GEOLOGY AND MINERALOGY OF SELECTED MINES IN THE TEMPLE MOUNTAIN ~~MINING~~ AREA, SAN RAFAEL SWELL, EMERY COUNTY, UTAH

by

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Mineralogy needs to be edited for content WBK 5-2-58

Figures all present, and none is obviously superfluous. W.B.M.

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ILLUSTRATIONS

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ILLUSTRATIONS (continued)

ABSTRACT

Seven uranium mines in the Temple Mountain area of Emery County, Utah, were mapped ~~in a study of the occurrence of ore and in search of criteria of its genesis and~~ to determine ore controls ~~influencing the distribution of uraniferous asphaltite.~~ for the relationship between uranium, asphalt and associated metallics, and a possible source of the uranium.

The mines in the area, except for variations in the size of the uranium ore bodies, are quite similar in most aspects. ~~Almost all of the~~ Most ore is found in the lower one-third of the Upper Triassic Moss Back member of the Chinle formation. The larger ore bodies ~~occur~~ are in a thinly to thickly cross-bedded sandstone, that is 5 ~~five~~ to 15 feet thick and 15 to 25 feet above the base of the Moss Back. No ¶

All of the ore is asphaltic. ~~and ranges in grade up to~~ Some high grade samples ~~of asphaltic ore~~ contained a maximum of 16 percent U_3O_8. The grade of ore shipped has averaged approximately 0.19 percent U_3O_8. Ore grade-thickness contour maps have proved useful ~~as an ore guide.~~ in finding ore.

The assemblage of minerals and elements ~~at Temple Mountain~~ is similar to that for typical uraniferous vein deposits of ~~. The mineral assemblage is~~ a ~~typical~~ low temperature-pressure hydrothermal type.

Deposition and localization of primary minerals from hypogene hydrothermal solutions was controlled by sedimentary features, tectonic structures, and variations in chemical environment in the host rocks.

Paragenetic studies suggest that uraninite, ~~and~~ montroseite, ~~with~~ galena, sphalerite, native arsenic, and marcasite were introduced prior to other minerals and asphaltic petroleum? fractions. Humic hydrocarbons appear to have been ~~supplied sites for precipitaion and were~~ the principal precipitating agents of uranium. The asphalt acted as a solvent on metallic sulphides in the presence of uraninite, and was polymerized by alpha and beta particle bombardment and gamma radiation in the immediate vicinity of uraninite.

INTRODUCTION

During the latter part of 1955 and the early part of 1956, seven mines were mapped: the Lopez Incline, North Mesa No. 9, Calyx No. 12, and the Vanadium King No. 1 Portal No. 2 mines on the calyx bench; the Vanadium King No. 7 and Campbird No. 7 mines on North Temple Mountain; and the Black Beauty mine on the southwest side of South Temple Wash (Figs. 1 & 2).

LOCATION

The Temple Mountain mining area, on the eastern flank of the San Rafael Swell in Emery County, Utah, is approximately 43 ~~road~~ miles southwest of the town of Green River, Utah ~~(Fig. 3)~~. The area is reached by traveling ~~four~~ 4 miles west from Green River on U. S. Highway 6 and 50, then 32 miles south on Utah Highway 24, and then ~~seven~~ 7 miles northwest to Temple Mountain (Fig. 1).

The San Rafael Swell, a northeast trending anticline ~~fold~~, is ~~located~~ in the western part of Emery County and is bounded on the north by the Book Cliffs, on the south by the Henry Mountains, on the west by Castle Valley, and on the east by the Green River and San Rafael River Deserts (Fig. 1).

PURPOSE OF REPORT

The purpose of this investigation was to determine factors influencing distribution of uraniferous asphaltite, ~~and~~ to gather evidence on the ~~that would shed light on genesis and~~ origin of the uranium, and ~~The mines were also studied in order~~ to determine possible ore guides and ~~the existance of any~~ zonal relationships between the ore bodies and the collapse structure at Temple Mountain (Figs. 2 + 3).

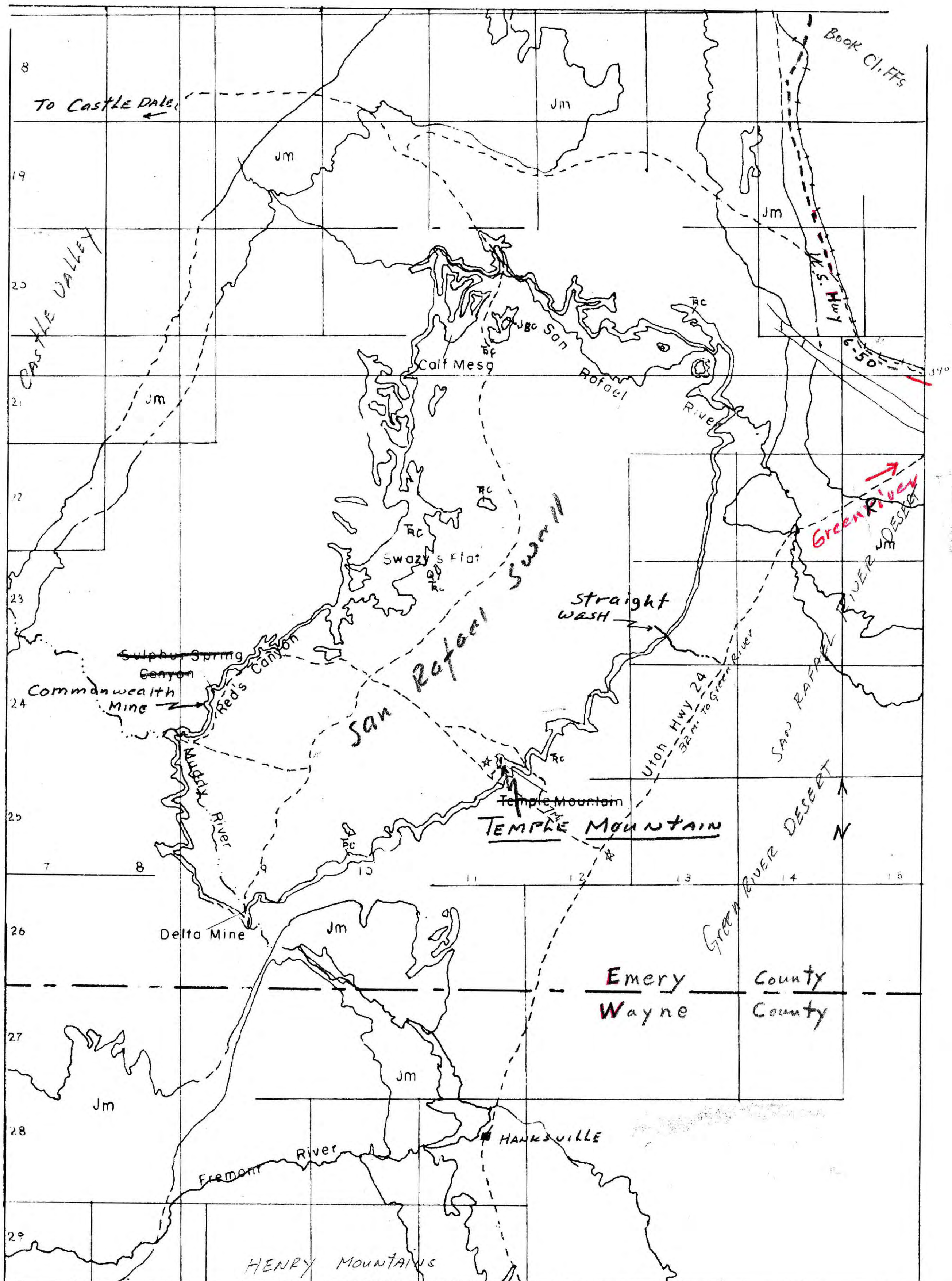


Figure 1. Index Map of ~~SAN RAFAEL SWELL~~ Temple Mountain, ~~Emery~~ County, Utah

SCALE — 1:500,000 1 inch = 41,667 feet

FIGURE 3. - Location of Mines, Temple Mountain Mining Area

HISTORY AND PRODUCTION

The uranium-vanadium deposits of Temple Mountain are believed to have been discovered prior to 1903. Mining was started in 1910 and continued intermittently until 1948. Since 1948, the mines have been in continuous operation. Production from 1948 until June 1952 exceeded 50,000 tons of ore with an average grade of 0.19 percent U_3O_8 and 0.54 percent V_2O_5. Since that time, the calyx mines have been opened, and production has averaged 6,000 tons per month. Most ore bodies [being] mined during this investigation were discovered by drilling conducted by the United States Atomic Energy Commission from December 1951 to May 1952 (Keys and White, 1956).

PREVIOUS WORK

Early reports on Temple Mountain ores were made by Boutwell (1905) and Hess (1913). Early reports on the geology of the Swell were made by Gilluly and Reeside (1928) and Gilluly (1929). Many reports of an economic or geologic nature made on the area in recent years are listed in the references.

