PROGRAM OF STUDY FOR THE CARNITITE ORES OF THE COLORADO PLATEAU

Trace Elements Investigations Report 92

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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General

DRESS REPLY TO:

W MATERIALS OPERATIONS
S. ATOMIC ENERGY COMMISSION
O. BOX 30, ANSONIA STATION
W YORK 23, NEW YORK

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UNITED STATES
ATOMIC ENERGY COMMISSION
RAW MATERIALS OPERATIONS
NEW YORK OFFICE

March 9, 1949

Dr. Thomas B. Nolan
Assistant Director
U. S. Geological Survey
Washington 25, D. C.

Subject: LEAD-RATIO AGE DETERMINATIONS OF COLORADO PLATEAU ORES.

Dear Dr. Nolan:

We have recently become especially interested in the desirability of having lead-ratio age determinations made of carefully selected ore samples throughout the Colorado Plateau area. We understand that Mr. Lauren Stieff of your mineralogical lab is currently engaged in making such determinations on 12 of more than 100 samples collected for mineralogic research.

We would greatly appreciate obtaining from Mr. Stieff a list of the samples he is working on, giving their geographic location, position in the stratigraphic column, and general mineralogic and petrographic make-up. It would also be helpful to have a statement of Mr. Stieff's aims and plans for research on the Colorado Plateau ores in order that we may keep our Grand Junction geologists fully informed of the research work that is going forward in the Survey.

Very truly yours,

NOTED
MAR 11 1949

Phillip L. Merritt
Assistant Manager

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MAR 14 1949
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Approved
John C. Rabbitt
3/25/49

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O : John C. Rabbitt DATE: March 24, 1949

ROM : L. R. Stieff

UBJECT: Program of study for the carnotite ores of the Colorado Plateau.

A progress report is now in preparation on the current results of the study of the mineralogy of the carnotite ores of the Colorado Plateau so the present work will therefore be only briefly summarized here, but the proposed field work and the accompaning laboratory work will be discussed in some detail. Before discussing the present laboratory program and the proposed laboratory and field programs, the sample procedure and a list of samples collected during the 1948 field program will be given.

SAMPLING PROCEDURE, 1948 FIELD SEASON

The sampling procedure was dictated by the following considerations:

1. The obvious necessity of beginning the study of the equilibrum conditions and the lead content of the carnotite ores.

2. The information obtained from the very brief exploratory electron microscope study of a few samples of the Colorado Plateau ores.

3. The time spent in collecting samples was controled by the realization that the 1949 field program would depend on the amount of time available for laboratory study and on the results produced.

The equilibrum and lead studies involved the following different considerations:

1. Collection of nearly pure carnotite for the initial phase of the study.

2. Collection of representative low- and intermediate-grade carnotite samples.

3. Collection of representative samples from different stratagraphic positions.

4. Collection of representative samples from different geographic localities.

The first consideration followed from the necessity of beginning the investigation with material which would present the least difficulty.

Differences due to chemical or radiochemical techniques would not be as significant in the analysis of high-grade samples as they would be in the analysis of low-grade material. Discrepencies reported by the different methods of analysis could then be attributed to an actual lack of equilibrum and not to experimental errors.

With the development of satisfactory techniques, the intermediate- and low-grade ores could be analyzed and greater confidence could be placed in the results obtained. The interpretation of the data from the high-grade samples could then be either confirmed or modified.

Because of the potentially important conclusions, such as the probable age of the deposits and the extent of migration which would follow from the establishment of a general lack of equilibrum in the Plateau deposits it was thought that the initial field work should be an attempt to first develop the existance of regional and stategraphic variations in the equilibrum of the carnotite rather than to attempt a detailed equilibrum study of a samll area or deposit. If the results of the regional survey were significant then the more expensive and detailed study would have additional justification.

The electron microscope study of a few samples of carnotite ore indicated that at least five mineral phases were present. The identification of these phases depended on the techniques of separation and on the possibility of finding a particular ore sample which showed a maximum development of one particular phase. The collection of samples with a wide regional and vertical stratagraphic distribution also gave the greatest promise of finding a certain phase of the ore well developed. In most of the work both electron microscope and equilibrum studies have been conducted on the same sample.

