UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

A mineralized breccia pipe in Mohawk Canyon

Lithologic and Geophysical logs

by

Karen J. Wenrich, Bradley S. Van Gosen, Richard A. Balcer, James H. Scott, Joseph F. Mascarenas, George M. Bedinger, and Betsi Burmaster[1]

Open-File Report 85-469

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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A MINERALIZED BRECCIA PIPE IN MOHAWK CANYON
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ABSTRACT

Hundreds of solution-collapse breccia pipes crop out in the canyons and on the plateaus of northern Arizona. The pipes originated in the Mississippian Redwall Limestone and stoped their way upward through the upper Paleozoic strata, locally extending into the Triassic Moenkopi and Chinle Formations. High-grade U ore, associated with potentially economic concentrations of Ag, Pb, Zn, Cu, Co, and Ni in some of these pipes, has stimulated mining activity in northern Arizona despite the depressed market for most of these elements.

More than 900 confirmed and suspected breccia pipes have been mapped during the past 6 years as a part of this study. Many exploration criteria for detecting mineralized breccia pipes were developed during the mapping. One pipe discovered on the W. side of Mohawk Canyon in 1983, was selected for exploratory drilling in 1984 because it exhibited the following exploration criteria:

1. Concentrically inward-dipping strata
2. Erosion along an encircling ring.
3. Anomalous radioactivity.
4. Goethite pseudomorphs and molds of pyrite.
5. Colloform celadonite-stained chalcedony.
6. Supergene Cu mineralization.
7. Breccia.
8. Anomalous concentrations in surface exposure of such trace elements as Ag, As, Cd, Co, Cr, Cu, Mo, Ni, Pb, Se, U, V, and Zn.

Five rotary and core holes were drilled into this pipe. Drilling problems, such as lost circulation, lost casing into 30-foot-high caverns within the breccia, and great water consumption, limited the drilling results. Core recovered from holes in the center of the pipe shows breccia to the total depth of 1010 ft, abundant pyrite, and minor galena. Gamma logs of a rotary hole penetrating to 1335 ft (no cuttings were obtained below 1000 ft) show a one-foot interval of 0.52% eU_3O_8 at a depth of 1191 ft, and a 20 ft zone averaging 0.04% eU_3O_8; this is at the same stratigraphic level as the tops of orebodies in mines located on similar plateaus capped with the Harrisburg Gypsiferous Member of the Kaibab Limestone. Sufficient mineralization was verified in the Mohawk Canyon pipe that further drilling is warranted to assess its economic potential.

INTRODUCTION

The Colorado Plateau of northern Arizona is host to hundreds of breccia pipes. Despite the depressed uranium market, exploration activity for mineralized breccia pipes in north-central and northwestern Arizona has remained high.

These breccia pipes are not classic breccia pipes in that there are no volcanic rock associations in time or space; instead, they are a result of solution collapse within the Redwall Limestone and stoping of the overlying strata. The pipes and associated mineralization transgress formation boundaries from the Mississippian Redwall Limestone to the Triassic Chinle Formation (fig. 1). No pipes have been observed during this study (nor during studies by Huntoon, Billingsley, and Clark (1981, 1982) and Billingsley and Huntoon (1983)) to occur in rock below the base of the Thunder Springs Member of the Redwall Limestone. The solution collapse produced extensive brecciation of the rock within the steep walls of the pipe. No rocks from underlying formations have been observed in any pipe; all material has been dropped downward into the pipe. As a result of the collapse, brecciated rock is surrounded by a steeply dipping (commonly near vertical) ring fracture that separates the breccia from the flat-lying wall rock.

The breccia pipes extend across northern Arizona to the Utah border and south to the Mogollon Rim, the southern margin of the Colorado Plateau. They are abundant from the edge of the Grand Wash Cliffs (the western margin of the Colorado Plateau), across the Hualapai Indian Reservation (which includes Mohawk Canyon), eastward across the Coconino Plateau to the Marble Plateau of the Navajo Reservation (fig. 2). No pipes are known east of the Echo Cliffs. Perhaps the area best known for breccia pipes is the Arizona Strip extending from the Grand Canyon north to the Utah border; the flurry of mining ventures, including the Hack Canyon mines and the Pigeon Mine, during the past 6 years has brought prominence to the Arizona Strip. The pipes likely exist along the southern margin of the Colorado Plateau, but for the most part are buried beneath the lavas of the San Francisco volcanic field.

Mining activity in breccia pipes of the Grand Canyon region began during the 19th century, when essentially all ore produced was for copper. It was not until the 1950's that these mines were first recognized to contain uranium mineralized rock. Metals produced from one or more pipes during the past century include Cu, U, Ag, Au, Pb, and Zn (Foord and others, 1978). Uranium ore from mines within these pipes is exceptionally high grade; 450,000 tons of ore from the Orphan Mine averaged between 0.30 and 0.60 percent U_3O_8 (Pierce and others, 1970). Other mined breccia pipes have, or had, similar uranium grade and tonnage to the Orphan Mine. These mines are presently being operated essentially for their uranium content, (uraninite is the ore mineral) although perhaps silver could be extracted as a by-product; the Orphan mine produced 81,000 oz of Ag during 1963 through 1966 (USGS file material). Analyses of uranium-mineralized rock from breccia pipes throughout the Grand Canyon region routinely yield silver concentrations of 10 to 100 ppm, with samples containing as much as 1150 ppm (35 oz/ton) (Wenrich, 1985). Minerals common in the unoxidized rock from these pipes are pyrite, marcasite, chalcopyrite, galena, sphalerite, enargite, tetrahedrite-tennantite, millerite, gersdorffite, barite, and calcite.

Dissolution of the Redwall Limestone began during the Mississippian, creating an extensive karst terrain; the Pennsylvanian Supai Group was deposited into many of these karst features. The breccia pipes include strata up through the Triassic Chinle Formation, but no pipes have been observed to extend into rocks younger than the Chinle Formation. Thus, it is probably safe to assume that the karst development in the Redwall, and hence breccia pipe formation, continued until, or at least reactivated, in the Triassic. A

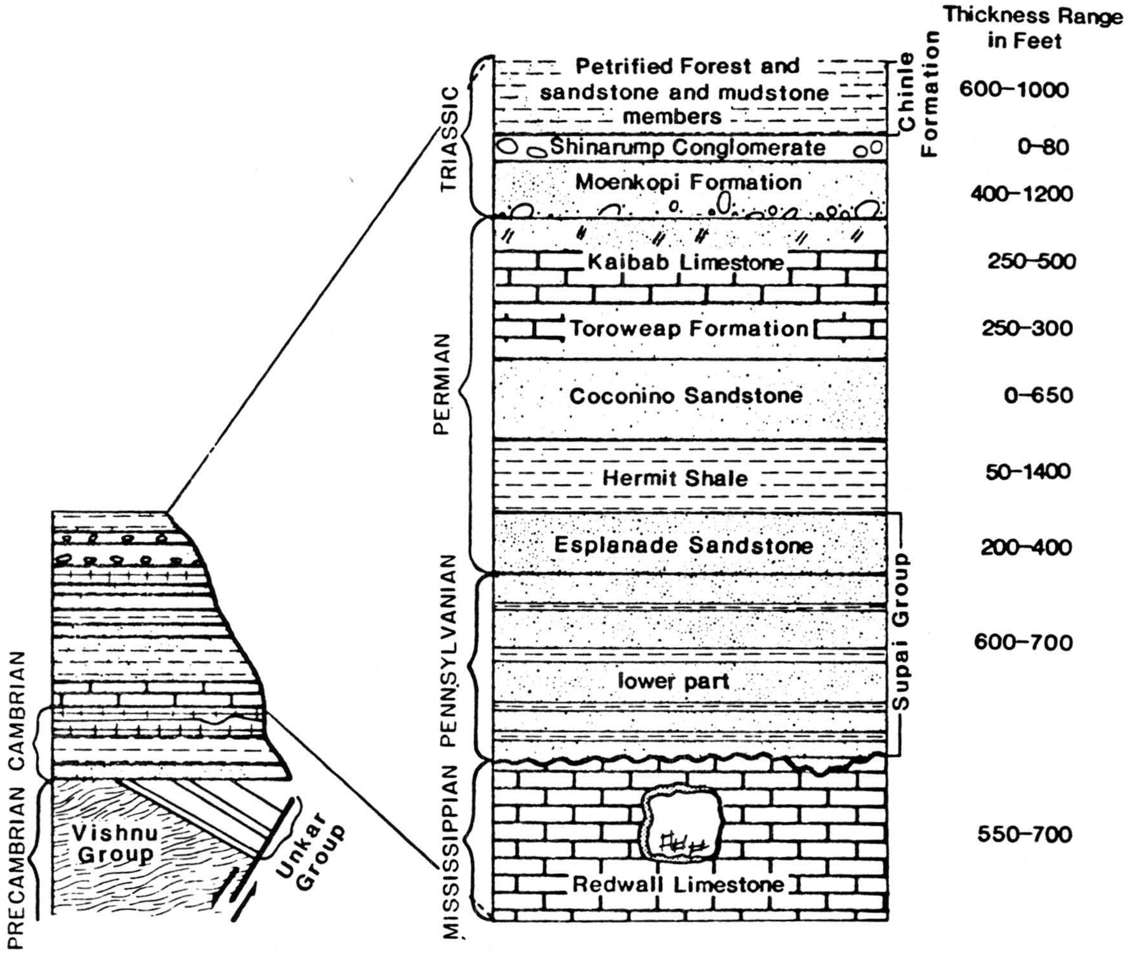


Figure 1.--Stratigraphic column showing rock units found in and near the Grand Canyon of Arizona. The thicknesses shown for each unit are those which occur over the area shown in figure 2 (thickness measurements from George H. Billingsley, personal communication).

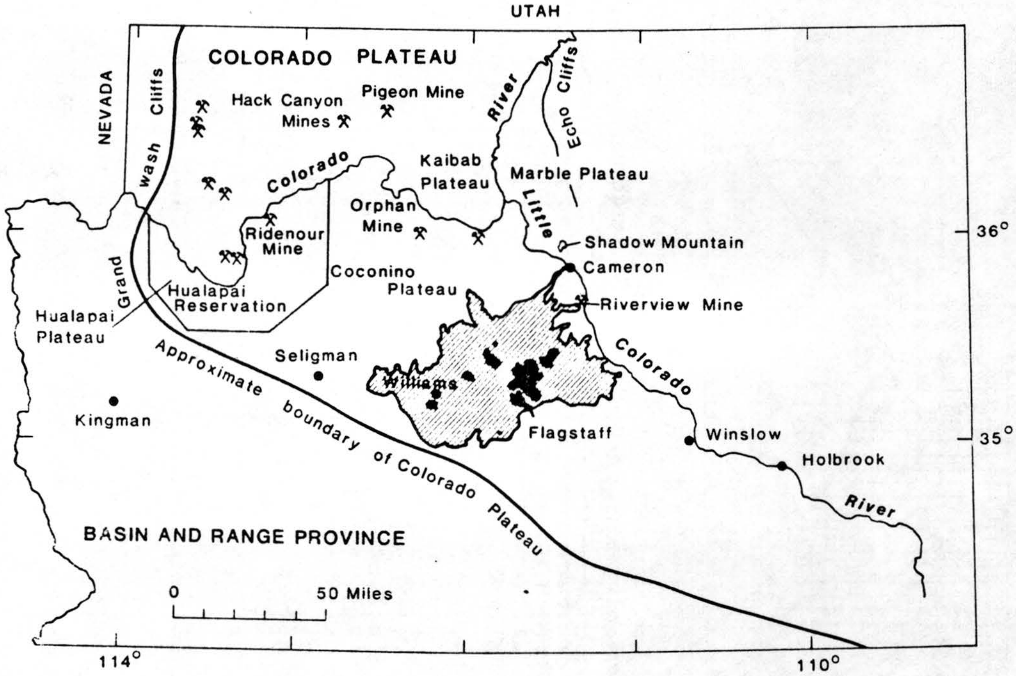


Figure 2.--Index map of northern Arizona showing the location of plateaus, Hualapai Reservation, breccia pipes developed into mines, and the San Francisco volcanic field (shaded area) which buries terrane with high potential for breccia pipes.

minimum age of 141 million years was determined for uraninite from the Orphan Mine by U/Pb dating (Gornitz and Kerr, 1970). Preliminary U-Pb isotope data for uraninite from the Hack breccia pipes suggest a main period of mineralization roughly 200 m.y. ago (Ludwig, K. R., 1983, oral commun.). Such an age is in good agreement with the break in observed mineralized rock between the Triassic and Jurassic, that is, there are known pipes with Triassic strata, but none with Jurassic or younger rock.

The geological and geochemical controls on the mineralization of these breccia pipes are poorly understood at present. A more detailed discussion on the mineralogy and geochemistry of breccia pipes in northern Arizona is provided by Wenrich (1985). There is strong evidence that the pipe location is structurally controlled on the Marble Plateau (Sutphin and others, 1983; Sutphin and Wenrich, 1983). It is also known that the pipes occur in clusters (figure 3 and Sutphin and Wenrich, 1983). This would be expected for karst formed breccia pipes exposed above underlying cave systems; where there is no cave there are no pipes. In addition, mineralized pipes occur in clusters (see the Bat Cave area of fig. 3). This clustering of mineralized pipes is especially obvious in the area of Hack Canyon where the Hack I, II, III, and old Hack Canyon Mines (4 separate pipes) all occur within a square mile (3 sq km) of each other. This suggests that the mineralizing fluids used a hydrologic system that connected multiple pipes and moved through those pipes connected by the same cavern; each mineralized cluster of pipes probably represents one Redwall Limestone cave system.

An extensive suite of elements is anomalously concentrated in mineralized rock within breccia pipes throughout northern Arizona. This association is remarkably consistent from pipe to pipe: Ag, As, Ba, Cd, Co, Cr, Cs, Cu, Hg, Mo, Ni, Pb, Sb, Se, Sr, U, V, Zn, and less commonly, the rare-earth elements. In addition to this suite of elements, a black glassy bitumen material is found associated with the brecciated rock in many of the mineralized pipes, including the Mohawk Canyon Pipe discussed in this report. This material appears to have solidified after its included blebs and veins of such minerals as pyrite, barite, and quartz. Samples from the breccia pipes containing pyrite and bitumen are visually indistinguishable (fig. 4a) from samples collected from Mississippi Valley deposits (fig. 4b).

Primary and secondary fluid inclusions in sphalerite, quartz, calcite, and dolomite yield filling temperatures in the range of 80°-173°C. Salinities in sphalerite are consistently above 10 wt. % NaCl equivalent. Secondary inclusions in sphalerite range from 86° to 173°C, while the few positively identified primary inclusions tend to be lower temperature, 80°C to 105°C. Primary inclusions in dolomite range from 105° to 161°C with high salinities, consistently greater than 17 wt. % NaCl equivalent. Two groups of primary inclusions in quartz were found in a silicified breccia spire, one group ranged from 91° to 107°C and the other from 256° to 317°C. These fluid inclusion filling temperatures and salinities are in agreement with those of 80°-137°C found in sphalerite from Mississippi Valley-type deposits (Hagni, 1983). Although this suggests a moderately low temperature fluid for the genesis of minerals such as sphalerite and galena, and the Co and Ni phases, it does not preclude the uraninite coming from a later different mineralizing fluid, as there are no known uranium occurrences in Mississippi Valley deposits (D. L. Leach, personal communication, 1985).

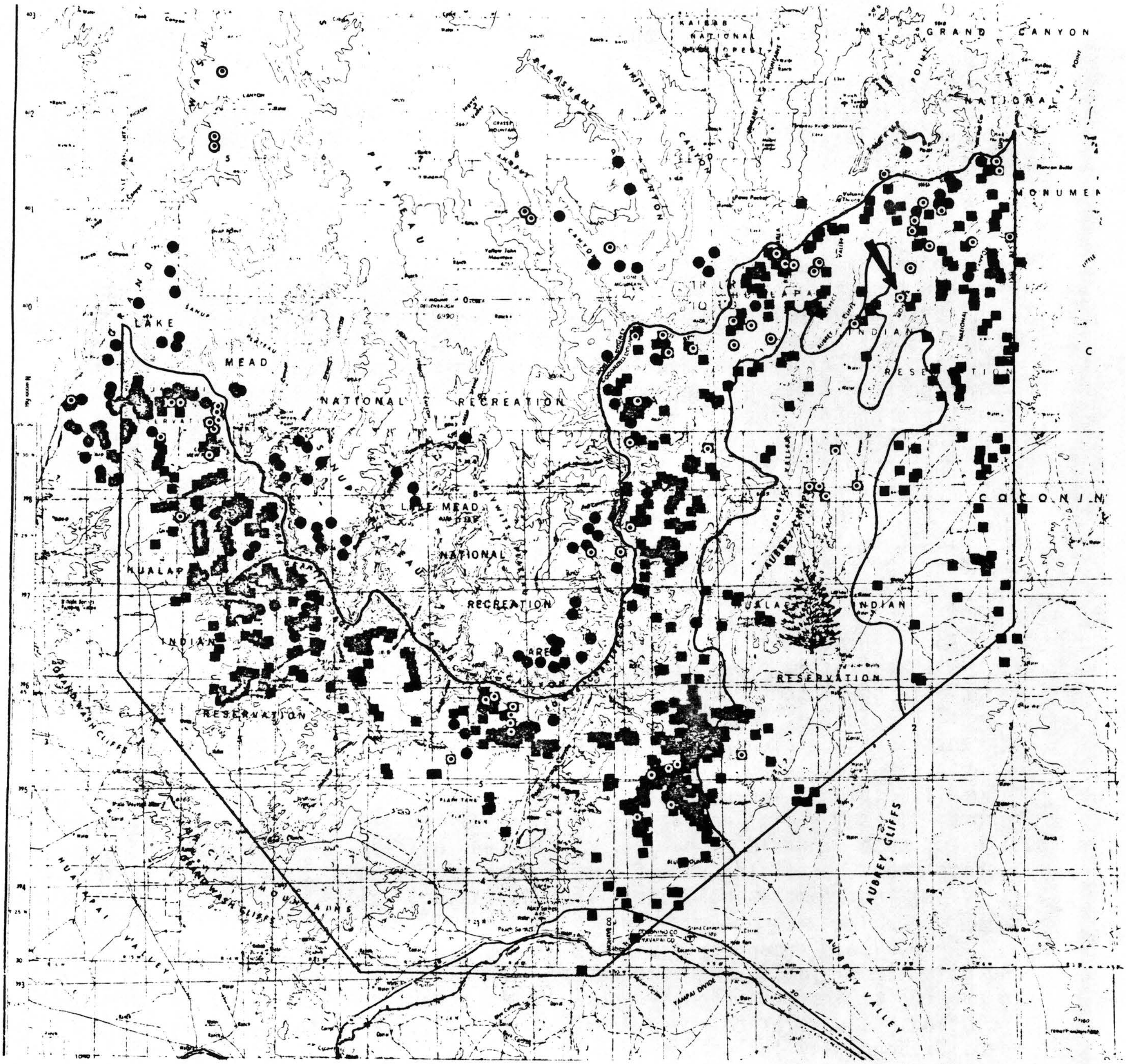
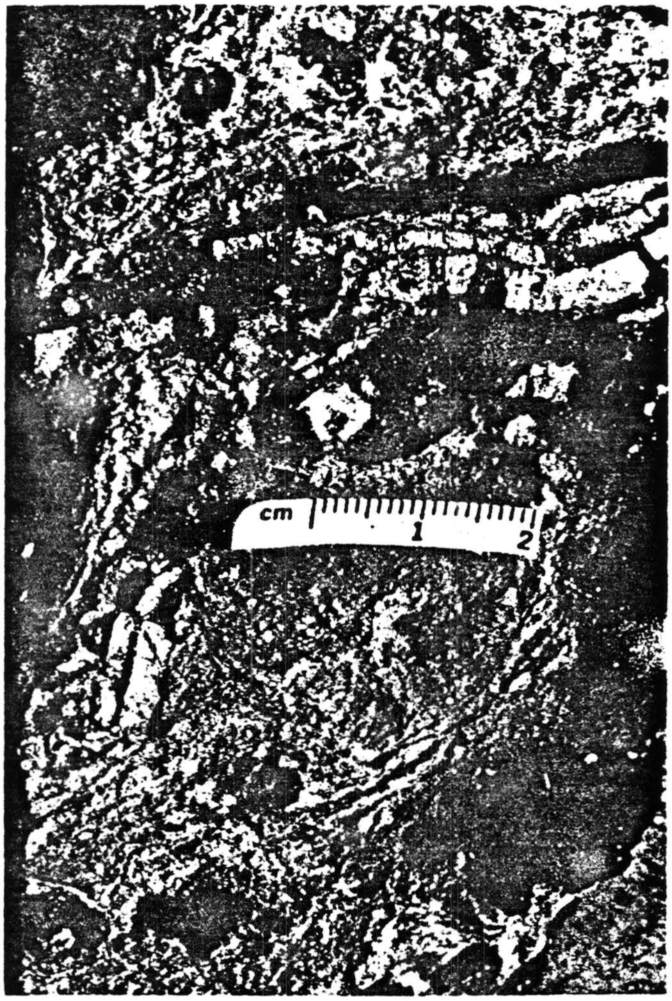


Figure 3.--Over 700 confirmed and suspected breccia pipes have been mapped on the Hualapai Reservation during the past 3 years. The western side has sparse vegetation which is reflected in the greater density of collapses. This area provides an example of the solution collapse density when detailed mapping is completed.
Mapped by G. H. Billingsley. Mapped during this study.
Mineralized pipe. Area outlined in black (shown with a tree symbol in the center) on east side of map is densely tree covered, preventing recognition of most pipes. The Mohawk Canyon pipe is marked by the arrow.

a.



b.

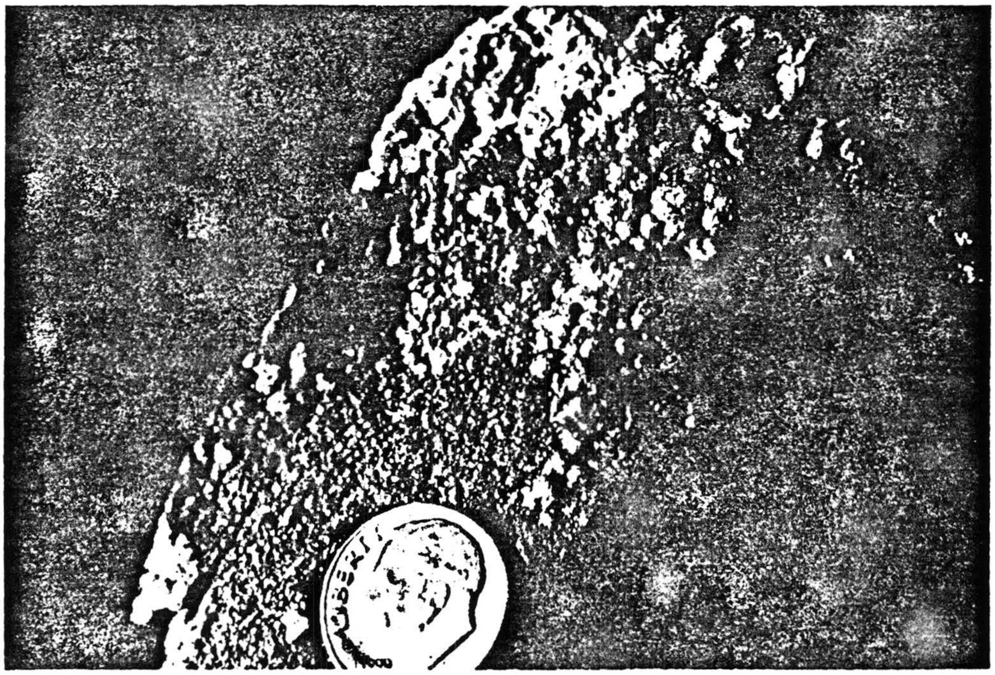


Figure 4.--Glassy organic material (bitumen) collected from (a) breccia pipes in northern Arizona looks similar to that collected from (b) Mississippi Valley type deposits (specimen of D. L. Leach).

PIPES ON THE HUALAPAI INDIAN RESERVATION

The Hualapai Indian Reservation is situated on the southwestern corner of the Colorado Plateau (fig. 2). The western half of the reservation is located on the Hualapai Plateau capped by the Redwall Limestone. This provides no more than 500 ft (175 m) of possible rock (vertically) to host an orebody, and in general the Redwall Limestone is not as favorable a host for uranium mineralization as are the overlying sandstones. Thus, this area is not considered favorable for economic breccia pipes, and was eliminated for potential drilling targets. In contrast, the eastern part of the reservation occupies the western edge of the Coconino Plateau which is capped, for the most part, by the Harrisburg Gypsiferous Member of the Kaibab Limestone. This provides a potential column of brecciated rock in excess of 2500 ft (800 m) high, and places the top of the mesas in the eastern part of the reservation at the same stratigraphic horizon as that above most breccia pipes hosting orebodies in northern Arizona.

Over 700 confirmed and suspected breccia pipes have been mapped on the Hualapai Reservation during the past 3 years (fig. 3). This density of collapse features is not unique to the Hualapai Reservation, the western edge of this pipe-rich region, but extends eastward where a similar concentration has been mapped on the Marble Plateau (Sutphin and Wenrich, 1983). Many exploration criteria for detecting mineralized breccia pipes were developed during the mapping. Mapping was begun on 1:24,000 color aerial photography, and then field checked. Many pipes exposed in the cliffs are not recognizable on the aerial photographs and are best spotted from a helicopter. One such pipe discovered, while mapping from the helicopter, on the west side of Mohawk Canyon in 1983, was selected for exploratory drilling in 1984 because it exhibited the following exploration criteria:

1. Concentrically inward-dipping beds of Kaibab Limestone (fig. 5).

2. A circular erosion pattern with erosion preferentially occurring along an encircling ring fracture.

3. Anomalous radioactivity: Although only 5 times background this is high for oxidized surface exposure of breccia pipes.

4. Goethite pseudomorphs and molds of pyrite.

5. Colloform celadonite-stained chalcedony.

6. Copper mineralization: expressed on surface exposure as the supergene minerals malachite, azurite, brochantite, and chrysocolla.

7. Brecciated Kaibab Limestone fragments within a comminuted matrix.

8. Anomalous concentrations in surface samples of such trace elements as Ag, As, Cd, Co, Cr, Cu, Mo, Ni, Pb, Se, U, V, and Zn.

MOHAWK CANYON PIPE

Physiography and Geology

The intermittent streams of Mohawk Canyon have incised a canyon over 2000 ft (600 m) deep beneath the Kaibab Limestone surface (fig. 6). At least 15 breccia pipes (figure 4) are exposed along the cliff walls, at least 7 of which show some sign of surface mineralized rock. One of these, mapped as pipe #494 during this study and locally referred to as the Mohawk Canyon Pipe, was drilled between July and November of 1984. Five holes were drilled into this pipe; two rotary drilled from top to bottom, one cored from top to bottom, and two rotary drilled to an approximate depth of 900 ft (300 m) and cored to bottom. The pipe is located in the SW 1/4 of Section 26, Township 32 North, Range 7 West of the Vulcan's Throne S.E. 7 1/2' quadrangle, Coconino County, Arizona (latitude: 36°07'30", longitude: 113°00'24") (fig. 7).

The pipe is exposed on two sides along the cliff of Mohawk Canyon and a side tributary, which provides a three-dimensional exposure of the upper 160 ft (50 m) of the pipe (fig. 5). The pipe is collared in the Harrisburg Gypsiferous Member of the Permian Kaibab Limestone (fig. 8), approximately 2500 ft (770 m) stratigraphically above the Redwall Limestone. A sheer cliff, formed by the Fossil Mountain Member of the Kaibab Limestone, 160 ft (50 m) below the rim of the canyon prevents access to the formations outcropping below.

At the surface, the Mohawk Canyon pipe is approximately 400 ft (125 m) in diameter. At least three concentric ring fractures bound the pipe (fig. 8). The innermost ring fracture is vertical, displays the most downward displacement, and forms the contact between a subhorizontal to shallowly dipping central plug of strata and the concentrically dipping outer beds. Outward from the innermost ring fracture, adjacent concentric ring fractures display shallower dips and less downward displacement away from the center of the pipe. Mapping and drilling data indicate that the overall downward displacement at the center of the pipe is approximately 100 ft (30 m). Several near vertical radial normal and reverse faults extend from outside into the central part of the pipe, cutting and displacing the ring fractures. These faults are later than the formation of the ring fracture and breccia pipe. Movement along these faults is less than that along the ring fracture.

Copper- and uranium-mineralized rock is exposed in outcrop along the eastern side of the pipe and occurs on, or immediately adjacent to, the ring fractures. Two adits (fig. 9) were driven into the Mohawk Canyon Pipe just above the sheer cliff on the east side of the pipe (fig. 8). They are located directly on the outermost ring fracture and extend back into the shear zone of the pipe about 20 ft (6 m). There is no known written record of this mining venture, although the former Hualapai Tribal Planner, Herb Voight, suggested that these might be the "lost turquoise mines of Mohawk Canyon" of which he had heard rumors. The presence of square nails used in the timbers suggests the mining activity probably occurred before the turn of the century. Samples removed from the adit and scattered about on the ground contain malachite, azurite, chrysocolla (perhaps mistaken for turquoise), bitumen, and minor uranium mineralization (sample 494-C-C83 location is shown on fig. 8). An exposure of fault gouge located due west of the adits, on the next inward ring fracture, yields gamma-ray counts 12 times background. Along this same zone are numerous cubes of limonite pseudomorphed after pyrite, interspersed with pyrite casts.

a.

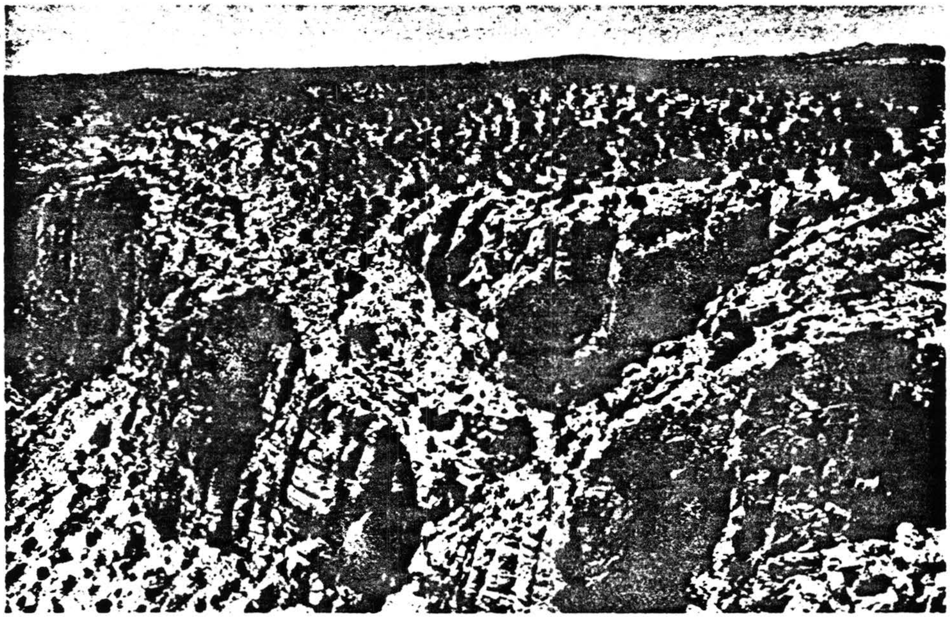


Figure 5.--Mohawk Canyon Pipe (photo taken looking west from Mohawk Canyon). Note the beds of Kaibab Limestone dipping in toward the center from both sides and the drainage eroded along the ring fracture.

b.