FIELD METHODS

Detailed longwall sketches were made; lineation trends, fractures, and other geologic features were mapped in each mine. The workings were mapped by use of a Brunton alidade on a plane table; distances were measured by tape. For further control, critical stations in the mines were established by transit survey. Nearly 700 chemical and radiometric assays were used for accurate ore grade-thickness maps (figs. 4, 5 & 6). Petrographic and X-ray analysis of selected samples were made by the Petrology and Mineralogy Section of the U.S. Atomic Energy Commission.

GENERAL GEOLOGY

STRATIGRAPHY

Strata cropping out in the Temple Mountain area range in age from Permian to Jurassic and have a total thickness of about 2,800± feet. Included are the Coconino sandstone and Kaibab limestone of Permian age; the Moenkopi formation, Chinle formation, and Wingate sandstone of Triassic age; the Kayenta formation of Jurassic (?) age; and the Navajo sandstone of Jurassic age (Fig. 7). Uranium is mined from the Chinle formation, described in detail below.

CHINLE FORMATION

In this area the Chinle formation is subdivided into three units. In ascending order they are: Temple Mountain, Moss Back and Church Rock members.

Temple Mountain member: The Temple Mountain member of the Chinle consits of siltstone, mudstone and sandstone. The siltstone is usually light-gray to mottled or banded purple and white. Mudstone colors are purplish red, or mottled purple white. The sandstone is light-gray to dark-brown, coarse-grained, calcareous, quartzose and locally cross-bedded. The member may be differentiated from the Moenkopi by lack of bedding, rounded ledges of light-gray to dark-brown sandstone; presence of abundant quartz sand-grains and pebbles, lenses of jasper, purple and white color; iron-oxide pebbles and humic matter (Robeck, 1956). It varies from a knife edge to about 35 feet in thickness. It appears to grade into the underlying Moenkopi in places and at other places is clearly disconformable.

Moss Back member: The Moss Back member of the Chinle is predomin-

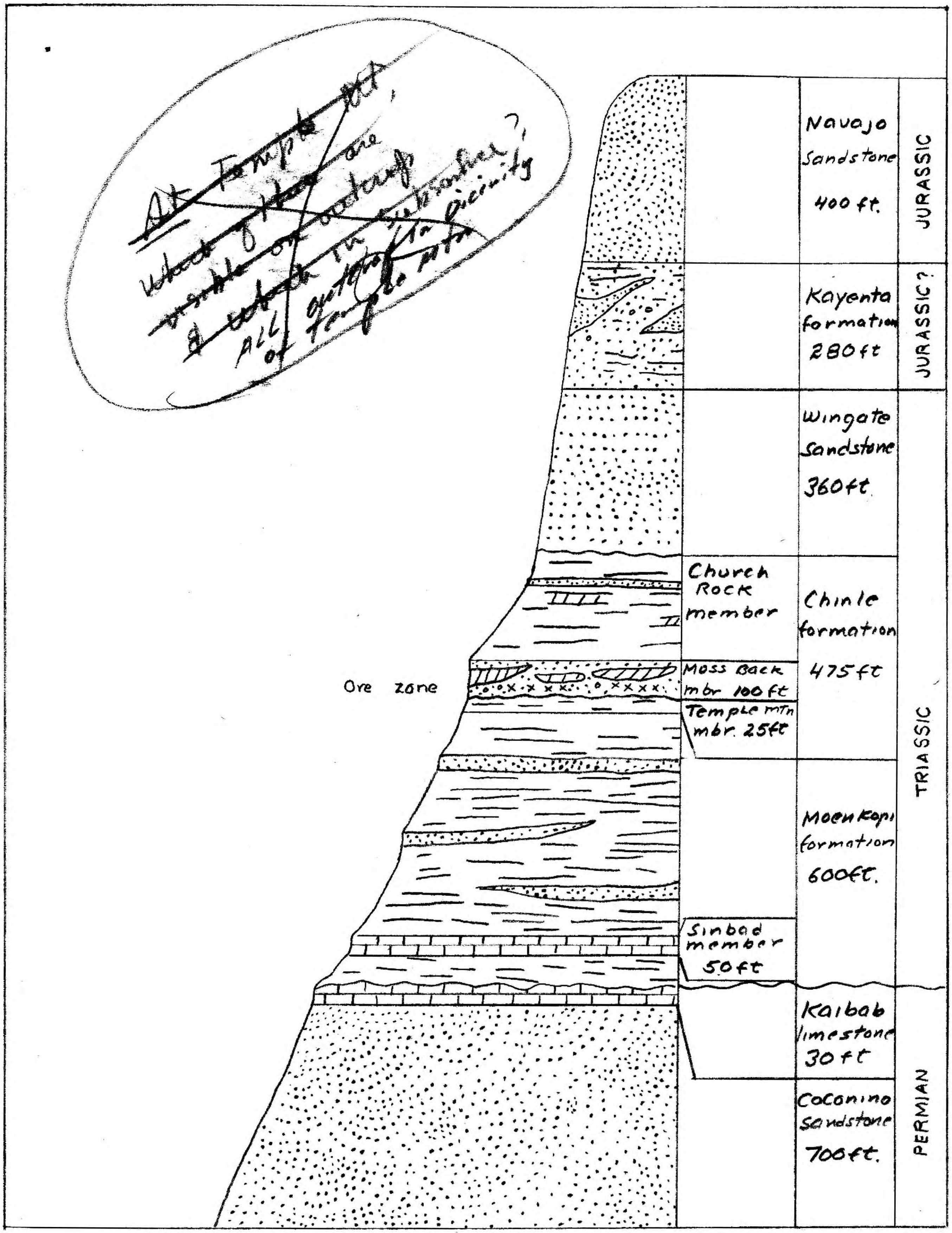


Figure 7. Geologic column at Temple Mountain, Emery County, Utah

~~Calcite cement is the most abundant cementing agent in this member.~~

ately a fluviatile sandstone with numerous lenses of mudstone and conglomerate. ~~The~~ sandstones ~~is~~ are light-gray to brown, poorly sorted, calcareous, and prominently cross-bedded. Sand grains are ~~range from~~ fine to coarse, ~~from~~ angular to well-rounded, and ~~are mainly~~ predominately of quartz with some chert and feldspar and minor amounts of accessory minerals. Calcite is the main cementing agent in this member and is very abundant. In uraniferous zones nearly all calcite cement has been removed, and abundant secondary quartz overgrowths are present. Interstitial clay (illite) is present in varying amounts in (random) some ? sandstone lenses. Gray-green mudstones, in the form of seams, splits, and scour fills, occur throughout the member. Conglomerates consist of subangular to well-rounded pebbles of limestone, quartz, quartzite, clay, and chert ~~up to three~~ as much as 3 inches in diameter. Chert pebbles, many of them replaced by uraniferous asphaltite, predominate. The matrix of the~~se~~ conglomerates in some lenses consists entirely of clean quartz sand; in others as much 40 percent clay is present in the form of mudstone galls, seams, and interstitial fillings.

Fossil plant remains are found throughout the member. This material ranges in size from minute discrete flakes of carbonaceous material disseminated through the sediments and along bedding planes to carbonized and/or silicified logs ~~up~~ as much as ~~to four~~ 4 feet in diameter and over 20 feet long.

At Temple Mountain the Moss Back is ~~ranges from~~ 50 to 125 feet ~~in~~ thick with an ~~ness but~~ thickness of average about ~~one hundred~~ 100 feet. It grades upward into the Church Rock member. The top of the Moss Back was placed at the bottom of the lowermost siltstone above the color change from light-gray to red-brown. This color change is gradational ~~occurs gradually~~ in a cross-bedded, fine-grained sandstone ~~without a~~ lithologic ~~change.~~

Church Rock member. The Church Rock member of the Chinle consists of varigated red-brown and purple shale, siltstone, ~~and~~ fine-grained sandstone, and a discontinuous conglomeratic sandstone lithologically similar to the Moss Back. This conglomerate is ~~up to~~ 20 feet thick, and lies about 75 feet above the Moss Back-Church Rock transition zone. At Temple Mountain the member is about 350 feet thick.

STRUCTURE

The San Rafael Swell is an asymetrical anticline trending northeast; beds on the flanks of the structure have dips ranging from a maximum of 85 degrees on the eastern ~~side, to~~ a minimum of ~~three~~ degrees on the western flank, ~~and breached by post-uplift erosion.~~ The ~~fold~~ is 70 miles long and ~~up to~~ 35 miles wide.

Several groups of high-angle normal faults ~~occur within~~ the Swell. These strike predominantly northeast in the northern part of the Swell and predominantly east ~~west~~ in the southen part. The boundry between these two fault sets is along an east-west line approximately one-half mile north of Temple Mountain. Displacement on the faults ~~ranges~~ from less than ~~one~~ foot to a maximum of ~~three hundred~~ feet. ~~Joints usually~~ parallel these faults.

Temple Mountain is situated in a small synclinal warp within a zone on minor subsidiary flexures on the eastern flank of the ~~San Rafael~~ Swell, approximately 12 miles southeast of Straight Wash ~~and between Straight Wash and the Muddy River~~ (Fig. 1). North of Straight Wash the flank of the Swell dips ~~very steeply, up to~~ 85 degrees; and south of the Wash there is a general flattening of the beds, with dips ~~ranging~~ from ~~five~~

to ~~sixteen~~ degrees. ~~Immediately~~ southeast of Temple Mountain on the calyx bench, dips steepen markedly to the southeast.

