GEOLOGY OF THE URANIFEROUS
BOG DEPOSIT AT PETTIT RANCH,
KERN COUNTY, CALIFORNIA

By
W. A. Bowes
W. E. Bales
G. M. Haselton

October 15, 1957

Salt Lake Branch Office, AEC
Grand Junction Operations Office
Salt Lake City, Utah
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GEOLOGY OF THE URANIFEROUS BOG DEPOSIT
AT PETTIT RANCH, KERN COUNTY, CALIFORNIA

ABSTRACT

Uranium associated with peat humus was discovered in a boggy meadow in the Sierra Nevada of Kern County, California, in the fall of 1955. The ore is an organic soil composed of growing grasses, mosses, and bog plants as well as peat mixed with detrital silt and sand derived from the underlying Jurassic (?) quartz diorite. The uranium is confined to the organic material and probably exists as a metallo-organic complex. No uranium minerals have been identified.

The bog is presently accumulating in a fault-depressed area continuously moistened by a series of springs which mark the position of the concealed Little Poso Creek fault. The spring waters contain an average of 0.11 ppm (parts per million) uranium, over 10 times that of local drainage waters.

The radioactive material is characterized by extremely low gamma radioactivity which may be due to the recent emplacement of uranium by spring waters.

Laboratory tests show that the ore is not amenable to present metallurgical processes. Preliminary roasting is necessary to obtain high extraction of the uranium. Tests indicate that the ore may be upgraded over 100 percent by first separating the detrital minerals from the organic matter, then roasting the organic fraction to ash. Roasting alone serves to upgrade the raw ore 25 percent.

Two geologically similar uraniferous bogs are known in Fresno and Madera Counties, California, 100 miles north of the Pettit Ranch. Two other bogs have been reported. The possibility for finding additional deposits of this type is favorable as boggy meadows and springs are common in fault terrane of the Sierra Nevada.

Primary ore controls at the Pettit Ranch deposit are: (1) waters of high uranium content, (2) a suitable collector for the uranium (peat), and (3) restricted circulation. These are important guides for
prospecting. Methods of prospecting, such as structural studies aimed at checking faults for springs and depressed boggy areas, systematic water sampling, or merely ground reconnaissance of boggy areas, could be employed. The effectiveness of airborne radiometric prospecting methods is limited by the low gamma radioactivity of the bog ore.

INTRODUCTION

Geography

Location and accessibility

The Pettit Ranch uranium deposit is on the western slope of the Sierra Nevada in north-central Kern County, 45 road miles northeast of Bakersfield, California, in sec. 26, T. 26 S., R. 31 E., Mount Diablo base line and meridian (fig. 1). The deposit is within a few hundred feet of a dirt road which is accessible 11 months of the year.

Topography and vegetation

The deposit is situated at 5,000 feet elevation in an open meadow surrounded by heavy pine and cedar timber near the headwaters of Little Poso Creek. Few outcrops are exposed in the Pettit Ranch area due to accumulations of heavy soil and vegetation. The dimension of the meadow is about 600 X 1,200 feet. Little Poso Creek is one of the major drainages on the west side of a prominent north-northeast-trending ridge called the Greenhorn Mountains and flows continuously from a late summer low of approximately 0.2 cfs (cubic feet per second) to an estimated spring high of 20 cfs. Kern River drains the east slope of the ridge. Elevations range from 2,500 feet above sea level in the Kern River channel to 8,305 feet on the crest of the Greenhorn Mountains.

Climate

The area has erratic yearly climatic variations with a pleasant warm dry summer season commonly lasting from May into November, followed by rains and occasional snows totaling 20 to 30 inches.

History

Discovery and previous production

Early in 1954, the discovery of uranium at the Miracle mine in the Kern River Canyon 6 miles southeast of the Pettit Ranch resulted
INDEX MAP
Showing location of
PETTIT RANCH
KERN COUNTY, CALIF.

Fig. 1
INDEX MAP
Showing location of
PETTIT RANCH
KERN COUNTY, CALIF.
in a flurry of weekend prospecting. Prospectors reportedly covered the easily accessible Pettit meadow, but no samples were taken due to the low radioactivity of the bog. In the fall of 1955, William Herndon collected samples of tree root, grasses, and peat near springs issuing into the bog and burned them to ash. He observed a sharp increase in radioactivity and reported the find to the Bakersfield office of the U. S. Atomic Energy Commission (AEC). Chemical assays confirmed the presence of commercial-grade uranium.

Ownership

The Pettit Ranch meadow was homesteaded by the Pettit family and patented in 1864. The Stockton family of Bakersfield purchased the Pettit property and are the present owners.

