GJBX-293(81)

National Uranium Resource Evaluation

# SUMMARY GEOLOGIC REPORT ON DRILLING IN WESTERN PRESCOTT AND WILLIAMS QUADRANGLES

## Mohave, Yavapai, and ~~Yuma~~ La Paz Counties, Arizona


Bendix Field Engineering Corporation

Grand Junction Operations
Grand Junction, CO 81502



September 1981



PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Nuclear Energy
Grand Junction Office, Colorado

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LaPaz

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Under Contract No. DE-AC13-76GJ01664

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## ABSTRACT

This drilling project in northwestern Arizona consisted of 18 holes drilled to depths ranging from 1,341 to 5,491 feet (409 to 1,673 meters). The holes were sited to determine the lateral extent of the uranium-bearing, paludal/lacustrine strata of the Anderson Mine in Date Creek basin and to obtain additional data to improve the resource estimates for the Date Creek and Big Sandy basins. In addition, one or more holes were drilled in seven other Tertiary basins in which no uranium occurrences had been found but which were thought to contain favorable lacustrine host rocks. In all, this was an attempt to evaluate the uranium potential of an area of 1,956 square miles (5,007 square kilometers).

In the Department of Energy (DOE) 1980 Uranium Assessment Report, the uranium potential of the Chapin Wash Formation, and equivalent sediments, was changed, partly due to the results of this drilling project, from the 1979 Interim Report estimate of 27,000 tons of "possible" potential $50/lb ore to 115,000 tons of "probable" potential and 71,800 tons of "possible" potential $100/lb ore.

Drilling began in June 1979 and was completed in October 1979. A total of 63,520 feet (19,361 meters) of hole was drilled, of which 283 feet (86 meters) were cored. Cores were taken at random intervals. A lithologic log and a suite of geophysical logs were obtained from each hole.

Possible lacustrine sediments were found in 10 of the 18 holes drilled. Four of the holes are in the Date Creek basin and anomalous radioactivity was found in three of these. Possible lacustrine sediments were encountered in four of the six holes drilled in Big Sandy Valley. Radioactive anomalies were recorded in three of these holes. In all, radioactive anomalies were recorded in a total of eight holes in the project. These were in Date Creek basin, Big Sandy, Sacramento, and Truxton Valleys. No anomalies were found in Aguila, Butler, Centennial, Congress, or Walnut Grove Valleys.

Principal conclusions of this study are: 1) Tertiary lacustrine sediments are widespread in the Tertiary basins investigated but are only locally developed within the basins; 2) subsurface stratigraphy of Tertiary sedimentary formations and volcanics is complex; 3) the fluvial sediments encountered in this project are generally unfavorable for the formation of uranium deposits because of the absence of clay or shale interbeds and fossil vegetal carbon or other reductant; and 4) partially as a result of this drilling project, uranium potential of Big Sandy Valley has been changed from Department of Energy's "speculative" class to the "possible" class because of the discovery in this basin of a thick sequence of lacustrine rocks containing significant radioactive anomalies.

## ACKNOWLEDGMENTS

An expression of thanks is owed to Rod Nielson for interpretation of the airborne radiometric survey data and Bob Clynch and Bert Morrison for their critical review and comments. The assistance of Paul Weiser in preparing the cross-sections is gratefully acknowledged.

## INTRODUCTION

The Southwest Prescott drilling project was conducted by Bendix Field Engineering Corporation in support of the United States Department of Energy (DOE) National Uranium Resource Evaluation (NURE) program. This work was performed under Contract Number DE-AC13-76GJ01664.

The Southwest Prescott project was composed of 18 drill holes having an aggregate total footage of 63,520 feet (19,361 meters). These holes obtained data relevant to the stratigraphy and uranium favorability of Tertiary intermontane basin sediments in Mohave, Yavapai, and Yuma counties, Arizona. The project area extends from Walnut Grove Valley southwest of the city of Prescott to Aguila Valley on the southern border of the Prescott 2° quadrangle, to the Sacramento and Centennial Valleys on the extreme western border of the quad, and north to the vicinity of Truxton in the Williams 2° quadrangle (see Figures 1 and 2). The area measures approximately 80 miles (128 kilometers) east to west and 100 miles (160 kilometers) north to south. The major portion of the project lies between the towns of Wickenburg on the southeast, Kingman on the northwest, and Havasu City on the west.

R. T. May and D. L. White, geologists of the Albuquerque District Office, Bendix Field Engineering Corporation (BFEC), proposed in December 1978 that a NURE drilling project be conducted in this area. They recommended a program of 29 widely spaced holes to test 15 Tertiary basins of the Prescott 2° quadrangle. This number was first reduced to nine during the planning stage then increased to 19 after drilling had begun and finally adjusted to 18 holes.

The purpose of the project was to obtain subsurface data on the uranium potential of the Tertiary basins of the project area. The NURE Interim Report of June 1979 assigned 7,000 tons of "probable" and 27,000 tons of "possible" $U_3O_8$ of $50/lb potential to the Chapin Wash and Artillery Formations in this area. More data were needed on these formations to try and obtain more accurate estimates of the uranium potential.

When proposed, it was intended that the results of this project would be incorporated in the Prescott quadrangle evaluation report completed on July 16, 1979. However, the time required to complete project planning and approval, land status studies, drilling permit acquisition, and drilling contractor procurement resulted in drilling not being completed until October 30, 1979.

The objectives of the project were:

a) To document the lithology, oxidation state, and uranium content of Tertiary basin-fill sequences at selected locations.
b) To determine the relative abundance and distribution of Tertiary lacustrine beds.
c) To make preliminary evaluations of the uranium mineralization potential of the sediments encountered.

## Known Occurrences

Uranium occurrences in the Southwest Prescott project area consist of two types: occurrences in Cenozoic sedimentary rocks and occurrences in veins in Mesozoic to Precambrian igneous and metamorphic rocks. The vein-type deposits are generally small and occur most commonly in fault planes bordering veins containing metalliferous minerals. The most common unoxidized uranium mineral in these deposits is uraninite. Autunite, kasolite, torbernite, and uranophane are the most common secondary uranium minerals in these occurrences. No commercial production of uranium has been obtained from these vein deposits.

