore been largely of an exploratory character and has not followed any general or established rule of procedure. A systematic study of brines, bitterns, and rock-salt deposit in all parts of the United States is included in the general plan. The Geological Survey has drilled a well approximately 1,000 feet deep near the center of the Carson Desert, in northern Nevada. This test is not regarded as completed. Elsewhere in Nevada and in California a number of shallow drill holes have been sunk in other ancient lake basins. Some of these experiments are yielding significant and possibly important results.

CLASSIFICATION OF POTASH-BEARING LANDS.

Congress, responding to the urgent recommendation of the President, has so amended the withdrawal act (p. 43) that deposits of potassium-rich minerals may be included in reserves until an appropriate law for their disposition is enacted. In view of the variety of such deposits in commercially available form and of their importance in industry, it is doubtless the intention of Congress, if the present search is successful, to make appropriate provision for their development and disposal. Meanwhile, as investigation by the scientists of the Government bureaus reveals promising localities, these localities, if they involve public lands, will be withdrawn from entry until their value as sources of potash can be demonstrated or disproved. If they prove to contain rich deposits the withdrawals will be maintained until Congress can act. Three reserves of this type have already been created by the President. They include 133,829 acres in Nevada and California.

The order of withdrawal by which potash reserve No. 2 was created is given herewith as an example of this type of action.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, February 20, 1913.

The honorable the SECRETARY OF THE INTERIOR.

SIR: Investigations by the Geological Survey in the State of California indicate that the lands listed below, which lie within a dry lake known as Searles Lake, probably contain valuable deposits of potash. I therefore recommend the submission to the President of the following order of withdrawal, which involves 69,840 acres.

Very respectfully,

GEO. OTIS SMITH,
Director.

FEBRUARY 20, 1913.

Respectfully referred to the President with favorable recommendation.

WALTER L. FISHER,
Secretary.

ORDER OF WITHDRAWAL.

Potash reserve No. 2—California No. 1.

Under and pursuant to the provisions of the act of Congress approved June 25, 1910 (36 Stat., 847), entitled "An act to authorize the President of the United States to make withdrawals of public lands in certain cases," as amended by act of Congress approved August 24, 1912 (Public No. 316), it is hereby ordered that the following described lands be, and the same are hereby, withdrawn from settlement, location, sale, or entry and reserved for classification and in aid of legislation affecting nonmetalliferous mineral deposits:

Mount Diablo meridian, California.

T. 24 S., R. 43 E., sec. 32, SE. ¼ of SE ¼;
sec. 33, S. ½;
sec. 34, SW. ¼, W. ½ of SE. ¼, SE. ¼ of SE. ¼;
sec. 35, S. ½ of SW. ¼.

An area bounded as follows: Beginning at the southeast corner of sec. 31, T. 24 S., R. 43 E.; thence west 2 miles; thence south 12 miles; thence east 9 miles; thence north 12 miles; thence west 2½ miles, more or less, to the south quarter corner of sec. 36, T. 24 S., R. 43 E.; thence west 4½ miles, more or less, along the south line of T. 24 S., R. 43 E., to point of beginning.

This withdrawal is made subject to all rights lawfully initiated under any valid mining locations made upon said lands so long as such rights are maintained in full compliance with law.

WM. H. TAFT,
President.

FEBRUARY 21, 1913.

As the geologic conditions under which potassium deposits are formed differ from those required for the deposition of the other nonmetalliferous minerals, except the related salines, special field methods have been used for their discovery. The steps to be taken in classifying lands as potash-bearing or potash-free subsequent to field examination are, however, identical with those followed in the classification of lands with regard to such other resources as phosphate and petroleum. The present laws do not provide for appraisal and sale, as in the case of coal lands, nor for lease.

MISCELLANEOUS NONMETALLIFEROUS MINERAL LANDS.

Some of the important minerals besides those already discussed are limestone, building and ornamental stones, cement materials, slates, glass sand, gravel, volcanic ash, diatomaceous earth, kaolin and other clays, fuller's earth, gypsum, borax, salt, sulphur, monazite, talc, soapstone, quartz, feldspar, cryolite, mica, gems and precious stones, strontium compounds, fluorspar, barytes, pyrite, graphite, asbestos, magnesite, abrasives, asphalt and other hydrocarbons such as gilsonite and ozokerite, mineral waters, mineral paints, and bromine, as well as guano and peat.

A great many of the so-called nonmetalliferous minerals contain metallic elements which either can not be extracted commercially or are regarded as of little or no value as metals but which by their union with nonmetallic elements from substances that are sought because of their nonmetallic properties. This is true of such minerals as corundum, an oxide of the metal aluminum, and gypsum, a sulphate of the metal calcium. Monazite is sought as the chief source of oxides of several rare metals. There are, however, so-called nonmetalliferous minerals whose metallic content is high and which may under certain conditions be regarded also as metallic minerals. A notable example is pyrite, a sulphide of iron, which is extensively employed in the manufacture of sulphuric acid because of its high content of sulphur. With advancement in industrial chemistry some minerals now classed as nonmetalliferous may be placed in the category of those which yield valuable metals and others now used may be discarded.

The geologic occurrence of the minerals named in the foregoing list is very diverse and the characteristics of the deposits containing them will therefore be referred to but briefly. Many of them exist in stratified or bedded form. Limestone, building stones, some cement materials, and some ornamental stones occur as sedimentary or metamorphic rocks. Slates are obtained usually from beds and are quarried in much the same manner as other building stone. Some glass sand is made by crushing a loosely consolidated sandstone or is obtained from beds of loose sand. Gravel is usually found in more or less bedded form in so-called "gravel banks." Volcanic ash and diatomaceous earth are ordinarily found in stratified deposits or beds. Clays, including kaolin and fuller's earth, result from the accumulation of the less soluble residues of the decomposition of preexisting rocks and minerals and are obtained almost entirely from bedded deposits. Some clays are obtained by dredging the bottoms of streams or lakes. Kaolin in its purest form results from the residual decomposition of pegmatitic feldspar in place.

Gypsum, borax, and halite, or common salt, are found in deposits that are related with respect to the manner of their geologic occurrence. They are found most abundantly in association with stratified rocks and are regarded as chemical deposits resulting from the evaporation of waters of inland seas and lakes. Some deposits of borax and halite occur in more or less stratified form in the beds of present-day salt lakes or marshes. Sulphur deposits large enough to be of economic importance occur as products of volcanic activity and are found near volcanic craters and also near some hot springs, either active or extinct.

Monazite, owing to its minute crystalline form and great weight, occurs in greatest quantity where it has been concentrated in placer deposits.

Talc and soapstone are very soft minerals which have presumably resulted from the alteration of other minerals. Soapstone, a talc schist, occurs with other rocks of various kinds, usually crystalline or metamorphic; talc occurs in beds intercalated in schistose limestone and in lenses or pockets in certain intrusive rocks.

Many minerals exist in veins or in the form of lode deposits. Quartz, feldspar, cryolite, mica, and some gems are found in veins in crystalline rocks. The strontium minerals occur principally in lenses, in granular and columnar masses, in bedded deposits, and in crystals that form nests and geodes in limestone. Fluorspar is found, as a rule, in veins in limestone, gneiss, schist, and sandstone. It is a common gangue of metallic ores, particularly those of lead, zinc, and tin. Barytes occurs in veins and beds associated with other ores, as well as in veins and masses in limestone.

Pyrite is found in fissure veins and along the bedding planes of sedimentary and metamorphic rocks. It occurs in various other forms in rocks of practically all kinds and ages. Graphite is found mainly in the older crystalline metamorphic rocks in embedded masses and veins, although in some places it occurs in beds.

Asbestos is an alteration product found in veins in older crystalline rocks. Magnesite is also generally regarded as an alteration product and is found in veins as well as in bedlike masses. Some abrasives, like corundum, emery, and garnet, occur in small crystals, principally in veins in igneous and metamorphic rocks.

Some asphalt impregnates sands, sandstones, and limestones and occurs in veins in these rocks. Other hydrocarbons, such as gilsonite and ozokerite, are found in veins or fissures, usually in sandstones.

Mineral waters are, of course, obtained from springs; and some common salt and sulphur, as well as the materials of some mineral paints, are obtained from deposits formed by the evaporation of spring water. Bromine is found in natural brines and bitterns.

Guano occurs in massive deposits, which in some regions are of considerable thickness. It is usually found in caves or other protected places. Peat results from the accumulation in bogs of plant remains that have undergone slight modification at the top, although if the deposit is thick its lower portion may have been reduced to a mass somewhat resembling lignite.

Sections 2320 to 2325, inclusive, of the Revised Statutes prescribe certain rules and regulations to govern the location and patenting of "mining claims upon veins or lodes of quartz or other rock in place bearing gold, silver, cinnabar, lead, tin, copper, or other valuable deposits." Section 2329 provides for "claims usually called 'placers,' including all forms of deposit, excepting veins of quartz or other rock in place." Thus, although the minerals in the foregoing list exist in nature in beds, in veins, in massive form, or as liquids, or even in more than one of these forms, the law divides them into only two great classes—those which occur in veins or lodes of quartz or other rock in place and those usually called placers, including all other forms of deposits. The distinctions as to mode of occurrence of these minerals in nature are considered in classifying as mineral or nonmineral the lands containing them; such distinctions are the primary factors that under the present mining laws must always be considered in determining the law under which the deposits may be acquired.

A large part of the information heretofore obtained by the Geological Survey regarding these minerals has been gathered in reconnaissance examinations and in connection with reports on mineral resources, with the result that in most of the areas examined much geologic information that would be necessary for land classification has not been obtained, although the data gathered are entirely adequate for the purposes for which they have been sought.

No particular method is at present followed in the field examination of deposits of these minerals, and there is no necessity for methods materially different from those pursued in detailed work on other metalliferous or nonmetalliferous deposits. Nor do the requirements as to the data to be gathered and the form in which they should be assembled differ essentially from those for other minerals. In addition to the location, a brief description of the nature and geologic structure of the rocks in which the deposits occur, with data regarding the thickness and succession of the rocks, their dip and strike, the extent of the deposits, and analyses of the material, are all important in the examination of bedded deposits. In the consideration of vein deposits data regarding the character of the vein, the systems and directions of joints, fissures, and fractures which may have formed the ore cavities, the dip and strike of the veins, the nature of the gangue material, and the wall rock are equally important. Statements of production are always desirable. The question of relative value—that is, of mineral value as compared with agricultural, power, or other values—must be considered in the classification of some lands because of the fact that the laws governing the disposition of certain minerals refer specifically to lands that are "chiefly valuable" therefor. Other factors, some or all of which are in many cases to be considered in judging the relative value of a mineral deposit, are the following:

1. Demand for the mineral, both present and future.
2. Character of the deposit; chemical and physical properties and extent.
3. Location with reference to market and in some cases to fuel supply.
4. Transportation facilities and rates.
5. Market price of the product.
6. Whether or not the particular deposit possesses other peculiar advantages rendering it more valuable than like deposits in the region and elsewhere.

The character of the deposits, their location, and the transportation facilities influence the cost of production by their effect on the cost of working the deposits, the cost of the plant, and in some places the cost of the fuel used in the manufacture of the product. These factors may also exert a most important influence on the selling price of the output by their effect on the cost of placing it in the market.

If the earlier geologic examinations had been made with a view to classification more precise instrumental work and a record of all the factors outlined as having a bearing on the deposits would have been required. No attempt has yet been made to systemize for purposes of land classification the available data regarding these minerals, and although the Geological Survey has prepared and submitted to the General Land Office many reports that have been a guide to action by that office and have been equivalent in many cases to nonmineral classification and in a few cases to mineral classification, no withdrawals and no formal classifications of lands because of their content of any of these minerals have been made. Although such minerals are useful and valuable, they are not in general of so great present or prospective use or value as coal and certain other nonmetalliferous minerals contained in lands for whose classification more specific provision has been made. Practically all minerals are of some value, but those of greatest value are naturally those which have the greatest present or future use and which are at the same time most easily or profitably marketable. Sand, for example, is of great use, but it is so common that in most localities it has almost no market value. Therefore, although the lands containing the nonmetalliferous minerals here discussed are, at the discretion of the President, subject to withdrawal and classification under the act of June 25, 1910, as amended by the act of August 24, 1912, there is no such public need for segregating these lands as there is for segregating lands containing deposits of such minerals as coal, oil, potash, and phosphate. Nevertheless, should it be deemed by the President to be in the public interest to withdraw or to classify as mineral land an area containing any of these deposits, because of a public need for a present or a future reserve supply, or with a view to preventing alienation of the mineral deposits under laws relating to nonmineral land, or as an aid to future disposition, his action would be based on a question of fact which it is the province of the Geological Survey to determine. So long as such withdrawal or classification is not deemed to be in the public interest, however, the land will remain open to exploration, discovery, occupation, and purchase under the mining laws unless Congress shall otherwise provide.

METALLIFEROUS MINERAL LANDS.

PURPOSE OF CLASSIFICATION.

The usual object in view in a consideration of the classification of nonmetalliferous lands as mineral land is to obtain their temporary withdrawal from entry, either to permit their appraisal, as in the case of coal land, or to await protective legislation, as in the case of potash or phosphate land. But metalliferous lands, as such, are not subject to withdrawal, and their classification is directed to other objects, which will be indicated by a brief account of some cases that have been considered by the Geological Survey.

