TEI-435

# DETRITAL-APPEARING URANINITE IN THE SHINARUMP MEMBER OF THE CHINLE FORMATION IN NORTHERN ARIZONA: A PRELIMINARY REPORT

by Richard G. Petersen

Trace Elements Investigations Report 435

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

March 3, 1849

IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON 25, D. C.

May 22, 1959

AEC - 327/9

Mr. Robert D. Nininger
Assistant Director for Exploration
Division of Raw Materials
U. S. Atomic Energy Commission
Washington 25, D. C.

Dear Bob:

Transmitted herewith are three copies of TEI-435, "Detrital-appearing uraninite in the Shinarump member of the Chinle formation in northern Arizona: a preliminary report," by Richard G. Petersen, March 1959.

We plan to submit this report for publication in Economic Geology.

Sincerely yours,

John H. Eric
for Montis R. Klepper
Assistant Chief Geologist

TEI-435

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

# DETRITAL-APPEARING URANINITE IN THE SHINARUMP MEMBER OF THE CHINLE FORMATION IN NORTHERN ARIZONA: A PRELIMINARY REPORT*

By

Richard G. Petersen

March 1959

Trace Element Investigations Report 435

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 Raw Materials of the U. S. Atomic Energy Commission.

USGS - TEI-435

## GEOLOGY AND MINERALOGY

| Distribution | No. of copies |
|---|---|
| Division of Raw Materials, Austin | 1 |
| Division of Raw Materials, Casper | 4 |
| Division of Raw Materials, Denver | 1 |
| Division of Raw Materials, Grants | 2 |
| Division of Raw Materials, Lima, Peru | 1 |
| Division of Raw Materials, Salt Lake City | 3 |
| Division of Raw Materials, Washington | 3 |
| Grand Junction Operations Office | 6 |
| Technical Information Service Extension, Oak Ridge | 6 |
| U. S. Geological Survey: | |
| Alaskan Geology Branch, Menlo Park | 1 |
| Foreign Geology Branch, Washington | 1 |
| Fuels Branch, Denver | 4 |
| Geochemistry and Petrology Branch, Washington | 1 |
| Geophysics Branch, Washington | 1 |
| Mineral Deposits Branch, Washington | 6 |
| TEPCO, Denver | 2 |
| TEPCO, Washington | 2 |
| | 45 |

# CONTENTS

## ILLUSTRATIONS

# TABLE

# DETRITAL-APPEARING URANINITE IN THE SHINARUMP MEMBER OF THE CHINLE FORMATION IN NORTHERN ARIZONA

by Richard G. Petersen

## ABSTRACT

A sample of uranium-bearing conglomerate from the Shinarump member of the Chinle formation in northern Arizona was disaggregated in an ultrasonic separator. The sample, weighing 187 grams, contained about 60 grains of uraninite (from 0.1 to 1 mm. diameter) which have the sphericity and polish suggestive of detrital grains.

The detrital-appearing grains are associated with abundant interstitial uraninite, sphalerite, and pyrite, which presents conflicting evidence as to the origin of the uranium deposit.

No definite conclusions are presented for the occurrence of these grains. However, the evidence strongly suggests that they are uraninite replacements of detrital grains; the original mineral may have been quartz.

## INTRODUCTION

An ultrasonic disaggregation of a sample of uraniferous conglomerate from the Shinarump member of the Chinle formation allowed recovery of about 60 grains of uraninite. These grains are as much as 1 mm in diameter, and have the appearance of detrital grains. The sample came from the Sun Valley uranium mine in Coconino County, Arizona. The sample is one of a group collected in the summer of 1956 as part of a geologic mapping program in the East Vermilion Cliffs area (fig. 1) conducted by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

The author wishes to thank Wendell Walker of the U. S. Geological Survey for the excellent photomicrographs which appear in this report. Gratitude is also expressed to the Uranium-Petroleum Company of Salt Lake City, Utah for their permission to collect samples from the Sun Valley mine.

## GEOLOGY

### Regional geology

The East Vermilion Cliffs area is located in north-central Coconino County, Arizona, and is part of the Colorado Plateau Province (fig. 1). Erosion in House Rock Valley on the west side of the area and in the Colorado River valley on the east side has exposed a section of sedimentary rocks more than a mile thick. This section includes rocks ranging from the Pennsylvanian and Permian Supai formation to the Jurassic Entrada formation (fig. 2). The major structures are the East Kaibab monocline in the western part of the area and the Echo Cliffs monocline in the east, bordering a gently folded structural terrace (fig. 1).