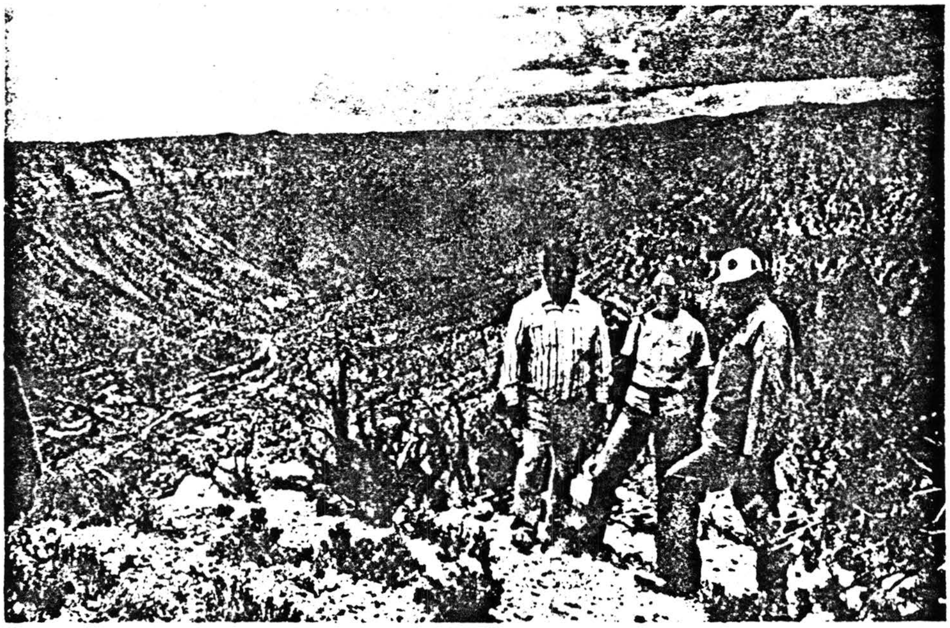


Figure 6.--Looking south at 2000 ft of sedimentary rock exposed along the fault controlled Mohawk Canyon. Edgar Walema (Hualapai Tribal Chairman) on right, Justin Powski (Hualapai Tribal councilman) on left, and Karen Wenrich (USGS geologist) in center.

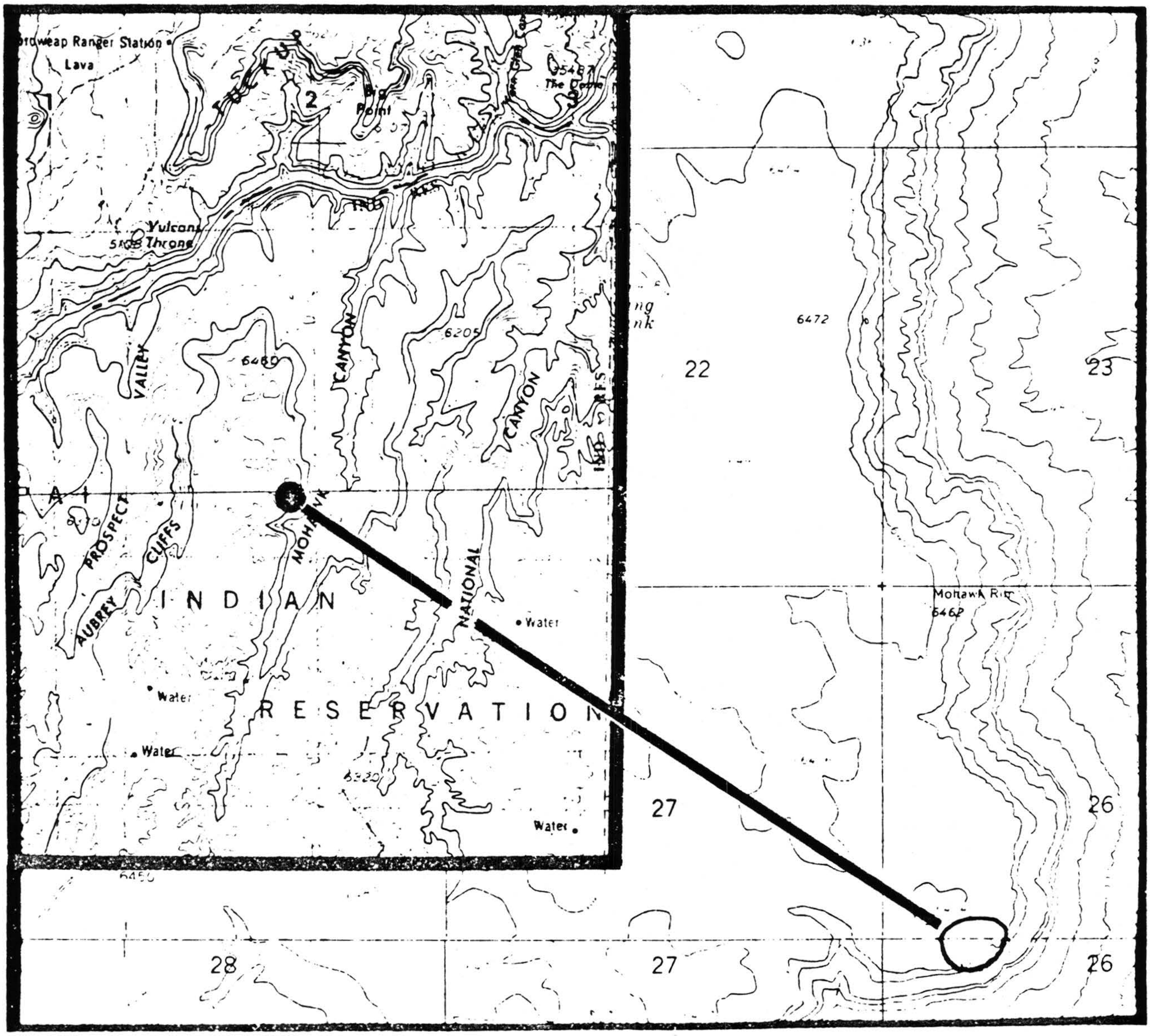


Figure 7.--The Mohawk Canyon pipe is located on the boundary between the Vulcan's Throne and Vulcan's Throne SE 7 1/2 ' quadrangles (each section is 1 sq mi). The inset (smaller scale map) map is from the Grand Canyon 2° quadrangle. North is up. Refer back to figures 2 and 4 for smaller scale locations.

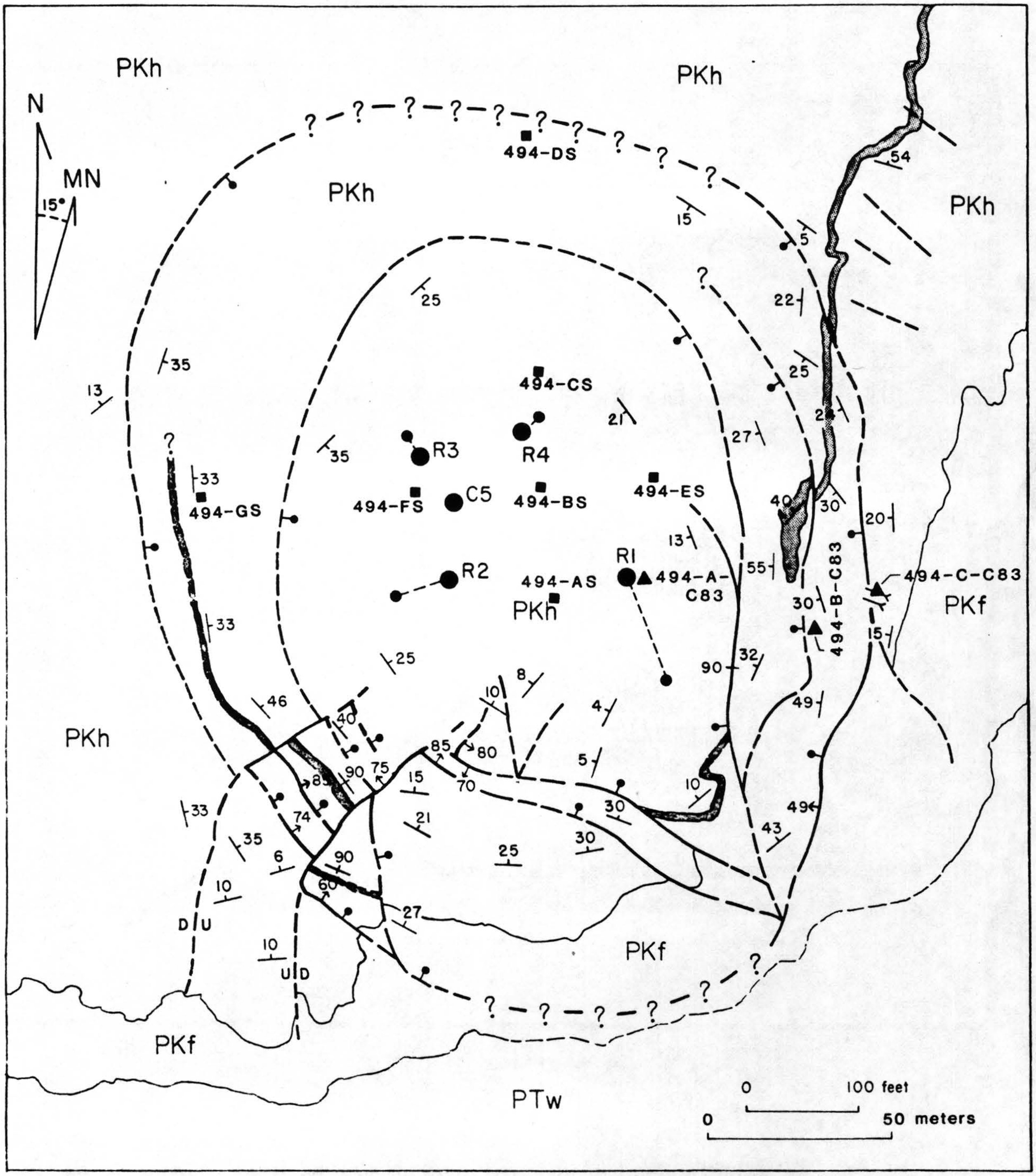


Figure 8a.--Geologic Map of the Mohawk Canyon Pipe.

494-BS
Center of pipe

Index to Geologic Map of Mohawk Canyon Pipe

PKh		Permian Kaibab Limestone, Harrisburg Gypsiferous Member- calcareous siltstone and fine-grained sandstone with minor micritic limestone. Very pale orange. Thin-bedded to massive. Contains an 8 foot thick marker bed composed of chert and chert breccia cemented by finely crystalline calcite. Forms alternating ledges and slopes. Approx. 62 meters(200 feet) thick
PKf		Permian Kaibab Limestone, Fossil Mountain Member - very finely crystalline limestone containing abundant concentrically laminated chert nodules approx. 10 cm. in diameter. Light brownish gray. Massive. Approx. 74 meters(240 feet) thick.
PTw		Permian Toroweap Formation, Woods Ranch Member - calcareous sandstone and siltstone with minor micritic limestone and gypsum interbeds. Pale red to grayish orange. Thin-bedded. Approx. 62 meters(200 feet) thick.
	?	Contact - dashed where inferred, queried where uncertain.
	65 ?	Surface trace of normal fault - showing dip of fault surface. Ball and bar on downthrown side. Dashed where inferred, queried where uncertain.
	U 74 D	Surface trace of reverse fault - showing strike and dip of fault surface. U on upthrown side, D on downthrown side. Dashed where inferred.
	25	Strike and dip of beds.
	BOTTOM R2 TOP	Drill holes with bottom location in map view.
		Adit
		Marker bed in Harrisburg Gypsiferous Member of Kaibab Limestone
	▲	Surface rock sample location
	■	Soil sample location

Figure 8b.--Index to the Geologic Map of the Mohawk Canyon Pipe.

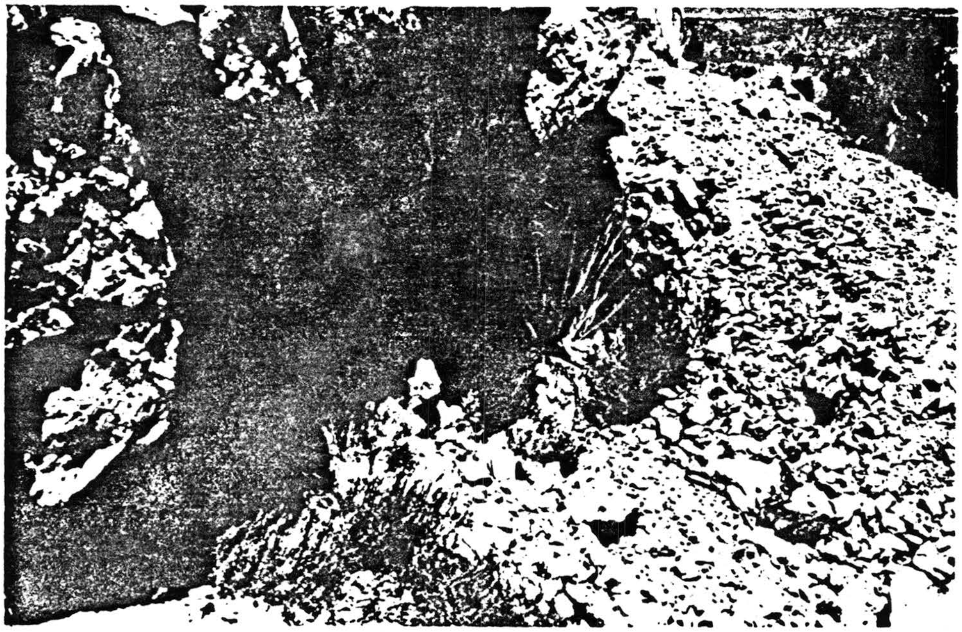


Figure 9.--Two adits were driven into the west side of Mohawk Canyon, probably sometime during the 19th century. These adits are located on the outermost east ring fracture of the Mohawk Canyon Pipe, and extend back into the pipe about 20 ft (6 m).

Geochemistry of Surface Samples

Surface samples taken from the Mohawk Canyon Pipe contain an identical a suite of anomalous elements similar to that found in mineralized breccia pipes throughout northern Arizona (Wenrich, in press). Table 1 shows 55 elements for each of three samples collected during 1983 when the pipe was discovered. Sample 494-A-C83 was collected from near the center of the pipe, on top of the plateau (near drill hole R1 on the geologic map, fig. 8). This sample is a vuggy silicified limestone with abundant celadonite-stained chalcedony. Small goethite concretions are scattered across the rock and the vugs are filled with quartz crystals. Although this is not a mineralized sample and SiO_2 makes up over 92% of this sample and Fe_2O_3 2.7%, it does contain anomalous concentrations of As, Ba, Cu, Se, V, and Zn (as compared to the average value for the Kaibab Limestone, and especially a silicified Kaibab Limestone).

Sample 494-B-C83 was collected from an outcrop of fault gouge located due west of the adits. The sample is a clay rich (as can be seen from the Al_2O_3 content of 14.4%) finely comminuted sandstone with abundant goethite concretions and bands of celadonite (the Fe_2O_3 content is 15.2%). This outcrop was 4 1/2 times background in gamma-ray counts (the uranium concentration is 17 ppm, which is approximately 4 1/2 times the average U concentration for the Kaibab Limestone).

Sample 494-C-C83 was collected from the northern-most of the two adits. It is a very fine-grained, brecciated, malachite and azurite encrusted sandstone. Gamma-ray counts from this outcrop were over 12 times background (the U content is 50 ppm, which is approximately 12 times the background U content for the Kaibab Limestone). Both samples 494-B-C83 and 494-C-C83 have enrichment ratios of over 10 (as compared to background Kaibab Limestone samples) for Ag (only 494-C), As, Ba, organic C (only 494-C), Cd, Cr, Cs (only 494-B), Cu (only 494-C), Lu, Mo (only 494-C), Ni, Pb, Sb, Se, Sm, Sr, Ta, Th (only 494-B), U, V, Zn, and Zr.

Soil Sampling Survey

Seven soil samples were collected from the Mohawk Canyon Pipe just prior to drilling; the data are shown in table 2 and the sample locations are shown on the geologic map (fig. 8). The samples were collected approximately 4 in. (1.2 cm) below the surface, although there was considerable difficulty in acquiring a sample of soil as opposed to one that was predominantly chips of Kaibab Limestone. The samples were dry sieved through 80 mesh (177 μm) stainless steel sieves to remove the large rock chips and organic debris. Two traverses were made across the pipe; unfortunately no samples were collected outside of the pipe, so there is no background for comparison. Figure 10 shows plots of these two traverses for selected elements (Co, Cr, Cu, Fe, La, Mg, Nd, P, Y, and Zn). Sample 494-BS is plotted at 0 ft, the center of the pipe, on figure 10. For some of the metallic elements, Co, Cu, and Fe, concentrations increase from the center to the outermost ring fracture, probably due to later remobilization by supergene fluids which migrated more freely along the ring fracture than in the less fractured center of the pipe. Elements such as Cr, La, Mg, Nd, P, and Y increase toward the center of the pipe. The increase in Mg over the center of the pipe is what would be expected considering the dolomitization that was observed in the drill core.

Table 1 -- Geochemistry of surface samples collected from Mohawk Canyon Pipe
[The first 3 digits of the sample number are the Mohawk Canyon Pipe number]

Sample #	Ag ppm ICP	Al2O3% X-ray	As ppm AA	Au ppm	Ba ppm ICP	Be ppm ICP	Total-C% X-ray	T-Org C% X-ray
494-A-C83	<10	.49	36	-	150	<5	.17	.05
494-B-C83	<2	14.4	72	-	* 329	<5	.88	.06
494-C-C83	100	2.24	400	<.05	* 180	<5	1.58	.57

Sample #	T-CO3 C%	CaO% X-ray	Cd ppm ICP	Ce ppm ICP	Co ppm ICP	Cr ppm ICP	Cs ppm AA	Cu ppm ICP	Dy ppm ICP	Er ppm ICP
494-A-C83	.12	.63	10	<20	<5	31	<1	40	<20	<20
494-B-C83	.74	2.28	10	*33.2	* 5.32	*110	*11.4	20	<20	<20
494-C-C83	1.01	2.8	30	*26.5	*11.9	*244	* 1.27	14000	<20	<20

Sample #	Eu ppm ICP	F%	T-Fe2O3% X-ray	Ga ppm ICP	Gd ppm ICP	Hf ppm INAA	Hg ppm AA	K2O% X-ray	LOI-900 X-ray	La ppm ICP
494-A-C83	<10	.01	2.68	<20	<50	-	.0500	.07	1.25	<10
494-B-C83	* .51	.33	15.2	<20	<50	7.46	.2000	4.6	11.5	* 19.3
494-C-C83	* .67	.16	18	<20	* 3.5	2.81	.3000	.35	12.2	* 27.4

Sample #	Li ppm AA	Lu ppm ICP	MgO% X-ray	Mn ppm ICP	Mo ppm ICP	Na2O% X-ray	Nb ppm ICP	Nd ppm ICP	Ni ppm ICP	P2O5% X-ray
494-A-C83	7	-	.23	40	<10	.08	<20	<20	20	.16
494-B-C83	99	.51	3.94	60	<10	* .35	<20	* 16.1	130	.45
494-C-C83	10	.18	2.34	70	140	* .92	<20	13.7	70	1.47

Sample #	Pb ppm ICP	Rb ppm AA	Total-S%	Sb ppm INAA	Sc ppm ICP	Se ppm AA	SiO2% X-ray	Sm ppm ICP	Sr ppm ICP	Ta ppm ICP
494-A-C83	50	<10	.01	-	<10	1.5	92.3	<50	20	<200
494-B-C83	130	*107	.02	2.22	* 8.86	4.6	45.5	* 2.96	870	* 1.32
494-C-C83	12000	* 13	.22	106	* 2.4	350	53.7	* 3.62	1600	* .26

Sample #	Tb ppm ICP	Th ppm ICP	TiO2% X-ray	Tm ppm ICP	U ppm DN	V ppm ICP	Y ppm ICP	Yb ppm ICP	Zn ppm AA	Zr ppm INAA
494-A-C83	<100	<20	<.02	-	4.99	60	<10	<5	440	-
494-B-C83	* .37	* 14.8	.5	.46	16.7	90	20	* 3.37	* 1740	238
494-C-C83	* .45	* 3.03	.16	.22	49.5	290	20	* 1.29	*12000	-

* INAA data
INAA-Induced Neutron Activation Analysis
ICP-Inductively Coupled Argon Emission Plasma Spectroscopy
AA-Atomic Absorption
DN-Delayed Neutron
X-ray-X-ray Fluorescence

Table 2 -- Geochemistry of soil samples collected from Mohawk Canyon Pipe
[The first 3 digits of the sample number are the Mohawk Canyon Pipe number]

Sample #	Al % ICP	As ppm ICP	Ba ppm ICP	Be ppm ICP	Ca % ICP	Ce ppm ICP	Co ppm ICP	Cr ppm ICP
494-A-SC84	3.2	<10	330	<1	10	41	7	170
494-B-SC84	2.3	<10	260	<1	12	34	4	150
494-C-SC84	3.4	<10	330	<1	9.9	41	8	99
494-D-SC84	4.3	<10	450	1	9	47	11	72
494-E-SC84	3.1	<10	310	<1	9.4	38	7	110
494-F-SC84	2.4	<10	370	<1	13	33	6	140
494-G-SC84	4.5	<10	450	1	.89	61	11	63

Sample #	Cu ppm ICP	Fe % ICP	Ca ppm ICP	K % ICP	La ppm ICP	Li ppm ICP	Mg % ICP	Mn ppm ICP	Na % ICP
494-A-SC84	19	1.5	8	1.1	49	21	4.4	360	.33
494-B-SC84	11	1	5	.87	47	16	4.3	310	.23
494-C-SC84	20	1.6	7	1.2	38	19	4.2	460	.36
494-D-SC84	22	2	11	1.6	31	26	2	470	.41
494-E-SC84	17	1.4	7	.97	36	20	3.9	430	.32
494-F-SC84	16	1.1	7	.89	38	17	4.7	290	.26
494-G-SC84	17	2.1	11	1.4	36	31	.56	400	.59

Sample #	Nb ppm ICP	Nd ppm ICP	Ni ppm ICP	P % ICP	Pb ppm ICP	Sc ppm ICP	Sr ppm ICP	Th ppm ICP	Th ppm DN	Ti % ICP
494-A-SC84	7	34	23	1.1	13	5	300	<4	7.7	.16
494-B-SC84	7	41	12	1.4	10	4	290	5	6.4	.11
494-C-SC84	9	31	18	.7	16	5	260	5	6.92	.17
494-D-SC84	7	28	34	.19	16	6	240	5	4.8	.23
494-E-SC84	8	28	15	.79	16	5	270	<4	4.7	.16
494-F-SC84	<4	32	19	1	11	3	320	<4	3.9	.13
494-G-SC84	7	31	21	.07	16	7	130	12	11.5	.3

Sample #	U ppm DN	V ppm ICP	Y ppm ICP	Yb ppm ICP	Zn ppm ICP
494-A-SC84	4.17	40	49	3	84
494-B-SC84	3.94	31	56	3	60
494-C-SC84	3.25	41	34	2	77
494-D-SC84	3.3	51	21	2	68
494-E-SC84	3.58	36	35	2	72
494-F-SC84	3.81	31	44	2	74
494-G-SC84	3.68	49	22	2	55

ICP-Inductively Coupled Argon Emission Plasma Spectroscopy
DN-Delayed Neutron

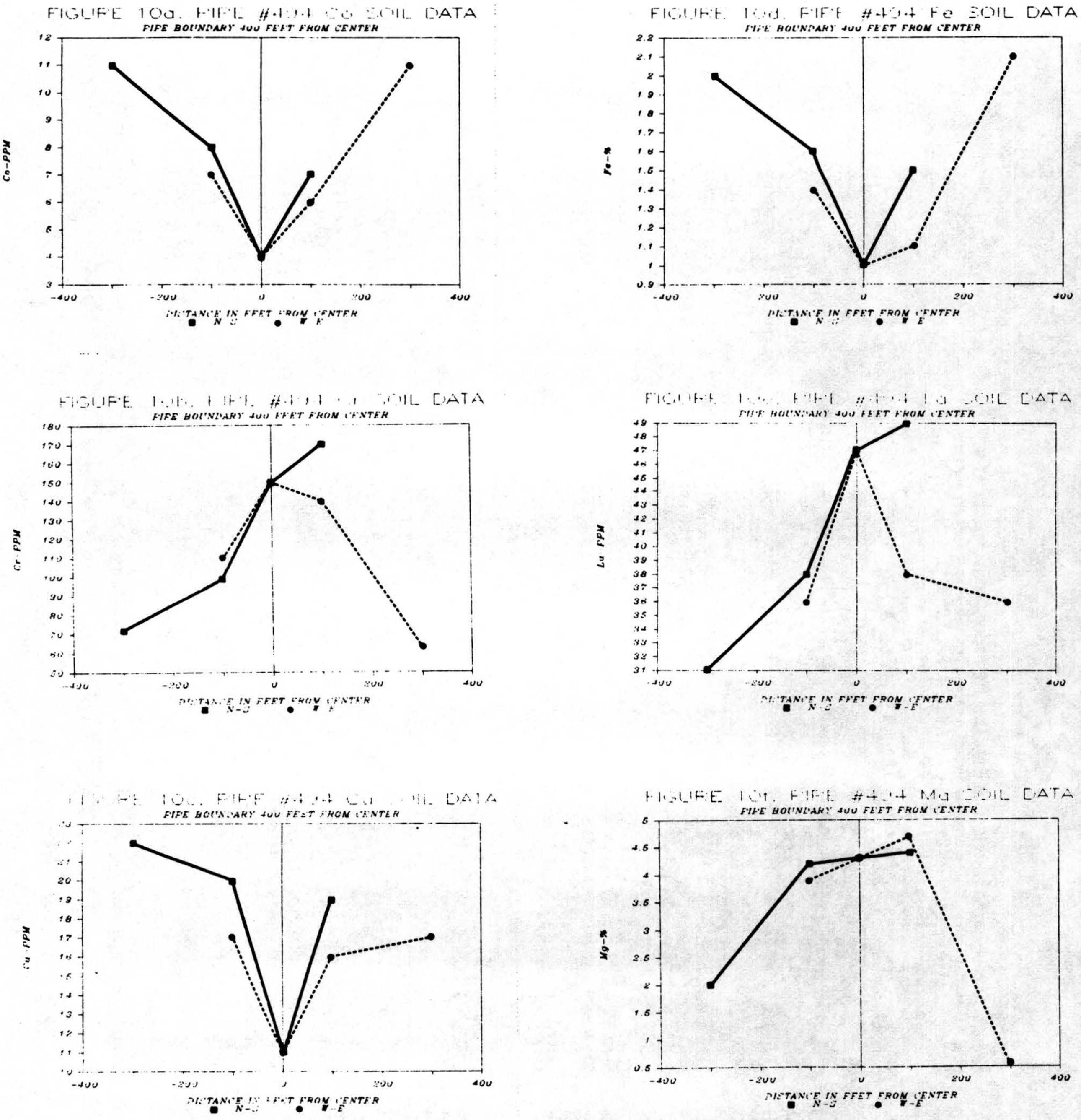


Figure 10.--Plots of results from a soil sampling survey for Cr, Co, Cu, Fe, La, Mg, Nd, P, Y, and Zn. Element concentration is shown versus distance from the center of the pipe.

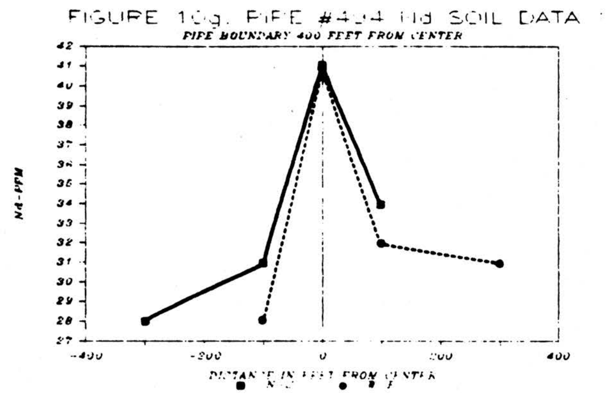
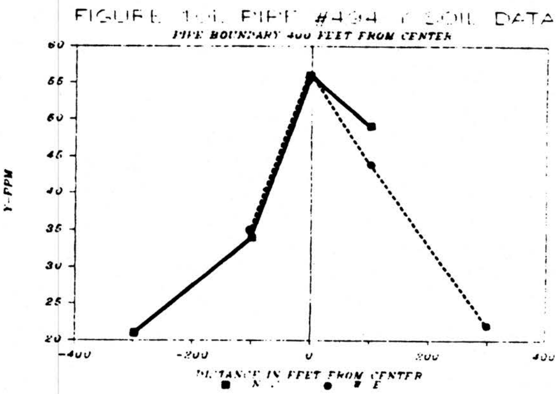
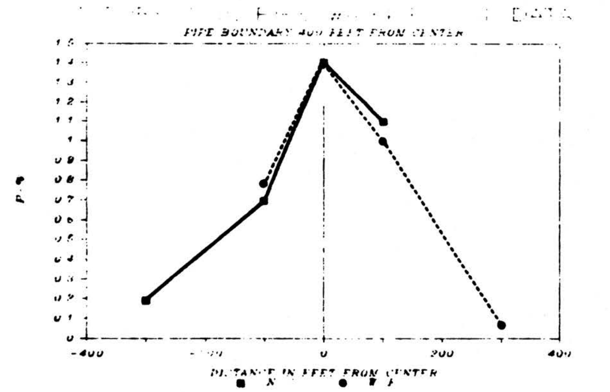
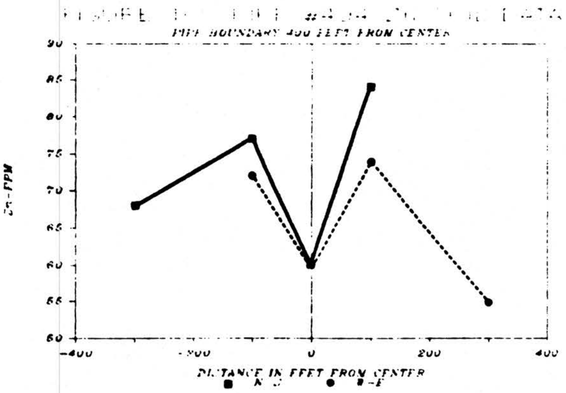


FIGURE 10g. PIPE #404 Na SOIL DATA
PIPE BOUNDARY 400 FEET FROM CENTER
NA-PPM
DISTANCE IN FEET FROM CENTER


PIPE BOUNDARY 400 FEET FROM CENTER
Y-PPM
DISTANCE IN FEET FROM CENTER


PIPE BOUNDARY 400 FEET FROM CENTER
DISTANCE IN FEET FROM CENTER


PIPE BOUNDARY 400 FEET FROM CENTER
DISTANCE IN FEET FROM CENTER

Although more soil samples, particularly background samples, are desirable, the concentration of these elements, particularly Zn, in the soil above the Mohawk Canyon Pipe are relatively higher than the background soils on this same plateau several miles away.

DRILLING RESULTS

Five holes were drilled into the Mohawk Canyon Pipe (fig. 11). Their collar locations and drifts are shown on figure 8. Hole 1 (R1) was rotary drilled to a total depth of 1120 ft (345 m); drill cuttings were recovered from top to bottom. Drilling was discontinued at 1120 ft (345 m) because the cuttings became oxidized and it was assumed that the hole had drifted out of the reduced and potentially mineralized part of the pipe. The hole was originally begun with a tri-cone tooth bit, but when drift exceeded the 5° limitation that had been placed on the drillers by the U.S. Geological Survey contract, the bit was switched to a hammer.

Hole 2 (R2) was also a rotary hole drilled to a total depth of 1335 ft (411 m); a hammer bit was used on the entire hole and produced cuttings to 870 ft (268 m), at which point circulation was lost and minor cuttings were available to 975 ft (300 m). Cuttings were again recovered from this point until a depth of 1020 ft (314 m), after which circulation was lost again and never recovered. The drillers refused to drill deeper without a pipe guarantee.

Hole 3 (R3) was rotary drilled to a depth of approximately 1014 ft (313 m), at which point coring began and continued until 1421 ft (437 m). The bottom 84 ft (26 m) were no longer reduced or brecciated, and appeared to be undisturbed Hermit Shale. Therefore, it was assumed that the hole was no longer in the pipe, and the drilling was stopped.

Hole 4 (R4) was rotary drilled to a depth of 1001 ft (308 m) with circulation lost below 855 ft (263 m). Coring began at 1001 ft (308 m), at the base of what the drillers interpreted to be a 30 ft (9 m) cavern, and continued to 1008 ft (310 m) where oxidized rock was encountered and the drill string, along with 900 ft (277 m) of casing, plummeted into a 40 ft (12 m) high cavern. The hole, drill string, and casing were lost.

