PRESENT INVESTIGATIONS OF RADIOACTIVE RAW MATERIALS BY THE GEOLOGICAL SURVEY AND A RECOMMENDED PROGRAM FOR FUTURE WORK

By A. P. Butler, Jr. and F. W. Stead

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PRESENT INVESTIGATION OF RADIOACTIVE RAW MATERIALS BY THE GEOLOGICAL SURVEY AND A RECOMMENDED PROGRAM FOR FUTURE WORK

ABSTRACT

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The Geological Survey's program of investigation of radioactive raw materials is presented herewith under present investigations, plans for future investigations, plan of operation, and cost of operation. This report was prepared at the request of the Atomic Energy Commission.

Present investigations are summarized to show the scope of the present Trace Elements program, grouping individual projects into related types of investigations.

Plans for future investigations on an expanded scale are outlined. These should provide sufficient data and knowledge of the occurrence and availability of uranium, thorium, and related elements, to permit a more complete evaluation of domestic resources. Reconnaissance projects are designed to discover possible new sources of uranium and thorium and to select areas and materials warranting further investigation. Typical projects leading to the estimation of reserves are the investigation of the carnotite ores of the Colorado Plateau by geologic mapping, exploratory drilling, and related research, and investigation of asphaltic sandstone in Emery County, Utah. Extensive research will be undertaken to establish the principles governing the geological and geochemical relations of uranium, thorium, and associated elements as an eseential guide in appraising domestic resources. Particular emphasis will be placed on phosphatic rocks and black shales which offer ultimate resources of uranium far greater than carnotite ores. All the foregoing investigations will be accompanied by chemical, geophysical, and mineralogical research and analytical work.

Under plan of operation is discussed the organization of the Trace Elements Unit, space requirements for laboratory and office, the scheduling of investigations, and other related problems. The proposed scheduling of work calls for approximately 109, 173, and 203 man years in fiscal years 1948, 1949, and 1950 respectively. Definite plans have been formulated only for the next three fiscal years, by which time it is assumed the program will reach stable proportions or can be altered as experience dictates.

Under cost of operation is set forth the funds available in fiscal year 1947, the status of funds transferred from Atomic Services (14-217/80920), and funds necessary in succeeding fiscal years. The estimate for fiscal year 1948 inclues a non-recurring item of $1,025,000 for establishing adequate laboratories for chemical, physical, spectrographic and mineralogic research and analytical work. The total funds required in fiscal years 1948, 1949, and 1950 to support the proposed program will be $2,440,000, $2,161,000 and $2,198,000 respectively. The Geological Survey anticipates contributing from its appropriation in fiscal years 1948, 1949, and 1950 approximately $243,100, $350,000, and $400,000 respectively; the balance of the necessary funds to be contributed by the Atomic Energy Commission in fiscal years 1948, 1949, and 1950 will be approximately $2,196,900, $1,811,000, and $1,798,000 respectively.

[redacted]

INTRODUCTION

This supplemental report, amplifying the Geological Survey's recommendations_/ for investigation of domestic resources of radio-

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_/ Status and general features of the Geological Survey's investigation of radioactive raw material: Trace Elements Investigation -- Report No. 35, January 1947. This report was transmitted to the Atomic Energy Commission on February 10, 1947.

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active raw materials, was prepared at the request of the Atomic Energy Commission. This report describes in detail what the Geological Survey considers to be a desirable and comprehensive long-range program for future investigations leading to an adequate knowledge of the occurrence and availability of radioactive raw materials and other related elements.

Under Present Investigstions, the projects undertaken in the current fiscal year are summarized to show the scope of the present Trace Elements Program. The results of the program since its inception in 1944 were summarized in the report of January 1947 and are more fully described in the reports transmitted to the Atomic Energy Commission and its predecessor, the Manhattan Engineer District.

Under Plans for Future Investigations, the specific projects which should be undertaken are set forth. These projects have been selected as outstanding problems that require study in order to evaluate our domestic resources.

The personnel and space requirements, the rate of progress, and the over-all costs for the proposed program are considered under Plan of Operation and Cost of Operation.

[redacted]

PRESENT INVESTIGATIONS

The investigations of domestic resources of radioactive raw materials currently being conducted by the Trace Elements Unit consist of a continuation of work that was summarized in Trace Elements Investigations Report 35/ and a start on work of the type described under Plans for Future Investigations.

/ op cit, January 1947, pp.3-8.

As the objectives of the several broad groups of projects are described in that part of the report and as current projects are all very similar to some of the future projects the reader is referred to Plans for future Investigations in later pages of the present report for a description of the groups of projects and the objectives of individual projects. Current projects, therefore, are summarized here only very briefly under the appropriate group.

The present overall cost of the program of investigation is difficult to estimate owing to the considerable contribution to the work of the Trace Elements Unit made by other branches and sections of the Geological Survey. The direct allotment of funds to the Trace Elements Unit does not express more than one-third of the overall cost of the program. In particular, because of the high priority assigned to the study of radioactive raw materials by the Geological Survey, the work of the chemistry and physics laboratories has been largely in the field of uranium, thorium, and related elements, thus preventing the laboratories from performing their normal routine and research functions for

other activities and projects of the Geological Survey.

In summarizing under Cost of Operation the present and proposed future costs of investigation of domestic resources of radioactive raw materials, only those functions which contribute direct data on radioactive materials are included in the overall costs. Although the cost of gathering and preparing geologic data, samples, and reports from other operating units within the Geological Survey is not included in the overall costs of the program, the magnitude and value of such contributory work can scarcely be overemphasized.

Reconnaissance investigation of raw material resources

Mid-Central States.--Reconnaissance in Mid-Central States includes designated points of interest in Kentucky, Indiana, Illinois, Missouri, and Arkansas. Major emphasis is placed on black shales, cobalt-bearing deposits, and miscellaneous occurrences.

South-Central States.--Reconnaissance in the South-Central States includes designated points of interest in Oklahoma, Texas, and New Mexico. Major emphasis is placed on black shales, coals and asphaltites, carnotite-bearing sandstone, and miscellaneous occurrences.