Most of the uranium deposits in the area occur in paleo-stream channels in the Shinarump member of the Chinle formation at or near the base of the member. The Shinarump is greatly variable in both thickness and lithology. In the paleo-stream channels the member attains a thickness of as much as 130 feet, but elsewhere it is absent. Where it occurs as a persistent bed, the Shinarump generally ranges in thickness from 20 to 40 feet. The Shinarump is composed mainly of grains and pebbles of chert

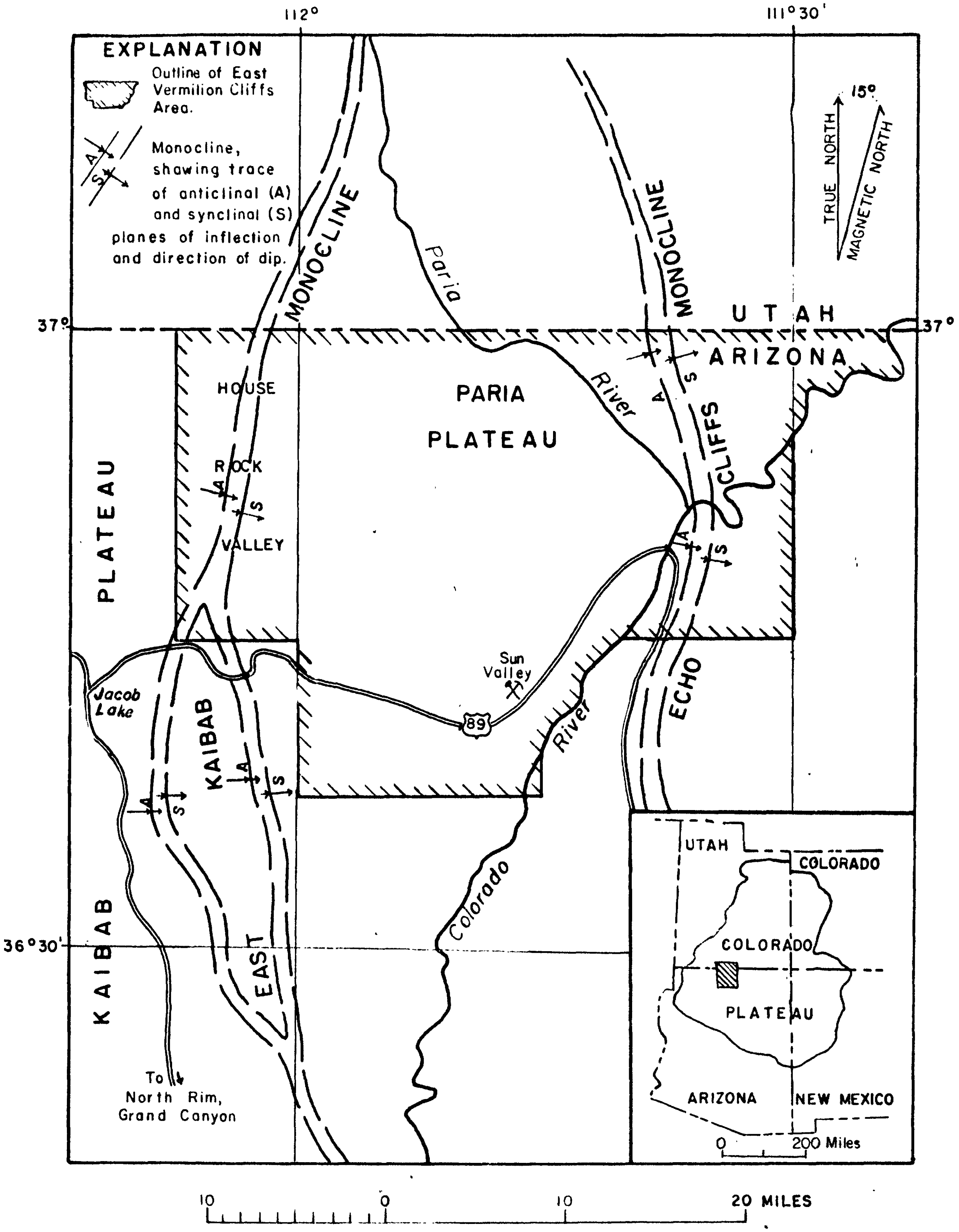

FIGURE 1. INDEX MAP SHOWING LOCATION OF EAST VERMILION CLIFFS AREA, COCONINO COUNTY, ARIZONA.

