DEPARTMENT OF THE INTERIOR

U. S. GEOLOGICAL SURVEY

The production history and geology of the Hacks, Ridenour, Riverview and Chapel breccia pipes, northwestern Arizona

BY

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THE PRODUCTION HISTORY AND GEOLOGY OF THE HACKS, RIDENOUR, RIVERVIEW, AND CHAPEL BRECCIA PIPES, NORTHWESTERN ARIZONA

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Abstract

During the uranium boom of the 1950's, prospectors located uranium in numerous old copper mines and prospects in Paleozoic rocks of the Grand Canyon region of northwestern Arizona. Most of these copper occurrences were later determined by geologists to be in collapse-breccia pipes. Similar radioactive pipe structures were located east of the Grand Canyon near Cameron, Arizona in Mesozoic and Paleozoic rocks.

The pipes are roughly circular in plan and contain sedimentary rocks that have been down dropped into the pipe, creating breccias. The ring fracture shear zone of the pipes is the favored site for mineral deposition. The pipes extend upward from the Mississippian Redwall Limestone to the Triassic Chinle Formation. Five separate properties, Hacks, Ridenour, Riverview, Chapel, and the Orphan Lode, produced uranium during the purchase program of the U.S. Atomic Energy Commission in the 1950's and 1960's. With the exception of the Orphan Lode, the properties are described in this report. Ore production from each of the four properties ranged from 5 to nearly 5,000 pounds uranium oxide (U_3O_8). In addition to the uranium, some copper and vanadium were produced. The upper portions of the pipes are highly oxidized and the mineralogy is complex. In addition to uranium, all of the pipes are enriched in copper, and others have significant amounts of vanadium and silver. Due to past exploration, the potential for additional ore to be discovered in these four pipes is regarded as very low.

Introduction

The Grand Canyon region of northwestern Arizona is host to thousands of breccia pipes. These are not classic breccia pipes in that there are no volcanic rocks associated with them; instead, they are the result of solution collapse within the Redwall Limestone and the stoping of the overlying strata (Wenrich, 1985). The pipes are roughly circular in plan, and contain sedimentary rocks that have been dropped downward into the pipe, creating breccias. Surrounding the pipes are ring-fracture zones which separate the breccias from the flat-lying wall rocks. The pipes extend upward from the Mississippian Redwall Limestone to the Triassic Chinle Formation (fig. 1).

Several of the pipes were mined for copper and silver during the nineteenth century. During the uranium boom of the 1950's most of the copper-bearing pipes were found to contain uranium, and ore was produced at five separate pipes. These were the Hacks, Ridenour, Orphan Lode, Riverview, and Chapel pipes (fig. 2). Since the late 1970's there has been a renewed interest in

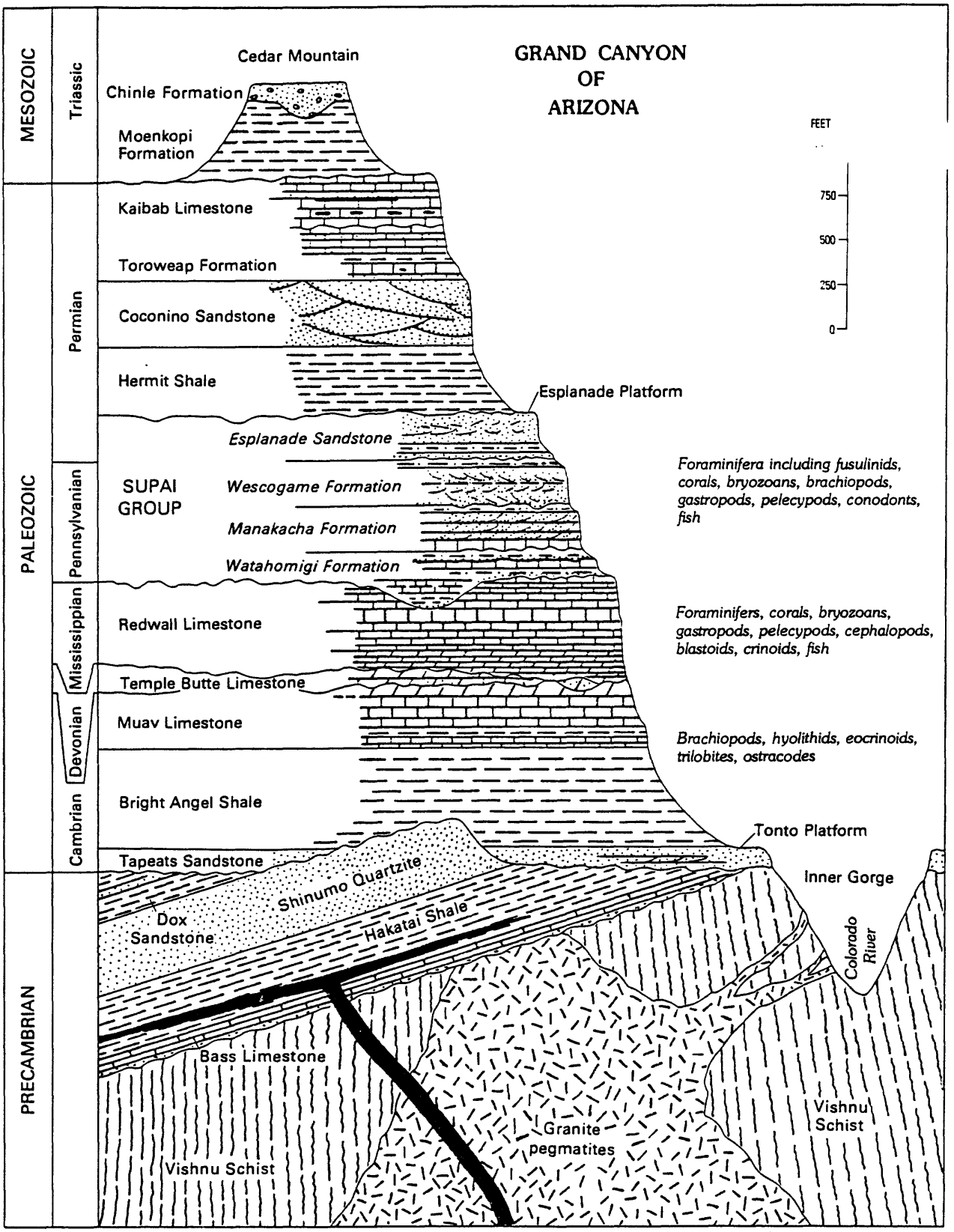

Figure 1. Geologic section, Grand Canyon, Arizona (from McKee, 1982)

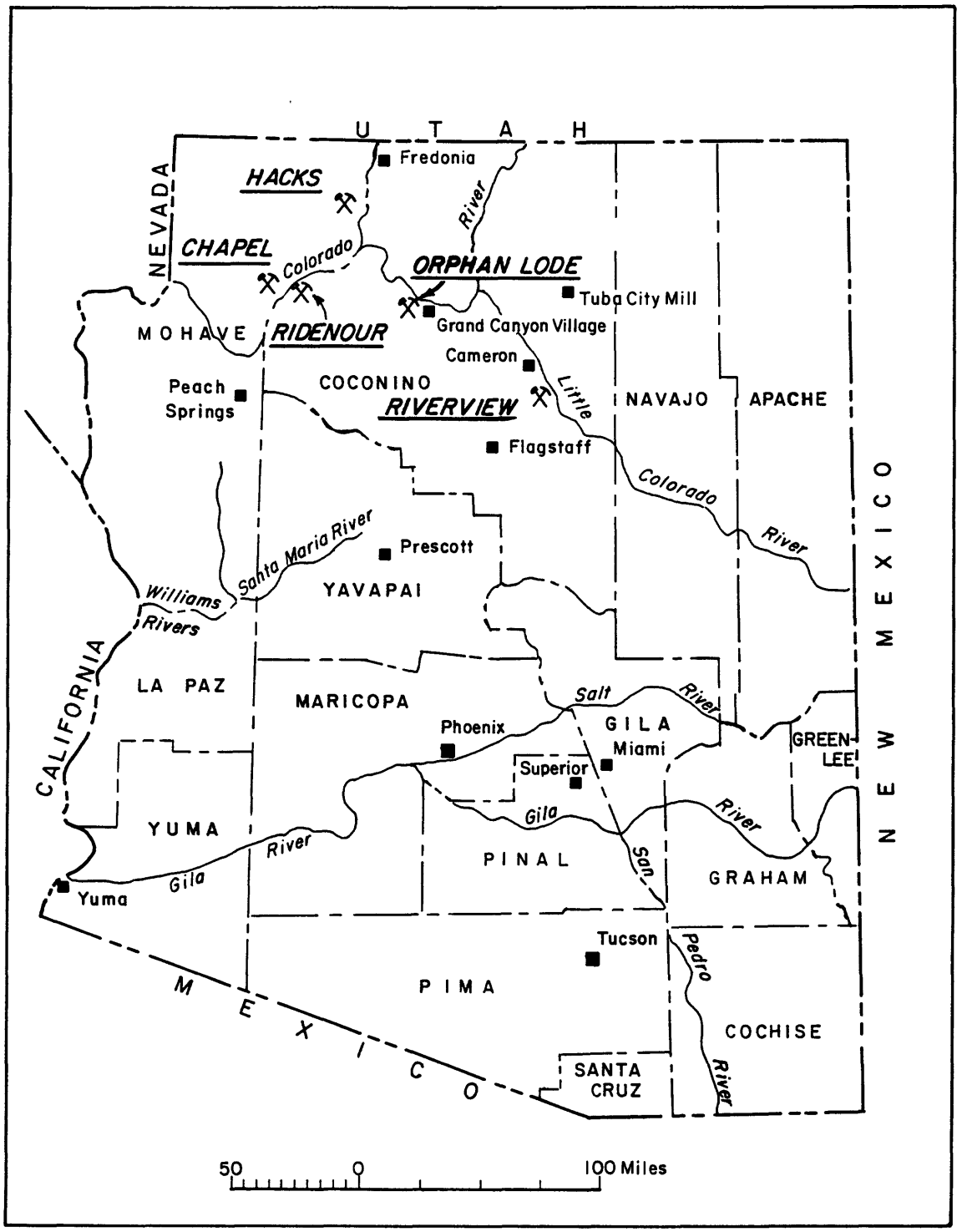

Figure 2. Index map of Arizona showing locations of Orphan Lode, Hacks, Ridenour, Riverview, and Chapel breccia pipes

the breccia pipes of the Grand Canyon region. The high-grade (greater than 0.60 percent U_3O_8) nature of these deposits has made them attractive exploration targets in the currently depressed uranium market (1988). Many additional ore-bearing pipes have been located, developed, and mined. An excellent summary of the mineralized breccia pipes is given by Wenrich (1985). The present report is a summary of the early production history and geologic setting of four of the early uranium producers. The other deposit, the Orphan Lode Mine, is the subject of a separate report (Chenoweth, 1986). The post-1970 uranium exploration activities in the general area of these properties is beyond the scope of this report.

Scope and Purpose

While I was a geologist with the U.S. Atomic Energy Commission (AEC), considerable time in the late 1950's and 1960's was spent examining uranium mines in Arizona for ore reserve calculations and production capability studies. This report is a summary of my observations of breccia pipe deposits during that time.

My field notes and internal AEC trip reports, and those of my co-workers, especially the late Ben Bowyer, have been drawn upon heavily to complete this summary. Geochemical analyses and mineral identifications of samples collected by the Department of Energy's contractors and the U.S. Geological Survey in the late 1970's and early 1980's are also included.

Acknowledgements

Several organizations have been extremely helpful in locating information on the breccia pipe deposits. The assistance of Larry D. Fellows, and John W. Welty, Arizona Geological Survey; Ken A. Phillips, Arizona Department of Mines and Mineral Resources; Larry M. Fukui, UNC Geotech, Inc.; and Leo E. Little, U.S. Department of Energy is gratefully acknowledged.

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A critical review of the manuscript by Karen J. Wenrich, and George H. Billingsley and Alfred L. Bush greatly improved it. Drafting by J.R. Kosta is also acknowledged. This project was supported by the U.S. Geological Survey's research work on breccia pipes of northern Arizona, with funds provided by the Bureau of Indian Affairs in cooperation with the Hualapai Tribe.

Exploration and Mining History

The breccia pipes of the Grand Canyon region were prospected and mined during the nineteenth century, primarily for copper. During the two World Wars, the need for copper renewed mining for a short period of time. The uranium needs of the U.S. Atomic

Energy Commission, after World War II, created a massive search for that metal and during the late 1940's and early 1950's, uranium was identified at most of the copper-bearing pipes as well as at pipes in the Cameron, Arizona area.

During the uranium boom of the 1950's the uranium-bearing pipes were regarded as geological curiosities rather than potential ore deposits. Small mining companies and prospectors could not raise the necessary capital to develop the deposits. The larger mining companies were more interested in exploring the Triassic Chinle and Jurassic Morrison Formations on the Colorado Plateau which were proven hosts for multi-million ton uranium deposits. Furthermore, the geologic nature and the ore potential of the pipes were not fully recognized until the development of the Orphan Lode Mine in the late 1950's (Chenoweth, 1986). Five pipes in Coconino and Mohave Counties, Arizona, produced uranium during the AEC program (table 1) (See the summary of the AEC program on page 6). They are the Hacks, Chapel, Orphan Lode, Riverview, and Ridenour. The Nuclear Exchange Corporation (1978) reported that the Copper Mountain pipe in Mohave County produced 75 pounds U_3O_8 in the 1950's, but no record of this production could be located in the AEC files. It is assumed that they confused a mine in the Owl Creek Mountains, Fremont County, Wyoming with a copper-bearing pipe in Parashant Canyon, Arizona.

Table 1, Uranium production from breccia pipes, northwestern Arizona, 1950's - 1960's

PROPERTY	YEAR(S) OF PRODUCTION	ORE (TONS)	U_3O_8 (%)	U_3O_8 POUNDS
Hack Canyon	1951-1954,1964	1,375.94	0.18	4,993.14
Chapel	1954	1.08	0.23	4.96
Riverview	1956-1957	508.41	0.38	3,839.15
Orphan Lode	1956-1969	495,106.63	0.43	4,266,264.47
Ridenour	1961	14.14	0.15	42.05
		497,006.20	0.43	4,275,143.77

Source: U.S. Atomic Energy Commission files
Grand Junction, Colorado Office

In the early 1970's, Western Nuclear, Inc. recognized the uranium potential of pipes of the Grand Canyon region, and began a program of geologic exploration and land acquisition. Energy Fuels Nuclear, Inc. acquired Western Nuclear's holdings in 1979 and began ore production in 1980 from another pipe (Hack 1 Mine) in Hack Canyon. Today, the breccia pipes around the Grand Canyon are the targets of extensive exploration. These small, but extremely high grade deposits, are very attractive in the currently depressed uranium market.

It is not the purpose of this paper to describe these recent developments, but only to document the early activities at the pipes that produced ore under the procurement program of the Atomic Energy Commission.

Summary of the AEC's Raw Materials Programs

Because the early exploration and the development of the breccia pipes was influenced by the programs and policies of the U.S. Atomic Energy Commission, a brief summary of the Commission's raw materials programs is presented here.

The AEC was created on January 1, 1947 to continue the secret wartime work on atomic weapons started by the Manhattan Engineer District of the Army's Corps of Engineers.

During the period 1947-1970, the AEC purchased uranium concentrate from private companies primarily for use in military weapons programs. Prior to April 1, 1962, the AEC also purchased uranium ores and guaranteed the prices to be paid by the milling companies for ores as an incentive to the uranium mining industry to provide feed for the processing mills. The prices the AEC paid for uranium concentrate were negotiated independently with each milling company (Albrethsen and McGinley, 1982).

In the beginning of the AEC program, ore producers were paid for their ores under the terms of the AEC's Circular 5, Revised. This schedule contained a base price of \$3.50 per pound of U_3O_8 for ores containing 0.20 percent U_3O_8 or greater. Ores containing less than 0.20 percent U_3O_8 received a base price grading down to \$1.50 per pound of U_3O_8 in ores containing the minimum acceptable grade of 0.10 percent U_3O_8. All ores received a mine development allowance of \$0.50 per pound, and ores containing 0.21 percent U_3O_8 and better received a \$0.75 per pound grade premium. Vanadium-bearing ores received \$0.31 per pound of V_2O_5 for their vanadium content. The AEC also paid \$0.06 per ton-mile haulage allowance for the first 100 miles. A bonus of \$35,000 was paid on the first 10,000 pounds U_3O_8 delivered from new discoveries (Albrethsen and McGinley, 1982). Buying stations were set up in areas where there were no mills or where mills were being built. The copper content of uranium ores was also purchased at the Marysvale and Monticello, Utah stations (U.S. Atomic Energy Commission, 1951).

These programs created a massive prospecting effort unsurpassed in any other metal. Exploration spread from the Colorado Plateau region to the entire western United States and, to a minor extent, into the eastern states.

On May 24, 1956, the AEC announced the establishment of a new domestic uranium procurement program for the period April 1, 1962, through December 31, 1966. The new program guaranteed a Government market for 500 tons of U_3O_8 in concentrate per year from any one mining property or operation at a flat price of \$8 per pound. Thus, in 1956, the stage was set for a continuing AEC concentrate procurement program after March 31, 1962, with an established price for concentrates rather than for ores. The prices, premiums, and allowances paid under Circular 5, Revised, would no longer be in effect. After March 31, 1962, the AEC required that the mill operator pay "reasonable" prices.