Southeastern placers.--Reconnaissance of southeastern placers consists of sampling to determine the occurrence of monazite and other radioactive minerals in placer deposits in North Carolina, South Carolina, and Georgia.

Alaska.--Reconnaissance in Alaska includes points of interest in the Seward Peninsula and the Yukon River Basin. Emphasis is placed on radioactive minerals in placer deposits, and their significance as a guide to possible bed-rock sources.

Investigations leading to estimates of reserves

Placers.--Heavy-mineral concentrates from placer deposits in Idaho and the Carolinas have been collected and studied to determine the mineral composition, the content of related radioactive elements, and the reserves of monazite and uranium in these deposits.

Asphaltic sandstone.--Investigation of asphaltic sandstone in Utah includes large-scale sampling of the outcrops, and laboratory determination of the uranium content. The purpose is to provide a basis for a preliminary estimate of reserves and for a decision with regard to additional work.

Broader problems related to specific types of occurrences of radioactive substances

Phosphate.--Florida and Rocky Mountain phosphate deposits have been examined to obtain quantitative data. Large samples for metallurgical research by the Battelle Memorial Institute have been collected, chemical, mineralogical, and radioactivity determinations have been made on hundreds of samples, and samples of commercial phosphate from foreign deposits have been studied. The objectives of this project are further described under Plans for Future Investigations.

Black Shales.--The study of black shales has consisted of the collection of large samples for metallurgical research, the study of representative samples by chemical, mineralogical, and radioactive techniques, and continued field investigation to establish the principles governing the relation of uranium to the host rocks. This project is more fully described below.

Asphaltic sandstone.--Sub-surface samples of asphaltic sandstone have been collected from oil wells in Utah and, in conjunction with the appraisal

project (see above), the mode of occurrence of uranium and related elements in these deposits is being investigated in the laboratory.

Rare elements, not radioactive.--Research on other rare elements including those of special interest to the Atomic Energy Commission is being continued. This work involves quantitative spectrographic and chemical determinations for rare elements in thousands of samples, the compilation of pertinent data from the literature, and the preparation of a report on the geochemistry, occurrence, and distribution of these elements.

Laboratory projects

Research on the improvement of techniques for chemical, spectrographic, and other analyses have been conducted concurrently with a considerable volume of routine analytical work on uranium content. Research is currently concentrated on improving methods of analyses for small quantities of thorium. Preliminary mineralogical investigations have been made of some types of radioactive materials. Because of limitations of personnel and space, and the pressure of other duties, this phase of the work has lagged behind other activities. Adequate facilities, personnel, and funds for work of this kind are urgently needed if the program is to contribute to useful understanding of the relation of uranium and thorium to their natural environments.

Miscellaneous activities

Bibliographic.--The Survey is operating the bibliographic unit formerly attached to the Union Mines Development Corporation. The present function of this unit is to collect, classify, and tabulate data on radioactive materials by examining all publications, both foreign and domestic, As examination of bibliographic data for a geographic unit is completed,

a report is prepared summarizing the available data on the occurrence of uranium and thorium in that particular area.

Brookhaven Laboratory.--The Geological Survey has served as coordinating agency for the compilation of data bearing on the establishment of the Brookhaven National Laboratory. The information compiled concerns water supply, the type of bottom sediment, flora and fauna, and tidal currents in Long Island Sound and the Atlantic Ocean off shore from the proposed site of the laboratory.

PLANS FOR FUTURE INVESTIGATIONS

General statement

The investigations proposed herein are designed to provide sufficient data and knowledge of the occurrence and availability of uranium, thorium, and related elements to permit a more complete evaluation of domestic resources. The sudden elevation of uranium and thorium from a position of subsidiary economic interest to one of great scientific and strategic importance demands that sufficient data on their occurrence must be obtained as rapidly as new and reliable methods of investigation will permit.

Carefully planned research along well-considered theoretical lines of approach based on comprehensive application of geologic, chemical, and physical techniques to fundamental problems is required for the development of an adequate knowledge of the mode of occurrence and distribution of uranium, thorium, and related elements. This knowledge in turn is necessary for the prediction of favorable sites of occurrence, evaluation of resources, and the interpretation of data not expressly stated in terms of radioactive raw materials. Unless and until such

knowledge is acquired, progress in evaluating our domestic resources will be restricted to large-scale and indiscriminate sampling of all raw materials in the hope that by chance deposits of radioactive raw materials will be found. A program for the evaluation of these resources, therefore, requires the application and coordination of geophysical, geochemical, and geological techniques.

Such a program requires an organization with broad experience and competence in these related fields and it is felt that the Geological Survey is uniquely qualified to undertake this work.

The program of future work which the Geological Survey plans to undertake if support is forthcoming, is summarized for convenience in five somewhat arbitrary categories; (1) Reconnaissance investigations; (2) Investigations leading to estimates of reserves; (3) Investigation of broader problems related to specific types of occurrences of radioactive materials; (4) Comprehensive studies of specific areas; and (5) Laboratory projects. These plans will require not only intensive field work but also a well-equipped laboratory staffed by personnel competent to make the routine analyses and conduct the laboratory research necessary for successful execution of the program. All phases of the work must be coordinated into a single integrated program.

Many of the investigations outlined below are essentially long-range research projects requiring an indeterminate number of years for completion. Therefore, it is difficult to formulate definite plans even for three years in advance because of the inherent nature of research and the variable factors of funds, space, and personnel. Consequently

under Plan of Operation and Cost of Operation, the personnel, space, and funds necessary to implement the proposed program of investigations are estimated only for the next three fiscal years, 1948 to 1950 inclusive. By the end of fiscal year 1950 the program should reach stable proportions. In general, projects are arranged within groups according to their relative importance. Under "Plan of Operations" they are listed chronologically in order of importance without regard to the general grouping.

Reconnaissance Investigations

Reconnaissance investigations are necessary to disclose possible new sources of uranium and thorium, and to select the materials or areas that warrant detailed geological, mineralogical, and chemical investigation. Reconnaissance projects are guided by: (1) radioactivity measurements of samples collected in the mill, smelter, and raw materials projects and from other sources; (2) probable geological associations of uranium and thorium already established by the Trace Elements program; and (3) information derived from the geologic literature.

