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URANIUM ORE CONTROLS OF THE HAPPY JACK
DEPOSIT, WHITE CANYON, SAN JUAN COUNTY,
UTAH

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WHITE CANYON, SAN JUAN COUNTY

UTAH

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ABSTRACT

The Happy Jack uranium deposit of White Canyon, San Juan County, Utah, was studied in connection with an Atomic Energy Commission exploration program. The major uranium ore control is a paleostream channel containing sediments of the Shinarump conglomerate. Intra-channel controls include organic matter, lithologic variations, and channel "lows".

Microscopic studies reveal that uraninite, the primary ore mineral, occurs as cement and as a replacement of organic material. Both the uraninite and copper sulfides replace secondary quartz overgrowths. Crystals of chalcopyrite, chalcocite, and pyrite occur one within the other. Exsolution of bornite and chalcopyrite is present. Uraninite is dated as later than the secondary overgrowths and of about the same age as the copper sulfides.

INTRODUCTION

Study of the Happy Jack uranium deposit was undertaken during April and May 1952, as preliminary work for a diamond drilling program carried out by the U. S. Atomic Energy Commission. The ore controls described herein were tentatively outlined by this study and have been largely confirmed by the drilling. The regional picture of the Shinarump conglomerate has been developed by the author and colleagues as part of a continuing study of the White Canyon uranium deposits carried out by the Grand Junction Operations Office of the Atomic Energy Commission.

The Happy Jack mine is located in the White Canyon of San Juan County, southeastern Utah, adjacent to Utah State Highway 95 (fig. 1). Exposed formations, all of which are continental deposits, range in age from Permian through Jurassic (fig. 2). The topography is rugged with the crests of the canyon walls 2,500 feet above the valley floor.

White Canyon is on the west flank of the Monument upwarp, a broad structural feature locally known as the Elk Ridge antiform (fig. 3). The beds have a uniform strike of N. 15° W. and dip 1½° SW. A conjugate joint system is manifest throughout the area with the dominant set striking N. 50° E. and the minor set N. 55° W. Both sets have a vertical dip.

Figure 1. Location map of Happy Jack mine,
 San Juan County, Utah

Figure 2. Generalized section of the Happy Jack area,
San Juan County, Utah

Figure 3. Tectonic map of Southeastern Utah

PREVIOUS WORK

Gregory (1938) carried out the earliest reconnaissance of the region. 1/ Fischer and King (1948), 2/ Smyth (1949), 3/ Granger and Beroni (1950), 4/ and Benson, et al (1952), 5/ have investigated the area and Dodd (1950), 6/ mapped a portion of the Happy Jack mine. Bain (1951) has also recorded his impression of the Happy Jack; 7/ Gruner and Gardiner (1952) have written a brief account of the mineralization. 8/

GEOLOGY

The Happy Jack has been the most productive among a number of uranium-copper deposits in the White Canyon area. All are in the Triassic Shinarump conglomerate. This formation is a lenticular sandstone fluvial in origin, conformable with the Chinle formation above, and disconformable with the Moenkopi formation below.

A distinctive feature of the Shinarump - one related to ore deposition - is the relation of its thickness to the configuration of the irregular erosion surface on which it was deposited. This surface, the top of the Moenkopi formation, is marked by paleo-drainage channels which are filled by Shinarump clastics. These sediments extend beyond the narrow confines of the channel and wedge-out in certain inter-channel areas.

Channel Structure

Each Shinarump sandstone lens has filled one to three channels. In cross section a typical channel is an asymmetrical trough, incised into the Moenkopi formation. It is 100 to 250 feet wide and 20 to 40 feet deep (fig. 4). Along its course the undulating basal surface of a Shinarump channel may have a relief as high as 40 feet (fig. 5). As a rule the channel maintains a relatively straight course; however, the Happy Jack channel is an exception for it changes direction abruptly in the eastern portion of the area.

Channel Sediments

On the basis of lithology, the Shinarump channel sediments may be subdivided into three sedimentary units (fig. 4).

	<u>Thickness, feet</u>
Unit 3 (upper unit) Sandstone, white, weathers to buff; quartzose, coarse-grained, poorly sorted, friable; grains sub-angular, clay cement, contains microcline fragments up to an inch in diameter; cross-laminated, caps the channels and occupies the intervening area; cliff-forming- - - - -	28
This unit is not usually ore-bearing, except locally in the Happy Jack mine.	