Hole 5 (C5) was cored to a total depth of 1012 ft (311 m), at which point the project ran out of money and drilling was terminated. With the exception of hole 1 the drift of the holes was minor, although as is common for these pipes, all holes drifted toward the outside of the pipe.

Lithologic Logs

Lithologic and geophysical logs for the five drill holes are shown in appendices 1-5. Because most of the holes penetrated brecciated rock as opposed to the normal stratigraphic sequences, the formation contacts were placed at levels where the first clasts were observed that could be recognized as belonging to the next formation in question. In most cases, it was impossible to determine from the chip samples whether or not the rock was brecciated. The contact between the Kaibab Fossil Mountain Member and the underlying Toroweap Woods Ranch Member was difficult to determine from the breccia, as most of the Woods Ranch Member appears to have been removed by

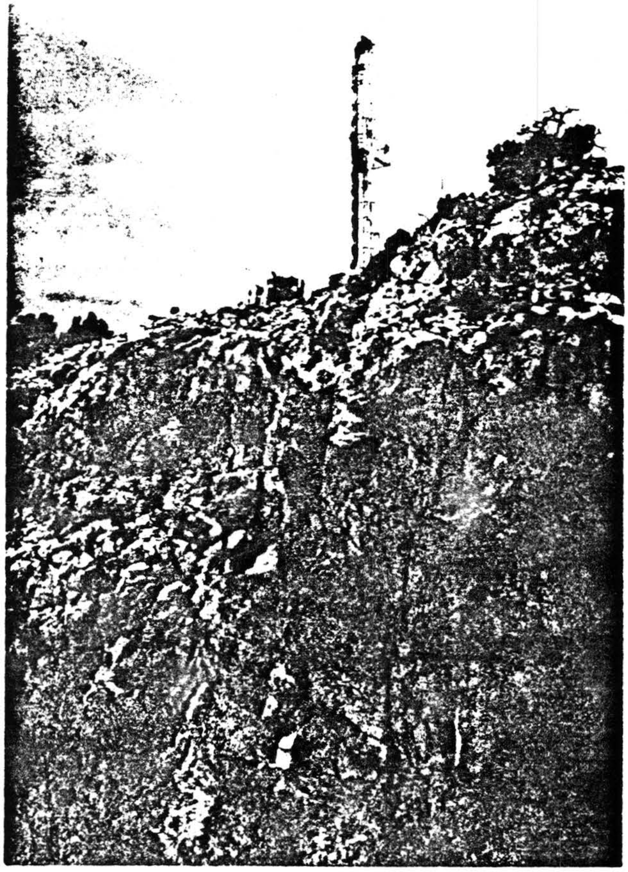


Figure 11.--Five holes were drilled, to an average depth of 1100 ft (338 m), in the Mohawk Canyon Pipe. The eastern inner ring fracture forms this cliff of the Harrisburg Gypsiferous Member of the Kaibab Limestone. The drill rig is sitting over hole R1.

solution, and the chert fragments from the Fossil Mountain Member appear to have been carried downward as much as 600 ft (184 m). Even though the Woods Ranch Member is present along the cliffs on either side of the Mohawk Canyon Pipe, the pipe itself was apparently such an efficient conduit for fluids that the gypsum in the Woods Ranch Member has been almost totally removed.

With the exception of hole 3, all holes commonly contain celadonite in the Harrisburg Gypsiferous Member of the Kaibab Limestone, and in the upper 150 ft (46 m) of the Fossil Mountain Member of the Kaibab Limestone. Again, with the exception of hole 3, all holes have copper carbonate (azurite, malachite or both) present in the Kaibab Limestone; it appears to be particularly prevalent between about 280 ft (86 m) and 320 ft (98 m).

Hole 3 is apparently outside or at the edge of the bleached unoxidized central pipe of breccia. Pyrite does not appear to be common above 1016 ft (313 m) in hole 3, as it is in other holes. The bottom 400 ft (120 m) that was cored (below 1014 ft, 313 m), is not brecciated, and beneath 1215 ft (373 m) the core becomes typical reddish-brown Hermit Shale, with the exception of occasional reduction spots and associated blebs and veins of pyrite.

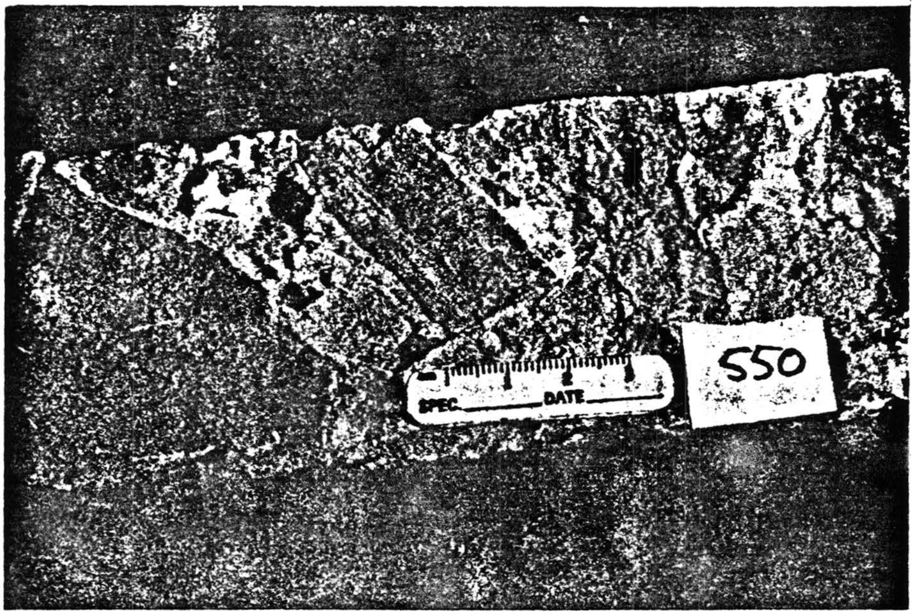
Hole 1 is apparently at the opposite (northwest) edge of the bleached unoxidized portion of the breccia pipe (fig. 8), although cuttings are bleached and contain pyrite throughout most of the hole below 635 ft (195 m). At 1085 ft (334 m) the cuttings became typical reddish-brown Hermit Shale and the hole was terminated, as it apparently either drifted out of the pipe, or at least out of the bleached/reduced zone.

Holes 2, 4, and 5 are entirely within the brecciated, reduced part of the pipe. All 3 holes encountered difficulty with lost circulation after the Coconino Sandstone was entered. Pyrite is moderately common in the cuttings and core from all 3 holes. The core from hole 5 and the 8 ft (2.5 m) of core from hole 4 were the most informative.

Hole 5 is brecciated from 125 ft (38 m) to the bottom of the hole (figs. 12a and 12b). In addition, at 969 ft (298 m) the movement of iron oxides was sufficient to produce liesegang banding (fig. 13) in the porous Seligman Member of the Toroweap Formation. The core from hole 5 provides a complete observable sequence of the brecciated center of the pipe, including clasts of strata from the top of the Kaibab Limestone down to the Coconino Sandstone.

The 8 ft (2.5 m) of core at the bottom of hole 4 (1000 ft, 307 m) that was recovered just prior to losing the drill string, is probably some of the more interesting rock. The top two feet are strongly oxidized and the contact with the underlying pyrite- rich reduced rock is very sharp. This oxidation was apparently caused by later oxidizing ground water, which must have flowed through the overlying 30 ft (9 m) cavern the drillers had carefully proceeded through. The 4 in (1.2 cm) of oxidized core at the bottom of this hole should perhaps have been taken as a warning by the drillers that they were about to enter another cavern through which oxidizing ground waters must have flowed. The 6 ft (1.8 m) of reduced rock contains approximately 1-3% pyrite as specks, thin wispy veinlets, elliptical to round patches up to 2 inches (6 cm) long, and as disseminated grains throughout the sandstone matrix. Several vugs, especially at 1007 ft (310 m) contain galena crystals. In addition, 1 mm blebs of black glassy bitumen material are scattered throughout the sandstone matrix in the reduced zone between the two caverns.

a.



b.

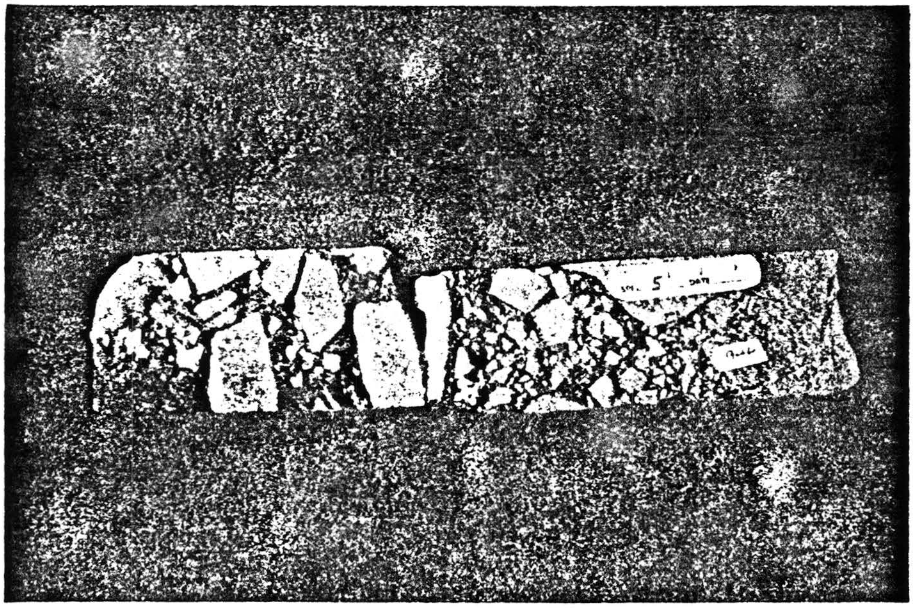


Figure 12.--Drill hole 5 is brecciated from 125 ft (38 m) to the bottom of the hole (1012 ft, 311 m). (a) Breccia at 550 ft (169 m) is comprised dominantly of fragments from the Fossil Mountain Member of the Kaibab Limestone. The Woods Ranch Member of the Toroweap has been largely dissolved out of the pipe. Although this sample is in the Woods Ranch and the matrix material is probably finely comminuted sand from the Woods Ranch, the fragments are downdropped from the Fossil Mountain Member above. (b) Sandstone breccia at 944 ft (290 m) from the Seligman Member of the Toroweap Formation.

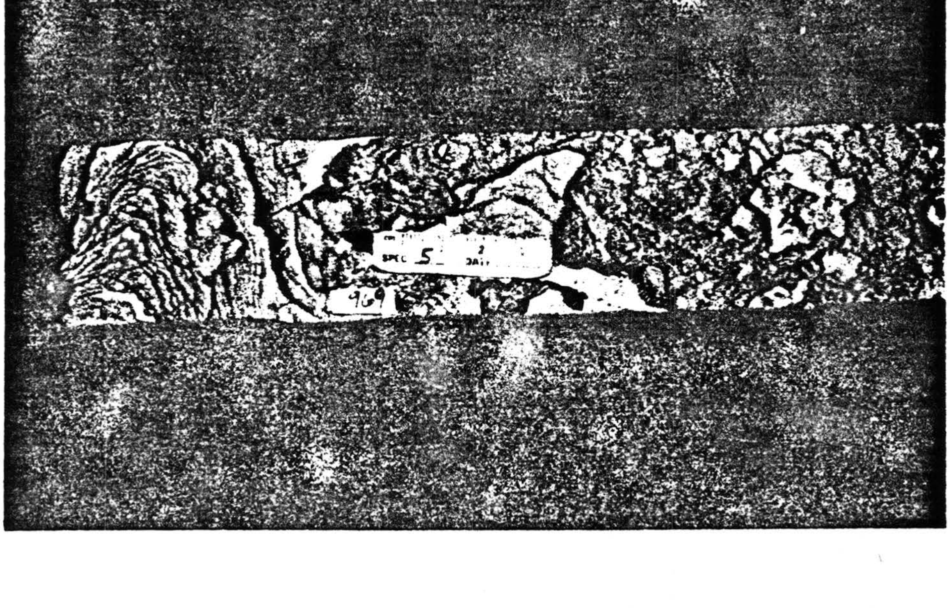


Figure 13.--At 969 ft (298 m) the movement of iron oxides within the Seligman Member breccia was sufficient to form liesegang banding.

The downward displacement in the center of the Mohawk Canyon Pipe is shown in figure 14. Here all 5 holes have been projected to one plane to illustrate the down dropping of as much as 170 ft (52 m) at the base of the Coconino Sandstone. The downward displacement becomes less toward the top of the pipe (in the Harrisburg Gypsiferous Member) because of the bulking effect. The contacts were difficult to determine in many cases, particularly where strongly brecciated and only rotary drilled chip samples (such as hole 4R), or no samples, were available. These contacts are queried in figure 14.

Geophysical Logs

Downhole geophysical logs were made of each hole. Top to bottom logs are available for holes 1 and 2, but the bottom 260 ft (80 m) in hole 3, the bottom 160 ft (50 m) in hole 4, and the bottom 234 ft (72 m) in hole 5 have no logs because the holes either caved in or were too narrow for the probe. Gamma-ray, density, and caliper logs are available for all other intervals. Magnetic susceptibility logs were also made on all holes except holes 3 and 5 (the core holes lined with steel casing). Resistivity and induced polarization logs were run in water-filled sections of the holes wherever possible, but due to the cavernous nature of the pipe, there were few holes that held water long enough so that more than the bottom 350 ft (107 m) could be logged.

The gamma logs show radiation levels below 0.002% eU_3O_8 for all holes, except hole 2 (note the gamma log scale for hole 2 is twice what it is for the other holes), and one interval around 650 ft (200 m) in all holes. At this horizon, just above the Woods Ranch-Brady Canyon contact, there is an interval of about 50 ft (15 m) in which the gamma-ray response ranges from two to four times the normal background for the hole. Thus, the gamma logs provide a good marker horizon for the base of the Woods Ranch Member. In hole 2, gamma logs from the lost-circulation portion of the hole show a one-foot interval of 0.52% eU_3O_8 at a depth of 1191 ft (366 m), underlain by a 20 ft (6 m) zone of 0.04% eU_3O_8 (fig. 15a). This is the same stratigraphic horizon as the top of the orebodies in the Hack I, II, III, and Pigeon Mines, located on similar plateaus capped with Kaibab Limestone (fig. 2).

An interesting problem in using gamma-logs to evaluate ore reserves became apparent at this horizon (fig. 15b). The initial gamma log, run just after the high grade horizon was encountered, and the drill string was removed once, is shown on the right side of figure 15b. On the left is the gamma log that resulted after the hole was completed, and the drill string had been repeatedly pulled from and put back into the hole. From this diagram the hole appears to have over 150 ft (46 m) of anomalous radiation, when, in fact, it is really 20 ft (6 m). The one-foot interval of high grade material was evidently smeared over 150 ft (46 m) of drill hole. If this contamination had not been recognized it could have resulted in an erroneously high estimate of ore reserves.

Under normal conditions density logs indicate the bulk density of the rock. However, in highly fractured rock where hole diameter increases abruptly, the density log appears to be a mirror image of the caliper log. Thus, most of the anomalously low density peaks indicate fracture zones in the breccia pipe.

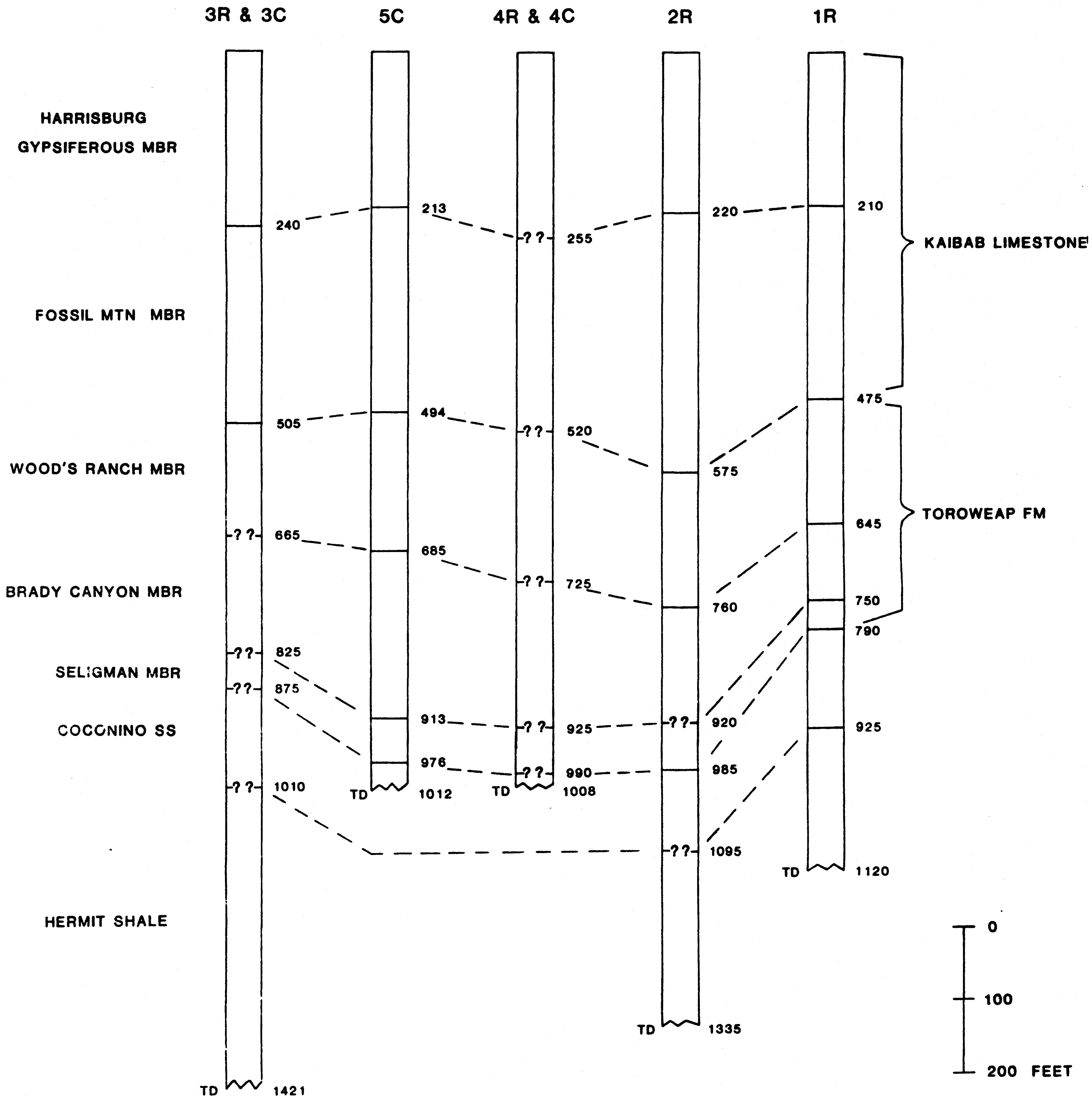


Figure 14.--Projection of the data for all 5 drill holes on to a cross section summarizing the approximate stratigraphic contacts. Note the downdropping of the strata by as much as approximately 170 ft (52 m) in the center of the pipe.

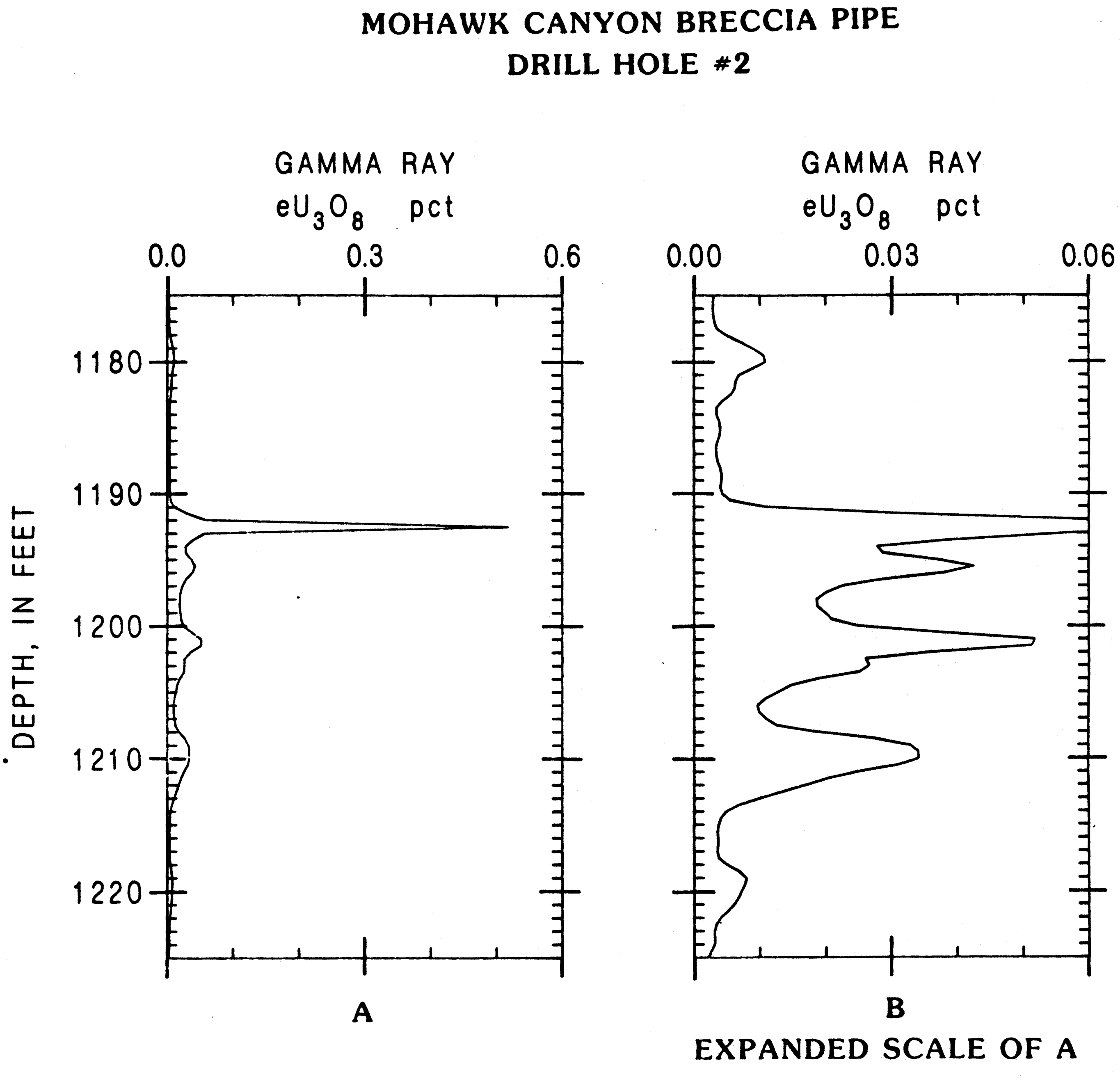


Figure 15a.--Gamma-ray log of hole 2R, 900 ft (277 m) to 1300 ft (400 m), showing a zone of high grade uranium mineralization (20 ft of average grade 0.04 with 1 ft of 0.6% eU_3O_8).

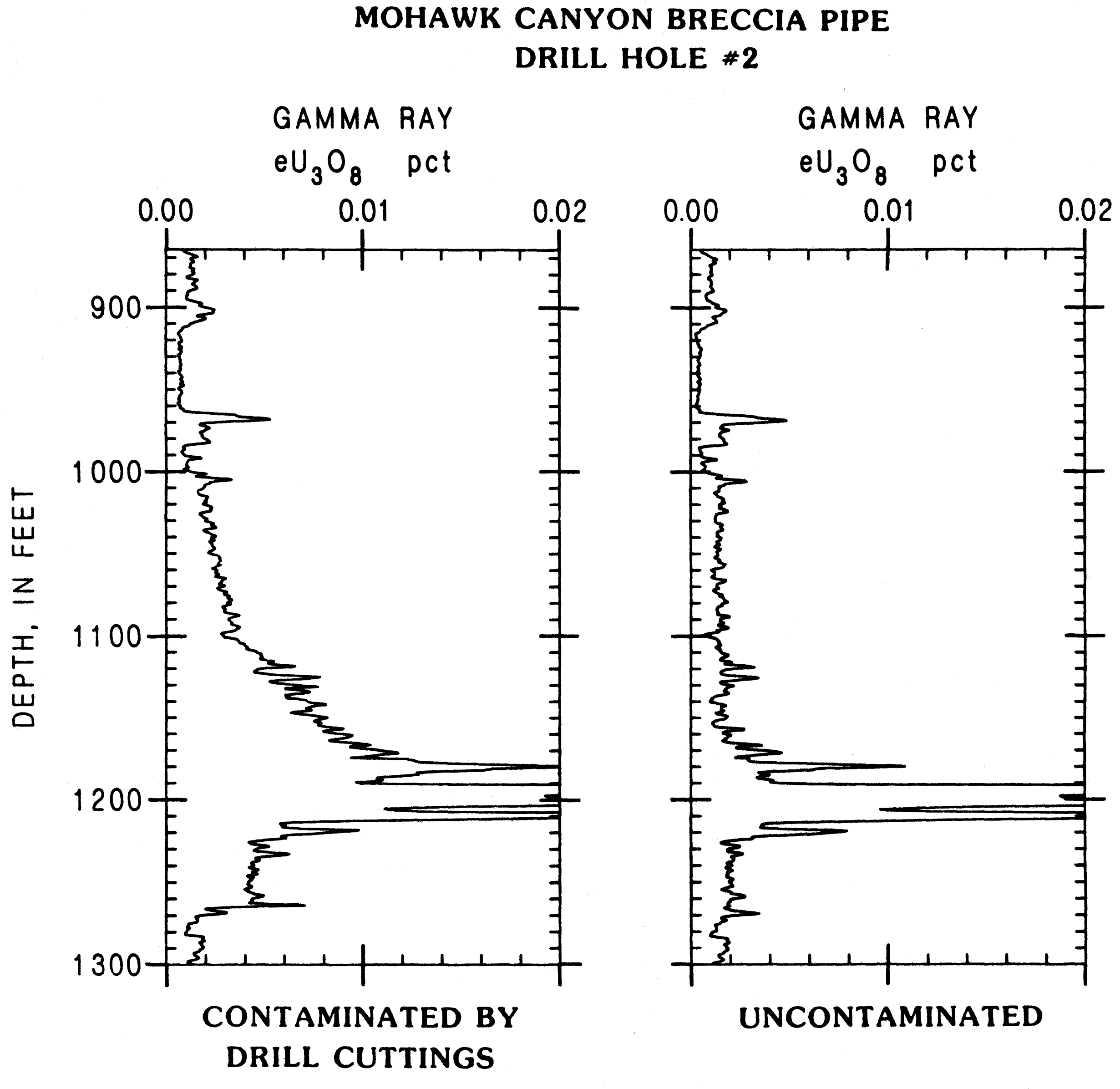


Figure 15b.--Gamma-ray logs showing the log made immediately after the high grade zone was penetrated (log on the right), and the log run after repeated trips with the drill string (log on left), which contaminated almost 150 ft of the drill hole with the higher grade cuttings. Logs such as this would result in an overestimate of ore reserves.

In general, the logs show that the magnetic susceptibility in the holes is low, which may be a reflection of the porosity of the pipe, permitting oxidizing ground waters to alter many of the ferromagnetic minerals that were originally present in the sandstones to limonite and other iron minerals with low susceptibilities. There is some suggestion that surface magnetic surveys (Senterfit and others, 1985) over breccia pipes show magnetic lows along the ring fractures where oxidizing ground waters have probably flowed. Just below the high grade uranium horizon (1191 ft, 366 m) in hole 2, the bottom 75 ft (23 m) of the hole show a significant increase in magnetic susceptibility. This suggests that the oxidizing fluids may not have penetrated this lower part of the pipe, and if an orebody did form at or below this interval, it may still be preserved.

Because of the difficulty in filling the holes with water there are few intervals with induced polarization (IP) and resistivity logs. It is fortunate that the logs are available in the high-grade uranium interval near the bottom of hole 2 where no samples were recovered due to lost circulation. The positive response of IP measurement to sulfide mineralization can be seen in hole 1 at a depth of 925 ft (285 m). Here pyrite is very abundant in the Hermit Shale (Appendix 1--lithologic log under mineralization column) and the IP measurement suddenly increases. In hole 2 the IP measurement becomes quite high for 40 ft (12 m) between 1100 and 1140 ft (338 and 351 m). This is immediately above the high grade uranium interval and may represent the pyrite cap over the orebody. In addition, the highest IP spike lies directly beneath the high-gamma ray anomaly at 1191 ft (366 m), suggesting the uranium is associated with high grade sulfide mineralization, as it is in all uranium mineralized breccia pipes that have been mined in northern Arizona.

Geochemistry

The geochemical data and petrographic descriptions will be published in a separate report, following completion of all chemical analyses by the U.S. Geological Survey analytical laboratory. Preliminary analyses of core from hole 5 show intervals of high concentrations of As, Pb, and Zn. The core was sampled and analyzed at approximately 15 ft (4.6 m) intervals. With the exception of from 407 ft (125 m) to 419 ft (129 m) (2 samples), within the Fossil Mountain Member, all As concentrations above 748 ft (230 m) were less than 100 ppm. At this interval, 407-419 ft the Ni, Pb, and Zn concentrations also increase dramatically, although, except for a sharp decrease in the density log, there is nothing unusual about this interval. Between 490 ft (151 m) and 540 ft (166 m), starting at the contact of the Kaibab Limestone and Toroweap Formation and going downward, there are some sharp increases in Pb and Zn, but none in As and Ni. The most dramatic geochemical anomaly begins at 748 ft (230 m) where As suddenly increases from 10 ppm to 3600 ppm and remains well above 100 ppm until the bottom of the hole at 1008 ft (310 m) where it is 2300 ppm. This increase is accompanied by an abrupt decrease in density, due to a lithology change from a siltstone to a limestone. In fact, there is a sizeable cavern at 748 ft which is indicated by the caliper log. Although there are two high Zn samples around 748 ft, the Zn concentrations aren't consistently high above a depth of 950 ft (292 m) where Ni is also enriched. This geochemical anomaly occurs in the middle of the Seligman Member where the grain-size is larger, and hence the permeability is greater. Hole 5 was terminated because contract money ran out. However, the most interesting geochemical anomalies occurred near the bottom of the hole.

CONCLUSIONS

The Mohawk Canyon Pipe was selected for drilling because it contained 8 criteria deemed to be surface indicators of a mineralized breccia pipe. Drilling has verified that this collapse feature (1) is a breccia pipe, and (2) contains reduced mineralized rock. Although the one-foot thick zone of high-grade uranium encountered in hole 2R is hardly an orebody, the grade of 0.52% eU_3O_8 is the average grade mined from those breccia pipes which host orebodies. Besides hole 2R only 2 other holes of the five drilled, penetrated to the depth of 1181 ft (366 m), which contains the uranium mineralized rock; both of these holes were either outside of the breccia pipe or outside of the reduced zone. This is the same horizon (1181 ft, 366 m--at approximately the Coconino Sandstone-Hermit Shale contact) as that at the top of the orebodies in the Hack Canyon and Pigeon Mines, located beneath a similar Kaibab Limestone capped plateau. Hole 4, which was lost when a 40 ft (12 m) cavern was encountered, contained the most sulfide mineralization, including galena and 1-3% pyrite in the reduced rock just above the cavern. The rocks in this hole appear to have been downdropped slightly more than the other holes, suggesting that they are closer to the center of the pipe.

Sufficient mineralized rock was verified in the Mohawk Canyon pipe that further drilling is warranted to assess its economic potential. Results from this study suggest that the ideal place for the next hole would be about 25 ft (8 m) south of hole 4, where the downward displacement and brecciation is probably greatest, and hence the permeability and U mineralization would have been highest. Hole 4 showed the most sulfide mineralization at the shallowest level (1000 ft).