Purpose and scope

Many features of this uraniferous bog are without precedent. The study was undertaken primarily to gain a knowledge of the deposit in order to outline characteristics useful for prospecting. Another objective was to determine the extent and grade of the ore present. In support of these studies tests were made to outline the economic possibilities of the unique ore.

Field work during the summer of 1956 included study of aerial photographs; preparation of a plane-table base map using a scale where 1 inch equals 50 feet; and collection of 224 samples from sixty-seven 2-inch diameter hand-auger holes of 6- to 8-foot depth, 43 surface samples, and 12 water samples.

Laboratory work included petrographic study and classification of granitic rock, radiometric analysis of samples, and upgrading tests.

Acknowledgments

The writers wish to thank the members of the Stockton family for their assistance and interest in making their property available for study. They wish also to thank Mr. Herndon for his cooperation in the preparation of this report.
GENERAL GEOLOGY

Lithology

Two lithologic units are present in the area studied: Quaternary alluvial cover which includes the presently forming bog deposit and quartz diorite bedrock of the Sierra Nevada batholith of Jurassic (?) age. The quartz diorite is an unaltered, coarse-grained, equigranular, light- to medium-gray rock. Random dark, hornblende-rich dioritic inclusions occur as saucer-shaped lenses of a few inches to a few feet in diameter and follow primary foliation. The foliation trends north-northeast and dips vertically to steeply eastward. Pegmatitic and aplitic dikes are common in the quartz diorite.

Structure

The most important structural feature in the mapped area is an inferred fault trending approximately N. 70° E. and of unknown dip (pl. 1). This structure is readily traceable on aerial photos into the Pettit Ranch deposit and appears to coincide with a line of water seeps. This fault will be referred to as the Little Poso Creek fault. Joints in the quartz diorite strike west-northwest and are nearly vertical.

Geologic history

Quartz diorite of the Sierra Nevada batholith is generally thought to have been intruded in late Jurassic (Nevadan) time. The final stage of the granitic invasion is represented by aplitic and pegmatitic granite dikes.

Erosion and intermittent re-elevation of the relatively low mountain mass occurred from Cretaceous through Pliocene time. The beginning of the Quaternary marked a time of active orogeny in which uplift and tilting commenced giving the Sierra Nevada, structurally a fault block of great magnitude, their present elevation. Most of the major breaks, such as the east-front Sierra Nevada and Kern Canyon faults, probably originated during this disturbance. The Little Poso Creek fault that may be contemporaneous with the same period of fault movement converges toward the north-northeast-trending Kern Canyon fault which is located 8 miles to the east. Fault movement continues to the present as evidenced by reported (Herndon, oral communication) wide fluctuation of spring flow both at Pettit Ranch and at the Lackey Ranch on the Little Poso Creek fault 2 miles west of the
Pettit Ranch following the 1952 Kern County earthquakes.

The present west-flowing drainage was developed during Quaternary time and the elevated region is now being eroded mainly by deepening of the stream channels and it is in an erosion cycle of late youth.

URANIUM DEPOSITS

General features and description of ore

Uranium in the Pettit Ranch deposit is associated with peat humus which has accumulated in a boggy area. The ore, a black organic soil, is characterized by growing grasses, mosses, and bog plants as well as peat including partly decomposed roots, stems, and other woody matter, all of which are intermixed with silt and sand derived from the decomposed quartz diorite bedrock. The bog is on a terrace above the main stream drainage. Several springs which are aligned N. 70° E. seep into the bog from the southeast margin and mark the approximate position of the Little Poso Creek fault.

The bog has accumulated in a basin that appears to be a local depression of fault origin.

Distribution and tenor of ore

Plate 1 illustrates the aerial distribution of uraniferous zones at the Pettit Ranch. The cross-sections shown in figures 2 and 3 indicate the depth and grade of the deposit as determined from 8-foot auger holes. All assays used for ore calculation were made from raw, naturally occurring bog material.

The highest assay of raw ore taken by AEC from the Pettit bog assayed 0.34 percent $U_3O_8$. This was a surface sample taken from a small pit, PR-10, shown on plate 1. The pit is in the central part of a surficial ore zone 350 feet long by 30 to 100 feet wide from which samples average approximately 0.12 percent $U_3O_8$. The average thickness of the 0.12 percent ore is 4.0 feet measured from surface downward. Holes 42 and 43, shown on cross-section B-B' (fig. 3) were bottomed at 8.0 feet in +0.10 percent ore.
Fig. 2

SECTION A-A'
LOOKING EAST
PETTIT RANCH
Fig. 3

SECTION B-B'
LOOKING NORTH
PETTIT RANCH
Surrounding this ore is 0.05-0.10 percent uranium-bearing bog material. This low-grade material is thin at the eastern margin but underlies all of the 0.12 percent ore and thickens to 4.0 feet beneath and beyond the western outcrop margin of the 0.12 percent ore. The 0.05-0.10 percent material averages 2.0 feet in thickness.