By late 1957, dramatic increases in reported ore reserves and in milling capacity prompted an AEC announcement that "it no longer is in the interest of the Government to expand production of uranium concentrate." Then, in November 1958, in order to prevent further expansion of production under its essentially

unlimited purchase commitment, the AEC redefined its 1962-1966 procurement program by withdrawing portions of the program announced in May 1956. The Government stated it would buy, in the 1962-1966 period only "appropriate quantities of concentrate derived from ore reserves developed prior to November 24, 1958, in reliance upon the May 24, 1956, announcement." Other aspects of the program announced in 1956 were retained: The AEC would buy only concentrates; the U_3O_8 price would remain at $8 per pound; ores would not be purchased nor ore prices guaranteed. Independent producers had to negotiate ore purchase contracts with milling companies in order to sell their ores. As a result of the November 24, 1958 announcement, exploration for new uranium deposits throughout the United States had virtually ceased.

In 1962, it was apparent to the AEC that the private market for uranium concentrates would not be sufficient to sustain a viable domestic uranium industry by the end of 1966 when the AEC procurement program was scheduled to end. Thus, on November 20, 1962, the AEC announced its "stretch-out" program for 1967 through 1970. Under the program, the milling companies could voluntarily defer delivery of a portion of their 1963-1966 contract commitments until 1967 and 1968 in return for an AEC commitment to purchase, in 1969 and 1970, an additional amount of U_3O_8 equal to the quantity so deferred. The "stretch-out" program was the last of the major policy changes made in the AEC procurement program. With the exception of the Orphan Lode Mine, which did not participate in the "stretch-out" program, all production from breccia pipes had ceased by early 1964.

The AEC procurement program ended at midnight December 31, 1970. Since that time all uranium produced in the United States has been for the electric utility market for power generation, both domestic and foreign.

Description of Deposits

The following descriptions of deposits are based on information located in my personal files as well as the files of the Grand Junction Office of the Department of Energy, and in the files of various state agencies. The completeness of information varies from deposit to deposit depending on how extensive exploration and mining was. The author never examined the Chapel pipe and its description is taken from two brief AEC reconnaissance reports. Previously published and/or open-filed descriptions are listed for each deposit.

Hacks Mine

The Hacks Mine, also known as the Hack's or the Hacks Canyon Mine is located approximately 30 miles southwest of Fredonia, Arizona in Mohave County (fig. 2). In 1951 the property consisted of 14 unpatented claims which were located in the N½ of Section 26, T.37N., R.5W., Gila and Salt River, Baseline and Meridian (fig. 3). The mine is located in the bottom of Hack Canyon, a tributary to Kanab Creek, that forms the boundary between Mohave and Coconino Counties on the north side of the Grand Canyon. The elevation of the floor of the original adit is 4,280 feet. In the production records of the AEC, the property was always referred to as the Hacks Mine, hence the name used in this report.

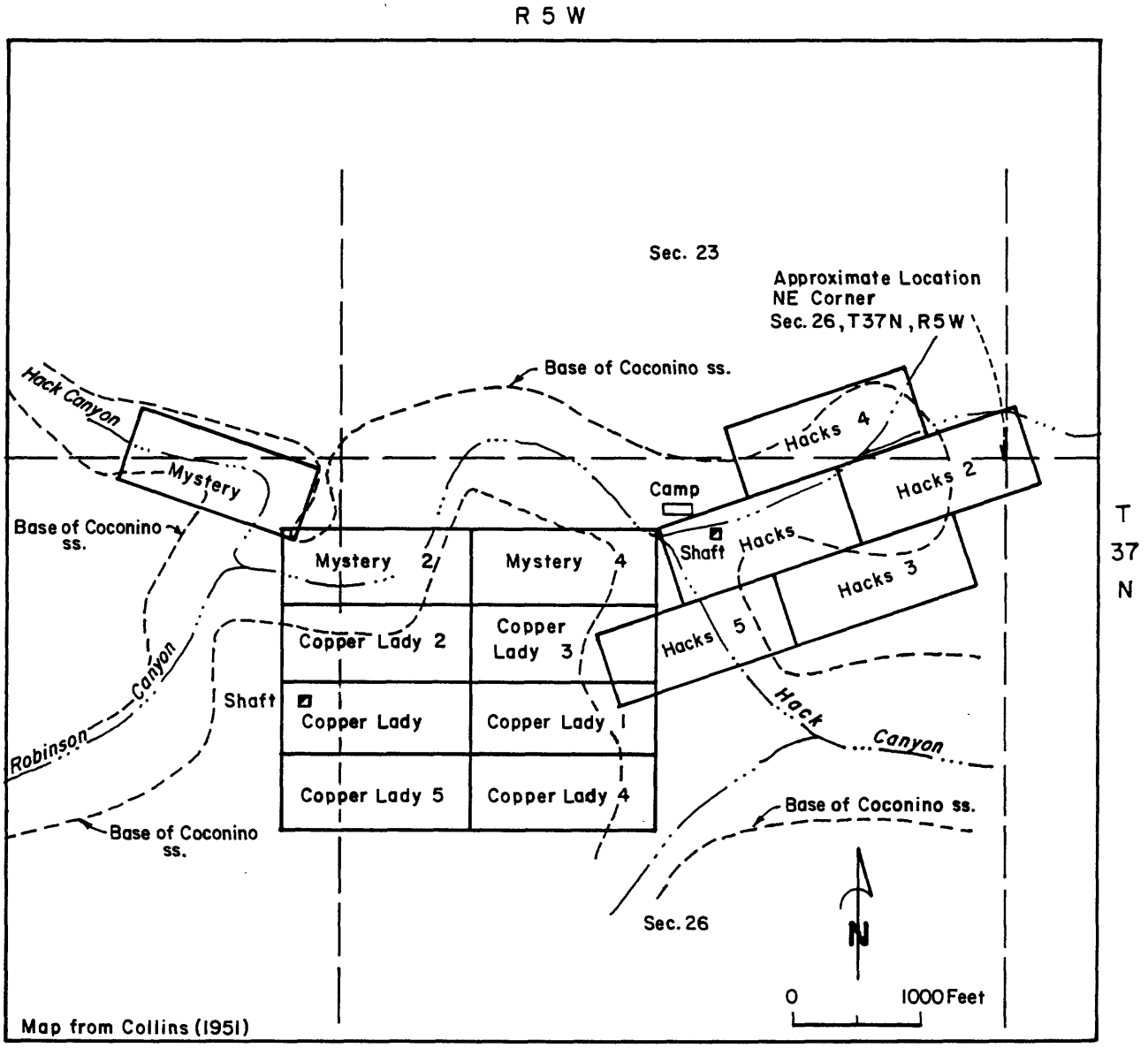


Figure 3. Location map of Hacks claims, Mohave County, Arizona

The mine site can be reached from a graded dirt road 9 miles west of Fredonia that heads southwest from Arizona Highway 389. This road provides access to the north rim of the western Grand Canyon National Park and passes near the head of Hack Canyon. A 6 mile road down the canyon provided access to the mine.

Some information on the geology of the Hacks Mine has been published and/or open filed. These include reports by Dunning (1948), Rasor (1949), Gruner and Gardner (1950a,b), Granger (1951), Chester and Cutter (1951), Granger and Raup (1962), and Granger (1970).

During World War I, copper-bearing exposures in Hack Canyon were located and prospected. There is no record of this production but it is doubtful that more than 1,000 tons of ore were produced (Dunning, 1948). The remains of an old tramway that was built down into the canyon was noted by Dunning in 1948.

The original 14 claims comprising the Hacks Mine were staked between 1937 and 1946. The Copper Lady was located on September 24, 1937, the Hacks on March 1, 1941, the Hacks No. 2 on April 12, 1941, the Hacks Nos. 3, 4 and Mystery on September 5, 1941, the Hacks No. 5 on March 16, 1943, and the Copper Lady Nos. 1-5 and the Mystery Nos. 2 and 4 were located on February 26, 1946 (Collins, 1951). The claims were located by A.F. Jensen of Fredonia, Arizona and his associates, Clair Pierson, Fredonia, Ray Pointer, Klondike, Arizona, and G.C. Harwood, Phoenix, Arizona (Collins, 1951).

During World War II the property was leased to the Canyon Copper Company. No production records were made available to Mr. Jensen, but he doubts that more than 200 tons of ore were produced (Rasor, 1949). Records published by the U.S. Bureau of Mines show that during the 1930's and 1940's the Hack Canyon Mine produced a total of 559 tons of ore containing 51,061 pounds of copper, 1,210 ounces of silver and 2 ounces of gold (table 2). The production in 1938 and 1939 may have come from the prospect on the Copper Lady Claim (fig. 3), as that claim was located in 1937 (Collins,

Table 2, Ore production, Hacks Canyon Mine, Mohave County Arizona 1938-1945, in terms of metals recovered

YEAR	ORE (TONS)	COPPER POUNDS	SILVER OUNCES	GOLD OUNCES	VALUE (DOLLARS)
1938	68	9,364	234	-	1,314
1939	1	96	3	1	47
1940	-	-	-	-	-
1941	-	-	-	-	-
1942	-	-	-	-	-
1943	226	11,400	284	1	1,719
1944	86	8,200	149	-	1,213
1945	178	22,000	540	-	3,354
TOTAL	559	51,060	1,210	2	7,647

Compiled from Miller and Luff (1939,1940), Woodard and Luff (1945, 1946) and Needham and Luff (1947).

1951). Shipments in 1943 and 1944 were sent to a smelter in the Salt Lake City area (Woodard and Luff, 1945, 1946), and the 1945 production was shipped to a smelter at Miami, Arizona (Needham and Luff, 1947).

A letter in the files of the Arizona Department of Mines and Mineral Resources indicates that on June 28, 1943, Mr. W.J. Graham of the Department wrote the War Production Board in Washington, D. C. In his letter, Graham stated that P.H. Ramsden and associates of the Copper Canyon Company had 10,000 tons of ore averaging 8.50 percent Cu at the Hacks Mine and needed capital to finance 5 1/2 miles of access road. No federal money was obtained and the company built the road themselves. (Dunning, 1948).

During the latter stages of this second copper mining operation, in 1945, a fluorescent coating was observed using a "black light" in the mine workings. A large sample of this material was brought to the Arizona Department of Mineral Resources where analysis determined it contained 1.56 percent uranium (Dunning, 1948). As there was no market for uranium at this time, the information was kept in the files.

The AEC came into being in 1947 and began an intensive uranium procurement program with guaranteed prices and other incentives for raw materials. In July 1948, Charles H. Dunning, Director of the Arizona Department of Mineral Resources, mapped and sampled the Hacks Mine and prepared a report of his investigations which he submitted to the Grand Junction, Colorado office of the AEC. When he mapped and sampled the mine, the old workings consisted of a 90 foot deep vertical shaft, a 55 foot long adit that connected to the shaft at the 31 foot level, an inclined shaft that reached the 105 level of the mine, and 400 feet of underground drifts on the 59, 69, and 105 levels. As used in this report, the various mine levels are numbered by their distance, in feet, below the collar of the shaft (fig. 4). A photograph of the Hacks Mine, as it appeared in 1948, is shown in Figure 5.

In October 1948, C.A. Rasor and Loren Warren of the Grand Junction of the AEC examined the mine and confirmed that it had production capabilities, but the lack of a nearby market would hinder development. On March 12, 1950 the AEC established an ore buying station at Marysvale, Utah to promote the development of mines in that area. Although it was 160 miles away, this was the nearest market for the Hacks Mine. A.F. Jensen and his associates began to organize a mining venture and improved the road down Hack Canyon. They began operating in May 1951, and the first shipment was received at the AEC's buying station at Marysvale, Utah on July 6, 1951. This shipment consisted of 33.05 tons of ore containing 125.58 pounds of U_3O_8, averaging 0.19% U_3O_8.

On July 13, 1951, the Hacks Mining Company was incorporated at Phoenix, Arizona. The original stockholders were A.F. Jensen 1/2 interest, Elliott Pierson 1/8 interest, Clair Pierson 1/8 interest, G.C. Harwood Trust 1/4 interest. During the period July 1951 through June 1952, the AEC purchased from Hacks Mining Company a total of 846 tons of ore averaging 0.19 percent U_3O_8 and 1.11 percent Cu. Records of the AEC also show that the 265 tons shipped in 1952 contained the average of 0.42 percent V_2O_5.

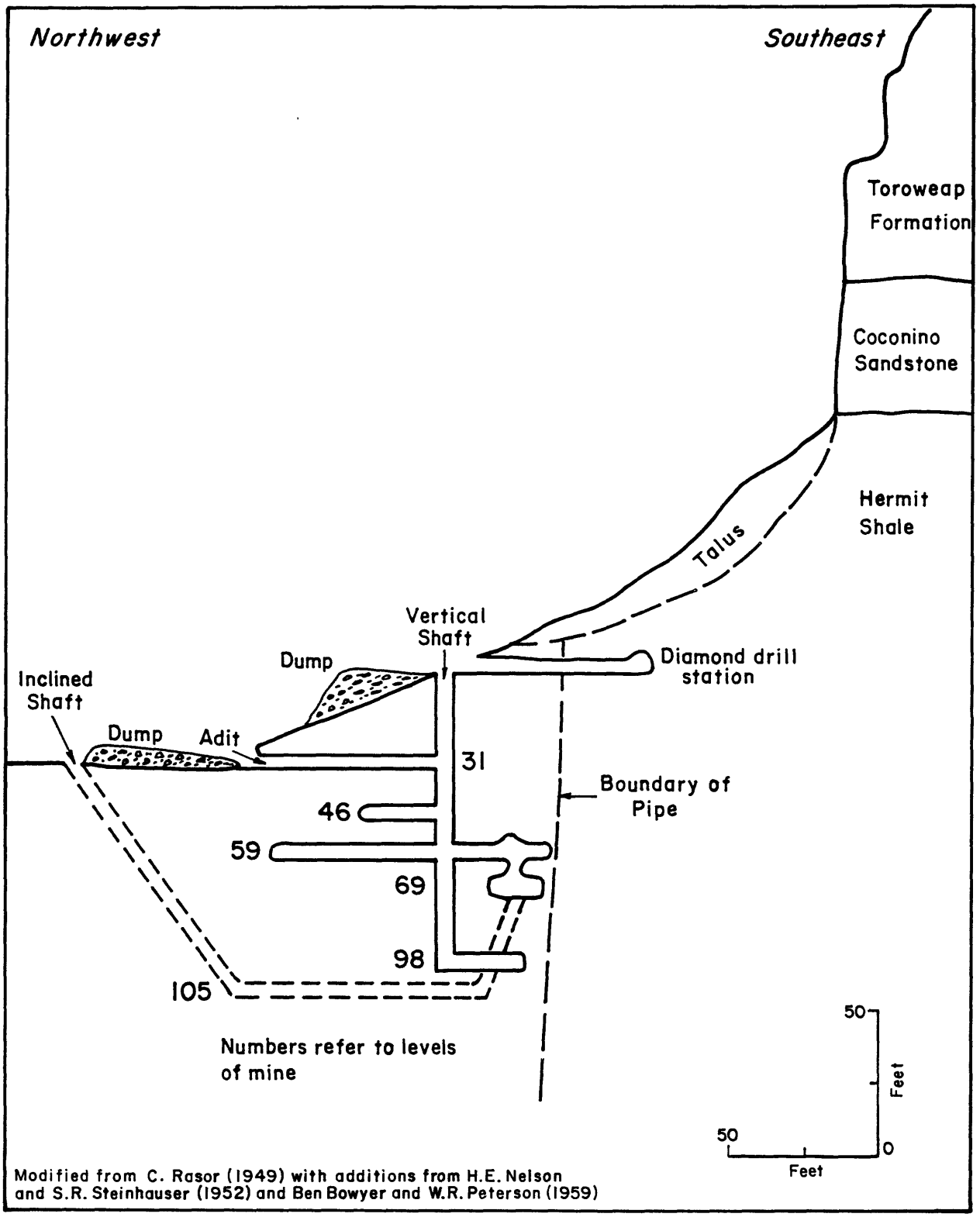


Figure 4. Generalized cross section, Hacks Mine, Mohave County, Arizona

Figure 5, Hacks Mine as it appeared in 1948 looking eastward. The collar of the vertical shaft is near the small headframe in the center. The headframe for the inclined shaft is the large structure in the left foreground. The portal of the adit is a short distance ahead of the pickup truck and men in the lower left corner. Coconino Sandstone forms the cliff at top of photo. Photo by C.H. Dunning, July 1948.

During April of 1952, Harry E. Nelson and Steve R. Steinhauser of the AEC's Richfield, Utah field office mapped and sampled the mine. A comparison of their maps (Nelson and Steinhauser, 1952) with Dunning's (1948), indicate that the Hacks Mining Company developed two new levels (46 and 98) off the vertical shaft as well as enlarging the workings on the 59 and 69 levels. A new 40 foot drift was driven into the cliff northeast of the shaft (figs. 6,7, and 8).

In 1952, the Defense Materials Procurement Agency provided $65,000 for an access road to the mine. The actual work was done by Bureau of Indian Affairs from the nearby Kaibab Indian Reservation.

