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TRACE ELEMENTS WORK OF THE GEOLOGICAL SURVEY

By
V. E. McKelvey

This preliminary report is released without editorial and technical review for conformity with official standards and nomenclature, to make the information available to interested organizations and to stimulate the search for uranium deposits.

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GEOLOGY AND MINERALOGY

TRACE ELEMENTS WORK OF THE GEOLOGICAL SURVEY

By V. E. McKelvey

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ABSTRACT

This report summarizes the general scope of the Geological Survey's Trace Elements investigations, their interrelationships, and the trends we expect them to take in the future.

Most of our effort has been concerned directly with the search for and appraisal of uranium deposits. Even though the chief emphasis in our work has been on economic objectives, it has been necessary to study many diverse problems and to apply many fields of knowledge to reach or approach the desired objectives. A general outline of these investigations includes research on (1) analytical methods, (2) petrographic instruments and tools, (3) systematic uranium mineralogy, (4) geochemistry of uranium and associated elements. (5) geobotanical prospecting, (6) geophysical investigations, and (7) isotope geology.

Although much has been done, much remains to be done and it is our hope that the information presented will help draw attention to important problems ahead and at the same time help provide a basis for the coordination of our respective activities.

TRACE ELEMENTS WORK

The Geological Survey's intensive work on uranium began early in 1944 when we were cautiously advised that uranium had become a critical material. Although we had done considerable work on the carnotite deposits of the Colorado Plateau prior to this time and in addition had studied the geology of some of the uranium-bearing districts of the Colorado Front Range and investigated the composition and mineralogy of a few uraniferous rocks and minerals, we shared the general ignorance prevaling in 1944 on the geology of uranium. The intensive work undertaken since 1944, first on our own, then in fiscal years 1946 and 1947 on behalf of the Manhattan District and since 1948 under the auspices of the Raw Materials Division of the Atomic Energy Commission, probably has uncovered more problems than it has solved but I feel safe in saying that it has brought us to the point now where we know as much if not more about the geology of uranium as we know about most other base and precious metals. To an exploration geologist this is perhaps just another way of saying that as a result of intensive effort our knowledge of radioactive materials in nature is now merely woefully inadequate instead of pitifully inadequate as it was 10 years ago, but by whatever standards we choose, progress has been measurable.

Because our work has involved a good many hundreds of man years it is not possible to give details on work already accomplished and planned for the future, but I do want to indicate the general scope of our investigations, their interrelationships, and the trend we expect them to take in the future. Messrs. Rabbitt, Butler, Botinelly, Stead, Cannon, and Faul will tell you more about our work in the several fields to be discussed in later sessions. In addition, I hope you will obtain a fair idea of the investigations completed and planned for the near future from the lists compiled in Trace Elements Investigations Reports 200 and 201 which most of you now have. I think you will see from the information presented that although much has been done, much remains to be done and it is our hope that the information presented will help draw attention to important problems ahead and at the same time help provide a basis for the coordination of our respective activities.

Until recently the directives guiding our work for both the Manhattan District and the Atomic Energy Commission have required us to concentrate most of our efforts on strictly economic objectives. Accordingly our work has consisted of four principal parts: about 55 percent of our effort, judged on the basis of funds expended, has been directed toward the search for and appraisal of minable deposits of uranium, chiefly those on the Colorado Plateau, or of deposits, such as the Florida phosphates, that give promise of early production; about 10 percent has gone into the search for and appraisal of uranium in districts or rocks not previously known to be uraniferous; approximately 6 percent has been devoted to the development of new prospecting, analytical, and mineralogic techniques and methods; and about 26 percent has gone into supporting investigations, services, and research, including such things as analytical service, mineralogic and petrographic studies, and the construction of chemical laboratories at Washington and Denver. These figures exclude work on the search for and appraisal of beryllium and thorium deposits, which have amounted to only about 2.5 and ½ percent respectively of the total effort.

Even though the chief emphasis in our work has been on economic objectives, it has been necessary in this, as it is in many other investigations with practical objectives, to study many diverse problems and to apply many fields of knowledge to reach or approach the desired objectives. Partly for this reason but partly also because of the rather unusual physical and chemical properties of uranium our studies have taken us into most of the other sciences and even more surprising, into every branch of geology itself.

As may be seen from the table of contents of Trace Elements Investigations Report 200, our specific investigations therefore include a wide range of subjects in many fields. I will take a few minutes to review the progress in each of them and to indicate the place they have and will occupy in our program.