In the Temple Mountain mining area beds strike ~~N33E to N55E~~ and dip from ~~three~~ to 12½ degrees southeast (Fig. 2). Average strike of the near-vertical faults in this area is east~~-west~~. Throw on these faults ranges from a few feet to several tens of feet with ~~great changes~~ in displacement ~~along the fault.~~ In many places displacement disappears entirely and the fault becomes a joint. Commonly a fault is paralleled on both sides by prominent joint-sets.

A unique structural feature at Temple Mountain is the Collapse. In a 500-by 1,500-foot area between North and South Temple peaks, Moss Back, Chinle and Wingate rocks have been ~~down-~~dropped as much as 300 feet. This was accompanied by plastic flow, alteration, and brecciation ~~in~~ the rocks. Strata surrounding this disturbed area dip inward as much as ~~25~~ degrees (Keys, 1955) (Fig. ~~1~~).

GEOLOGY OF THE ORE DEPOSITS

NATURE OF THE ORE BODIES

Uranium deposits in the Temple Mountain mining area ranges from small pods a few feet in lateral extent and a few inches in thickness to large ore bodies ten to twenty feet thick, ten to eighty feet wide and up to three hundred feet long. These uranium deposits are composed of uraniferous asphaltite. Smaller depits are found throughout the lower one-third of the Moss Back in both sandstone and conglomerate lenses. The larger ore bodies occur in a thick sandstone unit, very thinly cross-bedded to very thickly bedded, 15 to 30 feet above the base of the Moss Back. Individual ore bodies are not confined to single lithologic units of the host rock but, due to complex factors that controlled deposition of the metallic minerals, they may encompass parts of two or more distinctly separate sedimentary units. This is discussed further under factors influencing deposition. Ore bodies appear to posses an approximate parallelism to two prominant joint sets that appear in the rocks exposed at the surface (Fig. 1). Within uraniferous zones area of concentrations of high grade ore, 10 percent or greater. These areas appear to be linear in the direction of the major joint-sets (Figs. 1, 4-6).

Grade and thickness of ore bodies are shown in figures 4 to 6. Contours represent ore thickness and grade expressed as the equivalent number of feet of 0.20 percent U_3O_8. These maps show apparent size, shape, grade and orientation of ore bodies and distribution of high-grade ore within them.

By inferred projections of ore zones outlined

From data obtained by a similar survey in Calyx No. 3 mine, the mining engineer was able to establish four new ore headings. These new ore bodies had never been penetrated by drilling, but their mineralized edges had been drilled and the information from the holes was utilized for the construction of grade-thickness contours. Long-steel drilling in the direction of the indicated ore substantiated the validity of the maps. Further efforts of random drilling into the back and floor of the mine supplied information for discovery of additional ore bodies by plotting the assay values as contours.

Within the ore bodies uraniferous asphaltite occurs in all concentrations from discrete particles disseminated interstitially through sandstone to massive, solid botryoidal concentrations of asphaltite up to two feet in diameter. Between these two extremes are found nodules of varying size disseminated in sandstone, long,thin (a fraction of an inch to six inches thick) concentrations of uraniferous asphaltite along bedding planes, and uraniferous asphaltite halos of variable thickness surrounding logs and other fossil plant remains.

Numerous ore rolls are evident throughout the area. They are normally concave toward the ore and have a zone of the secondary vanadium mineral pascoite, adjacent to the convex side of the roll with a zone of chromium mica, mariposite, beyond. Certain fractures controlling ore appear to be rolls (Figs. 8 and 9), but do not have the pascoite and mariposite zones. Thin sections made across a fracture (Fig.9) reveal a zonal distribution of uraniferous asphaltite adjacent to each side of the fracture, and a zone of hard non-uraniferous asphaltite beyond grading into liquid asphalt. Ore rolls are normally confined to the edges of mineralized zones

L.c.
FIGURE 8. Termination of black ore at fracture in North Mesa No. 9 mine. Fracture strikes parallel to plane of photo. Pick lies on fracture.

FIGURE 9. Fracture control of ore in Campbird No. 7 mine.
Curved line above geology pick is fracture.

and usually contain only lowgrade deposits of uranium.

CALYX NO. 12, A TYPICAL TEMPLE MOUNTAIN ORE DEPOSIT

Ore bodies in Calyx No. 12 mine ranges from small pods and lenses a few inches thick and up to ten feet in lateral extent to bodies 20 feet thick, 40 feet wide and over three hundred feet long. These large ore bodies account for perhaps 90 to 95 percent of production. Large ore bodies average approximately 0.35 percent U_3O_8; small pods and lenses are much higher in grade and average approximately 5.0 percent U_3O_8. Ore shipped from this mine contained 0.27 percent U_3O_8 in approximately 18,500 tons. Unavoidable inclusion of waste with ore accounts for the discrepancy. The average uranium-vanadium ratio for this mine is 1 : 2.65 (TABLE I).

The Calyx No. 12 mine is structurally lowest of the mines examined and, except for the Lopez Incline and the Black Beauty mines, it is farthest from the Temple Mountain collapse. Ore in quantity was mined from the south-westward pinchout of two superimposed sandstone lenses separated by a conglomeratic unit one to three feet thick (Figs. 10 and 11). These sandstones range in thickness from a knife edge on the southwest to twelve feet on the northeast side of the workings. The base of the lower sandstone lens is approximately fifteen feet above the base of the Moss Back. These appear to be local scour fills within the Moss Back. They trend approximately N. 50° W. and are thickest on the northeast side (Fig. 10).

The lower sandstone is light-gray, moderately to highly cross-bedded, quartzose, fine-to medium-grained, sub-angular to sub-round, poorly sorted, well-cemented to friable, with secondary quartz over-

TABLE I

URANIUM-VANADIUM RATIOS FROM

THIRTEEN MINES IN THE TEMPLE MOUNTAIN AREA

	Mine	~~Ratio~~ Uranium-Vanadium Ratio
1.	Black Beauty	1 : 1.89
2.	Calyx No. 3	1 : 2.63
3.	Calxy No. 6	1 : 3.76
4.	Calyx No. 8	1 : 3.22
5.	Calyx No. 10	1 : 2.74
6.	Calyx No. 11	1 : 3.43
7.	Calyx No. 12	1 : 2.65
8.	Campbird No. 7	1 : 2.26
9.	Lopez Incline	1 : 1.47
10.	North Mesa No. 9	1 : 3.03
11.	Vanadium King No. 1 Portal No. 2	1 : 3.20
12.	Vanadium King No. 7	1 : 8.69
13.	Young's Eagles Nest	1 : 3.62

growths. The ~~unit~~ contains ~~occasional~~ disseminated flecks of liquid asphalt, greenish-gray mudstone galls and fragments~~, and~~ carbonaceous material. Near the pinchout margin of the lens, a thin ~~mudstone~~ conglomerate ~~zone~~ splits the sandstone. This is local in occurrence and consists of mudstone pellets, chert and quartzite ~~pebbles up to two and a half~~ inches in diameter, in a matrix of sub-angular to sub-rounded, fine- to medium-grained sand. The uraniferous asphaltite ~~ore~~ in the sandstone occurs as interstitial particles ~~and~~ along bedding planes in rich concentrations.

The ~~stratum of~~ conglomerate between the two sandstone lenses consists of sub-angular to well-rounded pebbles ~~up to two and a half~~ inches in diameter, ~~and~~ composed of quartz, quartzite, ~~and~~ chert, and greenish-gray mudstone galls, ~~in~~ a matrix of coarse unsorted quartz grains and in interstitial clay. Where the unit is mineralized, nearly all chert pebbles have been replaced by asphaltite. This bed is only ~~occasionally~~ mineralized and ore ~~usually occurs as~~ lenticular pods ~~one~~ to ~~five~~ feet in diameter. The upper half of these pods ~~are~~ anomalously high in vanadium content. A structure contour map was constructed on the base of this conglomerate (Fig. 12).

The upper sandstone is lithologically similar to lower except that the upper sandstone contains more clay, as small mudstone pellets along bedding planes, ~~and~~ is more intricately cross-bedded. Distorted cross-beds are common near the top of both sandstones (Figs. 13 ~~and~~ 14), and may or may not be uraniferous. This is discussed further under sedimentary ~~controls~~. Both sandstones are friable and ~~quite~~ permiable in and adjacent to ore bodies.

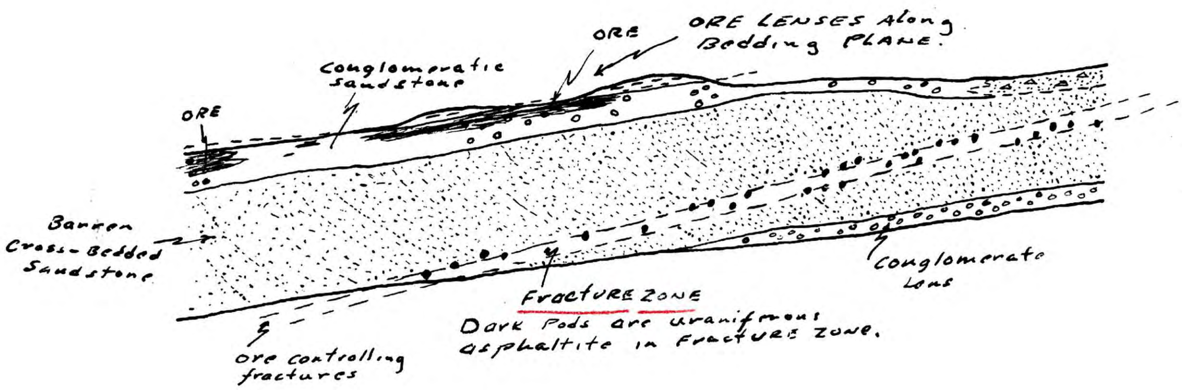
FIGURE 13. -Distorted cross-beds. Calyx No. 12 mine. Dark bands are interstitial uraniferous asphaltite.