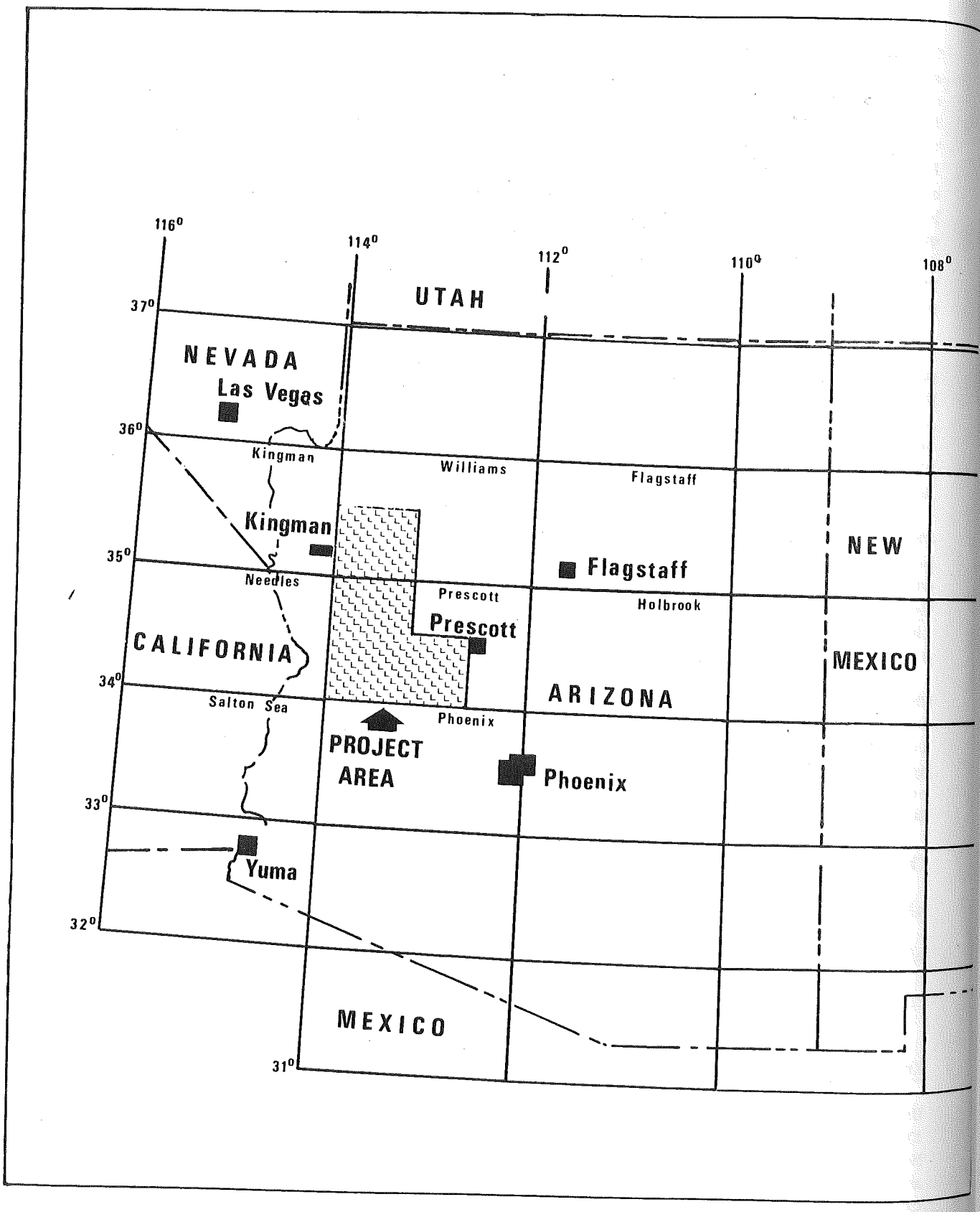



FIGURE 1. Index Map

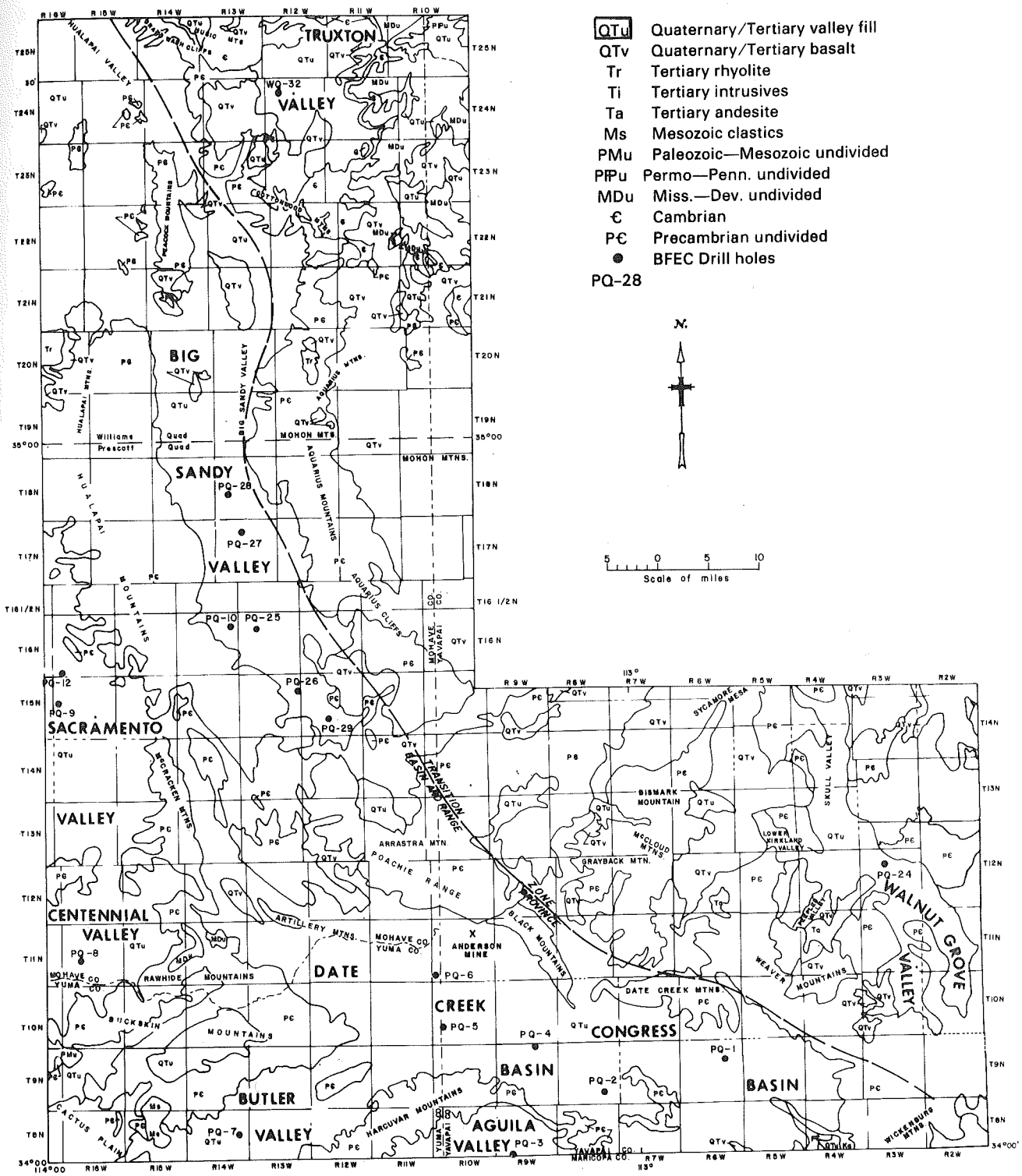



FIGURE 2. Generalized Geologic Map Showing Drill Hole Locations

The uranium occurrences in sedimentary rocks in the area of this project are in Tertiary lake deposits consisting of calcareous mudstone, carbonaceous and silicified tuffaceous mudstone, and impure limestone and marlstone. Fossil vegetal carbon has been identified in some of these occurrences.

Mineral claims have been staked on most of these occurrences. They are: the Catherine and Michael claims on the east flank of Big Sandy Valley, 8 miles (12.8 kilometers) northeast of Wickieup; the Masterson claims on the west flank of the Artillery Mountains; the Lucky Four claims on the south plunge of the Artillery Mountains; and the Uranium-Aire claims (Anderson Mine) on the north-central margin of the Date Creek basin. Only the latter claims have been thoroughly investigated and intensive drilling has been conducted downdip from the open-pit mine.

The known uranium occurrences in the Prescott 2° NTMS quadrangle are identified, located, and summarized by Clark (1979, pages 7 and 8).

Past and Present Activity

The discovery of anomalous radioactivity in the northern part of Date Creek basin in 1955 led to many hundreds of claims being staked on public domain. The only uranium produced as a result of this activity came from the Anderson Mine between the years 1955 and 1958. The small mill formerly located on the property produced 33,230 pounds of $U_3O_8$ from ore that averaged 0.15 percent $U_3O_8$.

The Anderson Mine properties have changed hands several times and are now (1980) owned by Minerals Exploration Company (MinEx), a wholly-owned subsidiary of Union Oil Company of California. Since acquiring the property in 1974, MinEx has drilled it out on 800, 400, and 200 foot (244, 122, and 61 meter) grids and is currently awaiting a Bureau of Land Management (BLM) environmental clearance for mill construction.

At least 24 companies are known to have drilled in the Date Creek and Congress basins and in Butler, Aguila, Centennial, Sacramento, and Big Sandy Valleys within the last few years.

Intensive exploration of the northern portion of the Date Creek basin has indicated that millions of pounds of recoverable, low-grade uranium are present in the Miocene paludal/lacustrine rocks. As a result, the Department of Energy changed its June 1979 estimate of 7,000 tons of probable and 27,000 tons of possible $30 per pound uranium resources in the Chapin Wash Formation to 91,075 tons and 65,965 tons respectively in the $100 per pound estimate in the October 1, 1980, Assessment Report on Uranium in the United States of America.

At the Anderson Mine the grade of uranium "ore" ranges from 0.03 percent to 0.10 percent and averages 0.06 percent $U_3O_8$ (Sherborne and others, 1979).

The DOE estimate of speculative potential for $30 per pound ore assigned to the Big Sandy Formation in the Big Sandy basin was changed from 3,000 tons in the 1979 report to 90,330 tons of possible potential in the 1980 assessment report. There have been some recent rumors of exploration success by industry in the Big Sandy basin.