California Tungsten Corporation, which later merged into Consolidated Uranium Company of Salt Lake City, leased the Hacks 1-5 claims in December 1952 for a period of 60 days. The company did some bulldozer work and drilled six diamond drill holes before forfeiting their lease in the spring of 1953. During February 1953, while the property was being explored by Consolidated Uranium, Nelson and Steinhauser made a scintillometer survey of the surface workings and probed the six drill holes (fig. 9, table 3).

Table 3 Radioactivity measurements, diamond drill holes, Hacks Mine, Mohave County, Arizona

DD HOLE NO. 2		DD HOLE NO. 4		DD HOLE NO. 6	
Depth (ft.)	Reading	Depth (ft.)	Reading	Depth (ft.)	Reading
0	5	0	40	0	4
5	5	5	90	5	15
10	20	6	90	10	10
15	30	7	96	15	15
20	30	8	30	20	20
25	20	9	20	25	30
30	35	10	16	30	24
35	30	15	25	35	25
40	15	20	10	40	30
45	10	25	5	45	20
50-110	0-4	30	5	50	20
		35-60	2-4	60	8
				65	5
				70	10
				75	50
DD Holes No.'s 1, 3, and 5 contained no radioactivity				80	12
				81	15
				82	25
				83	55
Measurements made with portable hole logging unit TW-2 May 19,1953. All readings are on No. 4 scale. Background count equals 4.				84	60
				85	60
				86	48
				87	80
				90	45
AEC after Nelson and Steinhauser, 1953.				92	55
				95	30
				100	30
				105	4
				110-135	0-4

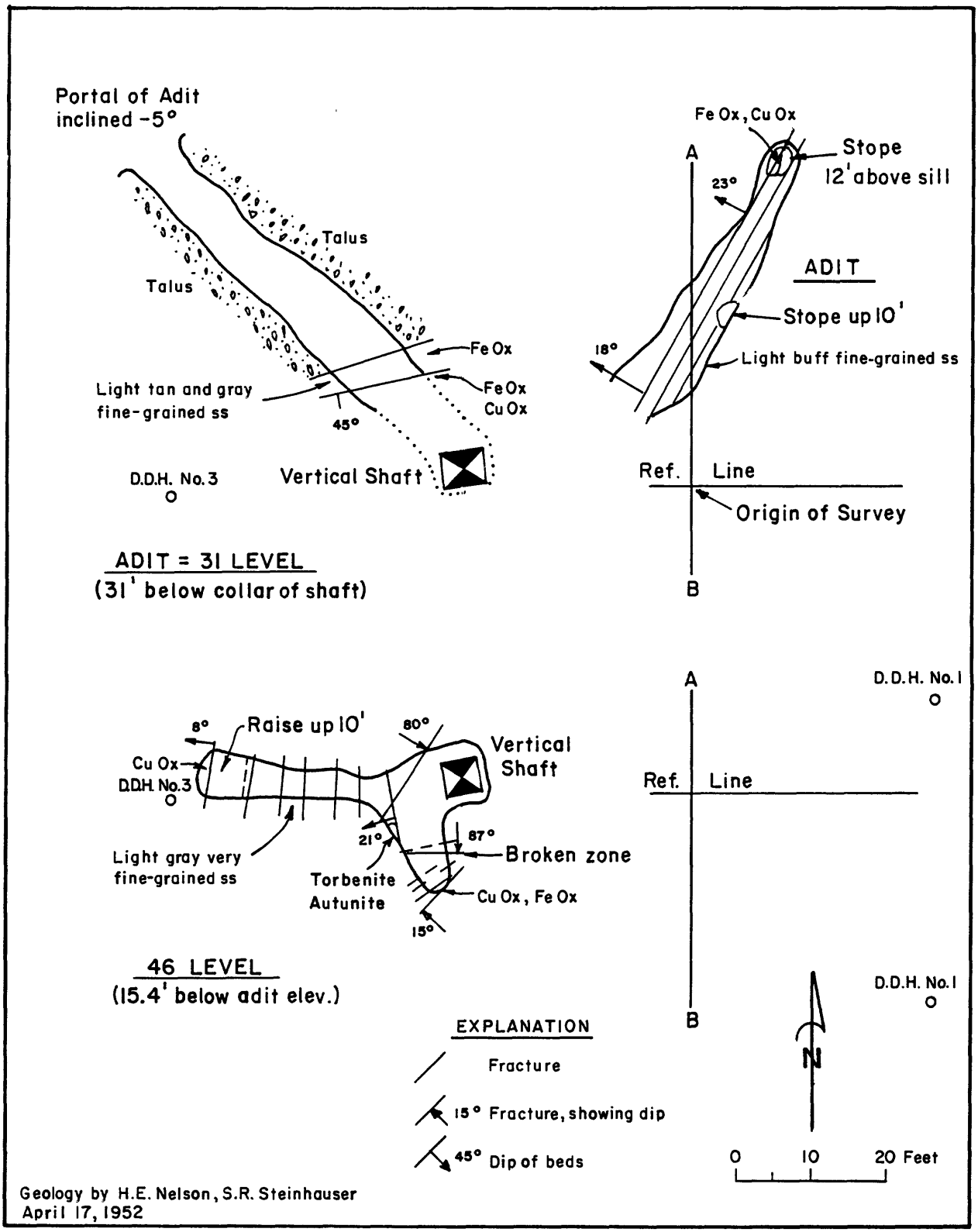


Figure 6. Geologic maps of the 31 and 46 Levels, Hacks Mine, Mohave County, Arizona (after Nelson and Steinhauser, 1952)

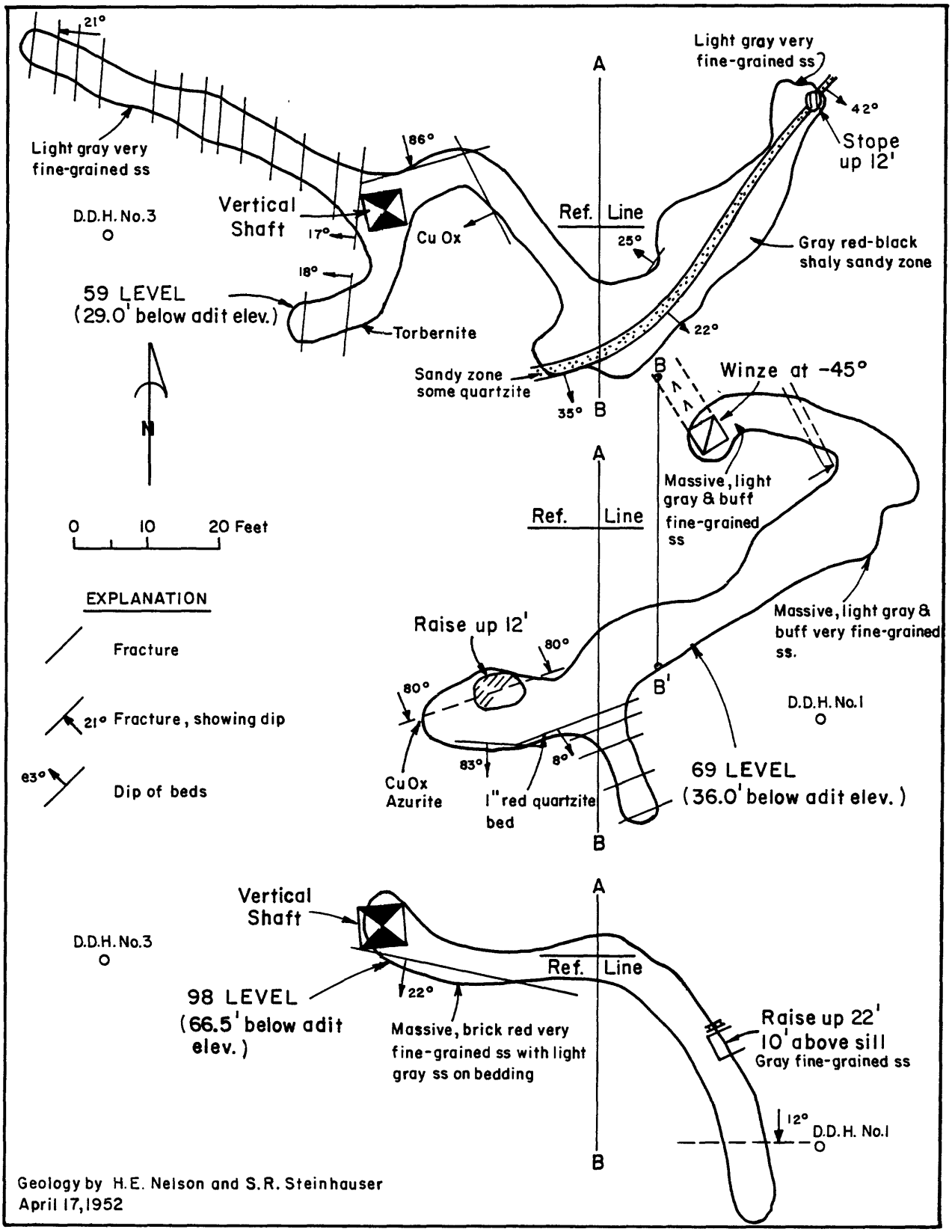


Figure 7. Geologic maps of the 59, 69 and 98 Levels, Hacks Mine, Mohave County, Arizona (after Nelson and Steinhauser, 1952)

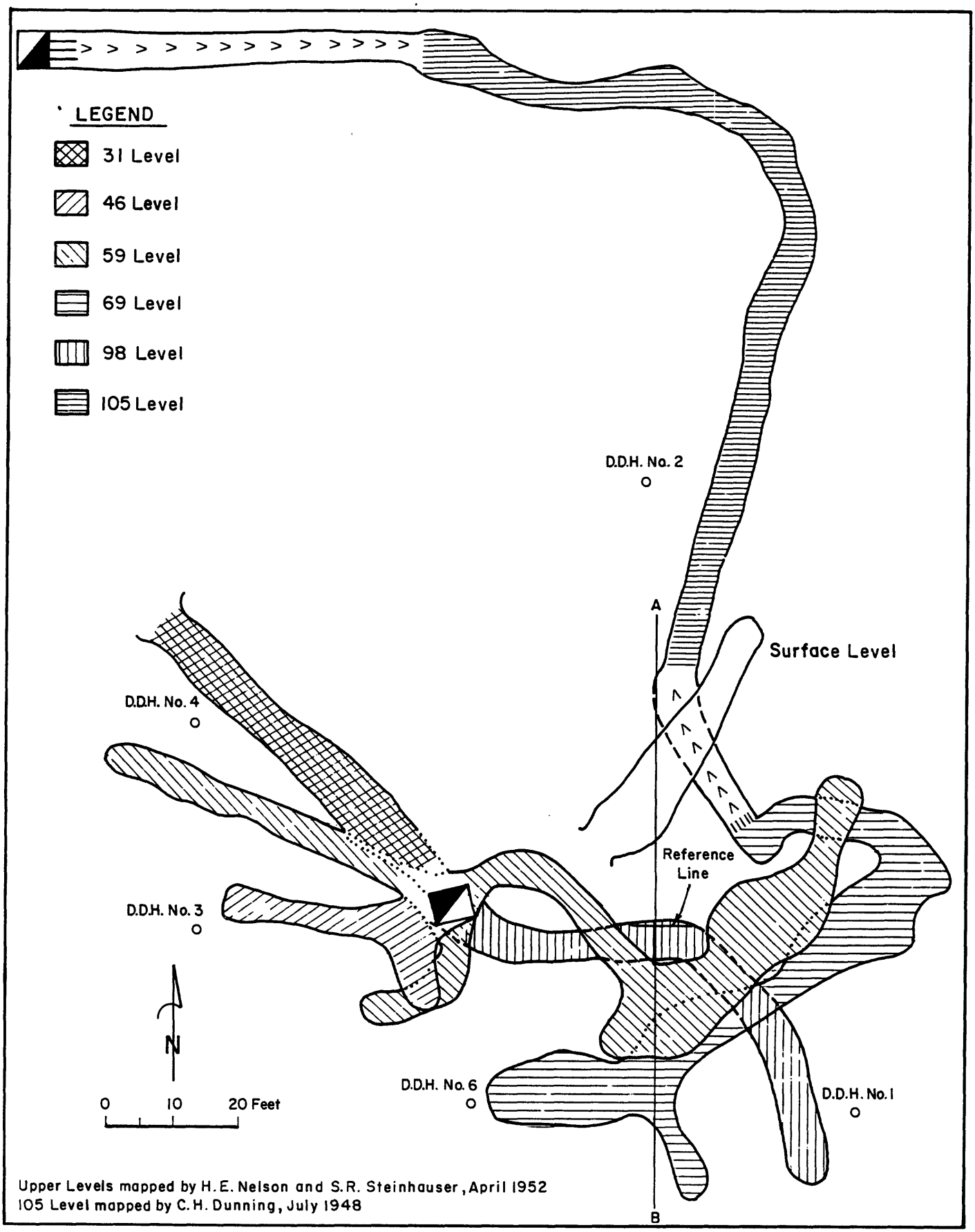
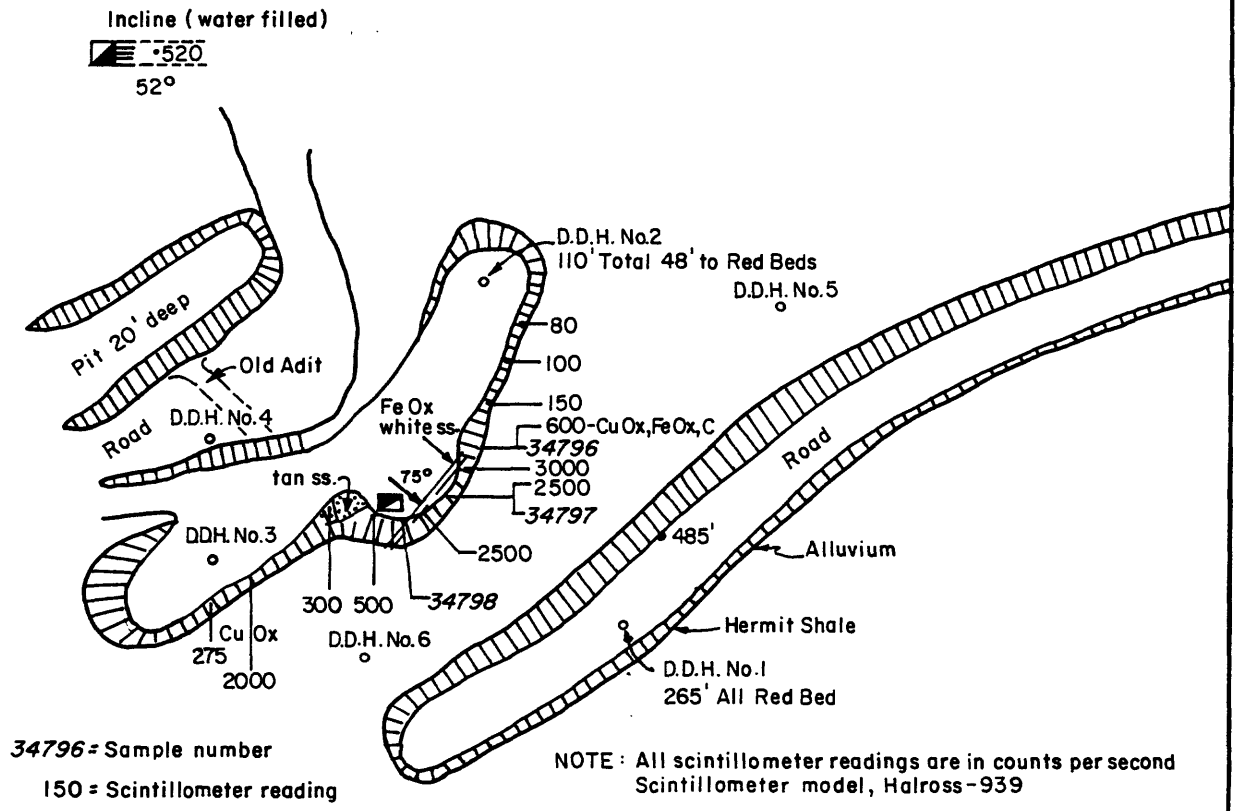
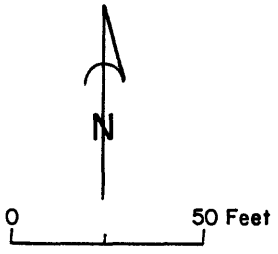


Figure 8. Composite map of underground workings, Hacks Mine, Mohave County, Arizona (after Dunning, 1948 and Nelson and Steinhauser, 1952)



SAMPLE ANALYSIS

FIELD NO.	% eU_3O_8	% cU_3O_8	WIDTH
34796	0.17	0.007	2'
34797	0.09	0.105	1'
34798	0.11	0.142	1'



Geology by H.E. Nelson and S.R. Steinhauser
February 10, 1953

Figure 9. Surface scintillometer survey, Hacks Mine, Mohave County, Arizona (after Nelson and Steinhauser, 1953)

Vanadium Corporation of America, of Durango, Colorado, took an option on the property in May 1953 that they dropped in July 1953, because they reportedly determined that exploration would have to be more extensive than they originally planned.

