Beneficiation of Monument #2 Oke
Apache County, Arizona

by

M. J. Sheridan

1952
UNITED STATES ATOMIC ENERGY COMMISSION
DIVISION OF RAW MATERIALS
GRAND JUNCTION EXPLORATION BRANCH

BENEFICIATION OF MONUMENT NO. 2 ORE
APACHE COUNTY, ARIZONA

By
M. J. Sheridan

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February 27, 1952
Grand Junction, Colorado
To the Files  February 27, 1952

M. J. Sheridan, Staff Mining Engineer, GJEB

TECHNICAL MEMORANDUM #21 - BENEFICIATION MONUMENT NO. 2 ORE

SYMBOL: GJEB:MJS

Introduction

The Monument No. 2 mine is in the Navajo Indian Reservation, Apache County, Arizona, about 20 miles southwest from the San Juan River at Mexican Hat, Utah, and 26 miles southwest from Mexican Water, Arizona. The property has been operated, since its discovery, by Vanadium Corporation of America, which holds a 10-year mining lease, granted through the Interior Department, to 43 acres of ground. History of the discovery of the deposit is vague, but reportedly it was first seen around 1942 by a Navajo who mentioned the occurrence to Harry Goulding, Indian trader, who in turn advised D. W. Viles of Vanadium Corporation of America. Minor portions of the deposit are held by Cato Sells and Harvey Black, Navajos, under mining permits issued by the Navajo Tribal Council. The Sells acreage is being operated by Climax Uranium Corporation.

The Monument No. 2 ore body might be considered the type locality of Shinarump channel deposits. The channel structure, which trends north-south, ranges from 400 to 600 feet wide and may be traced along its axis for 3,000 to 4,000 feet. The ore-bearing portion of the channel is believed to comprise one of the largest unit uranium reserves in the United States.

Production

Since the issuance of Atomic Energy Commission Circular No. 1 in April, 1948, the deposit has produced about 90,000 tons of uranium-vanadium ore nearly all of which has been processed at Durango. The grade of this total production has not been calculated but may approximate the grade of the eleven-month, January to November 1951, shipments which amounted to 25,666 tons at 0.62% U₃O₈. November shipments alone totalled 2,600 tons at 0.83% U₃O₈.
In 1951, the Monument No. 2 operation supplied Durango with 43% of incoming tonnage containing nearly 75% of all uranium received. In November 1951, the corresponding figures were 53% and 80%. It is probable that something on the order of 400 to 500 tons of contained U₃O₈ has been produced to date from this deposit.

Because of the 160-mile haul from the Monument No. 2 mine to Durango, Vanadium Corporation is shipping the highest grade ore it can produce, the lower grade being by-passed, left in roofs and floors, or discarded as waste on dumps. One advantage of this is obvious. With haulage estimated at $0.06 per ton-mile, cost of shipping 0.83% ore (November average) is $0.58 per pound contained U₃O₈; the corresponding figure for, say, 0.20% ore would be $2.40.

Exploration and Sampling

Wagon drilling was undertaken by the Grand Junction Exploration Branch in the summer of 1951 to test projected north-south extensions of the channel structure—not included in areas held by Vanadium Corporation, Sells, or Black—in anticipation of finding ore bodies comparable in size and grade to the main Monument No. 2 deposit. Diamond drilling is now continuing to explore certain portions of the area previously tested which, because of rock conditions encountered, could not be satisfactorily wagon-drilled. To date, only a few hundred tons of plus 0.10% ore has been discovered by this work indicating that the most potential parts of the structure are in areas controlled by the above-mentioned claim holders, mainly Vanadium Corporation.

No detailed exploration of the Vanadium Corporation-controlled portion of the deposit has been conducted, and without detailed drilling no accurate estimate of reserves can be made; however, as part of an overall appraisal of uranium occurrences in the Reservation, an approximate estimate of low-grade reserves (as distinct from reserves of shipping-grade) of the Monument No. 2 mine and adjacent holdings has been made by Commission geologists. Objectives of this investigation were 1) to estimate roughly the worth of the deposit from the standpoint of overall reserves of the country, 2) to determine whether detailed exploration of the VCA-Sells-Black portion of the deposit should be undertaken by the Commission, 3) to determine whether sufficient low-grade reserves exist to merit large-scale beneficiation testing which might ultimately lead to assured utilization of such reserves, 4) to collect metallurgical samples of low-grade rock for laboratory beneficiation tests.
To accomplish this, bulk samples were taken from waste dumps, open pit faces, weakly-mineralized rock layers between ore zones, mine pillars, etc., to determine tonnage and grade of that portion of the deposit not considered shipping ore by Vanadium Corporation. A preliminary estimate of 1,000,000 to 3,000,000 tons at 0.05% \( \text{U}_3\text{O}_8 \), exclusive of shipping-grade ore, has been calculated. It is further estimated that the uranium content of, say, one million tons would be improved by 0.10% by inclusion of material containing between 0.10% and 0.40% \( \text{U}_3\text{O}_8 \) which, apparently, is not considered shipping grade. Should this estimate be reasonably correct, this deposit, which has produced 400 to 500 tons of \( \text{U}_3\text{O}_8 \) may still contain over 1,000 tons of \( \text{U}_3\text{O}_8 \) which would constitute one of the largest unit uranium reserves in the country. Furthermore, most of this ore is comparatively shallow and could be cheaply mined by open pit methods.

It may be of interest to note, by comparison, the importance of 1,000 tons of \( \text{U}_3\text{O}_8 \). It is 1) nearly equal to uranium content of all plus-0.10% reserves, in many deposits, discovered by 360,500 feet of combined USGS-GJEB drilling on the Colorado Plateau in calendar year 1950, 2) greater than uranium content of reserves of the Grants, New Mexico, district, as reported in Denver monthly report for October 1951 (447,300 tons at 0.16% \( \text{U}_3\text{O}_8 \)), on which Anaconda is constructing a 200-ton plant, 3) greater than annual U. S. output of uranium, 4) greater, by 100%, than total estimated uranium content of the Happy Jack deposit, White Canyon, Utah, which may contain 150,000 at 0.30% \( \text{U}_3\text{O}_8 \).