Minerals Exploration, Pathfinder, Teton, Marline, Phillips, Urangesellschaft, and Ramparts appear to be the companies most interested in the area at present. Present activity appears to be concentrated in the northern half of Date Creek basin where exploration has been most successful. Little interest by industry has been shown in Congress basin, Butler, Aguila, Centennial, Sacramento, and Walnut Grove Valleys, although scattered exploratory holes have been drilled in each basin or valley.

A Hydrogeochemical Stream Sediment Reconnaissance (HSSR) program of the Prescott quadrangle has been completed by Lawrence Livermore Laboratory. The results of this study were released as an open-file report, GJBX-122(79), by DOE on August 22, 1979.

The results of the survey had little or no effect on the selection of drill sites in this project, inasmuch as the report had not been completed by the time the drilling was begun. The purpose of the drilling was to find favorable Tertiary sedimentary host rocks in the basins, and therefore drill sites were selected where it was believed favorable host rocks would be encountered.

An airborne radiometric survey of the Prescott quadrangle was made by Aero Service, Inc., under subcontract to BFEC. The results of this survey were released as an open-file report, GJBX-59(79), by DOE on May 29, 1979. Almost all of the radioactive anomalies recorded in this survey are in crystalline rocks - not considered for drilling in this project for the same reasons stated above. Also, many of the rocks in the vicinity of the airborne anomalies had been sampled during evaluation of the Prescott quadrangle for the NURE program.

## Regional Geology

The project area is predominantly in the Basin and Range Province portion of northwestern Arizona, with only small portions in the Transition Zone and Colorado Plateau Province.

The Basin and Range Province of the western United States is centered in Nevada, with portions extending into the adjoining states of Arizona, California, Idaho, Oregon, and Utah. The geology of the province is very complex. It consists of a thick series of late Precambrian through Jurassic geosynclinal sedimentary rocks that were folded, thrust faulted, and uplifted into mountain ranges in the Middle and Late Paleozoic and the Middle and Late Mesozoic periods. Igneous activity during the Cretaceous and Tertiary periods injected stocks and laccoliths into the already deformed sediments. During the Cretaceous period, huge volumes of material were eroded from the mountains and deposited in the geosyncline to the east, extending in a north-south line from central Utah eastward to the Great Plains states.

Block faulting in the Basin and Range Province began as early as the Oligocene and continued into Late Cenozoic time. It was during this time that the many basins were formed between the block-fault mountain ranges and were filled with fluvial and lacustrine sediments and volcanics of various types and compositions. It is these volcanics, particularly the tuffs, that are considered by many investigators to be the sources of the uranium deposits and occurrences in the paludal/lacustrine sediments in some of the Tertiary

basins. Each of the basins records a complex geologic history since it was formed by Basin and Range faulting, and, even though overall geologic history of the basins is similar, each appears to be a distinctly separate geologic feature.

In the Arizona portion of the Basin and Range Province, east of the Colorado River, the area in which this drilling project is located, the late Precambrian and Paleozoic sedimentary rocks are thin and are related more to the rocks of the stable platform (Colorado Plateau) than to those of the Basin and Range.

The province is rich in metallic and non-metallic mineral deposits. Metallogenesis accompanied the episodes of magmatism and is attributed to the action of hydrothermal convection associated with the magmatism. The non-metallic minerals accumulated in closed basins were formed by the Tertiary block faulting. These are non-marine evaporite minerals and brines.

## Geology of the Project Area

The major portion of the project area consists of northwest-southeast trending mountain ranges and intermontane basins. However, in the southern portion of the area the Date Creek, Harcuvar, Buckskin, and Rawhide Mountains trend in an east-west direction (Figure 2).

In general, the mountain ranges that extend in the northwest-southeast direction and the Date Creek Mountains, are geologically similar. They consist of Precambrian schists intruded by Precambrian granites and of granite gneisses and Cretaceous monzonites. Some of these older rocks are intruded by Tertiary dikes and some are partially to largely covered by Late Cretaceous or Tertiary rhyolites and andesites. These have, since the end of the Tertiary period, been partially eroded and locally buried by Quaternary basalts, tuffs, or ash flows. Several ranges (Black Mountains and Black Mesa) in the central part of the project area consist largely of thick accumulations of extrusive volcanic rocks. Black Mesa contains a poorly exposed granite core overlain by a 2,000- to 3,000-foot (609 to 914 meter) thick sequence of andesite, rhyolite and basalt that has been intruded by dikes.

The Rawhide Mountains, in the southwestern part of the area, have been interpreted by Shackelford (1980) to consist of a lower plate of Mesozoic-early Tertiary (?) mylonitic metamorphic gneisses, separated by the Miocene Rawhide detachment fault from an overlying complex "allochthon of commonly chaotically imbricate Precambrian (?) through Miocene rocks" (Shackelford, 1980). Younger basalt flows and sedimentary rocks lie unconformably on the deformed older rocks. Shackelford contends that the Rawhide Fault has been exposed by tectonic denudation in the Rawhide Mountains and that "the leading edge of this denudational terrane may be in the Artillery Mountains" (Shackelford, 1980) to the northeast.

Mineral deposits are widespread in the mountains within and surrounding the project area, but most deposits are relatively small. Copper and iron minerals form the most common ores, although gold, silver, lead, zinc, and manganese oxide have also been mined. Most of the mineral deposits occur as replacement deposits in limestone and Precambrian metasediments, fissure veins, and minor fractures. The mineralization is thought to have occurred in late Cretaceous or Tertiary periods.

Several areas of anomalous radioactivity have been delineated in the Airborne Radiometric and Magnetic Survey flown by Aero-Service Corporation and reported by the DOE (1979a). The anomalies are predominantly over Precambrian rock outcrops. Some of these anomalies show possible uranium and thorium enrichment in structures such as pegmatite dikes (Neilson, R., personal communication). These mineral occurrences may have served in part as sources of uranium for deposits in the adjoining basins. The largest known mineral deposits found to date are the massive sulfide replacement deposits in Precambrian metasediments intruded by late Cretaceous or Tertiary quartz monzonite stocks in the Bagdad area and the low-grade, bedded manganese oxide deposits in alluvial fan and playa sediments of the Miocene (?) Chapin Wash Formation in the Artillery and Buckskin Mountain areas.

The project area has undergone multiple tectonic events. Only the two most recent events have affected Tertiary basin fill sediments. The first of these, early Tertiary (Laramide) uplift, created high relief. Erosion then stripped vast amounts of detritus from the uplands, dissecting and exposing Mesozoic, Paleozoic, and later Precambrian rocks throughout the area. The detrital materials were transported by streams and deposited in intermontane basins and valleys. This was accompanied and followed by high-angle, normal faulting, which is present everywhere in the desert and mountain regions of Arizona. Most of these faults are middle and late Tertiary age, although some predate the Laramide orogeny and others are as young as Pleistocene. The early Tertiary basin deposits were tilted by the later faults and covered by later Tertiary deposits. In some basins, these fluvial and lacustrine sediments, accumulated to thicknesses of thousands of feet. Sedimentation during Tertiary time was accompanied by volcanic activity, and locally, volcanic flows are present in the sedimentary column. The effects of basement topography, discontinuous faulting, and volcanic activity were intermittently dammed streams, which created lakes, playas, and swamps. These effects and/or climatic changes resulted in the sporadic intercalation of lacustrine/paludal limestone, siltstone, clay, and mudstone beds within the predominantly fluvial sequence.

The second tectonic event reactivated Basin and Range-type faults and continued intermittently throughout the Quaternary. Both uplift and erosion were renewed. The resulting abundant detritus deeply buried the earlier Cenozoic basin-fill sequence under younger, predominantly fluvial and minor lacustrine deposits.

The stratigraphic relationships of the valley-fill sediments are complex. Depositional facies change over short distances and local unconformities are common. These factors make surface and subsurface correlations difficult.

Certain relations between older and younger rock sequences have been identified in the outcrops and several sequences have been named and assigned ages by various investigators. However, facies relations within these Tertiary units are intricate. They contain many unconformities and are exposed only locally on the basin margins and consequently are difficult to identify and trace even where subsurface information is available.

Lacustrine/paludal sediments are considered to be the most favorable uranium host in the project area because the best of the known occurrences and the Anderson Mine uranium ore occurs in rocks formed in these environments.