Perhaps the most important case yet considered is that relating to the Northern Pacific land grant. Every alternate section in a strip extending 40 miles on each side of the right of way was granted to the Northern Pacific Railroad Co. to assist it in constructing a transcontinental line, but the act provided that the railroad company should not receive any lands that were valuable by reason of their content of mineral deposits other than coal and iron. It therefore became necessary to classify the entire grant with respect to its value for such deposits, and in practice the chief problem of this classification has been to determine the presence or absence of valuable metalliferous deposits. A great part of this classification was accomplished by specially appointed commissioners, and the Geological Survey had no part in the work until 1905. In that year a Survey geologist, accompanied by a field agent of the Land Office, examined a large portion of the grant lying in Idaho and Montana in order to obtain information supplementary to that on which the special commissioners had recommended a mineral classification of the greater part of this tract. The Survey, however, took no further action regarding that particular examination. The greater part of the tract was classified as mineral land as the result of a hearing before the register and receiver at Cœur d'Alene, Idaho, but this classification was set aside by the Commissioner of the General Land Office on petition of the Northern Pacific Railway, on the ground that it was based on insufficient field work. In 1910, therefore, an appropriation was made by Congress (act of June 25, 1910; 36 Stat., 703, 739) for a new and much more thorough examination, for making which the Commissioner of the General Land Office requested the services of members of the Geological Survey. Four parties, each comprising a geologist, a geologic assistant, and the necessary camp hands, devoted the field season of 1910 to the work, which was completed in the season of 1911 by three similar parties. The resulting classification, however, was not sufficient to decide the status of all the lands in controversy. The railway company had the right to contest classifications adverse to its interests and exercised this right as to many of the lands which, because they were classified as mineral, would be excluded from the railroad grant. Hearings on the contested classifications are held before the registers and receivers of the appropriate land districts. An appeal can be taken from the decision of these officers to the Commissioner, and from him to the Secretary. No final decision has yet (February 28, 1913) been rendered concerning any of the classifications of the Survey that are under contest.

The Survey has also been required to classify several Indian reservations, in whole or in part, either before or after the reservations were opened to settlement, the question in the one case being whether or not the lands shall be allotted to the Indians, in the other what kind of entry or settlement on them shall be permitted. Lands valuable for minerals are withheld from allotment to Indians, as they are from the Northern Pacific Railroad grant, although for Indian lands no exception of coal and iron is made. A Survey geologist was engaged during the summer of 1912 in classifying the Flathead Reservation in Montana for the purpose of determining the mineral character of certain lands and their availability for allotment to the Indians, and many other classifications, both of individual allotments and of entire reservations, have been reported to the Indian Office.

Before Indian lands are thrown open to settlement it is desirable to know what parts of them contain valuable mineral deposits, in order that these parts may not be alienated as agricultural land. Failure to classify the lands in advance of the opening of the reservations is likely to result in conflict between agricultural and mineral claimants. This has occurred, for example, in the northern part of the Colville Reservation, which was thrown open to prospectors in 1898 and to agricultural claimants later. Numerous protests made by mineral claimants in this region against the issuance of patents to agricultural claimants have aroused the bitter resentment of the ranchers, who have been prevented by these protests from getting final patents. An examination of these lands for the purpose of determining whether the mineral claims showed deposits sufficiently valuable to entitle the claimants to mineral patents or whether these claimants were acting in bad faith, as alleged by some of the ranchers, was accordingly made by a geologist of the Survey in the season of 1912; and during the same season the unallotted part of the Colville Reservation was examined for the purpose of settling conflicts between mineral claimants and Indian allottees and of classifying the remaining unallotted lands.

Another type of classification has arisen of late, in which the Survey has been required to pass upon many and varied individual cases in which the propriety of granting patent to claimants was in doubt. It is sometimes suspected that attempt is being made to obtain valuable agricultural or timber land or strategic points for power development by the subterfuge of a mining claim on land where in reality no mineral deposit of substantial value has been found. On the other hand, there is sometimes danger lest a valuable lode or placer deposit be covered by some form of nonmineral entry. If these cases are important the department may call upon the Survey for any information that it may possess concerning a certain tract, or it may even direct that a geologist be detailed to make a special examination. One case of this type, of interest as one of the earliest examples of land classification by the Geological

Survey, was the determination of the nonmineral character of a "school section" on the edge of the city of Tacoma, Wash. This detailed examination was made in 1895 and resulted in the defeat of the mineral claimant, who had attempted to obtain under the placer law nonmineral land possessing large suburban value. As a result of the decision the title to this land passed to the State of Washington.

METHODS OF CLASSIFICATION.

AGENCIES EMPLOYED.

Classifications promulgated by the Survey are made by the metalliferous section of the land-classification board and are based on data gathered by the field geologist and by him presented to the section. Other geologists having special knowledge of the area or type of deposits under consideration may be called in, so that each classification represents the best scientific and technical judgment of the Survey.

PROBLEMS INVOLVED.

Each classification of metalliferous land involves one or both of the following problems: (1) Whether an alleged "discovery" of mineral constitutes valid ground for issuing a mining patent; (2) whether certain lands are without value for their metalliferous minerals and may therefore be patented under the laws relating to nonmineral land. The first problem is typically presented where the propriety of issuing patent to a mineral claimant is in question; a typical example of the second problem is that presented by the Northern Pacific land grant.

Evidently the first problem is the more concrete and the more readily solved. In order to determine the validity of a specific mineral claim all that is necessary may be to find and identify the claim and to estimate the value of the lode by sampling. The most difficult cases, on the other hand, are probably those that involve the classification of large areas in which little prospecting has been done. In order to reach an intelligent conclusion in such a case evidence of many kinds must be obtained, the gathering and effective presentation of which may involve the making of a fairly complete topographic and geologic map, a task which only a geologist can effectively perform.

In actual practice few cases present only one of the problems stated. Even if the main problem is the first one it is usually desirable that the examiner should learn something of the general geology of the district; and if, on the other hand, the main problem is the second the apparent value of particular claims is an important part of the evidence. It is not necessary or practicable, therefore, to separate the two main groups of cases in the detailed account of field methods that follows, despite their clearly distinct legal status. In most of the cases considered nearly all the kinds of information to be enumerated are used to a greater or less extent, and a geologic map of some kind invariably forms a part of the record.

The metalliferous deposits examined or looked for in most of the investigations preceding classification are veins, magmatic ore bodies, contact-metamorphic deposits, and bodies formed by replacement. In mining law these deposits are usually comprised in the term "lodes," and they may conveniently be so designated here. Some cases have to do with placer deposits, which are easier to examine and classify than lodes.

PRELIMINARY PROCEDURE.

As in the classification of nonmetalliferous lands and geologic field work in general, it is the duty of the geologist, before he takes the field, to gather information about the geology of the region to be examined and to provide himself with a base map. Other information that is especially desirable for work of this class relates to the location and status of the mining claims in the region. This is the only matter that requires further notice here, for the subject of base maps has been discussed elsewhere and the utility of geologic information is self-evident.

Plats and descriptions of patented mining claims are on file in the offices of the surveyors general of the several States and in the General Land Office at Washington. These show accurately the position of the claims with reference to land lines or location monuments. Provided with copies of these records, the examiner is able readily to find the patented claims. Less complete and accurate descriptions of the unpatented claims are filed in the offices of county clerks with the first records of location and the affidavits on assessment work.

FIELD WORK.

LOCATION AND TOPOGRAPHY.

The methods of location used in classification of this kind may be any of those described on pages 53–61. Some of the conditions of classifying metalliferous land, however, influence the selection of methods. The minute accuracy that characterizes much of the work on coal land is not often necessary in work on metalliferous deposits, and it is therefore feasible to use comparatively rough methods like that of the pacing traverse, which has been employed to a considerable extent. Another influential fact is that metalliferous land is more likely than nonmetalliferous land to be situated in mountainous territory. This is not obvious at first glance, but as metalliferous deposits are most common where the geologic structure is complex, and as mountains are regions of upheaval and disturbance, the connection between topography and mineral wealth is real. The ruggedness of the areas in which the greater part of the work of classifying metalliferous land is done precludes the use of some methods that are especially adapted to work in a flat country, such as that in which distance is measured by the paces of a horse. The plane table is much used in open country, and stadia traverses of roads or streams are sometimes made for purposes of control.

INVESTIGATION OF PLACER DEPOSITS.

Geologic relations.—Although theory is not so important in relation to placer deposits as in relation to lodes, the physiographic history of the region may afford some guidance in the search for valuable placer ground, as the following considerations will show.

The most important geologic principle relating to placers is that concentration sufficient to make a valuable deposit has usually been the result of long and perhaps repeated working over of the gravels by streams. Therefore, other things being equal, well-washed deposits consisting in part of reworked older gravels would seem most likely to be rich in gold. Moraines, on the other hand, or glaciofluviatile deposits close to the place of their origin are unlikely to contain gold in sufficient concentration to be extracted with profit.

With respect to the distance of the gravels from their source, however, a happy medium is favorable. Too great proximity is inconsistent with efficient concentration, but the gold, except in extremely fine division, is not carried so far as the gravels, and too great remoteness from the source is therefore also unfavorable. Gold-bearing placers are likely to show a definite relation to such areas of auriferous bedrock as can be outlined; they are partly within those areas but extend beyond their borders as a sort of fringe.

Testing.—Although a knowledge of the general geology and physiography of the region may be a guide in the search for placers, the classification of land as valuable placer ground is always supported by more direct evidence, for the reason that the extent and value of a placer deposit can be determined much more closely than those of a lode. The examiner is expected to pan the gravels of all important streams in the area classified in order to obtain evidence regarding their possible value as placers and, incidentally, evidence regarding the gold content of the bedrock from which the placers have been derived.

Testimony of miners.—Owing to their necessary limitations, the tests made by the examiner must be supplemented as fully as possible by the testimony of miners and prospectors. From these the examiner may learn the tenor of the gravels, the probable extent of the pay dirt, and whether mining has been profitable. This testimony may be taken under oath, if the examiner has power to administer it, and should be corroborated, so far as possible, by assay certificates and other evidence. A geologist is able also to criticize the testimony in the light of geologic facts and would perceive, for instance, that an assertion that morainal gravels had been worked with profit would be in especial need of corroboration.

INVESTIGATION OF LODE DEPOSITS.

Kinds of evidence available.—The evidence which must determine whether land is to be classified as mineral because of lode deposits may be subdivided as follows: (1) General geology; (2) occurrence of valuable minerals or gangue minerals, disseminated or in veins, found in outcrops or float; (3) prospects and mines; (4) assays; (5) history of the region. Evidence of the first two classes is especially important in regions that have not been thoroughly prospected.

General geology.—Certain geologic conditions, such as fissuring of the rocks, are generally recognized as favorable to the deposition of ore bodies; others, such as lack of deformation and very young country rock, are unfavorable. But ore deposits are the result of a happy combination of several factors, and it may be difficult to consider these factors separately and determine their relative weight. Of two districts geologically similar, one may be rich and the other poor in ore deposits, because of some difference not readily perceived. The most general cause of such differences, perhaps, is the variation in what Chamberlin and Salisbury call the " diffuse regional concentration " of the several metals, whether in sediments or magmas, which is presumably the cause of metallogenic provinces.

Now, it is evident that geologic conditions, including obscure conditions that may be largely determinative, are more likely to be similar in neighboring than in widely separated areas. Neighboring districts are the more likely, for one thing, to be in the same metallogenic province. Therefore, in judging whether a given geologic condition is favorable or not, the investigator should especially inquire whether it seems to favor the deposition of ores in the vicinity of the area to be classified. For example, if ore bodies are known in one locality at the contact of a batholithic intrusion with a certain limestone formation, it is probable that they will be found at the contact of the same rocks in neighboring localities.

This reasoning by analogy may form one of the arguments in support of a mineral classification, but it can rarely be made the sole ground for such classification of a large area, which can hardly be successfully defended against a contest unless it is supported by some definite discoveries of mineral, made by prospectors or by the geologist himself. In fact, such concrete occurrences of mineral are likely to have even more weight in a contest than strictly geologic evidence. It may pertinently be asked, then, what special qualification for gathering the evidence required is possessed by a geologist compared with a prospector or any other intelligent observer.

The geologist would perhaps have no special advantage if unlimited time were allowed for the examination. In fact, however, the time is limited, it may be all too strictly. It is impossible within the time allowed to explore every square foot of the area, and therefore observation must be concentrated where deposits are most likely to be found. Now, in determining what places are best worth examination the geologist finds abundant practical use for his knowledge both of general and of local geology. His general knowledge teaches him that some geologic conditions are more favorable than others to the formation of valuable deposits, and he distributes his attention accordingly. He does not, for example, waste his time in looking for quartz veins in undisturbed rocks, knowing as he does that deformation and fissuring are necessary to the formation of veins. The special knowledge of the region which he may already have or which he is prepared by training to assimilate rapidly will enable him to recognize in the geologic environment of the ore deposits that have been found the details that are significant. If, for example, most of the known deposits of a district are the result of interaction between a limestone and an igneous intrusive, the geologist will presumably be quicker than a layman to recognize this fact and will explore with especial care the contacts between these rocks in areas near those which have proved productive. The geologist, in short, is better prepared than the layman to follow clues.

The shorter the time allowed for the examination the more decided the advantage of the geologist over the man without geologic training. An exploration sufficiently thorough to discover even a large proportion of the valuable deposits in the region to be classified is rarely possible, and the value of many of the deposits found must be doubtful before they are thoroughly explored. It is correspondingly important, then, that the fullest and most reliable inferences be drawn from the data obtained in the field.

The following paragraphs are intended to show what kind of geologic evidence the examiner seeks.

Country rock.—The broadest generalizations that can be made regarding the influence of country rock, as indeed regarding other geologic factors, are of negative character. It is safe to say that very young unaltered volcanic rocks or imperfectly consolidated sediments are unlikely to contain metalliferous lodes. Further than this, however, the probable richness of a formation bears no direct relation to its age, for valuable deposits are found in rocks of all ages, from the Tertiary to the most remote.