In general, the distribution of the ore coincides with favorable peat-rich layers of bog material. Sections A-A' and B-B' (figs. 1 and 2) illustrate a transition from peat-rich material at the surface to heavy detrital sands at depth. Most of the 0.12 percent ore occurs at the surface with the exception of that shown in B-B' by holes 42, 43, and 44. In these holes, the best samples were taken from a depth of 2 feet or more. The holes contain peat humus down to the maximum depth augered (8 feet) and favorable layers of peat apparently account for the uranium enrichment at depth. Thus, surface radioactivity is not completely satisfactory as a guide to the best ore and must be supplemented by auger drilling.

**Mineralogy**

A discrete uranium mineral has not been identified in the Pettit Ranch bog ore. An average specimen of bog material containing 0.10 percent \( U_3O_8 \) may be separated by gravity into two fractions. The heavy fraction (54 percent by total weight) is composed of approximately 20 percent coarse sand, 50 percent fine sand, and 30 percent silt and clay. The light fraction (46 percent of sample by total weight) is composed mostly of vegetable material mixed with silt and clay.

Microscopic examination of the heavy fraction by the U. S. Bureau of Mines (USBM), Salt Lake City, shows the detrital minerals are chlorite, augite, tourmaline, andesine, biotite, muscovite, hornblende, quartz, zircon, and sphene. The light fraction contains plant material in various stages of decay with silt and clay. High-specific-gravity minerals from heavy-liquid separation contained no detectable radioactivity. These tests indicate that the uranium is confined to the light organic material and may exist as a complex metallo-organic compound.

Sample PR-11, taken from the surface; sample P-1, taken from a depth of 3 feet; and sample 5158, typical fresh quartz diorite taken from the Kern River Canyon and used for comparison purposes, were analyzed spectrographically. Results are shown in table 1.
The distribution and nature of elements are evidently identical for the fresh quartz diorite and the bog material taken from a depth of 3 feet (where proportionally greater detrital minerals are present). All of the elements in the bog material may be accounted for as constituents of the detrital minerals with the exception of U and Mo, which are probably externally introduced. Vanadium, though present in all of the samples of unaltered quartz diorite as well as pegmatitic granite tested in the area, may also be introduced with the U and Mo, as it has been found in veins at the Miracle mine 6 miles southeast of the Pettit Ranch. Molybdenum (in the hydrous mineral ilsemannite) is associated with the autunite-type vein ores of the Kergon mine located near the Miracle mine.

**Table 1. Spectrographic analyses**

<table>
<thead>
<tr>
<th>Quantity of elements present</th>
<th>Fresh quartz diorite No. 5158</th>
<th>Surface bog PR-1i</th>
<th>3-foot depth bog P-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plus 10%</td>
<td>Si</td>
<td>Si</td>
<td>Si</td>
</tr>
<tr>
<td>1-10%</td>
<td>Al, Fe, Mg, Na, K, Ca</td>
<td>Al, Fe, Mg, Ca</td>
<td>Al, Fe, Mg, Na, K, Ca</td>
</tr>
<tr>
<td>0.1-1%</td>
<td>Ti</td>
<td>Ti, K</td>
<td>Ti</td>
</tr>
<tr>
<td>0.01-0.1%</td>
<td>Mn, V, Cr</td>
<td>Mn, V, U, Mo</td>
<td>Mn, V, U, Mo</td>
</tr>
<tr>
<td>0.001-0.01%</td>
<td>Ga, Zr, Cu</td>
<td>Cr, Zr, Cu</td>
<td>Ga, Zr, Cu, Cr</td>
</tr>
</tbody>
</table>

Radioactivity

The broad area outlined in plate 1 encloses surface radioactivity of two times background (surrounding quartz diorite averages 0.01 MR/hr). The narrow strip showing anomalous radioactivity at the western portion of the meadow was not sampled. No locally "high" surface readings were noted, and much ore-grade material is not anticipated. A maximum surface reading of nine times background (0.09 MR/hr) is recorded at surface pit PR-10 in the northeast part of the map from which the high sample (0.34 percent) was taken. The radioactivity includes both beta particles and gamma rays as registered on a calibrated single-tube geiger counter with tube shield removed.
The surface samples recorded in table 2 may illustrate the extremely low radioactivity detected for the bog-type uranium ore. Both scintillation and geiger R/A readings are given for comparison.