Although strata of these types are widely scattered along the margins of many basins and valleys, they are known to be mineralized in outcrop only near the Artillery Mountains and at the Anderson Mine in northern Date Creek basin and in deformed sedimentary units near the Aquarius Mountains in Big Sandy Valley.

## Drilling Activities and Results

When this project was proposed in December 1978, most of the necessary preliminary geological work had already been completed by May and White (BFEC) for their assessment of the uranium potential of the Prescott NTMS 2° quadrangle. Based on their work and recommendations, a drilling plan for nine holes was approved and funded by the NPO/DOE for completion in fiscal year (FY) 1979.

Land-status research was completed in the spring of 1979 and drilling permits obtained. Two holes were drilled on lands held in fee and the remaining 16 holes were drilled on lands administered by the state or federal governments. An environmental assessment was completed and archeological clearances obtained for all drill sites.

Initially, the project was planned for drilling nine holes utilizing two rigs; however, when 10 additional holes were authorized and added to the subcontract, a third rig was mobilized. Drilling was started on June 9, 1979. The total number of holes was finally adjusted to 18 holes.

The total footage drilled (including core) was 63,520 feet (19,361 meters). Hole depths ranged from 1,341 to 5,491 feet (409 to 1,673 meters). A total of 283 feet (86 meters) of core was cut, of which 236.8 feet (72 meters) was recovered. The footage cored amounted to 0.4 percent of the total footage drilled. An engineering report on this project was released by the DOE as open-file report GJBX-86(80) in April 1980.

Drill locations were selected to test Tertiary basins for the presence of lacustrine rocks, zones of uranium minerals similar to those at the Anderson Mine and other sedimentary units having characteristics similar to mineralized strata elsewhere.

The complex and largely unknown stratigraphy of these intermontane basins made it impossible to predetermine core points. Cores were to be cut when favorable lacustrine rocks were identified in drill cuttings or to determine with certainty that basement rocks had been penetrated. It was anticipated that sometimes it would be difficult to distinguish between granite boulders and the parent rock. Very few cores were cut because few favorable lacustrine rocks were penetrated. Some cores were cut in rock types other than lacustrine or basement to verify identification of cuttings.

A sample of drill cuttings was collected from each 10-foot (3 meter) interval drilled (usually starting below surface casing). Practically all samples were washed and caught by a Cuttings Sample Master automatic sampler. Geologists of Exploration Services, Inc., a "mud logging" service company, examined drilling cuttings under 7X to 30X binocular microscopes and described them in considerable detail. A chip from each foot of core was collected, described, sacked, and retained for BFEC study. Cuttings and cores are permanently stored with the Arizona Bureau of Geology and Mineral Technology at their facilities in Tucson, Arizona.

Drilling progress was satisfactory, except for delays caused by lost circulation and by the necessity of drilling to depths much greater (as much as 350 percent) than those predicted. Project drilling was completed on October 20, 1979 with the termination of PQ-24, the 18th hole. The 19th hole was cancelled for budgetary reasons. See Figure 2 for drill-hole locations. All of the holes were logged by either BFEC Logging Department or Century Geophysical Corporation. Century units were used when Bendix logging trucks were not available within a reasonable time because of the requirements of other projects. KUT spectral logs for potassium, uranium, and thorium were run on eight holes by BFEC, only over intervals of anomalous gross-gamma radioactivity. The geophysical logs recorded for these holes, besides the KUT, include gross gamma, S.P., resistivity, neutron, and calipers on two holes. Microfiche copies of all but the KUT logs are included in the appendix section of this report.

Table 1 lists locations of the drill holes, total depths, cored intervals, and radioactive anomalies.

No cores were cut in anomalous radioactive zones; therefore, no core samples were submitted for analytical work. Two thin sections of cores were made for petrographic study to help identify the extremely fine-grained crystalline rocks recovered.

## Congress Basin

Hole number PQ-1 was the only one in this project drilled in Congress basin. It was drilled at the location of a prominent gravity low (West and Sumner, 1973, Otten and Wynn, 1978). The latter authors postulated that the gravity low might reflect the presence of a thick sequence of favorable lacustrine deposits similar to those at the Anderson Mine in Date Creek basin.

Surface exposures of Tertiary rocks have not been found in this basin or on its margins and Anderson Mine type sediments were not known to be present in the subsurface here. Certain authors, including Scarborough and Wilt (1979, pp. 39-40) have suggested that these types of sediments may have been deposited during the lower Miocene in a larger basin that included some of the areas now occupied by a number of the present smaller late Cenozoic structural basins. Based on the existence of the gravity low and the presumption of the existence of lacustrine sediments in the subsurface, PQ-1 was drilled.

No gamma-ray anomalies were recorded in the Congress basin in the aerial radiometric and magnetic survey (ARMS). Two water samples were collected from a well and a spring on the northern margin of Congress basin for the hydrogeochemical and stream sediment reconnaissance (HSSR) survey. These waters contained between 10 and 20 ppb uranium. These analytical results were not an influence in the selection of the site of drill hole PQ-1. The drill site was selected on the belief that the gravity low was the most favorable location to encounter possible paludal/lacustrine sediments.

### PQ-1

The rocks penetrated in this hole consist of cobbly overburden from ground surface to a depth of 87 feet (27 meters). Below this is sandstone, siltstone, and basalt sequences 80 to 600 feet (24 to 183 meters) thick. The

## TABLE 1. Drill Hole Data Summary

S.W. PRESCOTT PROJECT

| Drill Hole No. | Location Sec | TWP | RGE | 1/64 | 1/16 | 1/4 | Total Depth | Cored Intervals | Core Recovered | R/A Anomalies |
|---|---|---|---|---|---|---|---|---|---|---|
| PQ- 1 | 11 | 9N | 6W | SE | NW | SW | 2947' (898.8 m) | 2337'-2347' | 10' | None |
| | (34.13296°N, 112.85536°W) | | | | | | | 2945'-2947' | 2' | |
| PQ- 2 | 26 | 9N | 8W | SW | SW | SW | 2621' (798.6 m) | 2133'-2137' | 4' | 2047'-2049' (2'/770 CPS) |
| | (34.08662°N, 113.06653°W) | | | | | | | 2616'-2621' | 4.25' | 2054'-2055.5' (1.5'/600 CPS) |
| PQ- 3 | 29 | 8N | 9W | SW | NW | SE | 4333' (1320.7 m) | 3929'-3942' | 13' | None |
| | (34.00500°N, 113.21842°W) | | | | | | | 4326'-4333' | 7' | |
| PQ- 4 | 3 | 9N | 9W | NE | NE | NE | 5491' (1673.6 m) | 5188'-5208' | 18.5' | None |
| | (34.15701°N, 113.17359°W) | | | | | | | | | |
| PQ- 5 | 30 | 10N | 10W | NE | NE | SE | 5044' (1537.4 m) | 2510'-2522' | 12' | 4599.5-4608.5 (9'/0.019%) |
| | (34.17792°N, 113.33064°W) | | | | | | | 4040'-4041' | 1 | 4610.5-4614.5 (2'/0.012%) |
| | | | | | | | | 4480'-4490' | 10' | 4623.5-4628.5 ( 5'/0.012%) |
| | | | | | | | | | | 4779-4779.5 (.5'/0.012%) |
| | | | | | | | | | | 4795.5-4804 (8.5'/0.012%) |
| | | | | | | | | | | 4939-4940.5(1.5'/0.020%) |
| PQ- 6 | 31 | 11N | 10W | NW | NW | SW | 2998' (913.8 m) | 986'- 994' | 8' | 1349'-1349.5' (.5/0.010%) |
| | (34.25237°N, 113.34547°W) | | | | | | | 1671'-1692' | 19' | 1355'-1355.5' (.5'/0.010%) |
| | | | | | | | | 2508'-2528' | 20' | 1802.5'-1803' (.5'/0.012%) |
| | | | | | | | | | | 1805'-1809' (4'/0.010%) |
| | | | | | | | | | | 1810.5'-1811.5' (1'/0.011%) |
| PQ- 7 | 13 | 8N | 14W | NW | SW | NW | 1341' (408.7 m) | 1336'-1341' | 5' | None |
| | (34.03971'N, 113.67710°W) | | | | | | | | | |
| PQ- 8 | 20 | 11N | 16W | SW | SE | NE | 2456' (748.6 m) | 2433'-2439' | 3.5' | None |
| | (34.28226°N, 113.94362°W) | | | | | | | 2441'-2451' | 3' | |
| PQ- 9 | 18 | 15N | 16W | SW | NE | SW | 5191' (1582.2 m) | 1984'-1997' | 13.5' | 5094.5-5098.5 (4'/0.014%) |
| | (34.63850°N, 113.97659°W) | | | | | | | 4239'-4251' | 6' | 5171.5-5173.5'(2'/0.015%) |
| | | | | | | | | 5187'-5191' | 3.5 | 5183.5-5184.5'(1'/0.015%) |