Consideration is being given the possibility of detailed exploration of this deposit by the Commission. If this reserve is proved, what might be done to assure that the 1,000 tons of contained \( \text{U}_3\text{O}_8 \) is made available as raw material for atomic energy?

Possible Beneficiation Methods

Shipping this tonnage of 0.10% ore any distance is unfeasible and extraction by the usual acid or alkaline leach is apparently defeated by lack of water and insufficient uranium content to realize profit under present hydrometallurgical costs and final product price. (Results of recent investigation of ground water resources in the Navajo Indian Reservation by the U. S. Geological Survey indicate that possibilities of developing quantities of industrial water in the region are slight. The only assured water source is the San Juan River, 20 miles north.)
The comparatively short history of Colorado Plateau radium-uranium-vanadium metallurgy includes at least three installations of concentrators designed to produce a high-grade shipping product by size separation. Based on the interstitial occurrence of the ore minerals in sandstone, the processes developed partial liberation by, probably, semi-controlled wet or dry grinding, and concentrated the values by pneumatic or hydraulic classification. The Raymond mill (combined dry grinding and air classification) was commonly used. Heads were maintained at about 1.0% $\text{U}_3\text{O}_8$ and possibly 5% to 10% $\text{V}_2\text{O}_5$ (this must have been considered low-grade) and concentrates, comprising 25% to 30% of the original weight and containing 60% to 70% of original uranium, were produced. Because of settling and filtration difficulties, subsequent chemical treatment of such slimes proved even more costly than leaching of the original ore.

Now, because of 1) the present strategic position of uranium, 2) the new economic structure of the industry, 3) potential tonnage of 0.10% $\text{U}_3\text{O}_8$ rock believed to be contained in deposits such as the Monument No. 2, and 4) possible recent developments in attrition grinding (Mardun Disintegrator, paper being prepared by Schack and Zimmerley, U. S. Bureau of Mines; Wemco Attrition Machine, see Engineering and Mining Journal, February 1952, p. 44), improvements in air classification, filtration, etc., the possibility of dry mechanical concentration of lower-grade material—with continued shipping of the better grade ore—has again come up. Utilization of the Monument No. 2 low-grade, with simultaneous production of shipping grade, would permit nearly complete ore extraction and lessen the eventual probability of loss of uranium resources tied up in the floors and backs of mine workings which would cave on removal of pillars. Accordingly, a 280-pound sample of low-grade conglomerate was shipped September 26, 1951, to the Metallurgical Division of the U. S. Bureau of Mines in Salt Lake City with a transmittal letter (attached) suggesting concentration by separation of coarser clastics from the ore-bearing fines. Results of this work are explained in the attached correspondence and summarized below.

The metallurgical sample, containing 0.047% $\text{U}_3\text{O}_8$, 0.20% $\text{V}_2\text{O}_5$, and 0.3% $\text{CaO}$, equivalent to about 0.5% $\text{CaCO}_3$, was crushed to 5 mesh and passed, dry, through a laboratory Mardun Disintegrator. This is a steel cylindrical shell about 1 foot in diameter and 5 inches thick enclosing three rectangular alloy steel breakers set at 120 degrees on a center rotor shaft. The breakers do not swing like the hammers of a hammer mill, but rotate at a high speed disintegrating the material partially by impact and partially by attrition of the particles on themselves between the ends of the breakers and the inside surface.
of the shell. This clearance between breaker and shell is adjustable and usually set at about 1/2 inch to 3/4 inch. The attrition or abrasion promotes liberation of softer portions such as the mineralized interstitial material from the harder portions, such as the barren pebbles of a conglomerate. Concentration of values in the fines is apparent from the following results of air classification which follows disintegration:

<table>
<thead>
<tr>
<th>Product</th>
<th>Weight%</th>
<th>U₃O₈%</th>
<th>CaO%</th>
<th>Distribution</th>
<th>Ratio of U₃O₈ Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>100</td>
<td>0.047</td>
<td>0.3</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Dust</td>
<td>18.2</td>
<td>0.171</td>
<td>0.6</td>
<td>66%</td>
<td>5.5:1</td>
</tr>
<tr>
<td>Concentrates 1-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dust</td>
<td>10.2</td>
<td>0.069</td>
<td>0.2</td>
<td>15.3%</td>
<td></td>
</tr>
<tr>
<td>Concentrates 3-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combined</td>
<td>28.6</td>
<td>0.134</td>
<td>0.45</td>
<td>81.5%</td>
<td>3.5:1</td>
</tr>
<tr>
<td>Concentrates 1-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cost of a plant to provide crushing, screening, drying, Mardum disintegration, and air-classification has been roughly estimated (see attached correspondence) at $1,000 per ton of daily capacity. It is probable that cost advantages gained by cheap mining could not be realized at a scale of less than 500 tons per day. Thus, plant cost could be on the order of $500,000. Power requirements would be about 500 kw and a Diesel-electric plant to supply this would cost around $50,000. With open-cut mining costs, including mine-plant write-off, estimated at $1.00 per ton and beneficiation cost at an estimated $1.50 per ton, the following overall costs are obtained:

1,000,000 Ton Reserve—500 Tons Per Day, 150,000 tons Per Year, 6- to 7-year Operation

<table>
<thead>
<tr>
<th>Per ton of ore treated</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining, including mine plant write-off</td>
<td>$1.00</td>
</tr>
<tr>
<td>Beneficiation</td>
<td>1.50</td>
</tr>
<tr>
<td>Plant write-off ($550,000 against 1,000,000 tons)</td>
<td>5.50</td>
</tr>
<tr>
<td>Total</td>
<td>$3.05</td>
</tr>
</tbody>
</table>

(Interest charges not considered)
Under the above conditions, cost of producing dust-concentrate 1-2 containing 0.17% $U_3O_8$ would be 5.5 (ratio of concentration multiplied by $3.05$ or $16.78$ per ton. Cost of producing concentrate 1-4 containing 0.13% $U_3O_8$ would be 3.5 (ratio of concentration) multiplied by $3.05$ or $10.68$ per ton. Were these fine concentrates saleable at an existing plant, they would bring, according to Circular No. 5 revised, (vanadium content not considered) $11.56$ and $6.78$ per ton respectively. Thus, a loss would result.