LIST OF SAMPLES BEING STUDIED

About 100 samples were collected between August 25 and October 9, 1948.

The following 50 samples have been prepared for analysis and are now being studied:

Sample No.	Location	Stratagraphic Position
LRS/1/48	Parco (?), Yellow Cat Group, Grand Co., Utah.	Lower Saltwash ss
LRS/2/48	Allors (?), Yellow Cat Group, Grand Co., Utah.	Upper Saltwash ss
LRS/5/48	LS No. 1, La Salle No. 1 (?), Yellow Circle Gr. (?), Cane Canyon, San Juan Co., Utah.	Middle Saltwash ss

Sample No.	Location	Stratagraphic Position
LRS/6/48	Mine D, Yellow Bird Group, La Salle Creek, Montrose Co., Colorado.	Upper Saltwash ss
LRS/7/48	Butterfly Mine, Yellow Bird Group, La Salle Creek, Montrose Co., Colorado	Upper Saltwash ss
LRS/8/48	Butterfly Mine, Yellow Bird Group, La Salle Creek, Montrose Co., Colorado.	Upper Saltwash ss
LRS/9/48	Monument No. 2, Mexican Hat, Monument Valley, San Juan Co., Utah.	Shinarump Congl.
LRS/10/48	Monument No. 1, Monument Valley, San Juan Co., Utah.	Shinarump Congl.
LRS/11/48	Ridge No. 1, Dinasaur Group, Cottonwood Canyon, San Juan Co., Utah.	Upper Saltwash ss
LRS/12/48	Jo Dandy Mine, Jo Dandy Group, Montrose Co., Colorado.	Upper (?) Saltwash ss
LRS/13/48	Jo Dandy Mine, Jo Dandy Group, Montrose Co., Colorado.	Upper (?) Saltwash ss
LRS/15/48	Jo Dandy Mine, Jo Dandy Group, Montrose Co., Colorado.	Upper (?) Saltwash ss
LRS/16/48	Cougar Claim, Lower Group, San Miguel Co., Colorado.	Upper Saltwash ss
LRS/17/48	Cougar Claim, Lower Group, San Miguel Co., Colorado.	Upper Saltwash ss
LRS/19/48	Radium No. 6, Radium Group, San Miguel Co., Colorado	Upper Saltwash ss
LRS/20/48	Radium No. 6, Radium Group, San Miguel Co., Colorado.	Upper Saltwash ss
LRS/21/48	Radium No. 5, Radium Group, San Miguel Co., Colorado.	Upper Saltwash ss
LRS/22/48	Raven Mine, Raven Claim (?), VCA Camp Area, Gypsum Valley, San Miguel Co., Colorado.	(?) Saltwash, faulted
LRS/23/48	Gypsum No. 1, Gypsum Claim, VCA Camp Area, Gypsum Valley, San Miguel Co., Colorado.	(?) Saltwash
LRS/25/48	Calamity No. 13, Gateway Area, Mesa Co., Colorado.	Upper Saltwash ss
LRS/26/48	Calamity No. 13, Gateway Area, Mesa Co., Colorado.	Upper Saltwash ss
LRS/28/48	Calamity No. 13, Gateway Area, Mesa Co., Colorado.	Upper Saltwash ss
LRS/30/48	Garfield Mine, Garfield Claim, Garfield Co., Colorado.	Entrada ss
LRS/30A/48	Garfield Mine, Garfield Claim, Garfield Co., Colorado.	Entrada ss

