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GEOLOGICAL SURVEY
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Dr. T. H. Johnson, Director
Division of Research
U. S. Atomic Energy Commission
1901 Constitution Avenue, N. W.
Washington 25, D. C.

Dear Dr. Johnson:

Transmitted herewith is one copy of TEI-322, "The lead-uranium ages of some uraninite specimens from Triassic and Jurassic sedimentary rocks of the Colorado Plateau," by L. R. Stieff and T. W. Stern, April 1953.

We plan to add chemical and spectrometric data and submit this report for publication in the Bulletin of the Geological Society of America or the American Mineralogist.

Sincerely yours,

V. E. McKelvey
for W. H. Bradley
Chief Geologist

UNCLASSIFIED

Geology and Mineralogy

This document consists of 15 pages.
Series A.

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

THE LEAD-URANIUM AGES OF SOME URANINITE SPECIMENS FROM TRIASSIC AND JURASSIC SEDIMENTARY ROCKS OF THE COLORADO PLATEAU*

By

L. R. Stieff and T. W. Stern

April 1953

Trace Elements Investigations Report 322

This preliminary report is distributed without editorial and technical review for conformity with official standards and nomenclature. It is not for public inspection or quotation.

* This report concerns work done on behalf of the Division of Research of the U. S. Atomic Energy Commission.

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TEPCO, Washington:	
Resource Compilation Section	2
Reports Processing Section (Including master)	3
	83

CONTENTS

TABLES

THE LEAD-URANIUM AGES OF SOME URANINITE SPECIMENS FROM TRIASSIC AND JURASSIC SEDIMENTARY ROCKS OF THE COLORADO PLATEAU

By L. R. Stieff and T. W. Stern

ABSTRACT

As part of a study on the origin of the uranium deposits in the Triassic and Jurassic sedimentary rocks of the Colorado Plateau, 21 uraninite specimens and other primary uranium minerals from 13 deposits were collected for Pb^{206}/U^{238} age determinations. These uraninite specimens are believed to be the best of more than 80 ore samples from the Plateau on which age determinations have been made. The 21 samples have an average Pb^{206}/U^{238} age of approximately 78 million years when corrected only for common lead.

Chemical and mass spectrometric errors change the average Pb^{206}/U^{238} age by approximately $\pm$ 6 million years. Uncertainties resulting from the common lead corrections and from the possible presence of old radiogenic lead in the ores will decrease the average Pb^{206}/U^{238} age by approximately 5 million years. Corrections for the selective loss of uranium will decrease the average age, whereas selective loss of daughter products will increase the average age by approximately 5 to 10 million years.

Holmes gives 127 and 152 million years as the close of the Jurassic and Triassic periods, respectively. If the ages calculated for the uraninite samples are close to the true ages of the ores, then the uranium was probably introduced into the sediments not later than the Late Cretaceous or early Tertiary (55 to 80 million years ago). The average Pb^{206}/U^{238} age of 78 million years for the 21 primary uranium minerals differs markedly

from the age which would have to be assumed if the present deposits were formed in the Late Triassic and Late Jurassic sediments of the Colorado Plateau during or soon after the deposition of the rocks.

INTRODUCTION

During the past two years a study of the age of the Colorado Plateau uranium deposits has been undertaken by the Geological Survey on behalf of the Atomic Energy Commission because data on ages would aid in clarifying some of the problems on the origin of the Plateau uranium deposits and would aid indirectly in the search for and the economic development of uranium on the Colorado Plateau. These age determinations have been made specifically to help decide whether the uranium deposits in the Plateau were formed shortly after the enclosing Late Triassic and Late Jurassic sedimentary rocks were laid down, or whether the deposits were formed at some more recent time, perhaps at the end of the Cretaceous period or during the Tertiary. No attempt has been made in this study to set a precise age for the deposits of the Plateau. Instead, our initial objective has been to establish the age of the deposits within very broad limits, that is, whether they are of Triassic, Jurassic, Cretaceous, or Tertiary age.