In a particular district, however, the ores may show a preference for certain rocks. The favorable rocks may be those that contain minerals in a finely disseminated condition which may be valuable if they are anywhere sufficiently concentrated. Copper, for example, seems to be a constituent of some basic igneous rocks. Ready replaceability, or the power of reacting vigorously with mineralizing solutions, may be the determining favorable factor; and where the typical deposits of a district are replacements or contact-metamorphic deposits calcareous sediments are usually more favorable than others. Again, the presence of some constituent which acts as a precipitant may determine the concentration of a valuable mineral; organic matter probably precipitates gold under some conditions, and carbonaceous slates appear to be a common country rock of gold deposits. Finally, some purely physical feature may be determinative. The hard rocks of a district may be fissured to form breccias in which the ore-bearing solutions can circulate and deposit, while fissures in soft rocks would be clogged with impermeable gouge; and fissures which are large and persistent in massive rocks might ramify, on entering fissile rocks, into a multitude of small slips parallel to the bedding or cleavage.

Intrusions and metamorphism.—Although the nature and degree of the relation between igneous intrusion and ore deposition are still moot points, it is an established fact that ore deposits are especially abundant in the vicinity of intrusive contacts. Apart from stratiform deposits—such, for example, as those of iron oxide—ore bodies so remote from intrusive rocks as the lead and zinc deposits of the Mississippi Basin are rather exceptional, though not so exceptional as to make absence of intrusives a sufficient ground for classification of land as nonmineral. The general similarity in the distribution of ore deposits and of igneous rocks is particularly notable in the Western States. The presence of igneous intrusions must therefore be considered favorable, in general, to the deposition of ores.

Ore bodies related to intrusion are found both in the intrusive rock itself and in the surrounding sedimentary rocks. Those which are not contact-metamorphic deposits in the strict sense are not more likely to be at the immediate contact than at a considerable distance from it. The central portion of a very large batholith is likely to be barren, but the peripheral portion is commonly ore bearing, and all of the denuded portion of a small batholith or stock is likely to contain ore deposits, for none of it is far from the contact. Large dikes also form the country rock of many ore deposits. The ores are formed in the rocks cut by the intrusive, not only within but beyond the zone of contact metamorphism.

Structure.—The geologic structure of most mining districts is complex, and in regions of nearly horizontal unfaulted strata metalliferous lodes are scarce. Deformation, by giving rise to fault fissures and openings along bedding planes, probably determines the location of most lodes and is therefore favorable, in general, to the deposition of metalliferous ores.

Faulting is of greater importance in the formation of lodes than folding. Some faulting is doubtless a prerequisite to the formation of fissures transverse to the bedding, although fault fissures along which great displacement has been effected are not commonly filled with veins of commercial importance, for, inasmuch as they are likely to be choked with gouge and subject to repeated movement, they are less likely to be ore bearing than fissures along which the displacement has been slight or even imperceptible. Veins are accordingly looked for near and parallel to faults of large throw rather than along those faults themselves. That sort of faulting which gives rise to a rather coarse breccia is perhaps most favorable. At any rate, zones of brecciation afford the best clue for the tracing of small faults and are likely to be mineralized. They are therefore looked for and examined with especial care.

Folding, as well as faulting, may give rise to openings in which ores may be deposited. Saddle reefs constitute the most common type of deposits in openings thus formed.

Outcrops and float of lodes.—Outcrops of lodes afford the most direct evidence of mineral value that can be observed in the field apart from actual development, and they are therefore located and described with as great care as is practicable. If the deposits are veins, the direction and degree of persistence are determined if possible; this determination is particularly important if the classification must be close in the matter of location, but it is also important if in a neighboring region veins of a certain direction are known to be especially rich. Size and composition are other features noted. Size affects, of course, the degree of value, but the mineral content is of more immediate interest to the examiner.

In order to recognize lodes of probable value, the examiner endeavors to learn as much as possible concerning the appearance of the outcrops of lodes containing valuable minerals and familiarizes himself with the minerals likely to occur in the extremely oxidized portions of such lodes. Details regarding the surface indications along veins of proved importance in the region examined are sometimes obtained from prospectors and miners. The importance of these indications may be very great, for the minerals that make the lode valuable may not appear at the surface. More commonly than not the primary sulphides are represented at the surface by oxides or carbonates. The thoroughly weathered portion of a rich lode may even contain no compounds of the valuable metals. This is especially likely to be true of copper deposits, whose upper portions are commonly transformed to rusty porous masses containing quartz, iron oxide, and other substances that resist the action of the weather. This material, which is known as iron capping or gossan, may contain small amounts of the bright blue and green copper carbonates, but on the other hand it may be wholly devoid of copper minerals. Many lodes that weather to a gossan and others that are composed largely of easily weathered minerals do not project above the surface and are therefore likely to be overlooked. If a lode is about as hard as the country rock its outcrop is nearly level with the general surface, and the position of a lode composed of soft, easily weathered material may be marked by a trench instead of a ridge. Many veins, again, have no outcrop; they are covered with soil, and their position is indicated only by float. It is therefore evident that both careful observation and intelligent inference are required to find the lodes and judge whether or not they are likely to prove valuable.

The proximity of lodes containing minerals in sufficient concentration to be commercially valuable may be indicated by the presence of such minerals or of gangue minerals associated with them, disseminated through the country rock or in the form of narrow stringers. Some minerals commonly so found are calcite, pyrite, siderite, and chalcopyrite. The more easily weathered minerals are likely to be represented by their oxidation products. Siderite, for example, is usually and pyrite commonly represented by pseudomorphs of hydrated ferric oxide. Extensive rusty staining of the country rock therefore causes the examiner to look for more specific evidence of mineralization. Other characteristic alterations of the country rock, such as leaching, chloritization, and sericitization, commonly occur along the walls of lodes and are therefore useful as clues.

Probably the great majority of prospectors' discoveries are made by following float[1] to its source, and mineral classification likewise may rest in large measure upon the evidence afforded by float. Time will not always permit the tracing of float to its source, and the examiner must then be content with inferences drawn from the character and situation of the float as he finds it. In any case the first step is to consider how the float probably reached its actual position. It may have done so by either (1) hill creep, (2) water transportation, or (3) ice transportation, or by a combination of any of these agencies.

1. Most float has been transported to its present position by hill creep, which is constantly active on every slope. Angular float, without marks of attrition, which does not lie in an actual or former stream

[1] This term is commonly applied by prospectors to all fragments of lode matter not in place, however transported; it will be used in this sense here.

channel or in a glaciated area has presumably come to its place by hill creep, and its source should be looked for, after the method of prospectors, by following it straight uphill. Normally the parent lode will be found somewhere between the point where the float was discovered and the top of the slope. If a search is impracticable the probable source may perhaps be inferred, on the same principle, within narrow limits, especially if a good topographic map is available; the source may thus be assigned to a particular section or even to a smaller subdivision. Moreover, the probable source can often be judged within narrower limits than those set by the distance from the point of discovery and the top of the slope. The small fragments of vein quartz, mingled with soil, which may be found almost anywhere in a region of deformed rocks, are likely to have crept downhill for a long distance; but large blocks of quartz thickly strewn over a small and fairly well defined area, especially an elongated area on a moderate slope, may reasonably be presumed to have come but a short distance from a vein. It is evidently necessary, then, to note fully, on the spot, the size and character of the float fragments as a help in judging the source; and their size may also roughly indicate the thickness of the parent lode.

2. Rounded fragments or bowlders of float, especially if in a stream channel in an unglaciated area, may be presumed to have been transported by water. Float of this character is also frequently followed by prospectors up the streams and slopes to its source. This process is too slow and difficult to be employed often by the examiner. But stream-transported float may ordinarily be assumed to have originated in the drainage basin where it is found, and scrutiny of the stream gravels may tell the examiner what to look for in a particular basin.

3. Float that has been transported by glaciers is subject to much the same conditions as water-transported float. It is usually to be recognized by its association with moraines and glacial sculpture but may sometimes be confused with float of the other two kinds. It is less feasible to find its source by systematic tracing than to find that of other float, but where the glaciation is local the parent ledge is likely to be near by and well exposed.

As placer deposits are really one form of float in the broadest sense, this may be the appropriate place to point out their value as indicating the auriferous character of the country rock of the drainage basin in which they are found.

It may be remarked, finally, that exceptionally, owing to migration of divides or their transgression by glaciers, float is found outside of the drainage basin in which it originated. This is most likely to be true of old stream gravels.

Prospects and mines.—An important part of the examining geologist's work is to note the location of all prospects and mines and to examine all of them, with the possible exception of those that are well known as producers. The most obviously useful data to be obtained from mining properties concern the value and visible quantity of the ore and the production if the property is producing. The examiner checks one against another his own observations, the information given by assay certificates and smelter returns, and the testimony of owners or mine officials, which may be in the form of an affidavit if it is thought desirable by an examiner who is empowered to administer an oath.

The information gathered from a prospect or mine may do much more than indicate the mineral or nonmineral character of the claim on which it is located and that of a little land in its immediate vicinity. The most useful clues may be obtained in openings which permit comparison between the appearance of a lode underground and that of its outcrop. By making these comparisons the examiner is much aided in recognizing the outcrops of important lodes that have not been opened, and by study of the geologic environment of prospected deposits he may form an opinion as to where others are most likely to be found.

Samples and assays.—Ore samples and assays showing their value give the most concrete evidence and have great weight at public hearings. To obtain abundant samples and assays, therefore, is one of the examiner's chief duties, and quantity of material is not more important than full information indicating its value as evidence. Samples collected by biased persons are taken only too often either from the best part of a lode or from the worst part, or even from the wall rocks; and the procuring of truly representative samples requires both judgment and honesty on the part of the examiner. Full records regarding the collection of the samples are indispensable. Even after every precaution is taken in the matter of collecting and record there may be much room for inference, for the weathered, superficial portion of a lode, which alone may be accessible, is sure to differ in tenor from the unweathered portion from which the valuable metals are partly or chiefly to be won. Where ores of the base metals are concerned, values may sometimes be estimated by inspection closely enough to dispense with assays. Usually, however, and especially if values in gold and silver are to be found, the classification of any large tract calls for many assays, and material to be assayed for precious metals must be collected with special precautions. Each sample must be large enough to suffice for several assays, so that any result whose accuracy is doubted may be checked, and the material must be broken up and well mixed to insure its homogeneity before it is divided into portions.

The Geological Survey does not make assays, not being provided with the proper equipment or a sufficient force. Its assay work is therefore done by custom assayers of established reputation.

History of the region.—The question sometimes arises whether the mining possibilities of a region are fairly represented by the extent to which it is developed. If a region contains few prospects and no mines, or if many of its prospects have been abandoned, is it or is it not because valuable metalliferous deposits are really absent? Some light may be shed upon this problem by the history of the region.

If the region has long been accessible and is known to have been well prospected, lack of development should have some weight against classification of land as mineral. It must be considered, on the other hand, whether local prejudice against some kind of country rock or gangue material may not have lessened the value of prospecting, or whether the region may not contain deposits of a kind that has not been looked for.

Abandonment of prospects may not always indicate the worthlessness of the lodes; it is sometimes due to the miner's failure to recognize valuable ores. Many metal prospectors have little knowledge of the appearance of ores other than those of gold, silver, copper, and lead and do not always recognize the secondary ores of copper, lead, and zinc. For this reason the dumps of abandoned mines may reveal ores of rarer metals or others not formerly used or commonly searched for by prospectors.

Mining methods and facilities often, of course, determine the success or failure of a mine, and it is proper to consider in every case whether abandonment may not have been caused by inefficient mining, crudity of methods, or difficulty of transportation. The transportation problem may be largely disregarded, for if a region develops good metalliferous deposits transportation is pretty certain to be provided in time, but the presence or absence of roads and trails has an important bearing on the accessibility of the region, which in turn is a factor of prime importance in deciding whether the absence of prospecting indicates the absence of valuable deposits.

BY-PRODUCTS OF MINERAL-LAND CLASSIFICATION.

VALUE OF COLLATERAL INFORMATION OBTAINED.

The process of classifying the public lands as to their mineral character involves the gathering of a large amount of information which is not only essential to the classification but valuable for other reasons. Furthermore, the accuracy and completeness of field observation necessary for classification afford an opportunity to record many facts which are entirely extraneous to the classification itself but which may be now or at some later time of interest and value in other ways. These "by-products" of the process of land classification are of many kinds. Some are of value to home seekers and the public at large, others directly concern engineers and mining men, and still others are of present interest chiefly to scientists.

DATA OF DIRECT INTEREST TO THE PUBLIC AT LARGE.

While all information obtainable concerning the public domain is of ulterior interest to the people, information relating to such matters as the surface features, water supply, and character of the soil of a piece of land may prove to be of vital importance to the present or prospective settler. It is not practicable for the Geological Survey to make an exhaustive study of these features, but in the work of classification a certain amount of such information is always recorded. Thus, a map, supplemented by a written description, of each township examined for its mineral content is placed in the Survey files, showing in a rough way the agricultural character of the country. From these records it is possible to tell whether a section of land is suitable for dry farming or is adapted only to grazing, to obtain some idea of the number and size of the trees upon it, or to prepare a preliminary report as to its irrigability.

The field men engaged in work relating to land classification also record the position and size of all springs and water holes which they may find. This information is of direct value to the settler, but it also has another more general use. The more valuable agricultural lands of the public domain are rapidly passing into private ownership under the various settlement laws. It is recognized that most of the lands remaining are chiefly valuable for grazing or other uses not dependent on tillage, although the present laws do not adequately provide for their acquisition for these other uses. Congress has already given consideration to this problem and will doubtless reach a solution of it within the next few years. One of the most important factors to be considered in arriving at that solution will be the relation of the watering places to the range lands, for such lands can not be used without an accessible water supply. The accumulation of these data, therefore, in addition to being immediately useful to settlers and others, will be valuable in solving one of the public-land problems now confronting our lawmakers.