FIGURE 14. -Distorted cross-beds. Calyx No. 12 mine. Pod-like structure above drill hole near end of pick handle is an end view across apex of fold.

COMPARISON BETWEEN CALYX NO. 12 AND OTHER MINES

Calyx No. 12 mine, the largest and most productive of the mines mapped, in most phases, is typical of the whole group. Major ore-bearing units in all of the mines are sandstone and conglomerate beds similar to those in Calyx No. 12. Ore bodies in Calyx No. 12 are larger than those of the other mines. In the other mines the maximum dimension is approximately one hundred feet, as in North Mesa No. 9, Campbird No. 7, and Vanadium King No. 1 Portal 2 mines.

Local fracture control, by fractures on which no apparent movement was observed, causing linear zones of concentration of uranium mineralization was observed in all mines except the Black Beauty. In Calyx No. 12 mine, a fracture (Fig. 15) is the locus of many fragments of humic matter replaced by uraniferous asphaltite in an otherwise barren sandstone. In Campbird No. 7 and Vanadium King No. 7 mines (Figs. 9 and 16), fractures are filled with uraniferpus asphaltite in sandstone and conglomerate that otherwise contains no uranium minerals. Uraniferous asphaltite ore is concentrated in and adjacent to a fracture, which apparently controls the ore of a small ore body, in Vanadium King No. 1 Portal 2 mine (Fig. 17). In North Mesa No. 9 and Lopez Incline mines, fractures (Figs. 8 and 18) cut off ore which partially delimits the size of these ore bodies. In this later case the uranium was not introduced along the fractures but was probably cut off by an impervious filling in the fractures. Ore bodies in Calyx No. 12 as well as other ore bodies in the Temple Mountain area, parallel two major joint-sets as seen in the exposed Chinle rocks (Fig 2). Average strikes of these two joint sets are N. 45° W. and N. 10° E. Although these joints



SCALE: 1 : 120

FIGURE 15. -Longwall sketch showing fracture control of ore, Calyx No. 12 mine.

FIGURE 16. -Fracture control of ore, Vanadium King No. 7 mine.
Shaded area is ore.

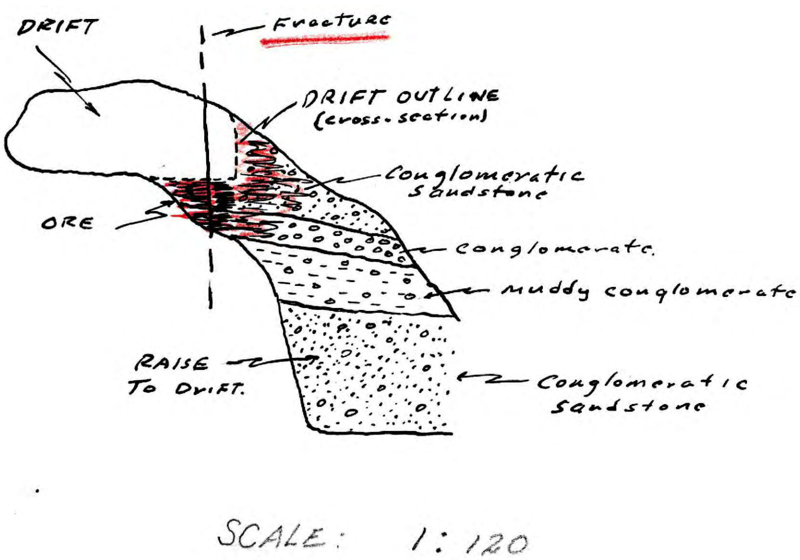


FIGURE 17.—Longwall sketch showing relation of fracture to ore in Vanadium King No. 1 Portal 2 mine. Ore confined to area adjacent to fracture.

FIGURE 18. - Fracture control of ore in Lopez Incline mine.
Dark band is ore.

were ~~also~~ noted in the other mines, none were seen in Calyx No. 12. This may be attributed, in part, to the fact that Calyx No. 12 is a considerable distance from the Moss Back rim and not subject to slumping and other surface influences that would make the joints distinguishable underground. This fracture control is dicussed further under tectonic controls.

Stokes (1947) recognized what appeared to be a northwest-trending channel, approximately as wide as the calyx bench, in the Moss Back. He based this idea on a general thickening of the sediments. In order to ~~test~~ this theory a structure contour map, based on drill logs and surface

mapping, was drawn on the base of the Moss Back. After correcting for regional dip, no channel, ~~but~~ only local scours with no appareant relationship to the ore bodies, was found ~~to exist~~. The ~~Temple Mountain~~ area lies in a synclinal warp ~~and~~ appears to be channel-like. Sedimentary trends in this area, based on measurments of cross-bed directions, averages northwest. Structure contours drawn on the base of a conglomerate in Calyx No. 12 (Fig. 12) also ~~displays~~ lineation in a northwest direction, but no apparent relationship to ore was noted.

Ore from Calyx No. 12 averages, as noted earlier, 0.27 percent U_3O_8. This value is slightly higher than the average grade of ore shipped from the Temple Mountain area, which is approximately 0.19 percent U_3O_8. In this calculation the average grade of ore bodies cannot be accurately determined since some waste unavoidably dilutes ore. The average uranium-vanadium ratio for ~~thirteen~~ mines in the Temple Mountain area, based on ore shipped and AEC assays, is 1 : 3.28, whereas the average uranium-vanadium ratio from Calyx No. 12 is 1 : 2.65 (TABLE I). There appears to be no zonal relationship between ~~the value of~~ uranium-vanadium ratio in ore from the various mines and the proximity of these mines to the collapse.

MINERALOGY

PARAGENESIS

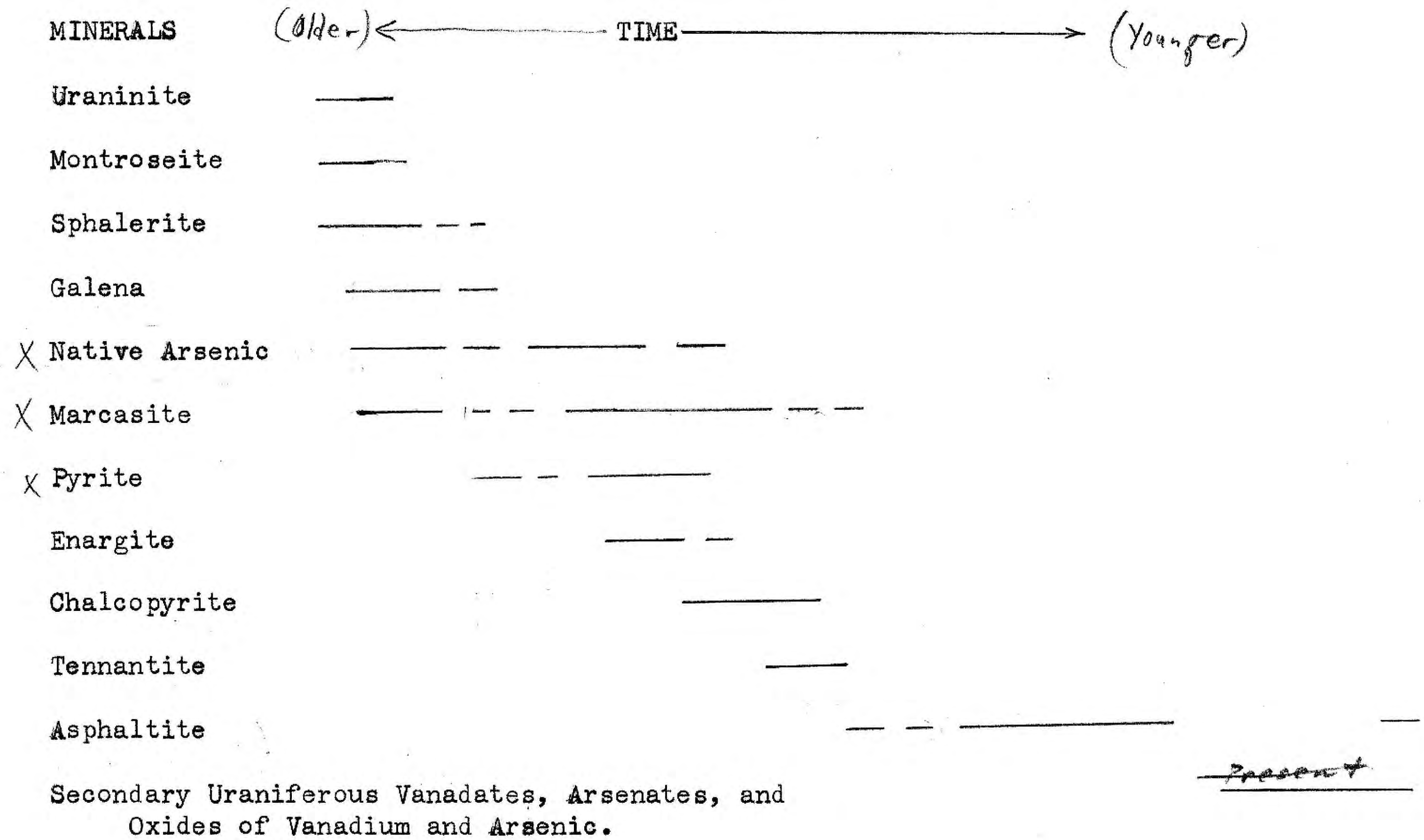
Unoxidized uranium and vanadium ~~ore~~ minerals found at Temple Mountain are uraninite and montroseite. These minerals are accompanied by galena, sphalerite, native arsenic, chalcopyrite, tennantite, enargite, pyrite and marcasite. Spectrographic analyses of ore show the presence of cobalt, chromium and selenium~~. The minerals in which these elements appear are~~ erythrite (?), mariposite (?), and cobaltomenite. 1/ Microscopic examination of the ore by the writers and the Mineralogy Section of the AEC, has shown the following paragenetic sequence: uraninite ~~along with~~ montroseite, sphalerite, galena, native arsenic and marcasite followed closely by pyrite, enargite, chalcopyrite ~~and~~ tennantite (TABLE II). There may have been some overlapping between these two assemblages, or the series may have been continuous. Similar mineral assemblages with identical paragenetic relationships have been found in core samples from deep drill holes in the Temple Mountain collapse area. A hypogene origin for the metalliferous components in the collapse area is supported by the identification of tennantite and enargite. Tennantite occurs typically in hydrothermal veins of copper, lead , zinc ~~and~~ silver minerals formed at low to moderate temperatures. Enargite occurs typically in veins and replacement deposits formed at moderate temperatures; it is also found rarely as a late mineral in low-temperature deposits. It can reasonably be assumed that the metalliferpus components in the collapse and in the North Mesa ore bodies have a similar origin.