The La Salle Mining Company of Grand Junction, Colorado, leased the claims from Hacks Mining Company on September 7, 1953, and purchased the equipment on the property for a reported $4,200. From October 1953 through April 1954, the AEC purchased from La Salle a total of 154 tons of ore averaging 0.24 percent U_3O_8 at Marysvale. An additional 4 tons averaging 1.05 percent U_3O_8 was purchased at the buying station at Murray, Utah for the Vitro Corporation of America's mill at Salt Lake City. During its mining operations, La Salle dug a 100 foot long, 30 foot deep trench across the pipe, east of the old adit (fig. 10).

In April 1954, La Salle subleased the property to Rainbow Uranium of Salt Lake City. During the period April through August 1954, Rainbow shipped a total of 85 tons averaging 0.20 percent U_3O_8 to Marysvale and Murray. Of this total only 35 tons averaging 0.38 percent U_3O_8 was purchased by the AEC. The remaining 48 tons averaged less than 0.10 percent, the minimum grade accepted by the AEC. All of the material that Rainbow mined came from the old underground working. In August 1954 Rainbow was reorganized into Urainbow Inc. Urainbow subsequently subleased the property to a group of miners and eventually a lawsuit developed between Hacks Mining, La Salle and other parties in which Hacks regained control of the property and was returned the mining equipment as part of the settlement.

The Marysvale buying station was closed on March 15, 1957. After the station was closed, the AEC sold the ore it had purchased to the Vitro Corporation to be processed at its mill in Salt Lake City. Neither the copper nor the vanadium that the AEC had paid for in the ores purchased at Marysvale were recovered (Albrethsen and McGinley, 1982).

The Hacks Mine remained idle for three years. On September 5, 1957, the Rare Metals Corporation of America of Salt Lake City, obtained a 90 day exploration lease on the property. Rare Metals drilled six core holes, with a maximum depth of 640 feet and relinquished the property.

Western Gold and Uranium, Inc., operators of the Orphan Lode Mine on the south rim of the Grand Canyon, leased the property in June of 1958. Western Gold drove a 90 foot adit, heading southeast from near the location of the old shaft. The end of the adit was enlarged to accommodate a diamond drill station (Figure 10). A total of five holes were drilled in December 1958. Because drill station was in red Hermit Shale outside the pipe, the holes were inclined to test the pipe in the area of the old workings. The drilling encountered only low-grade mineralization and the lease was dropped in early 1959.

An examination of the property was made by AEC geologists Ben Bowyer and Wilmer R. Peterson on April 14, 1959 to determine the reserves that were eligible under the AEC's November 24, 1958 announcement (Bowyer and Peterson, 1959). A total of 100 tons averaging 0.14 percent U_3O_8 were calculated based on surface exposures in the various pits and cuts and in an exposure near the portal of the adit driven by Western Gold. On July 29, 1959, the

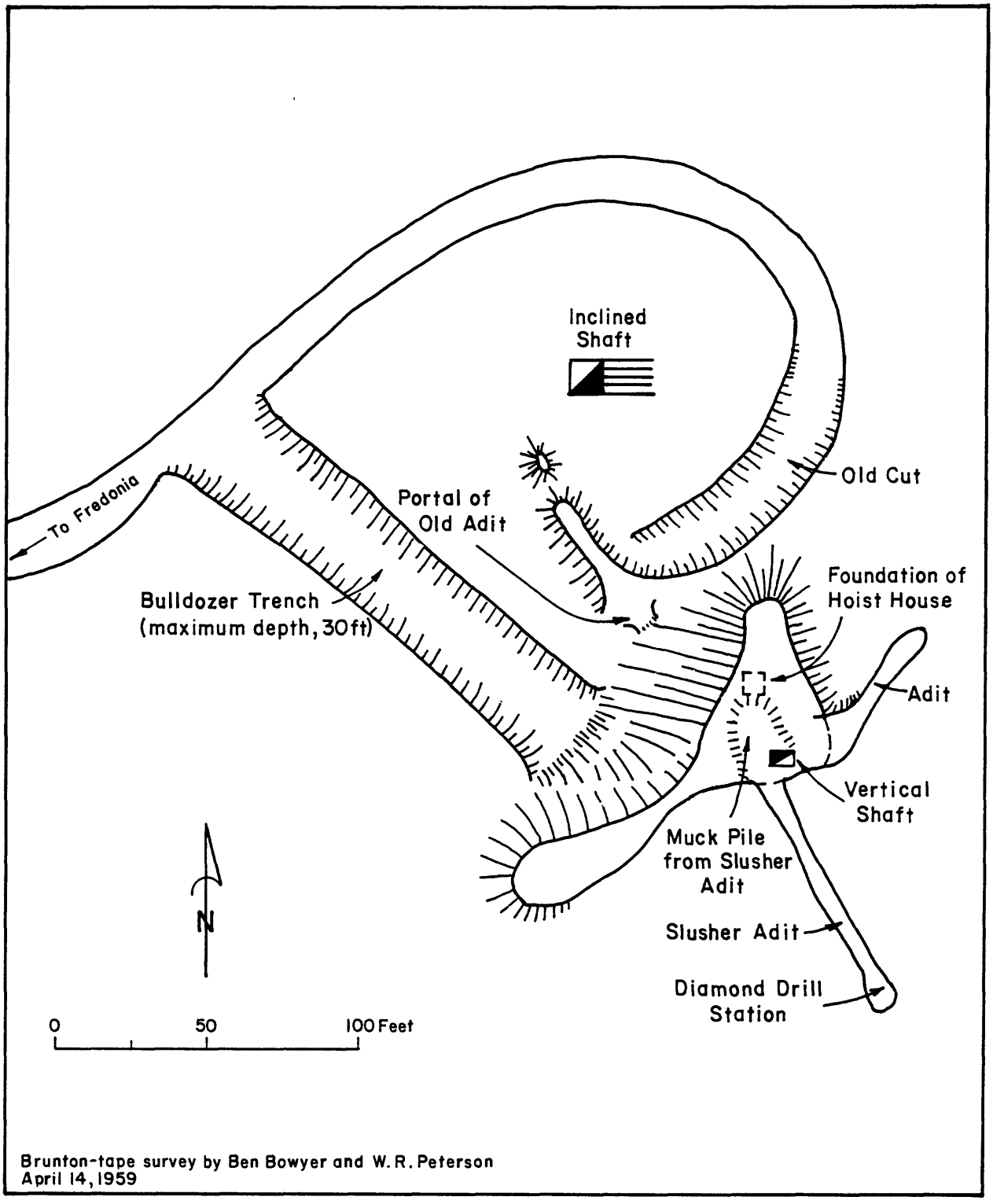


Figure 10. Map of surface workings, Hacks Mine, Mohave County, Arizona (after Bowyer and Peterson, 1959)

Hacks Mining Company, Inc. submitted an ore reserve estimated to the AEC of 20,000 tons averaging 0.20 percent U_3O_8. The company estimate was made without any backup material. Nevertheless, the property was eligible for the post-1961 market.

Atkinson Exploration Company of Cedar City, Utah, leased the property in the summer of 1959 and did considerable drilling. However, no ore was developed and the property was returned to Hacks Mining.

After a brief examination of the property in the summer of 1963, Ivor Adair, of Moab, Utah, doing business as A and B Mining Company, leased the Hacks mine from Hacks Mining Company on September 5, 1963. Early in 1964, A and B repaired the road down Hack Canyon and began shipping ore from the old open cut in March. During the period March through May 1964, a total of 206 tons averaging 0.13 percent U_3O_8 were shipped to the Vitro Corporation of America's mill in Salt Lake City under the AEC's ore purchase contract No. AT (05-1)-902.

In summary, during the period 1951 through 1964, the Hacks Mine shipped a total of 1,375.94 tons of ore containing 4,993.14 pounds U_3O_8 and averaging 0.18 percent U_3O_8 (table 4). Of this total, the AEC purchased 1,246.97 tons averaging 0.19 percent U_3O_8, and containing 4,825.20 pounds U_3O_8. Some 128.94 tons averaging 0.07 were below the minimum grade of 0.10 percent U_3O_8, and were not purchased by the AEC (table 4).

The property remained idle until 1972 when Western Nuclear, Inc. of Denver, Colorado acquired it for a reported $2 million. Drilling in the vicinity of the old mine located a new ore-bearing breccia pipe, about 800 feet to the northeast. This pipe was named the Hack 1 to distinguish it from the old mine. A second ore-bearing pipe (Hack 2) was discovered in 1979 some 3,000 feet southwest of the old mine. While doing development drilling at the Hack 2 pipe in 1980, a third ore-bearing pipe (Hack 3) was found nearby. Further exploration determined that the old copper prospect on the Copper Lady Claim (fig. 3) was the surface expression of the Hack 3 pipe (I.W. Mathisen, oral communication, 1987). The history and geology of these deposits are beyond the scope of this report.

The copper-uranium mineralization on the Hacks claim crops out on a steep slope just below the contact between the cliff-forming Coconino Sandstone and the underlying slope-forming Hermit Shale (fig. 5). At the surface many fractures in a down dropped block of Coconino Sandstone are stained with green copper and uranium minerals. The vertical shaft is collared in Coconino Sandstone talus. The upper levels of the underground workings are in highly fractured and brecciated Coconino Sandstone. Underlying the Coconino breccia, is fractured and bleached Hermit Shale (figs. 5, 6, 7).

The Coconino Sandstone talus at the shaft and exposures of Coconino in the mine workings caused early investigators (Dunning, 1948, Rasor 1949, Gruner and Gardner 1950a, b) to believe the deposit was in a block of Coconino Sandstone that had dropped into the Hermit Shale on the floor of Hack Canyon. They were all puzzled that no mineralization occurred in the Coconino in the canyon wall above the mine. Chester and Cutter (1951) believed the deposit was localized in a sandstone lens entirely within the Hermit

T A B L E 4

Uranium production by year, Hacks Mine, Mohave County, Arizona.

POUNDS	CALENDAR YEAR	ORE (TONS)	U_3O_8 (%)	U_3O_8 POUNDS	V_2O_5 (%)	V_2O_5 POUNDS
Hacks Mng. Co.	1951 3rd Qtr.	258.84	0.17	890.84	-	-
Hacks Mng. Co.	1951 4th Qtr.*	381.89	0.15	1,167.44	-	-
Hacks Mng. Co.	1952 2nd Qtr.	265.35	0.23	1,202.61	0.42	2,226.46
La Salle Mng. Co.	1953 4th Qtr.*	101.16	0.20	412.94	-	-
La Salle Mng. Co.	1954 1st Qtr.*	21.27	0.27	112.83	-	-
La Salle Mng. Co.	1954 2nd Qtr.*	56.52	0.29	324.39	-	-
Rainbow Uranium	1954 2nd Qtr.*	31.75	0.41	262.29	-	-
Rainbow Uranium	1954 3rd Qtr.*	53.22	0.08	85.80	-	-
A & B Mng. Co.	1964 1st Qtr.	138.00	0.13	358.00	-	-
A & B Mng. Co.	1964 2nd Qtr.	68.00	0.13	176.00	-	-
TOTAL		1,375.94	0.18	4,993.14	0.42	2,226.46
	AEC Purchases	1,246.97	0.19	4,825.20		
	"No pay ore"	128.94	0.07	167.94		

Quarterly production statistics include all shipments received during a three month period. Totals may include material that contained less than 0.10 percent U_3O_8 for which no payment was made by the AEC. Quarters marked with an asterisk (*) are known to include "no pay ore".
Source: U.S. Atomic Energy Commission files, Grand Junction Colorado Office

Shale. Harry C. Granger of the U.S. Geological Survey, after studying the Orphan Lode Mine, suspected the Hacks deposit was in a similar collapse-breccia pipe. However, this observation was not published for several years (Granger and Raup, 1962).

The mine workings (figs. 6, 7, and 8,) are located in the southeast side of a large breccia pipe that is poorly exposed in the floor of Hack Canyon. The Coconino Sandstone in the upper part of the pipe has dropped down a minimum of 120 feet. The majority of the rock exposed in the mine workings is a fine-grained, bleached, tan to medium gray sandstone of the Hermit Shale. This light colored, bleached sandstone can be traced into normal, unaltered reddish-brown sandstone in several areas of the mine. There are several breccia zones consisting of fragments of both fine- and medium-grained sandstone in a matrix of predominantly fine-grained sandstone. These zones dip steeply within the pipe and appear to be adjacent to the perimeter of the pipe. Some silicification in the form of quartz overgrowths has occurred in the pipe which makes it difficult to distinguish between sandstones of the Hermit and Coconino.

The diameter of the Hacks pipe is difficult to determine. The arcuate nature of the underground workings (fig. 8) roughly outlines the shape of the pipe on its southeast perimeter. Also, diamond drill holes nos. 1 and 5, were apparently drilled in undisturbed, red Hermit Shale outside the pipe (fig. 9). From this information the diameter of the pipe can be estimated to be approximately 200-250 feet in diameter.

Secondary minerals coat fractures and are disseminated in the sandstone especially in the breccia zones. Uranium minerals that have been identified from the Hack Mine include metatorbernite torbernite, tyuyaminite, and metazipplite (Gruner and others, 1954). Other identified minerals include chalcanthite, brochantite, erythrite or bieberite (Granger and Raup, 1962). A sample of dark, silicified sandstone was found to contain small amounts of covellite and uraninite (Gruner and Gardner, 1950a). Fukui (1982) identified coffinite in sample 070; and allanite in sample 688 (see Appendix pages 47 and 48).

Ridenour Mine

The Ridenour Mine is located approximately 45 miles northeast of Peach Springs, Arizona in the Grand Canyon (fig.2). It is within the Hualapai Indian Reservation in NW¼ NE¼ SE¼ and SW¼ SE¼ NE¼ Section 6, T.31N., R.8W., Gila and Salt River Baseline and Meridian in Coconino County, Arizona. Starting at Frazier Wells located on Indian Service Highway No. 18, 28 miles northeast of Peach Springs, the mine can be reached by a series of unimproved dirt roads that go through Prospect Valley to the rim of Grand Canyon, a distance of 25 miles. From the rim of the canyon, a steep, 4-mile trail leads down to the mine, a difference of elevation of 1,500 feet. The elevation of collar of the inclined shaft is 4,500 feet.

Richard D. Miller of the AEC investigated the Hualapai Indian Reservation for uranium, including the mine in 1953. The mine map and cross sections from his published report (Miller, 1954b) are included with this report.

William Ridenour was one of the first prospectors of written record in the Grand Canyon. In March 1880, he and William Hardy,

Charles Spencer and a man named Tilman located the "Grand Canyon Mine", a copper and silver prospect in the Grand Canyon, west of Prospect Valley (Billingsley, 1974). The claim was recorded on April 6, 1880 in Yavapai County and was subsequently transferred to Coconino County when it was created in 1891 (G. H. Billingsley, written communication, 1986).

Prior to the construction of the Atlantic and Pacific Railroad across northern Arizona in 1881-1883, the odd numbered sections in the vicinity of the mine were part of the huge railroad land grant. When the Hualapai Indian Reservation was created on January 1, 1883, all of the odd numbered sections within the boundaries of the Reservation were eventually transferred to the Hualapai Tribe (Crampton, 1972, p. 244). Since the Ridenour Mine was located in Section 6, it is very doubtful that it was ever controlled by the railroad as speculated by Miller (1954b).

It is not certain when copper production began at the mine. Rambosek and King (1970) state production reportedly began in 1887 and continued intermittently until 1916. Notes in the files of the Bureau of Indian Affairs at Truxton, Arizona dated November 10, 1910, state that "the mine has been worked for a depth of 100 feet, where a vein of over 300 feet in length of high grade ore has been discovered. Yields of 50-56 percent copper and 15-20 percent [probably meaning ounces] silver per ton had netted over $100,000 for Ridenour" (G.H. Billingsley, written communication, 1986).

A brief note in the Yavapai Magazine (1914) states that "Andy Frazier was taking large quantities of copper ore out of the Ridenour Mine....., and that many hundreds of tons running 15.00 percent copper will be left on the dumps". Mining apparently continued during 1915. In March of 1916, it was discovered by the Interior Department that no law existed to permit William Ridenour to continue mining on the Reservation and the matter was turned over to the General Land Office to determine the validity of the claim (G.H. Billingsley, written communication, 1986).

Data in the Arizona Bureau of Geology and Mineral Technology files lists the various operators of the mine as William Ridenour, Coconino Copper Company, Ashcroft Mining, and W.R. Kayser. Production was listed as 1,000 tons averaging 15.00 percent copper, for the period 1916-1918. These operations mined the copper carbonate minerals, which were apparently upgraded by hand methods. The ore was packed out on burros, 4 miles to the rim of the mesa and then hauled 60 miles by freight wagons to railroad at Nelson, just east of Peach Springs. Each wagon hauled two tons and a team of horses pulled two wagons. Two teams were used to make a weekly trip from the mine in 1915 and 1916 (Rambosek and King, 1970). The ore, which was stated to contain "a little silver and gold", was shipped to the Consolidated Arizona smelter at Humboldt, Arizona (Heikes, 1919, p. 298). Humboldt is located in Yavapai County, approximately 15 miles east of Prescott (fig. 2).

Detailed production statistics for the early copper and silver production from the Ridenour Mine can not be located. In a survey of the mineral resources of the region around Boulder Dam, Hewett and others (1936) listed the production statistics of the following six mining districts in Coconino County, Arizona - Francis, Grand Canyon, Pine Springs, Pipe Springs, Warm Springs (Jacobs Lake), and White Mesa. The Grand Canyon district included

"disseminated copper ore along fractures in Paleozoic sediments and small deposits in Precambrian rocks". It is assumed that the Ridenour Mine is included in this district together with Grandview, Bass, Tanner, and Bridal Veil Mines (Billingsley, 1974).