<table>
<thead>
<tr>
<th>Sample number</th>
<th>Mass surface reading at sample location (moist)</th>
<th>USBM, Salt Lake City, assays</th>
<th>Moist isolated 1 lb. sample</th>
<th>Dry isolated 1 lb. sample</th>
<th>eU₃O₈</th>
<th>cU₃O₈</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR-10</td>
<td>*0.09, **nil</td>
<td></td>
<td>*0.10, **nil</td>
<td>*0.16</td>
<td>0.18</td>
<td>0.337</td>
</tr>
<tr>
<td></td>
<td>**0.05</td>
<td></td>
<td>**nil</td>
<td>**nil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR-11</td>
<td>*0.06, **nil</td>
<td></td>
<td>*0.05, **nil</td>
<td>*0.08</td>
<td>0.09</td>
<td>0.218</td>
</tr>
<tr>
<td></td>
<td>**0.03</td>
<td></td>
<td>**nil</td>
<td>**nil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR-20</td>
<td>*0.03, **nil</td>
<td></td>
<td>*0.03, **nil</td>
<td>*0.04</td>
<td>0.04</td>
<td>0.091</td>
</tr>
<tr>
<td></td>
<td>**0.02</td>
<td></td>
<td>**nil</td>
<td>**nil</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* single-tube geiger counter, shield removed (beta and gamma sensitive).
** scintillation detector, 1\(\frac{1}{2}\)-inch by 1-inch crystal (gamma only).

When measured with a geiger counter, the samples contain as much or more radioactivity than the mass effect of the bog from which they were taken. This is not true for the scintillation detector for although slight mass radioactivity was noted over the bog, no detectable radioactivity was evidenced for isolated samples. Gamma radiation, with mass effect, appears to be nearly absent in the bog ore. Beta particles are apparently responsible for most of the radiation. This may be due to lack of equilibrium of the uranium because of recent emplacement. A geiger counter with unshielded tube is most useful for prospecting and multiple-tube units would be desirable for increased sensitivity.

The consistent chemical-radiometric equilibrium ratio of 2:1 makes possible reasonably accurate estimates of uranium content in the field.
Assuming average summer moisture condition of the soil, the uranium content of the Pettit bog material may be estimated by multiplying the mass surface reading in MR/hr for an unshielded tube geiger counter by three and converting to U₃O₈. Ore in place at the Pettit bog, which assays 0.10 percent indicates only 0.030 MR/hr, about 20 times less radioactivity than for "normal" uranium minerals. Saturation of the soil by water lowers the radioactivity of the bog material to less than half of that described here.

Springs

Plate 1 shows the distribution of springs and the drainage at the Pettit Ranch. Although no measurements have been made, all of the springs are cold to the touch, and little seasonal fluctuation in flow is apparent.

A total of 13 springs is shown. They are grouped along a trend of N. 70° E. marking the approximate position of the Little Poso Creek fault. The elongated depressed area of probable fault origin adjacent to the line of springs causes the spring waters to follow a restricted course. It is within this basin of restricted water circulation that the uraniferous bog material has accumulated.