1/Laboratory confirmation of identifiaation of the erythrite and mariposite has not been received ~~at this date.~~

Dobbs et al

TABLE II

PARAGENESIS OF TEMPLE MOUNTAIN MINERALS



Note: short lines represent periods of intermittent deposition.

Can you not present the factual evidence for this? you say: "through studies made by the writers ...." and that remains all the evidence, all the proof you allow the reader. If this report was for your aid and education, you could stop with only a first draft. If it is intended to inform the reader, you are obligated to present the details of every fact you observed.

Is it necessary to explain EVERYTHING in A topic Sentence? P.H.D.

This feature does not become a striking one until you stress (the fact?) carbonate as a common, usual, practically invariable cement. Then its absence at any one spot becomes unique

I am now stressing it by saying that it is a striking feature - thus cementing this idea in the readers mind. I feel that it is striking because I am familiar with the area. This is in essence the act of holding a supposedly ignorant reader by the hand.

A close spatial and genetic relationship between the collapse and the North Mesa mining area is apparent. Primary mineral assemblages common to both areas are uraninite, montroseite, sphalerite, chalcopyrite, galena, native arsenic, pyrite and marcasite. There is a zonal distribution of arsenic away from the collapse, with the greatest concentration in the collapse area. Several large nodules of native arsenic with a maximum diameter of two and one half inches were found in the collapse area by the writers and by Jesse Abernathy of Consolidated Uranium Corperation. Numerous small nodules of native arsenic were found in the Campbird No. 7 mine. The age relationship between the arsenic and the other minerals the collapse area and Temple Mountain mining area is somewhat confusing. Some nodules of native arsenic found in the collapse and in Campbird No. 7 mine, contain marcasite intergrowths of the same apparent age as the arsenic.

A direct relationship appears to exist between uranium and arsenic. That is, arsenic appears to be concentrated only in uranium ore zones. As the distance from the collapse increases the amount of arsenic diminishes but the uranium-arsenic relationship continues to exist. Keys and White (1956, pg. 295) observed that arsenic minerals appear to be related genetically to uranium in the collapse.

Numerous secondary minerals were formed subsequent to erosion and weathering of the ore zones. Alteration products include numerous uraniferous arsenates and vanadates and also oxides of arsenic and vanadium. Secodary minerals found at Temple Mountain (Gruner and Gardiner 1952) are metazeunerite, torbernite, metatorbernite, carnotite, tyuyamunite, rauvite, corvusite, metahewittite, realgar, alunite, erythrite and brochntite. In addition Weeks and Thompson (1945) list uvanite. Noted by Kerr et al (1955) were orpiment, pintadoite, halotrichite, copiapite, pascoite, and celadonite. Others, identified by the AEC Mineralogy Section through X-ray analyses are: bayleyite, hummerite, ~~and~~ roscoelite, ~~Samenite and~~ ~~the~~ iron analogue of bieberite. ~~were~~ identified by the Mineralogy Section, only by chemical and microscopic analyses. Cobaltomenite, a cobalt-selenium mineral, has been identified from this area (Weeks, 1956). Formulas for these minerals are given in Table III.

URANIFEROUS ASPHALTITE AND ITS RELATIONSHIP TO URANIUM

Studies made by the writers and the Mineralogy Section indicate that, following the crystallization of the uranium, vanadium, and sulfide minerals, asphaltic petroleum fractions were introduced into the Moss Back sediments. The petroleum fractions penetrated all permeable beds observed by the writers. Examination has shown that barren asphalt is more widespread than the ~~metalliferous,~~ uraniferous asphaltite. One striking feature evident throughout mines in the Temple Mountain mining area is the marked absence of carbonate, both in ore zones and in sediments saturated with non-uraniferous liquid asphalt. It is presumed that carbonate was removed by mineralizing solutions. Its removal would have increased permeability, a factor certain to facilitate movement of petroleum through the sediments. All primary ore minerals ~~have been corroded in varying degrees by asphaltite. Nowhere was it observed that primary ore minerals were not~~ either completely or partially replaced by asphalt by an apparent solvent action. This solvent action of the asphaltite on the earlier metallic minerals caused their nearly complete obliteration. Early minerals appear to have been almost entirely dissolved by the asphalt ~~during the~~ hardening. ~~process.~~ Submicroscopic granules of

Table III

Minerals of the Temple Mountain Area Ores

Uranium Minerals

Uraniferous asphaltite	
Uraninite	UO_2
Torbernite	$Cu(UO_2)_2(PO_4)_2 \cdot 8\text{-}12H_2O$
Metatorbernite	$Cu(UO_2)_2(PO_4)_2 \cdot 8H_2O$
Metazeunerite	$Cu(UO_2)_2(AsO_4)_2 \cdot 8H_2O$
Carnotite	$K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$
Tyuyamunite	$Ca(UO_2)_2(VO_4)_2 \cdot nH_2O$
Uvanite	$U_2V_6O_{21} \cdot 15H_2O$
Rauvite	$CaU_2V_{12}O_{36} \cdot 20H_2O$
Bayleyite	$Mg_2(UO_2)(CO_3)_3 \cdot 18H_2O$

Vanadium Minerals

Montroseite	$VO(OH)$
Corvusite	$V_2V_{12}O_{34} \cdot nH_2O$
sp? — Metahewettite	$CaV_6O_{16} \cdot 9H_2O$
Pintadoite	$Ca_2V_2O_7 \cdot 9H_2O$
Pascoite	$Ca_2V_6O_{17} \cdot 11H_2O$
Roscoelite	$(Al,V)_2(AlSi_3)(K,Na)O_{10}(OH,F)_2$
Hummerite	$K_2Mg_2V_{10}O_{28} \cdot 16H_2O$

Associated Minerals

Native arsenic	As
Pyrite	FeS_2
Marcasite	FeS_2
Covellite	CuS

Table III (Continued)

Sphalerite	ZnS
Galena	PbS
Realgar	AsS
Orpiment	As_2S_3
Enargite	$3Cu_2S \cdot As_2S_5$
Tennantite	$(Cu,Fe)_{12}As_4S_{13}$
Chalcopyrite	$CuFeS_2$
Bornite	Cu_5FeS_4
Erythrite(?)	$Co_3As_2O_8 \cdot 8H_2O$
Carminite(?)	$Pb_3As_2O_8 \cdot 10FeAsO_4$
Brochantite	$Cu_4(SO_4)(OH)_6$
Bieberite	$CoSO_4 \cdot 7H_2O$
Gypsum	$CaSO_4 \cdot 2H_2O$
Copiapite	$Fe_4(SO_4)_6(OH)_2 \cdot 20H_2O$
Halotrichite	$FeSO_4Al_2(SO_4)_3 \cdot 22H_2O$
Celadonite	Silicate of iron, magnesium and potassium
Cobaltomenite	Cobalt selenite
Mariposite(?)	Chromium mica
	<u>Alteration and Clay Minerals</u>
Alunite	$K_2Al_6(OH)_{12}(SO_4)_4$
Montmorillonite	$(Mg,Ca)O \cdot Al_2O_3 \cdot 5SiO_2 \cdot nH_2O$
Kaolinite	$2H_2O \cdot Al_2O_3 \cdot 2SiO_2$
Illite	$(OH)_4K_y(Al_4 \cdot Fe_4 \cdot Mg_4 \cdot Mg_6)Si_{8-y} \cdot Al_yO_{20}$
Calcite	$CaCO_3$
Dolomite	$CaMg(CO_3)_2$
Siderite	$FeCO_3$

uraninite, galena, native arsenic, and chalcopyrite are dispersed in halos around the borders of larger spheroids of the metallics. These fragments diffuse away from their common center. Thus their appearance that of a solid being dissolved in a liquid (fig. 19). Hardening of asphalt to asphaltite apparently terminated the process of replacement of metallics. The range of diffusion of the particles is so slight that there appears to have been practically no movement of asphaltite after its contact with primary minerals. These metalliferous granules possess a lattice-like orientation reflecting the woody structure of the humic material they replaced (Hausen, 1956).