Sample	Location	Stratigraphic Position
LRS/32/48	Vanadous No. 1, Vanadous Claim No. 1, Leopard Creek, San Miguel Co., Colorado.	Upper Entrada ss.
LRS/33B/48	Bear Creek Mine, Primus No. 1-5(?), Bear Creek, San Miguel Co., Colorado.	Lower Entrada ss.
LRS/34/48	Primus Claim, Bear Creek Group, Bear Creek, San Miguel Co., Colorado.	Lower Entrada ss.
LRS/35A/48	Dunning-Greysill (1-5)?, Hermosa Creek, Rico, San Juan, Colorado.	Entrada ss. (?)
LRS/37/48	Rock Raven No. 3, Rock Raven Group, Uravan, Montrose Co., Colorado.	Lower Brushy Basin
LRS/37A/48	Rock Raven No. 3, Rock Raven Group, Uravan, Montrose Co., Colorado.	Lower Brushy Basin
LRS/38/48	Roc Creek, (Claim BCI, 20019?), Roc Creek Area, Montrose Co., Colorado.	(?) Saltwash faulted.
LRS/39/48	Roc Creek, (Claim BCI, 20014)?, Roc Creek Area, Montrose Co., Colorado.	(?) Saltwash faulted
LRS/39A/48	Stone No. 1, Roc Creek (BCI, 20016)?, Roc Creek Area, Montrose Co., Colorado.	(?) Saltwash faulted
LRS/41/48	Bitter Creek, Bitter Creek Area, Montrose Co., Colorado.	Middle Saltwash
LRS/43/48	Bitter Creek, Bitter Creek, Montrose Co., Colorado.	Middle Saltwash
LRS/47/48	Bald Eagle Mine, Bald Eagle Claim, Gypsum Valley, San Miguel Co., Colorado.	? Hermosa ? faulted
LRS/48/48	West side of Montazuma Canyon, Cottonwood Group (?), San Juan Co., Utah.	Lower Saltwash
LRS/48A/48	Montazuma Canyon, San Juan Co., Utah., Cottonwood Group (?)	Lower Saltwash
LRS/55/48	Gap Claim, Klondike, Gypsum Valley, Montrose Co., Colorado.	Upper Saltwash (?)
LRS/56/48	Hidden Treasure No. 3 Mine, Klondike, Gypsum Valley, Montrose Co., Colorado.	? Saltwash
LRS/59/48	Club Mine, Uravan, Montrose Co., Colorado.	Upper Saltwash
LRS/60/48	Club Mine, Uravan, Montrose Co., Colorado.	Upper Saltwash
LRS/61/48	Club Mine, Uravan, Montrose Co., Colorado.	Upper Saltwash
LRS/62/48	Club Mine, Uravan, Montrose Co., Colorado.	Upper Saltwash
LRS/63/48	Club Mine, Uravan, Montrose Co., Colorado.	Upper Saltwash
LRS/64/48	Bob Tail, Monogram Group, Paradox Valley, Montrose Co., Colorado.	Upper Saltwash
LRS/64A/48	Bob Tail, Monogram Group, Paradox Valley, Montrose Co., Colorado.	Upper Saltwash
LRS/67/48	Wild Steer Mine, Wild Steer Canyon, Montrose Co., Colorado.	Lower Saltwash

Sample	Location	Stratigraphic Position
LRS/68/48	Wild Steer Mine, Wild Steer Canyon, Montrose Co., Colorado.	Lower Saltwash
LRS/69/48	Eastside Mine (VCA), East side Carrizo Mts., Navajo Indian Reservation, Arizona.	Saltwash ss.

About 50 of the remaining samples were collected for special studies which have not yet been started. This group includes samples of barren sandstone collected for comparison with mineralized rock, a few samples collected for a study of banding and weak mineralization, sample of the "galena band" from the Rifle deposit and other material from the Rico area for additional lead isotope studies, and finally samples of most of the common vanadium minerals.

PRESENT LABORATORY PROGRAM

The objective of the present laboratory program has been to develop reliable techniques for the rapid determination of the equilibrum conditions of the carnotite ores, to determine the equilibrum conditions of the samples collected, and to apply to the uranium-bearing material every method of identification which promises results.

The laboratory study of the field samples has been divided as follows:

Part 1. The study of 12 almost pure carnotite samples.

Part 2. The study of 38 intermediate- and low-grade carnotite ores.

The program which has been followed in the study of the samples collected is outlined below.