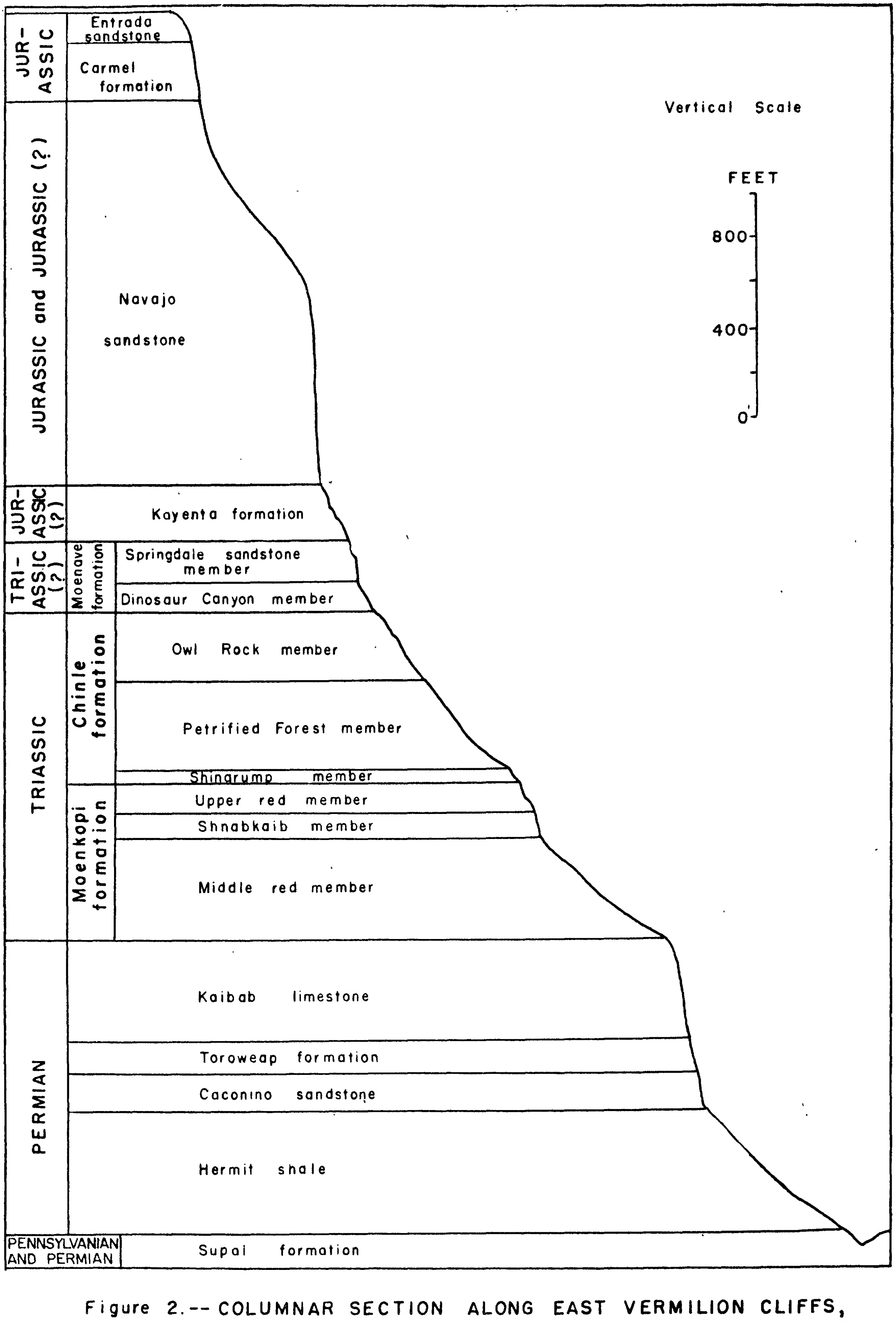

Figure 2.-- COLUMNAR SECTION ALONG EAST VERMILION CLIFFS, COCONINO COUNTY, ARIZ.

53285

and quartzite. It varies from a well cemented conglomerate to a deposit of friable, poorly sorted sand and gravel, and in places it is a clay-cemented crossbedded sandstone.

## Sun Valley mine

The Sun Valley mine is in a U-shaped bend of a Shinarump-filled paleo-stream channel which is at least 1,000 feet long and 400 feet wide. In the deepest part of the channel, the Shinarump is about 130 feet thick. It includes a basal bed of a chert- and quartzite-pebble conglomerate 40 feet thick overlain by about 90 feet of crossbedded sandstone. Uranium occurs mainly in ellipsoidal-shaped pods of ore, about 3 feet long and 2 feet wide, in the bottom 2 to 5 feet of the basal conglomerate of the Shinarump. Several hundred tons of uranium ore has been produced from about 400 feet of underground workings in this mine.

The only unoxidized uranium ore mineral identified in the conglomerate of the Shinarump member from the Sun Valley mine is uraninite. Other minerals recognized are pyrite, sphalerite (light amber), hematite, and galena (rare). Although some samples from the mine contained as much as 10 percent molybdenum no molybdenite has been recognized, but jordisite has been tentatively identified. The oxidized uranium minerals found forming on the mine walls and on outcrops of the Shinarump are zippeite, a zippeite-like mineral, and an unnamed uranyl phosphate. In addition to these, ilsemannite is forming rapidly on the walls of the older mine workings. The cementing material in the conglomerate is calcite with minor chalcedony. Carbonized wood and other carbonaceous material are found in the Shinarump deposits in the channel, but there is no close spatial association between the uranium and carbon.

## DETRITAL-APPEARING URANINITE

### Previous studies

The recent work of Liebenberg (1955) on the origin of gold and radioactive minerals in the Witwatersrand has stimulated interest in the possibility of detrital uraninite deposits. Probably the first important work on the detrital origin of the Rand gold is by Mellor (1916) who believed that the gold was deposited in the gravels of a delta. Later, Reinecke (1927) agreed with Mellor that the Witwatersrand is a placer deposit and added that a "variety of uraninite" was found associated with the gold. It is of interest that Reinecke also states seeing evidence of gold "replacing quartz metasomatically."

Liebenberg (1955), after a study of about 1000 polished sections and mine concentrates from the Witwatersrand system, is firmly convinced that the gold and uraninite grains were "deposited simultaneously with the other primary constituents of the banket." He has obtained uraninite grains, generally less than 80 microns in diameter, by superpanning mine concentrates. Liebenberg describes the grains as being a "shiny black" and "rounded to a varying degree, though irregular and angular fragments due to uneven fracturing during milling are common." Most of Liebenberg's conclusions, however, are based upon his study of the many polished sections.