In studying and mapping a coal or phosphate bed it is necessary also to observe rather closely the geologic structure or attitude of the inclosing rocks. In some areas structure may have no bearing on mineral-land classification and yet may be valuable in determining the probability of obtaining a good well or of striking artesian water. The principles governing the flow of underground water, though not generally understood by the layman, are yet comparatively simple, and a glance at the geologic map of a region may indicate at once the most favorable locality for sinking a well. As a minor illustration of the value of such information may be mentioned the fact that one of the geologists of the Survey had occasion during the summer of 1912 to advise two newly arrived settlers in the ceded lands of the Crow Indian Reservation, Mont., to sink their wells on the east side of a ridge rather than on the west side, as they had intended, because of the simple geologic fact that the rocks dip slightly to the east and the water follows down the dip, as is proved by the numerous springs on the east side and the few on the west. Such information is, of course, only of local application, but as the western country becomes more thickly settled and questions relating to city water supply arise, information of this kind gathered for the primary purpose of land classification may prove to be of considerable value.

Miscellaneous data of these types are utilized in various ways. Such of them as can with propriety be so used may be published in the bulletins in which the geologic material assembled in the course of land classification is made available for public use. Others, although not published and not used in mineral-land classification, are of the greatest value to the department in administering laws relating to nonmineral land, like the enlarged-homestead act, the desert-land law, or the Carey acts. Still others represent merely the accumulation of data likely to be needed if certain moot questions concerning public lands are to be decided by future legislation. All these actual or prospective uses, however, either directly or indirectly concern the public at large.

DATA RELATING TO PROSPECTING AND MINING.

Information regarding the character, location, and extent of each stratum of economic importance in the area examined forms a large part of the data on which classification is based. This information is published by the Survey in special bulletins or in the annual "Contributions to economic geology." A study of the map and of the plates of sections taken on the coal beds in any field, for example, will indicate to the prospective operator the most favorable location for a mine, and the text includes observations concerning the cover of the bed, the character of the roof and floor rocks, and the general structure, including faulting, of the inclosing strata.

Aside from the local and particular facts recorded for each area, as this work progresses the extent and character of each of the great mineral-bearing provinces are being accurately determined and more and more comprehensive and definite data concerning the mineral wealth available for the Nation's use are being gathered.

The study of the rock structure in an area is valuable not only in relation to its water supply, as has been indicated, but also as bearing on the occurrence of oil. The accumulation of oil and gas in the strata is governed by laws which are probably akin to those which direct the movement of water, and a knowledge of the rock structure is therefore, as a rule, of great assistance in the location of an oil well. Some new oil fields have been prospected and opened almost entirely on geologic evidence of this kind. It has also happened that the details of rock structure observed in a field examined merely for coal have been found to have an entirely new application and significance in subsequent prospecting for oil. In view of this close interrelation of geologic phenomena, therefore, the field geologist carefully records all the facts he observes in the course of his work, even though they appear to have no present bearing on the subject of land classification.

SCIENTIFIC DATA.

Data of interest at the present time chiefly to the scientist form another important "by-product" of the process of land classification. It is difficult, however, to select any group of facts as being of strictly scientific value alone, for new discoveries may at any time enlarge their significance and impart to them an unexpected economic importance. Many facts are, moreover, of equal interest to the pure scientist and to the engineer or the layman, so that while a great amount of scientific information has been collected in the work of land classification during the last six years, the purely economic value of much of it has already warranted the necessary expense.

Many data concerning the areal extent of different geologic formations have been gathered in the last few years and will be of use in connection with the geologic map of the United States which the Survey is now engaged in constructing. The stratigraphic relations of the formations, their composition, and their fossils constitute the only chronicle of conditions which have, at different times and divers places, existed on the earth. From this record some idea can be gained of the former geography of the country, of the great earth movements such as culminated in the formation of the Rocky Mountains, of the climatic conditions which formerly existed, and of the ancient plants and animals. These matters are at present chiefly of philosophic interest, but it has been by the accumulation of such facts in the past that science has been enabled to render valuable aid to mining and other industries. Furthermore, information of this kind, while perhaps of little present interest to the average layman, is of vital importance to the teachers of science in the universities of the country. As a case in point may be mentioned the recent discovery, by a Survey geologist engaged in the classification of coal lands in New Mexico, of a great unconformity which separates into two formations a great thickness of strata that had hitherto been considered as a unit. This discovery is important not only on account of its strictly scientific bearing, but because it indicates that high-grade coking coal occurs in rocks of comparatively recent (Eocene) age.

It therefore appears that much important and diversified information is obtained in this way. Science is continually garnering facts against the time when their economic importance will appear, or when they may be correlated with other facts to furnish a broad hypothesis which may profoundly affect methods of prospecting or developing some mineral, such as oil. In addition, much local information of direct and immediate value to the mine operator or prospector is so gathered. Finally, the best obtainable record of the topography, water resources, and soils of the area examined is officially made. While the classification of public land is the immediate object of the work described in this bulletin, it is evident that such work, because of its exacting requirements as to accuracy and thoroughness, furnishes the best possible basis for valuable scientific generalizations.

CLASSIFICATION IN RELATION TO WATER RESOURCES.

GENERAL PRINCIPLES OF WATER UTILIZATION.

One of the most important factors in the development and use of the remaining public lands within the United States is water supply. The development of power, the extension of agriculture and grazing, the growth of mineral industries, transportation, and various other activities depend directly on the quantity and quality of the underground and surface waters in what is, generally speaking, an arid region. To dispose of or to administer the remaining public lands without reference to their water supply is to ignore that natural resource which will, perhaps more than any other, affect their future utilization.

Water is unique among the mineral resources of the earth in that, within natural limits, its supply is continually replenished and is therefore, in a large way, inexhaustible. That is to say, within the limits of the natural yield of a basin a certain minimum quantity of water will be available year after year in any river channel for irrigation, for city supply, or for power, as may be required. Aside from the inherent value of the water, the ownership of an important source of water supply becomes of the greatest consequence, for such ownership carries with it a measure of control, for an indefinite time, of all industries dependent on that particular source.

Statutes and court decisions both recognize that water should be devoted to its highest use, and the laws of many States provide for the condemnation of an inferior use in the interest of a higher one. Such laws generally recognize a municipal or domestic use of water as the highest which may be made, because of its necessity in the support of life. Next in order comes the use of water in agriculture for irrigation, whereby the available food supply is affected. The use of water for power, though important and valuable, is inferior to either municipal use or use for irrigation and may, in general, be condemned if necessary to insure higher utilization. The greatest value of a source of water supply at any particular time will depend, however, on the demands for domestic or municipal use, on the proximity of a tract of arable land adapted to agriculture, and on the quantity of power that may be developed and the availability of a market for it. Such value may change with the development of the country, making necessary the abandonment of established industries in order that the water may be available to supply a greater need. Changes in use will, however, follow the economic law, as the damage to established industries must be paid for, and to that extent the cost of the water for other use will be enhanced.

Important conditions are inherent in the use of water for various purposes. Its use for power affects neither its quality nor its quantity, but its use for irrigation depletes its quantity and its municipal or domestic use not only depletes its quantity but impairs its quality. Various uses may be and in many places are compatible with one another. In other places the conflict in use may be only partial. Many of the most advantageous sites for developing power, which, under conditions of modern long-distance transmission, are not dependent on a near-by power market for their value, are located in the upper portions of river basins, where the slopes are steepest and where demands for other use are not likely to be made. Under such conditions the water may be utilized in a power plant or a series of power plants and still be available for other purposes by the sacrifice of only so much of the power head as may be necessary to obtain adequate pressure in the pipes of the city water mains or to maintain the elevation of canals required to cover irrigable lands. In similar manner water that has been used for a municipal supply may still be available, as sewage, for a certain amount of irrigation. The equalization of the stream flow in order to insure a continuous output of power will in general increase the value of the stream for municipal use. The use of water for irrigation, on the other hand, is limited to the growing season and requires the concentration of flow in accordance with the needs of crops during that season. The complete utilization for irrigation of a stream whose flow has been equalized for power will make necessary storage below the power plant of the flow of the nonirrigation season in order to render it available for the irrigation of crops in the following growing season. The practicability of such storage and redistribution of flow will depend on local topography and must be determined for each locality. The conditions which affect the present and future practicable utilization of water are therefore very complicated, and the classification of land as regards its water resources is correspondingly difficult.

In general the development and use of valuable power sites involves the construction of expensive systems for transmitting the power to distant markets and distributing it among small customers. A water-power development can be most fully utilized and therefore has its greatest value when connected into a system containing other hydroelectric or steam-power plants, because a large system will generally have relatively uniform power requirements on account of the varied use of the power and also a relatively flexible power output on account of the steam plants and of the storage capacity which may be available in connection with some or all of the water-power plants. In view of these conditions the combination of power plants into big systems is natural and tends to more economical and more complete utilization of the power resources. As a duplication of such a power system in any territory is uneconomical and in general is impracticable, a monopoly of the power market results, and such monopoly, if subject to proper public control, should be encouraged. Monopolistic tendencies in the control of water resources entail difficulties and dangers that have been recognized by Congress, as manifested by the laws governing rights of way, especially for the purpose of developing and transmitting power, on or across the public lands.

The protection of the people against the possible bad effects of monopoly and the retention of control of the use of this important source of power, which may be expected to increase in value with the decrease in available fuels, is at present accomplished by the United States through ownership of the land which is required for the use of the water resources. Congress has provided no means for the alienation of power lands as such and has sanctioned their use for commercial purposes only under a limited permit revocable by the secretary of the department having jurisdiction. It provided for rights of way for power-transmission lines under the same law but by a later act has authorized a fixed tenure for a period not exceeding 50 years.

CLASSIFICATION OF WATER-POWER SITES.

PRELIMINARY WITHDRAWALS.

The classification of lands as water-power sites and their reservation under the acts authorizing withdrawals is in general first made in the absence of detailed examination to determine power value and is of a preliminary or tentative character. Examination in the field provides a satisfactory basis for final classification and adjustment of withdrawals. The following paragraphs relate more particularly to preliminary classification and withdrawal but describe also the routine procedure followed and records prepared in all withdrawals for power-site purposes.

The principal steps taken in connection with the making of power-site and reservoir withdrawals are as follows:

1. Initiation of search for possible power or reservoir sites. The possibility of the existence of valuable power resources is brought to the attention of those charged with the duty of recommending withdrawals through general probability that such sites may exist, through requests for report on the possibility of there being such sites, or through information as to the possible existence of such sites derived from reports of field employees of the Geological Survey or other offices, from news items, from newly published maps, from the filing of applications for rights of way, and from other sources.

In general the initiative in the premises is taken by the Geological Survey, but it not infrequently occurs that some power company intending to make surveys for a hydro-electric development in new territory requests the withdrawal of the lands likely to be occupied. The purpose served by withdrawal of such lands is two-fold. The valuable power sites that might otherwise be alienated as nonmetalliferous claims, timber and stone entries, agricultural entries, or for some other purpose, are retained in public ownership, and the company or person eventually developing the resource, presumably but by no means necessarily the one who requested the withdrawal, is protected from the intervention of other rights and has merely to acquire the necessary rights from the United States instead of from the United States and a host of persons who might otherwise have succeeded to ownership of the land.

2. Estimation of character and value of probable development and approximate description of the lands under consideration. This step involves an examination of existing data on stream flow and rainfall, as well as of maps, engineering reports, and all other available sources of information. In some cases information definite and conclusive in character may be brought to light. On the other hand, it frequently happens that estimates of stream flow must be based on nothing more reliable than conditions of run-off in basins many miles distant and that estimates of available head for power development must be derived from elevations at scattered points culled from railroad folders and similar data of doubtful applicability.

3. Examination of status of lands and definite description of lands to be included in the order of withdrawal. The lands presumed to be valuable for power or reservoir sites are platted on township plats

of the public survey or tracings of them, and the status of the lands as to ownership is ascertained by examination of the records of the General Land Office and indicated on the township plats or tracings. All patented lands are eliminated from further consideration. Lands which are covered by location or entry but title to which still remains in the United States are included in withdrawals to the end that the order of withdrawal may become effective if for any reason the lands do not proceed to patent. Such withdrawal in no way affects the rights of an entryman who proceeds with the acquisition of his claim in accordance with the law, but it immediately becomes operative in case the claim is abandoned or for any reason becomes invalid.

Definite description of the surveyed lands to be withdrawn is made by legal subdivisions in conformity with the official survey. Unsurveyed lands are described by townships and some lands in townships that are partly surveyed by sections, in accordance with the probable protraction of the public survey; also by distance from the stream or streams having value as a source of power, in some such phrase as "all land within half a mile of Snake River."

All withdrawals are so made as to include the least area that will effectively protect the resources involved. Where data are meager or defective the withdrawals are at first necessarily of relatively great extent but are eventually reduced as more definite and reliable data are acquired. The area of the land to be withdrawn in each township is compiled from the plats of the public survey, or estimated for unsurveyed lands, and the total area of the withdrawal is computed.

4. Preparation of order of withdrawal. The draft of a formal order of withdrawal is next prepared, together with a letter to the Secretary of the Interior transmitting the order and recommending its approval. On approval by the Secretary of the Interior orders of withdrawal are transmitted to the President for his consideration and become effective on his approval. The following order is typical of the present form of withdrawals under the acts of June 25, 1910 (36 Stat., 847), and August 24, 1912 (37 Stat., 497):

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
October 12, 1912.

The honorable the SECRETARY OF THE INTERIOR.

SIR: In accordance with your general instruction, I recommend the withdrawal for water-power sites of the following areas, involving 240 acres. This order of withdrawal includes no lands covered by enlarged-homestead designations.

Very respectfully,

GEO. OTIS SMITH,
Director.

OCTOBER 19, 1912.

Respectfully referred to the President with favorable recommendation.

SAMUEL ADAMS,
Acting Secretary.