ACKNOWLEDGMENTS

The authors wish to thank George H. Billingsley (USGS), Russell L. Wheeler (USGS), and Earl R. Verbeek (USGS) for valuable criticisms on the manuscript. George Billingsley provided continual stratigraphic consulting throughout the duration of the project. James Rasmussen, Energy Fuels Nuclear, provided invaluable drilling advice during preparation of the drilling contract and throughout the drilling operation. Both George and Jim contributed significantly to the success of the drilling operation.

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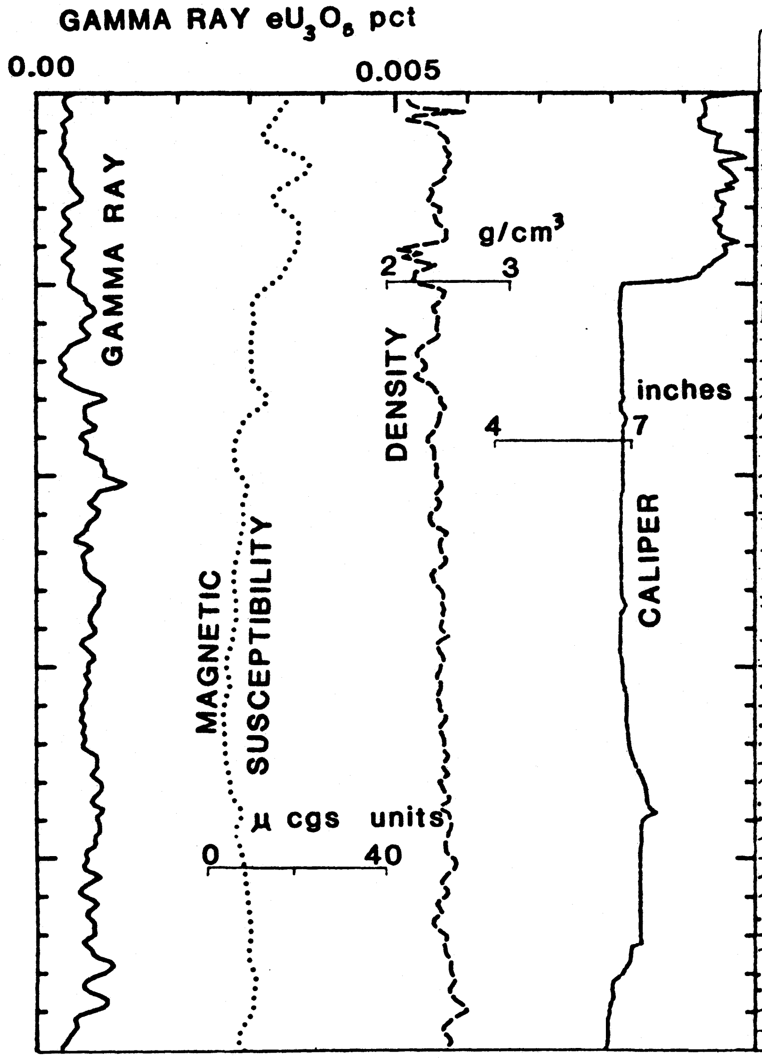
Appendix 1.-- Lithologic and geophysical logs for hole 1R, Mohawk Canyon Pipe

Hole no.: 494-1R Date: 7/18/84

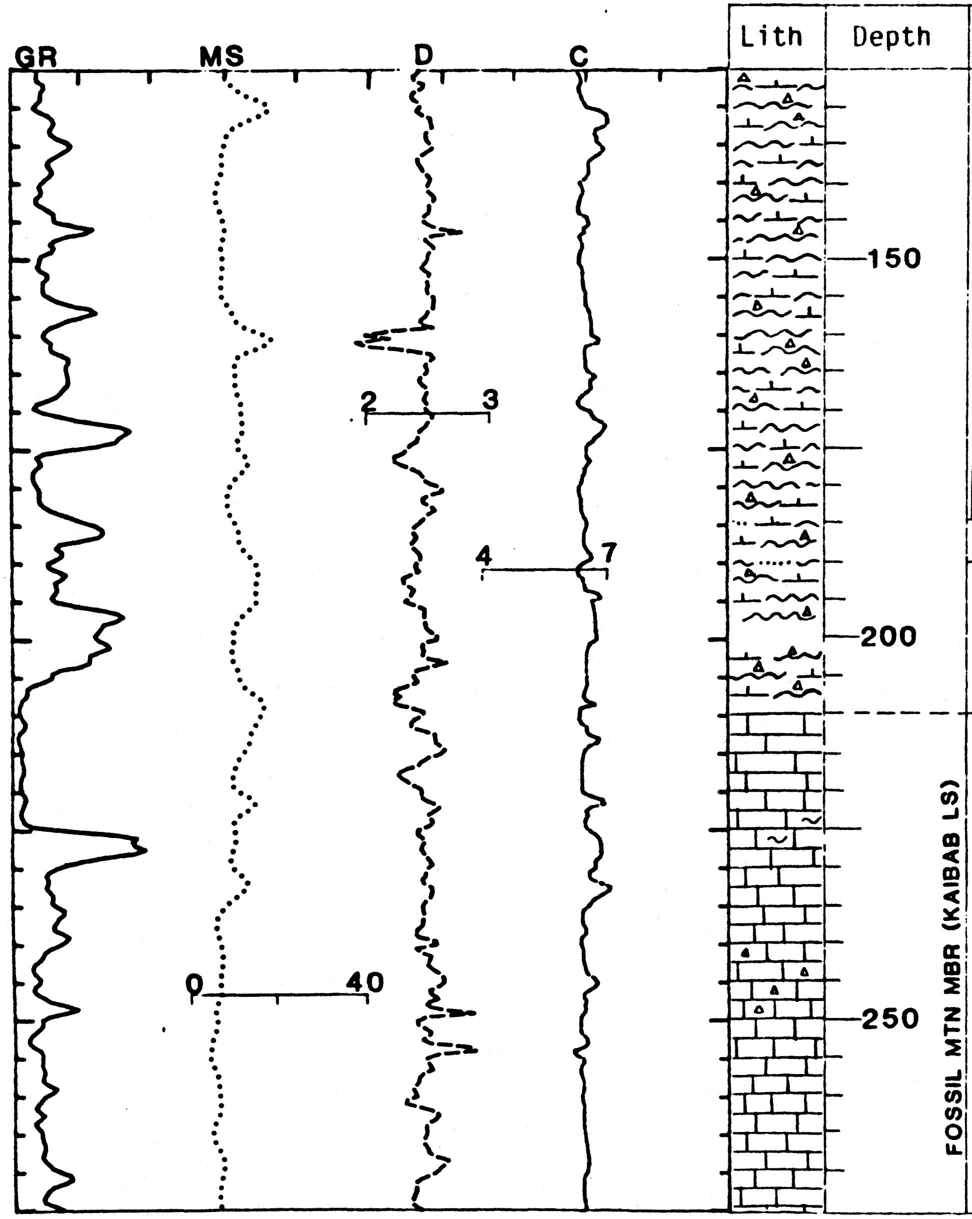
T.: 32N R.: 7W Section: 26 County: Coconino State: AZ

Lat: 36°07'30" Long: 113°00'24" Elev: 6340' TD: 1120' PD: 1119'

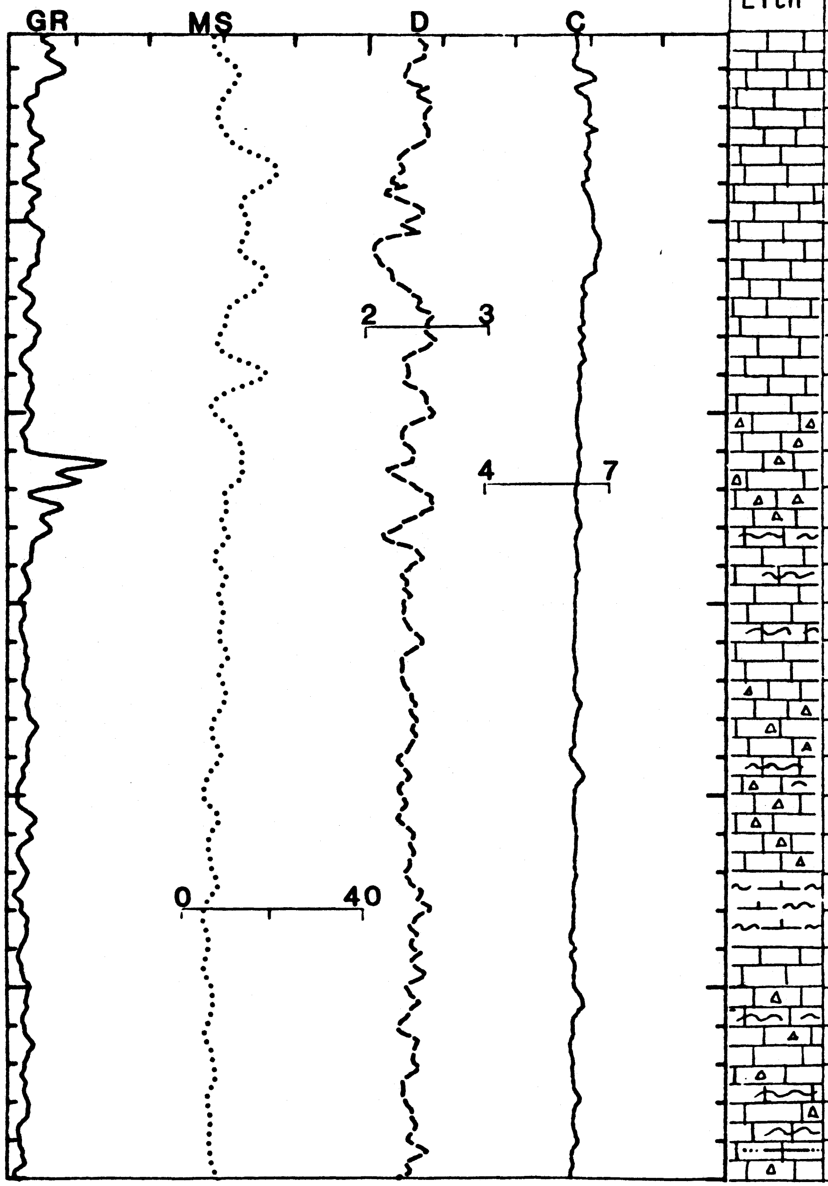


HARRISBURG GYPSIFEROUS MBR (KAIBAB LS)

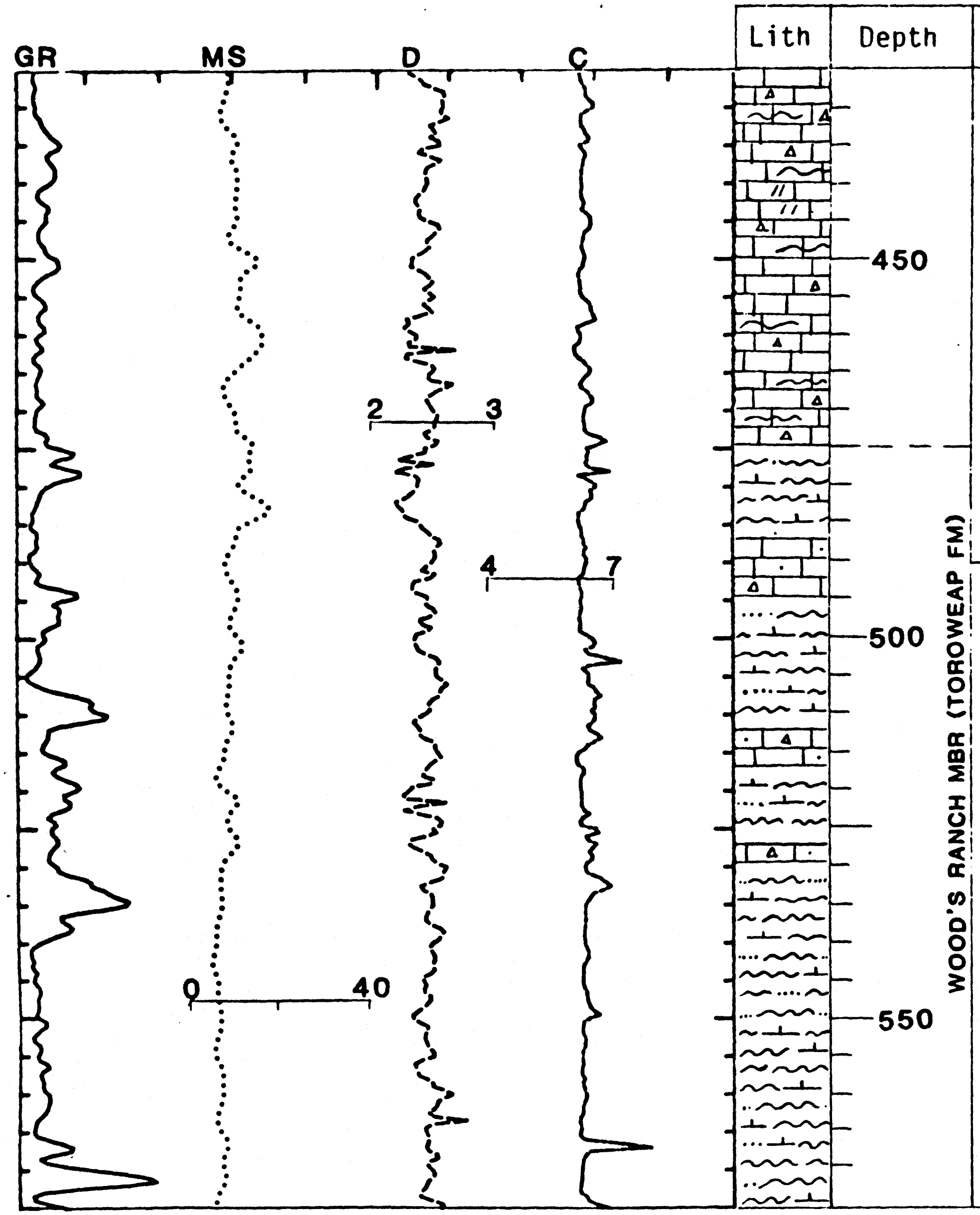
Lith	Depth	Mineral.	Color	Description
		0-35' celadon.	0-10':pale ylw-brn 10'-20' v pale orng 20'-35' grayish-orng pink	0'-35'. Limestone, dolomitic, macroxtal. Contains minor chert, sparse qtz sand (vfg to fg), minor organic matter.
	50		35'-55' v pale orng	35'-55'. Mudstone, calc, soft, porous. Contains vfg qtz sand & qtz veining.
		55'-75' Minor celadon, limonite	55'-100' lt olive gray	55'-75'. Qtz arenite, vfg, slightly calc. Contains 30% cement (clay or silica), minor chert, minor limonite streaks.
	100	75'-185' Minor celadon.	100'-135' grayish-orng	75'-210'. Mudstone, calc. Contains minor to abundant chert. Contains vfg qtz sand @75'-125'.



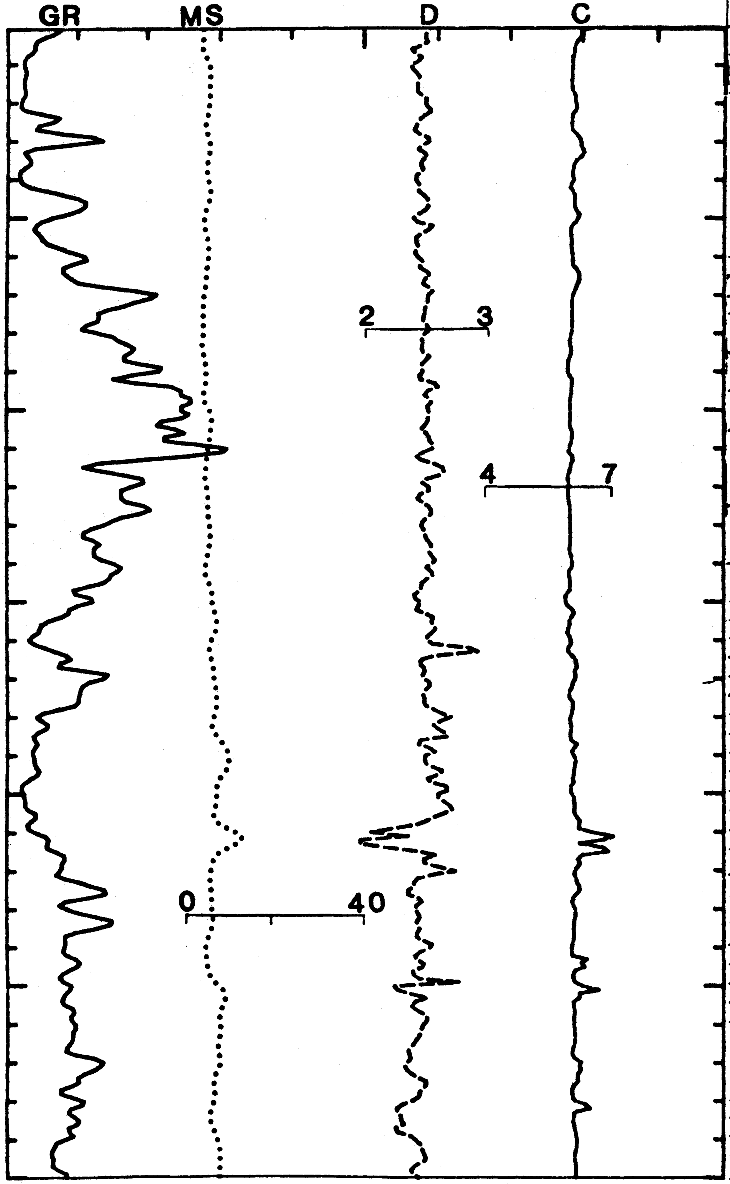
Mineral.	Color	Description
	135'-170' ylw-gray	
185'-190' See descript.	170-210' v pale orng to grayish-orng	Chalcedonic qtz, abundant celadonite, minor limonite & hematite @185'-190'.
190'-210' Minor celadon.		
Minor limonite, celadon. @225'. Minor goethite @240'.	210'-240' ylw-gray	210'-340'. Limestone, macroxtal (<vfg). Contains minor to abundant chert.
	240'-325' pale ylw-brn	Minor goethite coating on some cuttings @240'.



Lith	Depth	Mineral.	Color	Description
	300	Sparse mala-chite?, minor hematite @ 280' - 285'		Qtz veining @ 280'-285'.
			325'-455' grayish-orng pink to v pale orng	V cherty @ 325'-340'.
	350			340'-385'. Limestone, macroxtal (<vfg). Contains minor interbedded calc mudstone; minor to abundant chert.
				Clayey w/ fossil hash @ 370'.
		Goethite @ 380'.		Goethite grains & pieces @ 380'.
				385'-395'. Mudstone, calc.
	400	395'-410' Minor goethite		395'-475'. Limestone as 340'-385'. Minor goethite grains & flakes @ 395'-410'.
				Minor carb siltstone interbedded @ 420'.

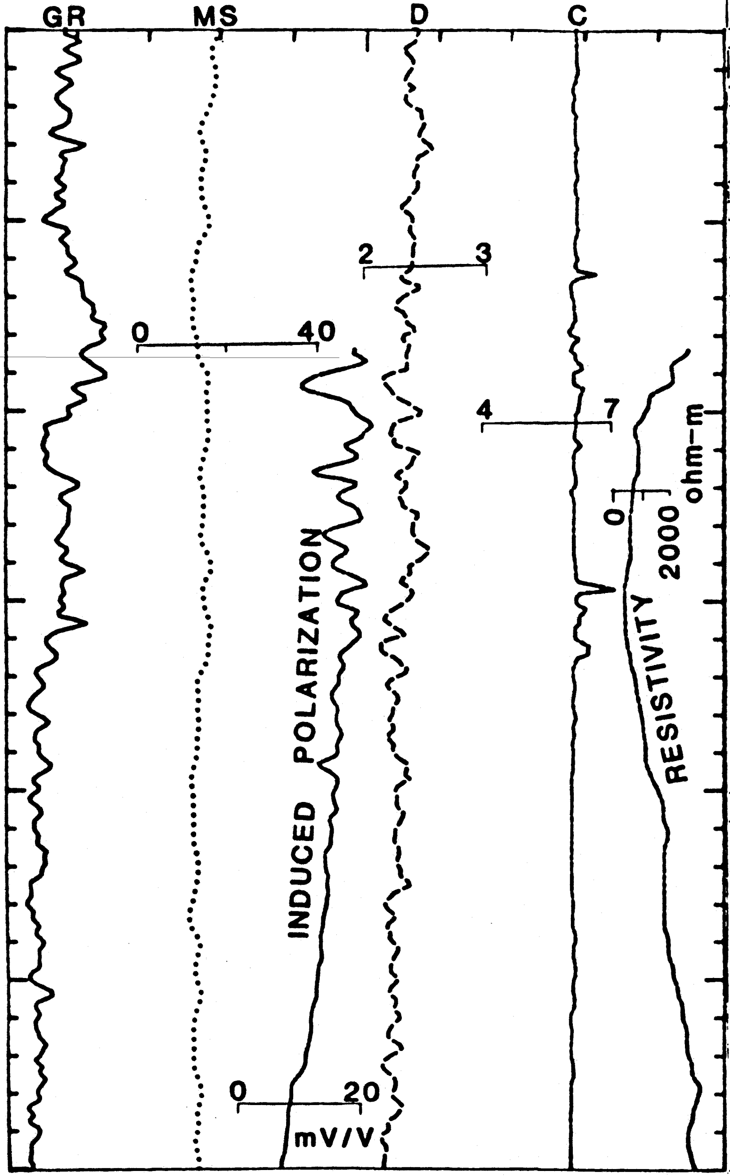


Mineral.	Color	Description
410'-490' Goethite, minor limonite, hematite?		Goethite flakes & grains w/ minor limonite stain (& hematite?) @410' - 490'. Minor gypsum? @ 440'.
	455'-540' grayish-orng	475'-530'. Limestone & mudstone, calc. Unit is sparsely sandy & contains minor chert.
	540'-610' v pale orng	530'-645'. Mudstone, calc, sandy (med to fg qtz grains). Contains minor Fe oxide stain.



BRADY CANYON MBR (TOROWEAP FM)

Lith	Depth	Mineral.	Color	Description
	600			
			610'-625' lt gray	Calc siltstone interbedded @610' - 615'.
		635'-640' pyrite	625'-645' ylw-gray	
	650			645'-650'. No sample.
		650'-750' Abundant limonite, goethite. Minor hematite, Mn oxide	650'-685' grayish-orng pink	650'-730'. Dolomite, fossiliferous. Contains v abundant limonite stain; abundant goethite as coatings & after pyrite cubes; minor bright red hematite; Mn dendrites. Mudstone @ 685'.
	700		685'-730' dk ylw-orng	



Lith	Depth	Mineral.	Color	Description
			730'-735' v pale orng 735'-750' gray-orng	730'-750'. Dolomite. Contains calcite & fg to vfg qtz sand.
	750 SELIGMAN MBR (TOROWEAP FM)	750'-790' Abundant limonite. Minor goethite.	750'-775' dk ylw-gray to lt brn 775'-800' dk ylw-orng	750'-790'. Qtz arenite, calc, fg to vfg, clayey, poorly sorted. Contains heavy limonite stain & grain coating; minor limestone interbeds; minor goethite flakes.
	800 850 COCONINO SS	790'-925' Minor limonite, goethite	800'-835' v pale orng to grayish-orng 835'-910' lt olive-gray to lt gray	790'-925'. Qtz arenite, mostly fg to vfg. Contains subrnd, frosted grains; minor limonite stain; minor goethite grains.

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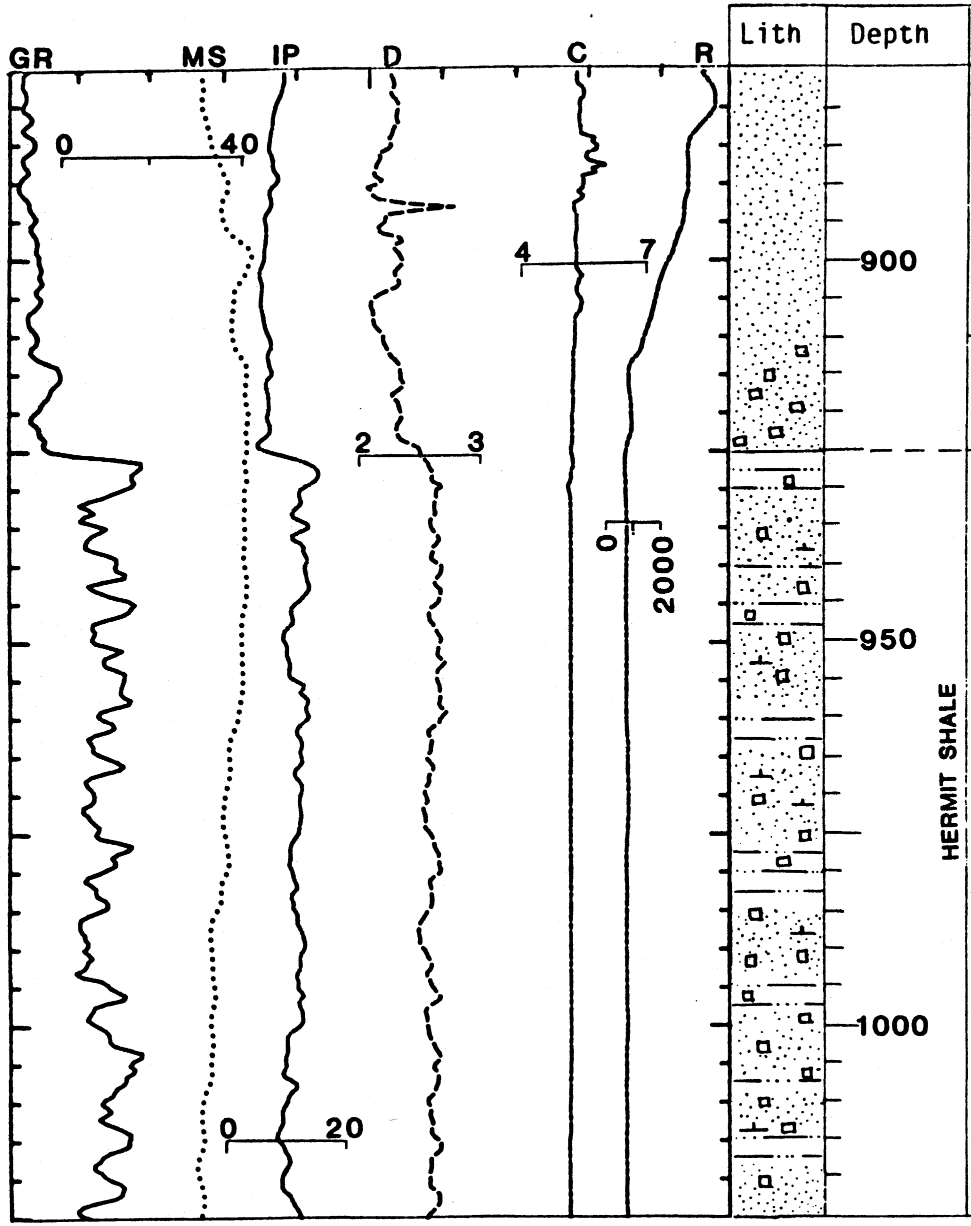
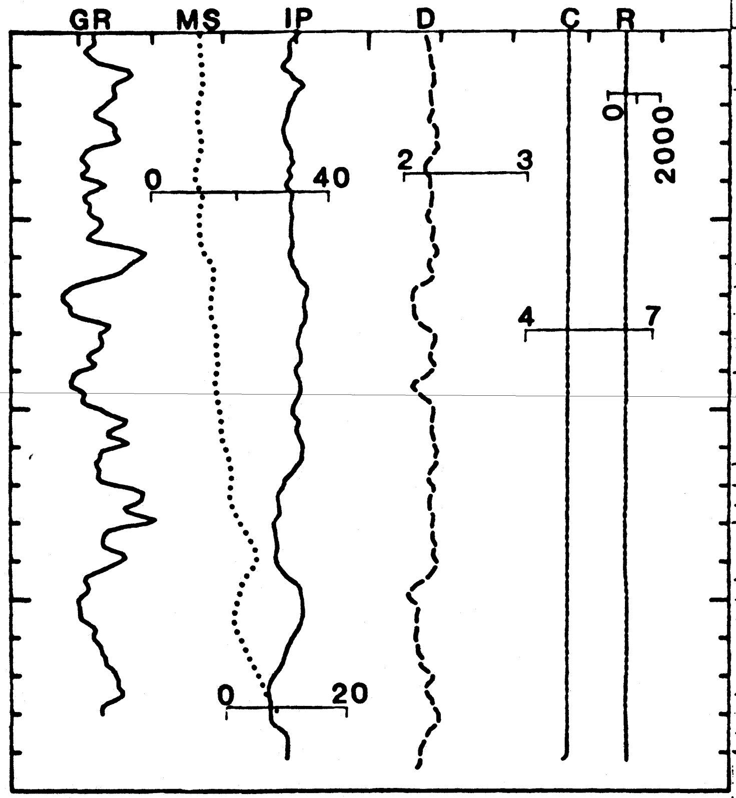


Mineral.	Color	Description
910'-925' Abundant pyrite	910'-925' lt olive gray to lt gray	
925' - 1085' Abundant pyrite, goethite, hematite	925'-950' v lt gray	925'-1085'. Qtz arenite & siltstone. Unit is vfg to silty, slightly calc & contains abundant pyrite & goethite grains; bright red hematite; frosted grains.
	950'-965' grayish-orng	
	965'-1000' v lt gray to lt gray	
Peacock tarnish-bornite? @ 1000'.	1000'-1080' lt gray	



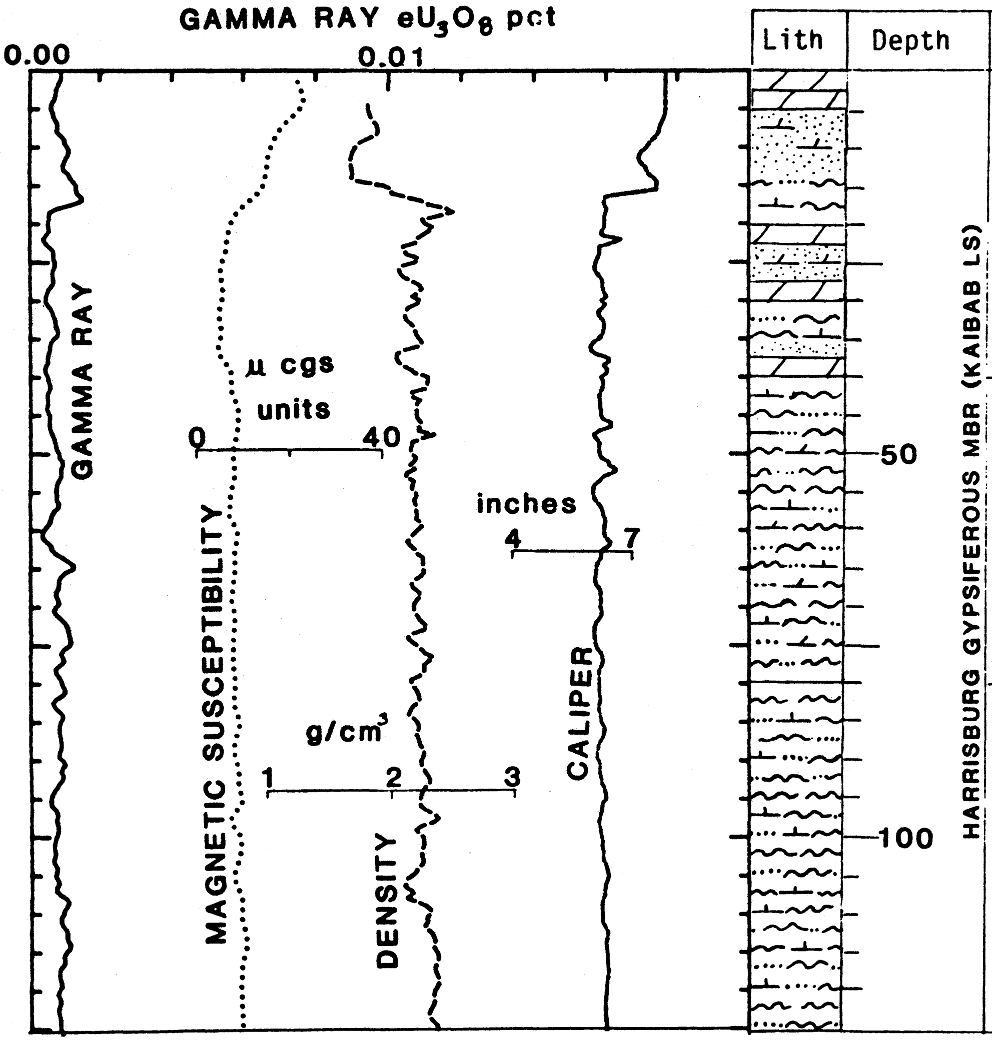
Lith	Depth	Mineral.	Color	Description
	1050			
	1100		1085'-1120' mod red-brn	1085'-1120'. Siltstone, poorly-sorted, sandy. Contains vfg sand.
	1150			