Upon completion of the reconnaissance projects outlined below, large areas, principally in the Central Plains States and in the Gulf and Atlantic Coastal Plains, will scarcely have been touched upon. Subsequent information may dictate that such areas be given more attention.

Reconnaissance projects will be undertaken in the following areas:

Northeastern States.--The New England States, New York, and Pennsylvania.

North-Central States.--Michigan, Wisconsin, and Minnesota

South-Central States.--Texas, Oklahoma, New Mexico, and Arizona.

Northwestern States.--Idaho, Washington, and Oregon.

Nevada.--A state-wide survey.

Alaska.--Includes only the more accessible portions at this time.

These areas are included in the areas of future investigations shown on Maps 1 and 4 that accompanied Trace Elements Investigations Report 3 /.

/ op. cit., January 1947.

Work planned in Alaska is still largely of a reconnaissance nature and selection of the precise areas in which more detailed appraisal of reserves would be profitable will depend on results of continuing reconnaissance.

Investigations leading to estimates of the grade and tonnage of reserves

Investigations leading to an estimate of reserves generally will be done in sufficient detail to determine inferred reserves or at least the order of magnitude of tonnage and grade of radioactive raw materials. It is expected that many of the investigations will be intimately related to projects falling in one of the other categories and that the consequent exchange of information will result in more effective work. An estimate of reserves is a primary objective in the projects described below.

Vanadium-carnotite areas of the Colorado Plateau.--Recommendations for physical exploration of the carnotite-bearing vanadium ores of the Colorado Plateau were submitted in more detail on April 4 at the request of the Atomic Energy Commission. They are, however, part of the overall program for investigation presented in this report. The known ore in present indicated reserves is variously estimated to be sufficient to

supply the existing mill capacity for a period ranging from one to five years. The project outlined here aims to increase known reserves by indicating extensions of the larger known deposits and locating unknown minable deposits.

In demonstrating the presence of new ore with a minimum amount of drilling, it is not planned to define completely the extent of all ore bodies discovered. The exploration would not yield sufficient data to make accurate estimates of ore and it would not disclose all the ore in favorable areas; however, it would give assurance of actual reserves and prove the presence of new ore bodies of sufficient size to justify their complete delimitation by additional exploration and development.

If the need is such that reserves found by the project outlined above should be measured more accurately by "blocking out" or perhaps by development, the exploratory drilling could be followed by more closely spaced drillings and even by actual mine development. Work of this detailed type would normally be done by the Bureau of Mines or individual mining companies.

In connection with the drilling gamma-ray logs will be made of the holes for comparison with results of sampling.

Both parts of the project will require about 400,000 feet of drilling to indicate two years' supply of ore at 1943 mill capacity.

Asphaltic sandstone.--Investigation of asphaltic sandstone in the vicinity of Temple Mountain, Emery County, Utah, will be continued to determine the origin of the uranium and its relation to the asphalt and whether or not this type of raw material may be a low-grade uranium ore offering sufficient tonnage to warrant metallurgical research.

Rocky Mountain phosphate.--The Geological Survey has planned, totally apart from the Trace Elements program, an expansion of the investigation of western phosphate resources to provide complete geologic information on these important phosphate deposits. The information available from this program together with additional work planned as part of the Trace Elements program will ultimately make possible an evaluation of uranium reserves in the whole phosphate field.

Correlated with this work will be a comprehensive investigation of the relation between uranium and phosphates as described further below (p. 14).

Monazite placers in the Carolinas.--Continued study is planned of the nature and distribution of the heavy-mineral concentrates in placer deposits based on comprehensive collection of samples in the field, and on mineralogical separation and uranium and thorium analyses in the laboratory. This study should result in an overall evaluation of reserves of monazite. It will be correlated with a more comprehensive study of the monazite-bearing granites of the Carolinas that is outlined on page 19.

Idaho placers.--Investigation of monazite and related radioactive minerals in Idaho is planned and would be similar in method and requirements to that performed on the Carolina placers.

Mineralized districts of Front Range, Colorado.--The igneous rocks and mineral veins of the Front Range in Colorado show greater than normal radioactivity, and locally the radioactivity of these rocks is much greater. A few small mines in the area have produced uraninite (a mineral rich in uranium), and the ores from some tungsten and fluorite mines contain a maximum of 0.072 percent equivalent uranium. The rocks and veins in the more promising areas should be carefully investigated and adequate sampling should be undertaken where necessary.

Mineralized districts of Montana.--This investigation will be essentially the same as that in the Front Range of Colorado. Particular attention will be shown to veins and zones other than those now being worked for other metals.

Broader problems related to specific types of occurrences of radioactive sbustances

Most of the projects planned to study broader problems of specific types of occurrences of radioactive substances are long range. Their primary aim is to improve our knowledge about the geologic relations of uranium and thorium in the expectation that by so doing, principles governing those relations will serve as a better guide to the resources of those metals. Many phases of the work in other groups of projects would be ultimately connected with the types of investigation outlined here.

Morrison formation.--A comprehensive study is planned of the Salt wash member of the Morrison formation, the zone which contains the important carnotite ores of southwestern Colorado and southeastern Utah. The aim of this study will be to determine the conditions of deposition, the character and drainage of the major streams which controlled the deposition, and the source of the materials which form the ore-bearing beds. Answers to these broader questions are necessary to understand the localization of the ore so that it can be used as a guide in prospecting. This work will require extensive field and laboratory study and will involve an exhaustive inquiry into the sedimentary petrology of the deposits. These investigations will be correlated with the propsecting program already outlined (see p. 10) and with the areal mapping project described below (p. 18). Information gained from all three of these projects should prove mutually beneficial.

Southeastern phosphate.--As shown by Map 4, entitled "Known deposits containing more than 100 tons of metallic uranium," accompanying the report of January 1947_/, it is clear that phosphates and black

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_/ op. cit., Memorandum Rept.