In an effort to obtain an acceptable answer to the fundamental question, "When were the deposits formed", two very general conditions should be observed: first, and most obviously, it is necessary to collect geologically representative ore samples. Secondly, completely reliable age determinations can be made only on ore samples which have not been altered in any way since their deposition. These two ideal conditions are seldom if ever completely fulfilled by the Plateau ores which have been studied.

In order that the ages calculated for the Plateau ore can be placed in their proper geologic sequence, it is also necessary to know accurately the ages of the sedimentary rocks which enclosed the deposits. Holmes (1946, p. 145) has considered this problem in some detail and on the basis of several different methods has assigned an age of 152 million years to the close of the Triassic period, an age of 127 million years to the close of the Jurassic period, and an age of 58 million years to the close of the Cretaceous period. Of these three ages, only the age of the end of the Cretaceous has been determined from specimens of uraninite by use of the lead-uranium method.

The more than 80 samples included in this age study represent every type of uranium ore that has been found in the Colorado Plateau. These samples have been collected from deposits in the Shinarump conglomerate, the Entrada formation, and the Morrison formation and from all of the major mining districts in the Colorado Plateau. The average age of these 80 samples is approximately 90 million years, and the ages range from 30 to 330 million years. The oxidized ore specimens, whose ages are impossibly great because they are older than the sediments in which they are found, reflect, we believe, the selective loss of uranium with respect to lead due to surface weathering and ground-water leaching.

This group of 80 samples also includes 24 specimens of uraninite and other relatively unoxidized black primary uranium minerals from 13 deposits in both Triassic and Jurassic sediments. These black ores generally are found at depth or in deposits protected from excessive alteration. They contain unweathered pyrite and other sulfides and, when secondary uranium minerals have been found in association with these ores, the secondary minerals have been excluded, when possible, from the material prepared for chemical analyses.

This paper presents the lead-uranium age determination of 21 of these black ores which are considered to be most reliable for age determinations. The specimens have been selected for presentation because it is generally agreed that the less oxidized ores are less susceptible to leaching by ground waters than are many of the secondary uranium minerals. This conclusion has been documented in considerable detail by Ellsworth (1932, pp. 105, 243) in his study of the altered Villeneuve uraninite. The age of the relatively unoxidized core of that specimen was 1100 million years. The apparent age of the alteration products containing no UO_2 was approximately 1750 million years. Similar studies by Nier (1939, p. 159) on uraninite and its alteration products from the Belgian Congo yielded analogous results. Recently Phair and Levine's work (1953) on the effect of sulfuric acid waters on partially oxidized but black pitchblende shows that, in the course of leaching, UO_2, radium, and lead were residually concentrated relative to UO_3. The amount of such concentration of both radium and lead was proportional to the amount of UO_3 leached.

DATA

All of the samples were analyzed volumetrically for uranium and colorimetrically for lead. At least duplicate analyses were made on all samples for both lead and uranium. The results of the analyses for uranium and for lead are reproducible to within 2 to 3 percent. For a sample whose Pb^{206}/U^{238} age is 65 million years, these analytical chemical errors result in a maximum uncertainty of $\pm$ 3 million years.

The calculated limits of error of the isotopic analyses rarely exceed 0.1 percent except in those samples where the amount of Pb^{206} is greater than 80 percent. The limits of error when Pb^{206} is greater than 80 percent do not exceed 0.2 percent of the measured isotopic abundances. From known sources of systematic mass spectrometric errors the results are believed to be accurate within 1 percent. However, additional systematic spectrometric errors have been detected which apparently exceed this estimated accuracy.

These additional systematic errors are not large and result in an estimated uncertainty in the Pb^{206}/U^{238} age of approximately $\pm$ 3 million years. Unfortunately, the Pb^{207}/Pb^{206} ages are completely invalidated by these small systematic errors because of the extreme sensitivity of this ratio to small changes. Hence, the Pb^{207}/Pb^{206} ages are not presented. Also, realistic corrections for the presence of old radiogenic lead and for selective loss of radon cannot be made until these small mass spectrometric errors are resolved. However, maximum corrections for radon loss will increase the average Pb^{206}/U^{238} age by not more than 10 million years, whereas the corrections for the presence for old radiogenic lead will decrease the average Pb^{206}/U^{238} age by approximately 5 million years.