A. Sample preparation
   1. Separation of -200 mesh fraction
   2. Development of separation techniques

B. Equilibrum studies
   1. Chemical analysis
   2. Radiochemical assay
   3. Radium determination
   4. Lead analysis
   5. Preparation of PbI_2
   6. Isotopic analysis

C. Electron microscope study
   1. Preparation of mounts
   2. Preliminary examination of mounts
   3. Electron diffraction and single crystal studies

D. Petrographic study
   1. Study of hand specimen
   2. Study of thin sections

E. Optical and physical properties
   1. Study of balsam mounts (-200 mesh)
   2. Index of refraction studies
   3. Specific gravity determinations

F. Alpha plate study
   1. Preparation of plates (-200 mesh)
   2. Preliminary examination of plates
   3. Detailed alpha count
   4. Studies of thin and polished sections

G. X-ray study
   1. Preparation of spindle
   2. Identification of sample by powder pattern

H. Spectrographic analysis

The accompanying table on pages 7 and 8 shows the progress to date of part one of the program.

Part two of the program has just begun. The remaining 38 samples have been prepared for chemical analyses, the initial radiochemical assays have been made, electron microscope and balsam mounts have been prepared, and the material has been submitted for thin sectioning.

PROPOSED LABORATORY PROGRAM

The objectives of the proposed laboratory program are, (1) to continue and to expand the different phases of the carnotite study already outlines, (2) to begin a study of the problems having a direct bearing on the physical and chemical processes of deposition of the uranium minerals and on the possible origin of the deposits.

Under these broad objectives, the following specific problems should be considered:

1. Synthesis of carnotite and related minerals
2. Deposition and migration studies
3. Base exchange characteristics of U and V

Synthesis of carnotite and related minerals

The purpose of this study is to determine the chemical and physical properties of synthetic carnotite and related minerals. This is imperative before any detailed theories on the methods of deposition of the

(X represents the completion of the procedure listed in the first column)

Sample Number	1	2	3	4	5	6	7	8	9	10	11	12
EQUILIBRIUM AND LEAD STUDIES												
1. Samples preparation	X	X	X	X	X	X	X	X	X	X	X	X
2. Chemical analysis	X	X	X	X	X	X	X	X	X	X	X	X
3. Radiochemical assay	X	X	X	X	X	X	X	X	X	X	X	X
4. Radium determination	X	X	X			X		X	X		X	
5. Lead analysis									X			
6. Preparation of PbI_2												
7. Isotopic analysis												
ELECTRON MICROSCOPE STUDY												
1. Preparation of mounts	X	X	X	X	X	X	X	X	X	X	X	X
2. Survey	X	X	X	X	X	X	X	X	X	X	X	X
3. Electron diffraction and single crystal studies												
PETROGRAPHIC STUDY												
1. Study of hand specimen	X	X	X	X	X	X	X	X	X	X	X	X
2. Thin section study	X	X	X	X	X	X	X		X	X	X	X
OPTICAL AND PHYSICAL PROPERTIES												
1. Study of balsa mounts (-200 mesh)	X	X	X	X	X	X	X	X	X	X	X	X
2. Index of refraction studies	X	X	X	X	X	X	X	X	X	X	X	X
3. Specific gravity determination												
ALPHA PLATE STUDY												
1. Preparation of plates	X	X	X	X	X	X	X	X	X	X	X	X
2. Survey of plates	X	X	X	X	X	X	X	X	X	X	X	X
3. Detailed alpha count		X						X				
X-RAY STUDY												
1. Preparation of spindle	X	X	X	X	X	X	X	X	X	X	X	X
2. Identification of sample	X	X	X	X	X	X	X	X	X	X	X	X
SPECTROGRAPHIC ANALYSIS	X	X	X	X	X	X	X	X	X	X	X	X

(For key, see next page)

KEY TO TABLE

LRS/1/48, Parco (?), Yellow Cat Group, Grand Co., Utah, Lower Saltwash ss.

LRS/9/48, Monument No. 2, Monument Valley, San Juan Co., Utah, Shinarump congl.

LRS/12/48, Jo Dandy, Jo Dandy Gr., Montrose Co., Colorado, Upper Saltwash ss.

LRS/13/48, Jo Dandy, Jo Dandy Gr., Montrose Co., Colorado, Upper Saltwash ss.

LRS/19/48, Radium No. 6, Radium Gr., San Miguel Co., Colorado, Upper Saltwash ss.

LRS/20/48, Radium No. 6, Radium Gr., San Miguel Co., Colorado, Upper Saltwash ss.