The value of such products to an organization with integrated mining, beneficiation, and extraction facilities, however, would be calculated, not on the Circular No. 5 schedule, but on the value of recoverable uranium. For instance, 0.13% concentrate contains 2.6 pounds of $U_3O_8$ per ton of which, at estimated 75% recovery, 1.9 pounds is extracted. If the final product is worth $12.00 per pound, the recoverable uranium in the concentrate is worth about $23.00. With mining and beneficiation estimated at $10.68 per ton of concentrate, haulage of concentrate not considered, chemical treatment at $20.00, a price for final product considerably in excess of $12.00 per pound still would be necessary.

The 0.17% concentrate contains 3.4 pounds of $U_3O_8$. At 75% extraction and $12.00 per pound for final product, the recoverable value is around $30.00. With mining and beneficiation estimated at $16.78 per ton of concentrate, concentrate haulage not considered, chemical treatment at $20.00, the final product would have to sell for around $20.00 per pound to realize a profit.

The Bureau of Mines is now conducting further tests on dry beneficiation of the original sample and leaching of the fine concentrates. It is realized that handling, haulage, chemical treatment, settling, and filtration of such a product—in effect, a slime concentrate—introduces problems known to be difficultly resolved.

It must be remembered that these tests were run on 0.047% material. Should the average grade be 0.10% as estimated by Commission geologists, correspondingly higher-grade concentrates would be produced. If the following hypothetical, but not impossible, figures could be realized, the economic aspect would improve considerably.

<table>
<thead>
<tr>
<th>Product</th>
<th>Weight</th>
<th>$U_3O_8$%</th>
<th>Distribution</th>
<th>Ratio Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>100%</td>
<td>0.10</td>
<td>100%</td>
<td>3.75:1</td>
</tr>
<tr>
<td>Concentrate</td>
<td>26.6%</td>
<td>0.30</td>
<td>80%</td>
<td></td>
</tr>
</tbody>
</table>

Cost per ton of this concentrate from previous estimation, would be: $3.05$ per ton ore treated x 3.75 (ratio concentration) equals $10.44; plus chemical treatment at $20.00 totals $30.44. Value of recoverable uranium at $12.00 per pound and 80% extraction would be $57.50. From
the apparent profit, $17.16, haulage of the 0.30%-concentrate to a leaching plant would have to be subtracted.

It may be of interest to compare the above hypothetical analysis, which may represent the best that can be done with dry concentration, with Vanadium Corporation's present set-up. November, 1951, is the example: 2,600 tons containing 0.83% U₃O₈ and 2.2% V₂O₅, shipped from Monument No. 2 to Durango. This is an estimate of their costs—

<table>
<thead>
<tr>
<th>Description</th>
<th>Per Ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining (100 tons per day)</td>
<td>$10.00</td>
</tr>
<tr>
<td>Haulage (160 miles at $0.06)</td>
<td>9.60</td>
</tr>
<tr>
<td>Delivered cost</td>
<td>$19.60</td>
</tr>
<tr>
<td>Treatment (estimated)</td>
<td>20.00</td>
</tr>
<tr>
<td>Total cost per ton</td>
<td>$39.60</td>
</tr>
</tbody>
</table>

Recovery: 62% of contained uranium and 61% of contained vanadium.

- 2,000 x 0.83% U₃O₈ x 62% recovery x est. $12.00 = $124.00
- 2,000 x 2.2% V₂O₅ x 61% recovery x est. $1.00 = 27.00
- Total estimated value = $151.00
- Approximate cost production = 40.00
- Estimated profit per ton = $111.00

Even if this estimate is in error 25%, it is difficult to argue that the present operation is not profitable. The point is that in order to realize this profit, despite comparatively low extraction, Vanadium Corporation is gutting what probably is the best uranium deposit in the country.

As previously stated, dry beneficiation of 0.10% ore should result in concentrates of higher grade than those produced in the testing of the 0.047% material. It is of interest, however, to compare the laboratory results obtained on the 0.047% rock, and corresponding cost estimates, with an actual operation. This requires considering the 0.17% concentrate which, from the standpoint of grade, could fit into one of the usual hydro-metallurgical flow sheets. (From the standpoint of physical characteristics this fine product probably could not be treated in any presently-operating plant.) It was estimated that, at 500 tons per day, 0.047% ore could be mined and beneficiated to 0.17% for $16.78 per ton of concentrate or for about $5.00 per pound of contained U₃O₈. (The Circular No. 5 value of this product, exclusive of any contained vanadium, as previously mentioned, is $11.56.) This cost of production might be compared to cost of crude ore at a straight custom leaching plant. For instance, it is estimated that cost of ore delivered to the Monticello coarse-ore bin, including ore cost, haulage, and sampling, but exclusive of bonus payment, is around $30.00 per ton. Of this
figure, about $5.00 is paid for contained vanadium much of which (in asphaltic ores) is not recovered necessitating, in effect, charging part of the vanadium pay to uranium. However, using an average grade of .24% U₃O₈ and charging $25.00 per ton, the cost per pound of contained uranium is $5.20 which is about equal to the estimated cost of production of uranium contained in the 0.17% concentrate. If this dry concentrate were amenable to chemical treatment at a nearby leaching plant, total cost of U₃O₈ production should be comparable to that obtained at Monticello.