ORDER OF WITHDRAWAL.

Power-Site Reserve No. 299.

Mill Creek, California.

Under and pursuant to the provisions of the act of Congress approved June 25, 1910 (36 Stat., 847), entitled "An act to authorize the President of the United States to make withdrawals of public lands in certain cases," as amended by the act of Congress approved August 24, 1912 (37 Stat., 497), it is hereby ordered that the following described lands be, and the same are hereby, withdrawn from settlement, location, sale, or entry and reserved for water-power sites:

Mount Diablo meridian.

T. 26 N., R. 1 W., sec. 24, SE. ¼ of SE. ¼;
sec. 26, SE. ¼ of NE. ¼, SW. ¼ of NW. ¼, NW. ¼ of SW. ¼;
sec. 32, S. ½ of SW. ¼.

WM. H. TAFT,
President.

OCTOBER 18, 1912.

Orders of withdrawal affecting lands within Indian reservations, made under sections 13 and 14 of the act of June 25, 1910 (36 Stat., 855, 858), are forwarded to the Secretary of the Interior through the Office of Indian Affairs. The following order illustrates the form in which such withdrawals are now made:

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, May 23, 1912.

The honorable the SECRETARY OF THE INTERIOR
(through the Commissioner of Indian Affairs).

SIR: In accordance with your general instructions, I recommend the withdrawal for water-power sites of the following areas, involving approximately 6,817 acres (in the Blackfeet Indian Reservation).

Very respectfully,

H. C. RIZER,
Acting Director.

JUNE 18, 1912.

I concur in the above recommendation.

R. G. VALENTINE,
Commissioner of Indian Affairs.

ORDER OF WITHDRAWAL.

Power-Site Reserve No. 275.

St. Mary River Tributaries, Montana.

It is hereby ordered that the following described lands, valuable for power sites, be, and the same are hereby, reserved from location, entry, sale, allotment, or other appropriation in accordance with the provisions of the act approved June 25, 1910 (36 Stat., 855), and that no trust or fee-simple patent be issued as regards these lands until further orders:

Montana meridian.

[Description of lands.]

SAMUEL ADAMS,
JUNE 22, 1912. *First Assistant Secretary.*

Withdrawals of this form receive the concurrence of the Commissioner of Indian Affairs before being forwarded to the Secretary of the Interior and become effective on approval by the Secretary, no action by the President being contemplated by the law.

Copies of approved orders of withdrawal are furnished to the Geological Survey, to the Office of Indian Affairs if affecting Indian lands, and to the General Land Office, and notification thereof is sent to the local land office of each district in which the reserved lands are located. Notation of the withdrawal is thereupon made on the tract records of the General and local land offices. Thereafter entries inconsistent with the purpose of the withdrawal, except under the mining laws pertaining to metalliferous minerals, are rejected. Modifications of a withdrawal may, however, be made to permit the allowance of an application that will subserve the purpose of the withdrawal or that involves a more beneficial use of the land than could be had under the purpose of the withdrawal. Withdrawals therefore in no way interfere with the proper development of the resources involved but tend toward their most complete and beneficial utilization.

5. Preparation of minutes. At the time each order of withdrawal is prepared minutes are written setting forth the object sought to be attained by the withdrawal, the extent and value of the resources involved, the data on which the withdrawal is based, and other pertinent facts. Orders of withdrawal are numbered consecutively in chronologic order, and successive withdrawals on any stream are also given consecutive numbers in connection with the stream name. The various sets of minutes for withdrawals on any stream therefore constitute a concise statement of its value for power or reservoir sites and of the data relating thereto.

6. Office records. When notice of the approval of an order of withdrawal is received at the Survey, the withdrawn area is plotted and numbered on a General Land Office State map. A township card is prepared for each township affected, showing the location of the stream and indicating the legal subdivisions withdrawn and the number of the withdrawal. If more than one withdrawal is made in a township, the card is prepared so as to show the withdrawals separately and constitutes a graphic record of all withdrawals and restorations of withdrawn lands. The numbers and dates of recommendation and approval of all power-site withdrawals and restorations

involved are tabulated on the back of the card. The front of a typical township card is shown in figure 8.

In a ledger kept for withdrawals and restorations are noted, when the order is prepared, the number and area of the withdrawal or restoration and the date of the recommendation of the Geological Survey. The date of approval is also noted in the ledger when the copy of the approved order is received.

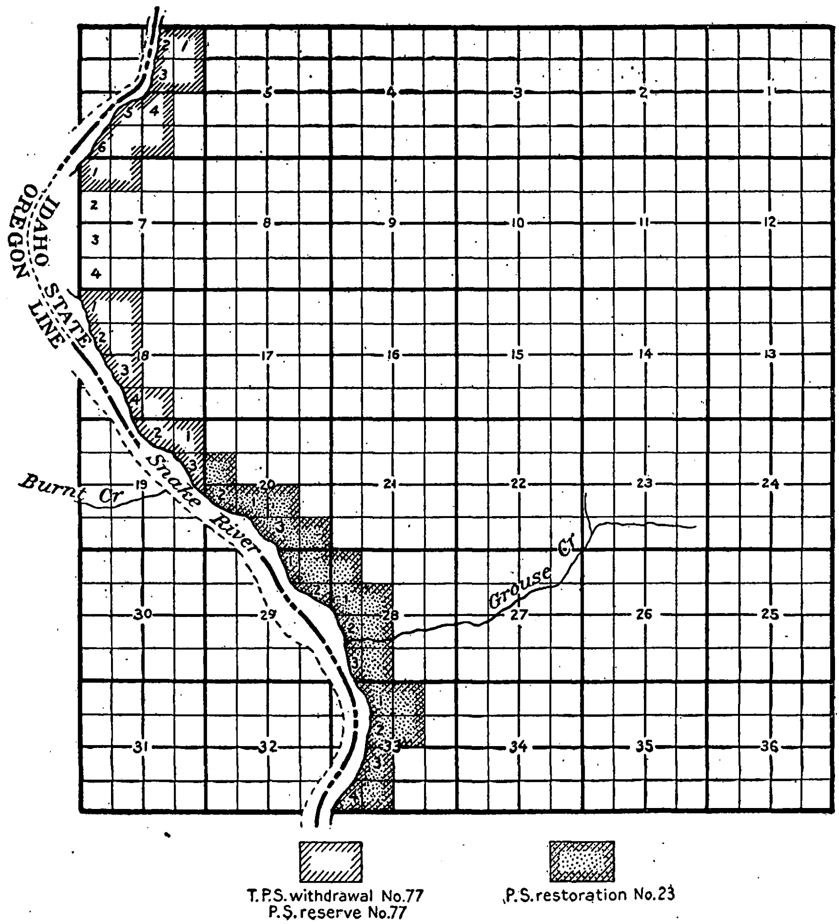

FIGURE 8.—Typical township card illustrating action taken by United States Geological Survey on power sites.

The complete record of the Survey relating to a power-site withdrawal consists of the following items:

(*a*) Order of withdrawal, filed by withdrawal number and therefore chronologically.

(*b*) Minutes, filed by number of withdrawal and therefore chronologically.

(*c*) Township plats showing status of lands as to ownership, filed in binders by number of withdrawal and arranged by principal meridian, range, and township.

(*d*) Township cards showing the extent and date of withdrawals and restorations, filed by States and arranged by principal meridian, range, and township.

(*e*) Mounted State map on which withdrawals and restorations are platted.

(*f*) Withdrawal ledger in which is kept a chronologic record of withdrawals and restorations showing the number, area, date of recommendation, and date of approval.

METHODS OF FIELD EXAMINATION.

DIVERSITY OF CONDITIONS.

The examination of lands and conditions along any stream for the purpose of locating a feasible power site is a fairly common and well-defined engineering operation. The examination of lands and conditions for the purpose of classifying the lands according to "power value," as the expression is interpreted in this bulletin, is quite another matter. In the first case, the effort is made to locate one or more sites that appear best adapted for development under the prescribed conditions of cost and prospective market which prevail at that particular time. The study is concentrated on the lands that will be involved in that particular development. In the second case, all the lands in public ownership adjoining or near the stream are presented for consideration, and the problem is to determine whether any or all of these lands could be used in the development of any feasible power site. Moreover, the feasibility can not be settled on the basis of present limitations of development but must be determined according to what are believed to be the limitations of a future day, when water power will be a more vital factor in our economy than it is now and when, by reason of increased demand, a development whose unit cost would now be too great would become thoroughly practicable. Power sites are classified according to their future possible utility as well as according to their present value.

There are other features which still further broaden the scope of an investigation of the kind here described. It is necessary to determine whether the lands examined may not be more beneficially devoted to the use of water for domestic supply or for irrigation than for power, and whether their use for power may not be prejudicial to the other uses at the site in question or at some other site more or less remote.

It must also be determined in many cases whether the land itself, irrespective of any distant lands which may be served, is of more value for agriculture or as a town or manufacturing site than as a power site. Such a consideration applies especially to lands that may be suitable for storage reservoirs. Usually the civic, industrial, or rural improvements that have previously been made in a reservoir site largely control the decision on this point, but the cases in which such influences are absent are still relatively frequent. Therefore the field of investigation again spreads beyond the actualities of the present and an estimate of prospective events must be made.

Finally, it must not be forgotten that human activities are not confined to the utilization of water—that a community which produces must, if its products are of value, have suitable means of transportation. Therefore it frequently occurs that consideration must be given to the relative usefulness of a piece of land as a power site or as a right of way for a railroad. In some places the bottom of a canyon that is suitable for power development or a basin that is suitable for a reservoir is also an advantageous railroad route. Although it is usually possible to locate an alternate railroad route, the cost of utilizing it may be so great as to outweigh the advantages that may accrue from development of power along the stream. It is thus necessary to appraise the relative values and comparative costs and choose the course that is or is likely to become of the highest human benefit.

The classification of lands for water-power sites therefore requires a broad perspective, and it comprehends the study of so many variable conditions and prospective changes in public demand that mistakes are easily made and mature consideration is always necessary. Field examination naturally falls into two classes. The first is reconnaissance, made in response to urgency. The second is final and detailed and involves all the precision of instrumental work and the careful deductions made possible thereby.

RECONNAISSANCE EXAMINATION.

A suitable report on a water-power site classification should cover as many of the subjects listed in the following syllabus as may be relevant:

I. Sources of data used in report:
  1. Personal examination—route followed and time consumed.
  2. Water-supply papers.
  3. Maps.
  4. Reports of engineers.
  5. Miscellaneous.

II. General introductory description, including location as to State, rivers, cities, township, and range.

III. Description of the power developments and possibilities on the river, showing by sketch on best available maps location of dams, power canals, and power houses already constructed and possible location of these essential features for other power developments. Ownership of plants already constructed and use made of the power.

IV. Physical characteristics:
  1. Topography at dam site.
  2. Relation of tract to a possible power development described under III above.
  3. Head available, how secured, whether by dam or by dam and canal.
  4. Character of dam sites, holding ground for canals, and site for power house.

V. Water supply:
  1. General description of drainage area.
  2. Actual records if available, showing maximum, minimum, and mean discharge for each month, also absolute seven-day minimum for the year.
  3. Storage already developed.
  4. Storage possibilities:
    (*a*) Location of reservoir sites.
    (*b*) Height of dam.
    (*c*) Capacity of reservoir.
  5. Prior water rights above and below power site.
  6. Ice conditions during winter months:
    (*a*) Without storage.
    (*b*) With storage.

VI. Possible power development:
  1. Horsepower at wheel shaft (without storage).
  2. Horsepower at wheel shaft (with storage).

VII. Cost of power development:
  1. Cost of diversion or forebay dam.
  2. Cost of canals.
  3. Approximate cost of complete installation per horsepower developed:
    (*a*) Without storage.
    (*b*) With storage.

VIII. Market for power:
  1. Present.
  2. Future.
  3. Length of transmission lines, etc.

IX. Suggestions and recommendations:
  1. Relative to lands withdrawn.
  2. Relative to other public land which has or may have value for development or transmission of power.

X. Appendixes:
  1. Water-supply records.
  2. Maps.
  3. Pictures.

Before entering upon field work the hydraulic engineer should collect all available topographic and hydrometric data relating to the stream under investigation. For many streams the topographic data may be obtained from the United States Geological Survey topographic sheets, the United States Land Office township plats, county and other maps, or railroad location surveys and profiles. Study should also be made of the precipitation records collected by the United States Weather Bureau and the river-discharge records made by the United States Geological Survey and by private citizens. After obtaining in advance as much information as may be available, the engineer proceeds to the field. His instrumental equipment usually consists of hand-level, steel tape, aneroid barometer, compass with sight alidade, and camera. In some investigations it is necessary to carry a current meter. These instruments and the notes, maps, and other data procured in advance, together with a map or description of the locations of the public land along the stream valley, constitute the working equipment. The engineer travels by wagon, on horseback with pack outfit, by boat, or on foot, as the conditions may require, and his personal equipment is made appropriate to the conditions.

The engineer, after examining all the lands in the stream valley and studying the relation of the critical features to the public lands, constructs what may be called a mental picture of the situation in its most productive condition of water-power development. He also works out the variations which might be made in his plan of development, knowing well that no other engineer covering the same ground independently would conceive the identical plan of development that he would. It is even necessary for the engineer to consider plans and possibilities that may appear to him impracticable or fantastic, for the serious proposal of such plans is a frequent occurrence in the routine experience of the department, and a relatively superficial glance over the country gives evidence that many such plans have been put into effect. Especially is it necessary for the engineer to gather local information concerning proposed developments of all kinds and to obtain as many working details of such developments as may be possible. To this end it is frequently essential to follow up rumors of prospective development. Although most of these rumors may prove inconsequential, they now and then lead to information whose importance fully compensates for the time spent on rumors that have no basis in fact.