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shales contain the bulk of the known uranium reserves of the United States. Accordingly, the Geological Survey plans to undertake a comprehensive investigation of the mineralogy and petrology, mode of occurrence, and probable conditions of deposition of the Florida phosphate and associated materials, including the uranium. In this investigation special attention will be given to variations in the uranium content of the phosphate and associated rocks, and additional samples will be collected for the metallurgical tests at Batelle Memorial Institute. As not all the Southeastern phosphate deposits contain uranium, it is also important to know what are the significant differences between the various deposits. The investigation will therefore include a general examination of all the southeastern phosphate deposits. This study, similar to that contemplated for the black shales, will be a major investigation which will require the work of a number of geologists for some years.

Rocky Mountain phosphate.--In addition to and in conjunction with the general appraisal of reserves in the Rocky Mountain phosphate field, a study of these deposits parelleling that of the southeastern phosphates is planned. The Geological Survey, totally apart from the Trace Elements program, expects to expand immediately the investigation of western phosphate deposits. Data and samples resulting from this investigation will be available to the Trace Elements program.

Black shales.--Certain black shales and boghead coals are possible sources of uranium comparable to the phosphatic rocks. A notable example is the Swedish kolm and the black shales with which it is associated. Although no close analogues of the kolm have been found in this country, the extensive Chattanooga black shale is appreciably radioactive. A comprehensive geologic study of the mineralogy and probable origin of various types of black shales is needed to indicate which type is most likely to be favorable for the accumulation of uranium. The investigation would also develop information on possible by-products. The results of this study would make possible a more effective evaluation of domestic resources and the indirect appriasal of foreign resources. This is a long-term investigation which will require the services of a number of geologists, chemists, and physicists for several years.

Mill, smelter, and raw material sampling.--Thousands of mill, smelter, and raw material samples have been collected and examined for uranium, thorium, and other rare and uncommon elements. The data thus obtained have furnished many useful leads in planning reconnaissance and research projects and have made possible the evaluation of many raw materials as sources of uranium, thorium, the rare earths, and other useful metals. This investigation and the data already accumulated will be subjected to a more thorough study than has thus far been possible. Adequate laboratory facilities are essential as it is estimated that this project will contribute about 500 samples per year for laboratory analysis.

Late-crystallizing phases of igneous rocks.--Late-stage magmatic products in the solidification of some masses of intrusive igneous rock, especially those of silicic and alkalic character, have considerably

higher radioactivity than average igneous rock. A varying content of radioactive elements is also found in several accessory minerals which are among the early products of crystallization in some igneous rocks. Further study of both of these stages in the solidification of the intrusive igneous rocks with respect to the concentration of the radioactive elements seems highly desirable on the basis of the reconnaissance work up to this time. Significant deposits of radioactive materials may be found during the cource of investigations, and information obtained on the relative stages at which concentration of the radioactive elements occurs would furnish a guide in further search for possible workable deposits of these elements.

Asphaltic sandstone.--If results of present work warrant, the investigation previously described (p. 5) will be continued.

Gamma-ray well logs.--Many companies producing oil and potash have systematically logged gamma-ray activity of the strata penetrated in their wells. Most of this information is in the files of the interested companies and has not been examined. A determined effort will be made to obtain access to this information, as it may be a most useful guide to possible new source rocks of uranium and thorium.

Radioactivity of modern marine sediments.--Many of the most extensive low-grade deposits of radioactive materials in this country and elsewhere (the Florida phosphates, the Phosphoria formation, the Chattanooga shale, the black shales that contain the Swedish kolm) are of marine origin. It is significant that many oceanographical investigations have shown that uranium, thorium, and several of their daughter elements are differentially segregated by various biologic, physical, and chemical processes that operate in the sea today. It is readonable

to suppose that the principles governing the segregation of radioactive materials in sea water, marine organisms, and bottom sediments today may afford valuable clues to a better understanding of the factors that controlled deposition of similar materials in marine sediments of the geologic past. A study of available oceanographic and other data on the occurrence of radioactive materials in modern marine sediments will be undertaken. Such a study may lead to the formulation of at least some generalizations applicable to ancient sediments. Some of these generalizations should, if possible, be tested by experiments in the laboratory and by the collection of bottom sediments at certain critical localities.

Helium-bearing natural gas.--Alpha particles emitted by radioactive disintegration of uranium or thorium become helium atoms by attrating two electrons. Thus it is reasonable to infer that abnormal accumulations of helium may be an indication of nearby sources of uranium or thorium. But an important question remains, namely, whether the helium is concentrated from disseminated deposits of large extent or from a more localized deposit of high-grade ore. The problem will be undertaken to determine whether helium-bearing natural gas can be used as a guide to source rocks of uranium and thorium.

Radioactive spring and oil-field waters.--In many places mineral springs and well waters are radioactive and some of these waters deposit radioactive materials. The objective in a study of radioactive waters will be to determine whether or not the radioactive materials, presumably radon gas and its daughter elements, are supplied by nearby rocks that contain appreciable quantities of uranium and thorium. Such a study would involve a careful examination of the circulation of ground water in the vicinity of the springs and wells.

Geothermal gradients.--The energy released during radioactive decay is largely dissipated as heat and it is therefore logical to expect that geothermal gradients will be steeper near large deposits of uranium and thorium than elsewhere. However, clear-cut evidence in support of this expected relationship seems to be lacking. It is proposed to examine this problem of radioactive heating quantitatively, considering the heat released by a given deposit, the thermal conductivity of adjacent rocks, and the available evidence of geothermal gradients. It seems probable that such an examination will show the need for measuring new geothermal gradients in certain critical areas. If the expected relationship is confirmed, geothermal gradients may become one line of evidence useful for detecting and estimating the extent of buried deposits of radioactive minerals.

Comprehensive studies of specific areas

Comprehensive geologic studies of some areas of radioactive raw materials are important to a knowledge of the occurrence and distribution of uranium or thorium therein and to a more effective evaluation and possible utilization of the resources. Such studies are planned for three areas. Doubtless investigations in other places pointed more directly toward appraisal of reserves or the special studies of the type just described will suggest additional area studies.