Although the deposits in the Grand Canyon district were known and worked prior to 1897 there is no record of production prior to 1904 (Hewett and others, 1936, p. 11). Shipments from the district were made in 1904-1908 and 1913-1919, and probably in 1929. Total production for the period 1904-1929 was 1,303 tons of ore, yielding 816,568 pounds of copper, 6,202 ounces of silver and 39.46 ounces of gold, valued in all at $145,470 (Hewett and others, 1936, p. 11).

In the U.S. Geological Survey's annual reports, Mineral Resources of the United States, there are no details on the ore shipped to the smelters for 1904-1906. For the years 1907 and 1908, ore shipments from Coconino and Maricopa Counties are combined. Details of the ore shipments for 1913-1919 from Coconino County are given in table 5. It thus appears that the early production from the Ridenour Mine was less than 1,000 tons of copper ore, which was shipped during 1915-1919.

Prospecting on the Reservation was discouraged until after the Congressional Act of June 30, 1919, and its amendment, the Act of December 26, 1926, were passed. In this respect, all unalloted Indian lands were subject to prospecting. In 1934, the Hualapai Indian Reservation was declared open to prospecting and leasing on the condition that a notice of location be filed within 60 days (G.H. Billingsley, written communication, 1986). What effect this action had on the Ridenour Mine is not known, but no doubt it was leased by some individual(s).

Table 5, Copper ore from Coconino County, Arizona shipped to smelters, 1913-1919

YEAR	CRUDE ORE TONS	COPPER POUNDS	SILVER OUNCES	GOLD OUNCES	VALUE (DOLLARS)	PRODUCING AREAS/MINES
1913	216	27,024	237	-	4,332	Francis District, and two other mines 1/
1914	63	19,672	145	0.24	19,672	Francis District
1915	200	66,774	913	37.01	12,912	Francis District, Grand Canyon Mine 2/
1916	138	41,813	455	0.63	10,598	Francis District, Grand Canyon Mine Warms Springs District
1917	1,511	346,538	4,576	1.11	98,399	Francis District, Grand Canyon Mine 3/, White Mesa District
1918	159	48,036	846	0.48	12,721	Francis District, Grand Canyon Mine 4/
1919	103	32,507	664	0.43	6,799	Francis District 5/

1/ Nearly all the ore came from the Francis District
2/ Grand Canyon Mine was the original name of the Ridenour Mine
3/ Two car loads of good grade ore shipped in 1917
4/ One car load of ore shipped in 1918
5/ Shipments made from "Emerald and Grand Canyon properties"
Compiled from Heikes (1914, 1916, 1917, 1919, 1921a, 1921b, 1922)

Following the completion of Boulder (now Hoover) Dam in 1936, an area of some 1,496,600 acres, largely behind the dam was designated the Lake Mead National Recreation Area and placed under the control of the National Park Service. Maps published by the Interior Department in the 1940's show the Ridenour Mine within the National Recreation Area. However, the Hualapais never recognized a portion of their Reservation being included in the Recreation Area, and maps published in the late 1950's show no portion of the Recreation Area on Hualapai lands.

Uranium at the Ridenour Mine was brought to the attention of the AEC by Dan Ming of Kingman, Arizona. The property was examined on December 28, 1951 and on August 19, 1952 by A.J. Rambosek and E.N. King. At that time, they indicated the property was controlled by E.L. and Dan Ming, and Pryor Evans, all of Kingman (Rambosek and King, 1970). Notes in the AEC files indicate that the Mings believed they had control of the mine through an agreement with William Ridenour's heirs.

Table 6, Chemical analyses, Ridenour Mine, Coconino County, Arizona

Analyses by American Smelting and Refining Company, Grand Junction, Colorado; all data in percent, (-) = less than, eU_3O_8 - equivalent, cU_3O_8 - chemical. Data from Miller (1954b).

SAMPLE NO.	LOCATION	Percent eU_3O_8	Percent cU_3O_8	Percent V_2O_5	Percent Cu
34979	Adit No. 4	1.10	1.20	9.35	
34980	Adit No. 4	1.70	1.84	5.66	
34981	Stope No. 1	0.17	0.102	3.92	
34982	Stope No. 1	0.21	0.195	1.15	8.13
34983	Stope No. 1	-0.01	0.008	4.20	
34984	Stope No. 1	0.10	0.026	9.92	
34985	Stope No. 1	-0.01	0.012	0.61	8.70
34986	Stope No. 1	0.02	0.009	7.97	
34987	Stope No. 1	0.33	0.272	7.31	
34988	Stope No. 1	1.23	1.38	2.74	14.15
34989	Stope No. 1	0.37	0.28	10.83	
34990	Stope No. 1	0.04	0.054	4.08	
34991	Stope No. 1 (E. end)	0.17	0.14	5.33	
34992	Stope No. 1 (E. end)	0.02	0.033	0.36	12.37
34993	Stope No. 1 (E. end)	0.03	0.015	5.40	
34994	Stope No. 2	-0.01	0.002	1.43	1.85
34995	Stope No. 2	0.52	0.46	6.84	9.65
34996	Stope No. 2	0.06	0.08	4.62	9.35
34997	Stope No. 2	-0.01	0.015	6.20	
34998	Dump	0.01	0.018	8.19	
100506	Dumps (Select)	0.01	0.017	7.99	
100506 A	Stope No. 1 (Select)	2.30	2.50	11.50	
100754	Stope No. 3 (Select)	2.10	1.80		

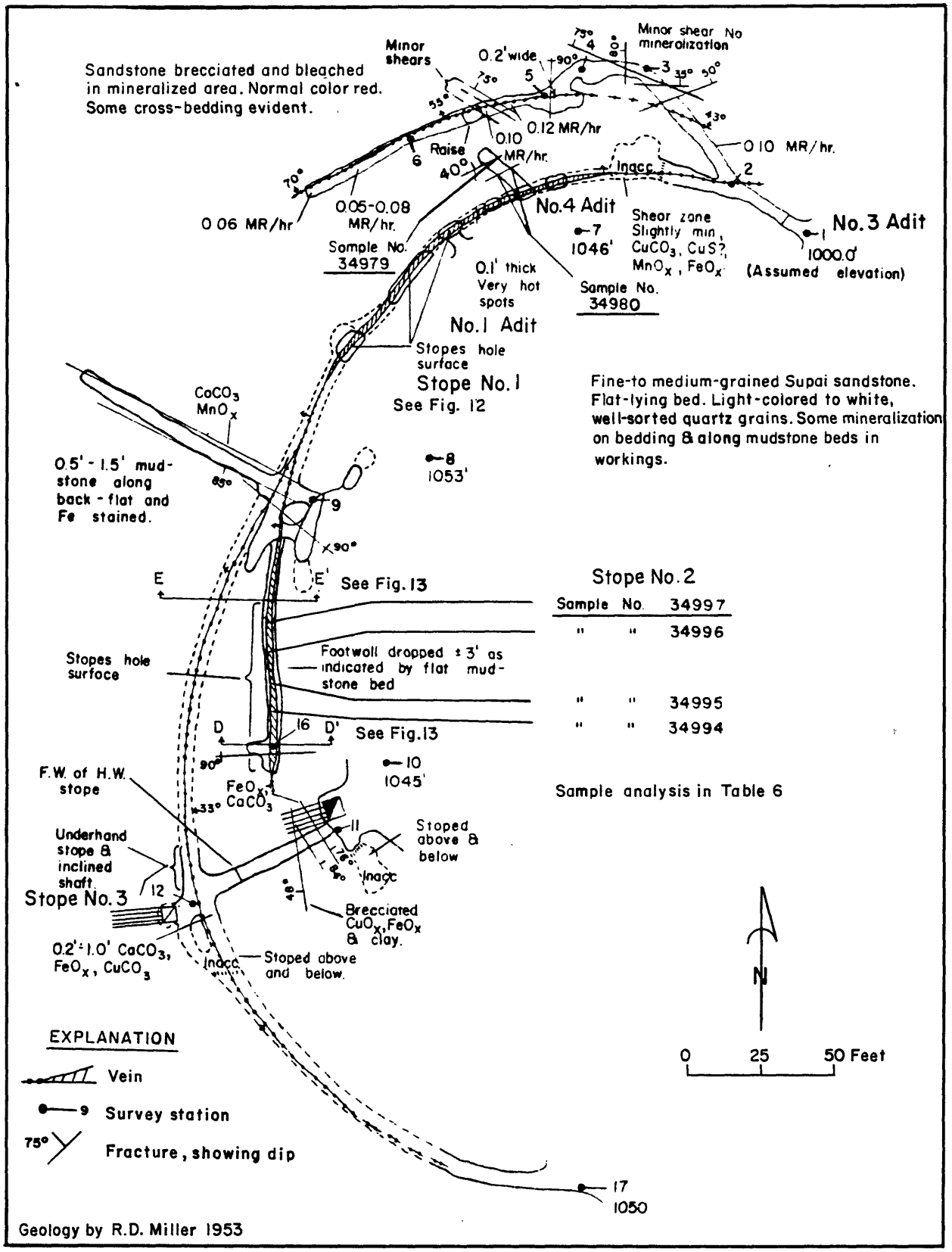


Figure 11. Map of workings, Ridenour Mine, Coconino County, Arizona (after Miller 1954b)

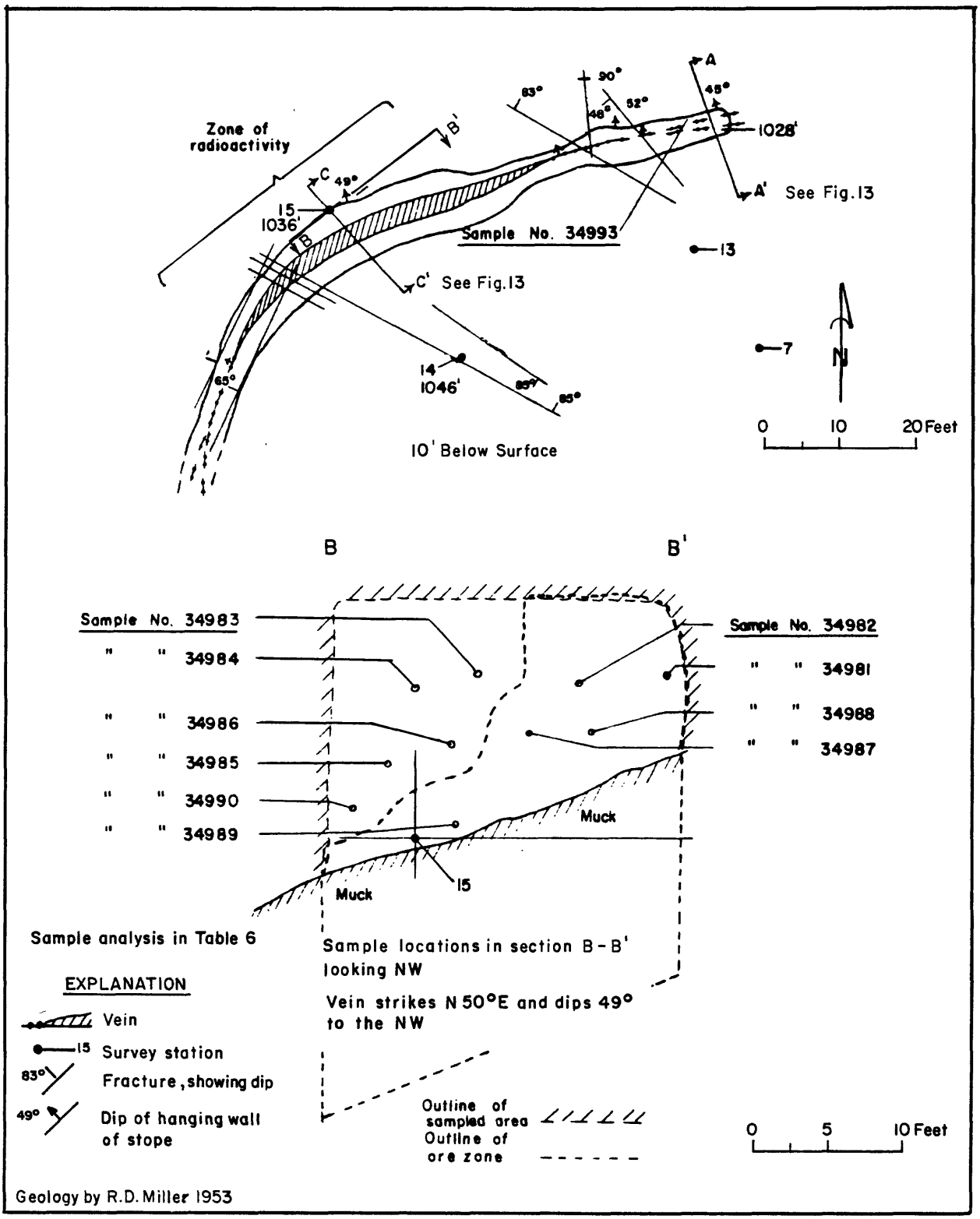


Figure 12. Plan and section Stope No.1 Ridenour Mine, Coconino County, Arizona (after Miller 1954 b)

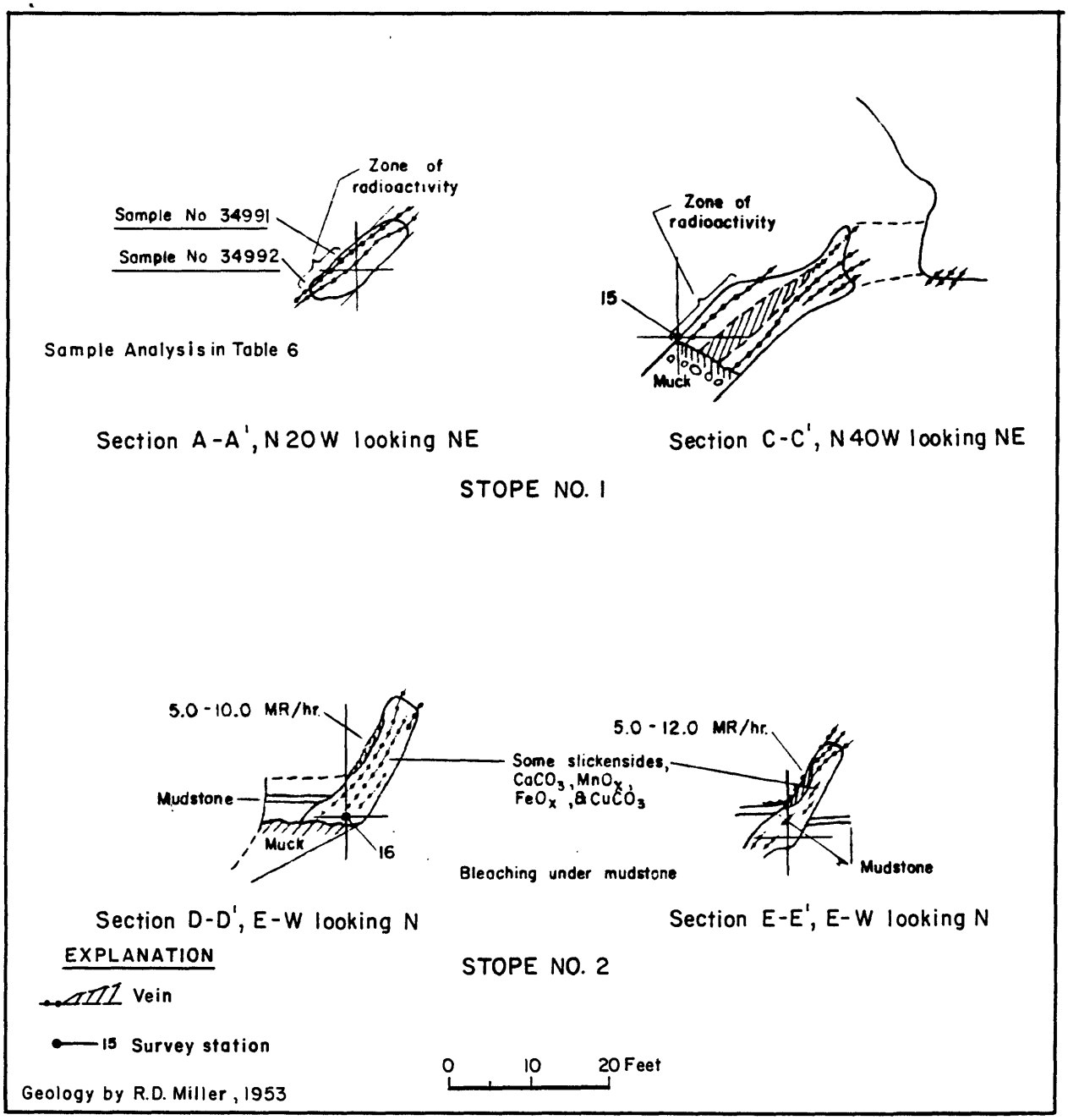


Figure 13. Vertical sections, Stopes No. 1 and 2, Ridenour Mine, Coconino County, Arizona (after Miller 1954b)

During the summer and fall of 1953, R.D. Miller of the AEC made a reconnaissance of the Hualapai Indian Reservation for uranium (Miller 1954a) and a detailed study of the Ridenour Mine (Miller, 1954b). He indicated that the mine was under the control of the Hualapai Tribal Council, and not leased. Maps and cross-sections from his report are included here as figs. 11, 12, and 13. Based on samples collected in the old workings (table 6), Miller calculated a total indicated reserve of 50 tons averaging 0.38 percent U_3O_8 and 5.10 percent V_2O_5. Included in this total were 40 tons averaging 0.45 percent U_3O_8 and 5.20 percent V_2O_5 in Stope No. 1, and 10 tons averaging 0.14 percent U_3O_8 and 4.80 percent V_2O_5 in Stope No. 2.