5187'-5191' 3.5 5183.5-5184.5'(1'/0.015%)

**TABLE 1. Drill Hole Data Summary (continued)**

| Drill Hole No. | Location Sec | TWP | RGE | 1/64 | 1/16 | 1/4 | Total Depth | Cored Intervals | Core Recovered | R/A Anomalies |
|---|---|---|---|---|---|---|---|---|---|---|
| PQ-10 | 12 | 16N | 14W | NE | SW | NW | 5000'(1524.0 m) | 3193'-3203'<br>3212'-3224' | 2.5'<br>6.5' | None |
| | (34.74414°N, 113.68136°W) | | | | | | | | | |
| PQ-12 | 31 | 16N | 16W | C | SE | SE | 1819'(554.4 m) | 1758'-1759.5'<br>1759.5'-1764' | 1.5'<br>4.5' | None |
| | (34.67861°N, 113.96806°W) | | | | | | | | | |
| PQ-24 | 9 | 12N | 3W | SE | SE | NW | 1563'(476.4 m) | No Core | None | None |
| | (34.39881°N, 112.57539°W) | | | | | | | | | |
| PQ-25 | 8 | 16N | 13W | NW | SW | NE | 5008'( 1526.4 m) | 2798'-2808' | 10' | 1794'-1863.5' (Several thin intervals-.5'-1.5',ave. 0.013%)<br>1891.5'-1902.5 (11'/0.015%)<br>1911-2291.5 (17-0.5/03.0'intervals ave. 0.011%);3231'-3231.5' (.5'/0.010%) |
| | (34.74404°N, 113.64114°W) | | | | | | | | | |
| PQ-26 | 12 | 15N | 13W | SW | NE | SE | 3434'(1046.7 m) | 3426'-3434' | 8' | 2330.5-2334'(3.5'/0.019%)<br>3014.5"-3015.5'(1'/0.023%)<br>3144.5-3151'(6.5'/0.013% |
| | (34.65520°N, 113.57114°W) | | | | | | | | | |
| PQ-27 | 9 | 17N | 13W | SE | SW | NE | 5000'(1524.0 m) | 3439'-3454'<br>4836'-4846' | 15'<br>6' | None |
| | (34.87116°N, 113.65789°W) | | | | | | | | | |
| PQ-28 | 20 | 18N | 13W | SE | SW | SW | 4122'(1256.4 m) | 2850'-2858'<br>2880'-2885' | 2'<br>1.5' | 3978'-3979'(1'/0.012%)<br>4069'-4070'(1'/0..013%) |
| | (34.92152°N, 113.57992°W) | | | | | | | | | |
| PQ-29 | 28 | 15N | 12W | SE | SW | NE | 3528'(1075.3 m) | 3467'-3477' | 10' | None |
| | (34.61306°N, 113.51740°W) | | | | | | | | | |
| WQ-32 | 8 | 24N | 12W | SW | NE | SE | 1624'(495.0 m) | 1618'-1624' | 6.1' | 763-764'(1'/0.007%)<br>1604-1606'(2'/0.009%) |
| | (35.47797°N, 113.57992°W) | | | | | | | | | |

GSA-293(81)

sandstones are unconsolidated, silty to clay-filled, fine- to coarse-grained, feldspathic, and poorly sorted, whereas the siltstones are tan, soft, and partly calcareous. The basalts are red to brown, very finely crystalline with vesicles filled with quartz and calcite. The interval 2,184 to 2,940 feet (666 to 896 meters) is occupied by "granite wash", a poorly stratified deposit of granite boulders and cobbles in a coarse-grained arkosic matrix. The deposit contains abundant biotite and a variable clay content. The hole bottomed in granite at a depth of 2,945 feet (898 meters).

Colors of most of the rocks penetrated in this hole are shades of brown or red and the rocks therefore are considered to be oxidized. No uranium minerals were recognized and no radioactive anomalies were recorded. Possible lacustrine rocks were encountered between the depths of 1,500 and 1,580 feet (457 and 482 meters). The gravity low in this basin indicated that the expected depth to basement at the location of PQ-1 would be approximately 5,300 feet (1,609 meters), however, actual depth to basement was 2,940 feet (896.1 meters).

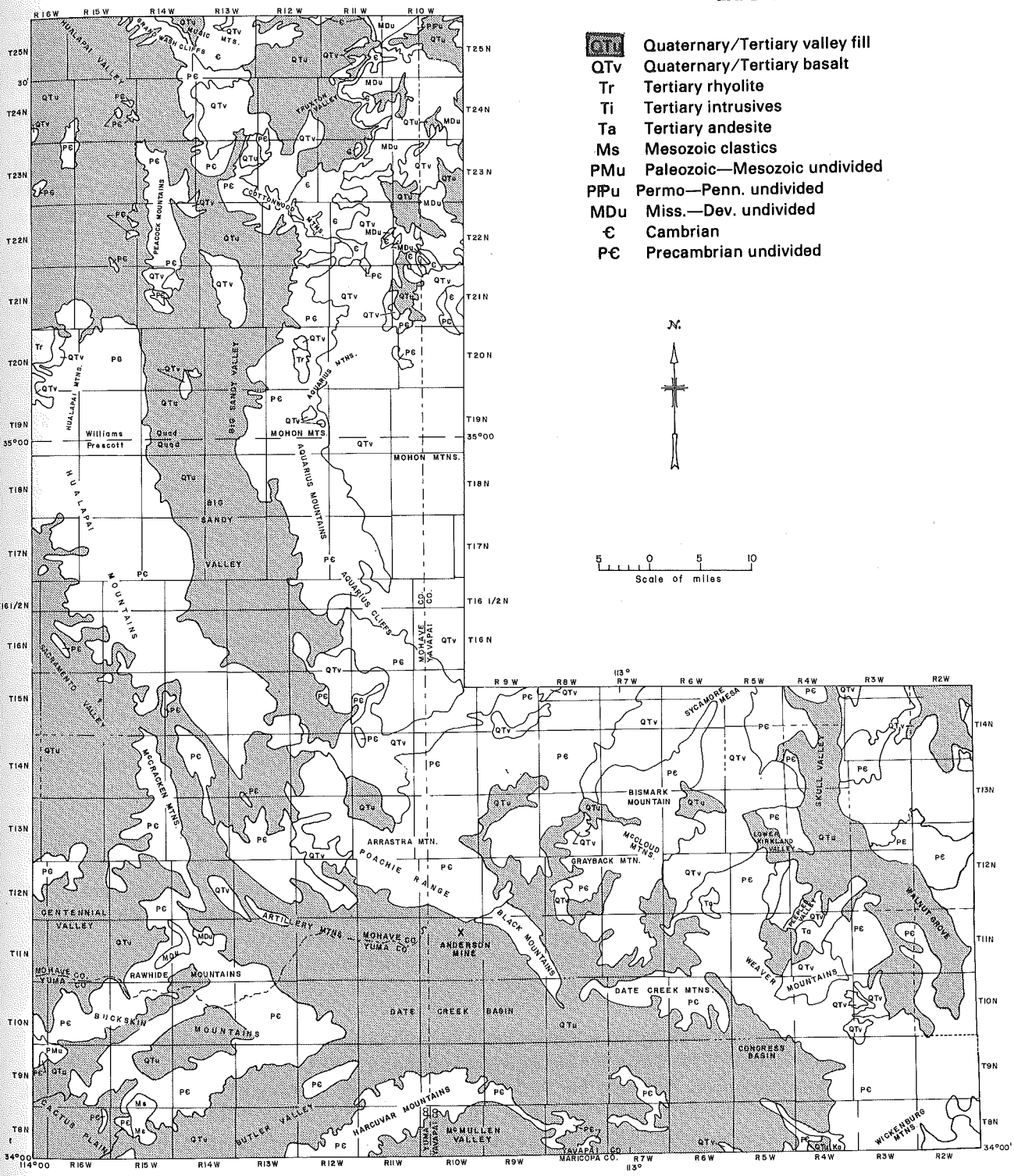
Date Creek Basin

The Date Creek basin is located in the southern part of the project area. The basin is elongate in a southeast-northwest direction, and is bounded on the northeast by the Black Mountains and Poachie Range, on the northwest by the Artillery Mountains, and on the southwest by the Rawhide, Buckskin, and Harcuvar Mountains (Figure 3). It is separated from Congress basin on the east and Aguila Valley on the south by low hills of intrusive and extrusive igneous rocks.