Uraniferous asphaltite appears to be extremely corrosive. It etches sand grains and in areas of greates concentration of uraniferous asphaltite only minute ~~particles~~ of ~~sand~~ are left. The corrosive quality of asphaltite appears to be directly related to the amount of contained uranium. Thin section examination shows ~~a zonal relationship between hard translucent non-uraniferous asphaltite and opaque uraniferous asphaltite.~~ ~~The~~ translucent, hard asphaltite ~~becomes~~ opaque ~~in the vicinity of~~ replaced uraninite grains ~~and where submicroscopic uraninite particles occur.~~ In the zone of translucent hard asphaltite there is little or no corrosion of sands grains, and alpha track plate studies ~~show~~ no uranium content. Bombardment of the asphaltite by radioactive emission particles from the uraninite possibly rendered the asphaltite corrosive, but the amount of SiO_2 in the asphaltite is too small to account for the quartz sand grains that have been removed by corrosion. Thus the possibility exists that before the asphalt was introduced, some of the primary minerals, or the mineralizing solutions in the presence of uraninite,

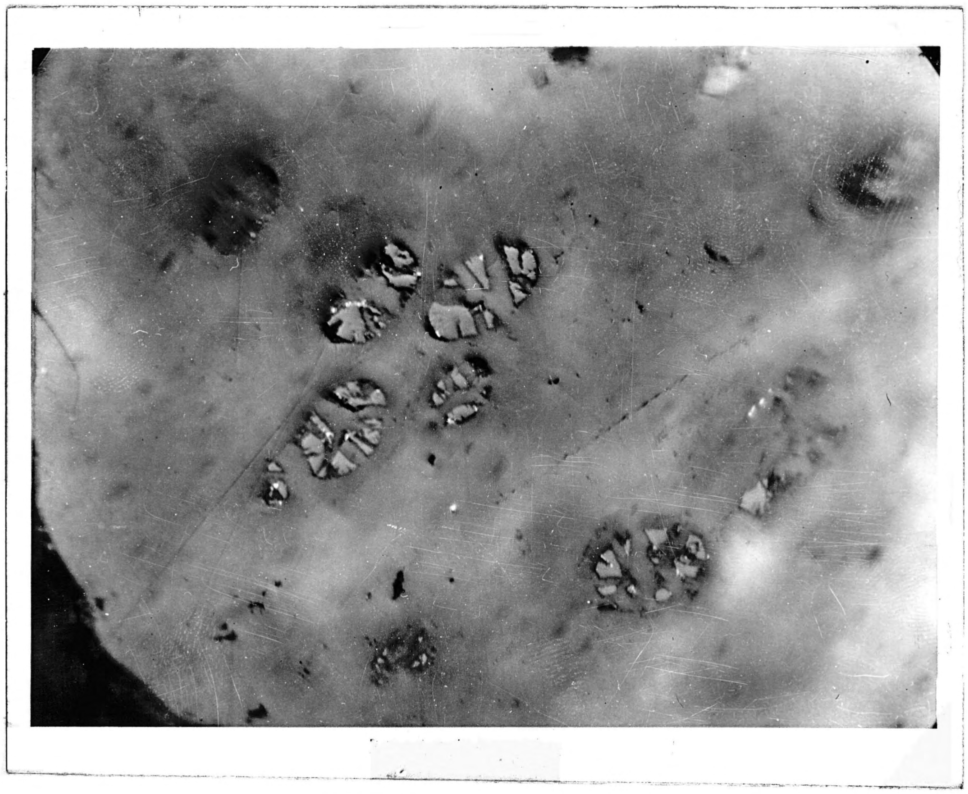


FIGURE 19. Corroded uraninite nodules in asphaltite. Light areas consist of high concentrations of submicroscopic granules of uraninite. X 1500. (after Hausen, 1957)

became corrosive and the SiO_2 was carried away in the mineralizing solutions. This is evidenced by the great amount of quartz overgrowth on sand grains in the vicinity of ore zones. Some chert pebbles were partially or wholly replaced by uraninite and other primary minerals. These were later corroded by asphalt, and where completely replaced, to form asphaltite pebbles. These asphaltite pebbles are extremely brittle; therefore, it is ~~very~~ unlikely that they are syngenetic ~~[It is not probable that soft asphalt pebbles]~~ as they could not survive the grinding action of ~~these~~ fluvial sediments at the time of deposition. There are no soft asphalt pebbles, even in conglomerate far removed from ore and where all asphalt is liquid. Another striking feature is the abundance of metallics in the uraniferous asphaltite, and their apparent ~~lack of them~~ absence in areas ~~occupied~~ where only ~~by~~ the non-uraniferous liquid type of asphalt was observed.

Two generations of asphalt appear to exist in the Temple Mountain area. This is evidenced by liquid asphalt in fractures cutting hard uraniferous and non-uraniferous asphaltite. Gypsum veins, cutting asphalt-saturated sediments and asphalt-replaced humic material, have been fractured and are now filled with asphalt (G. W. Chase, oral communication). However, if liquid asphalt continued to exist and remained mobile in the Moss Back from the time of its initial invasion, it would undoubtedly appear as more than one generation by later introduction into ~~cutting~~ these post-invasion fractures.

FACTORS INFLUENCING DEPOSITION

The factors which influenced deposition of uranium at Temple Mountain are (1) Sedimentary features; (2) chemistry of the mineralizing solutions and host rocks; (3) tectonic features.

Sedimentary Features

Certain characteristics of the sediments appear to have had a major influence in controlling distribution of ore. The most important appears to have been permeability. Pinchouts and truncation of permeable sandstone and conglomerate by impervious sediments and the nature of the bedding planes also played a major role in limiting or enhancing the extent of the ore bodies.

Variations in permeability undoubtedly had more influence upon movement and confinement of mineralizing solutions than any other factor. Permeability variations are both original and induced. Original permeability depends on at least three factors; amount of calcite cement, of interstitial clay, and the degree of sorting in a given unit. In general barren and non-asphaltic sandstones and conglomerates of the Moss Back are fairly uniformly cemented by calcite. The content of interstitial clay varies among the various sandstones and conglomerates. Some are quite clean with little or no clay and others contain clay in amounts to make them practically impervious. Often along bedding planes, both horizontal and inclined, the content of clay, light-green to gray-green, makes bedding more apparent by contrasts in color. Zones rich in clay, either interstitial or on bedding planes are quite impermeable and contain little or no mineralization. Sorting controls permeability to a minor extent, but few if any of the sandstones have poor enough sorting to render them completely impermeable.

Original calcite cement rendered the sandstones and conglomerates fairly impervious. However, it is conjectured that ore solutions removed nearly all ~~great amounts~~ of the calcite from uranium-mineralized zones and adjacent areas. Such removal ~~x~~ is usually complete, but ~~occasionally in a few~~ in some rocks that now contain~~ing~~ liquid asphalt, small, isolated, nodular remnants of calcite (~~one-eight~~ 1/8 to ~~two~~ 2 inches in diameter) remain. The material was carried by the solutions and redeposited in abnormal concentrations of calcite ~~short distances~~ beyond zones of metallic mineralization. These concentrations parallel mineralized fractures and bedding planes and lie between ore bodies and permeability barriers.