Looking North

EXPLANATION

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Figure 4. Cross section of Sunrise channel.
White Canyon, Utah

Figure 5. Channel structure contour map of Happy Jack mine and vicinity, White Canyon, Utah

	<u>Thickness, feet</u>
Unit 2 (middle unit), Mudstone, usually gray, commonly red; structureless, contains some fine to coarse sand grains; has small carbonized fragments; not present outside the channel; slope-forming- - - -	12
This unit is not ore-bearing, except when near the surface.	
Unit 1 (basal unit), Sandstone, white weathers to buff; quartzose, coarse-grained to conglomeratic, poorly sorted, contains Moenkopi shale and sandstone fragments; friable, grains angular, clay cement, contains organic matter such as small twigs and ferns; predominantly quartz pebbles; few chert, quartzite and jasperoid pebbles, contains microcline fragments up to 1 inch in diameter; some chert pebbles contain fossil (cryonoids and corals ?); not located outside channel; slope-forming- - - - -	5.0
This is the ore-bearing unit.	

The basal unit, which contains most of the ore in the Shinarump conglomerate, changes character abruptly along the bottom of the channel. It usually pinches out on the flanks of the channels and upon the "highs" along the paleostream's course. It is commonly conglomeratic only within the lows.

The clay cement of this unit is difficult to identify. The abundance of siliceous chards in the clay may indicate a volcanic origin.

The most common organic matter within this basal unit is compressed, broken twigs a few inches to 3 feet in length. Larger fragments are not commonly present.

Asphaltic material occurs in minute quantities and appears insignificant as an ore precipitant.

At White Canyon, the Shinarump rarely contains silicified wood. This is a marked contrast to the abundance of this material which is characteristic of the same formation in other areas.

Regional Distribution of Shinarump Conglomerate

The distribution of the sediments of the Shinarump conglomerate in the White Canyon area is characteristic of an alluvial fan deposit (fig. 6). This fan is elongate in a westerly direction and appears to have had its origin east of the Elk Ridge anticline as is evidenced by: (1) eastward increase in the proportion of pebbles in the Shinarump, (2) increase in thickness of the Shinarump to the east, (3) westerly dipping cross-bedding direction, (4) westerly channel orientations.

EXPLANATION

Unit 3 Shinarump conglomerate

Direction of stream flow

Preliminary map based on studies in progress on channel directions, X-bedding, thickness and pebbles.

Figure 6. Regional distribution of the Shinarump conglomerate
White Canyon, San Juan County, Utah

The Happy Jack deposit is located on the northwest "pinch-out" of the fan. The control that this feature may have on ore deposition is discussed under intra-channel ore controls.

Geomorphology and Climatic Change

A sharp change in stream drainage and climate took place at the end of Moenkopi time.

An incised cross-section testifies to the youth of Shinarump streams, and Moenkopi sandstone pebbles are an indication of an indurated Moenkopi formation. Scour and fill type sediments are within the channels. After the channels were filled, the streams migrated within the inter-channel areas and deposited unit No. 3 (figs. 4 & 6). The meandering streams which deposited these sediments filled broad erosional valleys and reached a late stage of maturity. As these streams reached old age, they deposited the shales of the overlying "D" member of the Chinle formation.

Vegetal remains are extremely rare in the red Moenkopi formation; whereas in the variegated Chinle formation, carbonized plants, large silicified trees, fresh water pelecypods and Triassic vertebrates are abundant. This may indicate that conditions were more suitable for burial during the Chinle time. A better explanation may be that a climatic change from dry to moist took place after Moenkopi time.

Both the sharp geomorphological and possible climatic changes indicate a period of diastrophism between the Moenkopi and Chinle formations. An angular unconformity between the two formations near Castle Valley, Utah, east of White Canyon, bears this out.

MINERALOGY

The general character of the ore is an intergrowth of uraninite with copper sulfides, associated with minor secondary derivatives of uranium and copper.

Uraninite is the primary ore mineral of uranium in the Happy Jack deposit. Its characteristic occurrence is as replacement of wood and as cement of quartz grains. Decomposition products, the hydrated sulfates of uranium, are common at the outcrop of the ore-horizon and on the walls of the mine. The most common are johannite, sippeite, and uranopilite.