Should it be proven that the Monument No. 2 deposit contains the estimated 1,000 tons of U₃O₈, consideration might be given the possibility of erecting a leaching plant at the mine site to treat 0.10% crude ore. If mining costs plus treatment costs plus plant amortization could be kept below $15.00 per ton of through-put, with 75% extraction recovering 1.5 pounds of U₃O₈ at a selling price of $12.00 per pound, a unit profit of $3.00 per pound or a total potential profit of $4,500,000 could be gained. It is realized in making this estimate that treatment costs per ton may not be considerably reduced by large-scale, say 500 ton-per-day, treatment—that roasting and reagent costs per ton, probably the main items of treatment cost, remain somewhat constant. However, some saving over present 100 to 200 ton-per-day costs should be realized in a larger plant. If ore costs at presently operating plants are running between $15 to $20 per ton, certainly the ore cost advantage of a large-scale, integrated operation would partially compensate for low uranium content. If the cost of .25% U₃O₈ ore is averaging $20.00 per ton at the plants, contained uranium costs $4.00 per pound. In large-scale $1.00-per-ton mining of 0.10% ore, contained uranium would cost $0.50 per pound.

Minimum water requirements of a leaching operation are probably around three tons per ton of feed. A 500-ton plant would therefore require 15,000 tons per day or 250 gallons per minute. A rough estimate of cost of pump station and pipeline installation to supply a plant at the Monument No. 2 mine with water from the San Juan River follows:

<table>
<thead>
<tr>
<th>Static head, estimated</th>
<th>200 feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friction head, 105,000 feet 8-inch pipe</td>
<td>150 feet</td>
</tr>
<tr>
<td>Total head</td>
<td>350 feet</td>
</tr>
</tbody>
</table>
Pump equipment with motors (two lifts at 250 gpm and 200-foot head each) $5,000
105,000 feet 8-inch pipe at $2.00 per foot 210,000
Installation 150,000
Operation cost: estimated two 25 horsepower motors
or 37 kw @ 24 hours equals 900 kwh @ 1¢ equals
$90.00 a day or about 20¢ per ton treated. To
treat 1,000,000 tons, pumping cost would be 200,000

Total possible cost $565,000

This cost which approximates $0.60 per ton of ore treated would have
to be weighed against cost of hauling crude ore to a plant on the river.
At $0.06 per ton-mile, haulage would cost $1.20 per ton.

Such an expenditure will at first appear to border on the ridiculous.
But the cost to date of hauling the 90,000-ton production 160 miles
from the Monument No. 2 mine to Durango at $0.06 per ton-mile totals
$865,000.

Had the deposit been systematically explored and its potential deter-
mined a few years ago, the nearly $1,000,000 which has been spent for
haulage alone to date might have put water at the mine and at least
started plant construction. State and federal funds probably would
have provided for first-class access to the mine from the north or
east.

The potential still exists, if only partially. If Vanadium Corporation
does not object, it is only logical that the Commission determine how
much uranium the deposit contains. In knowing this, the Commission or
Vanadium Corporation will certainly take the steps necessary to get it
out. Possibly the present set-up cannot be improved.

Possible Exploration

The potentially-mineralized portion of the Monument No. 2 channel
covers a 3,000- by 600-foot area. To drill this on 100-foot centers,
as the Temple Mountain deposits are now being explored, would require
around 200 holes. As the area is partially developed by underground
and surface workings, mine mapping and sampling could eliminate a
certain percentage of grid holes. However, with offsets, it is prob-
able that something on the order of 250 holes would be the minimum
necessary to thoroughly evaluate the deposit. Average hole depth
would be 50 feet; total footage between 13,000 and 18,000. Because
of the Commission's previous wagon drilling experience in this area,
the Monument No. 2 deposit would have to be tested by diamond drilling.
It is appreciated that improvements in uranium metallurgy cannot be forced. If at present 0.10% ore, even at zero mining cost, cannot be treated profitably, then such reserves at the Monument No. 2 may have to wait out reduced treatment cost or higher final product prices. However, detailed exploration of this deposit will probably prove 1) a seven-figure tonnage of plus 0.10% ore, 2) a six-figure tonnage of plus 0.20% ore, 3) that the tonnage of 0.70% to 0.80% ore now being shipped is relatively low—that the Monument No. 2 is not a 0.70% or 0.80% ore body. It may indirectly prove that the economic potential of this ore body may never be realized and that ultimate chances of near complete extraction are being seriously risked by the present high-grading operation unless, of course, final product prices periodically increase as the better ore is mined out, which is probably what Vanadium Corporation is figuring on anyhow.

Many of the items dealt with in this memorandum have been discussed with mining and metallurgical engineers of the Colorado Raw Materials Office.

APPENDIX

1. Copy of letter Oster to Zimmerly, dated 9/26/51
2. Copy of letter Potter to Oster, dated 10/24/51
3. Map and list of samples, dated 12/51
4. Copy of letter Potter to Sheridan, dated 12/13/51
5. Copy of memo Oster to Merritt, dated 1/9/52
6. Copy of letter Oster to Potter, dated 1/14/52
Mr. S. R. Zimmerly  
U. S. Bureau of Mines  
1600 East First South Street  
Salt Lake City, Utah  

Dear Mr. Zimmerly:

We are shipping to you under Bill of Lading No. AT80132, a sample weighing approximately 280 pounds contained in four boxes.

This material is a low-grade, conglomerate ore from the Monument No. 2 mine in Monument Valley, Utah. This low-grade material is associated with shipping-grade ore now being mined by the Vanadium Corporation of America. It is estimated that there are at least 50,000 to 100,000 tons of conglomerate which would run 0.10% U_3O_8 or somewhat better. The higher grade ore usually found directly under the low-grade material is being mined in large rooms, with pillars being left to support the back. When the extremities of the ore bodies have been reached, the pillars will be pulled and the back will cave. This will probably mean that much, if not all, of the low-grade material will be unrecoverable after the present mining operation is completed. There is comparatively little cover, and much of the low-grade material could be mined cheaply with bulldozers if it could be done during the next two or three years.