Tertiary sedimentary and volcanic rocks are exposed along the northern margin of the basin, where the older Tertiary rests on pre-Tertiary metamorphics to the northwest, and on Precambrian intrusive rocks on the east. Both the Artillery Formation (Late Eocene to Early Miocene) and the Chapin Wash Formation (Miocene) consist of coarse clastics, monolithic breccias, volcanic material, and local paludal/lacustrine deposits, indicating deposition during a period of tectonism. Late Tertiary volcanic and sedimentary rocks and Quaternary alluvium largely cover the basin.

The fairly widespread exposures of the Chapin Wash Formation over western Arizona strongly suggests it was deposited in a much larger basin than any of the present basins. Neither the Chapin Wash nor the Artillery Formation have been clearly identified in the subsurface in this project.

Uranium occurrences have been found in carbonaceous zones in the paludal/lacustrine rocks in the 2,500 foot (762 meter) thick Artillery Formation, near the bottom and the top of the formation, west and south of Artillery Peak, in the western part of Date Creek basin. In the north-central part of the basin, uranium occurrences are found in rocks similar to those found in the Artillery Formation to the west. However, because of the lack of continuity of sedimentary units and difficulty in lateral correlation, the "Anderson Mine" rocks of the Date Creek basin cannot easily be tied to any specific interval in the sections of the Artillery or Chapin Wash Formations in that area. The Anderson Mine rocks were tentatively correlated with fanglomerates of the Chapin Wash Formation to the west by Reyner and others (1956). Otten (1977b) placed the fluvial/lacustrine facies at the Anderson Mine in the Miocene (?) Chapin Wash Formation, whereas earlier he (Otten, 1977a) had correlated them




S.W. PRESCOTT PROJECT, ARIZONA

**FIGURE 3. Generalized Geologic Map Showing Quaternary/Tertiary Basin Deposits**

with unnamed lower Miocene silicic volcanic and tuffaceous sedimentary rocks in the western part of the basin. The host rocks at the Anderson Mine are thought to be lower Miocene in age, based on K/Ar age dating of basalts in the section, suggesting a chronological overlap with the Artillery Formation (Scarborough and Wilt, 1979). At present however, the question of exact placement of the Anderson Mine rocks within the lower Miocene stratigraphic section is not completely resolved.

A Bouger gravity map of Arizona (West and Sumner, 1973) and a more detailed gravity survey by the U.S. Geological Survey in 1977 (released as OFR 78-362, 1978) both show a prominent gravity low in the central Date Creek basin. Otten and Wynn (1978) called the gravity low "the Anderson Mine anomaly" and related it to distribution and thickness of the lacustrine rocks in the Anderson Mine and to the thicker drilled lacustrine section southward toward the center of the gravity low.

Although four of the holes in this project were drilled in this basin, none was specifically located to test the lithology in the center of this gravity low. El Paso Natural Gas and Brown and Thorpe Oil Company had drilled in the center of this anomaly to a depth of 5,685 feet (1,733 meters), intersecting basement at a depth of 5,620 feet (1,712 meters). Only minor zones of lacustrine rocks were logged in this hole.

Drill sites PQ-2, PQ-4, PQ-5, and PQ-6 in the basin were selected to test each portion of the basin in which they are located for the existence of Anderson Mine type rocks in the subsurface. Industry exploration drilling has demonstrated that this stratigraphic unit and uranium occurrences persist for several kilometers basinward from the outcrops at Anderson Mine. The purpose of PQ-6 was to try to intercept a section of Chapin Wash Formation, fairly close to intensive industry exploration area, as a reference section for the other three project drill holes in this basin. Both holes, PQ-5 and PQ-6, were on the edge of the aforementioned gravity low, PQ-6 on the west and PQ-5 on the south. PQ-4 is located approximately another 8 miles (12.8 kilometers) southeast of PQ-5. The locations of the holes drilled in this project are spotted on the geologic map (Figure 2).

Hole PQ-6 was projected to be drilled to a depth of 3,120 feet (951 meters) and bottom in Precambrian basement rocks. It was drilled to a total depth of 2,998 feet (914 meters) and terminated at that depth because of mechanical problems caused by severe lost circulation. Because of bad hole conditions, geophysical logs were run only from 2,264 feet (690 meters) to surface. This was the only hole of the 18 drilled that had to be terminated because of mechanical problems.

PQ-6 penetrated several slightly anomalous radioactive zones between the depths of 1,332 and 2,122 feet (406 and 647 meters). Thickness of these intervals ranged between 0.5 to 18 feet (0.15 to 5.5 meters). These anomalies are associated with limestones that are interpreted to be of lacustrine origin. Similar zones have been penetrated by industry at comparable depths in drill holes within 4 miles (6.4 kilometers) of PQ-6. In some of these holes 2X to 7X background radioactive anomalies were recorded over intervals as much as 200-feet (61 meters) thick.

The top 1,140-foot (347 meter) interval of this hole was occupied by fine- to coarse-grained, light tan to pink, feldspathic sandstone, and conglomerate

containing a variety of lithic clasts, and basic lava flows. This portion of the sedimentary section in PQ-6 appears unfavorable for the occurrence of uranium deposits, inasmuch as it is entirely coarse-grained clastics and basic lava flows, with no shale or clay sequences, no vegetal carbon, and no radioactive anomalies.

Underlying this upper interval of coarse-grained fluvial rocks is a 940 foot (286.5 meter) section of rocks that are predominantly white to gray, tan and pink, calcareous to argillaceous, fine- to coarse-grained sandstone with several scattered intervals containing white to gray dense limestone. This section also contains some tuffs and claystone intervals, and is thought to be partially of lacustrine origin, and may be equivalent to the ore-bearing rocks at Anderson Mine. Most of the zones of anomalous radioactivity in this hole were found in a 748 foot (228 meter) interval in this part of the section, between the depths of 1,332 and 2,080 feet (406 and 643 meters) (see Appendix A). The colors of most of the rocks in this interval suggest that they may be in a reduced chemical environment. However, no reductants such as fossil vegetal carbon were found in any of these rocks. A total of 59 feet (18 meters) of low-grade uranium mineralization was found in this interval. No cores of these zones were obtained.

The rocks between the depths of 2,080 and 2,998 feet (634 and 914 meters), total depth, are predominantly red and red-brown. They consist of red conglomeratic sandstone, calcareous red claystone, and calcareous red siltstone. The color of the sandstone is derived from the color of the iron-stained quartz grains, which also form the matrix of the conglomerates.

The rocks in this part of the section do not appear to be favorable for the occurrence of uranium deposits. Although the sandstones exhibit many of the characteristics of uranium-bearing sands in other areas (see page 40 for criteria), apparently they are oxidized, and vegetal carbon is absent. A minor radioactive zone was logged at the contact of an overlying fine-to coarse-grained red sandstone, and a red tuffaceous claystone at the depth of 2,120 feet (646 meters).

PQ-5 — Has halite

The purpose of this hole was to determine the basinward extent of Anderson Mine Member paludal/lacustrine sediments. It was drilled in the central part of the basin and was expected to encounter basement at approximately 4,640 feet (1,414 meters) from surface. No basement rocks were encountered at the final total depth of 5,044 feet (1,537 meters).

The upper 2,450 feet (747 meters) of the geologic column at this location consists of yellow to brown, slightly to moderately calcareous feldspathic, poorly sorted, very fine- to coarse-grained sandstone and conglomerate, with volcanic and metamorphic clasts. This part of the section appears unfavorable for the occurrence of uranium deposits. The coarse-grained sandstones are lacking in clay or shale, fossil vegetal carbon, and radioactive anomalies.