We have been fortunate to have collected or to have received from Geological Survey and Atomic Energy Commission geologists samples of galena from almost every uraninite locality that has been included in this paper. For this reason the uncertainties resulting from the common lead correction have been reduced and in general do not exceed $\pm$ 3 million years.

In spite of the unaltered appearance of the uraninite and other black primary ores, the major source of the remaining error in our age determinations is due to the preferential loss of uranium with respect to lead as a result of recent leaching by ground waters. A correction for this source of error cannot be made at this time, although almost every sample is certain to have been altered to some extent. A correction for the preferential loss of uranium will make the final ages less than the calculated Pb^{206}/U^{238} ages which we have presented.

Table 1 presents data on the Pb^{206}/U^{238} ages of uraninite specimens from the Shinarump conglomerate of the Colorado Plateau. The finest specimen of uraninite collected on the Colorado Plateau was obtained from the Happy Jack mine, San Juan County, Utah (Stieff and Stern, 1952, p. 706). This specimen had a specific gravity of 9.1 and a very high UO_2 content. It was hard and fresh in appearance and completely free from secondary uranium minerals. The age we have obtained for the Happy Jack uraninite is believed to be most nearly correct although it should be emphasized that even this age is probably too great. The increasing ages of the remaining specimens of uraninite from the other deposits in the Shinarump conglomerate reflect, in general, the greater selective loss of uranium as the UO_3 content increases and reflect in part the larger common lead corrections that have been made. The more highly oxidized uraninite specimens are much more susceptible to the selective loss of uranium by ground-water leaching than are the unoxidized specimens. If, however, all of the specimens from the Shinarump conglomerate are considered to be equally reliable, an average of 72.5 million years is obtained for the 10 samples. This maximum age may be contrasted with Holmes' age for the end of the Triassic of 152 million years.

Table 1.--Pb^{206}/U^{238} ages of some Colorado Plateau uraninite specimens from the Shinarump conglomerate (Late Triassic)

Location	Number of samples	Average age in million years
Happy Jack mine	2	55
Cato Sells mine	1	60
Lucky Strike mine	1	65
Shinarump No. 1 mine	1	75
Camp Bird mine	2	80
Monument No. 2 mine	3	85
Average age of 10 samples		72.5
Holmes' age for the end of the Triassic		152

Table 2 gives the Pb^{206}/U^{238} ages of some uraninite specimens and of a new black tetragonal uranium mineral, all from the Morrison formation of Late Jurassic age. The best specimen from the Morrison formation for age determinations was collected by C. A. Rasor (1952, p. 89) of the Atomic Energy Commission, from the Grey Dawn mine, San Juan County, Utah. This uraninite gives an age of 65 million years. The greater ages of the new mineral specimens reflect, we believe, their higher UO_3 content and consequently their greater solubility in ground-water solutions. If, however, all of the specimens from the Morrison formation are considered to be equally satisfactory for age-determination purposes (and this is definitely not true), an average age of the 10 samples is 82 million years. This average age of 82 million years may be compared with Holmes' estimate for the end of the Jurassic period of 127 million years.

Table 2.--Pb^{206}/U^{238} ages of some Colorado Plateau uranium minerals from the Morrison formation (Late Jurassic)

Location	Number of samples	Uranium minerals	Average age in million years
Grey Dawn mine	1	Uraninite	65
Corvusite mine	1	Uraninite and new tetr. mineral	70
Matchless mine	1	New tetr. mineral	80
La Sal No. 2 mine	5	New tetr. mineral	85
Arrowhead mine	1	New tetr. mineral	90
Black Mama mine	1	New tetr. mineral	90
Average age of 10 samples			82
Holmes' age for the end of the Jurassic			127

Table 3 gives the Pb^{206}/U^{238} ages of some uraninite specimens from the Colorado Front Range. Two of these specimens, the Wood mine (Nier-Holmes) and Gilpin County (Nier-Holmes) were used by Holmes (1946, p. 141) for dating the end of the Cretaceous period. In addition to these two specimens, we have analyzed and dated four samples of uraninite from the Colorado Front Range collected by George Phair of the Geological Survey. Again, the variationsin the ages of these uraninite specimens from the vein deposits in the Colorado Front Range do not reflect actual differences in the ages of the ores but are primarily due to the differences in the suitability of the material for age determinations. If all of these samples are considered to be equally reliable (and this is certainly not true), the average age of these six samples is 61.7 million years. This result is in close agreement with Holmes' age for the end of the Cretaceous at 58 million years. These vein deposits, however, are spatially and genetically related to intrusive rocks which are known only to be younger than the surrounding Upper Cretaceous sediments, and therefore the age of these veins does not give a precise age for the close of the Cretaceous period.