With regard to the uranium deposits of the Colorado Plateau, Fleck and Haldane (1907) reported some 50 years ago that the then-recently-discovered carnotite deposits of southwest Colorado may have been formed from a "concentration of vanadiferous pitchblende particles by action of water currents and subsequent decomposition." However, they were unable to discover "pitchblende or other primary uranium compounds" in the deposits.

Chenoweth (1956) reports radioactive placer deposits on the Colorado Plateau in New Mexico and Colorado, but the radioactivity was attributed to uraniferous zircon and monazite. Murphy and Houston (1955) have made a study of a similar deposit in Wyoming, and Mackin and Schmidt (1956) report the uranium-bearing minerals, euxenite and uranothorite, in placer deposits in Idaho. None of these authors, however, found any uraninite.

The only report of uraninite in a placer deposit is by Steacy (1953) who writes of finding some uraninite grains in a "black sand reputedly taken from a placer deposit in British Columbia and sent to the Geological Survey of Canada."

Bain (1952), in his study of the Shinarump deposits of the Colorado Plateau, concludes that "jasperoid pebbles, sand and silt are the primary uranium carrier and represent detritus from a leptothermal uranium deposit of Permian age."

In a discussion of Mellor's report on the Witwatersrand (Mellor, 1916) Dr. J. W. Evans writes that he could remember a time when it was thought "a rather amiable eccentricity" to believe in the detrital origin of the Rand gold. It is not the purpose of this present paper to agree or disagree with those who believe in a detrital origin of some uraninite deposits. The author intends only to present the facts associated with the discovery of some detrital-appearing uraninite grains and some possible interpretations for their formation.

## Mineralogy

Almost all of the uraninite observed in polished sections of ore from the Sun Valley mine apparently has been introduced into the conglomerate as interstitial material. The interstitial uraninite embays and fills fractures in the quartz grains (figs. 3 and 4). Rounded uraninite grains also are present, but in small amount (figs. 5 and 6). Pyrite is present in the centers of a few uraninite grains and as interstitial material associated with interstitial uraninite. Although not visible in the photographs, polished sections show that light-amber sphalerite is abundant as interstitial material. It also fills fractures in the interstitial uraninite and therefore is probably younger. The probable paragenetic sequence is: (1) uraninite, (2) pyrite, and (3) sphalerite. The uraninite and pyrite may be contemporaneous. There are probably two stages of calcite deposition: one accompanying the uraninite and a later, post-ore, stage.

### Uraninite grains

Figure 7 is a photograph of several of the rounded and polished uraninite grains that were recovered from a sample of uranium ore from the Sun Valley mine. These rounded grains, along with angular fragments of uraninite in much greater amounts, were separated from a sample of poorly cemented conglomerate of the Shinarump member in an ultrasonic transducer (Bendix, model UTL-4A-1). The relative proportions of rounded grains and angular fragments suggest that the ultrasonic transducer itself cannot be considered a factor in the rounding of the grains. There was no visible evidence to suggest that any of the angular pieces of uraninite are

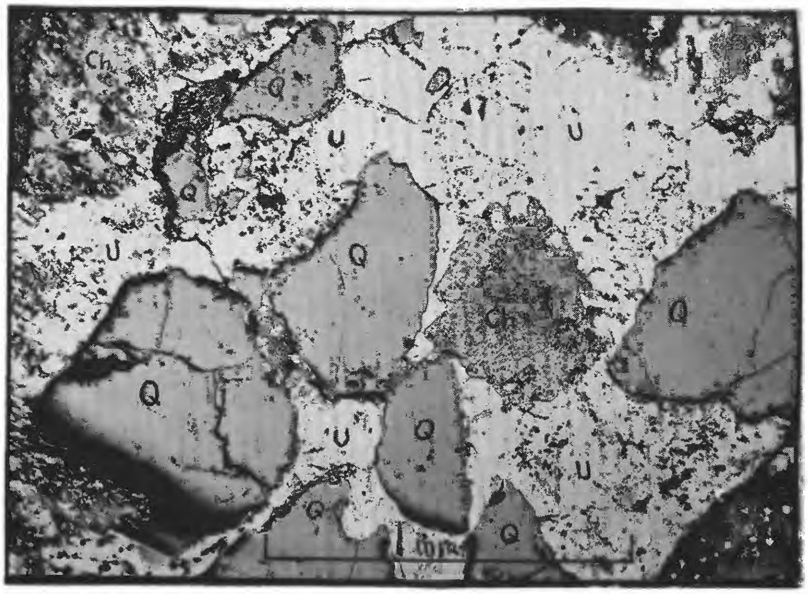

Figure 3. Photomicrograph of polished surface of conglomerate from the Shinarump member of the Chinle formation from the Sun Valley mine. White area is interstitial uraninite (U) with some sphalerite (also white and indistinguishable in this photograph). The large gray grains are quartz (Q). The darker gray areas are chalcedony (Ch) containing sphalerite (white spots) and hematite (darker areas). Plane-polarized light.