Seven of the springs have been sampled and assayed for uranium. Additional samples have been taken to test the uranium content of the Little Poso Creek and also the waters draining from the bog. Following is a tabulation of water-sample results:
<table>
<thead>
<tr>
<th>Sample number</th>
<th>Uranium ppm</th>
<th>pH</th>
<th>Analysis By</th>
<th>Field reading geiger R/A over water of flow</th>
<th>Approx. summer volume of flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRW-4 (dup)</td>
<td>0.32</td>
<td>7.4</td>
<td>Riley, USGS</td>
<td>Not detectable</td>
<td>30 gal/hr</td>
</tr>
<tr>
<td>PRW-4</td>
<td>0.3</td>
<td></td>
<td>USBM, SLC (Bureau of Mines, Salt Lake City)</td>
<td>do.</td>
<td>30 gal/hr</td>
</tr>
<tr>
<td>PRW-7</td>
<td>*0.2</td>
<td></td>
<td>USBM, SLC</td>
<td>do.</td>
<td>20 gal/hr</td>
</tr>
<tr>
<td>PRW-8</td>
<td>*0.2</td>
<td></td>
<td>USBM, SLC</td>
<td>do.</td>
<td>20 gal/hr</td>
</tr>
<tr>
<td>PRW-2</td>
<td>0.04</td>
<td></td>
<td>USBM, SLC</td>
<td>do.</td>
<td>10 gal/hr</td>
</tr>
<tr>
<td>PRW-1</td>
<td>0.06</td>
<td></td>
<td>USBM, SLC</td>
<td>do.</td>
<td>20 gal/hr</td>
</tr>
<tr>
<td>PRW-3</td>
<td>0.07</td>
<td></td>
<td>USBM, SLC</td>
<td>do.</td>
<td>15 gal/hr</td>
</tr>
<tr>
<td>PRW-10</td>
<td>0.095</td>
<td>7.1</td>
<td>Riley, USGS</td>
<td>0.2 MR/hr</td>
<td>10 gal/hr</td>
</tr>
<tr>
<td></td>
<td>(all of the above samples were taken from springs feeding the bog)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRW-6</td>
<td>*0.1</td>
<td></td>
<td>USBM, SLC</td>
<td>Not detectable</td>
<td></td>
</tr>
<tr>
<td>PRW-5</td>
<td>*0.2</td>
<td></td>
<td>USBM, SLC</td>
<td>do.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(the above samples were taken from water draining the bog)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRW-9 (dup)</td>
<td>0.008</td>
<td>7.2</td>
<td>Riley, USGS</td>
<td>Not detectable</td>
<td>0.2 cfs (summer)</td>
</tr>
<tr>
<td>PRW-9</td>
<td>*&lt;0.1</td>
<td></td>
<td>USBM, SLC</td>
<td>do.</td>
<td>do.</td>
</tr>
<tr>
<td></td>
<td>(the above samples were taken from Little Poso Creek)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*These samples were determined to the nearest 0.1 and are not consistent in accuracy with others listed.
The highest water sample collected contained 0.32 ppm. The average of the springs shown is about 0.11 ppm. Radioactivity was detectable over only one of the springs (PRW-10) where an increase of 0.02 MR/hr was noted over a background of 0.01 MR/hr. This spring is much farther from the bog than any of the others, and is detectable due to the lower background radioactivity.

The uranium content of Little Poso Creek water is 0.008 ppm which is consistent with the uranium content of other waters sampled in the Kern River area. The Pettit Ranch springs are over 10 times the normal uranium content of waters in the general area.

The highest water sample listed (PRW-4) is from a spring at the upper east end of the bog, which traverses the full length of the 0.12 percent $U_3O_8$ portion of the bog before draining toward Little Poso Creek.

An interesting speculation on the quantity of uranium now being deposited by the spring waters can be made by considering the inflow of the springs and the 0.11 ppm uranium content. The quantity of uranium now being carried into the bog is approximately 60 pounds per year.

**ECONOMIC ASPECTS**

*Exploration methods*

The surficial environment and softness of the bog material permit sampling by shovel or soil auger. A radiometric grid survey on 50-foot centers was used to guide the sampling at the Pettit Ranch. After defining the area of anomalous radioactivity, surface samples were taken on a 100-foot grid. This assay information determined the initial position of auger holes on 50-foot centers and subsequently on 25-foot centers where additional data were necessary.

Results of the Pettit Ranch auger drilling have shown that the best ore is not always at the surface. For this reason, a more effective method of sampling would be to follow the radiometric survey (50-foot grids) with augering on 100-foot centers including those areas where only slight surface radioactive anomalies are indicated. Samples should be collected from at least two intervals of depth in the preliminary holes. A truck-mounted power auger may be more effective in the drier portions of the Pettit Ranch bog to speed the work.
The consistent radiometric-chemical ratio of the uranium in the Pettit ore permits close approximation of the uranium content. In the field it is rapid and convenient to burn each sample to ash and check the radioactivity with an exposed-tube geiger counter (set up for use as a scaler and calibrated with ashed laboratory-analyzed control samples).

**Amenability**

Two amenability tests have been made on duplicate samples of the Pettit bog material. One test was made by the USBM Intermountain Experiment Station in Salt Lake City, Utah, and the other by the Raw Materials Development Laboratory of the National Lead Company in Winchester, Massachusetts.

**Sample No. 1**

The Bureau of Mines report lists the following assays of the raw ore: 0.196 percent $\text{U}_3\text{O}_8$, 0.02 percent $\text{V}_2\text{O}_5$, 0.02 percent Mo, 13.5 percent organic C, 0.5 percent $\text{RCO}_3$, 0.23 percent $\text{RSO}_4$, 0.25 percent S, 3.0 percent $\text{CaCO}_3$.

Acid and carbonate leaching tests were made on the raw materials, and on the ash after roasting for 3 hours at 450° C. Weight shrinkage during roasting was 37 percent.