Red calcareous siltstone was drilled between the depths of 2,450 and 4,040 feet (747 and 1,231 meters) and similar siltstone with halite stringers was drilled from 4,040 feet (1,231 meters) to a depth of 5,044 feet (1,537 meters).

Within this bottom interval containing halite, seven radioactive anomalies of 0.01 percent or greater $eU_3O_8$ concentration were recorded between the depths of 4,599 and 4,941 feet (1,402 and 1,506 meters). These are listed individually in Appendix A of this report. They range in thickness from 0.5 to 9 feet (0.15 to 3.7 meters) and $eU_3O_8$ grade from 0.012 percent to 0.02 percent. Traces of organic carbonaceous material were logged between the depths of 4,500 and 4,900 feet (1,372 and 1,494 meters), and possibly the uranium mineralized zones correspond to the zones containing the organic carbon. No part of the sedimentary section penetrated in PQ-5 bears any resemblance to Anderson Mine paludal/lacustrine uranium-bearing rocks.

The existence of the thick section of red, calcareous siltstone, with halite in the lower 860 feet (262 meters) indicates a sedimentary depositional environment previously unknown in the project area, although possibly known in other basins (Luke, Red Lake) in northwestern Arizona. In the immediate vicinity of this drill hole, the red calcareous siltstone would appear to have been deposited in a warm, relatively dry climate, in a shallow body of standing water with a salinity high enough to prevent activity of sulfate-reducing bacteria.

The thickness of at least 2,450 feet (747 meters) of calcareous red siltstone indicates a stable depositional environment in a subsiding basin for a fairly long period of time. A sharp southwest up slope, on the gravity map (Otten and Wynn, 1978), immediately southwest of PQ-5 strongly suggests a fault, downthrown on the northeast, with a northwest-southeast trend that roughly parallels Bullard Wash. Subsidence of the downthrown block may have continued for a long period during the Tertiary, resulting in a closed basin in which the saline red siltstones were deposited. Although the cumulative thickness of salt in the hole is unknown, there was enough to supersaturate the drilling mud at downhole temperature. The source of the salt deposited in this section is unknown.

The nature of the uranium occurrences in the saline portion of the red siltstone is unknown, inasmuch as no cores were cut in the mineralized zones. Some of the mechanisms suggested for the concentration of uranium in calcrete deposits (Carlisle and others, 1978) may have been effective in precipitation of uranium.

PQ-4

This hole is located approximately 10 miles (16.0 kilometers) east-southeast of PQ-5, and 13 miles (20.9 kilometers) southeast of the Anderson Mine. The purpose of this hole was to test another portion of the Date Creek basin for the presence of Anderson Mine-type sediments and also for the existence of fluvial rocks favorable for the formation of uranium deposits. The top 290 feet (88 meters) of the section drilled is vari-colored conglomerate composed largely of quartz and feldspar granules and pebbles.

From 290 to 2,000 feet (88 to 610 meters) the section is largely sandstone, although a significant percentage (38 percent) is volcaniclastics. The sandstone is predominantly coarse- to very coarse-grained, gray to light brown and red, feldspathic, calcareous, and unconsolidated. The volcanic fragments are light to dark, aphanitic to vesicular, and contain phenocrysts of hornblende, quartz and hematite, and are generally calcareous. The interval from 2,000 to 5,552 feet (610 to 1,674 meters) is predominantly volcanics and

volcaniclastics with scattered units of calcareous conglomerate and coarse-grained sandstone. The conglomerates contain quartzite and volcanic fragments. Included in this 3,491-foot (1,064 meter) interval is one section of granite wash 150-feet (46 meters) thick, and a 15-foot (4.5 meter) thick calcareous siltstone. Traces of red clay were logged in some of the conglomerates but no fossil vegetal carbon was found anywhere in the section. A 15-foot (4.5 meter) thick calcareous siltstone section was logged from 5,035 to 5,050 feet (1,535 to 1,539 meters). No rocks resembling the Anderson Mine section were found. PQ-4 was bottomed in volcanics at 5,552 feet (1,674 meters).

The sandstones penetrated in this hole do not appear favorable for the formation of uranium deposits. They lack interbedded clay or shale, vegetal organic matter, and radiometric anomalies.

PQ-2

This hole was drilled for the same purpose as the other holes in this project. The location of the drill site is in the extreme southeastern part of Date Creek basin, in an area of low density industry drilling activity. No information was available prior to drilling regarding the lithologies that would be encountered in the sedimentary section in this hole.

From 200 to 1,640 feet (61 to 500 meters) the section consists of fine to coarse-grained, feldspathic, locally silty, unconsolidated sandstone. The sandstone is predominantly white, but varies from white to buff, pink, and yellow. This unit is followed by 90 feet (27 meters) of tan, calcareous siltstone.

The interval from 1,730 to 2,550 feet (527 to 777 meters) is occupied predominantly by "granite wash". Within this interval are two 30-foot (9 meter) sections of very fine grained medium to light colored igneous rock (see Appendix A), partially highly altered, hematitic, that may represent volcanic flows or ash-fall tuffs. Except for these two sections of fine crystalline rocks (see Appendix A) the granite wash consisted of very large angular fragments of feldspar, quartz, biotite, and muscovite.

The granite wash section was partially stained with limonite and hematite, and altered feldspar is common. This section does not contain rocks favorable for the formation of uranium deposits. It contains no interbedded clay or shale, no fossil vegetal carbon, and no significant anomalous gamma-ray readings were recorded on the downhole geophysical logs. The hole bottomed in biotite gneiss at a depth of 2,619 feet (798 meters). The top of basement rocks was encountered at a depth of 2,550 feet (777 meters).

## SUMMARY - DATE CREEK BASIN

The Anderson Mine is the only known uranium deposit in sedimentary rocks in the project area. Four of the holes drilled in this project were located in Date Creek basin, at fairly widespread sites (Figure 4), to try and determine the lateral extent of the Anderson Mine host rocks.