The appearance of the ore suggests the possibility that a simple, cheap washing method of concentration might be successfully employed. It appears that if the hard pebbles and stones could be washed clean and separated from the fines, the uranium content of the shipping product could be increased to perhaps twice its original assay. If such a process is practical and the cost of operation is low, it would be feasible to build a plant at the mine for concentration of these low-grade ores. The present haul to the mill is in the neighborhood of 150 miles, and such a haul is prohibitive under present conditions.
It would be appreciated if you could run tests to determine the practicability of a washing process of concentration of this material

Very truly yours,

Thomas W. Oster, Chief
Grand Junction Exploration Branch

CC: w/samples u/sep. cover
P. L. Merritt

COPY/mjb
January 27, 1983

Mr. Thomas W. Oster, Chief
Exploration Branch
Atomic Energy Commission
Grand Junction, Colorado

Dear Mr. Oster:

We have completed preliminary wet and dry attrition concentration tests on sample AEC-121 from Monument No. 2 mine, Monument Valley, Utah. The sample is described in your letter of September 26, 1951. A head sample split from this low-grade conglomerate ore assayed 0.047 percent $U_3O_8$, 0.20 percent $V_2O_5$, and 0.3 percent CaO.

The dry attrition test was made in a laboratory Mardun dry concentrator on ore crushed to 6-mesh. Eight successive passes or treatments were made on the material; a dust product being removed after each pass. The dust products were composited in pairs for analysis. Data are given in the following table:

<table>
<thead>
<tr>
<th>Product</th>
<th>Weight, percent</th>
<th>Assay, percent</th>
<th>Distribution, percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$U_3O_8$</td>
<td>CaO</td>
<td>$U_3O_8$</td>
</tr>
<tr>
<td>Dust 1-2</td>
<td>18.2</td>
<td>0.171</td>
<td>0.6</td>
</tr>
<tr>
<td>Dust 3-4</td>
<td>10.4</td>
<td>0.069</td>
<td>0.2</td>
</tr>
<tr>
<td>Dust 5-6</td>
<td>6.8</td>
<td>0.037</td>
<td>0.1</td>
</tr>
<tr>
<td>Dust 7-8</td>
<td>5.1</td>
<td>0.022</td>
<td>0.1</td>
</tr>
<tr>
<td>Fine sand</td>
<td>24.3</td>
<td>0.005</td>
<td>0.05</td>
</tr>
<tr>
<td>Coarse sand</td>
<td>35.2</td>
<td>0.006</td>
<td>0.05</td>
</tr>
<tr>
<td>Calculated head</td>
<td>100.0</td>
<td>0.045</td>
<td>0.17</td>
</tr>
<tr>
<td>Combined dust 1-4</td>
<td>28.6</td>
<td>0.134</td>
<td>0.45</td>
</tr>
<tr>
<td>Combined dust 1-6</td>
<td>35.4</td>
<td>0.113</td>
<td>0.39</td>
</tr>
<tr>
<td>Combined sands</td>
<td>39.5</td>
<td>0.006</td>
<td>0.05</td>
</tr>
<tr>
<td>Combined sand, dust 7-8</td>
<td>64.6</td>
<td>0.007</td>
<td>0.05</td>
</tr>
<tr>
<td>Combined sand, dust 5-3</td>
<td>71.4</td>
<td>0.010</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Copy to: Dr. George R. Marvin
Mr. Frank W. McQuiston, Jr.
Although the ore heads were very low in uranium content, the ore proved readily amenable to concentration by the dry process. The data indicate that the combined first four dust products contained 84.7 percent of the uranium in the ore and assayed 0.134 percent U₃O₈ and 0.45 percent CaO. This combined dust contained 28.6 percent of the original weight of the ore. The corresponding sand tailing assayed 0.010 percent U₃O₈. Higher recoveries of the uranium were obtained on correspondingly lower grade dust products, and sand tailings as low as 0.006 percent U₃O₈ were obtained. It should be noted that all of the concentrate products were relatively low in lime.

Treatment of a larger sample of the ore by the Mardun process is now in progress, and the products will be turned over to the hydrometallurgical section for leaching tests.

In order to compare wet and dry attrition methods, another sample of the ore was screened wet on 200-mesh and treated by wet attrition in three successive stages of 15, 30, and 45 minutes duration, respectively. After each stage, the material was screened wet on 200-mesh to remove the fines. An iron laboratory ball mill with boiler punchings as grinding media was used. The data are shown in the following table.

### Wet Attrition Test

<table>
<thead>
<tr>
<th>Product</th>
<th>Weight, percent</th>
<th>Assay, percent U₃O₈</th>
<th>Distribution, percent U₃O₈</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 original -200-mesh</td>
<td>8.4</td>
<td>0.242</td>
<td>41.1</td>
</tr>
<tr>
<td>2 first stage -200-mesh</td>
<td>7.6</td>
<td>.224</td>
<td>34.4</td>
</tr>
<tr>
<td>3 second stage -200-mesh</td>
<td>4.6</td>
<td>.058</td>
<td>5.5</td>
</tr>
<tr>
<td>4 third stage -200-mesh</td>
<td>6.5</td>
<td>.035</td>
<td>4.7</td>
</tr>
<tr>
<td>-200-mesh tailing</td>
<td>72.9</td>
<td>.009</td>
<td>14.3</td>
</tr>
<tr>
<td>Calculated head</td>
<td>100.0</td>
<td>.049</td>
<td>100.0</td>
</tr>
<tr>
<td>1 and 2 combined</td>
<td>16.0</td>
<td>.233</td>
<td>75.5</td>
</tr>
<tr>
<td>1, 2, and 3 combined</td>
<td>20.6</td>
<td>.194</td>
<td>31.0</td>
</tr>
<tr>
<td>1, 2, 3, and 4 combined</td>
<td>27.1</td>
<td>.156</td>
<td>85.7</td>
</tr>
</tbody>
</table>

The data indicate that, after the first stage of wet attrition, the combined fines contained 75.5 percent of the total uranium in the ore and assayed 0.233 percent U₃O₈. After the third stage of treatment, the total recovery was 35.7 percent of the total uranium in a combined product.
assaying 0.156 percent $U_3O_8$ and representing 27.1 percent of the original weight of the ore.