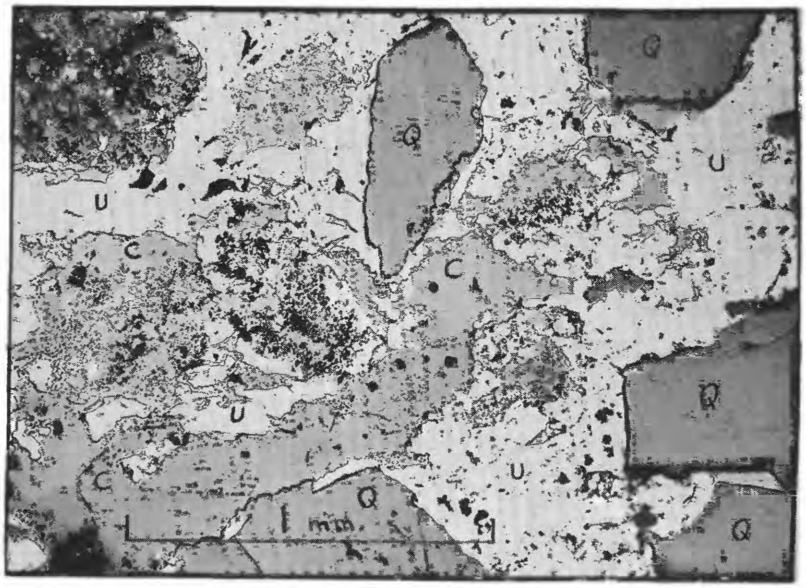

Figure 4. Photomicrograph of polished surface of conglomerate from the Shinarump member of the Chinle formation from the Sun Valley mine. White area is interstitial uraninite (U) with some sphalerite (also white and indistinguishable in this photograph). The large light-gray grains are quartz (Q) and the darker gray grain is chalcedony (Ch) containing grains of uraninite (white spots). The light-gray areas are calcite (C) with the different shades of gray indicating more than one optical orientation. Plane-polarized light.

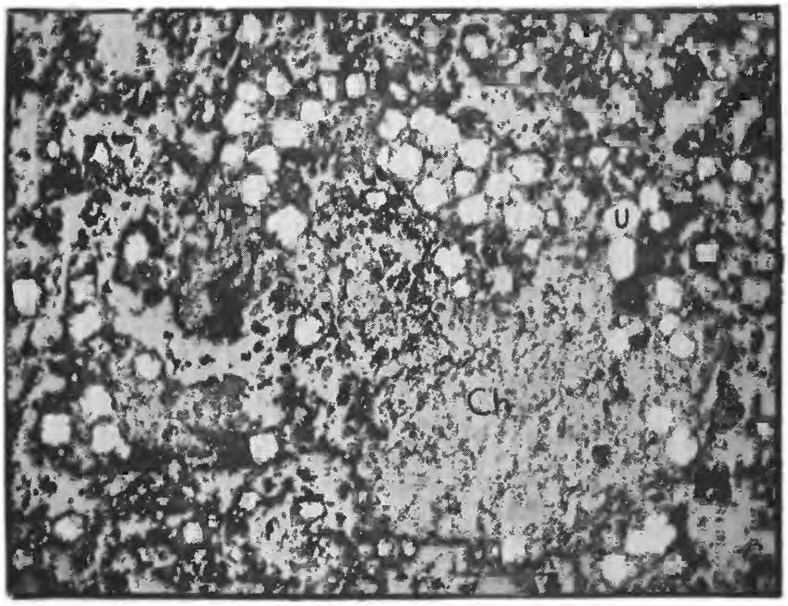

Figure 5. Photomicrograph of a polished surface of conglomerate from the Shinarump member from the Sun Valley mine. White rounded grains are uraninite (U). Gray matrix is chalcedony (Ch). Plane-polarized light.

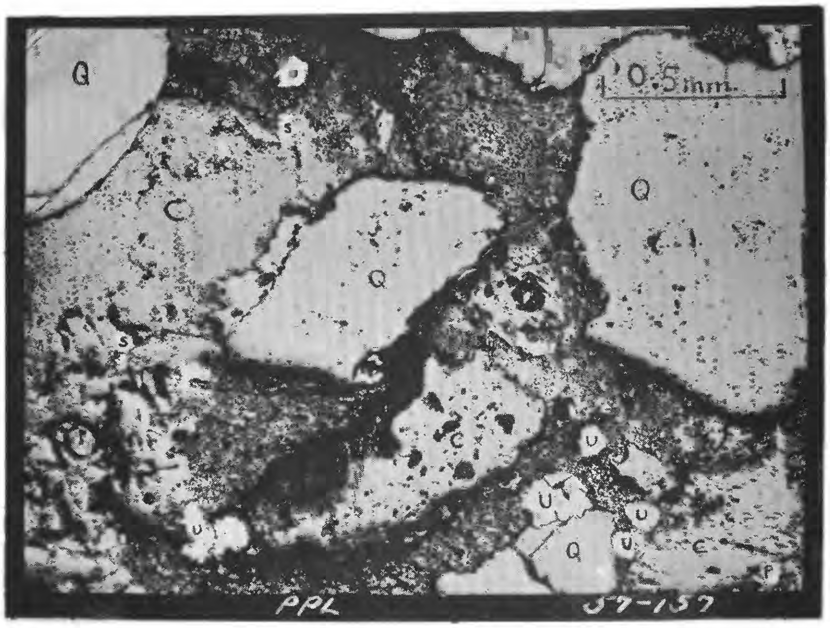

Figure 6. Photomicrograph of polished surface of conglomerate from the Shinarump member from the Sun Valley mine. White rounded grains are: uraninite (U), pyrite (P), and sphalerite (S). Some of the uraninite grains have pyrite centers (indistinguishable in this photograph). Large light-gray grains are quartz (Q) and the darker gray matrix is calcite (C) containing hematite (black). Plane-polarized light.