The primary ore minerals of copper are the sulfides: Chalcopyrite, chalcocite, and bornite. These, like uraninite, replace fossil wood and cement the sand grains. Secondary copper minerals include antlerite, covellite, brochantite, chalcantite, azurite, and malachite. Gruner's compilation of 1952, given here as table 1, is a complete list of minerals at the Happy Jack mine.

TABLE 1. - List of minerals from the Happy Jack mine as reported
by John Gruner, et al, 1952

Uraninite (UO_2 , UO_3)
 Zippeite (hydrous uranium sulfate)
 Uranopilite ($\text{CaO} \cdot 8 \text{UO}_3 \cdot 2\text{SO}_3 \cdot 25 \text{H}_2\text{O}$)
 Johannite (Cu, Fe, Na_2) $0 \cdot \text{UO}_3 \cdot \text{SO}_3 \cdot 4\text{H}_2\text{O}$)
 Metazeunerite ($\text{Cu (UO}_2)_2 \text{As}_2\text{O}_8 \cdot \text{X H}_2\text{O}$)
 Torbernite ($\text{Cu (UO}_2)_2 \text{P}_2\text{O}_8 \cdot 8\text{H}_2\text{O}$)
 Schoepite ($\text{UO}_3 \cdot 2\text{H}_2\text{O}$)
 Chalcocite (Cu_2S)
 Chalcopyrite (Cu Fe S_2)
 Covellite (CuS)
 Bornite ($\text{Cu}_5 \text{FeS}_4$)
 Antlerite ($\text{CuSO}_4 \cdot 2\text{Cu (OH)}_2$)
 Chalcanthite ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$)
 Brochantite ($\text{Cu SO}_4 \cdot 3\text{Cu (OH)}_2$)
 Azurite ($2 \text{CuCO}_3 \cdot \text{Cu(OH)}_2$)
 Malachite ($\text{CuCO}_3 \cdot \text{Cu(OH)}_2$)
 Pyrite (Fe S_2)
 Sphalerite (ZnS)
 Gersdorffite (NiAsS)
 Goethite (FeO(OH))
 Siderotil ($\text{Fe SO}_4 \cdot 5\text{H}_2\text{O}$)
 Erythrite ($\text{Co}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$)
 Ilsemanite ($\text{Mo(SO}_4)_4$)

TABLE 1. - List of minerals from the Happy Jack mine (cont'd)

Barite (BaSO_4)

Gypsum (CaSO_4)

Jarosite ($\text{K}_2\text{Fe}_6(\text{OH})_2(\text{SO}_4)_4$)

Cyanotrichite ($4\text{CuO}, \text{Al}_2\text{O}_3, \text{SO}_3, 8\text{H}_2\text{O}$)

Sulfur (S)

$(\text{Co}, \text{Fe})\text{SO}_4 \cdot 4\text{H}_2\text{O}$ not described before

$(\text{Mg SO}_4 \cdot 6\text{H}_2\text{O})$ not described before

The ore textures of the Happy Jack deposit are of two types: (1) replacement and (2) exsolution. The following discussion is based on a study of 30 polished surfaces and 6 thin sections.

Replacement Textures

Organic Matter

The most common and obvious replacement texture within the deposit is that of uraninite and chalcopyrite replacing wood cell structure (pl. I-A). Uraninite usually replaces the cell walls and chalcopyrite occupies the central portion of the cell. The reverse situation, that of uraninite in the center and chalcopyrite in the walls of the cell, is not common. The cell border contact of uraninite and chalcopyrite is severely etched, but due to the primary structure of the wood, it is not possible to judge the time relationship between the two minerals.

Uraninite, in the absence of chalcopyrite, completely replaces the cell structure. Where this occurs the cell form is not as easily identified.

Bornite also replaces organic matter (pl. I-B). Here it is shown in two forms: (1) in replacement of cells, (2) in complete replacement of sandstone or complete replacement of wood without the pseudomorphic texture of wood.

Pyrite, chalcopyrite, and chalcocite have formed crystalline haloes of dipyrmaid form within the cell (pl. II-A). The extreme case is the following sequence in dipyrmaid form within the cell structure: first chalcopyrite surrounded by chalcocite, then pyrite, chalcocite again and finally chalcopyrite. Chalcopyrite was formed first with each succeeding ring formed later.