Appendix 2.--Lithologic and geophysical logs for hole 2R, Mohawk Canyon Pipe

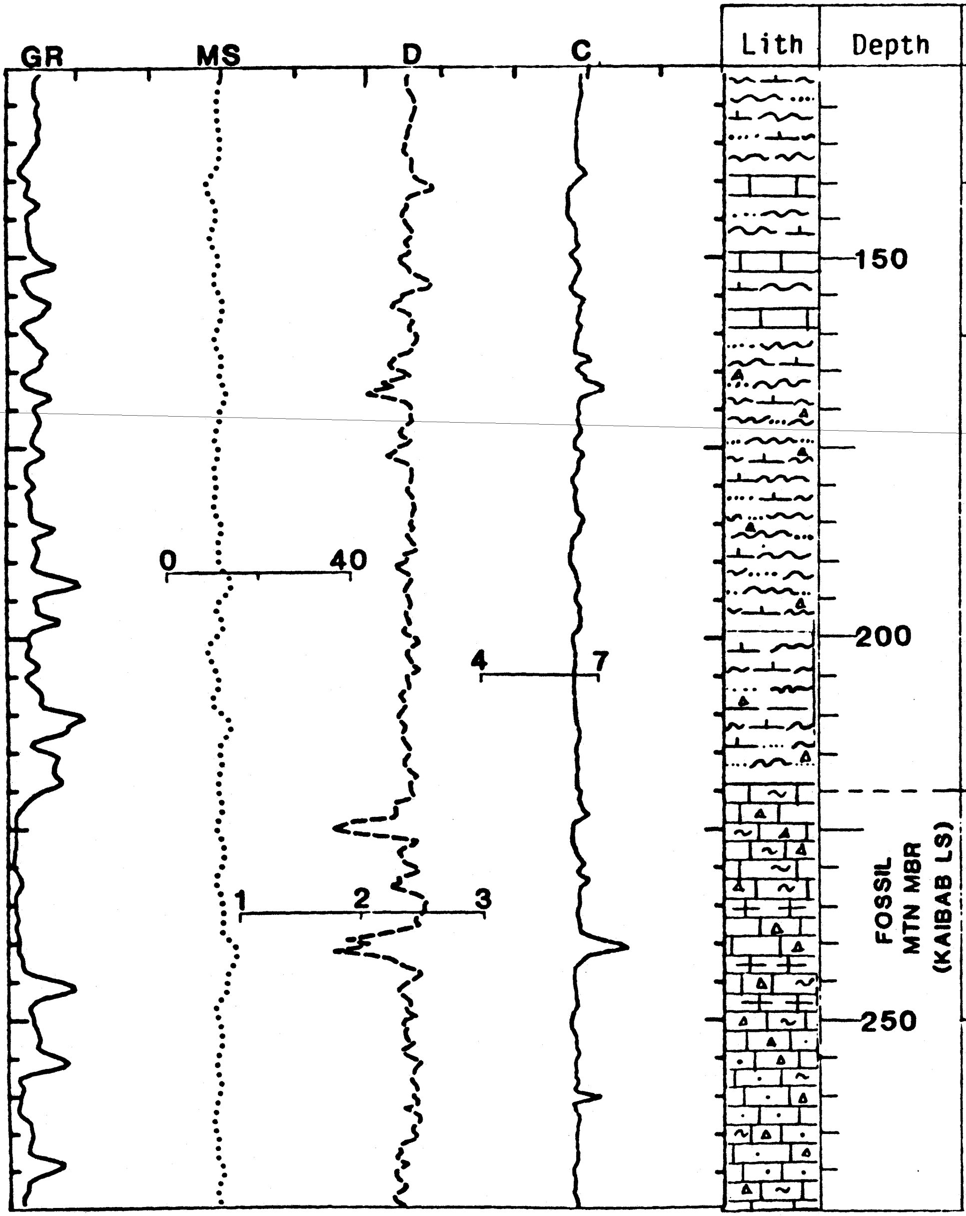
Hole no.: 494-2R Date: 7/25/84

T.: 32N R.: 7W Section: 26 County: Coconino State: AZ

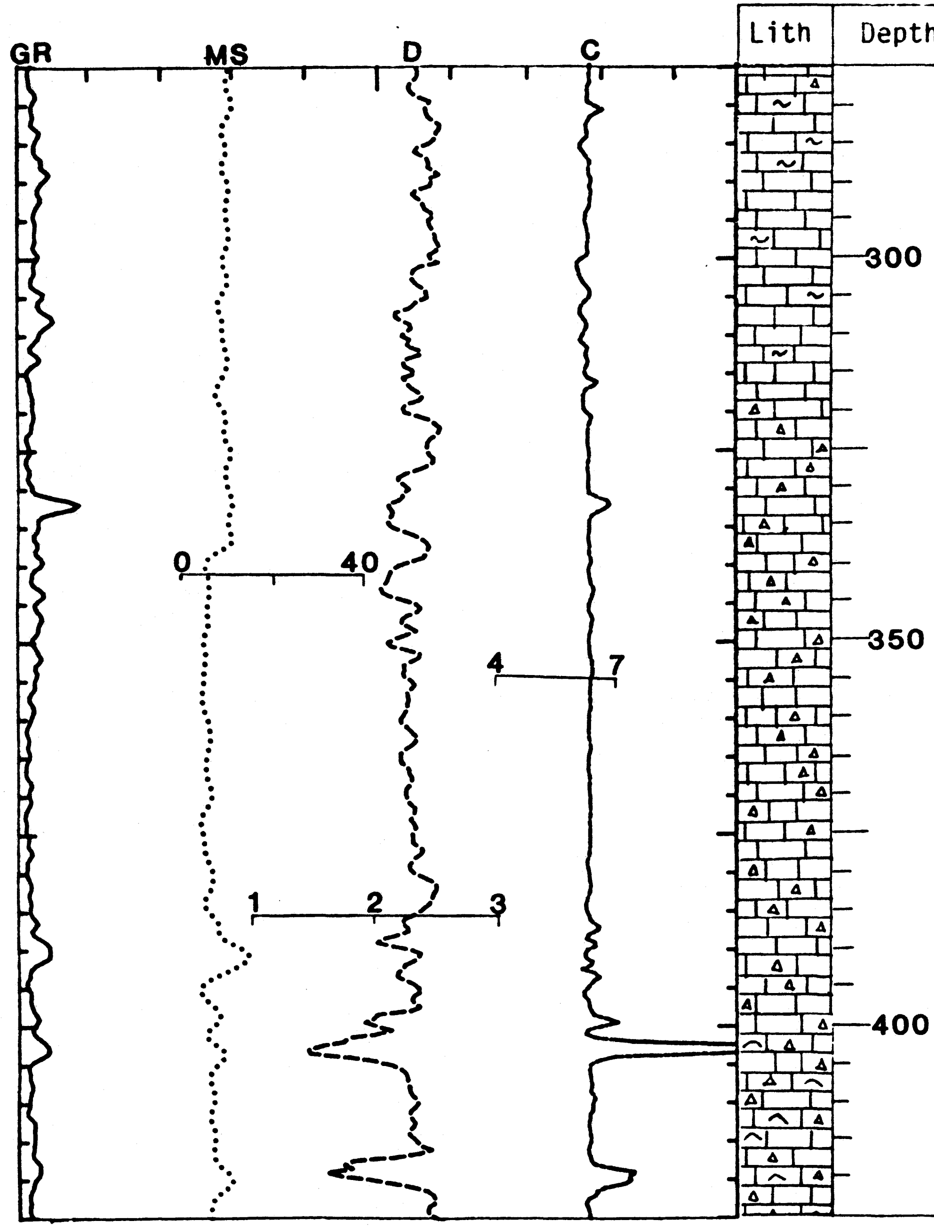
Lat: 36°07'30" Long: 113°00'24" Elev: 6345' TD: 1335' PD: 1324'



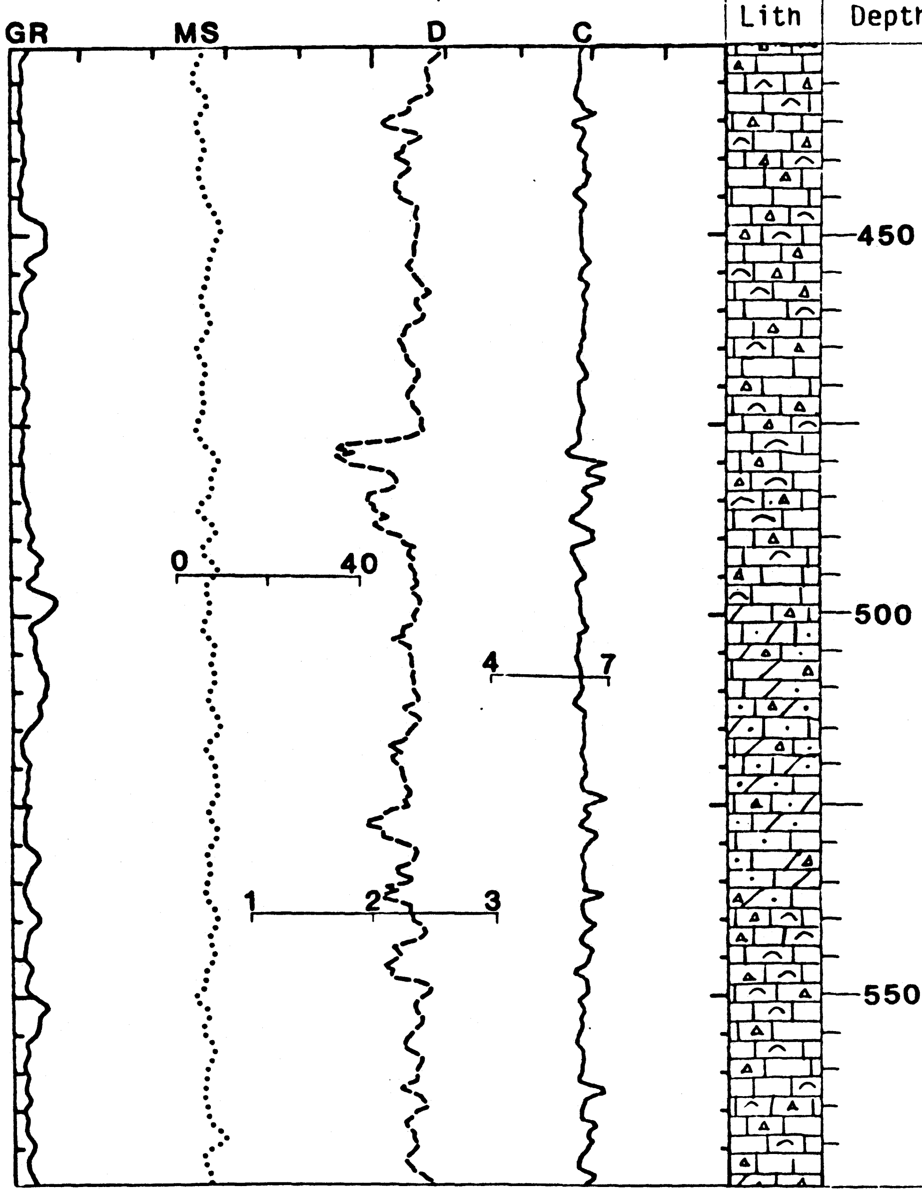
Mineral.	Color	Description
0-40' Minor celadon, limonite, hematite	0-65' v pale orng	0-40'. Dolomite, dolomitic ss (vfg to fg, w/ subrnd qtz grains) & sandy, calc, mudstone (w/ qtz sand, vfg to fg, subrnd grains). Unit contains minor celadonite in sandy intervals, minor limonite mud, hematite flakes & stains.
40'-80' Minor celadon.	65'-110' ylw-gray	40'-80'. Mudstone, calc to dolomitic. Contains abundant vfg qtz sand & silt. Minor celadonite coating sides of cnips.
Malachite @ 95'. 80'-160' Minor limonite, hematite, celadon,	110'-135' gray-ylw	80'-160'. Mudstone, calc, sandy & silty. Contains qtz sand, vfg.



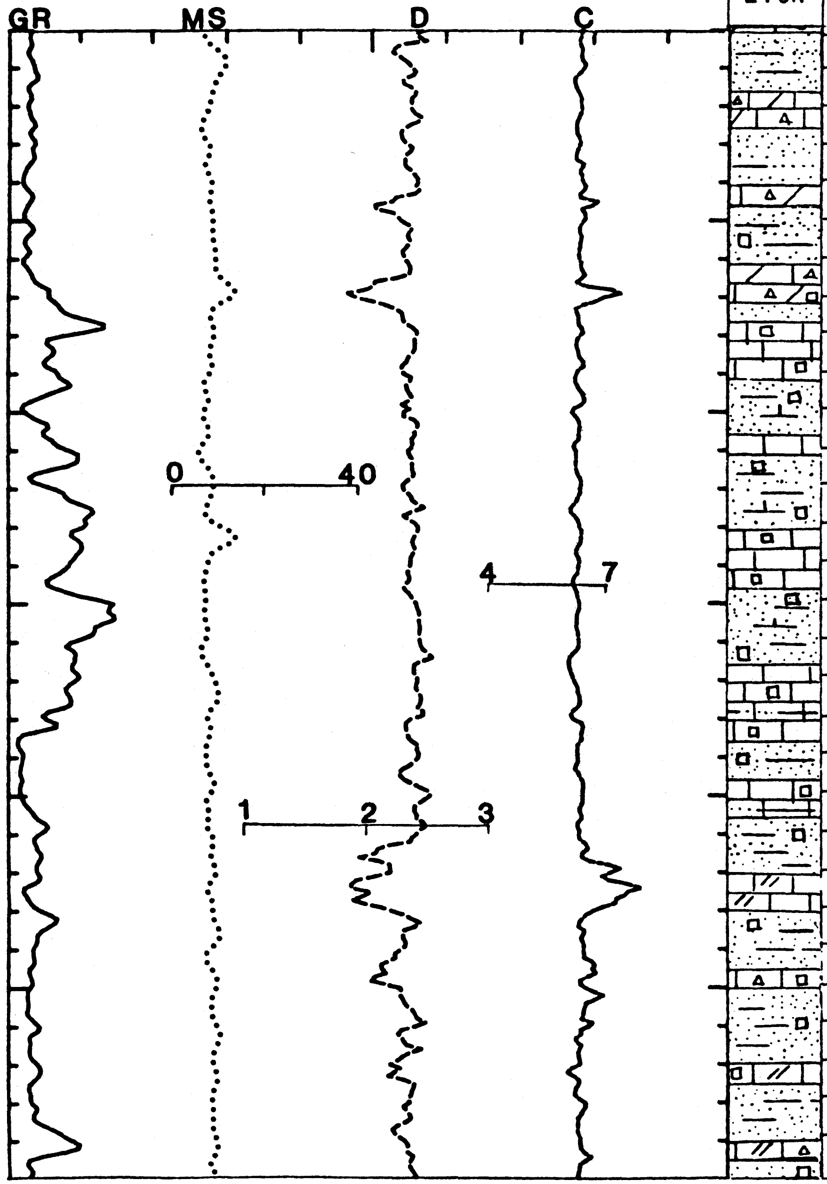
Mineral.	Color	Description
140'-160' Abundant celadon.	135'-150' v pale orng	Unit is interbedded w/ micritic limestone @ 140'-160'.
160'-220' Minor limonite, hematite, goethite. Abundant celadon.	150'-195' ylw-gray 195'-205' gray-orng 205'-250' v pale orng to grayish-orng	160'-220'. Mudstone, calc, sandy & silty, slightly cherty. Contains vfg qtz sand; minor limonite stain; hematite coatings; goethite flakes & grains.
220'-250' Abundant celadon, limonite, hematite, goethite.		220'-250'. Limestone, micritic, or dolomite; slightly clayey. Contains abundant chert.
250'-320' V minor celadon. Minor goethite, limonite.	250'-355' ylw-gray	250'-320'. Limestone, micritic. Contains abundant chert & minor qtz sand @ top of interval; minor but persistent goethite as coatings & sparse limonite stain.



Mineral.	Color	Description
Pyrite? @ 330'. 320'-370' Minor hematite, limonite, goethite.		320'-500'. Limestone w/ abundant chert. Assoc. minor hematite & limonite w/ goethite.
370'-400' Abundant limonite, hematite, goethite	355'-445' v pale orng to grayish-orng-pink	Limonite, hematite, & goethite abundant & replace pyrite @ 370'-400'.
400'-500' Abundant limonite, goethite		Fossils & recrystallized calcite present @ 400'-500'.



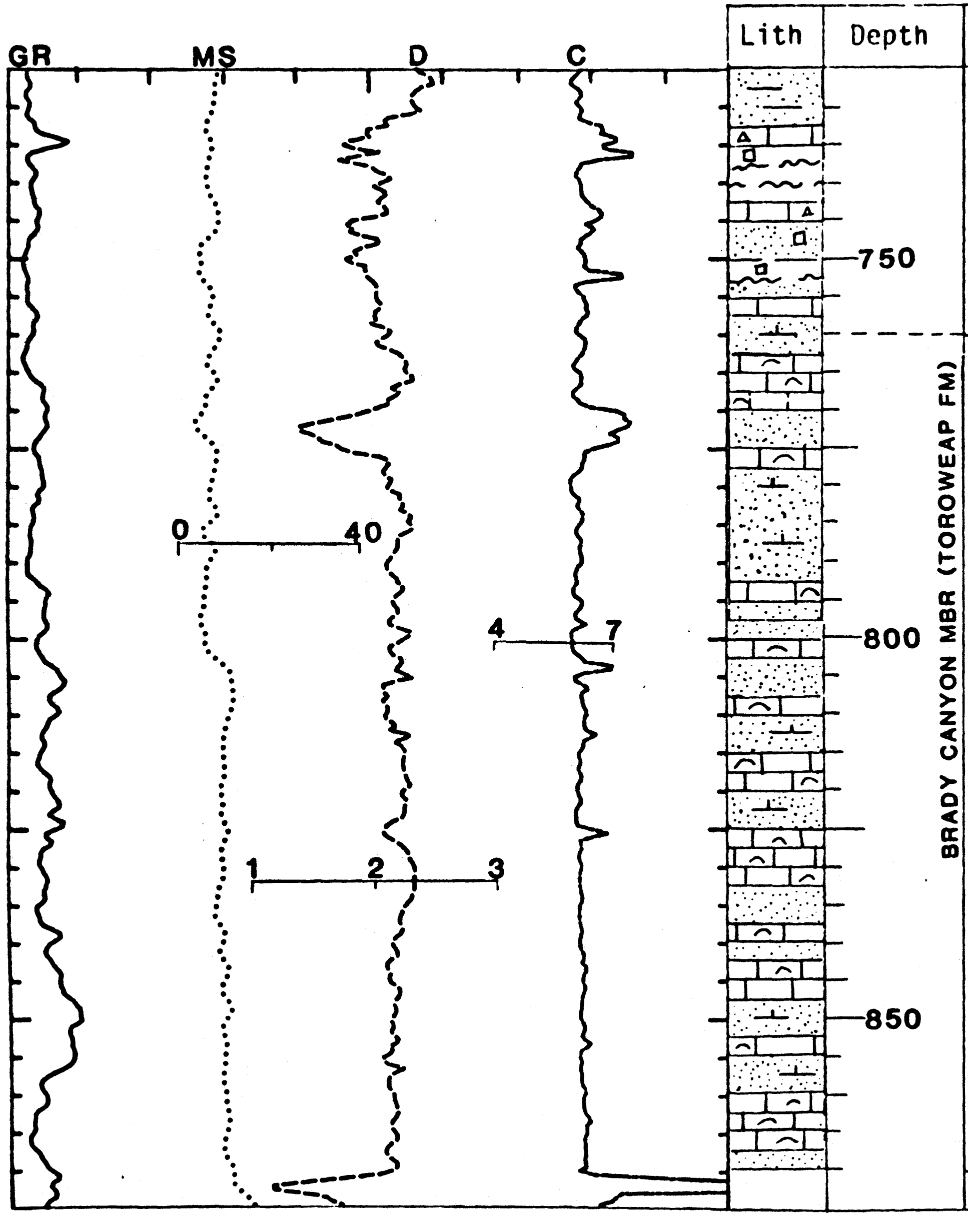
Mineral.	Color	Description
	445'-615' gray-orng to pale ylw-brn	
		500'-540'. Limestone, dolomitized. Contains chert & abundant fg qtz sand.
		540'-575'. Same as 400'-500'.



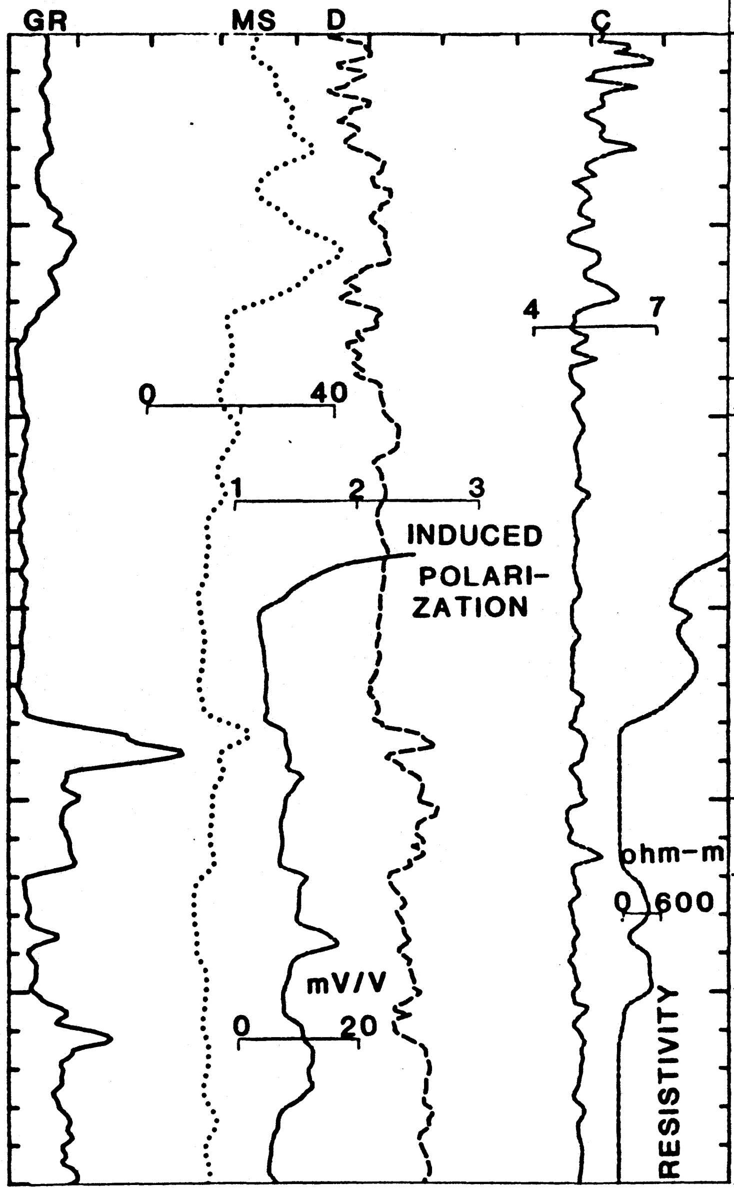
Depth: 600, 650, 700

WOOD'S RANCH MBR (TOROWEAP FM)

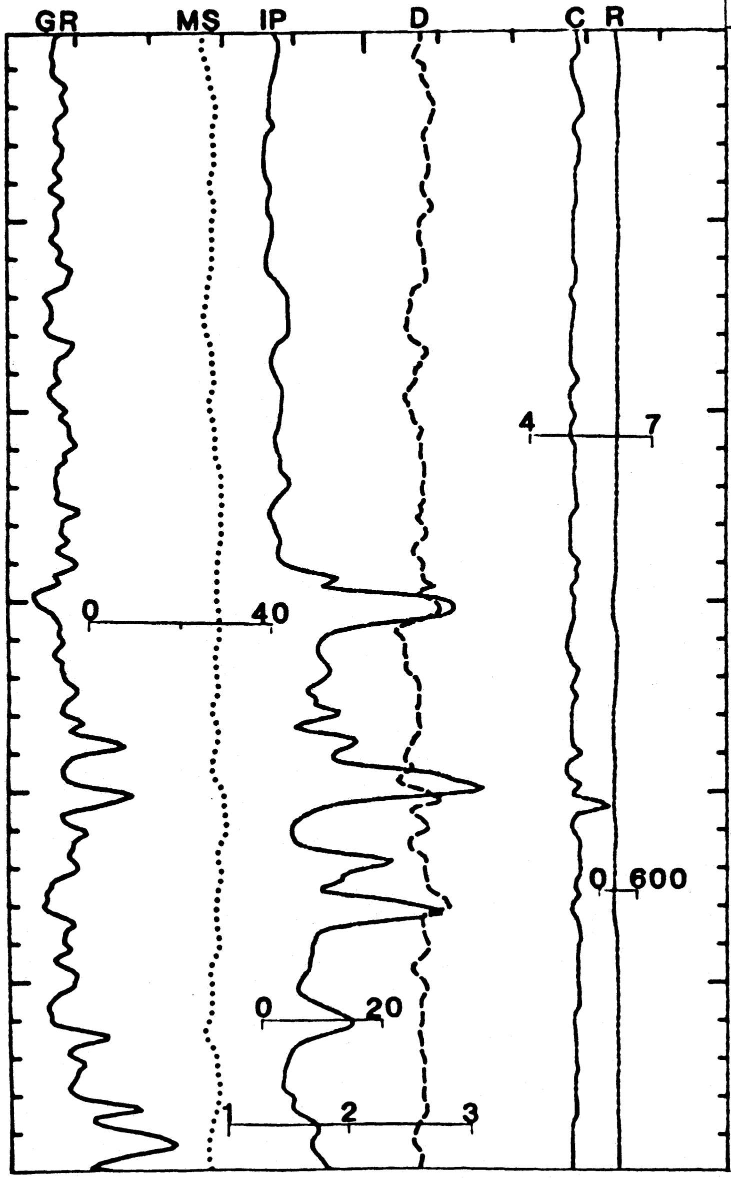
Mineral.	Color	Description
Chalco-pyrite @ 580'.		575'-615'. Limestone, dolomitic, & ss w/ abundant chert. SS is fg, silty; contains qtz grains & abundant Fe oxid, esp @ basal contact.
615'-680' Abundant pyrite. Limonite, hematite	615'-635' lt gray 635'-650' ylw-gray 650'-665' lt gray	615'-680'. SS & limestone (macroxtal). SS is fg, slightly calc, clayey; contains subang qtz grains, abundant pyrite masses & cubes. Limestones contain limonite & hematite stain. Limestone beds more abundant w/ minor siltstone lams @ 665'-680'.
680'-760' Abundant hematite, limonite. V minor pyrite.	665'-750' gray-orng	680'-760'. Limestone, clayey ss, & mudstone (lower ½ of interval). Contains minor gypsum; abundant hematite & limonite stain; minor chert.



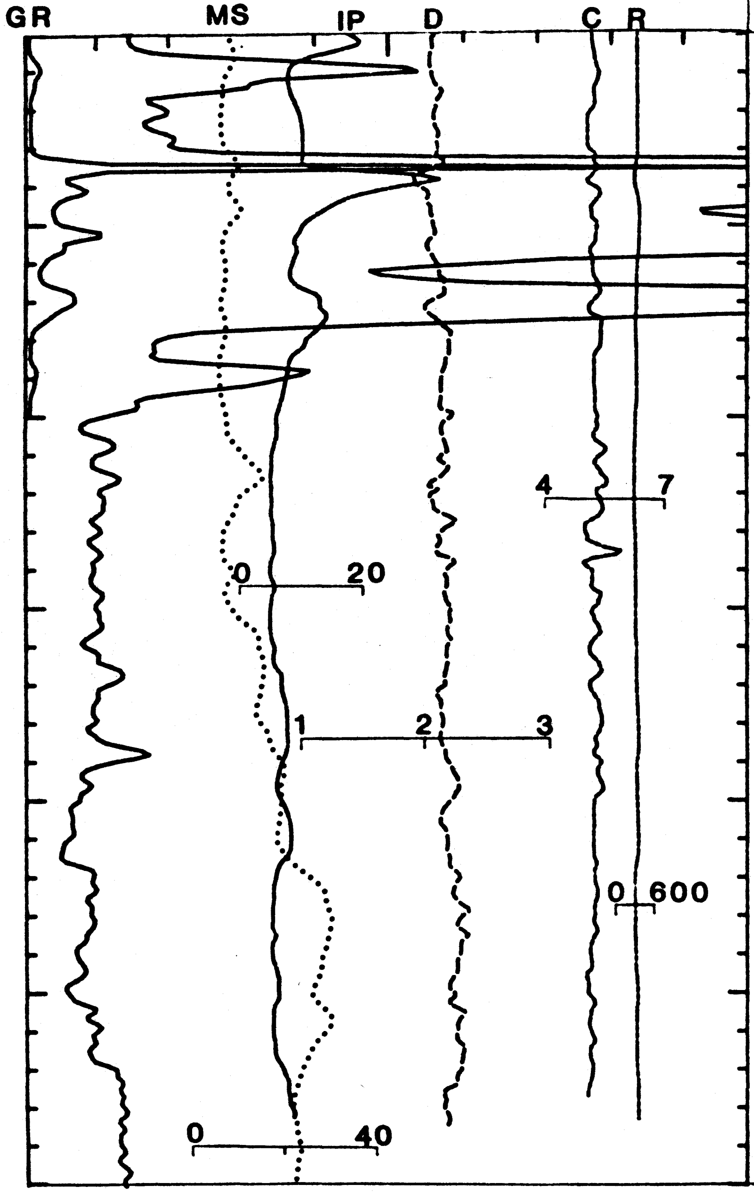
Mineral.	Color	Description
760'-870' Abundant limonite, hematite	750'-870' gray-orng to mod ylw-brn	760'-870'. SS & limestone, fossiliferous. SS is arenitic, vfg to fg, subrnd to subang qtz grains, slightly calc; contains abundant limonite staining & hematite coatings.



Lith	Depth	Mineral.	Color	Description
	900 ? ? 950 SELIGMAN MBR (TOROWEAP FM)			870'-975' Minor sample available, lost circulation (no description). A green substance or a substance which the ARS solution turned green is @ 895'. Contains minor gypsum (or void qtz); coarse euhedral grains. A qtz arenite, orange @ 920'.
		975'-985' Abundant pyrite, limonite	975'-985' lt gray	975'-985'. Qtz arenite, vfg. Contains abundant masses of pyrite; coarse, clear, subhedral to euhedral qtz grains. Many chips & grains limonite stained.
	1000 COCONINO SS	985'-1020' Abundant limonite.	985'-1020' ylw-gray	985'-1020'. Qtz arenite, fg. Contains abundant limonite stain; subrnd & frosted qtz grains.