In comparing the data on the wet and dry attrition tests, it is evident that the first products from the wet process are somewhat higher in uranium assay than the products from the dry process. However, after approximately 85 percent of the total uranium has been removed as a fine product in each case, the combined concentrate from the wet process assays only slightly higher than the combined dry product. On the basis of the test work to date, it was concluded that the wet process has little if any advantage insofar as grade and high recovery are concerned.

We hope these data will be helpful in evaluating the Monument Valley ore sample submitted.

Sincerely,

G. M. Potter, Acting for
S. R. Zimmerley, Chief
Metallurgical Division
Region IV
### SAMPLE LIST

**CHEMICAL ASSAYS**

by

R. C. Cutter

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>U$_3$O$_8$ (%)</th>
<th>V$_2$O$_5$ (%)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>15178</td>
<td>.09%</td>
<td>1.16%</td>
<td>Composite grab sample made up of several channel samples and some grabs of waste represents an area 8' high and at least 150' wide; 10' of weathered overburden to strip off.</td>
</tr>
<tr>
<td>15179</td>
<td>.08%</td>
<td>.40%</td>
<td>Composite grab Climax Uranium; east waste pile 75' x 75' x 10' or more.</td>
</tr>
<tr>
<td>15180</td>
<td>.13%</td>
<td>.81%</td>
<td>Composite grab Climax Uranium; west waste pile.</td>
</tr>
<tr>
<td>15181</td>
<td>.05%</td>
<td>.54%</td>
<td>Composite grab VCA waste pile.</td>
</tr>
<tr>
<td>15182</td>
<td>.11%</td>
<td>1.24%</td>
<td>Composite grab VCA waste pile.</td>
</tr>
<tr>
<td>15183</td>
<td>.01%</td>
<td>1.09%</td>
<td>Composite grab VCA waste pit.</td>
</tr>
<tr>
<td>15184</td>
<td>.10%</td>
<td>.93%</td>
<td>Composite grab from VCA waste pile.</td>
</tr>
<tr>
<td>15185</td>
<td>.21%</td>
<td>1.21%</td>
<td>Composite grab from VCA waste pile.</td>
</tr>
<tr>
<td>15186</td>
<td>.36%</td>
<td>1.21%</td>
<td>Composite grab from VCA waste pile.</td>
</tr>
<tr>
<td>15187</td>
<td>.19%</td>
<td>1.01%</td>
<td>Composite grab from VCA waste pile.</td>
</tr>
<tr>
<td>15188</td>
<td>.03%</td>
<td>0.67%</td>
<td>Composite grab from VCA waste pit.</td>
</tr>
<tr>
<td>15189</td>
<td>.05%</td>
<td>1.13%</td>
<td>Composite grab from VCA waste pit.</td>
</tr>
<tr>
<td>15190</td>
<td>.03%</td>
<td>0.59%</td>
<td>Composite grab from VCA waste pit.</td>
</tr>
</tbody>
</table>
15191 10\% \text{U}_3\text{O}_8 \text{ and } 1.26 \text{V}_2\text{O}_5 - 15' \text{ channel sample VCA open pit.}

15192 35 lbs.

15193 \text{.17\% U}_3\text{O}_8 \text{ and } 1.03 \text{V}_2\text{O}_5 - 15' \text{ channel sample VCA open pit.}

15193 \text{.18\% U}_3\text{O}_8 \text{ and } 1.35 \text{V}_2\text{O}_5 - 10' \text{ channel sample VCA open pit.}

15194 \text{.08\% U}_3\text{O}_8 \text{ and } \text{.45\% V}_2\text{O}_5 - \text{Composite grab Climax Uranium open pit.}

15195 \text{.11\% U}_3\text{O}_8 \text{ and } \text{.25\% V}_2\text{O}_5 - 10' \text{ channel sample east side of north rim Monument No. 2.}

15196 \text{.09\% U}_3\text{O}_8 \text{ and } \text{.52\% V}_2\text{O}_5 - 9' \text{ channel sample } 50' \text{ west of 15195.}

15197 \text{.21\% U}_3\text{O}_8 \text{ and } \text{.39\% V}_2\text{O}_5 - 10' \text{ channel sample } 30' \text{ west of 15196.}

15198 \text{.08\% U}_3\text{O}_8 \text{ and } 1.26 \text{V}_2\text{O}_5 - \text{Grab sample } 5' \text{ below 15195, 15196, and 15197.}

15199 \text{.10\% U}_3\text{O}_8 \text{ and } \text{.27\% V}_2\text{O}_5 - \text{Grab sample New Climax incline.}

15200 \text{.05\% U}_3\text{O}_8 \text{ and } \text{.55\% V}_2\text{O}_5 - \text{Grab sample Harvey Black claim.}
December 13, 1951

Mr. Jack Sheridan  
U.S. Atomic Energy Commission  
Grand Junction, Colorado

Dear Mr. Sheridan,

In response to your request made during your recent visit to the Salt Lake station, we have prepared a rough flow sheet and equipment cost estimate for a Mardun dry concentrating unit to treat 150 to 250 tons per day of sandstone carnotite-type ores.

These data are intended to serve only as a rough approximation of the actual treatment flow sheet and cost of plant because they were assembled in haste and without knowledge of an actual plant site. Nevertheless, we think they will be useful to give an idea of the treatment and costs involved.

In making these estimates, we have assumed that all utilities, such as power, and roads will be available at the plant site. No estimate for these facilities has been included. Also, we did not estimate the cost of the building as this would vary in different locations.