An important phase of our work from the very beginning has been the development of chemical, radiometric, and spectrographic analytical methods, not only for uranium and thorium but also for associated elements such as phosphorus, vanadium, aluminum, iron, oil, and minor metals. With the simple quick methods now in use that permit our laboratories to make about 45,000 chemical analyses for uranium a year, it seems hard to believe that only a few years ago a single chemical analysis for uranium in many rocks required several days of hard work on the part of a good analytical chemist, but many of you will recall that situation, I am sure. This and similar achievements, which are the result of research in other laboratories as well as our own, have done as much as anything else to make possible large-scale exploration and sampling of uraniferous deposits. We will continue to place considerable emphasis on the search for ways and means to shorten and improve the accuracy of analytical methods. Incidentally, thorium, particularly in amounts less than 1 percent, is one of the elements which continues to pose a difficult analytical problem and its determination is one of those on which additional work is needed most.

Although we have undertaken some research on the development of new petrographic instruments and tools, including the development of a set of high-index liquids, the refinement of stripping-film techniques, and the application and refinement of many other older techniques and instruments to the study of radioactive minerals and rocks, our work in the development of new mineralogic techniques has been largely incidental to other studies. In view of the fact that many of the uraniferous rocks are exceedingly fine-grained and therefore difficult to study by ordinary means, we consider the need for the development of new methods, particularly those permitting physical separation of fine-grained minerals, one of the most pressing.

Our work in mineralogy and petrology has focused mainly on the carnotites, phosphates, and pitchblende ores in the Colorado Front Range but we have undertaken also a considerable amount of work on systematic uranium mineralogy in cooperation with Dr. Frondel of Harvard and Dr. Switzer of the National Museum. Theodore Botinelly will tell you more of our work in these fields later. Suffice it to say for now that although progress has been made, the complexity of uranium mineralogy is such that it will be a long time before we know the identity, physical properties, and chemical composition of uranium-bearing minerals in the important ores, much less understand their origin and paragenetic relationships.

The field that has been neglected most in the study of uranium under what amounts to continuous emergency conditions is that of the geochemistry of uranium and associated elements. As J. C. Rabbitt will outline in more detail this afternoon, we have done a little on the synthesis of apatite and carnotite, a little on the transportation of uranium in various types of deposits, and have collected much data on the distribution and abundance of uranium in a wide variety of rocks. Under the sponsorship of the Atomic Energy Commission's Division of Research, we have recently begun work on two phases of the uranium cycle—namely the distribution of uranium in igneous rocks and the behavior of uranium during the weathering of certain source rocks, and we are also currently studying the solubilities of common salts of a number of the trace elements in sea water.

These studies as well as those begun recently by others of you here will help fill in the gap in our geochemical knowledge but additional work is needed to help provide the understanding of basic principles that will be required to pursue the search for uranium in the future. Particularly needed are measurements of the solubilities of both primary and secondary uranium-bearing minerals in natural waters, data on the temperature of formation of hypogene minerals, and information on the factors controlling the sorption of uranium by various adsorbents under various conditions.

Our work in the field of bio-geochemistry has been limited to geobotanical prospecting. These studies have been successful in that they have proven the applicability of two methods to the search for ores of the sandstone type in certain areas and have provided much information on the uptake of uranium and the variations in its distribution in plants, but they have not touched upon many problems of geologic significance, such as the role plants and animals, particularly micro-organisms, play in the precipitation and concentration of uranium. Although we hope to do more on some of these problems in the future we are anxious to see work begun along these lines in other institutions better fitted for biological experimentation.

F. W. Stead and Henry Faul will describe our geophysical investigations tomorrow and Friday. Until recently they likewise have been aiming primarily at the development of prospecting techniques and instruments, including field counters, carborne counters, airborne counters for use in both large and small planes, and drill-hole counters. We have enjoyed the close cooperation of other laboratories in this work — in fact since 1947 most of the instrumentation has been done at the Oak Ridge National Laboratory and by the Radiation Instrument Branch of the Atomic Energy Commission. In recent years we have done some experimental work in the application of electrical resistivity methods to the search for ore on the Plateau and we plan to investigate the applicability of other electrical methods there in the future. Recently we have done some basic work on the measurement of absorption of various types of radiation in different media, partly in collaboration with the Oak Ridge National Laboratory and the Bureau of Standards. We plan additional work on radiation techniques and instruments in the future but we want to concentrate more on the measurement of geophysical constants, such as the absorption and scattering of gamma and neutron radiation, that will help in the interpretation of radiometric survey data of all types and we hope that some of you may also be able to undertake studies in this field.