Acid leaching tests:

(a) 25.3 percent recovery of uranium was made on raw ore from an 18-hour leach of 35-mesh ore at 40 percent solids with 150 pounds of $\text{H}_2\text{SO}_4$ per ton of ore (21.2 percent recovery with 10 pounds of $\text{MnO}_2$ oxidant).

(b) 83.9 percent recovery was made on raw ore by using 500 pounds of $\text{H}_2\text{SO}_4$ (81.0 percent recovery with 10 pounds $\text{MnO}_2$ oxidant).

(c) 93.2 percent recovery was made on ash from roasted ore by using 500 pounds $\text{H}_2\text{SO}_4$ per ton calcine (315 pounds $\text{H}_2\text{SO}_4$ per ton ore).

(d) 95.1 percent recovery was made on roasted ore by using 795 pounds $\text{H}_2\text{SO}_4$ per ton calcine (500 pounds $\text{H}_2\text{SO}_4$ per ton ore).
Carbonate leaching tests:

(These tests were made on 65-mesh ore at 33 percent solids for 24 hours at 90° C. Three hundred grams of ore used in a solution containing 50 grams Na₂CO₃ and 20 grams NaHCO₃ per liter.)

(a) 32.2 percent recovery was made on raw ore.

(b) 37.2 percent recovery was made on raw ore with addition of 10 pounds KMnO₄ per ton ore.

(c) 91.1 percent recovery was made on ash from roasted ore (27.5 pounds Na₂CO₃ consumed per ton ore).

The USBM report concludes with the remark that the bog material appears to entail problems similar to those encountered in handling uraniferous lignites. The report further states that, although a low-temperature roast rendered the ore amenable to a carbonate leach, experience indicates close temperature control would be required to avoid insolubilizing the uranium.

Sample No. 2

The National Lead Company report lists an assay of 0.167 percent U₃O₈ for the raw ore. Acid leaching tests were made on both raw and roasted ore (2-hour roast at 450° C. weight loss 23 percent). The raw ore was leached at 45 percent solids and the roasted ore at 50 percent solids. All tests were made at ambient temperature with agitation on laboratory rolls. No carbonate leaching tests were reported.

Acid leaching tests:

<table>
<thead>
<tr>
<th>Ore</th>
<th>Tyler mesh</th>
<th>Time (hours)</th>
<th>Lb/ton H₂SO₄</th>
<th>Terminal conditions pH</th>
<th>Terminal conditions mv</th>
<th>Residue assay %U₃O₈</th>
<th>Ext'n. %U₃O₈</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>-10</td>
<td>4</td>
<td>150</td>
<td>0</td>
<td>-420</td>
<td>0.083</td>
<td>50.0</td>
</tr>
<tr>
<td></td>
<td>-10</td>
<td>4</td>
<td>150</td>
<td>10</td>
<td>-600</td>
<td>0.064</td>
<td>61.4</td>
</tr>
<tr>
<td></td>
<td>-10</td>
<td>16</td>
<td>200</td>
<td>10</td>
<td>-600</td>
<td>0.067</td>
<td>59.5</td>
</tr>
<tr>
<td>Roasted</td>
<td>-10</td>
<td>4</td>
<td>116</td>
<td>0</td>
<td>2.7</td>
<td>-435</td>
<td>0.0066</td>
</tr>
<tr>
<td></td>
<td>-10</td>
<td>4</td>
<td>154</td>
<td>0</td>
<td>1.6</td>
<td>-495</td>
<td>0.0029</td>
</tr>
<tr>
<td></td>
<td>-35</td>
<td>4</td>
<td>154</td>
<td>0</td>
<td>1.6</td>
<td>-400</td>
<td>0.0025</td>
</tr>
</tbody>
</table>

1 Based on raw ore.
The National Lead Company report concludes that the roasting appears necessary to obtain high extraction.

Although there is disagreement in the two reports regarding acid consumption in relation to uranium recovery, both reports show that roasting is necessary to obtain good extraction from the bog ore. On the basis of the USBM report, the only other conclusion is that the ore entails problems similar to the lignites and is not completely amenable to present plant treatment. If a commercially feasible process is developed to treat lignite ores, the carefully calcined bog material may be amenable to the same treatment.

**Upgrading**

Brief tests were run to determine the feasibility of upgrading the bog material. The distribution of radioactivity in four samples ranging from 0.05 to 0.34 percent \( \text{U}_3\text{O}_8 \) is shown in table 4.