If the engineer's investigations show that the slope of a river along a certain section affords a working head which, in connection with the known or supposed flow of the stream, indicates the possibility of a power site, he determines in a rough way the method or methods by which that site may be utilized. It is unnecessary for him to make final location surveys, because the fact that the power site exists is usually sufficient for the purposes at hand. The particular method of development will eventually be determined largely by the state of the science at the time the development is to be made. It is recognized that the details of location and equipment depend on the progress attained at the time of construction. We know, for example, of many old developments which if constructed to-day would be of an entirely different type.

The standards of capacity which warrant the withdrawal of public lands for power sites vary with the location, and in many cases the decision rests largely on the abundance of power sites in the immediate region. A stretch of river having a fall of 10 feet to the mile may, in regions where power sites are not abundant, be worthy of withdrawal, whereas a similar stretch in a region abundantly supplied with sites of greater capacity may not be of sufficient importance for departmental action. The determination of the proper course is difficult, for the question of feasibility must be partly answered with regard to future conditions. All the factors discussed in the beginning of this section, such as domestic water supply, irrigation, and transportation, must be borne in mind, and it is imperative that the engineer remember the fact that Government control of a small amount of land may be quite as effectual in the ultimate control of the development at the power site as if every element of that site were in public ownership. A small tract of land, even a fractional subdivision, located within a storage-reservoir site or along a diversion right of way has been sufficient to determine the control of the development. Having reached a decision on all the points above discussed, the engineer makes appropriate report.

Detailed surveys are not attempted in reconnaissance work. Approximate cross sections are taken at possible dam sites and, after the most feasible height of the dam is determined, a rough estimate of the area that would be submerged is made by means of the hand level. Where no profile of the stream channel is available, the fall over a short distance is determined with an aneroid barometer. This instrument, however, must be used with caution, especially during changeable weather. Photographs of all the critical points are taken. The possible dam sites suitable for storage or for diversion having been located and the type of development roughly determined, it is then necessary to consider the run-off. If the problem is one of storage, it will be sufficient to know the approximate mean annual run-off; the height of the storage dam can then be so fixed that the capacity of the reservoir may, as nearly as practicable, be sufficient to afford complete control. Of course, as a rule, sufficient storage capacity is not available, yet on the other hand there are situations in which the dam might be raised to a height that would give greater storage capacity than is necessary. In case no storage is to be provided, the mean daily flow of the stream must, if possible, be determined in order that the primary power capacity of the site may be appraised. If the available site is located in a canyon, it becomes necessary to determine within reasonable limits whether the maximum fall may be secured by a low diversion dam and conduits or whether it would be more economical to obtain the necessary height by the construction of a high dam.

Much of the land along the streams of the West has passed into private ownership, and where good facilities exist for the development of water power or the diversion of water for irrigation private interests may have established rights to the use of the water. Another complication on many streams consists in the location of railroad rights of way. Thus the problem of land classification may be greatly complicated, and considerable thought and good judgment are required to determine on a plan whereby the stream may be utilized to a reasonable capacity and the vested rights already acquired by private owners may not be violated. Many of the power plants already installed use only a small percentage of the maximum available power. In such cases either the plans for ultimate maximum power development involve the utilization and enlargement or improvement of such plants or they are omitted from consideration, it being assumed that when the demand for power increases to a certain point ordinary commercial procedure will settle all questions relative to the destiny of power plants in operation.

In case a railroad is already constructed parallel to the stream, plans for immediate development must avoid any interference with the railroad rights. Few plans that would require relocation of railroads are feasible under present market conditions, but the future demand for power will probably change the aspect of the case, and on this account the problem is treated as if the railroad did not exist, it being assumed that whenever the demand for power is sufficient to justify the expense of railroad relocation the power will be developed. It is quite as desirable to provide means for future control by the Government in such an event as it is to provide such control in situations where no complications of this kind exist. Therefore, an important part of the field work consists in the determination of possible relocations, so that in fixing the value of any land reserved for a power site the department may have information whereby it can render an opinion as to the possibility and cost of relocating such lines as are already constructed or as to the feasibility of requiring the relocation of rights of way for which application may subsequently be made.

DETAILED FIELD INVESTIGATIONS.

Investigations of detailed character are made to obtain data for final departmental action. The statements in the preceding section indicate that the chief object of the reconnaissance work is to locate lands suitable for power sites. The capacity of the power sites is determined in connection with such work largely for the purpose of justifying the preliminary withdrawal of the lands from entry. Incidental information of a more or less final character is collected during the reconnaissance examination, for the most part with a view to convenience and economy in the final detailed surveys. The withdrawals of lands for power sites on the basis of a reconnaissance examination are usually made liberal in extent, the purpose being to restore to entry any of the legal subdivisions which on detailed survey prove to be of no value in connection with the plans finally adopted. The detailed investigation consists of surveys to determine river profiles, surveys of reservoir site, soundings at dam sites and other places, and a more or less careful examination of the character of the underlying formations that must serve as foundations, especially for dams. In addition, it is necessary to establish river gaging stations, if none have already been established, for the purpose of determining, with a high degree of accuracy, the amount of water discharged by the river, so that the economic capacity of the reservoirs and power plants may be determined.

The gaging stations are selected, equipped, and maintained according to the standard methods followed by the United States Geological Survey in its regular hydrometric work. The processes are fully described in the annual progress reports on investigations of stream flow published by the Survey.

The investigation of dam sites for the purpose of determining the security of the underlying formations that must serve as foundations has, up to the present time, been based largely on general geologic information concerning the holding qualities of the formations known to exist in the localities examined. Final work of this character, none of which has been attempted in connection with the classification of water-power sites, will consist of the usual soundings and borings to determine the depth of the holding material, its permeability, its strength, and all the other factors that enter into its suitability for foundations.

Special river surveys delineating the alinement and water-surface contours of streams and the topography of the adjacent land are made on a scale of 2 inches to the mile by the plane-table and stadia method. The survey maps are accompanied by profiles showing clearly the stream gradient. The contour interval on water surfaces is usually taken as 5 feet but may be increased to 25 or even to 100 feet for sections of steep slope where the delineation of a lesser interval could not be clearly made. The topography of the land adjacent to the stream is shown by a contour interval of 25 feet and in general is carried to an elevation 100 feet above the stream by survey and an additional 100 feet by sketching. General features of culture, gaging stations, existing hydraulic works, all lines of land subdivisions by public survey, and other relevant data are shown on these maps. Promising reservoir and dam sites are shown with contour intervals of 5 feet to an elevation equal to the height of the possible dam.

Engineers executing these surveys are instructed to obtain and furnish to the Washington office all available data as to the water resources involved, supplementing the data shown on the maps by detailed description of existing or proposed developments.

COMPILATION OF RESULTS AND REVISION OF WITHDRAWALS.

When results of field investigation are available, much the same procedure is followed in the office in revising withdrawals as in making the preliminary withdrawals. The problem at this stage becomes one of limiting the withdrawals to the least possible area. Careful scrutiny of plans and profiles of the streams makes it possible to determine the power value of each smallest legal subdivision, and withdrawn areas containing no sites that are or may be valuable for the development of power are restored to the public domain. If the stream is of relatively flat gradient, where power development must be restricted to the low-head type and the construction will consist of power houses in conjunction with dams developing the available head, it is possible in many cases to locate definitely the favorable dam sites and divide the stream into successive units of probable development, from which no very great departure in construction is likely. On such streams the power-site reserves can be defined with a high degree of accuracy, and the use of each tract, whether for dam site, power-house site, flowage, or other purpose, can be forecast with considerable assurance. A minimum area of land is retained in power-site reserves on such streams. If the stream has a relatively steep gradient, however, where the natural development for power will consist of a low diversion dam and a long conduit leading to a power house perhaps several miles below and developing a high effective head, there can be a wide range of selection for the units of a comprehensive power project. On such a stream no specially favorable dam site is necessary, and relative expense of construction is generally the factor determining a choice among several different locations for the conduit. A definite use for any particular tract can seldom be assigned with development of this type, and the power-site reserve must be maintained so as to include all possible conduit locations if it is to be effective. A final revision of withdrawals along such a stream must be made as the power sites are developed. Even in such cases, however, restorations are frequently possible as soon as field examinations are made.

Restorations are recommended by the Survey and recorded in the Survey files in much the same way as withdrawals. The usual form of power-site restoration is as follows:

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, November 12, 1912.

The honorable the SECRETARY OF THE INTERIOR.

SIR: Investigation of lands included in power-site reserve No. 117, Snake River, Idaho, indicates that the portion of the lands included therein described in the following order of restoration is not valuable for the conservation of water power, and I therefore recommend that the said order of restoration be submitted to the President for appropriate action. The area involved in this restoration is 85.7 acres.

Very respectfully,

GEO. OTIS SMITH,
Director.

DECEMBER 3, 1912.

Respectfully referred to the President with favorable recommendation.

WALTER L. FISHER,
Secretary.

ORDER OF RESTORATION NO. 82.

Snake River, Idaho.

So much of the orders of withdrawal made heretofore for the purpose of reserving water-power sites as affects the lands hereinafter described is hereby revoked.

And it is further ordered that all of such lands not otherwise reserved or withdrawn are hereby restored to the public domain and shall become subject to settlement and entry under the laws applicable thereto upon such date and after such notice as may be determined upon by the Secretary of the Interior.

Boise meridian.

T. 5 S., R. 4 E., sec. 30, lot 6;
sec. 32, lots 7 and 8.

WM. H. TAFT,
President.

DECEMBER 3, 1912.

ADVERSE CLAIMS.

In many cases there is a conflict between the purposes of a power-site reserve and of some other claim to or proposed use of the lands affected. There is at present no satisfactory law under which land withdrawn for power purposes under the acts of June 25, 1910 (36 Stat., 847), and August 24, 1912 (37 Stat., 497), can be used for other purposes without jeopardizing the interest of the United States in the power possibilities. Under the acts relating to rights of way title to land by legal subdivisions is not granted and, as described elsewhere (p. 28), the interest of the United States may be preserved. Under the laws relating to agricultural land and mining, however, title to the land embraced in entries or claims passes from the United States and there appears to be no way in which the power estate may be satisfactorily reserved. Relative priority of reserve and claim, special exceptions, and relative value are the principles that govern in adjudicating the conflict. A power-site withdrawal is of no effect as against bona fide metalliferous mineral claims, without regard to priority of initiation. A power-site withdrawal is without effect as against a prior occupant or claimant of oil or gas lands who is diligently prosecuting work leading to discovery, but it becomes immediately effective against such occupant or claimant if diligent prosecution of work leading to discovery is discontinued. A power-site withdrawal is without effect as against a valid subsisting homestead or desert-land entry or claim of valid settlement so long as it is maintained and perfected pursuant to law, but the withdrawal becomes effective whenever the entryman or settler no longer continues to comply with the law under which the entry or settlement was made. With the foregoing exceptions, a power-site withdrawal under the acts of June 25, 1910, and August 24, 1912, is effective against all claims or entries on which rights have not vested prior to the date of the withdrawal.

Withdrawn lands having valuable possibilities for the development of power are alienated in the usual way if they are included in the excepted classes described above, although possibly the claims for such lands are subjected to a more careful scrutiny. If it appears that the claimant is attempting to obtain title to land because of its value for power, and if its power value is greater than its value for the alleged purpose of the claim, patent may be refused and the entry canceled. Cases of this nature arise most frequently in connection with metalliferous mineral entries, although not a few power sites have been homesteaded or acquired under the timber and stone law.

In the case of claims against which a power-site withdrawal is effective, a most unfortunate situation occasionally arises. For example, title to land may be sought by the application of scrip, and the claim may be initiated in advance of a power-site withdrawal. The claimant may have expended considerable sums in improvement and cultivation and have proceeded throughout in good faith. Nevertheless, the land sought to be acquired may be worth for power many times its agricultural value, and when this dominant power value is ascertained the land is naturally included in a power-site reserve. In such cases it is always a grave question whether the public interest is best served by the defeat or confirmation of the claim. Under the strict rule of the law the claimant has no rights in the case. No provision of law makes it possible to give him agricultural rights and reserve to the United States the rights of power development. Unless, therefore, the value of the land for the development of power is so great as to demand reservation for that purpose, public interest appears to sanction the claim of the individual as against that of the Nation, and elimination of the land from the power-site reserve is recommended

NONPOWER CLASSIFICATION.

In connection with the office studies incident to the report on the power-site possibilities of lands embraced in subsisting claims and with the investigation of power sites a mass of information is gradually being accumulated. This information is of negative as well as of positive character and shows where power sites are not located as well as where they are located. For convenience in making later reports on adjacent areas, this information is summarized from time to time and State maps are prepared showing the lands that are of no value for power development. This essentially constitutes a negative power classification and the use of such maps greatly facilitates the future work. In connection with these maps minutes are prepared in which are set forth the data on which the classification is based and the conclusions drawn therefrom.

ADDITIONAL REQUIREMENTS TO MAKE POWER CLASSIFICATION EFFECTIVE.

In order that the classification of land as chiefly valuable for the development of power may be made effective, it appears desirable that there be additional legislation providing for the control and utilization of land so classified under such conditions and regulations as Congress may decide to be necessary and for the proper administration of such land if, as now seems desirable, the title is to be retained in the United States.

As a feature, or perhaps as a preliminary step in such legislation, a "separation act" would be desirable, providing for the disposition of power and agricultural estates independently of each other in a manner similar to that now provided for coal land and for oil and gas land in Utah. Such independent disposition of these estates is believed to be entirely feasible, because, except where reservoirs are provided, the land actually occupied by a power plant constitutes only a small part of the legal subdivisions on which the dam, flowage, water conduits, power house, and transmission lines are located. The bulk of the land is available for agricultural or other use and may be largely so utilized without detriment to the power development.