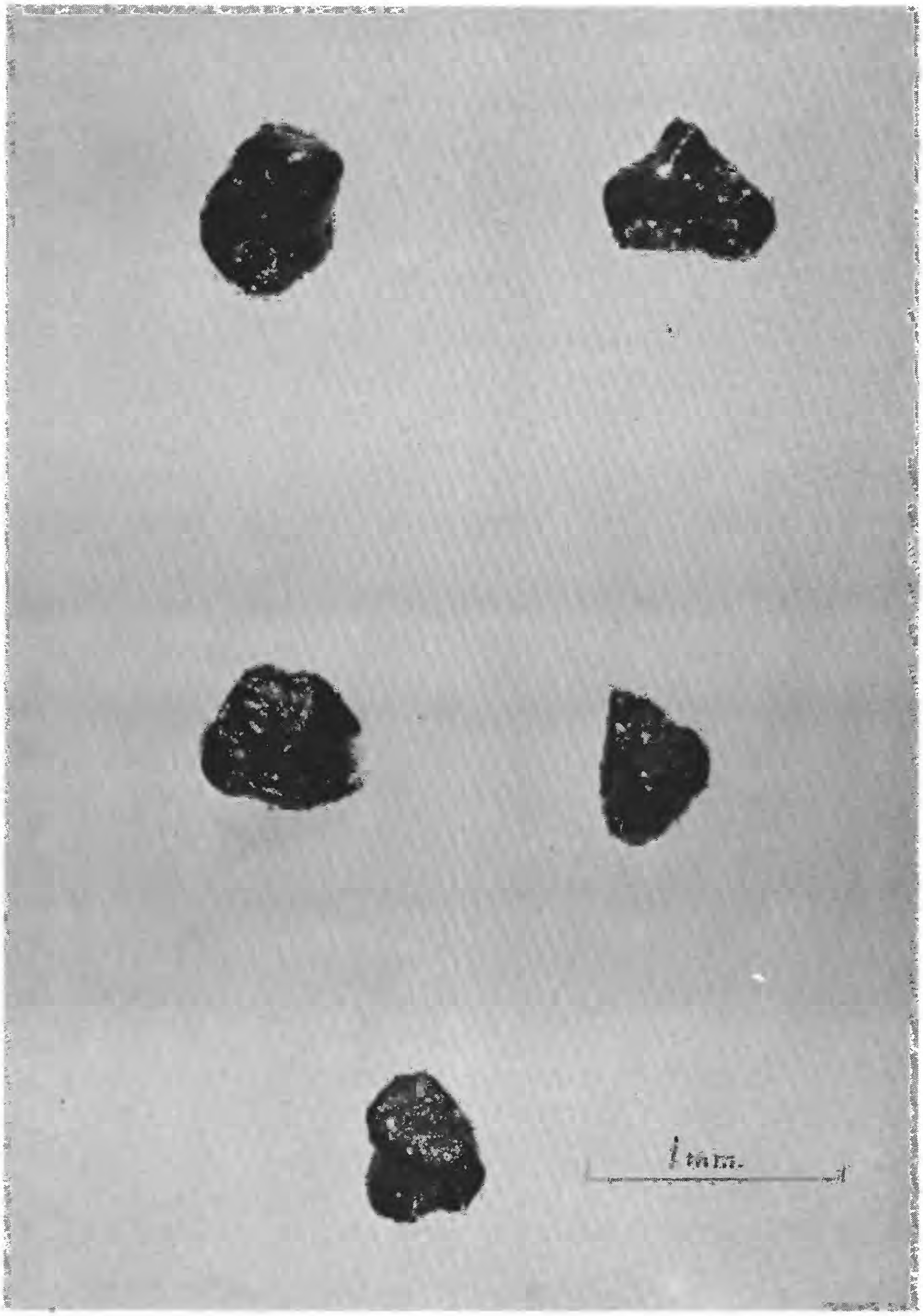

Figure 7. Photomicrograph of uraninite grains separated from the conglomerate of the Shinarump member from the Sun Valley mine showing roundness and high polish. Plain light.

fragments of rounded grains. If any of the rounding of the grains by cavitation of the uraninite could be attributed to the transducer, it certainly would have resulted in the rounding of the sharp edges of the fragments broken early in the treatment.