As the first step, the naturally occurring bog ore was mixed with water and the constituents allowed to settle out. The water was evaporated off and the samples allowed to dry. Two principal gravity separates were taken from each of the samples: light peat humus and the heavier detrital minerals. The peat-humus fraction was taken down to the layer of detrital biotite (sp gr 2.8) in each of the samples. No attempt was made to obtain clean concentrates; intermixing is moderate. A third fraction was taken only from sample PR-10 for comparison purposes. This was the lightest floating fraction consisting of slightly decomposed stems, twigs, roots, and other woody matter common to all of the surface samples.

Each of the gravity fractions was analyzed for uranium, then roasted to ash. (Peat-humus fractions PR-10, 50111 and 50117 smoked heavily and burned briefly.) The ash was analyzed for uranium.

An upgraded product of 0.31 percent \( \text{U}_3\text{O}_8 \) was obtained from raw 0.12 percent ore by means of gravity separation followed by roasting. Recovery was poor in these tests as evidenced by the calcined residue of 0.085 percent \( \text{U}_3\text{O}_8 \). Concentrations should be greatly improved with use of commercial gravity separation and washing as the uranium remaining in the heavy fraction is held as a film on detrital minerals and in organic material. With efficient means of concentration there is a possibility that the 0.05-0.10 percent material may be mined with the 0.12 percent ore.
Table 4
UPGRADING TESTS
URANIFEROUS BOG MATERIAL
PETTIT RANCH

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>GRAVITY SEPARATION</th>
<th>BEFORE ROAST</th>
<th>ROASTING</th>
<th>AFTER ROAST</th>
<th>Table 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>% U₃O₈ raw ore</td>
<td>% total weight</td>
<td>U₃O₈</td>
<td>% weight loss</td>
<td>U₃O₈</td>
<td></td>
</tr>
<tr>
<td>PR-10</td>
<td>Floating Woody mat. Peat Humus</td>
<td>54</td>
<td>0.42%</td>
<td>35</td>
<td>0.64%</td>
</tr>
<tr>
<td>0.34%</td>
<td>Detrital min. plus organic</td>
<td>41</td>
<td>0.21%</td>
<td>32</td>
<td>0.30%</td>
</tr>
<tr>
<td>50116</td>
<td>Peat Humus</td>
<td>40</td>
<td>0.19%</td>
<td>0.31%</td>
<td>24</td>
</tr>
<tr>
<td>0.12%</td>
<td>Detrital min. plus organic</td>
<td>60</td>
<td>0.07%</td>
<td>0.085%</td>
<td>53</td>
</tr>
<tr>
<td>50117</td>
<td>Peat Humus</td>
<td>47</td>
<td>0.11%</td>
<td>0.19%</td>
<td>29</td>
</tr>
<tr>
<td>0.073%</td>
<td>Detrital min. plus organic</td>
<td>53</td>
<td>0.04%</td>
<td>0.04%</td>
<td>47</td>
</tr>
<tr>
<td>50118</td>
<td>Peat Humus</td>
<td>39</td>
<td>0.075%</td>
<td>0.10%</td>
<td>30</td>
</tr>
<tr>
<td>0.05%</td>
<td>Detrital min. plus organic</td>
<td>61</td>
<td>0.04%</td>
<td>0.04%</td>
<td>56</td>
</tr>
</tbody>
</table>

Note: Size of box represents percentage of original sample.

AVERAGE
of above:

0.15% U₃O₈

Average (weighted)
0.20% U₃O₈ if calcined only. 75% of original weight.
Roasting alone (necessary to obtain good extraction of the uranium) serves to upgrade the ore by an average of 25 percent of its original value.

Mining

Should market conditions warrant it, and should amenability problems for the material be solved so that the deposit becomes economically exploitable, low-cost surface mining methods could be used at the Pettit Ranch bog deposit.

CONCLUSIONS AND SUGGESTIONS FOR PROSPECTING

Origin of the deposit

Origin of the fractures

The Little Poso Creek fault, considered active, is the controlling structural feature at the Pettit Ranch deposit. Ore solutions (uraniferous spring waters) emerge from this fault zone. The fault is probably sympathetic with major fault movement initiated in the Sierra Nevada region during the beginning of Quaternary time.

Method of ore emplacement

Observations regarding ore emplacement are as follows:

(1) Uranium is largely confined to peat humus presently accumulating in the Pettit Ranch bog.

(2) Peat has been found by G. W. Moore (1954) to be most effective along with subbituminous coal and lignite for the extraction of uranium from cold aqueous solution.

(3) The Pettit Ranch bog is confined to a basin of restricted circulation fed by spring waters.

(4) The Pettit Ranch spring waters contain anomalous amounts of uranium, averaging 0.11 ppm, or more than 10 times the normal content of waters in the area.
The Pettit Ranch ore is anomalously low (20 times less than normal) in radioactivity, indicating disequilibrium due to recent emplacement.