The alienation of the agricultural estate and the retention of the water-power estate in any land, with provision for payment of proper damages to the agricultural estate when the power is developed, appears to be practicable and desirable in the interest of the orderly development of the natural resources involved. In fact, a separation of estates and a disposition of each estate as such appear to be desirable, even though it may be decided not to retain control by the United States of the water-power estate.

Whether or not a law providing for separation of the power estate is enacted, laws providing for the development of power on public land under such conditions that the industry would be materially encouraged and capital attracted would be most beneficial. The true purpose of power-site withdrawals is the use of valuable power lands primarily for developing power, not the withholding of such lands from any use. It is true that withdrawn lands are now available for use under the right of way acts, but they can be used for power development only under a permit revocable at will. Such a method is hopelessly inadequate and tends to discourage development. Recommendations for additional legislation have been repeatedly made by the department, and several very satisfactory bills have been introduced in Congress, but so far no suitable laws have been enacted.

CLASSIFICATION OF LANDS AS REGARDS IRRIGABILITY.

FIELD METHODS.

GENERAL CONSIDERATIONS.

The general considerations and particular features already discussed under "Classification of power sites" apply to the classification with respect to irrigability. They include determination of the relative value of water in its different uses and, in the case of reservoirs and headworks, the value of the land for other purposes. The field of investigation must be quite as broad and comprehensive for this purpose as for the classification of water-power sites. The engineer who performs the investigation is required to equip himself with the preliminary facts available in the office, such as maps and records of stream flow, and his instrumental equipment is practically the same as that already described.

A suitable report on the classification of lands as regards irrigability should cover as many of the subjects listed in the following syllabus as may be relevant:

I. Sources of data used in report:
  1. Personal examination; route followed and time consumed.
  2. Water-supply papers.
  3. Maps.
  4. Reports of engineers.
  5. Miscellaneous.

II. General introductory description:
  1. Name of project.
  2. Where located.
  3. When started.
  4. Estimated time of completion.
  5. Concise description of project, including—
     (a) Area involved.
     (b) Source of water supply.
     (c) Outline of irrigation system.
     (d) Important or critical structures involved.
  6. Nature and extent of control of the lands:
     (a) Carey Act.
     (b) Municipal district.
     (c) Ownership by developing company.
     (d) Contracts with land owners.
     (e) Contracts with desert-land or homestead entrymen who have no titles.
  7. Railroad and other transportation facilities.

III. Rights of way:
 1. Ownership and extent of those already secured.
 2. Applicants for those pending.
 3. Additional, across public lands, needed for the complete project.

IV. The lands:
 1. Topography.
 2. Geology.
 3. Vegetation.
 4. Soil:
  (*a*) Soil analysis.
  (*b*) Depth of soil.
  (*c*) Depth to impervious strata.
 5. Drainage.

V. Climatology:
 1. Temperature.
 2. Precipitation.

VI. Crops:
 1. Kind of crops.
 2. Probable markets.
 3. Transportation to markets.

VII. Value of lands:
 1. Without irrigation.
 2. Unimproved, but under ditch.
 3. Improved and irrigated.

VIII. Water supply:
 1. Source of supply:
  (*a*) Discussion of stream.
  (*b*) Discussion of drainage basin.
  (*c*) Stream-flow measurements.
  (*d*) Storage already developed.
  (*e*) Other storage possibilities.
 2. Rights in water:
  (*a*) Amount and date of water filing.
  (*b*) Prior rights, adjudicated and unadjudicated.
 3. Amount of water available for project.
 4. Duty of water.
 5. Amount of land that can be irrigated.

IX. Character of irrigation works:
 1. Storage dam.
 2. Location.
 3. General description.
 4. Type of dam, material, etc.
 5. Outlet tunnel.
 6. Area of reservoir.
 7. Capacity of reservoir in acre-feet.
 8. Diversion dam:
  (*a*) Location.
  (*b*) Type of dam, material, etc.
  (*c*) Size of dam.
 9. Pumping:
  (*a*) Source, kind, and cost of power.
  (*b*) Lift.

(*c*) Motors:
 (a) Number and kind.
 (b) Capacity of each.
(*d*) Pumps:
 (a) Number and kind.
 (b) Capacity of each.
(*e*) Station equipment.
(*f*) Transmission line.
(*g*) Buildings.
(*h*) Pipe lines:
 (a) Kind, size, and capacity.
 (b) Thickness of material.
 (c) Length.
(*i*) Receiving basins.

X. Canals:
1. Size.
2. Grade.
3. Capacity.
4. Slopes.
5. Wasteways.
6. Drops.
7. Lateral systems.
8. Flumes:
 (*a*) Kind (wood, metal, or concrete).
 (*b*) Size.
 (*c*) Grade.
 (*d*) Capacity.
 (*e*) Carrier.
 (*f*) Foundation.
 (*g*) Description of construction.
9. Tunnels:
 (*a*) Length.
 (*b*) Size.
10. Pipes:
 (*a*) Kind (wood, metal, or concrete).
 (*b*) Size.
 (*c*) Length.
 (*d*) Grade.
 (*e*) Capacity.
 (*f*) Pressure boxes.
11. Gates:
 (*a*) Headgates:
  (a) Kind.
  (b) Size.
  (c) Capacity.
  (d) Number.
  (e) Controlling device.
 (*b*) Lateral gates: Kind, etc.
12. Miscellaneous:
 (*a*) Bridges.
 (*b*) Trestles.
 (*c*) Riprapping.
 (*d*) Protection.

XI. Cost of construction:
  1. Detailed estimate.
  2. Bases for estimate.

XII. Present status of project:
  1. Work completed:
    (a) Amount.
    (b) Character.
    (c) Criticisms.

XIII. Revenue:
  1. Water rights.
  2. Number of acres covered.
  3. Number of acres sold.
  4. Town sites.
  5. State contract.
  6. Settlers' contract.

XIV. Appendixes:
  1. Maps.
  2. Geologic sheets.
  3. Photographs.
  4. Precipitation records.
  5. Stream-flow records.

XV. Suggestions.
Recommendations.
Conclusions.
Extensions.

To determine whether or not an area of land is commercially feasible of reclamation by irrigation the following matters require especially careful study:

Available water supply.
Present utilization of water for irrigation.
Duty of water.
Character of lands to be irrigated.
Crops.
Character of irrigation works.

AVAILABLE WATER SUPPLY.

To determine the available water supply a careful investigation is made of the streams from which the water is to be diverted. A study is made of all stream-flow measurements, and if records of daily discharge are available for a number of years, hydrographs are prepared showing graphically the daily fluctuations of the stream. On these hydrographs a line may be drawn representing the equivalent of prior rights. This done, the unutilized flow may be readily determined. Where irrigation has been practiced for a number of years, these hydrographs may show clearly that the normal flow during the irrigation season is already appropriated and that the unutilized flow occurs during the winter and during flood stages. To utilize fully the run-off from the streams under such conditions reservoirs must be constructed to store the water that is now wasted.

The study of available water supply therefore involves an investigation of the possibilities of storage. Unless information is available from private surveys, a reconnaissance examination is made of the drainage area for the purpose of locating storage sites. The methods followed are merely approximate and do not differ from those used in reconnaissance power surveys.

If no actual records are available showing the discharge of the stream, it is necessary to establish gaging stations at once and make a careful study of the drainage area and records of precipitation. If reliable maps are available from which the area of the drainage basin can be measured, and records are available showing the average precipitation on the basin, it is then possible to figure roughly the probable run-off. This method of determining the available water supply is unsafe and is used only where no records of discharge are available.

After determining the gross run-off from the basin the unutilized flow or the water available for the reclamation of new lands is determined by deducting the amount of water required to satisfy prior appropriators.

PRESENT UTILIZATION OF WATER FOR IRRIGATION.

Mention has already been made of the necessity for allowing for prior water rights in determining the amount of land that can be successfully irrigated from any stream. Irrigation systems already installed at the time of the examination furnish one of the most troublesome problems the engineer has to investigate. Under the law, as usually interpreted in the West, the water is public property, permission for its use being granted by the State, and wherever lands are classified for irrigation in the West it is nearly always true that the State has granted prior rights to the use of the water. In the earlier days of irrigation these rights were granted with the utmost liberality, without much regard for the amount of water actually flowing in a stream. It is therefore common to find that these prior rights exceed in aggregate amount the volume of water carried by the stream during irrigation seasons. This condition has been recognized by persons desiring to use water from such streams, and many of them have secured rights to use the flood waters which flow in the stream channels at periods of the year when irrigation is not practiced. Such utilization is dependent, of course, on the construction of storage reservoirs. Thus it may occur that, however well adapted for agriculture a piece of public land may be, on superficial examination there appears to be no available water for its reclamation. It is necessary for the engineer to bear in mind the liberality with which prior rights have been conferred and to examine the records for the purpose of determining what proportion of the water so granted can be beneficially used for irrigation. Such a study involves a determination of the duty of water, a subject which is discussed below. It is clear, however, that the determination of beneficial use involves an examination of the reservoirs, headworks, canals, and ditches, and the amount of lands embraced in irrigation systems under operation, and this is frequently a most difficult matter. It is the rule rather than the exception that the irrigator uses more water than is necessary for the growth and maturity of his crops; indeed, his use of water is not uncommonly so extravagant that the agricultural value of his land is greatly damaged. On few of the irrigation systems of the West, especially the older ones, has any record of the amount of water used been collected or preserved or the capacity of the irrigation canals been determined. This capacity may be variable, depending largely on the care with which the canals are maintained. Thus the engineer is obliged to investigate thoroughly all the working features of the systems already installed, so that he may make a report as to the actual amount of water necessary and thereby determine how much if any is available for the irrigation of new lands. Water-right matters are usually complicated and a proper study of them requires some working knowledge of the water laws and the decisions relating thereto. Although in many of the Western States the water laws are similar, they differ in some respects and some of the differences are very wide. To cover all the necessary points the engineer must examine into the grants and adjudications at the county or State offices where such matters are on record. Closely connected with this study of water laws is the observation and possibly the measurement of flow in existing canals to determine seepage losses. Such losses frequently represent 50 per cent or more of the water that is diverted from the streams, and it is necessary to consider the question of preventing such losses so that the water may be applied to lands not under cultivation. Where extravagant use or unreasonable loss is discovered the question then arises whether that water may not be filed upon for the benefit of the new lands under consideration. The determination of this point usually requires adjudication either by the courts or by State officials appointed for this specific purpose.

DUTY OF WATER.

The determination of the duty of water, or the amount of water necessary to irrigate a piece of arid land suitably, is another difficult task of the engineer. In some parts of the West the necessary amount of water has been determined by scientific study. Over the greater portion of this region, however, the amount has been determined largely by experience, so-called, and has usually been greater than is necessary. Frequently the lower limit has been determined in dry seasons when the supply of water was meager. Therefore the duty of water is susceptible of a very flexible interpretation. On each irrigation project there is a generally accepted idea of the amount necessary, and whether a larger or smaller amount than this is delivered by the canals is rarely determined. As a rule, however, the discriminating engineer can, by examining all the evidence, fix upon an approximate standard that may be considered reasonable, and unless that standard approaches too closely the total amount of water available adjustment is comparatively easy. Determination of the duty of water is, after all, an agricultural problem, some crops requiring more than others on the same land and different kinds of soils requiring different amounts for the same crops. Having determined this amount, the engineer then measures or estimates the losses which occur in transmission through canals and other conduits from the source of supply to the cultivated fields, for duty of water is, unless otherwise specified, referred to the field itself. This amount is sometimes called the net duty. To the amount required for actual application to the crops must be added that lost by seepage and by evaporation, and the farther the supply from the place of utilization the greater the amount which must be allowed for such losses. It is necessary also to consider losses in the storage reservoirs, especially the loss due to evaporation. Having summed up all these items and having previously determined the total supply available, the engineer can then determine how much is available for new lands. To this quantity is applied the duty previously determined, allowance being made for the prospective losses in the conduits that will carry the water to the new land. The result of this computation will show the amount of new land that can be irrigated.

CHARACTER OF LAND TO BE IRRIGATED.

The elements in the investigation of the character of the lands to be irrigated include topography, geology, character and depth of soil, and general drainage conditions. These are partly engineering and partly agricultural factors, but the engineer must take them all into consideration, because it is apparent that, with a given prospective cost of irrigation, a project would be feasible if the soil and physical conditions were of one kind and not feasible if those conditions were of another kind. The climate is another essential factor, and a study must also be made of the kind of crops adapted to the particular locality. It is apparent that a greater investment can be made for irrigation in a region adapted to citrus fruits than in one where, on account of climate, soil, or altitude, hay is the principal possible commodity. The determination of these points by the engineer rests largely on his general knowledge of related conditions and on the experience that has been gained by the people in the region. The transportation facilities and the market are subject to change and should usually be considered merely to determine whether present or future development is desirable. Transportation facilities will, under ordinary conditions, be provided in response to production, and market is a feature which, in the long run and under the present conditions of rapid growth and consumption in this country, will ultimately offer few difficulties.

CHARACTER OF IRRIGATION WORKS.

Having reached a favorable determination as to water supply, duty of water, and the economic features above set forth, the engineer must then investigate the character of irrigation works that are adapted to the physical conditions of the area. The character of such works depends entirely on the physical problems to be met. It may be necessary to construct storage reservoirs in order to utilize the highest possible proportion of the available water. On the other hand, the source of supply may be a very large stream, having a capacity sufficient to furnish all the water required for practicable irrigation in the entire region, and the studies are then confined to the determination of suitable diversion sites and canal routes reaching from the headworks to the lands to be irrigated. As in the case of reconnaissance power surveys, no final locations are determined by the engineer, it being considered preferable to leave such matters of detail to those who may in the future develop the project. The location of the headworks and of reservoirs and the routes, lengths, and capacities of canals can be determined approximately by field investigation of the type herein described, and while the results may be inaccurate for purposes of final location and development, they are sufficient to afford information suitable for departmental action. The public lands located in reservoir sites or along the courses of prospective conduits are carefully considered by the engineer with respect to their relation to the ultimate problem under consideration.