Prior to this fiscal year our work in isotope geology has focused mainly on the problem of determining the age of the Plateau deposits, on the isotopic composition of ore lead, and on the radon-helium problem, but we have recently begun a more comprehensive investigation of variations in the isotopic ratios of uranium and thorium to their daughter elements in natural materials. These studies have broad, though practical, objectives such as establishing an absolute time scale and correlating it with the paleontologic record, fixing the date and sequence of origin of ores and host rocks, and providing information on the source from which ores were derived and the geochemical processes by which they are concentrated. Our past work in this field has involved close cooperation with the Division of Research and Medicine at Oak Ridge and we hope that in the future it will involve close cooperation with some of the other groups represented here.

R. S. Cannon and Henry Faul will describe our activities and plans in more detail Friday morning. Lorin Stieff, who has done most of our work on geochronology, and Garland Gott, who with J. W. Hill discovered radon in the Amarillo helium field, are here also in case any of you wish to explore further problems in these fields.

As I mentioned earlier, most of our effort has been concerned directly with the search for and appraisal of uranium deposits, particularly those minable under present economic conditions. The biggest part of this work, even that done under our own auspices prior to 1946, has been on the geology and exploration of sandstone-type deposits on the Colorado Plateau but an important part of our work from the early stages has been the search for uranium in rocks and districts not previously known to be uraniferous. Both phases have been more successful than anyone could have hoped. Primarily as the result of the acquisition of basic data on the geology, distribution, and habits of the carnotite deposits acquired during the 1939-1945 period we have been able to increase markedly the ore found per foot of diamond drilling on the Colorado Plateau and even more important we have acquired an understanding of some of the large- and small-scale ore controls and guides that will enable us to maintain a good discovery record in the future. Our reconnaissance studies have resulted in the discovery of large tonnages of uranium in both the northwest and southeast phosphates, in black shales in several parts of the country, and in lignites, and of smaller reserves in many other types of deposits in several other areas. Partly as the result of new discoveries and partly as the result of geologic field appraisal of deposits first reported by others we now are doing more detailed geologic mapping and sampling in several districts and will begin other district studies soon. We do not feel by any means that we have reached or are even close to the bottom of the barrel in the search for new deposits. We do not expect to find many new deposits of uraniferous phosphates but we do look for important new discoveries to come in virtually every other known type of occurrence including the black shales, and we fully expect to find significant deposits of uranium in some rock types not thus far known to contain them. A. P. Butler will tell you more about our geologic work in the session tomorrow morning and in addition L. R. Page, who is in charge of our reconnaissance unit, A. L. Bush of our Plateau project, J. F. Smith, who is in charge of our geologic work on the pre-Morrison formations of the Plateau, and Garland Gott, who has done much of our reconnaissance of uraniferous sandstones and shales, are here in case you wish to discuss various aspects of our field studies in more detail.

What little work we have done on the search for thorium deposits has been restricted largely to the Idaho and southeastern placer fields but we have also studied a few other deposits in which thorium is associated with uranium. We may place somewhat greater emphasis on the search for thorium deposits in the future for we believe the prospects are bright for developing important reserves.

From this review, even though it has been a hasty one, it should be evident that our work in these various fields, extensive as it has been, represents no more than a healthy start on the problems of the geology of sources of fissionable materials. Although some fields have been more neglected than others, all of them abound with challenging and important problems and will continue so for some time to come. As may be seen from

Trace Elements Investigations Report 201 we are actively working now on some of these problems and plan to work on others in the future but neither our current work nor our plans begin to meet the needs or eliminate the desirability of work on the part of other researchers. We are, therefore, glad to see others entering the field and we hope that, as the information-dispersal program recently begun by the Atomic Energy Commission takes effect, still others will be attracted to the fascinating field of uranium geology. In this connection let me say that the discovery of nuclear fission is one of the best things that has happened to geology in some time if in no other way at least in that interest in uranium has attracted the attention of many chemists and physicists to geologic problems. Geology is, after all, merely the application of all the sciences to earth materials but too often in the past this application has been made only by those more familiar with earth materials than with the other sciences. We expect, therefore, that the activities of some of the physicists and chemists here will give geology a much needed boost.

With regard to the choice of problems which deserve the attention of other individuals and organizations, I have already indicated some and my colleagues will indicate others in which help is especially needed. I do not want to place too much emphasis on these specific needs, however, for needed as much as anything are the new ideas and approaches that result from work on basic principles that may appear to go beyond the needs of an economic problem. We will be glad to cooperate with all of you in any way that we can and I hope you will feel free to call on us for information, specimens, or such other assistance as you feel we can give and to visit our laboratories and field parties.

In conclusion I want to thank Professor Edwards, Professor Cohee, and their associates of the University of Arkansas for the fine opportunity they have provided us to discuss mutual problems and plans with other participants in raw-material studies.

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