The original sample of conglomerate, which weighed 187 grams, produced about 60 rounded grains of uraninite (1 mm. or less diameter), which weighed about 50 milligrams. Each grain was assayed radiometrically, and all were found to contain more than 60 percent equivalent uranium. One grain was mounted, as a single grain, in an X-ray camera. The resulting film showed the "line" pattern of a cryptocrystalline uraninite aggregate rather than the "Laue" pattern of a single crystal. Table 1 shows the results of a semiquantitative spectrographic analysis of a 10-milligram sample of the uraninite grains:

Table 1.--Semiquantitative spectrographic analysis[1] (reported in percent) of a 10-milligram sample of rounded uraninite grains from the Shinarump member of the Chinle formation, Sun Valley mine.

| | | | | | |
|---|---|---|---|---|---|
| Si | 1.5 | Eu | 0 | Ru | 0 |
| Al | 1.5 | F | - | Sb | 0 |
| Fe | .3 | Ga | 0 | Sc | 0 |
| Mg | .3 | Gd | 0 | Sn | 0 |
| Ca | 3.0 | Ge | <.05 | Sr | .015 |
| Na | - | Hf | 0 | Sm | 0 |
| K | 0 | Hg | 0 | Ta | 0 |
| Ti | .15 | Ho | 0 | Tb | 0 |
| P | 0 | In | 0 | Te | 0 |
| Mn | .15 | Ir | 0 | Th | 0 |
| Ag | 0 | La | 0 | Tl | 0 |
| As | 0 | Li | - | Tm | 0 |
| Au | 0 | Lu | 0 | U | M |
| B | 0 | Mo | .3 | V | 0 |
| Ba | .015 | Nb | 0 | W | 0 |
| Be | .0015 | Nd | 0 | Y | .03 |
| Bi | <.05 | Ni | 0 | Yb | .003 |
| Cd | 0 | Os | 0 | Zn | <.1 |
| Ce | 0 | Pb | .7 | Zr | .07 |
| Co | .007 | Pd | 0 | | |
| Cr | .003 | Pr | 0 | | |
| Cs | - | Pt | 0 | | |
| Cu | .015 | Rb | - | | |
| Dy | 0 | Re | 0 | | |
| Er | 0 | Rh | 0 | | |

[1] Spectrographic analyses
Figures are reported to the nearest number in the series 7, 3, 1.5, 0.7, 0.3, 0.15, etc. in percent.
Sixty percent compliance with results of analyses by quantitative methods may be expected.
Symbols used are:
M = major constituent; greater than 10 percent.
0 = looked for but not detected (below limit of sensitivity).
< = below number shown.
- = not looked for.

Analyst: J. C. Hamilton Sample no. EVC-56; lab. no. 255003

Table 1 shows that the uraninite grains contain about 7 percent of the common major elements other than oxygen. Calcium, aluminum, and silicon make up the largest part of this percentage. The calcium can be accounted for by the calcite inclusions in the uraninite grains (fig. 8). Clay, sticking to the surface of the grains, could provide the aluminum and silicon. Most of the trace elements are probably disseminated through the uraninite.

Figure 8 is a photomicrograph of a polished section of the rounded uraninite grains. An examination of these grains under a microscope (up to X 1500) revealed no internal botryoidal structure. Calcite is the only mineral inclusion identified in the grains.

Figures 5 and 6 are photomicrographs of polished sections of the conglomerate of the Shinarump member in which rounded forms of uraninite can be seen. These may be the rounded uraninite grains, of the type that were separated, in place in the conglomerate. These particular rounded forms are, however, much smaller in diameter than the majority of the separated uraninite grains. Figure 6, and other polished sections not photographed, show rounded grains of sphalerite and pyrite. Sphalerite also has been observed as having replaced parts of quartz grains.

## Lead-uranium ratios

If the uraninite grains are truly detrital they would have to be as old as or older than the enclosing Shinarump sediments (Late Triassic: approximately 160 x $10^6$ years). The uraninite grains were analyzed for lead by quantitative spectrographic methods and for uranium by the volumetric method (chemical). The uraninite grains contain 0.45 percent lead and 49.8 percent uranium (Laboratory serial nos. 255003 and 256174

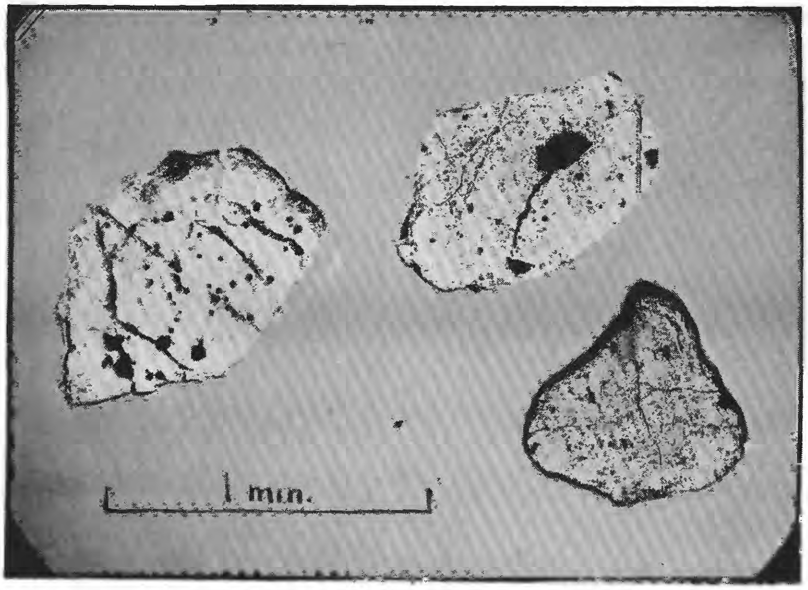

Figure 8. Photomicrograph of polished surface of the uraninite grains mounted in Lucite. Black spots in the grains are calcite. Plane-polarized light.

respectively; Sample no. EVC-56i for both). On the assumption that all the lead is radiogenic, derived in the grains, and that the grains have been closed systems since they were formed, the calculated age of the grains is about 68 x $10^6$ years (Late Cretaceous or early Tertiary). This figure is likely to be the maximum permissible age because the calculation does not take into consideration the possibility that some of the analyzed lead is nonradiogenic. In all probability the true age of the uraninite grains is somewhat less. Stieff and Stern (1952) report that all of the lead extracted by them from Colorado Plateau uranium ore contained some nonradiogenic lead.