Lith	Depth	Mineral.	Color	Description
				1020'-1335'. No samples, lost circulation.
	1050			
	? ?			
	1100			
	HERMIT SHALE			
	1150			



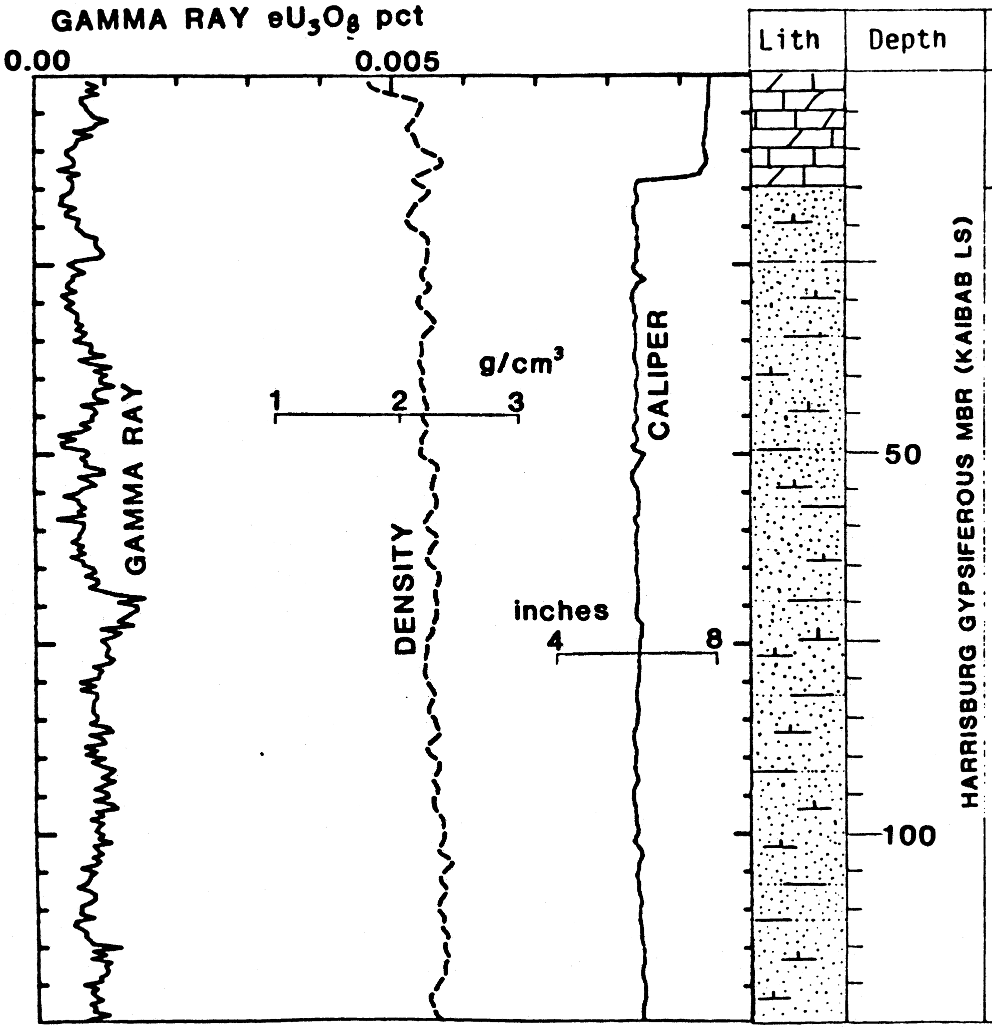
Lith	Depth	Mineral.	Color	Description
	1200			No samples. See fig. 14a., expanded gamma ray scale, for 1175 feet to 1225 feet.
	1250			
	1300			

Appendix 3.-- Lithologic and geophysical logs for hole 3R and 3C, Mohawk Canyon Pipe

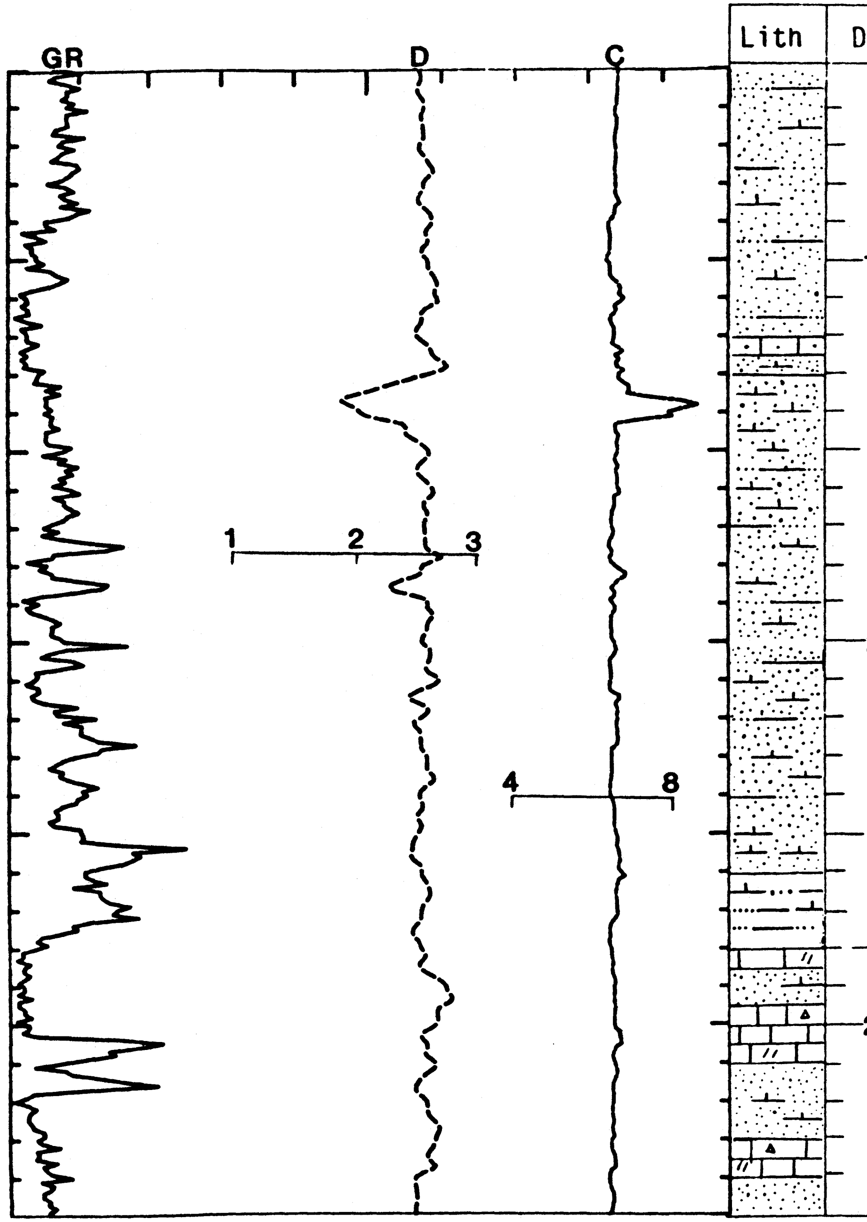
Hole no.: 494-3R & 3C Date: 8/07/84

T.: 32N R.: 7W Section: 26 County: Coconino State: AZ

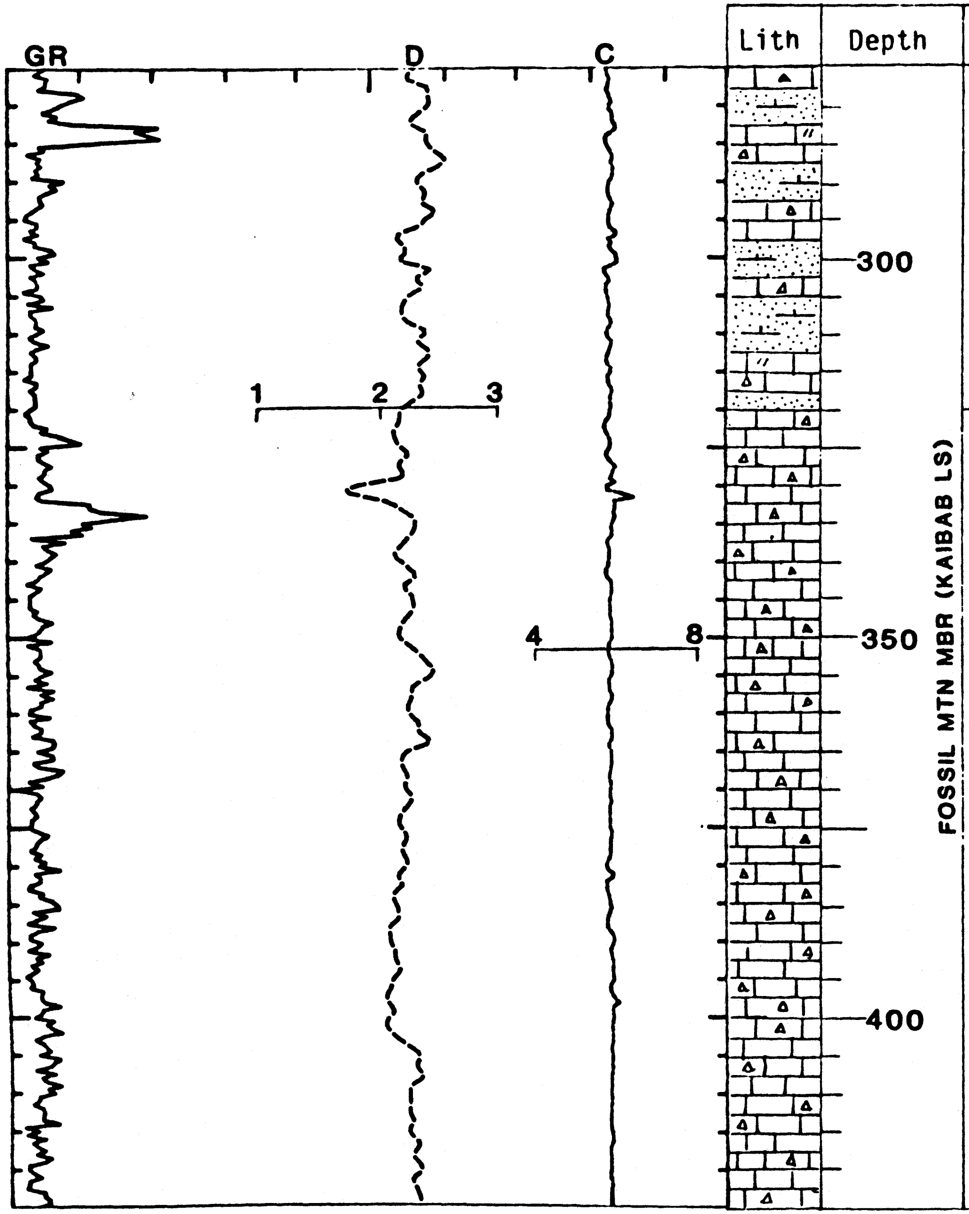
Lat: 36°07'30" Long: 113°00'24" Elev: 6340' TD: 1421' PD: 1170'



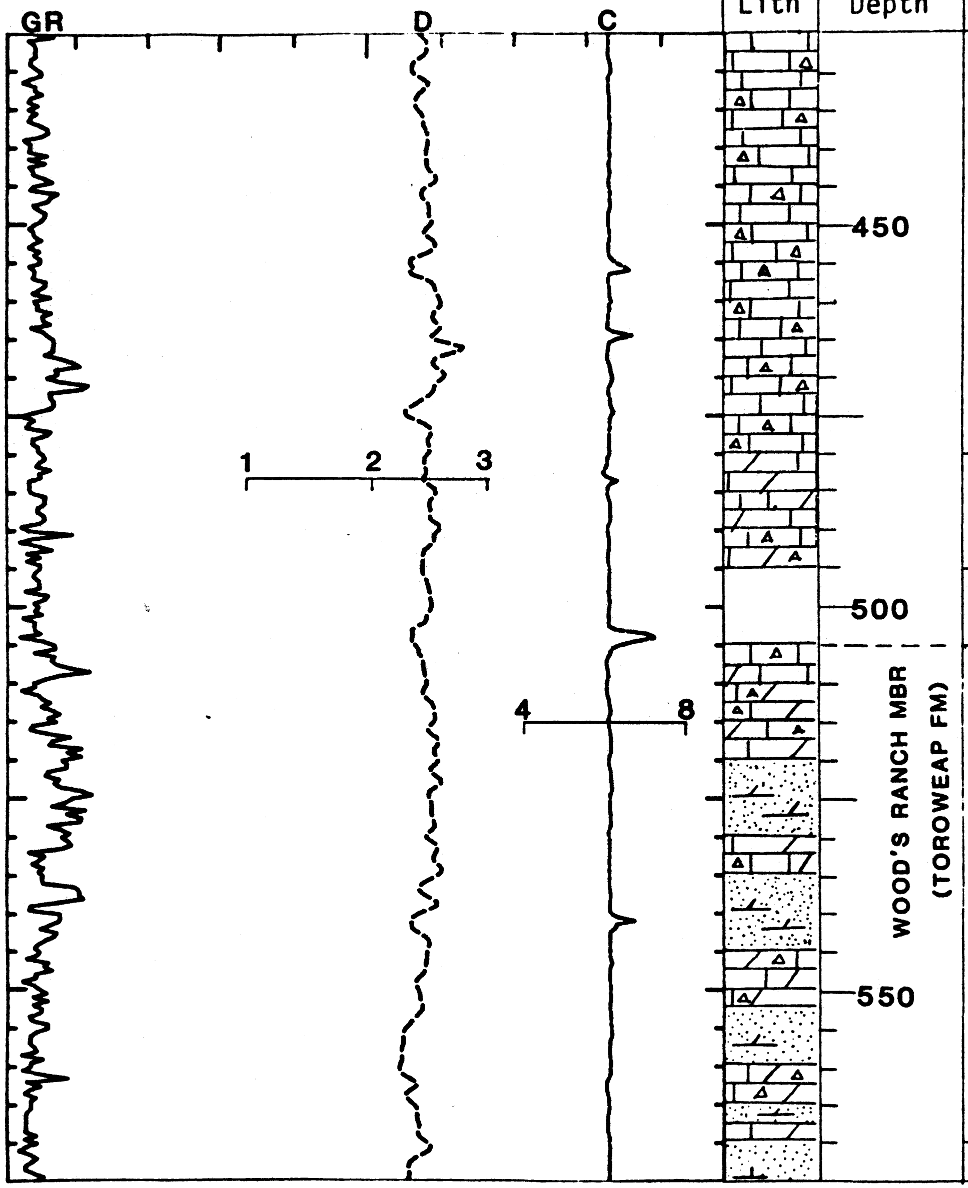
Mineral.	Color	Description
		0-15'. Limestone, dolomitic.
15'-160' Minor limonite	0-115' ylw-gray	15'-160'. SS (qtz arenite), vfg, silty, calc. Contains subrnd to subang grains; minor limonite staining.



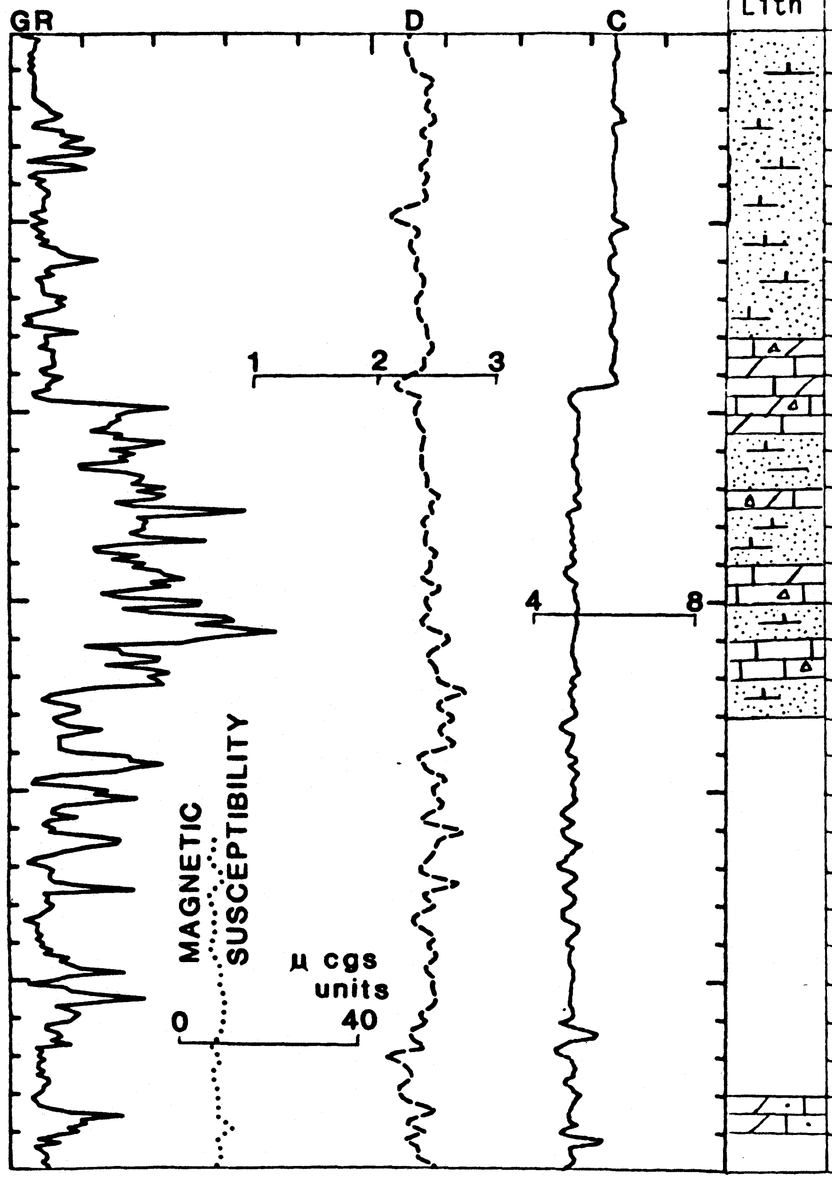
Mineral.	Color	Description
	115'-175' v pale orng to grayish-orng	
160'-165' Sparse Mn oxide, hematite?		160'-165'. Limestone, sandy to ss, vfg, limey. Contains sparse dendritic Mn oxide (hematite) coatings.
165'-230' Minor limonite	175'-180' lt gray	165'-230'. SS (qtz arenite), silty, v calc.
	180'-235' dk ylw-orng	
230'-240' Minor limonite, v minor hematite		230'-240'. Siltstone, calc. Contains fg sand.
	235'-265' gray-orng	240'-320'. Limestone & ss. SS is qtz arenite, calc, vfg. Unit contains limonite stains; v minor gypsum as small nodules; minor chert.
	265'-290' ywl-gray	



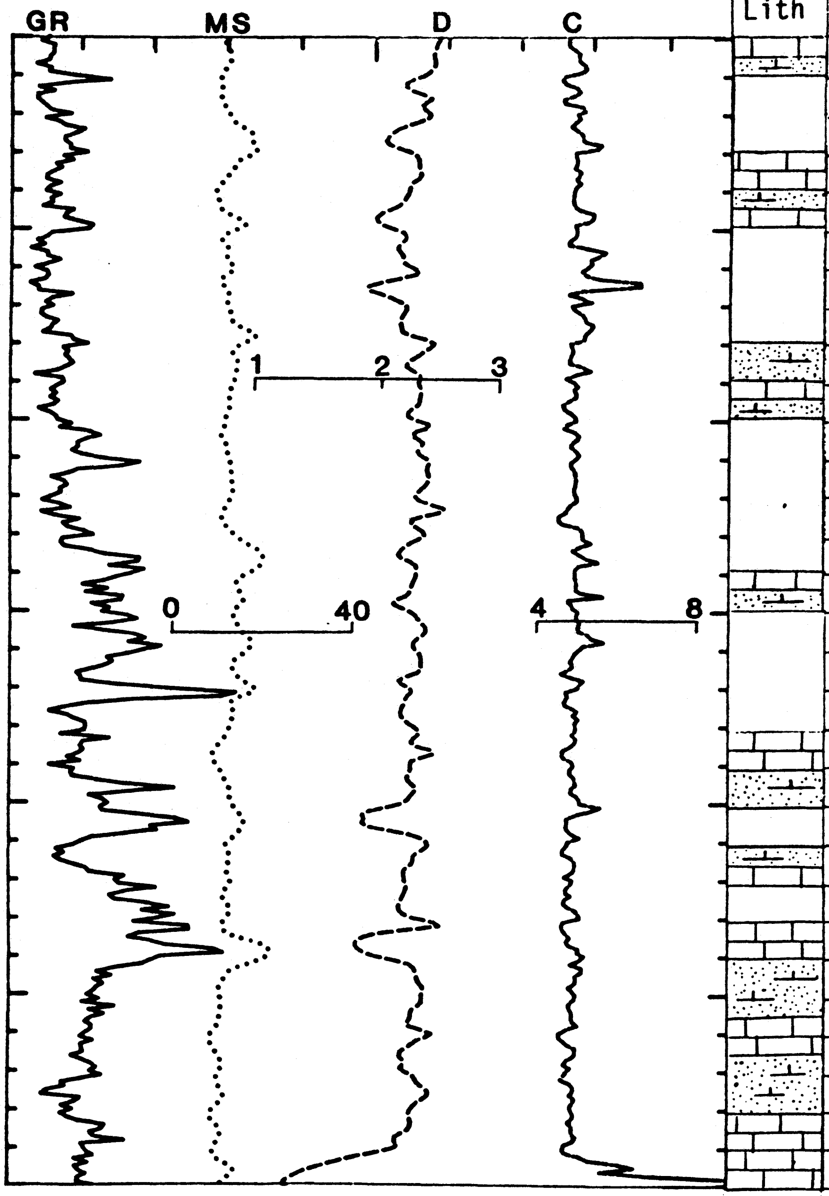
Mineral.	Color	Description
Goethite @ 280'. 240'-320' Limonite	290'-300' gray-orng 300'-320' v lt gray	Goethite psuedomorphs present as v small (0.3 mm) black, cubic xtals after pyrite in macroxtal limestone @ 280'.
320'-480' Minor limonite, goethite	320'-465' v pale orng to pale orng	320'-480'. Limestone. Contains goethite coatings & v lt gray chert. Small, v dk blue, octahedral xtals @ 335'.



Mineral.	Color	Description
	465'-480' v lt gray	
480'-495' Mn oxide	480'-495' med lt gray	480'-495'. Limestone, dolomitic w/ minor dendritic Mn oxide coatings. Chert frags in lower 5' of unit.
		495'-505'. No samples.
505'-570' Abundant hematite, limonite	505'-560' ylw-gray	505'-570'. Limestone & ss. Unit is dolomitic & contains chert; abundant hematite & limonite stains.
560'-565' Goethite	560'-585' mod brn	Goethite as pseudomorphs of galena cubes truncated by an octahedron cube .003 mm in dia. @ 560'-565'.



Depth	Mineral.	Color	Description
600		585'-640' v lt gray	570'-615'. SS, vfg, slightly calc. Contains qtz grains.
650		640'-665' med lt gray	615'-665'. Limestone, dolomitic & ss, calc. Unit contains chert except in less abundance than in above units. Dolomite decreases in lower 1/2 of interval.
? ?			665'-715'. No samples.
700		715'-720' pale brn	715'-720'. Limestone, dolomitic, slightly sandy.
			720'-725'. No samples.

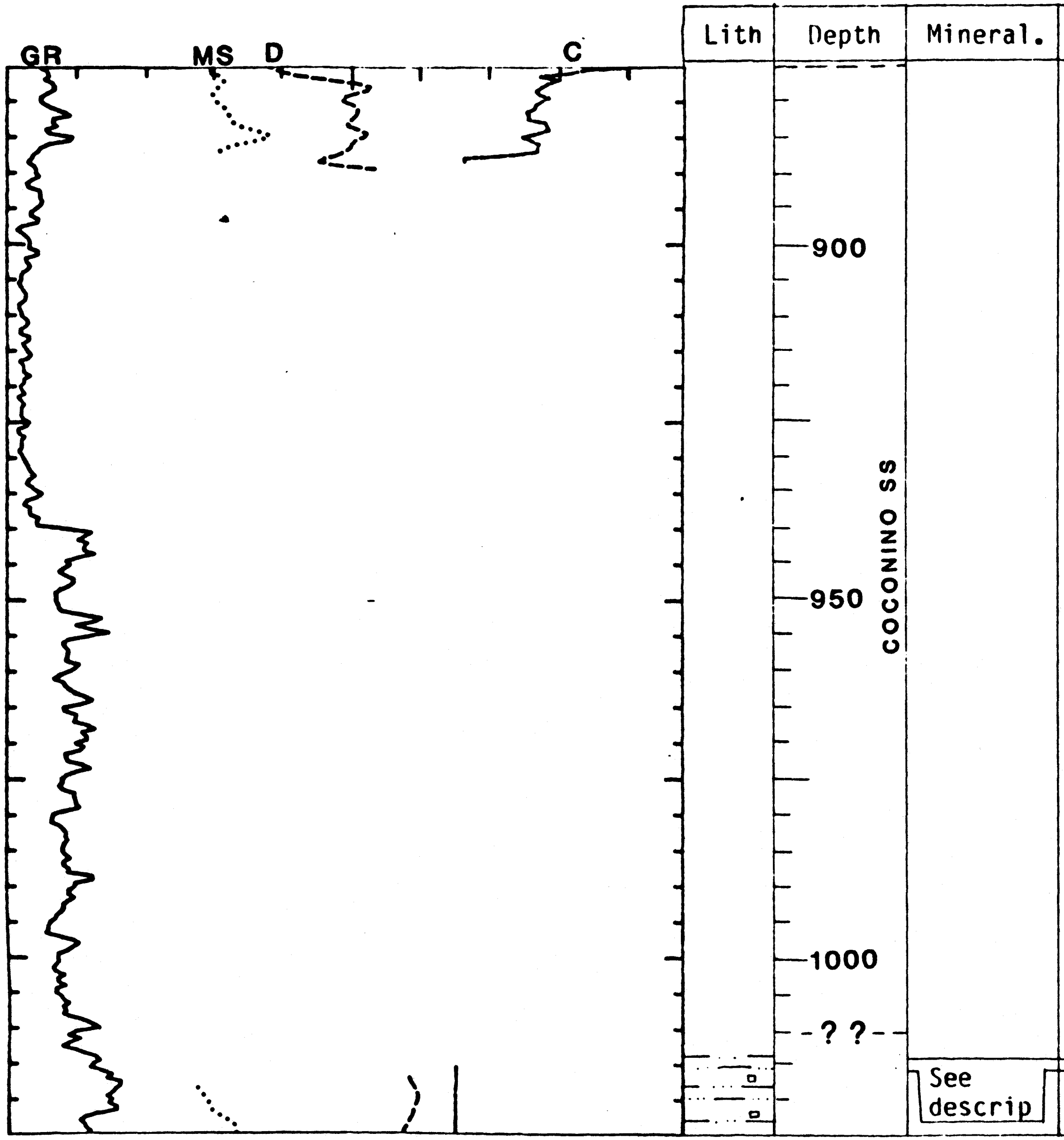


Depth: 750, 800, ? ?, 850

BRADY CANYON MBR (TOROWEAP FM)

SELIGMAN MBR (TOROWEAP FM)

Mineral.	Color	Description
725'-730' Hematite	725'-730' pale brn	725'-730'. Ls & ss, vfg, calc. Ls chips are hematite stained.
		730'-740'. No sample.
740'-750' Hematite	740'-750' pale brn	740'-750'. Same as 725'-730'.
		750'-765'. No samples.
765'-775' Hematite	765'-775' lt brn	765'-775'. Same as 725'-730'.
		775'-795'. No samples.
795'-800' Hematite	795'-800' mod orng-pink	795'-800'. Same as 725'-730'.
		800'-815'. No samples.
815'-825' Hematite	815'-825' lt brn	815'-825'. Same as 725'-730'.
		825'-830'. No samples.
830'-835' Hematite	830'-835' lt brn	830'-835'. Same as 725'-730' w/ more abundant ss.
		835'-840'. No samples.
840'-875' Hematite	840'-875' lt brn	840'-875'. SS and limestone. SS is calc, vfg w/ qtz grains. Unit contains hematite coated chips.

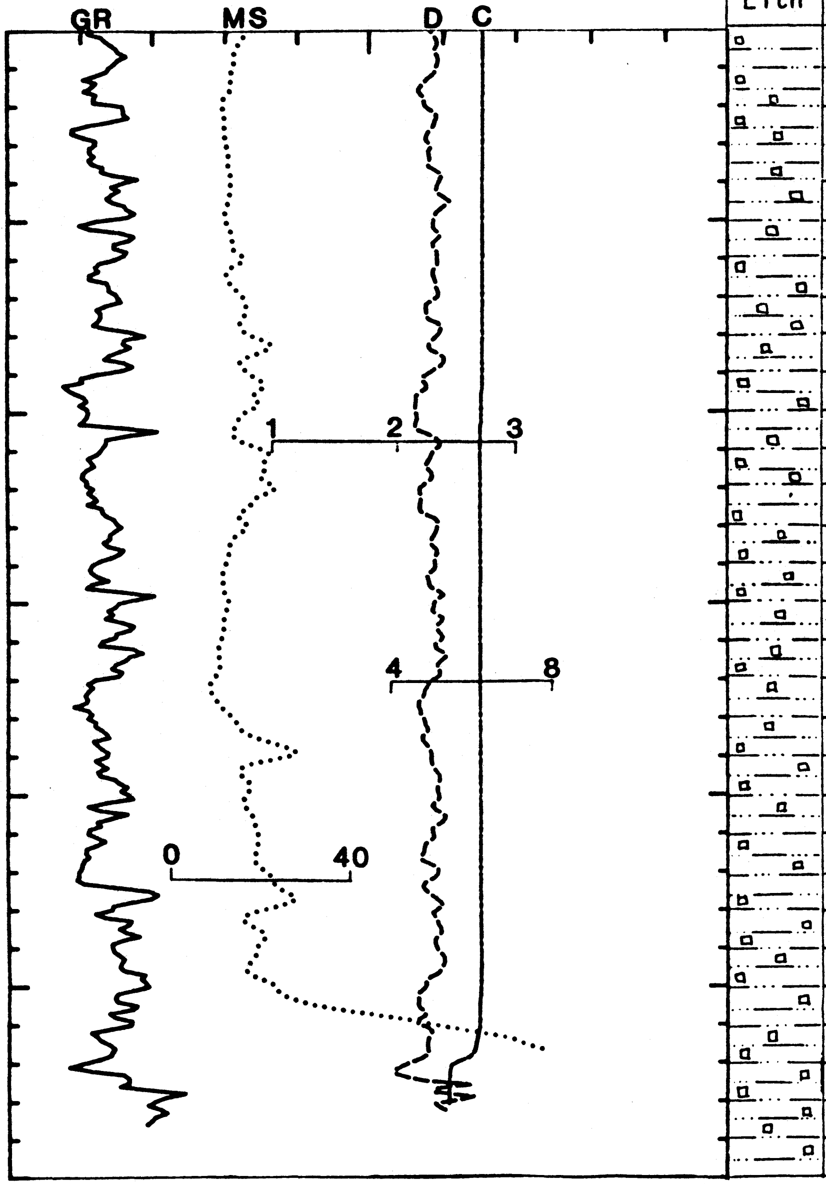


Color & Description

875'-1014'. No samples.

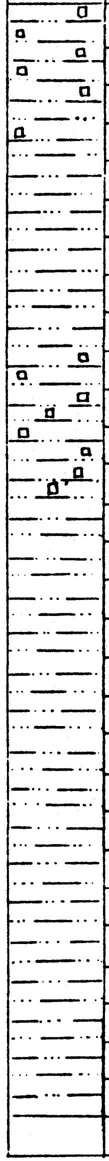
Description from core samples @ 1014' - 1421'.

1014'-1016'. Siltstone, pale ylw-orng & lt gray, mod well-sorted, massive, ...



Lith	Depth	Mineral.	Color & Description
			1014'-1016' cont..... well-cemented. Color changes are sharp & represent oxid/reduc contacts. Bleached sections contain limonite & v minor hematite alteration. Sharp contact w/ unit below.
	1050 1100 1150	HERMIT SHALE 1016' - 1215' Pyrite	1016'-1215'. Siltstone to v v fg ss, reduced, lt gray, mostly massive to faintly fissile, well-cemented. Contains persistent silt-size disseminated pyrite throughout; scattered spherical to irregular, med gray patches & blebs filled almost entirely w/ silt-size pyrite; pyrite also in wispy veinlets; occasional clayey, fissile intervals up to 1' thick w/ v thin clay laminae, esp. @ 1130', 1134', 1139' & 1144'; oxidized pale ylw-orange lens 7" long @ 1151'. Sharp contact w/ unit below.