Chalcopyrite After Pyrite

The complete replacement of pyrite by chalcopyrite is common throughout the deposit (pl. II-B). The relic structure is always a cubic pseudomorph.

Replacement of Quartz and Microcline

Quartz and microcline were readily etched by the ore minerals (pl. III, A and B). It is not likely that some previous mineral etched the quartz, as quartz is not replaced where it is not in contact with the ore minerals. Microcline is replaced predominantly along cleavage planes, but is not so susceptible to replacement as quartz.

Quartz overgrowths on quartz grains are common in the Shinarump conglomerate in the White Canyon area. These secondary overgrowths in specimens from the Happy Jack mine have been locally replaced by uraninite and the copper sulfides (pl. IV-A). Etching of the secondary overgrowth is usually no more intense than that of the original quartz grain.

Replacement of the Clay Cement

The clay cement is replaced more completely than quartz, though not as extensively as organic matter (pl. IV-A). The adhesion between the replaced clay cement and the quartz is relatively strong--adequate for thin or polished sections.

Irregular Border of Uraninite and the Copper Sulfides

The contact between uraninite and chalcocite, chalcopyrite and covellite is always irregular (pl. V-A). This intergrowth structure does not exist between uraninite and bornite, since chalcocite, chalcopyrite or covellite is always between the two minerals. Covellite also forms alteration or reaction rims between bornite and uraninite (pl. V-A). This occurrence has also been reported by Rosenzweig and Gruner (1952). 2/

Replacement in Fractures

Uraninite has not been observed within fractures except as replacement of probable shrinkage cracks in chalcopyrite (pl. V-B). Chalcopyrite very rarely replaces cracks in quartz grains (pl. VI-A) and seldom replaces fractures in mudstone and well cemented sandstone (pl. VI-B).

Covellite replaces fractures in chalcopyrite, bornite, chalcocite and uraninite (pl. VII-A).

Exsolution

Chalcopyrite and bornite, where found together, are always in a grating pattern, bornite being the included mineral (pl. VII-A). This is apparently an exsolution texture, as described by Schwartz (1931), 10/ Edwards (1947), 11/ and Bastin (1950) 12/. The texture has the following exsolution features: (1) chalcopyrite blade-like inclusions with no enlargement where the blades cross or join, (2) the boundaries of the inclusions are sharp, (3) bornite, the included mineral, is absent outside the intergrowths and occurs as disconnected units inside the intergrowth area.

Schwartz induced this texture in chalcopyrite-bornite ore from Globe, Arizona, by artificial heating and quenching at a minimum temperature of 475° C. 10/ The significance of this temperature is uncertain as this was primarily a heating experiment. Pressure and the chemistry of the Happy Jack ore solutions may well have had a temperature lowering effect for the precipitation of uranium oxide.

Time Relationship Between Minerals

Due to the intergrowth of minerals, the replacement and the exsolution relationships, it is apparent that there is no orderly sequence of mineralization for the ore minerals.

Certainly the ore minerals are later than the quartz cement and quartz overgrowths, and covellite is later than any of the ore minerals. There is a suggestion that uraninite may be later than chalcopyrite, bornite, and chalcocite; as there are some cross-cutting relationships and uraninite in many cases encloses chalcopyrite.

The lack of a clear time sequence of mineral growth suggests a simultaneous deposition of the ore minerals.

Alteration

Alteration is not present in the Happy Jack deposit except as local bleaching of the red sediments to green. The lack of argillization and sericitization of the feldspars is conspicuous along with the absence of calcium carbonate and silicification (excluding secondary quartz growth). The red coloration which is common to hydrothermal uraninite deposits elsewhere in North America (Kerr, 1950) is lacking. 13/ This lack of alteration points to deposition of the minerals from a low temperature solution. It is evident, however, that the host rock consisting of quartz, siliceous cement, and microcline is not susceptible to alteration even at the temperature of 475° C. mentioned above in exsolution. More polish surface work may solve the high or low temperature problem.

INTRA-CHANNEL ORE CONTROLS

All of the uranium ore in the White Canyon area is confined to Shinarump-filled paleostream channels. Some of these channels have been traced for 15 miles, but the ore bodies within them are not continuous. There must be intra-channel features which control ore deposition and produce deposits such as the Happy Jack. This uranium deposit is located on the downstream edge of a large alluvial fan. It is believed that the current and sedimentation peculiar to this position on the alluvial fan produced intra-channel features favorable for ore deposition.