Vanadium-uranium area of southwestern Colorado and southeastern Utah.--Regional geologic mapping of the main parts of the carnotite-bearing region of southwestern Colorado and southeastern Utah is planned in connection with exploration for deposits of carnotite ore (p. 10) and study of the ore-bearing member of the Morrison formation (p. 13). This geologic mapping is necessary for the following reasons: (1) The

deposits have a wide but spotty distribution, many are small, and only a few containing more than 50,000 tons have been mined; (2) Most of the known deposits which have been discovered at the outcrop and followed underground by mining are now completely or partly exhausted; (3) New discoveries will have to be made by the more costly methods of subsurface prospecting; and (4) Regional mapping would help to guide subsurface prospecting more efficiently and economically by indicating regional trends, variations in the character of the deposits and conditions of localization of ore and permitting comparative evaluations of the chances of finding ore in different areas.

Topographical maps which can be prepared by the Topographic Branch of the Geological Survey are essential for effective interpretation of the geology.

This investigation would be a continuation of work previously started for evaluation of the vanadium and other resources of this region.

Monazite-bearing granites, streams placers, and beach sands of the Carolinas.--The Geological Survey plans to make a reconnaissance geologic map of the monazite-bearing granite of the Carolinas. This is the source rock of the most extensive monazite deposits in North America, the placer deposits of the Carolinas. This mapping together with additional sampling of alluvial concentrates in the streams that drain the belt of outcrop would provide data on which to base a detailed investigation of the more promising areas of monazitic sands and guide reconnaissance examinations to trace the monazite down stream, and if possible into beach sands of parts of the Atlantic Coast.

The Carolina monazite is known to vary in composition and in its physical properties. The project will require considerable laboratory

study and many analyses to discover the relations of differences in composition, radioactivity, specific gravity, and magnetic properties of the pure monazite.

Schroeckingerite area of Wyoming.--A small and relatively low-grade deposit of schroeckingerite (hydrated uranium carbonate) in Wyoming has been examined in sufficient detail to determine the probable order of magnitude of the reserves. The deposit, however, raises many unsolved questions about the conditions favorable to deposition of this unusual mineral and the ultimate source of the contained uranium. For these reasons this occurrence merits a thorough study of the mineralogy, chemistry, and geologic setting, in order to assess the likelihood of more extensive deposits in the vicinity or in other localities.

Laboratory projects

Nearly all the foregoing projects will involve more or less laboratory work in the form of chemical, spectrographic, and radiometric analyses, and mineralogic and petrographic examinations. Many of them will also require considerable research on problems that must be conducted in the laboratory. Without adequate laboratory facilities for research and a large volume of routine analyses a well-founded knowledge of the mode of occurrence and origin of radioactive raw materials cannot be attained.

Further research in the improvement of various techniques for determining the presence, amounts, and nature of radioactive substances is essential to reducing the load of routine work involved in a comprehensive program and to evaluating information obtained in the field. Typical research problems to be undertaken in the laboratory are:

Chemical.--(a) Accurate but slow methods of chemical analysis for small amounts of uranium have been developed but more rapid methods

are needed. Progress on determining thorium has not been so rapid and studies are being continued by the Geological Survey.

(b) Ratio of uranium and thorium to other elements.--Intensive research is needed to determine the ratio in naturally occurring materials between uranium and organic carbon, thorium and carbon, uranium and the rare earth elements. Highly significant information on the mode of occurrence may result from such research. This work will involve many complete or partial analyses of rocks and minerals. These should be directly integrated with geologic field studies.

Spectrographic.--The application of the spectrographic method to the quantitative determination of uranium and thorium in the smaller ranges of concentration has not been entirely successful to date. The time consumed by chemical methods of analysis is a severe handicap at all stages of evaluation of the quantity and usefulness of radioactive raw materials. Because of the large amount of analytical work that will be required by the various investigations proposed here, methods of improving the sensitivity and accuracy of the spectroscope should be pursued energetically.

Radiometric.--Many problems remain to be solved in evaluating measurements of radioactivity in terms of uranium and thorium content, such as the effect of the size to which a sample is ground, packing effect in samples of different densities, and effect of storage of samples. Research is needed on efficiency of counters for beta-ray and gamma-ray measurements as applied to controlling radioactivity determinations, on the shielding effect of various natural substances, and on the development of techniques for the direct measurement of thorium by radioactivity determinations. Solution of these problems is pertinent to the signi-

ficance and usefulness of radiometric measurements in field and laboratory.

Mineralogical and petrographic studies.--Investigations to determine the mineral or minerals that carry radioactive materials have, because of the pressure of other duties, lagged behind the recent investigations that have disclosed new and hitherto unknown associations of uranium. Information on mineralogy and petrography of the radioactive materials is important as a guide in further prospecting and in suggesting methods to recover uranium and thorium from the materials that carry them. Not only must the backlog of accumulated work be undertaken but work on projects enumerated here must be kept current. Comprehensive mineralogical and petrographic studies using various techniques of micromineralogy will be an essential component of all investigations of radioactive raw materials. Although the actual work employs laboratory techniques, such a program must be well integrated with programs of field investigation, especially those related to fundamental geologic research and the beneficiation of ores.

Miscellaneous projects

Bibliographic.--It is planned to continue to use the bibliographic unit in the collection and classification of data on radioactive materials by examining all foreign and domestic publications. Such services will be maintained at approximately the present rate although the objectives and methods will be modified to conform with our advance in overall knowledge of radioactive raw materials. It is expected that the unit can also assemble information that will be of value in appraising potential foreign resources of radioactive raw materials by study of fragmentary data which is not expressed directly in terms of uranium and

thorium. Nearly all geologic investigations require examination of published information and it is expected that the bibliographic unit, within its field of competence, can contribute to this phase of several of the projects enumerated in this report.

Topographic mapping.--Topographic mapping in the area of the Colorado carnotite ores will be undertaken to provide adequate base maps for the large scale geologic mapping needed to guide sub-surface prospecting and for preliminary planning of mine development and access roads. The cooperation of the Topographic Branch of the Geological Survey will be required. As the program progresses, topographic mapping may prove to be desirable in other places.