METHODS OF CLASSIFICATION.

PROCEDURE UNDER THE CAREY ACT

In the administration of the Carey Act and its amendments classification of lands with respect to irrigability is a necessary incident, for under the conditions of this act the land granted must be nonmineral, desert, and irrigable. The first step in the present procedure is the withdrawal of lands under the act of March 15, 1910 (36 Stat., 237), at the solicitation of the State in which the lands are situated. This is essentially a withdrawal for the purpose of classification, and the area withdrawn may be far in excess of that eventually constituting the irrigable area of the project. The withdrawal is made on the assumption that the area includes some land susceptible of irrigation under the Carey Act, but investigation may show this not to be the case. During the period of withdrawal, which is limited to one year, the promoter of the project has opportunity to investigate the area, plan the details of the project, and make a reliable classification as to irrigability without fear of alienation of the lands and resulting interference with the successful conduct of the project. In case such investigations and a request by the State for segregation are not made, the land is restored to the public domain without classification. If, on the other hand, the plans for the project are perfected and application for segregation is made, the lands listed in the application are further reserved until action is taken on the case, and the remainder of the withdrawn lands are restored to the public domain and may thereafter be assumed to be nonirrigable. The regulations require that the application for segregation shall include full data to show that the land is nonmineral and desert land and is irrigable and that the project is feasible. A field investigation is made by the General Land Office and the case is referred to the Geological Survey for report. A careful analysis of the water supply of the project is then made by the Survey, and sufficient investigation of probable costs and returns is made to show whether the reclamation and settlement can probably be accomplished at a cost warranted by the value of the reclaimed lands. If the existing data relative to the amount of water available for the project are insufficient to warrant a reasonably definite conclusion as to the area that can probably be irrigated, a hydraulic engineer of the Geological Survey may be called upon to supplement them by stream gagings and such other determinations as seem advisable. When all the data are considered, an estimate of the allowable area is prepared and a definite report and recommendation on the case are made. Final adjustment of the area to be segregated and of the terms of the contract between the Secretary of the Interior and the State devolves upon the General Land Office.

The approval of the segregation list under present departmental practice is in effect a fairly reliable classification of the land as nonmineral, desert, and irrigable. The aim of the work as now conducted is to safeguard the welfare of prospective settlers, the necessary investment of capital, and the interest of the Government. Some attention is being paid also to construction and settlement on Carey Act projects. When data obtained after the segregation is made indicate that the area included in a project exceeds the land that can be successfully irrigated, or when it is learned that constructing companies are attempting to increase the area of the project by selling water rights to owners of private lands and thus depriving the segregated lands of a portion of the water supply necessary for their complete reclamation, conferences are held with State authorities and prompt measures are taken to insure the protection of the settlers. It is hoped by such means to avoid the disastrous results that have heretofore too often attended operation under the Carey Act, to eliminate speculation, so far as possible, and to insure, so far as the department has the power, that the settler who seeks a home on segregated lands will receive a sufficient area of land with a satisfactory water right at a reasonable cost.

IRRIGATION RESERVOIR SITES.

Withdrawals of sites for irrigation reservoirs under the acts of June 25, 1910 (36 Stat., 847), and August 24, 1912 (37 Stat., 497), are made in the same way as withdrawals of power sites whenever the investigations of the Geological Survey indicate that feasible locations exist. Such withdrawals are made in the interest of bona fide development and to withhold from adverse possession reservoirs required in connection with large irrigation projects, both public and private. Modifications of the withdrawals to permit occupation and use of the sites under the applicable right of way acts are made when the development is warranted and applications for modification are made by responsible parties.

PROCEDURE UNDER THE ENLARGED-HOMESTEAD ACT.

The classification of lands under the enlarged-homestead acts also devolves upon the Geological Survey, the Director having been instructed by the Secretary of the Interior to make recommendations of lands suitable for designation thereunder. Nearly 193,000,000 acres of land have been designated in the States to which the provisions of the acts apply. Of this area, approximately 157,000,000 acres were designated within three months after the passage of the earlier acts. This result was achieved in part by the use of topographic maps, the accumulation of 35 years of work, in connection with a large number of which unpublished land-classification sheets were on file; in part by the application of available data on rainfall, run-off, and stream flow; in part by consultation with the Reclamation Service; and in part by the cooperation of the several State engineers. In spite of the uncertainty incident to rapid work covering large areas, later information has shown that these designations were in general properly made. The cancellations of erroneous designations amount in the aggregate to about 615,000 acres, or less than 0.4 per cent of the early designations. Since the first general designations were made numerous requests for the designation of additional areas have been received, and the work incident to the designation of lands under the enlarged-homestead acts now consists largely of the consideration of such requests, with office and field studies to determine whether the lands involved may properly be designated. The office studies include investigation of township plats, topographic maps, records of irrigation projects, rainfall and stream-flow data, and other sources of information from which a conclusion as to the suitability of the land for designation may be reached. In case field examination is made, the results are used in the office studies preceding designation.

Not all nonirrigable lands, however, may properly be designated, for it would obviously be useless to designate lands that could not be entered under the acts. Unsurveyed lands are not designated and newly surveyed lands are, by departmental order, withheld from designation until six months after the filing of the approved plats of survey in the local land office. Patented lands are, of course, not lands of the United States and are therefore eliminated from proposed designation. Lands on which there is sufficient rainfall for the production of ordinary crops without recourse to unusual methods of cultivation are not designated. Lands on which there is merchantable timber or which contain valuable minerals other than coal (in Utah coal, oil, or gas) are not properly subject to designation. Coal lands and in Utah coal, oil, or gas lands may be designated and entered subject to the terms of the acts providing for agricultural entries of the surface rights on such lands. Lands included in withdrawals or reservations of any kind or in Carey Act segregations are not properly subject to designation. Lands entered and in process of acquisition under the public-land laws may be designated if otherwise subject to the act, but lands included in subsisting entries under the desert-land act, being prima facie irrigable lands, are not properly subject to designation. Lands including sections granted to States as school lands are not designated unless they are excepted from the school grant.

Although no form of petition is specified for the use of those requesting the designation of lands under the enlarged-homestead acts, it is desired, in order that the Survey may have such information concerning the character of the land as the petitioner can supply, that such petitions be made on the usual form of application for entry of such lands, wherein the applicant sets forth under oath statements as to important features of the character of the land. Where this form is not used an affidavit setting forth essentially the same information is requested of the petitioner.

Orders of designation originating in the Geological Survey have been serially numbered both with general and State numbers. The form of letter and order used is here shown:

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, January 6, 1913.

The honorable the SECRETARY OF THE INTERIOR.

SIR: The following areas of land to which the enlarged-homestead act of February 19, 1909 (35 Stat., 639), as construed by the department, is applicable are, in my opinion, not susceptible of successful irrigation at a reasonable cost from any known source of water supply, and I therefore recommend their designation under the said act:

ENLARGED-HOMESTEAD DESIGNATION No. 210.

Montana No. 59.

Montana meridian, Montana.

T. 9 N., R. 7 E., sec. 22, lots 2, 3, 4, and 5, NW. ¼ of SE. ¼.
[Here follows remainder of land description.]

The above-listed lands will be enterable under the provisions of the enlarged-homestead act in so far as they may be vacant, public, nontimbered, and nonmineral and unaffected by any special provision of law, withdrawal, or reservation inconsistent with the provisions of said act. The surface of coal lands may, however, be entered subject to the reservation of the coal to the Government.

The area included in this designation is approximately 1,485 acres. None of the lands listed above are withdrawn in oil, phosphate, or power-site reserves.

Very respectfully, GEO. OTIS SMITH,
Director.

Approved January 28, 1913, and referred to the General Land Office to become effective February 27, 1913. SAMUEL ADAMS,
First Assistant Secretary.

The office record of the Survey relating to enlarged-homestead designations consists of State maps on which the designated lands are platted, a file of orders of designation arranged by serial numbers, a file of minutes similarly arranged showing the data on which the designation is based, and township cards on which are platted the designated areas. Cancellations are similarly recorded and filed, all designations and cancellations affecting any township, however, being shown on a single township card.

CLASSIFICATION AS REGARDS DOMESTIC USE.

GENERAL PRINCIPLES.

The problem of domestic water supply in an arid region is closely associated with the agricultural development of the region. In the broadest meaning of the term the use of water for domestic purposes includes not only its use in the household but by farm animals, by cattle on the range, and by the prospector in the desert wastes.

Permanent agricultural settlement depends on the presence of a water supply suitable for household purposes and for farm use. Under homestead laws requiring as their fundamental conditions both residence and cultivation, the extension of settlement to new areas is possible only where the prospective homesteader finds water within a reasonable distance of his chosen location. Where water suitable for such use does not exist on the surface the homesteader must resort to wells; failing there, he must haul water. The labor and therefore the expense of hauling water are great. Uncleanliness and insanitation are almost enforced by the resulting economy of use. The conditions of water storage on the homestead do not usually tend to insure purity and frequently cause disease. The possibility of procuring a domestic water supply from wells in regions where surface waters are impure or altogether absent is thus a question of great importance.

In areas where the underground water resources are unexplored geologic investigation may determine the more favorable localities for putting down test wells, and in regions where the position of the water table is not known or is known but imperfectly the application of principles well known to the geologist may be of great assistance to the farmer and the well driller in forecasting the possibilities. To this end large areas in the arid region have been geologically investigated. The data relative to underground waters have been compiled and maps prepared, not only showing the position of the water table in proved areas but indicating the probable location of the water table in adjacent unexplored areas. The data thus obtained by the Geological Survey, many of them in cooperation with the States, are published and widely distributed in water-supply and professional papers.

FARM WATER SUPPLY.

A modification of the homestead laws to relieve the entryman of the necessity of residence on lands where a domestic water supply is not available and can not be obtained is operative in Idaho and Utah under the enlarged-homestead acts, whose provisions have been mentioned. The provision in these acts relating to domestic water supply has been construed by the Department of the Interior as referring not only to surface waters but to the underground waters which could be reached by wells of reasonable depth. In determining the existence of such a domestic water supply and in recommending suitable lands for designation under the provisions of these acts, in regions where no potable surface waters exist, the Geological Survey takes into consideration the depth below the surface and the quality of the underground water, the amount of labor necessary to reach it by a well, and the cost of development compared with the agricultural value of the lands. The provisions of the law are considered particularly applicable to areas where substantial but fruitless efforts have been made to obtain such a water supply by digging wells. In procuring data for classification of lands of this class the Geological Survey has been assisted by special agents of the General Land Office. To January 1, 1913, areas comprising 1,199,638 acres had been designated in Utah and 7,801 acres in Idaho as not having a suitable domestic water supply.

RANGE WATER SUPPLY.

The problem of the disposition of grazing lands is still largely unsettled. By the creation of national forests a large part of the summer range has come under the general scheme of forest administration and is leased by the Forest Service at a specified price per capita, but the unreserved public lands still include considerable areas of summer range, much of the fall and spring range, and a large proportion of the winter range. The control of the spring, summer, and fall range is rapidly passing into the hands of individuals and live-stock associations, not in general by securing title to the public lands as a whole but by the simple expedient of acquiring title to the water holes. The owner of the springs and streams located on an otherwise waterless range has obtained the use of the grazing land on far more favorable terms than if he had acquired absolute ownership. He is free from State land tax, he pays no rent to the Government, and no rival sheep or cattleman may water at his wells. Except for the period when snow, by providing water, may make invasions by rival stockmen possible, he is secure in his possession.

As a remedy for this situation, disposition of the grazing lands by sale and by lease has been advocated, and several bills dealing with the situation have been introduced in Congress. If, as is advocated by the Interior Department, a leasing system is adopted, it is apparent that the Government would be at a serious disadvantage in proper administration unless watering places were also available for lease. As a step in the working out of a definite policy for the administration of public grazing lands outside of national forests the withdrawal of public watering places under the authority conferred by the acts of June 25, 1910 (36 Stat., 847), and August 24, 1912 (37 Stat., 497), has been sanctioned by the President. The first withdrawal for this purpose was approved by him on March 29, 1912. The effect of withdrawals of this character is to prevent alienation of the lands pending legislation governing their use under public control, but the use of the watering places by all is meantime possible under such conditions that no user can acquire the right of permanent exclusive occupation.

These withdrawals are based upon field investigation by members of the Geological Survey and some of them on reports of General Land Office inspectors. Careful consideration is given to the relation of the watering place to the surrounding range and its value in connection with grazing on the public lands. Agricultural lands susceptible of successful cultivation have been excluded from withdrawal except in regions where most of the watering places have passed into private ownership and it becomes imperative to reserve water for stock, even at the expense of settlement.

MUNICIPAL WATER SUPPLY.

An incidental classification of lands as valuable for domestic water supply arises through right of way applications for municipal systems. In general, where sources of water supply are sought for municipal purposes their value therefor far exceeds their value for power or irrigation. Approval of such right of way applications therefore amounts to a definite classification of the lands affected. The lands may be used for reservoirs, conduits, stream protection, or any other purpose relating to municipal water supply.

Such right of way applications are referred to the Geological Survey for report. In view of the relatively high value of water for municipal supply, the question whether the application provides for the highest use is seldom considered. The most troublesome question is to determine whether the application is really made for municipal purposes. If the application is made by a municipality this question is readily answered, but if a private water company makes the application it may be difficult to determine whether the purpose is private or municipal. A strict showing of municipal authorization to the private company is required in such cases and constitutes the chief criterion for classification.

Lands embraced in permits for municipal water supply are withdrawn and reserved in order that occupation in the interests of the municipality may be suitably protected.

INDEX.

O