During the uranium boom of the 1950's there was apparently no or very little, activity at the Ridenour Mine. Confusion about who controlled the mineral rights - the Hualapais, National Park Service, or the Ridenour heirs - discouraged exploration at a time when other breccia pipes in the region were being explored and developed. However, in August 1955, the AEC was contacted by the Sawyer Exploration Company of Los Angeles, California, who stated that they controlled the mine and requested government assistance to develop it. Sawyer claimed to have leased the mine "from the heirs of William Ridenour on March 30, 1955", whose claim "predated the establishment of the Hualapai Reservation". The company built a small airstrip on the mesa above the mine, improved the road to the mine, and cleaned out and mapped the old workings. The Bureau of Indian Affairs informed the AEC that Sawyer Exploration did not have a valid lease and were trespassing on the Hualapai Reservation.

In 1959, Western Gold and Uranium, Inc. obtained an exploration permit from the Hualapai Tribe. The trail to the mine was improved and two core holes (560 feet and 740 feet) were drilled to test the ore-bearing ring fracture zone on the west side of the pipe below the existing mine workings. Drilling took place during July and August 1958. Results of this drilling were reported as negative for uranium, as only low-grade copper mineralization was encountered. The drillers reported considerable difficulty in coring the highly fractured rock.

Early in 1960, Clyde Hutcheson, of Flagstaff, Arizona, inquired of the AEC about the eligibility of the Ridenour Mine to market ore in the post-1961 period. The AEC determined that the small reserve calculated by Miller in 1953 made the property eligible, since the ownership - Hualapai Tribal Council - had remained the same since the reserve was calculated. Hutchison signed a 10 - year lease with the Hualapai Tribe on May 21, 1960, and began to improve the trail from the top of mesa down to the mine. The lease covered some 76.8 acres surrounding the old mine.

In January 1961, Hutcheson made a 14.14 ton shipment to the uranium mill at Shiprock New Mexico, operated by Kerr-McGee Oil Industries, Inc. Although the mill at Tuba City, Arizona was much closer, it did not process vanadium-bearing uranium ores. This small shipment averaged 0.15 percent U_3O_8 and 2.36 percent V_2O_5 (table 7). Considering the long haul (430 miles) and the low grade (less than 0.20 percent U_3O_8) the shipment was not

economic. The ore was selectively mined from the old workings, mainly the No. 1 Stope. It was shuttled from the mine to the mesa rim in a jeep. On the mesa, all of the jeep loads were loaded into a truck for the trip to Shiprock.

In March 1961, Hutcheson told the author he had made a 10-ton shipment to the smelter at Superior, Arizona which had averaged 8 percent copper. Further copper shipments apparently did not materialize and Hutcheson cancelled his lease in 1963 or 1964.

During the period of increased uranium activity in the late 1970's, several companies obtained permits from the Hualapai Tribe to examine the property. The only reported exploration was by Western Nuclear, Inc., who drilled the property in 1977 and 1978. Three holes, with a total footage of 1,754 feet, were drilled into the pipe. Weak radioactivity was encountered in two of the holes (Wenrich and others, 1986).

Table 7, Uranium production by year, Chapel and Ridenour Mines, Mohave and Coconino Counties, Arizona

SHIPPER	CALENDAR YEAR	ORE TONS	U_3O_8 (%)	U_3O_8 POUNDS	V_2O_5 (%)	V_2O_5 POUNDS
			CHAPEL			
C.M. Bundy	1954 (1st Qtr)	1.08 1/	0.23	4.96	-	-
			RIDENOUR			
Clyde Hutcheson	1961 (1st Qtr)	14.14	0.15	42.05	2.36	667.09

1/ This shipment also contained 4.02 percent Cu and 1.10 percent $CaCO_3$

Source: U.S. Atomic Energy Commission files, Grand Junction, Colorado Office

The breccia pipe containing the Ridenour Mine is exposed on the west side of a small canyon that is a tributary of the Colorado River, 2 miles to the northwest. The pipe crops out in the middle part of the Esplanade Sandstone of the Supai Group (fig. 1). The Esplanade is composed of about 300 feet of light reddish-gray to reddish-brown, fine- to medium-grained, crossbedded sandstone with thin red mudstone beds. In the vicinity of the pipe the sandstone is bleached to a light gray to buff color.

The pipe has largely been eroded away by canyon cutting, and the mine dumps cover much of the remaining core of the pipe (fig. 14). The old copper workings extend around the perimeter of the pipe for nearly 500 feet (fig. 11). Here, ore in the ring fracture zone has been mined for a vertical distance of over 80 feet.

Figure 14, Ridenour Mine and dump looking north, northeast. Adit No. 3 is to the left of center in the photo. Beds above mine are undisturbed Esplanade Sandstone outside of the breccia pipe. Photo by W.L. Chenoweth, March 1961.

The main level of the mine is about 100 below the exposed top of the pipe and was reached by two inclined shafts and a haulage adit whose portal is blocked by dump material. The upper stopes have access holes to the surface, and the remaining workings consist of short prospect adits and small open cuts.

The west side of the pipe either flares or rakes to the west. The ore-bearing ring faults and fractures, marking the perimeter of the pipe, are exposed in the small, narrow stopes dip as much as 45 degrees (fig. 13).

Some of R. D. Miller's unpublished field notes best describe the uranium occurrences. "Stope No. 1. Carnotite and dark vanadium minerals are conspicuous on the hanging wall of this small near- surface working. Uranium-vanadium minerals appear to be terminated to the west by open fractures, and dark vanadium minerals are found in greater quantity than carnotite toward the top of the stope to the east [fig. 12]. Samples and radioactive readings show that uranium persists to the east along the top of muck filling the stope until the uranium zone is no longer exposed by the hanging wall where the workings narrow. Crevices into the hanging wall show that the uranium zone is at least one foot wide and perhaps greater. Readings taken in lower workings on the same structure ranged from 0.05 to 0.12 MR/hr. [milliroentgen/hour]; however, the narrow workings may not have reached the uranium zone in back of copper minerals now exposed on the hanging wall."

"Stope No. 2. Carnotite is found in close association with copper minerals on the hanging wall near the center of this working; dark vanadium minerals extend north and south of the carnotite along the shear zone [figs. 11 and 13]. Uranium minerals are cut off by mudstone at both the top and bottom of the stope, although a thin zone may follow horizontal bedding planes at the hanging wall at the lower mudstone. Actual width of the uranium- vanadium zone is unknown."

"Stope No. 3 was found to have very high radioactivity.... . Extent of the mineralized area along the hanging wall was not determined and no ore calculations are made. A grab sample (No. 100754) taken later by an Indian prospector assayed 1.8 percent cU_3O_8."

"Lack of adequate sampling and insufficient data on extent of ore bodies prevents accurate estimation of ore reserves in other localities in the mine. These include the extreme east end of Stope No. 1 (Sample No. 34991) [shown on figure 13], Adit No. 4 (crosscut into radioactive hanging wall of Stope No. 1-- Samples Nos. 34979 and 34980)[shown on figure 11], and Adit No. 3 (down-dip from Stope No. 1). A detailed radiometric survey of the mine workings may locate additional occurrences of uranium not found during this preliminary investigation."

In summary, the uranium-vanadium minerals form a separate, thin zone on the outside of the main copper zone, within the ring fault zone on the west side of the breccia pipe. In many places, the old copper workings do not penetrate areas where uranium-vanadium minerals should occur. The mine dumps, with an estimated 12,000-15,000 tons of material, contain appreciable amounts of copper and some vanadium, but very little uranium (table 6).

Tyuyaminite the principal uranium mineral. Although Miller (1954b) reported carnotite at the Ridenour Mine, X-ray analyses of

15 samples of yellow material all were tyuyaminite or metalyuyaminite (K.J. Wenrich, oral communication, 1988). Volborthite, a copper vanadate is very common. Copper minerals include chalcocite, malachite and azurite with smaller amounts of bornite, chalcopyrite, and chrysocolla. Pyrite and limonite are the chief gangue minerals. The minerals commonly fill fractures in the brecciated sandstone but are also disseminated in the sandstone. Miller (1954b, p.11) noted that laboratory studies of one sample found carnotite [tyuyaminite] in association with organic carbon. Chenoweth (1986) noted a similar occurrence in the Esplanade Sandstone at the Orphan Lode Mine. Carbonate cement is common in the ore zone. In some samples of copper ore, malachite is the cement. Fukui (1982) identified the following minerals in samples collected for the NURE program, Sample 007, vesignieite, a barium copper vanadate; Sample 008, naumannite, a silver-lead selenide; and bromargyrite, a silver bromide; Sample 009, illite; Sample 685, tyuyamunite and calciovolborthite. (See Appendix page 52 for a description of these samples).

Riverview Mine

The Riverview Mine is located approximately 16 miles south-southeast of Cameron, Arizona in Coconino County (fig. 1). The property consists of nine patented claims in the N½ Section 8, T.26N., R.10E., Gila and Salt River Baseline and Meridian (fig. 15). Chenoweth and Blakemore (1961) have briefly described this uranium occurrence. It can be reached by 11½ miles of unimproved ranch roads which join U.S. Highway 89, 16 miles south of Cameron. The mine is located south of Black Point basalt flow on the Black Point monocline. The mine shaft collars at an elevation of 4,480 feet, about 250 feet above the Little Colorado River, which lies 1 mile to the east.

Uranium was discovered in the Cameron area in 1950 and by 1956 a large number of mines were producing ore from deposits in the Chinle Formation. In early August 1956, Guy Boldman and Elbert T. Mayes were prospecting the Triassic Moenkopi Formation south of the main mining area when they located uranium minerals in a sinkhole.

The original Riverview No. 1 claim was located on August 7, 1956 and was recorded as being in Section 4, T.26N., R.10E. Subsequent investigations by the locators determined the mineralized outcrop was actually in Section 8, and an amended location was filed on October 9, 1956 (Hansen, 1957). On November 8, 1956, the Riverview Nos. 2-9 claims were filed to surround the original No. 1 claim (fig. 15). On the same date, the entire Riverview group of claims were leased by Boldman and Mayes to the Utco Uranium Corporation of Flagstaff, Arizona for a period of 5 years (Hansen, 1957).

Utco began developing a small open cut on the outcropping mineralized sandstone blocks, and on December 12, 1956, an initial 10-ton shipment was made to the ore buying station at the Tuba City mill. This plant, operated by the Rare Metals Corporation of America, was located 6 miles northeast of Tuba City, Arizona. This initial 10-ton shipment averaged 0.51 percent U_3O_8. During the month of December 1956, Utco mined a total of 126 tons of ore which averaged 0.46 percent U_3O_8 and 0.04 percent V_2O_5 (table 8).

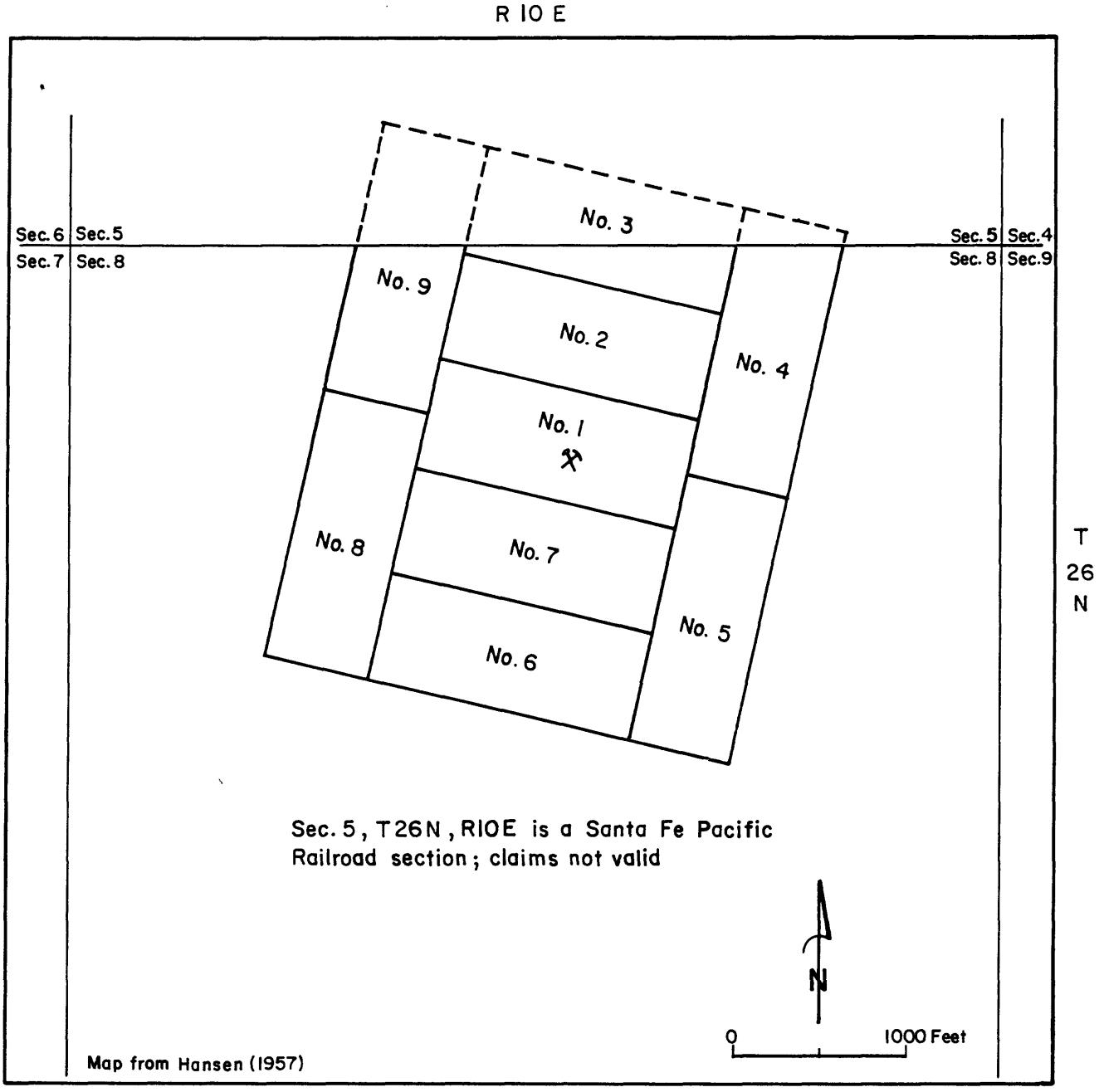


Figure 15. Location map of Riverview claims, Coconino County, Arizona

During January 1957, a 12 foot high wooden headframe was erected near the margin of the pipe on its southwest perimeter, and the excavation of a 5 X 10-foot shaft began. The hoist for the shaft consisted of a 40 horsepower Gardner-Denver slusher (U. S. Atomic Energy Commission, 1959).

As the Riverview Mine was a new uranium discovery, Utco applied to the AEC for a discovery bonus of $35,000 under the terms of the Domestic Uranium Program Circular 6. Investigations by AEC engineers on January 11, 1957, determined that the mine was located in the SW¼, NW¼, NE¼, Section 8, T.26N., R.10E. The NE¼ and the N½, SE¼ of Section 8 were found to be withdrawn from mineral entry by a First Form Reclamation Withdrawal Act of June 17, 1902 (Hansen, 1957). Because the claims were not valid, Utco shut the mine down in late January 1957, after mining 96 tons averaging 0.22 percent U_3O_8 and 0.02 percent V_2O_5 earlier in the month (table 8).

Table 8, Uranium production by year, Riverview Mine, Coconino County, Arizona

SHIPPER	CALENDAR YEAR	ORE (TONS)	U_3O_8 (%)	U_3O_8 POUNDS	V_2O_5 (%)	V_2O_5 POUNDS
Utco Uranium Corp	1956 (4th Qtr)	125.95	0.46	1,153.63	0.04	104.00
Do.	1957 (1st Qtr)	95.73	0.22	428.32	0.02	29.00
Do.	1957 (2nd Qtr)	139.42	0.42	1,168.64	0.03	94.00
Do.	1957 (3rd Qtr)	147.31	0.37	1,088.56	0.04	104.00
Total		508.41	0.38	3,839.15	0.03	331.0

Source: U.S. Atomic Energy Commission files, Grand Junction, Colorado Office

Utco, and Boldman and Mayes petitioned the Federal Government to restore the NE¼ Section 8 for mineral entry. On April 22, 1957, the land was restored to mineral entry and claim location (Federal Register, March 26, 1957, p. 1992) and Boldman and Mayes filed new location notices (Hansen, 1957).

Mining resumed in late April and continued through September 1957. The shaft was sunk to a depth of 125 feet with several high grade pods of ore mined at various depths. Long-hole drilling from the shaft failed to locate any additional ore in this portion of the ring fracture zone. When mining operations ceased in September, a total of 508 tons averaging 0.38 percent U_3O_8 and 0.03 percent V_2O_5 had been produced (table 8). Assuming that all of the production for the period April through September 1957 came from the shaft, the underground workings in the peripheral shear zone would account for nearly 60 percent of the total uranium produced.