An age was also calculated for the interstitial uraninite, based upon the ratio of total lead to uranium content. The interstitial uraninite was analyzed for lead by quantitative spectrographic methods, and the value adopted for the uranium content is an average of six fluorimetric determinations. The interstitial uraninite contains 0.7 percent lead and 40 percent uranium (Laboratory serial no. 262633; Sample no. EVC-56x). In this case the calculated age of the interstitial uraninite is about 130 x $10^6$ years (Late Jurassic). On the basis of the same assumptions as above, this also is the maximum age of the interstitial uraninite.

The quantitative spectrographic lead analyses for both samples were done by John C. Hamilton, the volumetric uranium analysis of the grains by Henry H. Lipp, and the fluorimetric uranium determinations by Edward J. Fennelly.

The difference in calculated ages for the grain-form and interstitial uraninite may be due to the presence of a higher proportion of contaminating lead in the interstitial uraninite. Stieff reports (Lorin R. Stieff, U. S. Geological Survey, written communication, February 5, 1959) that the "higher age, 130 x $10^6$ years, of the interstitial uraninite may reflect loss of uranium due to relatively recent oxidation and alteration of the uraninite." He also states that the "higher lead-uranium ages may be attributed in part to the presence of radiogenic lead derived from a pre-existing source of uranium."

## SUMMARY AND CONCLUSIONS

The data developed in this study are insufficient to form any definite conclusions, but the data do suggest certain hypotheses on the formation of the uranium in the Sun Valley mine.

The detrital-appearing uraninite grains probably have formed by the replacement of some common detrital mineral grains (probably quartz) by uraninite. This hypothesis is suggested by the following observations:

1. The maximum permissible age of the uraninite grains is apparently too low for them to have existed as grains before or during deposition in the Shinarump member, although calculations based on just one set of analyses may be inconclusive.

2. The uraninite grains are in the same crystalline form as the interstitial uraninite.

3. Uraninite appears to have replaced quartz (figs. 3 and 4).

4. Although it is very difficult to see in the photographs (fig. 3 and 4), sphalerite also appears to have replaced quartz in the conglomerate.

5. Rounded grains of sphalerite and pyrite also occur in the conglomerate (fig. 6). None of these grains, however, have been separated to prove their sphericity.

Although no botryoidal structures are visible, it is also possible that the detrital-appearing uraninite grains may have formed by recrystallization of pre-existing uraninite.

The evidence presented in this paper points strongly toward a non-detrital origin for the uraninite grains. The possibility that these grains are truly detrital, as suggested by their shape, is remote.

## REFERENCES

Bain, G. W., 1952, Uranium in the Dirty Devil Shinarump channel deposit: U. S. Atomic Energy Comm., RMO-66.

Chenoweth, W. L., 1956, Radioactive titaniferous heavy-mineral deposits in the San Juan basin, New Mexico and Colorado (abstract): Geol. Soc. America Bull., v. 67, p. 1792.

Fleck, Herman and Haldane, W. G., 1907, A study of the uranium and vanadium belts of southern Colorado: Colorado State Bur. Mines, Rept. for the year 1905-1906, p. 47-115.

Liebenberg, W. R., 1955, Occurrence and origin of gold and radioactive minerals in the Witwatersrand System, Dominion Reef, and the Black Reef: Geol. Soc. South Africa Trans., v. 58, p. 100-254.

Mackin, J. Hoover, and Schmidt, Dwight L., 1956, Uranium- and thorium-bearing minerals in placer deposits in Idaho, <u>in</u> U. S. Geol. Survey Prof. Paper 300, p. 375-380 (contributions to the geology of uranium and thorium by the U. S. Geological Survey and Atomic Energy Commission for the United Nations International Conference on Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1955, compiled by Lincoln R. Page, Hobart E. Stocking and Harriet B. Smith, 739 p.).

Mellor, E. T., 1916, The conglomerates of the Witwatersrand: Min. and Met., v. 25, p. 226-348.

Murphy, J. T., and Houston, R. S., 1955, Titanium-bearing black sand deposits of Wyoming: Wyoming Geol. Assoc., 20th. Ann. Field Conference Guidebook, p. 190-196.

Reinecke, L., 1927, The location of payable ore-bodies in the gold-bearing reefs of the Witwatersrand: Geol. Soc. South Africa Trans., v. 30, p. 89-119.

Steacy, H. R., 1953, An occurrence of uraninite in a black sand: Amer. Mineralogist, v. 38, nos. 5 and 6, p. 549.

Stieff, L. R., and Stern, T. W., 1952, Identification and lead-uranium ages of massive uraninites from the Shinarump conglomerate, Utah: Science, v. 115, p. 706-708.