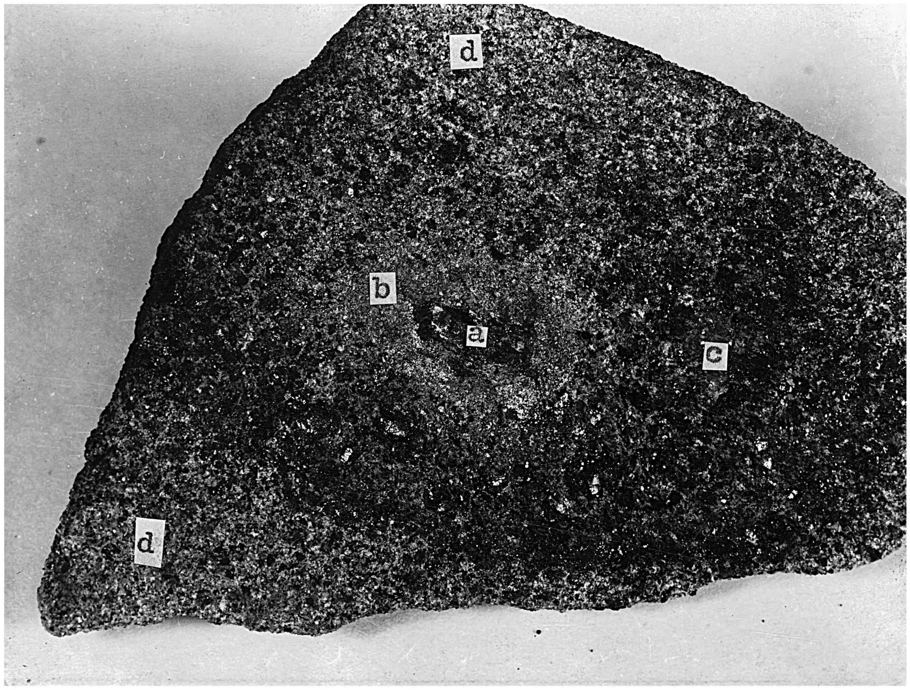
Pinchouts and truncations of ore-bearing lenticular sandstones and conglomerates ~~occur frequently~~ are common throughout the Moss Back ore zones, and, in many places, are important factors in limiting the extent of ore bodies. ~~Due to the fluvial origin of the Moss Back these features are xxx quite common.~~ Where the pinched-out bed lies between impermeable sediments, ~~the~~ mineralization ~~is~~ was confined to the permeable bed. ~~On the other hand,~~ The pinchout ~~may or~~ may not be a limiting ~~x~~ factor if it is bounded by permeable beds. Beds may be truncated by ~~xx~~ a mudstone-filled scour, and the ~~scour filled with sandstone and conglomerate. Rxxx xxxbxxxxxxx Here again,~~ permeability of the truncating bed is the controlling factor for mineralization (fig. 20).

Bedding planes ~~may limit or increase mineralization.~~ If ~~the planes are~~ relatively open, ~~they~~ may have served as channelways for ~~mineralization in a that particular area.~~ Where mineralizing solutions ~~passed along bedding planes,~~ carbonate cement ~~has been~~ that removed ~~in many cases~~ from rock several inches on each side of the bedding plane. ~~and in most instances,~~ in many places the bedding plane is usually mineralized. Where mineralized, bedding has been partially or completely obscured by subsequent invasion of asphalt.

Features shown in figures 13 and 14 have been identified by a series of thin sections as distorted cross-beds. The thin-section study of the folded cross-beds revealed that the upper portion of these beds is upside down. This was evidenced by the gradation of coarse to fine sand to silt grains from bottom to top of individual cross-beds. This distortion or folding of the beds was apparently accomplished prior to or contemporaneous with consolidation of the sands. In the above figures, uraniferous asphaltite occupies many of the overturned bedding planes shown as curved black bands. Barren cross-beds of this type have also been observed. This feature has also been observed at the Commonwealth Mine in the San Rafael Swell in the Moss Back (fig. 3).

Chemical Factors

Chemical environment and local changes in it strongly influenced deposition of uranium and associated metallics. Marcasite is most commonly a product of acidic solutions and its presence is interpreted as indicative of that environment. The supposition is supported by the absence of calcite cement from the collapse and from mineralized portions of the Moss Back from which it is believed to have been removed by acidic solutions. Local aid in the form of S^- ions is thought to have been supplied by decaying humic material. Many ore pods have centers of fossil wood. This "wood" has in most cases been replaced by asphalt and is not commonly uraniferous. Often surrounding these centers are concentric ore zones of marcasite, uraniferous asphaltite and non-uraniferous asphaltite, in that order (fig. 21). This is discussed further under "Role of Humic Hydrocarbons".



Natural size

FIGURE 21. - Concretionary uraniferous asphaltite pod. Marcasite core surrounding asphaltized twig. (after Hansen, 1959)

~~magnification or scale~~

a. Twig replaced by asphalt

b. Marcasite

c. Massive uraniferous asphaltite in sandstone

d. Disseminated non-uraniferous asphaltite

Illitic clay may have been effective to some extent in precipitating uraninite and other primary minerals, although the nature of the reaction, chemical or physical, is not known. The possibility exists that clay particles adsorb uranium. Small pods and botryoidal masses of uraniferous asphaltite are found in scattered localities intimately associated with and/or within illitic mudstone. Microscopic examination shows other minute specks of asphaltite. These probably were formed by the precipitation of uranium on pollen and very small bits of woody material that were later replaced by asphalt. Illite was apparently formed from kaolinite or montmorillonite in an acid environment.

An increase in pH caused by the neutralizing effect of carbonate upon the mineralizing solutions may also have facilitated the deposition of metallics. There is, however, no direct evidence of this, and the statement is offered only as a suggestion.

Tectonic Factors

The role of tectonic structures in localization of the Temple Mountain uranium deposits is not fully understood. Similarity between mineral suites of the collapse and of the principal mining area, as well as other factors noted under "Origin of Mineralizing Solutions", lead the writers to believe that the collapse structure was important. Also, as noted under "Geology of Ore Deposits", a parallelism exists between elongation of ore bodies and strike of major joint-systems seen at the surface in the mining area. Either the parallelism is merely coincidental, or zones of weakness and/or indistinguishable fractures persist at depth, serving as zones of increased accessibility for the mineralizing solutions. The writers feel that the latter explanation is the more applicable.

Two major normal faults (fig. 1) not associated with the collapse are located near the Temple Mountain mining area and appear to have had little or no influence on ore deposition. Both strike approximately east-west and are downthrown to the south. They are located at the northern and southern extremities of the calyx bench. The northern fault passes through the Vanadium King No. 1 Portal 2 mine and has about 15 feet of vertical throw. The southern fault passes immediately to the north of the main tunnel of the Lopez Incline mine and has 68 feet of vertical displacement. In the Lopez Incline, located on the downthrown block, numerous small faults of six inches to three feet displacement cut the ore. The presence of ore as drag on the fault planes indicates post ore movement (fig. 22).

In the Calyx No. 12 mine is a set of low-angle 20 (10 to 20 degrees) fractures striking N40-50°E. These fractures control mineralization. In one mine (fig. 15) they cut a sandstone unit about eight feet thick. The lower half of this unit contains abundant interbedded carbonaceous debris. In every place where one of these low-angle fractures cuts through a particle of the carbonaceous material, there is a small pod of high-grade uraniferous asphaltite. Only that carbonaceous material cut by the fractures is mineralized; carbonaceous material away from the fractures contains no uranium.

In the North Mesa No. 9 mine, near mine survey station seventeen (fig. 5) a fracture dipping 83° cuts off a small ore body. A strong concentration of rich ore occupied the hanging-wall of the fracture while the foot-wall contained only isolated specks of uraniferous asphaltite.

In Vanadium King No. 1 Portal 2 mine a vertical fracture striking N47W appears to control the ore in the upper stope in the vicinity of mine survey stations $5b^4$ and $5b^6$ (figs. 6 and 17). This fracture is filled with high-grade uraniferous asphaltite and occupies a position in the richest part of the ore body.

FIGURE ~~14.~~ 22. -Post-Ore Fault in Lopez Incline Mine.
Dark bands are uranium ore.

In Campbird No. 7 mine, the drift from mine survey station 1 to mine survey station 10 follows a sinuous, vertical, or nearly vertical, mineralized fracture. This fracture terminates at a stope from which considerable ore was removed. Figure 18 shows a portion of this fracture.

In Vanadium King No. 7 mine, low-angle fractures effectively control ore. At the west portal a fracture cuts an impervious sandstone unit, and only along the fracture is there any uranium. Above and below this sandstone unit, ore occupies two separate lenses of conglomerate (figs. 12, 16 + 23).

No apparent movement was observed on the above ore-controlling fractures.

From the data just given, it can be concluded that certain local pre-ore fractures exerted some control of the ore, however, other sedimentary and chemical factors probably were involved in localizing the ore by forming passageways that allowed the mineralizing solutions to move into the rocks.

ORIGIN OF MINERALIZING SOLUTIONS

The first report concerning uranium and vanadium deposits at Temple Mountain was made by Hess (1922), who suggested that uranium and vanadium might have been leached from other rocks and precipitated by asphaltic fractions in a shallow sea or lake, and that "hot water" had played a minor part in ore deposition. Murphy (1944) stated that the Temple Mountain ore-deposits were attributed, in part, to a selective impregnation of sandstone and in part to a sedimentary origin. Webber, in the report by Murphy (1944), stated that the ore deposits were of hypogene hydrothermal origin, which he related to igneous intrusions. Stokes (1947) assumed that the origin of uranium and vanadium was through an aquifer which ~~deposited~~ allowed the uranium and vanadium to be deposited on carbonaceous or organic material (asphalt). Bain (1951) suggested structural as well as sedimentary influence upon the ore. He felt that this structural influence indicated that the distribution of uranium and hydrocarbon occurred after the joint-systems were established. Sheridan (1951) suggested a low-temperature hydrothermal origin for the ore. Brooke (1952) postulated that the ore was deposited from hot aqueous solutions rising from fault-feeders ~~which~~ and migrating laterally along fractures or through porous ~~rock~~ strata. Wyant (1953) believed that the uraniferous asphaltite at Temple Mountain is the residue of weakly metaliferous crude oil which was introduced into the more permeable sandstone and conglomerate after the formation of the San Rafael Swell ~~anticline~~. Kerr and Lapham (1954) tentatively ~~considered~~ postulated a hydrothermal origin for the ore on the basis of the similarity of the ore to thucholite (Ellsworth, 1928) and the association with arsenic. Keys and White (1955) recognized a belt-like arrangement of ore bodies on the calyx bench. They attributed this arrangement to an oil-water interface in an unbreached anticline. Hausen (1956) reported that the ore was deposited under reducing conditions of low temperature and pressure. The ore-bearing solutions were probably hydrothermal and moved upward rather than downward.