Commercial-grade uranium assays have been made from the ash of partly decayed roots of tree stumps cut during the past 50 years.

From the above evidence, the writers conclude that the uranium in the Pettit Ranch bog is now being deposited by the spring waters.

Source of the uranium

Some possible sources of the uranium are listed as follows:

1. The spring waters could conceivably leach the uranium from the quartz diorite in their passage through the rock. Experiments by Hurley (1950) have shown that a large percentage of the radioactive elements present in some granitic rocks are loosely held in the "mineral interstices and intra-crystalline fractures" and can be easily taken into solution.

2. The uranium may be leached and transported by the spring waters from a geologically older concealed uranium deposit located somewhere in the fault zone (Poso Creek fault) from which the spring waters issue.

3. The uranium may have a contemporary hypogene source. Hydrothermal solutions rich in uranium could intermix with circulating ground waters and emerge along the fault.

In the author's opinion, the source of the uranium is more likely hypogene: (1) a number of springs are present in the area many of which are hot mineral springs (pointing to volcanic activity and the possibility of hypogene uranium), (2) no geologically older uranium deposits are known in the immediate area from which circulating ground waters might leach uranium, and (3) there are no indications either from uranium content of local drainage waters or local background radioactivity which might indicate that the basement quartz diorite in the Pettit Ranch vicinity is anomalously high in uranium (from which ground waters might extract uranium).
Supporting this view of hypogene-source uranium, another bog ore body associated with springs emerging from a fault located 100 miles north of the Pettit Ranch has a similar setting in Fresno County; no known geologically older uranium deposits are known in the area, but a number of active mineral springs, both hot and cold, are present. Nearly all of the uranium found in that area of Fresno and Madera Counties appears related to spring waters, some of which have been tested and found to be anomalously high in uranium.

**Ore controls, guides, and methods for prospecting**

The following are important ore controls at the Pettit property:

1. **Presence of waters of high uranium content.**

2. **Presence of a suitable basin of restricted circulation for the high uranium waters.** If none is present, the metal-bearing waters might be dissipated and lost in the normal drainage. All of the spring-fed uranium-enriched waters at the Pettit Ranch traverse the peat-filled bog which is situated above the regular stream drainage.

3. **Presence of a suitable collector for the uranium.** Peat is a most effective medium of adsorbing or precipitating the uranium from solution.

As the first two factors may be related to faulting, structural studies are probably an effective guide for prospecting. Systematic water sampling of drainage waters may also guide the prospector into areas favorable for uranium deposition.

Airborne radioactivity surveys have been employed in prospecting although the small amount of gamma radiation typical of the bog ore limits the effectiveness of the method. Routine ground reconnaissance of bogs is a good method, but is slow and difficult in the more remote areas of the Sierra Nevada.

Slight increases in radioactivity over a bog should be checked closely. If an increase over background radioactivity is noted, the prospector should then make a small hole in the bog material and insert the counter. If further increase is noted, a sample should be taken.
Favorability for new discoveries

Bog deposits of the Pettit Ranch type could prove to be an important future reserve as the possibility for finding new deposits is geologically favorable. The Pettit Ranch deposit is typical of two other known deposits in Fresno and Madera Counties, California. Verbal reports and assay information have been received from prospectors indicating the existence of additional deposits.

Because of cooler climate and higher-moisture content of the soil, peat-forming conditions are common in the innumerable meadows of the Sierra Nevada region and due to a history of volcanic activity and recent faulting mineral springs are common (although springs carrying uranium could be uncommon).

SUMMARY

The Pettit Ranch uranium deposit is not a fossil but is an ore body in the making. Uranium has been and is being deposited by uraniferous spring waters emerging from an active fault. The uranium is probably hypogene in origin. Important ore controls at the deposit include (1) waters of high uranium content, (2) the presence of a basin of restricted circulation for the uraniferous waters, and (3) a suitable collector (peat) for the uranium. These are primary guides for prospecting.

The Pettit Ranch bog material, although not presently available as a uranium ore at the present time, may be used in the future if the amenability problems can be solved. Two similar deposits are known and two more have been reported. The geologic favorability for finding other bog-type deposits is good, and efficient methods of uranium separation should surely result from the discovery of sufficient ore reserves to seriously consider the economics of processing the material locally.
SELECTED REFERENCES


U. S. Bureau of Mines, 1956, Amenability test report No. 382-1: Intermountain Experiment Station, Salt Lake City, Utah.

U. S. Bureau of Mines, 1956, Microscopic examination report No. UP-5555-1: Intermountain Experiment Station, Salt Lake City, Utah.