Attached hereto are the flow sheet and cost estimate data sheets. You will note that the cost of a 150- to 250-ton per 24 hour plant (capacity depending on ore amenability) is estimated to be about $275,000 completely erected, but without building and power. This amounts to a little over $1,000 per ton daily capacity installed. The installed drive motors are estimated to total 311 hp. but actual operating power would probably be considerably less.

We hope this information will prove helpful to you.

Sincerely,

G. M. Potter, Acting for  
S. R. Zimmerley, Chief  
Metallurgical Division  
Region IV
Flow Sheet

Mardun Dry Concentrator

150 to 250 tons per 24 hours (depending upon amenability of ore)

I. Crushing and Drying Section

Ramp
   ↓
12-in. grizzly
   ↓
Receiving bins, 50 tons
   ↓
Feeder
   ↓
   (alternate)
   ↓
Hammer Mill
   ↓
Jaw crusher 12 in. by 24 in.
   ↓
   (alternate)
   ↓
20 tons per hour to 2 in.
   ↓
Conveyor
   ↓
24 in. cone crusher
   ↓
Elevator or conveyor
   ↓
Vibrating screen, approx. 1/4-in. opening
   ↓
Oversize
   ↓
Dryer 60 in. by 40 ft.
   ↓
Conveyor or elevator
   ↓
Cross conveyor
   ↓
Storage bins (250 tons)
   ↓
Mardun unit
   ↓
Mardun unit
(Sae II, next page)
II. Mardun Unit (only one of the two identical units is shown)

Storage bin
↓
Hardinge constant weight feeder
↓
Automatic sampler
↓
Elevator or conveyor
↓
Raymond double-Whizzer air separator, 8 ft. (preliminary dust separation)

Dust concentrate
↓
Screw conveyor

18 in. Mardun Disintegrator with 15 in. rotor (No. 1)
↓
Air separator (No. 1)

Dust concentrate
↓
screw conveyor

Air separator (No. 2)
↓
Disintegrator (No. 2)

Dust concentrate
↓
screw conveyor

Air separator (No. 3)
↓
Disintegrator (No. 3)

Dust concentrate
↓
screw conveyor

Final sand tailing
↓
Conveyor
↓
Storage

Note: Dust collectors must be provided for health reasons and to save any leakage of dust concentrates.
<table>
<thead>
<tr>
<th>Item</th>
<th>Total horsepower</th>
<th>Cost with motors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiving bin, 50 tons</td>
<td>-</td>
<td>$500</td>
</tr>
<tr>
<td>Feeder</td>
<td>2</td>
<td>2,000</td>
</tr>
<tr>
<td>Hammermill</td>
<td>40</td>
<td>10,000</td>
</tr>
<tr>
<td>Elevator</td>
<td>5</td>
<td>1,500</td>
</tr>
<tr>
<td>Vibrating screen</td>
<td>3</td>
<td>2,000</td>
</tr>
<tr>
<td>Dryer 60 in. by 40 ft., complete, feeder, dust collector, stack</td>
<td>17</td>
<td>15,000</td>
</tr>
<tr>
<td>Elevator and cross conveyors</td>
<td>7</td>
<td>2,500</td>
</tr>
<tr>
<td>Storage bins, two at 150 tons</td>
<td>-</td>
<td>2,400</td>
</tr>
<tr>
<td>2 Constant weight feeders</td>
<td>2</td>
<td>4,000</td>
</tr>
<tr>
<td>2 Automatic samplers</td>
<td>1</td>
<td>1,500</td>
</tr>
<tr>
<td>4 Elevators</td>
<td>12</td>
<td>6,000</td>
</tr>
<tr>
<td>8 8-ft. Double Whizzer separators</td>
<td>120</td>
<td>62,800</td>
</tr>
<tr>
<td>8 Screw dust discharge conveyor</td>
<td>4</td>
<td>2,000</td>
</tr>
<tr>
<td>6 15-in. disintegrators</td>
<td>90</td>
<td>4,500</td>
</tr>
<tr>
<td>Tailing conveyor</td>
<td>5</td>
<td>2,000</td>
</tr>
<tr>
<td>Dust conveyor</td>
<td>2</td>
<td>1,500</td>
</tr>
<tr>
<td>Dust bin, 100 tons</td>
<td>-</td>
<td>1,000</td>
</tr>
<tr>
<td>Accessories:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dust collection system</td>
<td>?</td>
<td>15,000</td>
</tr>
<tr>
<td>2 Automatic samplers</td>
<td>1</td>
<td>1,500</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>311*</td>
<td>$137,700</td>
</tr>
<tr>
<td>Excavation, foundations, freight, erection, contingencies</td>
<td></td>
<td>137,700</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$275,400</td>
</tr>
</tbody>
</table>

Note: Building not included, 100 ft. by 50 ft. by 25 ft. ht. for main Mardun units-crushing building separate.

*Exclusive of dust collector.
During a conversation with Bob Nininger recently, he requested that I submit a copy of a Bureau of Mines report we recently received, giving the results of preliminary beneficiation tests on a low-grade sample of Monument No. 2 ore.

We have conducted a rather careful sampling and ore reserve estimate of the low-grade ores found on a Monument No. 2 claim and adjacent properties. A report is in preparation which will present this ore reserve estimate and, if it appears feasible, will suggest the construction and operation of a concentrating plant near the property. It is our plan to include the data presented in the Bureau of Mines report, together with an analysis of the cost of construction and operation of a plant of appropriate size. This report is being prepared by Mr. Sheridan, and it is our hope to have it completed in the near future.

A copy of this report was previously submitted to CRMO.

Encl:
1. Cy ltr to TWO frm GMP 10/24/51
Mr. G. M. Potter
Region IV
Metallurgical Division
U. S. Bureau of Mines
1600 East First South Street
Salt Lake City, Utah

Dear Mr. Potter:

Thank you very much for your letter of December 13, the accompanying flow sheets, equipment lists, and cost estimate of a Mardun dry concentrating unit for treatment of carnotite ores. This information will be of extreme value to us in estimating the potential of certain low-grade uranium deposits of the Colorado Plateau.