Water resources.--The special facilities, techniques, and skills of the Water Resources Branch of the Geological Survey can be expected to contribute materially to phases of some problems. Typical problems in which such participation would be useful are: (1) The relation of the movement of graund water through the carnotite-bearing member of the Morrison formation in the Colorado plateau to the distribution of uranium; and (2) Investigation of radioactivity in spring and oil-field waters.

Recommendations for other research

Many other problems that are of direct geologic interest and significance or that depend upon the application of geologic information and principles fall into a somewhat different category from those listed above because of the facilities required. The investigation of problems of this type calls not only for geological guidance and interpretation in varying degree, but also for scientific personnel and instruments not normally available in a strictly geologic organization. For such problems a broad and flexible pattern of co-operation with other AEC laboratories and contractors seems desirable. This pattern should be broad enough to include

(a) projects in which the Geological Survey would sub-contract specialized instrumental work to other laboratories, (b) projects in which other laboratories or contractors would use Survey personnel for the collection of samples and as consultants, and (c) projects on which employees of the Survey and of one or more other laboratories would work together, on an administratively equal basis, as joint authors.

Problems of this kind that deserve investigation both for their theoretical significance and possible application, include (1) evidence of natural fission in the geologic past, (2) variations in the U_{235} - U_{238} ratio in different types of deposits, (3) the degree of radioactive equilibrium in different materials and different geologic environments, and (4) the methods of treatment to recover uranium from different kinds of source materials. Exchange of information between the Geological Survey and laboratories engaged in research of this kind would be mutually beneficial. Provision should be made for ready access by one agency to related work in another agency in order to obtain such exchange so that results may be more readily applied to the problems of each.

PLAN OF OPERATION

General statement

The plan of operation for conduct of the program of investigation outlined herein includes consideration of: (1) The organization for carrying out the program; (2) Space for such an organization; (3) The schedule of work; and (4) Other related problems.

Organization

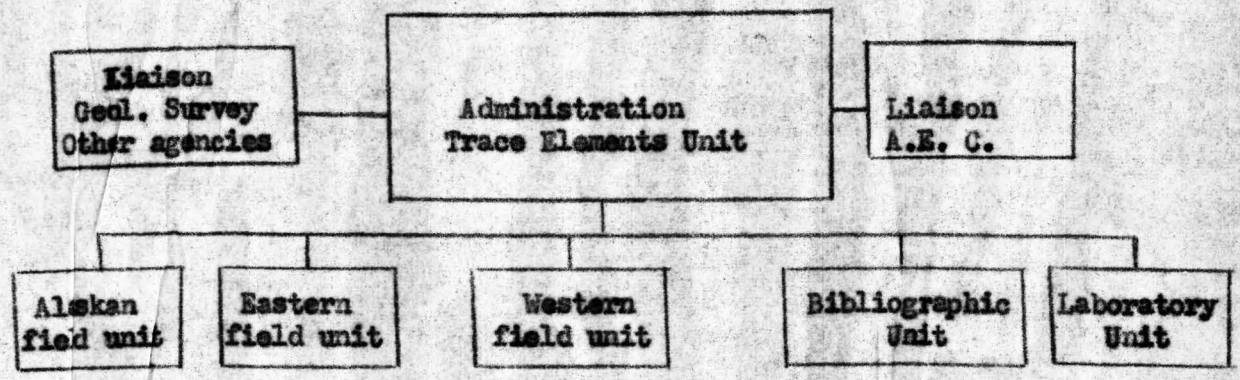
The general scheme of organization for conduct of the program is shown in Exhibit I. This organization will require expansion of the geologic field staff, a greatly increased staff and facilities for related chemical, physical, and mineralogic work, and centralized administrative control and coordination of the interrelated geologic, mineralogic, chemical, and physical investigations.

Geologic field units.--In the organization of the unit men engaged primarily in geologic investigations are assigned to Geologic Field Units.

[redacted]

Exhibit I

Organization of the Trace Elements Program



[redacted]

The geologic personnel required to staff the augmented program proposed here will require a large increase over the numbers now engaged. Securing or training of competent men can not be done hurriedly but they can be obtained by recruitment of new personnel and transfer of present personnel once the program is approved.

Laboratory unit.--In support of the geologic research a large staff of chemists, physicists, and mineralogist-petrographers will be required. This staff will be needed not only for routine analysis of uranium and thorium, but especially, if the program is to achieve the anticipated objective of understanding why some associations are particularly favorable for these elements, for complete rock analyses, spectrographic analyses of associated elements, and research on chemical methods and on the geochemistry of these elements.

Neither the present facilities nor staff of the Geological Survey's laboratories are adequate for the scale of the contemplated program. Thus, the facilities now available for such work would be a serious restriction to smooth operation of the program. Under the necessity of war at least half of the Geological Survey's laboratory personnel and facilities were devoted to wok on uranium and thorium. This was done, however, at the expense of attention to important work on other mineral resources and broader aspects of geochemistry. Consideration must now be given to restoring the balance upset by the war and making the laboratory facilities once again available for their normal functions of supplementing all phases of the Geological Survey's work. Thus, an expansion of facilities is necessary not only to permit resumption of other work but also to meet the anticipated demands of an expanded program of investigation of radioactive raw materials.

The laboratory facilities for research and routine analyses will

have to be expanded to obtain the proper balance between the various phases of the program. It is estimated that demands will be made for the various following types of determinations:

Number and Type of Determinations per Year

Radioactivity	Chemical	Spectrographic	Mineralogical
9000	5000	5000	1500

In addition to routine analyses, provision must also be made for such research as development of new techniques and the relations between uranium and thorium and other constituents of the enclosing rocks.

These mineralogical, chemical, and physical analyses and the accompanying research have a close affinity to other phases of the program. Effective coordination of all phases of the program requires that they be under the same general supervision and grouped in one administrative unit. For this reason a special laboratory is necessary and will be set up by the Geological Survey if funds are available.