Organic Matter

In the Shinarump conglomerates, carbonaceous debris is readily seen but is very difficult to map by quantitative methods. An examination of drift walls in the Happy Jack mine (fig. 7, DD', HH', fig. 8, NN', PP') reveals an abundance of carbonaceous plant debris (ferns, twigs, and logs) within the ore shoots. A small amount of low rank coal is present. All of the sandstones associated with ore bodies have a high percentage of organic matter which is in part or completely replaced by uranium and copper sulfides. All organic material, however, is not associated with an ore body. It would be illogical to assume that the ore solutions penetrated all portions of the deposit. It is certain, however, that carbonized wood tissue, and presumably other carbonaceous fragments which are at a maximum in the ore shoots, contain the reducing agents necessary to precipitate uranium and copper. In this and other regions, concentrations of carbonaceous material have served as leads to ore.

Lithologic Controls

The Happy Jack channel deposit is unique among the other channel deposits in the White Canyon area; intertonguing of sandstone and mudstone on a large scale produced favorable traps for the deposition of ore. Scour and fill sedimentation created a large number of bedding planes which were channelways for solutions. Where conditions of impermeability exist, as in tightly cemented sandstones and mudstones, there is no ore (fig. 8, QQ'). The lithologic controls considered here are: (1) bedding planes; (2) petrological traps; (3) intra-channel scours; and (4) basal Shinarump mudstone.

Bedding Planes

Ore is distributed in large quantities along bedding planes. It takes the form of massive tabular uraninite, as much as two inches thick, and bands of disseminated uraninite, ranging in thickness from one to twelve inches (pl. VIII-B). The copper sulfides form massive laminae up to 3 inches thick and also form disseminations throughout the sandstone bed.

Specimens taken from bedding planes display some cell structure indicating that here, too, organic matter played an important role in the precipitation of ore.

Bedding plane ore shoots can be traced for short distances (fig. 7, DD'); however, an attempt to correlate these planes from drill hole logs has proven unsuccessful.

Petrological traps: An interesting and local phenomena in the Happy Jack channel is the presence of the high-grade ore in a porous carbonaceous sandstone which is a wedge in an impervious mudstone (fig. 8, HH'). These ore shoots appear to have no relationship to the present regional dip. This circumstance may be an indication of movement of ore solution under pressure that involved either artesian circulation of ground water or hypogene solutions.

Intra-channel scours: Scours into the Shinarump mudstone are filled with a coarse carbonaceous sandstone, unit 1, which in many places carries high-grade uranium mineralization (fig. 7, GG'). It is possible to correlate this feature for distances through the deposit by the aid of a fence diagram (fig. 9). The porous sandstone within the scour may have acted as a pipe through the mudstone for the ore solutions.

Basal Shinarump Mudstone: The workings on the east side of the Happy Jack mine have a floor of Shinarump mudstone overlain by sandstone; on the west side of the mine, the Shinarump sandstone rests directly on the Moenkopi formation (fig. 10). The rich ore shoots are confined to the sandstone which rests on Shinarump mudstone, whereas the sandstone which rests directly on the Moenkopi is lacking in high grade ore. Two explanations are offered for this phenomenon: (1) the mudstone provided an impermeable floor for the solutions; or (2) the mudstone contains an abundance of organic flakes which during the petrification produced enough uranyl reducing gases to precipitate the uranium from the ore solutions in the overlying sandstone.

This mudstone unit can be traced for some distance (figs. 9 and 10) and a logical prediction of its location can be made.

There is a strong possibility that Shinarump sandstone lies beneath the mudstone floor on the east side of the Happy Jack mine (fig. 7, cross section DD' in the vicinity of sp. 27). It is possible that more ore exists in this locality under the floor.

Channel Lows

The Happy Jack channel system has intra-channel "lows" as deep as 40 feet (fig. 5). The richest ore in each channel is within these "lows". The ore may persist between the "lows" but becomes quite thin. These "lows" are filled with the three lithologic units of the Shinarump conglomerate; the basal unit is usually absent on the "highs". The inter-tonguing of these units in the "lows" has produced favorable sedimentary structures for the concentration of ore.