Lith	Depth	Mineral.	Color & Description
	1200		
			1215'-1230'. Siltstone, Fe oxidized, mod red-brn, mainly massive to faintly fissile, well-cemented. Contains scattered lt gray reduction spots [elliptical- up to 4 cm long (i.e. @1220') & in irregular patches].
			1230'-1252'. Siltstone, Fe oxid, med red-brn to dk red-brn, mottled staining, mainly fissile w/ v thin clay lams to massive. Occasional irregular, lt gray reduction patches.
	1250		1252'-1260'. Siltstone to v vfg ss, Fe oxidized, mod red-brn, massive (nonfissile), well-cemented, homogeneous, well-sorted.
		1260' - 1271' Limonite, pyrite	1260'-1271'. SS, v vfg, v pale orng to lt gray, mod well-srtd, limonite stained, massive (non-fissile). Color contacts are sharp & are oxid/reduct contacts. Scattered irregular, med gray patches, blebs, & veins filled almost entirely w/ pyrite. Sharp contact w/ unit below.
		1271' - 1291' Pyrite	1271'-1291'. Siltstone to v vfg ss, reduced, lt gray, mod well-sorted, v homogeneous, massive, well-cemented; contains scattered med gray patches, blebs & veins filled w/ pyrite.
	1300		
			Description of 1291' - 1421' on page 10.

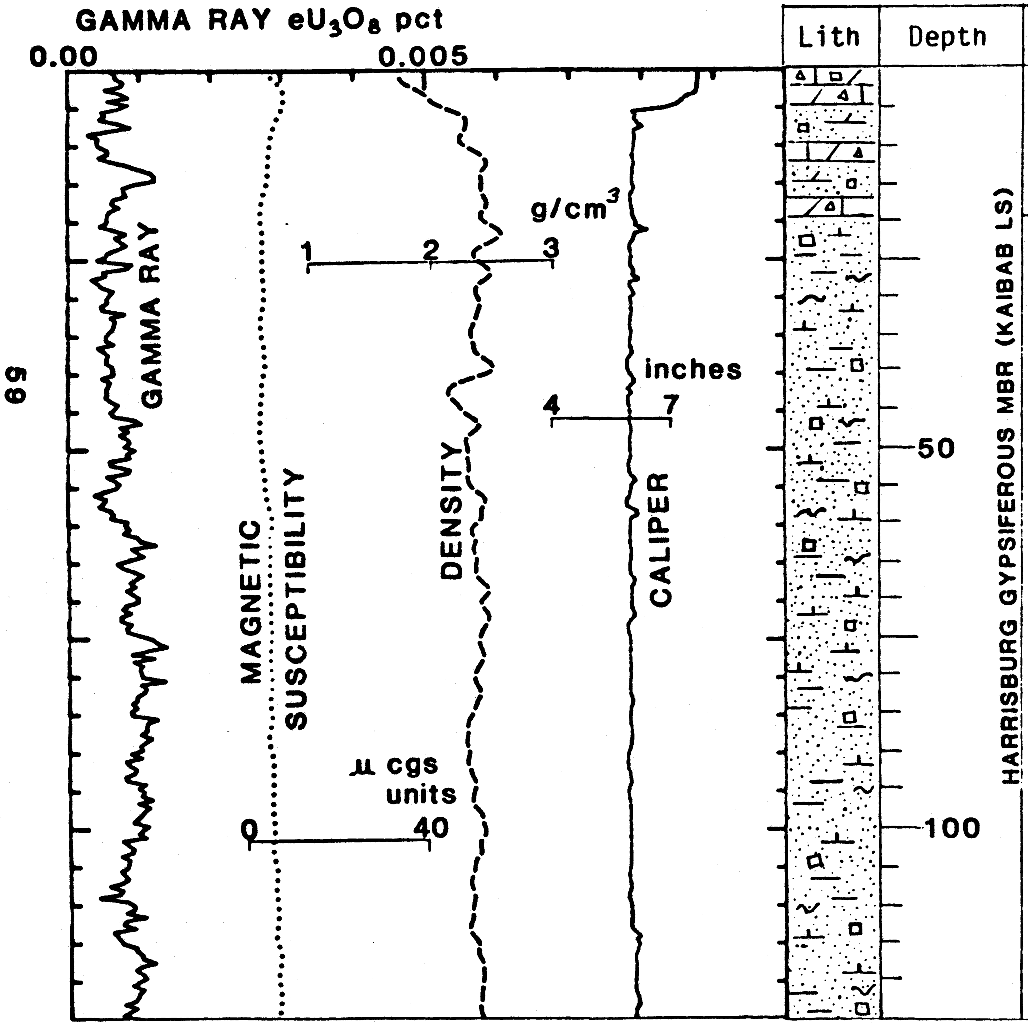
Lith	Depth	Mineral.	Color & Description
			Page 9 continued. Sharp contacts between all units below.
	1300	1291' - 1295' Pyrite, minor Mn oxide	1291'-1295'. Siltstone to v vfg ss, lt gray & v pale orng, mod well-srtd, massive, well-cmtd. Color changes are sharp oxid/reduc contacts. Reduced lt gray sections contain blebs & veinlets filled w/ pyrite. Oxid sections are devoid of pyrite w/ minor blebs of Mn oxide.
			1295'-1297'. Siltstone, reduced, lt gray, bioturbated (worm tubes) w/ wavy fissility. No sulfides apparent.
			1297'-1320'. Siltstone, Fe oxid, mod red-brn to dk red-brn, mod well-srtd, mainly well-cmtd to poorly cmtd; mottled staining; massive bedding to fissile w/ wavy lams (massive in lower 5'; clayey & v fissile @1314'-1315'); primarily qtz grains, ±10% mica grains, trace dk opaque min.
	1350	1320' - 1337' Pyrite	1320'-1337'. Siltstone, reduced, v lt gray, mod well-srtd, homo, massive, well-cmtd; shaly & sandy in lower 0.5'; v thin veinlets of swelling clay @1330'; occasional v small pods of pyrite & silt size pyrite scattered throughout.
	1400		1337'-1421'. Siltstone, Fe oxidized, mod red-brn to dk red-brn, mainly massive to fissile, fractured (esp. @ 1394'-1401'). Contains scattered spherical to irregular, lt gray reduction spots; v thin laminae of dk opaque minerals; mainly qtz grains, ±10% mica grains, trace dk opaque minerals; shaly intervals a few cm to several ft thick w/ mildly wavy lams (ie @1380'-1382'); intervals of mottled staining.

Appendix 4.-- Lithologic and geophysical logs for hole 4R and 4C, Mohawk Canyon Pipe

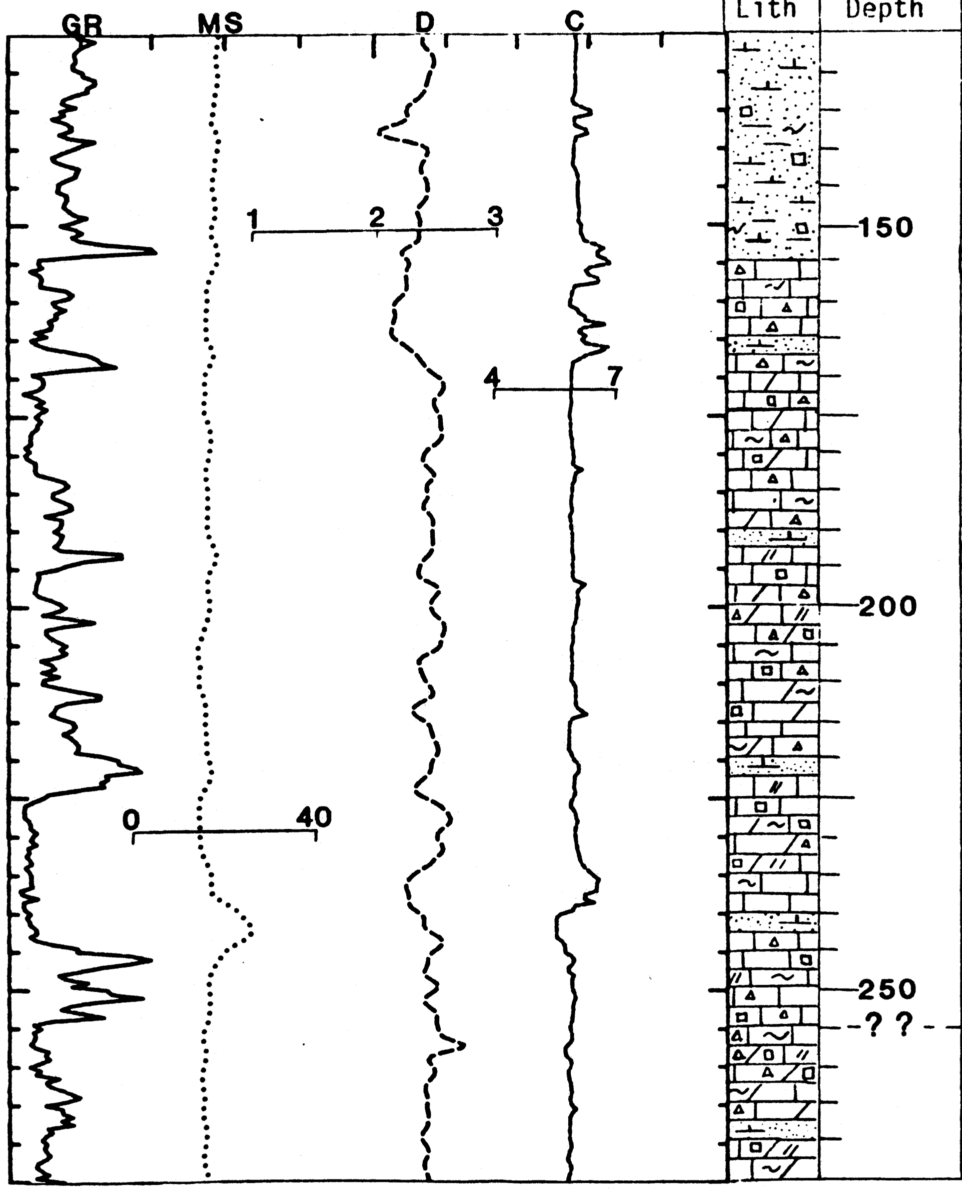
Hole no.: 494-4R & 4C   Date: 8/11/84

T.: 32N R.: 7W Section: 26 County: Coconino State: AZ

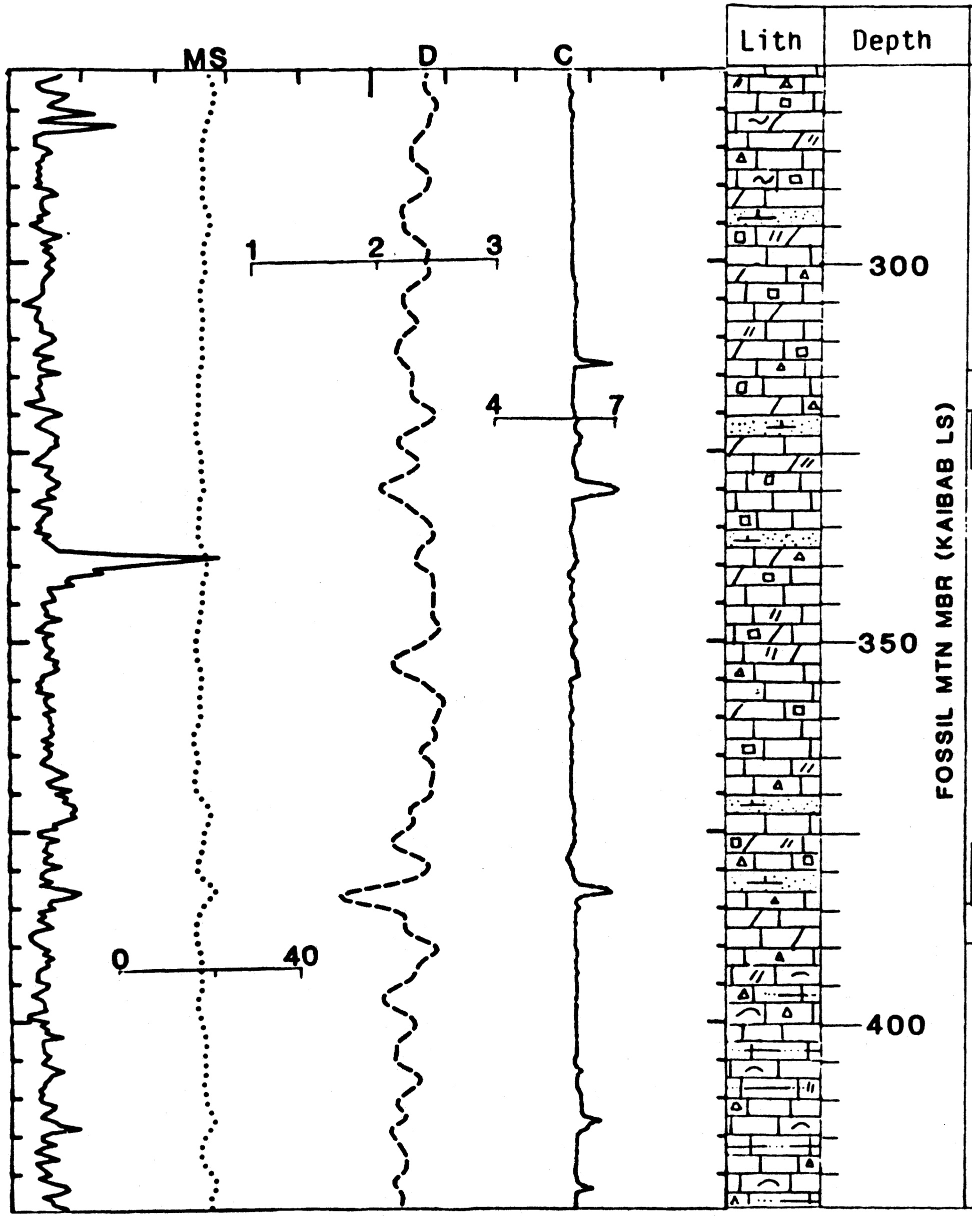
Lat: 36°07'30" Long: 113°00'24" Elev: 6345' TD: 1008' PD: 948'



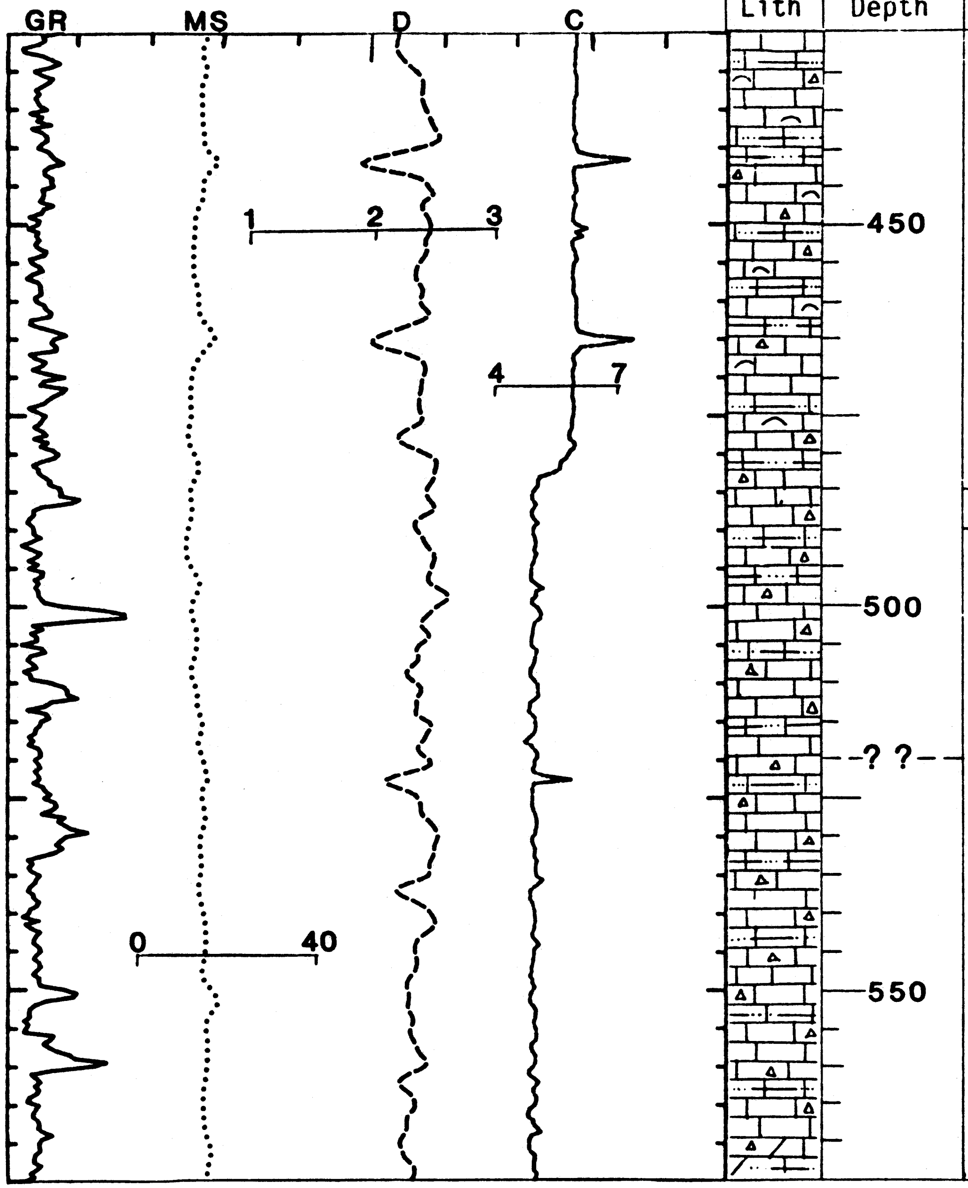
Mineral.	Color	Description
0-20' Abundant limonite, minor pyrite	0-20' v lt gray 20'-25' lt gray	0-20'. SS & ls. SS is dolomitic, fg to vfg; contains subang to subrnd grains. Ls is micritic & dolomitic. Entire unit contains abundant ylw limonite stain; chert frags; & minor silt-size pyrite.
20'-155' Goethite, hematite; minor limonite, pyrite & celadon.	25'-120' lt gray to v pale orng	20'-155'. SS (qtz arenite), limey, slightly clayey, vfg. Contains subang grains; goethite/hematite grains scattered to 80' & reappear @ 130'-160'; minor limonite stain, mod grn celadonitic clay lenses, & silt size pyrite throughout unit.



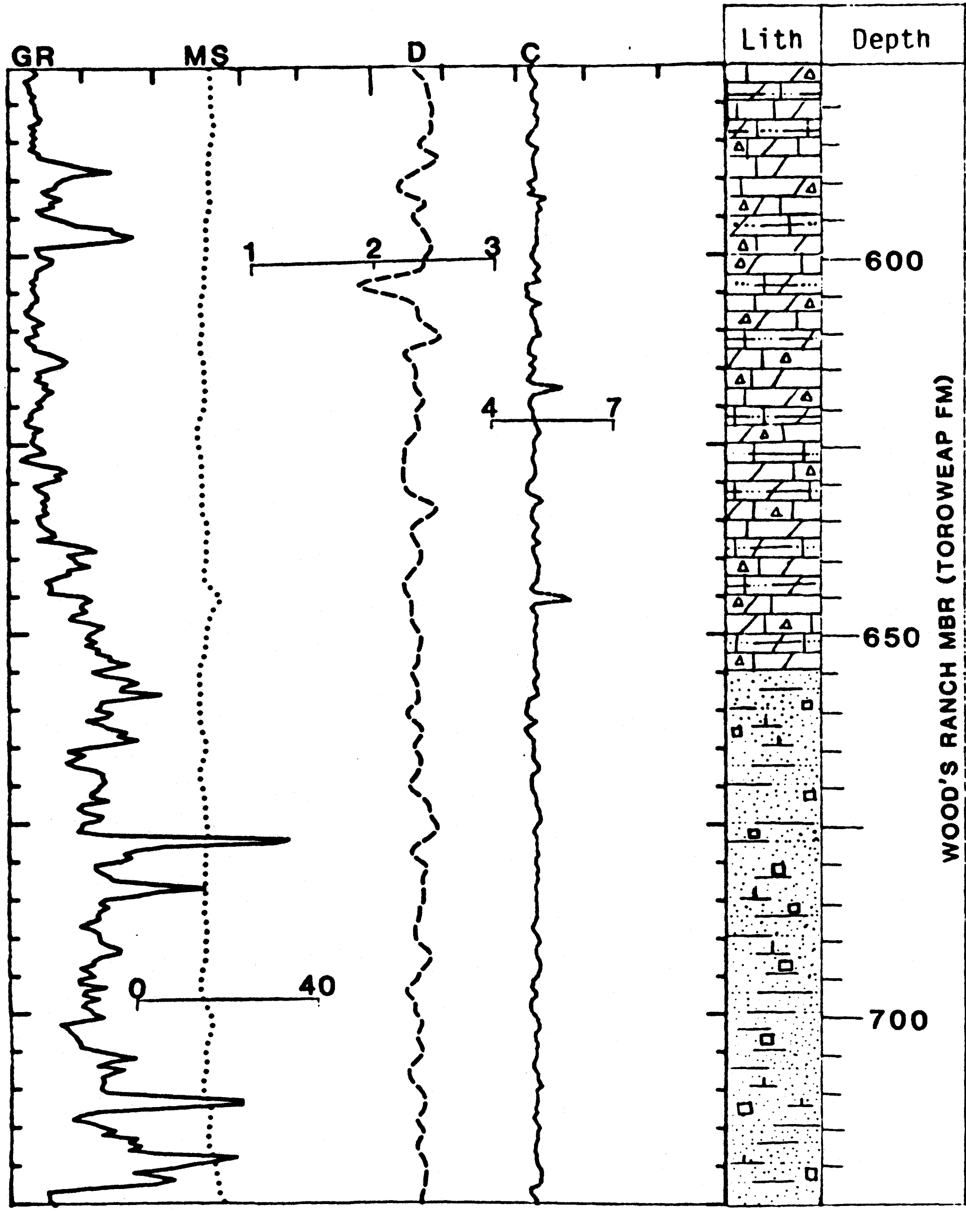
Mineral.	Color	Description
	120'-145' v pale orng	
	145'-155' pale ylw-orng	
155'-385' Minor pyrite 200'-205' Minor hematite/ goethite 155'-290' Minor celadon.	155'-160' mod orng-pink 160'-250' gray-ylw to blue-white	155'-385'. Ls w/ minor ss, calc, vfg. Ls is micritic; contains chert. Unit contains minor silt-size pyrite; minor mod grn celadonitic clay lenses to 290'. Abundant zones of recrystalization & dolomitization begin @ 170'. Minor gypsum begins @ 190'. 200'-205'. Minor hematite/goethite staining. Some of the chert nere appears to contain v small (>0.01 mm) dark inclusions.
	250'-260' pale ylw-orng	Limestone appears to be slightly coarser-grained than above @ 255'. Also chert appears to be less abundant & more milky in color.



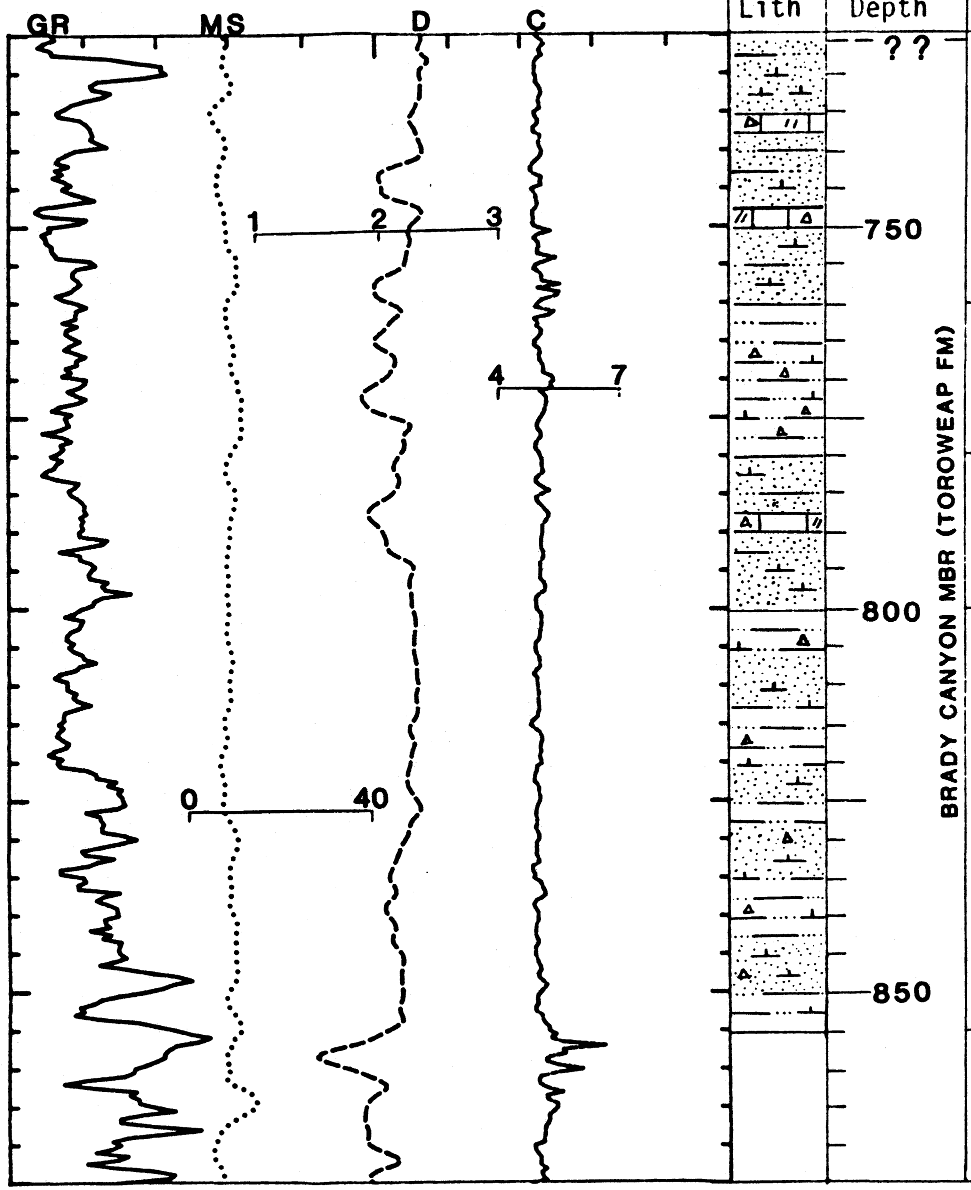
Mineral.	Color	Description
	260'-300' v pale orng	
315'-320' Minor azurite	300'-350' white	Small, minor azurite xtals @ 315'-320'. Recrystallized calcite, euhedral & rhombohedral, as void fillings @ 330'-335'.
385'-390' Abundant limonite	350'-400' v pale orng	385'-390'. Limestone, dolomitic. Contains abundant limonite stain.
390'-570' Abundant goetnite, minor limonite	400'-475' pale ylw-orng	390'-570'. Limestone, cherty. Contains minor fossils in upper part of interval; calcite, some euhedral in void fillings; minor gypsum; abundant goethite grains; minor limonite stain; abundant siltstone laminae.



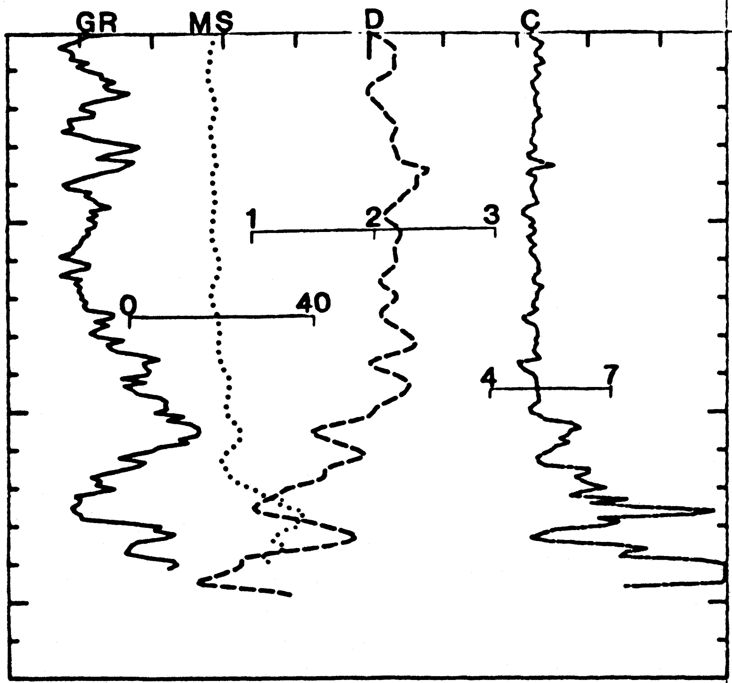
Depth	Mineral.	Color	Description
475'-555'	485'-490' Abundant goethite, limonite	475'-555' lt brn	Goethite & limonite in greatest abundance in section @ 485'-490'. Limonite is bright ylw-orange & goethite is dark metallic blue (could be sulfide?).
555'-655'		555'-655' gray-orng	



Mineral.	Color	Description
570'-655' Minor goethite, limonite		570'-655'. Limestone, dolomitic, silty. Contains chert as above; minor goethite frags (± 1%); minor limonite stain.
655'-725' Pyrite, minor limonite	655'-725' lt gray	655'-725'. SS, vfg, slightly calc, v silty. Contains subang to subrnd, frosted grains; pyrite (± 1-3%) as small grains, several chunks, & a few subhedral xtals; minor limonite stain.



Mineral.	Color	Description
725'-760' Abundant goethite, limonite	725'-780' lt brn	725'-760'. SS, vfg, silty, calc. Contains minor limestone; abundant goethite & limonite stain; chert; minor gypsum.
760'-780' Goethite, limonite		760'-780'. Siltstone, calc, sandy. Contains chert, goethite, & limonite stain.
780'-800' Abundant goethite, limonite	780'-835' pale ylw-orng	780'-800'. Same as 725'-760'.
800'-855' Abundant goethite		800'-855'. SS & siltstone. SS is vfg, silty, calc. Siltstone is sandy, calc. Unit contains abundant goethite chips; minor chert.
	835'-855' dk ylw-orng	
		855'-1001'. No samples.