Utco cancelled their lease in 1958. In March 1959, Western Gold and Uranium, Inc. leased the property from Boldman and Mayes

and began a diamond drilling program on March 23, 1959. The drilling was directed to test the Coconino Sandstone, one of the uranium host rocks at the Orphan Lode Mine at Grand Canyon. After drilling two holes with negative results, Western Gold cancelled their lease in the summer of 1959.

During the large increase in uranium exploration activities in the late 1970's, several companies leased and drilled the Riverview pipe at various times. To the author's knowledge, drilling has not demonstrated where the pipe bottoms. It has been speculated that it bottoms in the Kaibab Limestone, but it could continue downward to the Redwall Limestone.

The ore deposit is in a collapse-breccia pipe collared in the Wupatki Member of the Moenkopi Formation. The original discovery was made by noting the presence of large mineralized blocks of sandstone, many standing vertically, which seemed to fill a "sinkhole" in the Wupatki Member, 45 feet above the base of the Member. These blocks appear lithologically similar to sandstone in the upper part of the Shinarump Member of the Chinle Formation. The pipe contact at the surface is irregular in shape and measures 135 feet in its maximum north-south dimension and 95 feet in an east-west direction.

Mining at the surface has stripped as much as 25 feet of the upper part of the pipe, and a shaft, which is sunk to a depth of 125 feet, is located within the pipe near the south margin of the structure on a strong northwest shear. A plan map of the mine workings prepared by the author in 1959 could not be located during this study.

The blocks of upper(?) Shinarump originally filling the pipe at the surface (elevation about 4,505 feet) indicate that the pipe originally continued to a higher elevation. Assuming a thickness of 365 feet for the Moenkopi Formation and 80 feet for the Shinarump Member, the blocks have been displaced downward perhaps 360 feet from their initial stratigraphic position. Drilling during 1959 indicated that the pipe may be flared slightly at depth and rakes to the southeast. This observation (Chenoweth and Blakemore, 1961) may not be totally correct, as the drill holes were not surveyed for drift and their exact position in the subsurface was not determined.

The core of the pipe is irregular in shape and consists of blocks of arkosic, coarse- to very coarse-grained sandstone and conglomerate of the Shinarump Member, and sandstone and siltstone of the Moenkopi Formation. A concentric ring of collapsed greenish-gray and reddish-brown siltstone and mudstone of the Moenkopi encircles the core, and at the east margin of the pipe the mudstone is stained with manganese.

Uranium minerals reported from the Riverview Mine include uranophane and sporadic grains of carnotite (Chenoweth and Blakemore, 1961), metatorbernite (Austin, 1964), and minute black uraninite grains disseminated in small quantities in the Moenkopi in the lower parts of the mine workings (Barrington and Kerr, 1963). Evans (1956) reported that the uranophane, carnotite, and malachite occur with clay, calcite, and iron oxide cementing a fine-grained quartz sandstone. Some azurite is present in subgrade ore material on the property. More copper is present in the deposit than in other uranium deposits in the Cameron area (Chenoweth and Blakemore, 1961).

Kaolinite, present in undisturbed and unaltered Moenkopi, is reported by Barrington and Kerr (1963) to be altered to illite in the peripheral zone of the pipe and in breccia fragments of red Moenkopi within the collapse. Illite is also characteristic of clay in the Shinarump Member which is present in the pipe core. Red Moenkopi has also been bleached to a whitish green by removal of ferric iron from the clay, and by reduction of the ferrous iron content.

In addition to the reported clay alteration, silica and calcite have been introduced into the rocks of the pipe (S.R. Austin, written communication, 1975). Cryptocrystalline silica is present in small veins of the peripheral zone of the collapse and in small lenses in the bleached Moenkopi of the core and adjacent host rock. Bleached, fine-grained sandstone of the core is sporadically cemented by calcite, giving a nodular appearance to the weathered surface. H.B. Sutphin (written communication, 1987) observed that disseminated malachite enhanced the micro-crossbedding in a sample of bleached Moenkopi siltstone, from the perimeter of the pipe. In this same sample (172-D-C81, see Appendix page 57), he observed that uraninite occurred as scattered, very thin coatings around framework grains, and that it tended to be concentrated along microfractures. A uranium X-ray map of a sample of ore-bearing Shinarump sandstone (172-E-C81, see Appendix page 58) is shown in Wenrich (1985).

Chapel Prospect

The Chapel prospect (fig. 2) is located about 15 miles south of Mt. Trumbull, Mohave County, Arizona in the NW¼ SE¼ SW¼ Section 25, T.33N., R.10W., Gila and Salt River Baseline and Meridian. Mt. Trumbull is located approximately 65 miles south of St. George, Utah. The prospect is on the west side of Parashant Wash (Mule Canyon) and is accessible by a series of jeep trails from Mt. Trumbull. The area of the prospect is within the Lake Mead National Recreation Area, and is administered by the National Park Service. The Recreation Area is closed to claim staking but land for mineral exploration can be leased from the National Park Service through the Bureau of Land Management.

The only geologic information that has been published on the Chapel prospect is a brief reconnaissance report by Nelson and Rambosek (1970), and a brief description in a National Park Service (1977) report regarding uranium leasing in the Lake Mead National Recreation Area.

The copper occurrence at the Chapel pipe may have been located in the mid 1870's when prospectors discovered numerous mineralized outcrops in the Mt. Trumbull mining district (Crampton, 1972, p. 151). An old 55 foot adit and numerous surface excavations were noted on the property when it was examined in 1952. The elevation of the adit is approximately 4,200 feet.

Samples submitted to the AEC in May 1952 by C.M. Bundy of Mt. Trumbull, Arizona confirmed that the property contained uranium. Since this was a new discovery in a remote area, the property was examined by Harry E. Nelson and Albert J. Rambosek of the AEC on July 10, 1952. Nelson and Rambosek (1970) mapped and sampled the occurrence, although they mislocated it in the NE¼ NE¼ Section 25, and the north arrow on their map appears to be magnetic north instead of true north (fig. 16). At the time of the examination, the area of the old adit was claimed by C.M.

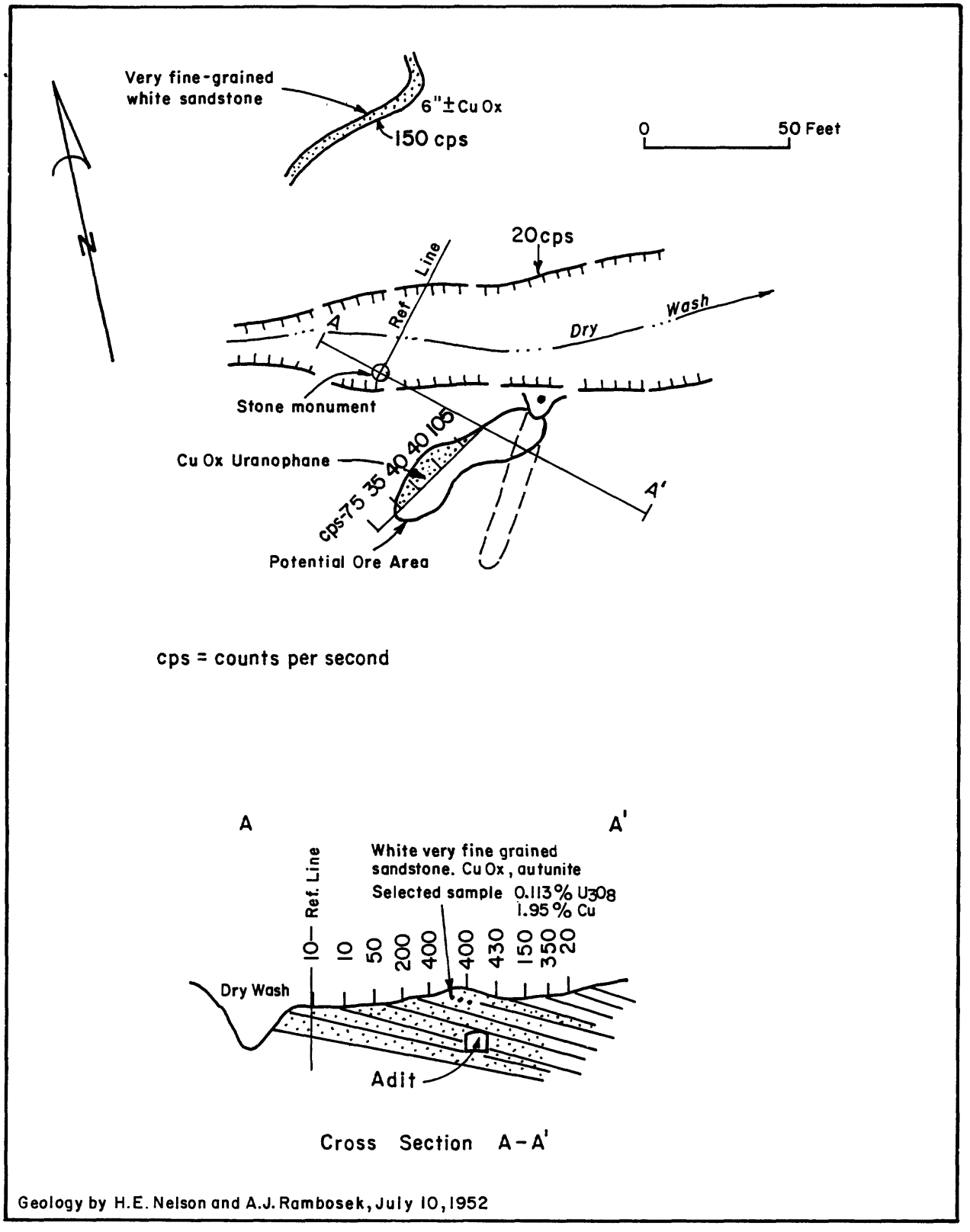


Figure 16. Surface map and radiometric survey, Chapel Prospect, Mohave County, Arizona (after Nelson and Rambosek, 1970)

Bundy of Mt. Trumbull, Arizona and Omer Bundy of St. George, Utah. It was determined that Section 25 was within the Lake Mead National Recreation Area and that the claim might be invalid. However, on February 24, 1954, C.M. Bundy shipped 1 ton of ore averaging 0.23 percent U_3O_8, 4.02 percent Cu, and 1.10 percent $CaCO_3$ to the AEC buying station at Marysvale, Utah (table 7).

Correspondence in the AEC files indicate that Michael Beck of Long Beach, California had an option to lease the Chapel claim in 1954. Beck was unable to obtain permission from the National Park Service to conduct exploratory drilling and dropped his option in 1955.

In April 1955, the AEC was informed by the Interior Department that a bill to open up the Lake Mead National Recreation Area under the general mining laws of the United States had been approved by the National Park Service and Bureau of Land Management (BLM). Under the new regulations, mining leases could be approved and issued by the BLM. During August 1955, the Arizona State Office of the BLM in Phoenix received four applications to lease Section 25, T.33N., R.10W. No action could be taken on these applications due to a protest that was filed by C.M. Bundy. This protest was based on the assertion that Bundy's claim location pre-dated the establishment of the National Recreation Area. For over 10 years, the BLM investigated Bundy's protest and kept the applications pending.

On August 1, 1956, the BLM issued Lease AR-09911 to Audrine Knight Fawcett for Section 25, T.33N. R.9W. Mrs. Fawcett had been led to believe that this section contained the Chapel prospect. Following considerable correspondence with the AEC, the property was examined on November 9, 1959, by Byron J. Sharp and Richard D. Miller of the AEC, accompanied by Mrs. Fawcett. This examination verified that the Chapel prospect indeed was in the SW¼ Section 25, T.33N., R.10W., not in the section Fawcett had leased (Sharp, 1961). Sharp and Miller mapped the property and confirmed Nelson and Rambosek's (1970) earlier observations. They also observed that the ore-bearing structure was a collapse-breccia pipe.

On April 1, 1966, the BLM approved Lease AR-03556 to Audrine C. Knight for Section 25, T.33N., R.10W. Bundy's protest was apparently found to be invalid, and the other applications had been dropped. A.C. Knight sought to interest various companies in exploring the pipe on Section 25, which she called the Chapel House. In 1968, the Cotter Corporation, the operator of the Orphan Lode Mine, drilled five holes into the pipe. Although some anomalous radioactivity was encountered, no ore grade material was located (National Park Service, 1977, p.II-14). The lease was transfered to the Exxon Company, USA of Denver, Colorado on November 1, 1974. Exxon planned to drill the pipe, which they called the Parashant breccia pipe (National Park Service, 1977, p.II-14). Permission to drill two holes was not obtained, and the renewal of the lease was denied on December 9, 1978 (Larry Bauer, BLM, written communication, 1987).

The breccia pipe containing the Chapel prospect is poorly exposed in the lower part of the Hermit Shale. A 55 foot long adit driven southward along a fracture zone that strikes N 55°E, exposed a bleached, fine-grained sandstone. The red Hermit rocks were extensively bleached. Sandstones in the vicinity

of the adit show slumping but no breccia was noted. Extensive talus in the canyon has obscured the extent of the breccia pipe but it is estimated to be at least 250 feet in diameter (Sharp, 1961). The host sandstone at the portal of the adit dips about 15° to the southeast. Sharp (1961) noted a shear zone striking N25°W and dipping 80° NE which is superimposed on the pipe. The main uranium-bearing zone at the Chapel prospect is 21 feet above the old adit. The host rock is a white, fine-grained sandstone in the lower Hermit Shale.

Based on sampling and radiometric surveys, Nelson and Rambosek (1970) calculated a "potential ore reserve" of 120 tons averaging 0.20 percent U_3O_8. Sharp and Miller did additional sampling and delineated a small tabular ore body, ranging from 0.5 to 3 feet in thickness. They calculated an indicated ore reserve of 250 tons averaging 0.25 percent U_3O_8 and an inferred ore reserve of 250 tons averaging 0.25 percent U_3O_8 (Sharp, 1961).

Nelson and Rambosek (1970) noted uranophane, autunite, and copper oxides at the prospect. Exxon personnel identified autunite, torbernite, uranophane, and pitchblende, which occurred as fracture fillings, veinlets, and dissemination in sandstone (National Park Service, 1977, p.II-14). In thin section studies of samples collected for the NURE program, Fukui (1982) identified traces of uranium associated with carbonaceous material in sample no. 296 (see Appendix page 60). The following copper minerals were identified from a sample (no. 682) of copper ore found as float: azurite, chalcocite, covellite, and brochantite (Fukui, 1982). The copper minerals occurred as joint fillings (see Appendix page 60).

Summary

All four of the collapse-breccia pipes described in this report have certain common features. The pipes are roughly circular in plan. They vary in diameter from about 100 feet at the Riverview to nearly 350 feet at the Ridenour. The amount of displacement of the sediments in the pipes ranges from only slumping at the Chapel to over 300 feet at the Riverview. The peripheral shear zone is the most favorable location for mineral deposition at three of the pipes, but deposition can occur in permeable beds within the pipes.

Bleaching of the normal reddish-brown sandstone and siltstone has occurred at all of the pipes. The bleaching is not restricted to the pipe, but can extend a few tens of feet outside of the pipe. Other alteration features noted at the pipes include silicification and calcification of the breccias. Argillization, in the form of illite was noted at the Ridenour and Riverview pipes.

In addition to uranium, copper occurs in all of the pipes. The common copper minerals are chalcocite, malachite, and azurite. Uranium is present as uraninite and in a variety of secondary minerals. Gangue minerals include calcite, dolomite, siderite, barite, limonite, and hematite.

The pattern of mineralization in the breccia pipes is not uniform. The Ridenour pipe is extremely enriched in vanadium and also has significant silver. A definite zoning of the copper minerals and the uranium-vanadium mineralization was noted at the

Ridenour, but not at the others. Besides Cu, V and Ag, other elements showing some enrichment are As, Cd, Co, Cr, Ni, Pb, Zn, and Zr. Supergene alteration has taken place at all the pipes, giving rise to a large number of secondary minerals.

The Hacks, Ridenour, and Chapel pipes, no doubt owe their origin to the collapse of the overlying sedimentary rocks, e.g. Supai Group, Hermit Shale, and Coconino Sandstone, into the Redwall Limestone, as has been observed at numerous pipes in the Grand Canyon region (Wenrich, 1985). The Riverview and other collapse pipes in the Cameron, Arizona area are exposed in the Kaibab Limestone and younger rocks (Barrington and Kerr, 1963). Many of these collapse structure appear as sinkholes within the Kaibab, and may be developed entirely within that unit. It is possible that some of these structures, such as the Riverview pipe, may extend downward into the Redwall Limestone. Drilling to date has not determined the vertical extent of the Riverview pipe (K. J. Wenrich, oral communication, 1986).

Three of the pipes, Hacks, Ridenour, and Riverview, were mined during the uranium boom of the 1950's and 1960's, and most of the known ore was removed. Limited exploration at the three pipes failed to locate any additional reserves. At the Chapel pipe, where only a small trial shipment was made, there has been limited exploration to locate ore at depth, hence this pipe has a small potential for additional resources. The potential for the discovery of additional resources at the other previously mentioned pipes is considered to be very low. Exploration in the late 1970's and early 1980's has located three additional ore-bearing pipes (Hack 1, 2, and 3) in the immediate vicinity of the Hacks pipe described in this report.