The setting up and staffing of a laboratory group coordinated with the rest of the program will require much money and additional space. Nevertheless, such coordinated supporting activities are essential to the success of the program. The space requirements are further elucidated below and the funds necessary for laboratory facilities are discussed under Cost of Operation.

Bibliographic unit.--The effectiveness of the program also can be aided and improved by the maintenance of the Bibliographic Unit and coordinating its work with the program presented here. For reasons similar to those applicable to the laboratory group it should also be under the same administrative control as the geologic and laboratory groups.

Liaison:--The administration of the organization would provide liaison with the Atomic Energy Commission and its subcontractors, such as the Battelle Memorial Institute, to which its activities are related, and with other sections and branches of the Geological Survey. For example, another section of the Geological Survey is conducting investigation of western phosphate resources. The Trace Elements Unit as a functional part of the Geological Survey is in a position to relate results of this work, which is important on its own merits, to the uranium investigations, as well as to participate in some phases of that work. It is expected that, similarly, the Trace Elements Unit will be in a position to relate other investigations by the Geological Survey to the investigations of uranium, always consistent with the demands of security.

Of paramount importance would be the maintenance of liaison with other agencies and laboratories engaged in research on radioactive raw materials or closely related fields such as those described above under "Recommendations for other research". For maximum gain in knowledge and to prevent needless duplication, all data from other sources which are pertinent to the Geological Survey's program should be available through liaison.

Space

At the present time or in the recent past about 10,400 square feet of space has been used in the work of the Trace Elements Unit. When renovation of the Geological Survey's chemical laboratories is completed in the near future, the facilities of the laboratory, as pointed out above, will have to be shared with the long-deferred activities related to geologic investigations other than of radioactive raw materials, thus reducing the total space allotted to investigation of radioactive materials.

The proposed program, however, will require not only a greatly enlarged staff but also additional space for this staff and facilities. For smooth functioning of the internal operation of the unit, it is believed that its administration, offices for part of the field personnel, and most of the laboratory personnel and functions should be centrally situated. For good coordination of the work of the Trace Elements Unit with other sections and branches of the Geological Survey and with other related agencies, its administration should be centered in or near Washington. Thus it is probable that space for about 130 people and laboratory facilities in or near Washington will be required by the end of fiscal 1949.

For effective work a well-equipped modern laboratory will have to be set up with facilities for making the necessary chemical, spectrographic, X-ray, and radiometric measurements, for undertaking comprehensive mineralogical and petrographic investigations, and for preparing material for all the foregoing activities.

When the laboratories have attained their maximum rate of activity, it is estimated that about 35,000 square feet of space will be needed for the laboratory facilities. If the administrative and geologic personnel could not be adequately housed in space now available to the Geological Survey, an additional 21,000 square feet would be needed.

Acquisition of the proper space is a problem that will require careful attention and may call for the combined efforts of more than one agency.

Schedule of projects

In determining the schedule of work the relative importance of specific projects, the rate at which competent personnel can be obtained or trained,

and the rate at which adequate facilities can be prepared are considered. Generally there is some lag between the starting of a field investigation and the time the maximum load from that particular investigation is transmitted to the laboratory. It is believed, therefore, that the program of field investigation can be enlarged more quickly than the supporting laboratory activities. After allowing for all these factors it is estimated that the program should reach a maximum stable rate in the fiscal year 1950. At the present time it is expected that projects will be started within the fiscal years indicated and in the order listed below:

1948

Vanadium-carnotite areas of the Colorado Plateau including
  Prospecting by drilling
  Study of the Morrison formation
  Areal geologic mapping
Asphaltic sandstone
Alaska reconnaissance
Southeastern phosphate
Black shales
Rocky Mountain phosphate
Reconnaissance in Northwestern States
Monazite-bearing granite and placers of the Carolinas
Reconnaissance in Northwestern States
Mill, smelter, and raw material sampling

1949

Idaho placers
Mineralized districts of Front Range, Colorado
Late-crystallizing phases of igneous rocks
Gamma-ray well logs
Reconnaissance in South-Central States
Reconnaissance in North-Central States
Radioactivity in modern marine sediments
Reconnaissance in Nevada

1950

Mineralized districts of western Montana
Helium-bearing natural gas
Wyoming schroeckingerite area
Radioactive spring and oil-field waters
Geothermal gradients

Many of the projects enumerated above, for example, the investigation of carnotite ores, phosphates, and black shales, and reconnaissance in Alaska, will continue through several fiscal years. The length of time required for many individual projects will depend on the results obtained, on reappraisal of the merits of various possible sources based on new information both geologic and metallurgical, and the rates at which manpower and funds are available. As a result, the precise length of time for most of the projects is now indeterminate. These reasons also make it difficult to formulate plans for individual projects even three years in advance. Consequently the schedule of operations ispresented only through fiscal year 1950.

The rate at which it is estimated that the work can be done in terms of total man-years per year is summarized in the following table of personnel who would be regular employees of the Geological Survey. The estimate does not include the personnel of drilling contractors nor temporary field assistants.

Estimated rate of work by fiscal years

	1947	1948	1949	1950 et seq.
Man years of work	40	109	173	203

Other related problems

In developing the organization and arranging for the facilities necessary to establish the comprehensive program of research, some other problems deserve consideration.

Continuity of support.--Reasonable assurance of opportunity to continue the program over a period of years is necessary for several reasons. In the first place, the initial expenditures required for the

laboratory, essential research, and analytical work, as indicated in discussing Organization above and Cost of Operation below, are large. These expenditures can be justified only on a long-term basis. Secondly, the program cannot achieve the desired objective on a short-term basis, for the large amount of data that must be acquired will require time for proper evaluation and interpretation. Thirdly, from two to three years will probably be required to recruit and train the full complement of competent personnel necessary for the maximum rate of operations.