Figure 7. Cross sections AA' - GG' of Happy Jack mine, White Canyon, Utah

Figure 8. Cross sections HH' - VV' of Happy Jack mine, White Canyon, Utah

Figure 9
Fence diagram, Happy Jack mine, White Canyon, Utah

Figure 10
Lower Shinarump mudstone map, Happy Jack mine, White Canyon, Utah

Fractures

Three types of fractures are present in the Happy Jack mine: (1) joints, (2) small faults (displacement 1-foot) caused by regional tension, (3) minor faults that are the result of pene-contemporaneous compaction. There is no primary uranium mineralization associated with any of these.

Many geologists (oral communication with Plateau geologists) believe that regional stress produced local zones of shear which fractured the quartz grains, and increased the porosity of the sandstone. This theory has no relation to facts. The quartz grains in the primary ore at Happy Jack show no uranium in fractures; they show instead an interstitial replacement of the grains and their cement. It is common in the area for the secondary minerals of uranium, which form near the surface, to lie along joint surfaces and even fractures within the grains (pl. VIII-A). This is to be expected where the erosion of the overburden has released the pressure allowing open spaces to form both in the sandstone units and quartz grains. Ground water dissolves the uraninite and re-precipitates it in open spaces, usually as a sulfate.

CONCLUSIONS

There are several theories on the occurrence of uranium in the Happy Jack area which have substantial proof:

1. All of the uranium ore is confined to a Shinarump stream channel.
2. The ore within the channel is largely controlled by organic matter, lithologic features, and channel lows. Most of these controls can be mapped and with their aid favorable ore-ground may be predicted beyond the outcrop and beyond the mine heading.
3. The ore, from evidence gathered, is not the result of syngenetic activity. It replaces the cement of the sandstone and the secondary growth on quartz grains.
4. Structures of tectonic origin appear to have been unimportant in the localizing of ore bodies.
5. There is no alteration of the minerals within the deposit.
6. The Happy Jack mine is a replacement ore deposit.

Not enough evidence has been assembled in this paper to contribute any new ideas on genesis of the Happy Jack ore deposit. It is clear, however, that the deposit is of epigenetic origin.

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Plate I-A. Filling of wood cells by chalcopyrite.
 Uraninite surrounds the chalcopyrite and
 largely replaces the cell walls.
 Polished section of specimen No. 3. 400x

Plate I-B. Filling of wood cells by bornite. Note
 also massive bornite. Chalcocite replaced
 cell walls.
 Polished section of specimen No. 19A. 100x

Plate II-A. Crystalline halos of chalcocite, pyrite,
and chalcopyrite within a wood cell.
Polished section of specimen No. 27. 1940x

Plate II-B. Psuedomorph of chalcopyrite after pyrite.
Polished section of specimen No. 20. 100x

Plate III-A. Replacement of quartz by uraninite.
Polished section of specimen No. 19. 100x

Plate III-B. Replacement of microcline along cleavage
planes by chalcopryrite and uraninite. Thin
section of specimen No. 3. 200x

Plate IV-A. Intergrowth of uraninite and chalcopyrite. Note dark alteration rim of covellite encircling the chalcopyrite and bornite grain. Polished section of specimen No. 18. 100x

Plate IV-B. Uraninite cross cutting chalcopyrite and bornite. Note exsolution texture in bornite. Polished section of specimen No. 18. 400x

Plate V-A. Replacement of a fracture in quartz by chalcopyrite. Polished section of specimen No. 15. 100x

Plate V-B. Replacement of a fracture in mudstone by chalcopyrite. Note grain of uraninite outside fracture. Polished section of specimen No. 17. 28x

Plate VI-A. Replacement of quartz overgrowth by chalcopryrite and uraninite. Thin section of specimen No. 8. 200x

Plate VI-B. Replacement of mudstone by chalcopryrite and uraninite. Thin section of specimen No. 9. 200x

Plate VII-A. Replacement of a fracture in chalcopyrite by covellite. Polished section of specimen No. 19. 100x

Plate VII-B. Exsolution texture of chalcopyrite and bornite. Polished section of specimen No. 18. 1940x oil immersion

Plate VIII-A. Brochantite within fractures in quartz.
Thin section from North Point No. 6. 100x

Plate VIII-B. Band of uraninite mixed with copper sulfides
1-foot thick along a bedding plane. Note
how ore fills cross beds.

chn = chalcantite	cc = chalcocite
up = uranopilite	bo = bornite
u = uraninite	py = pyrite
cp = chalcopyrite	zp = zippeite