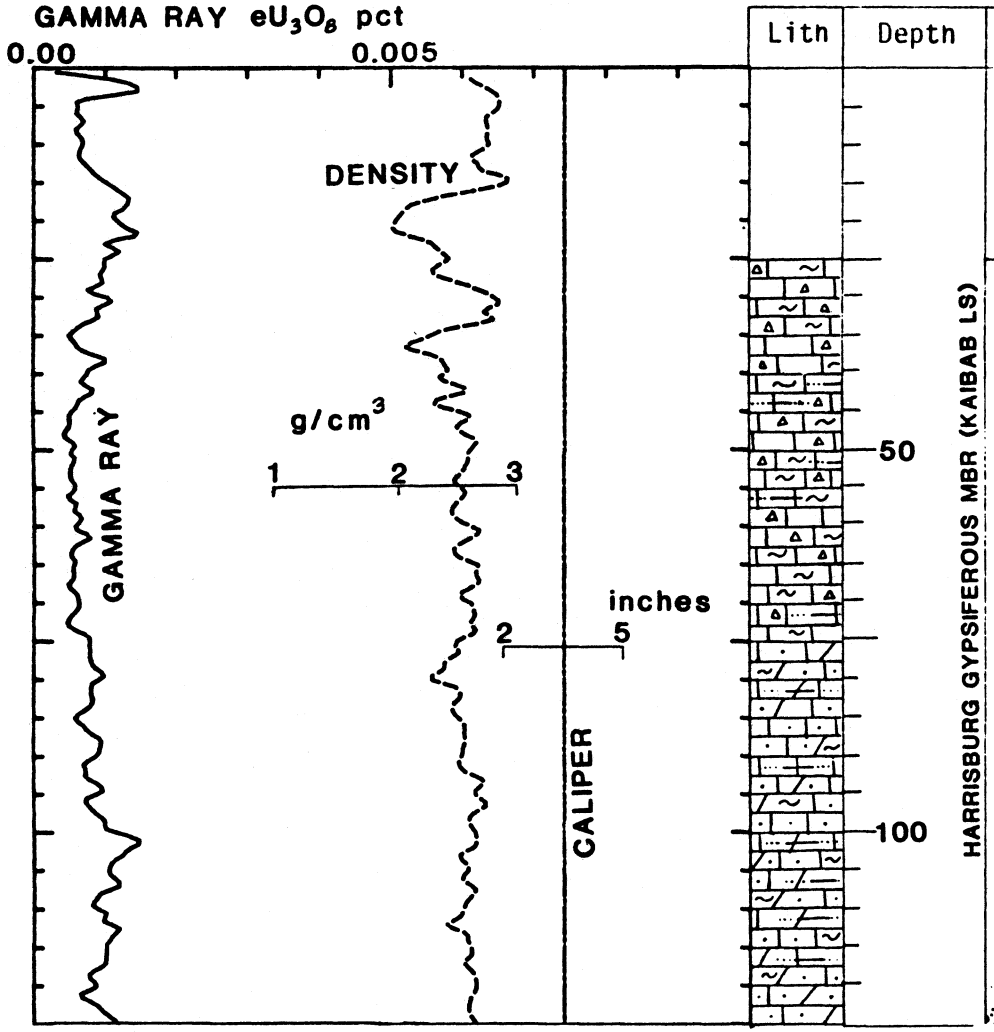
Lith	Depth	Mineralogy, Color & Description
	900 ? ? 950 ? ? 1000	855'-1001'. No samples. Description from core samples @ 1001' - 1008'.
	SELIGMAN MBR (TOROWEAP FM)	1001'-1003'. Brecciated ss, oxid, gray-orng to v pale orng, fg w/ frosted, subrnd qtz grains, mod well-sorted, mostly massive to scattered wispy lams, well-cemented w/ v slightly calc cement (possibly dolomite). Contains abundant limonite & minor hematite staining; scattered, persistent goethite as specks, veinlets, & spherical to irregular nodules up to 3 cm long, esp. in lower 2' (these goethite specks and spherical nodules were likely pyrite, as in the core from 1003' - 1007.5', before this interval was oxidized); subrnd siltstone clast @ 1002.5' Sharp contact w/ unit below. 1003'-1007.5'. Brecciated ss, reduced, med lt gray, vfg w/ frosted, subrnd quartz grains, massive to wispy lamd, mod well-sorted, slightly vuggy (vugs may be up to 5% of the rock), well-cmntd w/ noncalc cement. Contains abundant disseminated, silt-size pyrite throughout, also pyrite in thin wispy veinlets, & esp. abundant in med gray, silty, subrounded patches up to 5 cm long. Clasts include: (1) scattered lt olive gray, subang mudstone clasts up to 4 cm long, (2) very white, vfg ss w/ essentially no matrix-probably Coconino SS, (3) pinkish-white vfg ss w/ a noncalcareous (clay ?) matrix (maybe Brady Canyon) and interstitial metallic grains (<10 um in size). Pyrite comprises about 1-3% of the rock. Some 1 mm blebs of black, glassy, finely granular organic material. Sharp contact w/ unit below.
	COCO-NINO SS	1007.5'-1008'. Brecciated ss, heavily oxidized, dk ylw-orange to mod ylw-brown to mod red, vfg, vuggy. V abundant limonite & hematite staining obscures lithology. Contains med lt gray, subangular clast 5 cm long from above unit; disrupted bedding; v minor goethite.

Appendix 5.-- Lithologic and geophysical logs for hole 5C, Mohawk Canyon Pipe

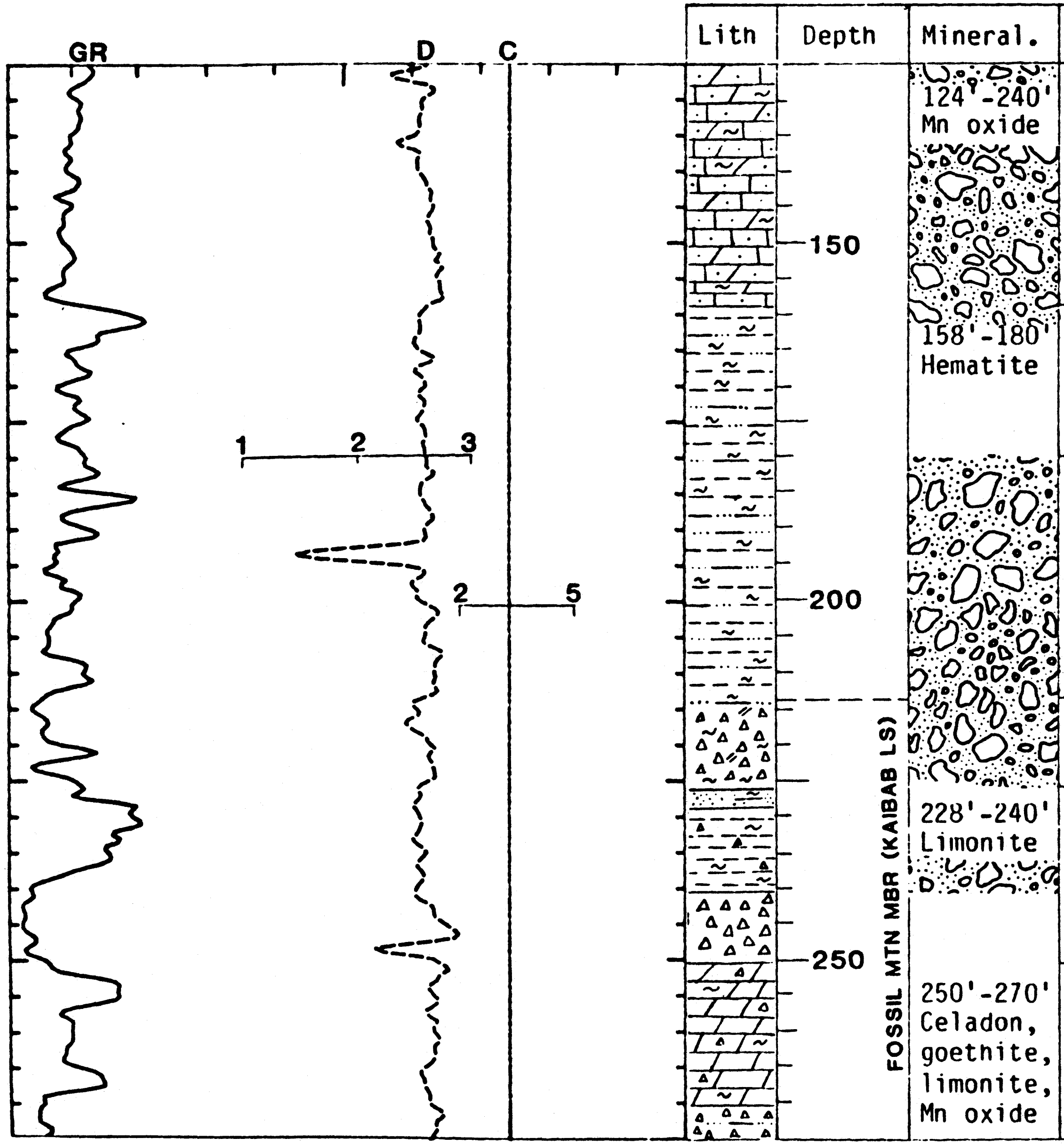
Core no.: 494-5C Date: 9/28/84

T.: 32N R.: 7W Section: 26 County: Coconino State: AZ

Lat: 36°07'30" Long: 113°00'24" Elev: 6340' TD: 1012' PD: 770'



Mineral.	Color & Description
	0-25'. No sample. Rock drill to set casing.
25'-240' Celadonite	25'-73'. Limestone, lt gray to white, micritic, sandy & silty, massive. Contains abundant pale-ylw orange silt lenses in lower 5'; thin, wavy celadonitic clay veinlets & staining throughout; abundant chert nodules. @40' unit becomes vuggy w/ v lt gray clay & minor pale ylw-orange silt. Gradational contact w/ unit below. V silty @ 29'.
73'-228' Goethite	73'-124'. Sandy, dolomite/limestone, v lt gray to ylw-gray, silty, micritic, massive, v uniform. Contains vugs w/ void-filling qtz grains & a v soft powder (anhydrite or zeolite); minor wispy veinlets of celadonitic clay; v minor chert; v minor silt lenses; v occasional specks & nodules of goethite.



Color & Description

124'-158'. Brecciated pieces of above sandy, dolomitized limestone in limy matrix. Clasts are ang to subang. Unit contains celadonitic veinlets, esp. coating breccia frags; v minor veinlets of goethite; v minor Mn oxide specks.

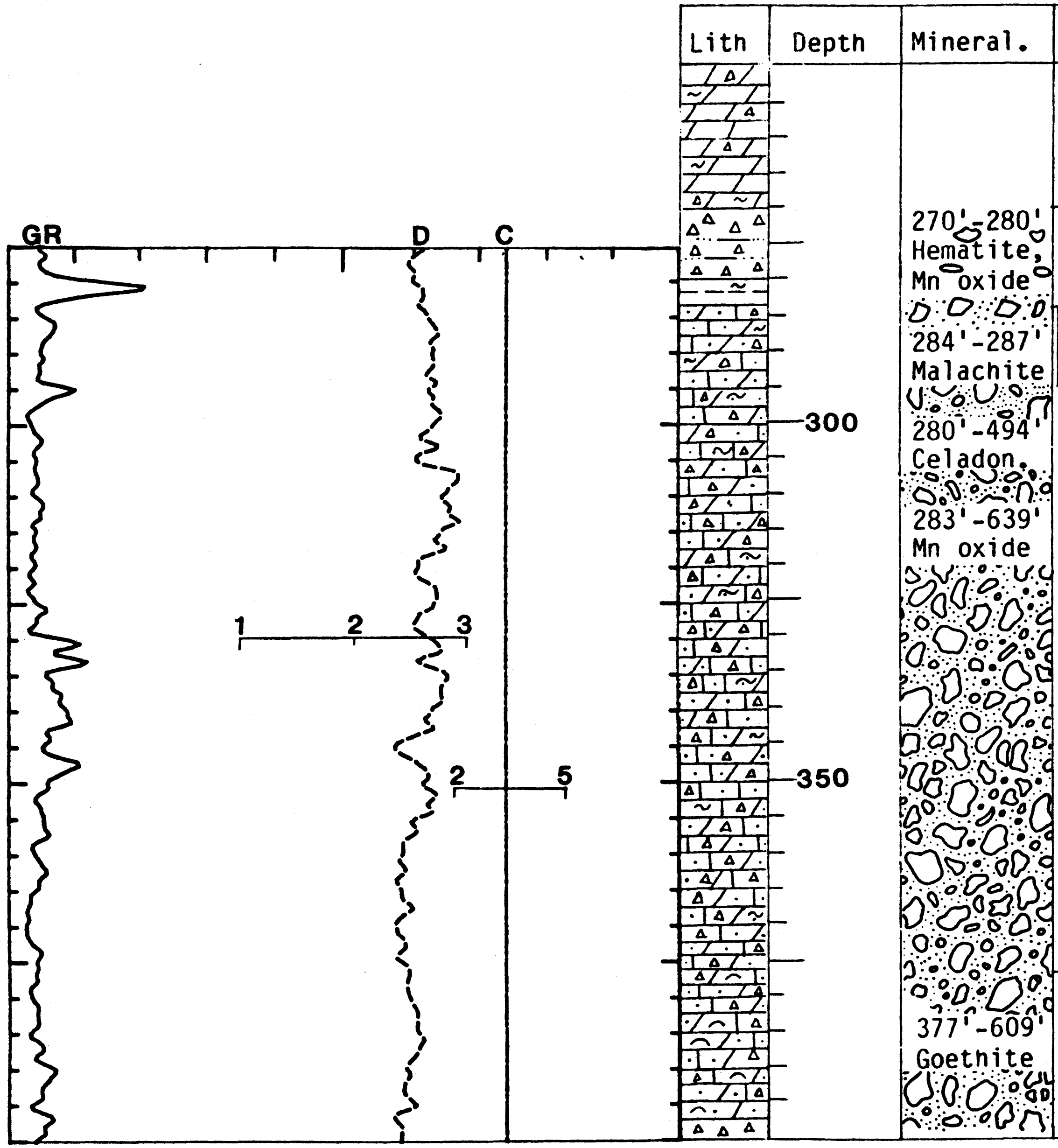
158'-180'. Claystone, pale ylw-orng to v lt gray, silty, slightly vuggy w/ calcite, kaolinite, & dickite in vugs, massive to crumbly w/ calc cement (dolomitic?); minor Mn oxide coatings & dendritic specks; abundant wavy celadonitic clay veinlets & stain; minor lenses of hematite/goethite; v minor hematite. No obvious breccia. Grades w/ unit below.

180'-213'. Brecciated siltstone & claystone w/ calc cement (dolomitic?). Sltst is ylw-gray sandy, massive. Clayst is pale ylw-orng, massive to crumbly, silty. Unit contains minor Mn oxide & goethite specks; abundant celadonite clay veinlets; minor chert, goethite in lower 15'. Most brecciated in lower 5'.

213'-226'. Brecciated chert clasts, v lt gray in ylw-gray ls/dolomite matrix; minor goethite dendritic Mn oxide specks; celadonitic clay veinlets; vuggy w/ gypsum & qtz xtals in voids.

226'-228'. SS, ylw-gray, vfg, silty, massive w/ calc cement; minor thin celadonitic clay veinlets; v minor Mn oxide staining; v minor chert; scattered goethite specks & nodules.
228'-240'. Brecciated calc claystone, pale ylw-orng, sandy; abundant limonite & minor Mn oxide stain; minor celadonitic clay veinlets; chert.
240'-250'. Chert, v lt gray.

Description for 250'-275' on page 3.



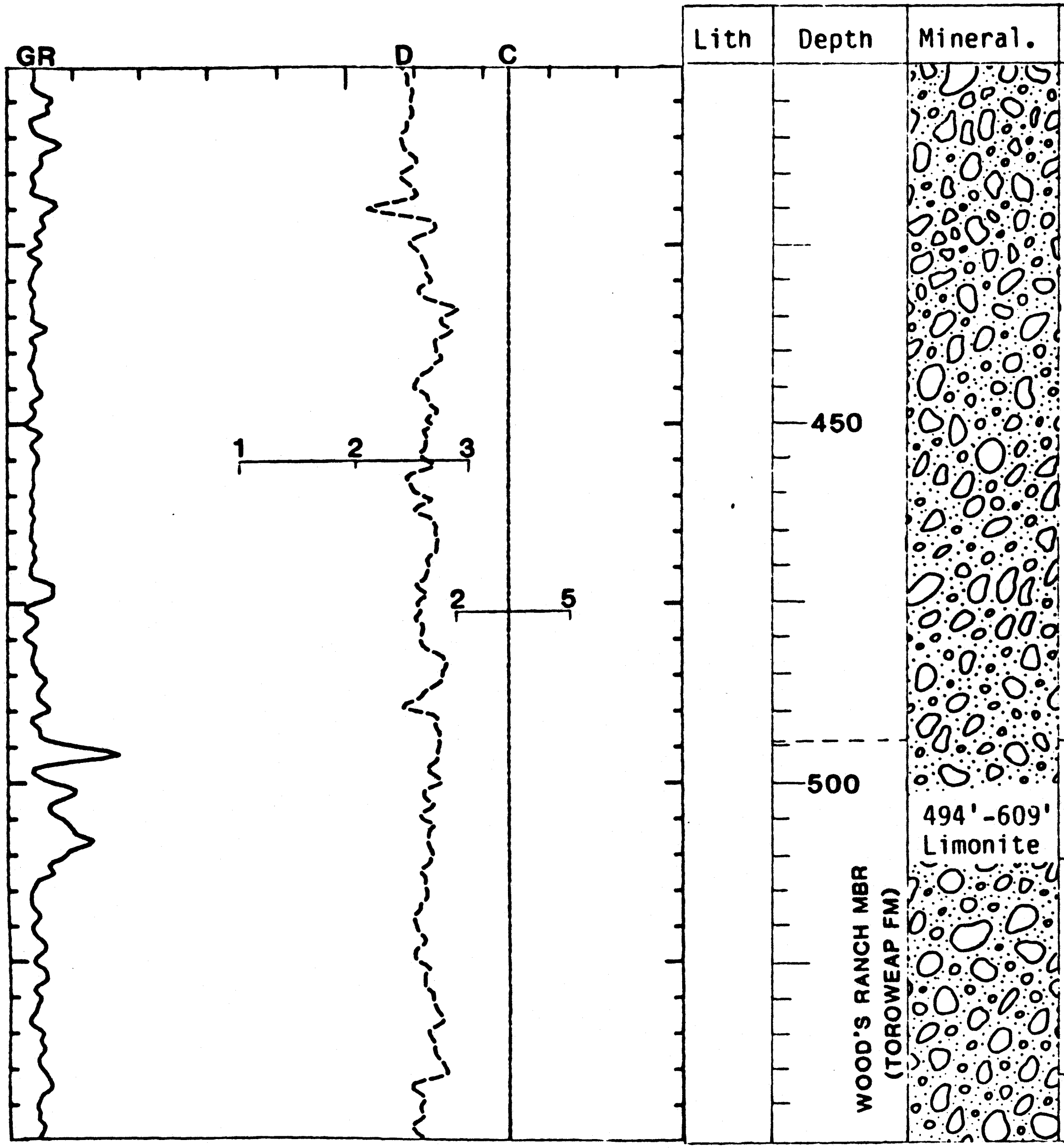
Color & Description

250'-270'. Dolomite, v lt gray, massive. Contains abundant limonite; goethite, some as pseudomorphs after pyrite; minor Mn oxide specks, chert, & celadonitic clay veinlets.

270'-280'. Brecciated lt gray chert in a v lt to lt gray calc (dolomitic?) matrix w/ thin pale ylw-orng silt lams; minor hematite & Mn oxide staining; calcite xtals on frac surfaces.

280'-283'. Claystone, lt olive-gray, crumbly, well-sorted; contains minor celadonite.

283'-377'. Brecciated sandy, dolomite/limestone w/ abundant chert (up to 90% chert in intervals up to 10'thick). Unit is lt gray to v lt gray to white, vuggy. Contains minor celadonite; minor Mn oxide staining; calcite xtals in vugs. Abundant disseminated malachite @284'-287'. Unit most brecciated from 340'-377'.



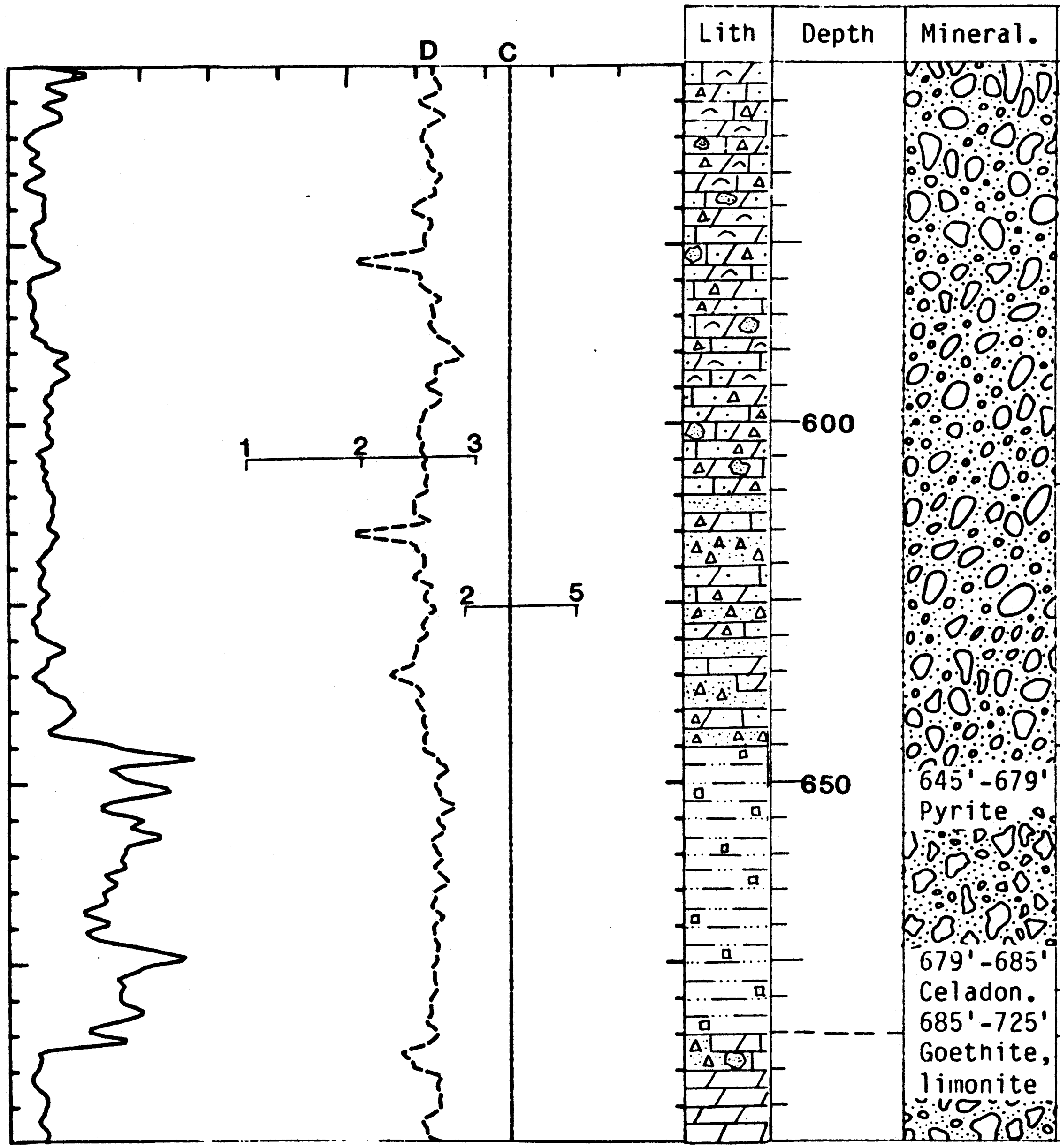
Color & Description

377'-494'. Brecciated sandy, v vuggy, dolomite/limestone, ylw-gray to white w/ lt gray to v lt gray chert. Matrix is calc (possibly dolomite). Unit contains: v abundant goethite as specks, veins, & nodules; fossils scattered throughout; v minor Mn oxide staining. Minor celadonite @470'-471'. Crystalline anhydrite @451'. Dolomite/limestone is v dense w/ up to 50% frags @444'-492'.

Fossils noted:
- 439' - Rugotia (small productoid brachiopod)
- 447' - Peniculauris bassis (diagnostic fossil of Kaibab & Toroweap Formations)
- 449' - Stenocisma
- 483' - Derbyia (brachiopod)
- 541' - Brachiopods & crinoid stem

494'-511'. Breccia consisting of chert & dolomite/ls, ylw-gray to lt gray in calc, sandy matrix w/ thin, wavy lams. Unit is non-vuggy w/ v minor goethite specks & nodules; minor pale ylw-orng limonite staining; v minor Mn oxide specks. First sign of sand in matrix.

511'-542'. Breccia of chert & dolomite/ls frags in a calc, vuggy, sandy matrix. Unit is ylw-gray to lt gray w/ frags, mainly pebble to cobble size; vuggy w/ vugs filled w/ dolomite rhombs; contains pale ylw-orng limonite stain. Scattered goethite specks & nodules. Mn oxide specks common on fractures. Frags are probably downdropped from Fossil Mountain Member.



Color & Description

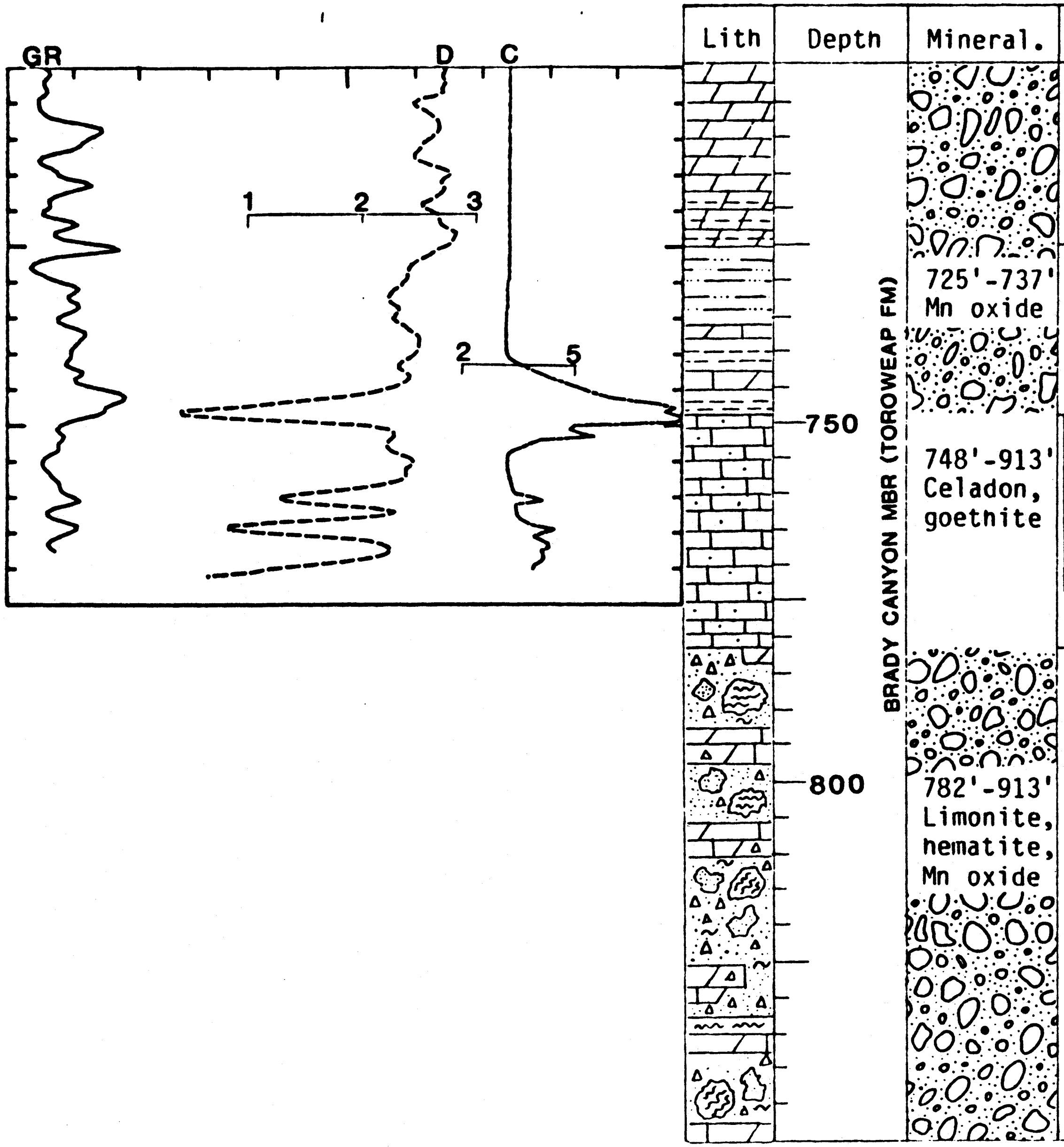
542'-609'. Similar to 377'-494' except the slightly sandy, ls/dolomite matrix is pinkish-gray to lt gray & there are minor ss clasts.

609'-639'. Breccia of v lt gray chert, ylw-gray ss, & minor v lt gray to lt gray ls/dolomite clasts in a ylw-gray, calc, vfg ss matrix. V minor Mn oxide specks. Good examples of Wood's Ranch Mbr. matrix w/ Fossil Mtn. frag of ls/dolomite containing a chert clast.

639'-645'. Breccia, ylw-gray, matrix supported. Matrix is calc ss w/ wavy lams. Clasts as 609'-639' except less in proportion @ top of interval & all are small pebble size (±4-20 mm).

645'-679'. Brecciated & reduced siltstone, lt gray, in silt & sand matrix w/ noncalc cement. Matrix contains wavy lams w/ med gray sulfides. Occasional small blebs (±2-5 mm) & veinlets of silt-size pyrite throughout. Probably most sulfide rich unit in core. Vugs filled w/ a white powder (kaolinite or anhydrite).

679'-685'. Breccia, pale ylw-orng to ylw-gray, consisting of chert, ss, dolomite, & ls clasts ranging in size from pebble to cobble size, mainly small pebble size. Carbonate clasts are vuggy. Matrix is wavy laminated, slightly calc siltstone w/ v minor celadonitic veinlets. @681'-682' is abundant disseminated graphite.



Color & Description

685'-725'. Dolomite, brecciated, lt gray, micritic, vuggy. Vugs are calcite lined w/ bladed anhydrite (or gypsum) xtals up to 10 mm long. Dolomitized crinoid stem @ 685'. Contains minor pale ylw-orng limonite staining; clay, Mn oxide & goethite specks common on fractures; scattered goethite nodules. Vuggy/moldic porosity & wavy lam claystone lenses ±50 mm thick near bottom of interval.

725'-737'. Siltstone, v pale orng, calc, massive to v finely lam. Mn oxide specks throughout unit. Vuggy @734'; vugs lined w/ calcite. Unit may represent one large block of siltstone dropped into the pipe.

737'-748'. Breccia of calc, wavy lam, white claystone & v pale orng to pale ylw-orng limestone/dolomite.

748'-782'. Limestone, v lt gray, micritic, slightly sandy, fractured w/ calcite, v occasionally celadonite & esp. goethite coating frac surfaces; vuggy/moldic porosity w/ calcite & goethite in vugs; minor brecciated lenses up to 0.4' thick; minor pale ylw-orng stain; goethite specks & nodules scattered throughout.

782'-913'. Breccia of sandy ls/dolomite clasts, v lt gray to lt gray, in calc vfg ss matrix. Unit is vuggy w/ calcite in vugs & goethite in vugs, veinlets, & specks; scattered gray-orng limonite stain. Breccia also contains v lt gray chert nodules; pale ylw-orng, calc (dolomitic?) ss clasts; and v lt gray, noncalc mudstone clasts; clasts are ang to subang. Unit contains: thin celadonitic veinlets & stain to 880', mainly @806'-832'; goethite pseudomorphs after pyrite scattered throughout; ....

Lith	Depth	Mineral.	Color & Description
	900		782'-913' cont.....scattered dendritic Mn oxide specks; v minor dusky red hematite stain in lenses; rare dk ylw-orng mudstone lenses up to 0.5' thick w/ abundant goethite. V sandy @871'-882' w/ vfg sand. Limonite stain most abundant @782'-882'. Chert nodules v minor @817'-913'. Calcite replaces fossils @807' & 823'. Mudstone lenses abundant @782', 784', & 799'.
	SELIGMAN MBR (TOROWEAP FM) 950	913' - 1012' Goethite, limonite, hematite	913'-976'. Brecciated frags of fg, calc ss in a more limonite stained fg, calc matrix. Breccia contains pale to dk ylw-orng to gray-orng pink, ang to subang clasts; mainly massive bedded w/ zones of leisegang banding. "Picture ss" @969'-971'. Unit is heavily Fe-oxid w/ abundant limonite stain (dk to pale ylw-orng to mod ylw-brn); vuggy; fractured w/ fractures stained w/ goethite & minor calcite. Contains: calc cement (dolomitic?); heavily hematite altered zones (dusky red to mod red), esp. in lower 8'; goethite pseudomorphs replacing pyrite scattered throughout; occasional silty lenses; vugs filled w/ calcite & goethite.
	COCO-NINO SS	Celadon. @ 1009'	976'-1012'. Brecciated med to fg, noncalc ss in med to fg sand matrix w/ noncalc cement. Breccia contains v abundant dk ylw-orng to mod ylw-brn limonite stain & abundant mod red-brn to dk red-brn hematite stain; goethite as stain & in veinlets common. Clasts are v lt gray & pale to dk ylw-orng, ang to subang, porous, massive to leisegang banding. Occasional pink-gray mudstone clasts. Unit is heavily Fe-oxid; vuggy w/ goethite common in vugs, calcite less common. Sylvite & celadonite @1009'.