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Appendix
GEOCHEMICAL DATA
HACKS MINE
SAMPLE NUMBERS

	068	069	070	071	072	073
U_3O_8	6	3	10	6	1	1
Ag	-0.5	-0.5	-0.5	-10	-0.5	-0.5
Al	50,000	70,000	30,000	55,800	70,000	20,000
As	-200	-200	-200	NA	-200	-200
B	15	30	20	91	30	10
Ba	100	200	150	260	200	200
Be	1	1	2	-10	2	-1
Bi	NA	NA	NA	-50	NA	NA
Ca	20,000	20,000	50,000	15,900	10,000	7,000
Cd	NA	NA	NA	-50	NA	NA
Co	-5	-5	-5	-10	-5	-5
Cr	50	100	70	76	50	30
Cu	7	7	7	45	20	5
Fe	15,000	20,000	10,000	8,380	10,000	500
K	NA	NA	NA	264,000	NA	NA
La	-20	20	20	-100	-20	-20
Li	-100	-100	-100	-3,000	-100	-100
Mg	NA	NA	NA	10,400	NA	NA
Mn	300	200	300	107	200	-10
Mo	-5	5	5	-10	-5	-5
Na	5,000	5,000	5,000	733	7,000	-1,500
Nb	-10	-10	-10	-100	-10	-10
Ni	20	30	30	-50	20	10
P	NA	NA	NA	NA	NA	NA
Pb	10	20	10	-40	10	10
Sb	-100	-100	-100	-5,000	-100	-100
Sc	-5	10	10	53	5	-5
Si	NA	NA	NA	379,000	NA	NA
Sn	-10	-10	-10	52	-10	-10
Sr	-100	-100	100	87	-100	-100
Ti	2,000	3,000	3,000	3,190	2,000	900
V	30	50	30	383	20	10
W	-50	-50	-50	766	-50	-50
Y	-10	20	30	-40	10	10
Zn	-200	-200	-200	503	-200	-200
Zr	150	300	500	-40	100	150

Fluorimetric uranium and emission spectrographic analysis. All values are in parts per million (ppm). (+) = greater than; (-) = less than; NA = not analyzed for

Sample Descriptions

068 - Hermit Shale, unaltered, very fine- to fine-grained argillaceous sandstone.
069 - Hermit Shale, unaltered near bleached zone, very fine- to fine - grained argillaceous sandstone.
070 - Hermit Shale, partly altered, near edge of bleached zone, very fine- to fine-grained, argillaceous sandstone.
071 - Hermit Shale, bleached zone near breccia, very fine- to fine-grained sandstone.
072 - Hermit Shale, unaltered sandstone, 500 feet north of shaft.
073 - Coconino Sandstone, white sandstone, 575 feet north of shaft.

Samples collected by Baillieul and Zollinger, July 1979 (Baillieul and Zollinger (1982).

Analysis by Bendix Field Engineering Corp.

GEOCHEMICAL DATA (Continued)
HACKS MINE
SAMPLE NUMBERS

	140	141	142	143	688
U_3O_8	126	39	1,200	600	17,980
Ag	7	3	7	5	
Al	30,000	30,000	70,000	70,000	
As	200	-200	200	200	
B	15	10	20	10	
Ba	70	100	150	700	
Be	1	-1	2	1	
Bi	NA	NA	NA	NA	
Ca	700	700	500	-500	
Cd	NA	NA	NA	NA	
Co	-5	5	20	5	
Cr	50	150	100	70	
Cu	100	30	7,000	2,000	
Fe	20,000	10,000	3,000	1,500	
K	NA	NA	NA	NA	
La	-20	-20	-20	-20	
Li	-100	-100	-100	-100	
Mg	NA	NA	NA	NA	
Mn	-10	-10	10	10	
Mo	500	100	10	15	
Na	2,000	2,000	3,000	2,000	
Nb	-10	-10	-10	-10	
Ni	15	15	50	30	
P	NA	NA	NA	NA	
Pb	70	50	20	10	
Sb	-100	-100	-100	-100	
Sc	-5	-5	5	-5	
Si	NA	NA	NA	NA	
Sn	-10	-10	-10	-10	
Sr	300	-100	100	200	
Ti	1,000	2,000	3,000	1,500	
V	50	70	150	70	
W	-50	-50	-50	-50	
Y	10	-10	-10	-10	
Zn	-200	-200	-200	-200	
Zr	100	200	150	150	

Fluorimetric uranium and emission spectrographic analysis. All values are in parts per million (ppm). (+) = greater than; (-) = less than; NA = not analyzed for

Sample Descriptions
140 - Mineraized breccia, northeast of shaft
141 - Barren sandstone, near No. 140
142 - Ore sample from the 46 level of the mine
143 - Ore sample from the 46 level of the mine
688 - Hermit Shale - mineralized, very fine- to fine-grained sandstone with pyrite cement

Samples 140-143 collected by Baillieul and Zollinger, July 1979 (Baillieul and Zollinger (1982).

Sample 688 collected by Fred Dotterrer and Bruce Reid, May 8, 1977 (Baillieul and Zollinger (1982).

Analysis by Bendix Field Engineering Corp.

Appendix
GEOCHEMICAL DATA
RIDENOUR MINE
SAMPLE NUMBERS

	006	007	008	009	010	685
U_3O_8	6	900	42	33	-1	21,000
Ag	0.5	5	1,500	50	10	
Al	60,000	50,000	50,000	30,000	10,000	
As	-200	500	700	-200	-200	
B	15	10	-10	15	-10	
Ba	150	1,500	100	50	50	
Be	1	2	2	1	-1	
Bi	NA	NA	NA	NA	NA	
Ca	50,000	7,000	30,000	3,000	10,000	
Cd	NA	NA	NA	NA	NA	
Co	-5	150	300	300	5	
Cr	70	50	100	20	20	
Cu	5	2,000	+20,000	+20,000	1,000	
Fe	5,000	1,500	5,000	10,000	700	
K	NA	NA	NA	NA	NA	
La	-20	-20	-20	-20	-20	
Li	-100	-100	-100	-100	-100	
Mg	NA	NA	NA	NA	NA	
Mn	100	150	10	-10	30	
Mo	-5	10	30	-5	-5	
Na	2,000	2,000	2,000	2,000	2,000	
Nb	-10	100	10	-10	-10	
Ni	15	150	300	1,000	30	
P	NA	NA	NA	NA	NA	
Pb	-10	1,000	3,000	100	-10	
Sb	-100	700	-100	-100	-100	
Sc	-5	20	-5	-5	-5	
Si	NA	NA	NA	NA	NA	
Sn	-10	-10	-10	- 10	-10	
Sr	-100	-100	-100	-100	-100	
Ti	1,000	1,000	700	700	200	
V	30	10,000	3,000	300	20	
W	-50	-50	-50	-50	-50	
Y	10	10	-10	-10	-10	
Zn	-200	-200	-200	-200	-200	
Zr	100	200	300	70	-10	

Fluorimetric uranium and emission spectrographic analysis. All values are in parts per million (ppm). (+) = greater than; (-) = less than; NA = not analyzed for

Sample Descriptions

006 - Fine- to medium-grained, red Esplanade Sandstone outside pipe.
007 - Dark gray mineralized fine-grained sandstone from breccia zone.
008 - Malachite-bearing fine-grained sandstone from pipe.
009 - Breccia fragment with extensive clay alteration.
010 - Unaltered, very fine- to medium-grained Esplanade Sandstone south of pipe.
685 - Bleached, very fine- to fine-grained Esplanade Sandstone with veinlets of tyuyamunite.

Sample 685 - collected by Fred Dotterrer and Bruce Reid, June 8, 1977. (Baillieul and Zollinger, (1982).

Samples 006-010 collected by Baillieul and Zollinger, June 1979. (Baillieul and Zollinger, (1982).

Analysis by Bendix Field Engineering Corp.

GEOCHEMICAL DATA (Continued)
RIDENOUR MINE
SAMPLE NUMBERS

	28	29	30	31
Ag	20	30	4	140
Al_2O_3%	H	6.71	4.67	6.43
As	2050	790	110	3200
Au	.05L	.05L	B	.05L
Ba	904	720	380	140
Be	14	87	16	120
Bi	20	50	10	20
Total C%	.01L	.39	.05	.10
Total Organic C%	.01L	.04	.03	.04
Total CO_3C%	.01	.35	.02	.06
CaO %	H	1.00	.08	.49
Cd	4L	10L	2L	4L
Ce	106	30	23	42
Co	202	120	52	45.4
Cr	18.3	54	28	16.7
Cs	8	6	4	2.77
Cu	5500	1900	510	8800
Dy	30.6	20	B	19
Er	12	20L	4L	12
Eu	13.4	10L	3	10.2
F%	.06	.05	.03	.05
Total Fe_2O_3%	H	.41	.29	.87
Ga	13	80	23	110
Gd	43	50L	10L	38.1
Hf	9.52	B	B	8.21
Hg	.62	.30	.01	6
Ho	8L	20L	4L	8L
K_2O%	H	3.21	2.36	3.40
LOI%	H	2.67	1.09	1.90
La	23.1	10.0	9.0	4.52
Li	40	10	7	16
Lu	1	B	B	.553
MgO%	H	1.15	.44	.64
Mn	21	20L	11	8L
Mo	260	10	87	56
Na_2O%	H	.15L	.15L	.16
Nb_2	26	180	34	160
Nd	100	90	32	68.8
Ni	520	260	120	250
P_2O_5%	H	.05	.05	.06
Pb	4200	330	810	11000
Pr	30	50L	10L	20
Rb	128	94	55	102

GEOCHEMICAL DATA (Continued)
RIDENOUR MINE
SAMPLE NUMBERS

	28	29	30	31
Total S%	.01L	.01L	.01L	.01L
Sb	2.89	B	B	5.43
Sc	6.83	10L	3	3.76
Se	6.8	1.1	.30	5.7
SiO_2%	H	77.2	88.4	74.1
Sm	39.4	50L	10L	40.3
Sn	8L	20L	4L	8L
Sr	290	300	41	45
Ta	80L	200L	40L	.265
Tb	5.7	100L	20L	4.59
Th	4.84	20L	4L	2.82
TiO_2	H	.24	.23	.14
Tm	1.39	B	B	.952
U	3090	1800	6.13	76.10
V	40000	27000	5200	36000
Y	72	50	19	55
Yb	8.1	10	3	4.83
Zn	150	89	34	101
Zr	720	B	B	B

All analyses are in parts per million (ppm) except as noted. L= less than the given detection limit; B= blank, not analyzed for; H= analytical interference, no data.

Unpublished data on samples collected by U.S. Geological Survey personnel.

Analysis by U.S. Geological Survey, Denver, Colorado

Appendix
GEOCHEMICAL DATA
RIVERVIEW MINE
SAMPLE NUMBERS

	MBY-180	MBY-181
U	75.20	4,270.00
Th	-21.00	-1,300.00
Al%	5.40	4.10
Ca%	.08	.54
Fe%	3.90	2.00
K %	1.80	2.80
Mg%	.12	.24
Na%	-.15	-.15
P %	.04	.06
Si%	-40.00	-40.00
Ti%	.31	.30
Ag	-1.00	3.40
As	-200	-200
Av	-10	-10
B	60	52
Ba	330	530
Be	2.3	5.5
Bi	-10	-10
Cd	-2.0	-4.0
Ce	-100	-100
Co	7.7	32.0
Cr	55	31
Cu	810.0	940.0
Ga	15	15
Hg	-500	-500
La	41	26
Li	-50	-50
Mn	-200	-200
Mo	-10	82
Nb	-25	-25
Ni	21.0	110.0
Pb	15	330
Re	-50	-50
Sb	-100	-100
Sc	-10	11
Se	-200	-200
Sn	-10	28
Sr	150	310
Te	-50	-50
Ti	-10	-10
V	150	140
W	-100	-100
Y	22	38
Zn	-50	92
Zr	220	330

All analyses are in parts per million (ppm) except as noted. All elements except U and Th measured by emission spectrography. (-) = less than.

Sample Descriptions

MBY-180 - Sandstone from outcrop
MBY-181 - Sandstone from mine dump

Collected by Karen J. Wenrich, September 9, 1979

Analysis by U.S. Geological Survey, Denver, Colorado

GEOCHEMICAL DATA (Continued)
RIVERVIEW MINE
SAMPLE NUMBERS

	172-D-C81	712-E-C81
Ag	21	41
Al_2O_3%	10.6	6.16
As	4,600	3,800
Au	-.05	-.05
Ba	270	340
Be	2	5
Bi	50	-40
Total C%	.09	.04
Total Organic C%	.09	.04
Total CO_3 C%	-.01	-.01
CaO %	.12	.10
Cd	-4	-4
Ce	40	70
Co	28	34
Cr	27	120
Cs	53	7.2
Cu	15,000	3,100
Dy	20	10.9
Er	10	-10
Eu	8	1.52
F%	.03	.02
Total Fe_2O_3%	.53	2.35
Ga	30	20
Gd	029	-20
Hg	1.75	.68
Ho	-8	-8
K_2O%	1.85	1.97
LOI%	4.52	2.85
La	16	31
Li	23	27
MgO%	.36	.27
MnO%	-.02	-.02
Mo	190	450
Na_2O	.11	-.10
Nb	-10	-10
Nd	20	27
Ni	300	330
P_2O_5%	.16	.12
Pb	380	980
Pr	-20	-20
Rb	52	70
Total S%	.01	.01
Sb	NA	103
Sc	-8	13
Se	-.1	.5
SiO_2%	74.7	79.6

GEOCHEMICAL DATA (Continued)
RIVERVIEW MINE
SAMPLE NUMBERS

	172-D-C81	712-E-C81
Sm	20	NA
Sn	10	-10
Sr	100	190
Ta	NA	6.6
Tb	100	1.5
Th	4,200	6.5
TiO_2	.79	.42
U	13,800	16,600
V	120	260
Y	160	76
Yb	12	7
Zn	210	260

All analyses are in parts per million (ppm) except as noted. All elements except U and Th measured by emission spectrography. (-) = less than; NA = not analyzed for.

Sample Descriptions

172-D-C81 - Grayish-white, non-calcareous siltstone. Bleached Moenkopi from ring fracture on the southeast edge of the pipe. Disseminated malachite.
172-E-C81 - Very fine- to medium-grained, arkosic sandstone. Shinarump float from southwest portion of pipe. Visible metatorbenite.

Collected by Hoyt B. Sutphin in 1981 (Sutphin, 1986).

Analysis by U.S. Geological Survey, Denver, Colorado

Appendix
GEOCHEMICAL DATA
CHAPEL PROSPECT
SAMPLE NUMBERS

	293	294	295	296	297	682
U_3O_8	3	4	29	1,400	2,100	3,100
Ag	-10	-10	-10	-10	-10	
Al	49,300	32,900	30,900	42,600	29,200	
As	NA	NA	NA	NA	NA	
B	68	46	56	76	43	
Ba	274	348	219	324	251	
Be	-10	-10	-10	-10	-10	
Bi	-50	-50	-50	-50	-50	
Ca	50,400	17,200	38,300	16,700	7,640	
Cd	-10	-10	-10	-10	104	
Co	-10	-10	99	120	930	
Cr	22	21	19	-10	31	
Cu	157	24	1,680	1,730	6,770	
Fe	21,000	11,300	8,630	6,070	8,830	
K	20,300	17,000	15,000	21,000	14,500	
La	-100	-100	-100	-100	-100	
Li	-3,000	-3,000	-3,000	-3,000	-3,000	
Mg	21,200	1,390	22,400	8,570	2,230	
Mn	276	123	356	135	86	
Mo	13	-10	-10	16	23	
Na	710	539	-100	981	-100	
Nb	-100	-100	-100	-100	-100	
Ni	-50	-50	-50	60	574	
P	-100	-100	-100	134	284	
Pb	-40	-40	-40	-40	-40	
Sb	-5,000	-5,000	-5,000	-5,000	-5,000	
Sc	5	-3	-3	-3	-3	
Si	357,000	361,000	284,000	447,000	336,000	
Sn	-10	-10	-10	-10	- 10	
Sr	71	67	53	60	48	
Ti	3,030	1,920	2,410	2,400	2,310	
V	250	200	222	244	164	
W	-100	-100	-100	-100	-100	
Y	-40	-40	-40	- 40	-40	
Zn	-100	-100	-100	-100	-100	
Zr	330	376	265	391	241	

Fluorimetric uranium and emission spectrographic analysis. All values are in parts per million (ppm). (+) = greater than; (-) = less than; NA = not analyzed for

Sample Descriptions

293 - Red, very fine-grained sandstone, siltstone, northeast of adit.
294 - Bleached, very fine-grained sandstone, south of adit.
295 - Pink, fine-grained sandstone northeast of adit.
296 - Limonite stained, bleached, fine-grained sandstone with copper stains, at adit.
297 - Copper ore, float, very fine-grained sandstone, east of adit.
682 - Bleached, fine-grained sandstone, with copper minerals, filling joint, northeast of adit.

Sample 682 - collected by Fred Dotterrer and Bruce Reid, June 3, 1977. (Baillieul and Zollinger (1982).

Samples 293-297 collected by Baillieul and Zollinger, August 1979. (Baillieul and Zollinger (1982).

Analysis by Bendix Field Engineering Corp.