LRS/25/48, Calamity No. 13, Gateway Area, Mesa Co., Colorado, Upper Saltwash ss.

LRS/28/48, Calamity No. 13, Gateway Area, Mesa Co., Colorado, Upper Saltwash ss.

LRS/61/48, Club Mine, Montrose Co., Colorado, Upper Saltwash ss.

LRS/62/48, Club Mine, Montrose Co., Colorado, Upper Saltwash ss.

LRS/63/48, Club Mine, Montrose Co., Colorado, Upper Saltwash ss.

LRS/64/48, Bob Tail, Montrose Co., Colorado, Upper Saltwash ss.

Colorado deposits can be made. A thorough knowledge of the carnotite and carnotite-like mineral systems as tested by synthesis studies must also preceed any experiments on the controls of ore deposition.

Mr. K. J. Murata of the Investigation Section, working independently has synthesized tyuyamunite, carnotite, and the Sr, Ba, and NH_3 analogues of carnotite. X-ray powder patterns of these synthetic materials have been made and they have been used to aid in the identification of natural carnotite and tyuyamunite. Preliminary electron microscope studies in addition to revealing the form of the minerals, show that more work on the growth of synthetic carnotite will be necessary before either optical properties can be accurately determined or very good x-ray powder patterns can be obtained.

The proposed program of study includes the following:

A. Chemistry of carnotite
   1. Chemical synthesis of minerals
   2. Determination of exact formula of minerals
      a. Study of hydration states

B. Thermal differential analysis

C. Phase equilibrum studies
   1. 3 and 4 component systems
   2. Possibility of solid solution
   3. Stability of hydration states

D. Cation exchange or replacement studies
   1. Ca-K - carnotite system, reversibility, etc.
   2. Exchange power of Ca, K, Sr, Ba etc.

E. "Solubility" and decomposition studies
   1. Distilled water
   2. Different acid systems
      a. Different pH
   3. Extremely dilute solutions

F. Electron microscope study
   1. Study of crystalline phases
   2. Electron diffraction study
      a. Powder
      b. Single crystal
      c. Reflection

G. Growth of megascopic synthetic crystals

H. Optical and physical properties
   1. Optical studies
      a. Index of refraction, etc.

H. Optical and physical properties (continued)
   2. Determination of physical properties
      a. Specific gravity, crystal structure, etc.
   3. Photosensitivity studies

I. X-ray studies
   1. Powder diffraction studies
   2. Single crystal studies
   3. Determination of structure

Deposition amd migration studies

The purposes of the deposition and migration studies are to isolate and investigate by controlled laboratory experiment, the chemical and physical condition necessary for deposition of the uranium and vanadium minerals and to determine under controlled leaching experiments the extent to which uranium, its daughter product, lead, and vanadium will migrate.

In order to duplicate the types of deposition found on the Colorado Plateau samples of barren sandstone should be saturated with solutions of synthetic minerals. By varing the concentrations and the physical conditions, the chemical and physical controls of deposition can be studied.

The migration studies would be an integral part of this program. Controlled experiments should be conducted on the migration of uranium and vanadium solutions in barren sandstone, partly mineralized sandstone, and in ore specimens. The program would, (1) involve dye experiments, (2) alpha-plate and autoradiographic techniques to follow the path taken by the radioactive solutions, (3) porosity and permeability studies, and (4) controlled studies of the leaching and migration of uranium, its daughter products, and vanadium when the sample is treated with distilled water, and with solutions of known pH and with different concentrations of cations.

Base Exchange Studies.

Should electron microscope and alpha-plate studies of the low- and intermediate-grade carnotite ores suggest that the clay minerals are also acting as a carrier of uranium, a study of the base exchange characteristics of the clays in the Colorado deposits will be undertaken. This study will identify the most abundant clays found in the ore-bearing sandstones of the Colorado Plateau, and will investigate the conditions under which base exchange of uranium and vanadium will occur.

Controled experiments should be conducted with similar clay minerals and with solutions containing known concentrations of uranium and vanadium in an effort to determine the amount of material involved in the base exchange reactions and the tendency of these elements and others to undergo base exchange.