Table 3.--Pb^{206}/U^{238} ages of uraninite specimens from the Colorado Front Range

Location	Age in million years
Wood mine (Nier-Holmes)	57.3
Wood mine (Phair)	60
Gilpin County (Nier-Holmes)	59.8
Iron mine (Phair)	70
Copper King mine (Phair)	55
Copper King mine (Phair)	68
Average age of 6 samples	61.7
Holmes' age for end of the Cretaceous	58

SUMMARY

Table 4 summarizes the Pb^{206}/U^{238} ages of the black, less oxidized uranium minerals from the Colorado Plateau and the Colorado Front Range. If the average ages for the specimens from the Morrison formation and the Shinarump conglomerate are compared with the ages of the Colorado Front Range uraninite samples, it will be seen that the difference between them is not large, particularly when it is recognized that the average ages are undoubtedly too high. When the lowest and most reliable ages for the Morrison and Shinarump ores are compared with the ages of the Colorado Front Range ores, almost complete agreement is obtained. It is also interesting to note that a specimen of uranium-bearing carbonaceous material from the Black King mine, Placerville area, Colo., gives an age of 65 million years. This material is definitely a vein deposit.

Table 4.--Comparison of Pb^{206}/U^{238} ages of uranium mineral specimens from the Colorado Plateau and the Colorado Front Range

Deposit	Number of samples	Average age in million years
Morrison formation, Colorado Plateau	10	82
Shinarump conglomerate, Colorado Plateau	10	72.5
Black King mine, Placerville, Colorado (vein)	1	65
Colorado Front Range	6	61.7

Three general observations can be made from the data which we have presented:

1. The most reliable ages that we have obtained from ores from the Morrison formation are lower by a factor of two than the best estimated ages for the Morrison formation. The most reliable ages that we have obtained from the Shinarump conglomerate ores are lower by a factor of three than the best estimate of the age of the Shinarump conglomerate. These ages are, however, in very close

agreement with the best available estimates for the age of the end of the Cretaceous or the beginning of the Tertiary. This means that the present ores do not contain enough radiogenic lead to be syngenetic or penecontemporaneous.

2. There is no significant difference between the average ages which we have found for the ores in the Morrison formation of Jurassic age and the Shinarump ores of Triassic age. We believe that this fact should have a very important bearing on the general plan of study of the origin of the Colorado Plateau ores. It means that a satisfactory solution of the problem of the origin can only be obtained when these ores are considered as a group and are not broken up into Morrison deposits, Shinarump deposits, and Entrada deposits.

3. The similarity in ages of the ores from the Colorado Plateau and Colorado Front Range very strongly suggests that we are dealing with a major uranium province in these two areas. This fact should enable us to broaden our approach to the problem of the occurrence of uranium in the Colorado Plateau. We should not restrict ourselves to the study of only those formations in which uranium has now been found but should seriously consider the possibility of searching for uranium in the older rocks of the Colorado Plateau.

Most of the lead-uranium data that we have obtained strongly suggest that the deposits are not syngenetic but were emplaced in the sediments during the Tertiary, long after the enclosing sediments were laid down. If, however, the deposits are syngenetic in origin, an event must have occurred at the end of the Cretaceous or during the Tertiary which completely redistributed the uranium and localized the ore in its present sites. Therefore, regardless of the source of the ore-bearing solution, it seems certain that the search for new deposits must rest in part on a thorough understanding of the Tertiary tectonic and sedimentary history of the Colorado Plateau. If the ages that we have found for the Colorado Plateau ores are close to their true ages, it is possible that the potentialities of the Plateau as a uranium-bearing province have just been touched.

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