According to Hausen (oral communication) contemporaneous mineralizing solutions in both the collapse and the Moss Back appear to have been responsible for deposition of uraninite, base metal sulfides, native arsenic and sulfarsenides and simultaneous removal of carbonates from the rocks. Mineral assemblages at Temple Mountain area were typical low-temperature hydrothermal types.

McKelvey, et al. (1951) point out numerous mineralogic similarities between uraniferous deposits at Temple Mountain and typical uraniferous vein deposits. Metals most abundantly associated with uranium in veins are Fe, Cu, and Pb. Iron usually occurs as pyrite and/or marcasite frequently associated with lead and zinc in galena and sphalerite. Marcasite, pyrite, sphalerite, and galena have all been identified in Temple Mountain uraniferous ore. According to McKelvey this is an assemblage similar to that found in the Si-Fe-Pb type veins in many parts of the worlds. McKelvey also states that copper is possibly the second most common metal associated with uranium in hydrothermal deposits. In the Temple Mountain mining area nearly all the sulfides and sulfarsenides have been noted, some of which were found in cores from asphalt-free sandstone in the collapsed area. Chalcopyrite, tennantite and enargite, an assemblage which commonly occurs in epithermal vein deposits, associated with uraninite are mutually intergrown in the sandstone interstices. No such syngenetic assemblage has been reported.

Co, Ni, As, Ti, and V are additional metals which McKelvey states are associated with uranium vein deposits, and each of these has been detected in abnormal amounts in the mineralized sediments at Temple Mountain. The hydrothermal characteristics, that is, the physical and chemical ~~environment~~ necessary to precipitate vanadium minerals are little known ~~at present~~. Rankama and Sahama (1950) list ~~it~~ as an accessory constituent of uraninite in ~~Ni-Co-U~~ type veins. The role of montroseite is not understood ~~at present~~. Further similarities between the Temple Mountain deposits and typical vein deposits may be pointed out by McKelvey's citation of the occurrence of amorphous hydrocarbon in widely scattered vein deposits. Some of these hydrocarbons are of the thucholite type (Ellsworth, 1928). ~~Thucholite is a carbonaceous uranium-bearing mineral.~~ The name is derived from the contained thorium, uranium, carbon, hydrogen and oxygen. McKelvey also notes significant amounts of carbonate gangue concentrated in uraniferous veins that cut metasediments. Most common gangue minerals are dolomite, siderite, and ankerite. A close parallelism is seen in the concentration of large volumes of dolomite and siderite transported and redeposited in the overlying Wingate, probably by mineralizing solutions, at Temple Mountain.

This supports the theory ~~of~~ hydrothermal mineral assemblages ~~is~~ the flow direction of the solutions in the collapse ~~which were~~ upward rather than downward. Removal of large volumes of $CaCO_3$ from the Kaibab and Sinbad limestones and deposition of compensating amounts of dolomite and siderite in the Wingate below and above collapse respectively, must surely be more than ~~bare~~ coincidence.

That mineralizing solutions came up along fissures associated with the collapse and spread laterally into permeable Moss Back is supported ~~by the above evidence and~~ further by field observation of carbonate in the mines in the area. The redistribution comprises removal of carbonate cement within and adjacent to ore bodies and its redeposition in abnormal concentrations from a few inches to a few feet away. The metallic compounds, presumably from a deep seated source, were precipitated under low temperature-pressure conditions from very dilute solutions.

ROLE OF HUMIC HYDROCARBONS

Many forms of carbonaceous debris ~~xxx~~ discussed under "Stratigraphy" are present in the Moss Back sediments. ~~These~~ This debris ranges from microscopic pollen to logs ~~four~~ 4 feet in diameter and 20 feet long. Much humic material has been partially or completely replaced by asphaltite and exhibits no recognizable cellular structure. Humic hydrocarbons appear to have played an important role in the precipitation of uraninite. Plants absorb uranium, but not in sufficient quantity to account for the amount present in the fossil humic matter; ~~There~~therefore, other processes must be responsible for the introduction of uranium into the carbonaceous deposits (Breger and Deul, 1956). Most ~~Ore~~ ore pods ~~commonly~~ enclose logs and twigs, and ore zones are in or near ~~closely associated with~~ beds having an original high content of humic hydrocarbons. ~~content.~~ Uranium ~~will~~ is precipitated under reducing conditions. At Temple Mountain Breger and Deul (1955) obtained specimens of humic hydrocarbon which they called coalified wood. This so-called coalified wood contained both ~~fxxx~~ fusain and vitrain. They found that fusain, which is ? relatively chemically inert, contained no uranium. Vitrain on the other hand is chemically reactive and contains functional groups which are ~~x~~ capable of combining with uranium. The vitrain was found to contain uranium. If uranyl ion UO_2^{++} comes into contact with H_2S the reduction reaction

$$UO_2^{++} + H_2S \rightarrow UO_2 + 2H^+ + S$$

will take place. One of the best reducing agents for uranium and vanadium in nature appears to be H_2S or $S^=$ ions which ~~is~~ are commonly ~~associated with~~ liberated during the ~~decayed~~ decay of organic material (Gruner, 1956). An anomalous amount of free sulfur, ~~is~~ present in uraniferous asphaltite, ~~and~~ may be accounted for ~~xx~~ by the above reaction. H_2S from freshly broken ore samples from mines at Temple Mountain ~~mines~~ can be readily detected by ~~x~~ its noxious odor.

In some cases the reducing action was so strong that the uraninite, along with other metallics, was precipitated in a halo around the carbonaceous matter. The reducing action was continuous throughout the time that the mineralizing solutions were present, and exerted enough exterior influence that the carbonaceous portion was never replaced. Figure 20 illustrates the accretion of uraniferous asphaltite around a twig replaced only by non-uraniferous hard asphaltite. A halo of marcasite surrounds the twig and is in turn surrounded by massive uraniferous asphaltite, which becomes less concentrated away from the center until only disseminated flecks are present.

This should probably be omitted! Why?

CONCLUSIONS

Previous papers on Temple Mountain uranium ore have proposed essentially four explanations for origin of the uraniferous asphaltites: (1) Syngenetic; (2) introduction of uraniferous petroleum derivatives with concentration of uranium by fractional distillation in situ; (3) precipitation of uranium by asphalt; (4) asphalt prior to uranium; (5) hydrothermal origin of uranium; (6) uranium prior to asphalt.

The writers favor a hydrothermal origin for the primary minerals of the Temple Mountain ores. From evidence supplied by laboratory and field work it is concluded that:

1. Uraninite, montroseite, sphalerite, galena, native arsenic, and marcasite were introduced by hydrothermal solutions in advance of all the other metalliferous components and the asphalt.
2. The precipitation of uraninite was controlled by carbonaceous debris, certain chert pebbles, illitic clay, pre-ore joints, and permeability.
3. Most of the asphaltic material migrated into the sediments after deposition of metallics; it has served only to obscure original mineral relationships and did not introduce nor control the distribution of uranium and vanadium. Rather, the asphalt was polymerized and immobilized by alpha and beta particle bombardment and gamma radiation from the earlier uraninite.

The mines that were mapped are all ~~quite~~ very similar, and the only zonal relationship between the collapse and the mining area is in the percentage of arsenic found in the ore.

The nature and trend of ore bodies on the calyx bench suggest fracture-control of mineralizing solutions, but more work should be done to check the validity of this hypothesis. Certain local fractures control ore, but many other fractures observed in mines appear to be post-ore and have had no control.

Ore grade-thickness contour maps illustrate size, quality and the trends of the ore bodies. They are an asset to mine operators because they can help solve some problems of finding ore bodies without expensive drilling. However, the information from additional drill holes is desirable.

In summary, organic debris was present in the Moss Back in ample amounts to provide sites for precipitation of ore from the mineralizing solutions. Replacement of carbonate, chert and quartz by the solutions appears to have been contemporaneous. After ore deposition the Moss Back was invaded by petroliferous fluids. Access to ore zones was facilitated by induced permeability provided by prior removal of interstitial material by mineralizing solutions. Those portions of petroleum that came into intimate association with uraninite were polymerized into asphaltite. Since the polymerization stage, weathering and erosion have altered the deposits in varying degrees and have resulted in formation of secondary minerals and partial breakdown and leaching of some of the asphaltites.

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