THE PROPOSED PROGRAM FOR THE 1949 FIELD SEASON

The objective for the 1949 field season will be to collect those samples which will completely complement the laboratory investigations and to supplement these samples with detailed field observations. Specific projects (in order of priority) under these broad objectives are as follows:

1. The detailed equilibrum study of a significant area or small deposit .

2. A general survey of the uranium deposits of the Colorado Plateau for the purpose of collecting comparative material and for obtaining certain statistical data on the ore deposits.

3. Chemical analyses of possible source rocks.

   A. Sedimentary
   B. Volcanic and intrusive

4. Chemical analysis of Ground water samples.

It is possible that because of the number of geologists required for this program some omission or modification will be necessary. However, these recommendations embrace the major problems that will have to be considered within the next one or two years.

The program for the field season of 1949 will largely depend on the results obtained from the laboratory investigation of the samples collected during the 1948 field season. The results are still incomplete but if the remaining results confirm the conclusions now held the program outlined above would seem advisable.

Detailed study of an undeveloped carnotite deposit

The objectives of the detailed equilibrum study of a significant area or small deposit are:

1. To obtain samples relating to the radioactive equilibrum and possible origin of the deposit.

2. To obtain field evidence on the relation of the structure of the deposit to its mineralogy.

3. To test the value of equilibrum data as a geochemical prospecting method.

This information will be derived primarily from a radioactive-equilibrum study of the samples collected and from the lead ratio determinations. The samples will be obtained by drilling done by the exploration group. Splits taken of samples of barren and mineralized sandstone will be analyzed by radiochemical, and chemical means for uranium, vanadium, and lead.

The equilibrum data obtained from the laboratory will be plotted and contoured on level maps and cross sections. The extent and direction of migration of the uranium may be apparant from the contours. Perhaps from this and other evidence the source of the uranium can be determined. The approximate age and probable origin of the deposits might be obtained from a consideration of the overall equilibrum conditions and the migration of the lead isotopes.

The area or deposit selected for study should not have been disturbed by mining activities. The best solution of this requirement would be to select one of the areas or deposits recently discovered during the exploratory drilling on the Plateau. For example, the new deposits found at Calamity Mesa or in the Radium Group might be satisfactory. This selection will probably be governed not only by geological and financial considerations but also by the conclusions which follow from the present equilibrum studies.

If the equilibrum study of a significant area is combined with the explanatory drilling, the additional cost of collecting the samples for this study would probably not be great. The major objection would be the insufficient number of drill holes in the mineralized areas.

If the samples for the equilibrum study are collected from one samall deposit by a special drilling program, all the necessary material and data would be available. The major objection would be the high cost of obtaining the information and the samples.

General Survey of the uranium deposits of the Colorado Plateau

The collection of samples for a comparison of material on a regional basis should be expanded to include those areas which were not covered in the short field season of 1948. The electron microscope study of the samples already collected will probably suggest that some areas could be profitably revisited. Also more samples should be collected for the purpose of comparing local differences in the mineralogy of the deposits and to further develop the study of other related minerals.

Chemical analysis of possible source rock

The objective of this study would be to determine if the "barren" rock of either the ore-bearing Saltwash sandstone or the overlying sedimentary rocks (or both) are the source of the uranium and vanadium deposits.

Because of the great amount of information will have to be collected before the results would begin to be significant it is uncertain when this phase of the study of the carnotite deposits may be completed. However, selected material has already been collected for this purpose and additional samples will be collected during the summer.

In addition, a preliminary survey of the volcanic and intrusive rocks would be undertaken for the purpose of identifying the rocks, the mineral assemblages and the radioactive constituents. Samples would be collected from the Uncompagre uplift and the La Salle and Blue Mountains. Also, any contact alterations between these igneous rocks and the sediments could be studied.

Chemical analysis of ground water samples

The purpose of this study would be to determine the amount of uranium and vanadium in the ground water samples from the deposits and springs in the mineralized areas of the Colorado Plateau. This information would have a direct bearing on the questions of radioactive equilibrum and on the origin of the deposits.

The field and laboratory program outlined in this report can be adequately staffed by existing Geological Survey people.

Lorin R. Stieff