Gratefully,

Thomas W. Oster, Chief
Grand Junction Exploration Branch
PLAN FOR SAMPLING AND POSSIBLE DEVELOPMENT OF LOW-GRADE RESERVES AT THE MONUMENT #2 MINE IN NORTHERN ARIZONA

SYMBOL: GJEB:EVE

Please refer to Technical Memorandum #21, "Beneficiation Monument No. 2 Ore" (M. J. Sheridan, February 1952) to which this memorandum is supplementary.

South Ridge

During the summer of 1951, wagon drilling under Contract AT(30-1)-1142 was conducted on the Monument No. 2 channel for the purpose of determining whether ore existed in the channel north and south of the main mine workings. The wagon drills were unable to penetrate to the ore horizon and little ore was discovered. It was believed at the time the drilling was being done that the difficulty in reaching the ore horizon could be traced to moisture in the bottom of the channel. It is now known that the channel is dry and that the drills could not penetrate because of "fitchering" in a bed of cherty conglomerate which overlies the ore horizon.

In February 1952, the Investigative core drills were placed in operation on South Ridge, situated south of the Monument No. 2 mine, to complete the work of the wagon drills. About 2,000 feet of drilling at this location disclosed that the channel had narrowed from a maximum width of 700 feet in the main workings to 100 feet on South Ridge and that the ore within the channel averages 50 feet wide. Continuous ore was found for a distance of 450 feet south of the rim and the most southerly lens of ore was found 650 feet south of the rim. At a distance of 1,250 feet south of the rim exposure, the channel becomes so reduced in depth that it scarcely exists.

In order to make an appraisal of the value of the material above the ore horizon, cores from the 14 ore holes were sacked from surface downward to the bottoms of the holes and were sent to assay. All samples which assayed higher than .02% $U_3O_8$ radiometrically were assayed chemically.

Three estimates, based on these assays, are being prepared as follows:

1. Grade and tonnage of material assaying 0.10% $U_3O_8$ or 1.0% $V_2O_5$ or higher (standard grade A ore). These figures will be placed in the regular monthly report and will correspond to the grade-tonnage estimates from other drilling contracts. The figures are 12,000 tons containing 0.42% $U_3O_8$ and 3.67% $V_2O_5$.

2. Grade and tonnage of all the channel material from surface downward and including the "grade A" ore at the bottom. This estimate will be based on both chemical and radiometric assays as it will include some material which the radiometric assays indicated to contain less than 0.02% $U_3O_8$. The value of this estimate is reduced by the fact that Vanadium Corporation of America is now rapidly mining the best of this material, using a cut-off of 0.20% $U_3O_8$. 
3. Grade and tonnage of the residue material after the "grade A" ore has been removed to as full an extent as the present mining method will permit. It is considered probable that 25% of the total "grade A" ore will be left in the mine on the floor and back and in pillars. Both tonnage and grade in estimate No. 3 will, therefore, be increased by this residue of "grade A" ore after mining operations cease.

The last two estimates will be employed as a portion of our over-all estimate of the entire channel deposit when our full data are at hand. These partial data will be forwarded to the New York office as soon as they are completed.

It should be noted that the grade figures will be conservative as much of the carnitite exposed on the surfaces of the cores is washed away by the drilling water.

Monument No. 2 and Climax Mines

Mr. Bell, Superintendent of the Monument No. 2 mine, requested that we drill a few holes in an unexplored portion of his claim to determine whether it was worth the expense to sink a new incline. We have now drilled 20 holes and have succeeded in disclosing a substantial tonnage of ore. We have also discovered that there is a lower horizon of "grade A" ore beneath the stratum which has been mined to the present time.

The three types of estimates outlined under South Ridge drilling will be made on this material in the main part of the channel. Without assays, it may be stated, after visual inspection of a portion of the core, that the material above the ore horizon is of better grade than on South Ridge.

Recently, the drills were moved to another portion of the channel owned by Climax Uranium and adjoining the Monument No. 2 mine to expand a reserve discovered by Climax. This reserve lies under sand dunes and could not be explored by wagon drills so we were requested to explore the area with our core drills. This core will be assayed from the base of the sand dunes to the bottom of the ore and the three types of estimates outlined above will be prepared from the assay results.

Yazzie Mesa

Upon concluding the drilling on Climax, the drills will be moved to Yazzie Mesa which contains the northern extension of the Monument No. 2 channel. Here, too, all holes located in ore bodies will be sampled from the surface of the rock to the bottom of the holes and the three types of estimates will be made.

General

The only estimate concluded at this time is of "grade A" ore on South Ridge, the results of which were given above. A rapid scanning of assays indicates that the second estimate, with the thought in mind of mining the whole ore body from surface downward as a unit, will yield results on the order of 0.08% U3O8 in about 73,000 tons. Rough scanning of figures also indicates that the third estimate on residue material after mining 75% of the "grade A" ore will approximate 0.03% U3O8 in about 64,000 tons.
Some of the core from "Main Ridge" over the Monument No. 2 mine arrived in Grand Junction recently and is being prepared for assay. Because of the slow communication between Monument Valley and Grand Junction, the time required to prepare the core for assay, the delay in assaying, first radiometrically and then chemically and finally, the necessarily tedious process of sorting out and correlating hundreds of assays, the final results on all phases of the drilling may not be ready before the middle of June.

It is now considered probable that the results of drilling on Main Ridge will show that the material on type 3 estimate will average between 0.04% and 0.10% $U_3O_8$. If the average does fall within this range, we shall immediately recommend a drilling program of 15,000 to 25,000 feet to prove that the entire channel on Main Ridge has a similar grade.

Considering that the grade might fall below 0.04% $U_3O_8$, we would appreciate your giving us a minimum grade figure below which no further drilling should be recommended.