Need for excepted appointments.--obtaining the competent personnel necessary to staff and manage many phases of the program, especially the supporting laboratory, will be a major problem in achieving anadequate rate of operations. In competition with commercial concerns able to make commitments quickly, and having great freedom in rates of pay, the recruiting will be difficult. For this reason, the authority to hire without regard for existing regulations, as provided for in the Atomic Energy Act of 1946, Sec. 12 (a) (4) should accompany any funds allotted. Such authority would have the advantage that commitments for promising people could be made without the long delays inherent in the normal procedures under present regulations, during which a man may turn elsewhere.

COST OF OPERATION

Funds available in 1947

On the accompanying exhibit II are shown the funds available for Trace Elements investigations in the fiscal year 1947. These include the funds for work directly related to the Trace Elements investigations, and operating under the same security control. They do not include any part of the cost of other investigations conducted by the Geological

Survey from which much information is readily available to the Trace Elements Unit.

It should be noted that the amount expended in the laboratory for routine analyses and research in support of field investigations was much curtailed owing to the closing down of the Chemical Laboratory for long over-due renovation. The amount expended for such work was only 20 percent of the cost of field investigations and their direct administration, whereas in previous years laboratory expenditures equaled 80 percent of the cost of field investigations and the amount of work was still inadequate to answer many important problems on the geochemistry of uranium and thorium. In future investigations the ration of laboratory expenses to field expenses will have to be more nearly commensurate with the ratio prior to 1947, if the laboratory is to furnish proper support to the field program.

Status of funds transferred from Atomic Services.--During 1947 funds transferred to the Geological Survey under the Atomic Services section of the War Department's 1947 Appropriation Act have been used to supplement the domestic investigations, and to maintain and furnish the space for a bibliographic unit transferred from the Union Mines Development Corporation. Because of the inevitable hiatus in policy decisions involved in the transfer of authority over matters of atomic energy from the old agency to the new, execution of plans for use of all the transferred funds has been delayed. At the present rate of expenditure about $120,000 will be unused at the end of the current fiscal year. The appropriation symbol for this fund, 217/80920, indicates that it is a two-year allotment. If any balance can be retained for use in the fiscal year 1948, it could be considered available for increasing

the rate of investigations, or for expansion of the much needed laboratory facilities. In this way expansion to the rate proposed in the program outlined here could be attained more efficiently.

Funds necessary in succeeding fiscal years

The projects described above under Future Investigations represent an increase in the rate of investigation and will require funds larger than those previously available for similar work. The Geological Survey expects to contribute as much of the necessary funds as can be obtained by increase in its total budget and not at the expense of its other activities. Any difference between the amount which would thus be available and the total amount required can only be met by transfer from the Atomic Energy Commission. The total amount required, the amount currently available, and the supplemental amounts necessary to carry out the program at the proposed rate are given by fiscal years in exhibit II.

As pointed out above, effective operation of this program requires a laboratory properly staffed and equipped for chemical, physical, and mineralogical work in support of the more strictly geologic aspects of the work. Because of the already overcrowded conditions, facilities greatly in excess of those now operated by the Geological Survey are necessary. As the effective coordination of supporting laboratory functions with the geologic activities requires that both be under the same supervision, the financial requirements for fiscal 1948 include the amount necessary to equip properly a laboratory of a size required for handling the estimated volume of work. This figure assumes that building space which can be adapted to laboratory equipment without undue alteration is available or can be procured. If a structure

Exhibit II

Estimated Expenditure by Fiscal Years

	1947	1948	1949	1950 et. seq.
Operations (reconnaissance, detailed geologic research, and supporting projects)	214,300	1,295,000	2,041,000	2,178,000
Fitting out laboratory for supporting projects		525,000 1/		
Adapting building for laboratory use		500,000 2/		
Rent or interbureau transfer for space		120,000	120,000	120,000
Total	214,300	2,440,000	2,161,000	2,198,000
Source of Funds:				
Geological Survey	143,000	243,100	350,000 4/	400,000 4/
Atomic Services transfer from War Department	71,300	128,700 3/		
Deficiency		2,068,200	1,811,000	1,798,000
Total	214,300	2,440,000	2,161,000	2,198,000

1/ These items are non-recurring capital expenditures.

2/ This item is a crude estimate -- see text. If a suitable building can be found it may be eliminated entirely

3/ The account number of this item 217/80920 indicates it is a two-year allotment. The amount shown is the balance from $200,000 not expended in 1947. It is considered availsble on the assumption that permission to carry over to 1948 will be granted.

4/ See text

has to be altered, additional funds will be necessary in an amount that can only be determined with reference to a specific building. Tentatively it is believed that such alterations might equal the cost of the laboratory equipment and installations. Such an amount is, therefore, shown in the estimate for 1948 to provide for this contingency.

The cost of fitting up and installing laboratory facilities and any building alterations would be a non-recurring item not applicable to fiscal years after 1948. Besides the direct costs of operations, it is estimated that either a rental cost for leasing commercial space or a reimbursable charge to the Public Building Administration would be incurred. This, including guard services, would amount to about $120,000 annually.

SUMMARY OF PLANS, RATE OF WORK, AND COST

Future Projects in order of commencement /

1948 Fiscal Year

Laboratory investigations a continuous activity
Vanadium-carnotite areas of the Colorado Plateau
Asphaltic sandstone
Alaska reconnaissance
Southeastern phosphate
Black shales
Rocky Mountain phosphate
Reconnaissance in South-Central States
Monazite-bearing granite and placers of the Carolinas
Reconnaissance in Northwestern States
Mill, smelter, and raw material sampling

1949

Idaho placers
Mineralized districts of Front Range, Colorado
Late crystallizing phases of igneous rocks
Gamma-ray logs of wells
Reconnaissance in Northeastern States
Reconnaissance in North-Central States
Radioactivity of modern marine sediments
Reconnaissance in Nevada

1950

Mineralized districts of western Montana
Helium-bearing natural gas
Schroeckingerite area of Wyoming
Radioactive spring and well waters
Geothermal gradients

/ Most projects continue more than one year and are listed only in the year they are started.

	Estimated rate of work by fiscal years			
	1947	1948	1949	1950 et. seq.
Man years of work	40	109	173	203

Estimated expenditure by fiscal years			
1947	1948	1949	1950
$214,300	2,440,000	2,161,000	2,198,000