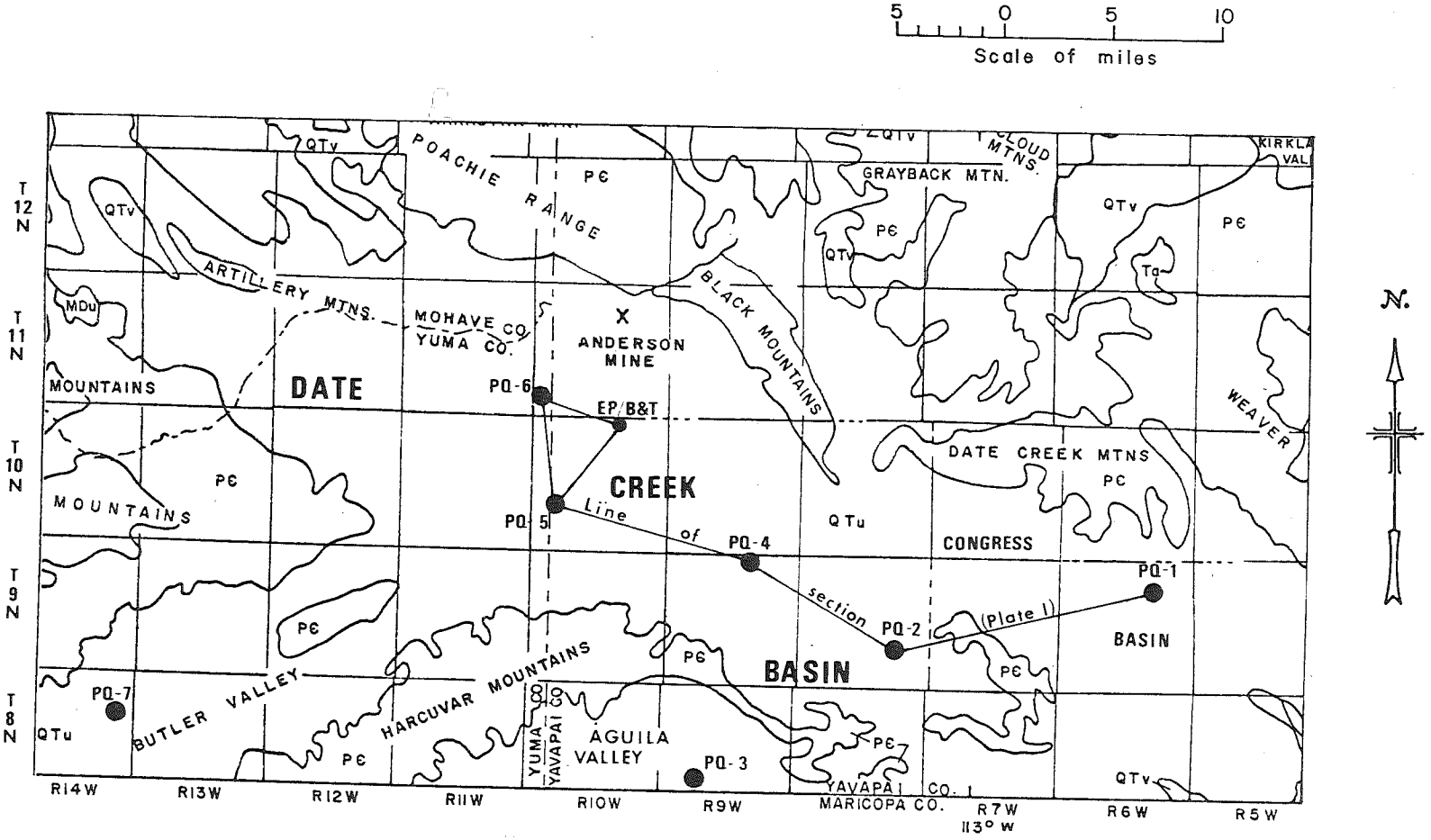



FIGURE 4. Data Creek Basin—location of drill sites

**EXPLANATION**

| | |
|---|---|
| QTu | Quaternary/Tertiary valley fill |
| QTv | Quaternary/Tertiary basalt |
| Tr | Tertiary rhyolite |
| Ti | Tertiary intrusives |
| Ta | Tertiary andesite |
| Ms | Mesozoic clastics |
| PMu | Paleozoic—Mesozoic undivided |
| PPu | Permo—Penn. undivided |
| MDu | Miss.—Dev. undivided |
| € | Cambrian |

PMu Paleozoic—Mesozoic undivided
PPu Permo—Penn. undivided
MDu Miss.—Dev. undivided
Cambrian

FIGURE 4. Data Creek Basin—location of drill sites

These four holes were planned to penetrate basement rocks at their final depths; however, three failed to reach basement because of excessive depths or lost circulation problems.

Plate 1 shows the complex stratigraphic relationships of the sections penetrated in these holes and another hole drilled as a gas storage project. On this cross section the rocks penetrated have not been divided into Artillery and Chapin Wash formations as described in the literature from surface exposures. However, the bottom 940 feet (287 meters) of PQ-6 somewhat resemble "Member 4" of the Artillery Formation of Shackelford (1976), and the middle sections of the El Paso Natural Gas/Brown and Thope (EP/B&T) and BFEC's PQ-6 holes show some lithologic similarities to the Anderson Mine beds and may be their lateral equivalents. The EP/B&T hole penetrated a 3,200-foot (975 meter) interval of these sediments. It was drilled in the center of the gravity low mapped by Otten (1978), whereas PQ-6, drilled on the western margin of the gravity low, penetrated 1,000 feet (305 meters) of somewhat similar sediments. At the Anderson Mine, beds range from 262 to 492 feet (80 to 150 meters) thick (Sherborne and others, 1979). No rocks were found in PQ-4 or PQ-2 that bear any resemblance to the Anderson Mine beds. In PQ-5 the lower half of the section is dominated by fine-grained sediments deposited in an arid, lacustrine or playa environment and the upper half is dominated by high energy fluvial deposits.

The information obtained from these four holes shows that the paludal/ lacustrine host rocks of the Anderson Mine beds do not extend throughout the basin. The type of section that may include favorable host rocks appears to be confined to an area south and southwest of the Anderson Mine in the north central part of the basin. This could be an area of 50 to 60 square miles (129 to 155 square kilometers). Geological data from less than 20 of the more than 200 industry exploration drill holes scattered across the central part of Date Creek basin, has been made available to BFEC. In these holes the mineralized zones are scattered over intervals ranging from 250 feet (76 meters) close to the mine, to 925 feet (282 meters) farther out in the basin. Depths to the top of the first mineralized sediments in the holes range from 700 feet (213 meters) near the mine to 1,825 feet (556 meters) 5 miles (8.0 kilometers) to the southwest. The sections in which the mineralized zones occur in these holes consist of sandstone, siltstone, claystone, limestone and marl, and a trace of tuff. These sections presumably correlate with the "Anderson Mine" Formation at the mine to the north; however, our incomplete data and the complex facies relations prevent positive correlation from the subsurface to outcrops. The colors of the mineralized intervals suggest that they are in a reduced chemical state in the favorable area shown as the "potential resource area" in Figure 7. However, very little or no reductant was found in the drill holes.

In hole number PQ-5 the mineralized zones are in the saline, lower portion of the calcareous red siltstone section. This is the only hole drilled in the project in which "organic carbonaceous material" (OCM) was noted in the sample descriptions. The OCM was found in the section of red siltstone containing the interbedded salt.

Big Sandy Valley

The Big Sandy Valley is in the west central part of the project area. The valley is about 48 miles (77.2 kilometers) long in a northwest-southeast

direction (Figures 3 and 5). It is bounded on the east by the Aquarius Mountains and Aquarius Cliffs and on the west by the Hualapai Mountains. Big Sandy River and its northern tributaries flow southeastward through the valley and the river flows southward out of the valley in a gap between the Hualapai Mountains and Poachie Range. Big Sandy Valley is in the Basin and Range province. The valley probably is a graben, bounded on the east and west by normal faults.

The Hualapai and Aquarius Mountains are composed of granitoid igneous rocks which also underlie the valley. These are overlain in part by volcanic rocks in the northern and southeastern parts of the area. The basin contains several thousand feet of Tertiary sedimentary rocks, locally interstratified with volcanics.

Three of the six drill holes in this project area were terminated in granite or quartz diorite. The other three holes had not encountered basement when terminated at a depth of 5,000 feet (1,524 meters).

In places on the east side of the valley, sections of deformed sedimentary deposits have been described by Scarborough and Wilt (1979), as "pre-basin fill". They described a section of an estimated 6,500 feet (1,981 meters) of NE dipping pre-basin fill sediments "in high angle fault contact to the east with Precambrian crystalline rocks of the Aquarius Mountains" (Scarborough and Wilt, 1979). South of the section (Tule Wash) thin partial sections are exposed as eastward dipping downthrown fault blocks. These sections consist of low to moderate energy clastics interlayered "with occasional dark volcanic flows, devitrified tuffs, and limestones". A K/Ar age date of 12 million years was obtained from one of these basalt flows. Scarborough and Wilt assigned an age of Middle to Late Miocene to these sediments. Several limestones and mudstones in these sections gave anomalous gamma-ray readings of 2X to 16X background. One of the uranium occurrences in the sections examined is recorded in AEC Preliminary Reconnaissance Report PPR-1. The sections described above are overlapped by basin fill sediments.

The Tertiary basin fill sequence has been divided informally into five units (Davidson, 1973). From bottom to top they are: arkosic conglomerate, arkosic gravel, volcanic rocks of Sycamore Creek, basalt flows, and lower basin fill. The lower basin fill is the only Tertiary sequence that contains rocks considered favorable for uranium deposits.

Davidson (1973) states that as much as 3,000 feet (914 meters) of sedimentary rocks of the lower basin fill crop out along the dissected ridges east of the Hualapai Mountains and in canyons and on low ridges east of the Big Sandy River. The total thickness of the lower basin fill is not known. Davidson also included the flat-lying Big Sandy Formation of Sheppard and Gude (1972) in the lower basin fill sequence, as well as the tilted and faulted sections described later by Scarborough and Wilt (1979) and identified as "pre-basin fill rocks". The lower basin fill consists of sandy gravel that "gives way to silt and marl in the southern part of the area" (Davidson, 1973). Granite gneiss fragments are dominant in the sandy gravel whereas volcanic fragments are minor. Matrix of the gravel is sand, silt, and clay.

The Big Sandy Formation consists of green and brown lacustrine mudstone, or calcareous silty or sandy mudstone, and contains several altered tuff marker beds. The formation is essentially flat lying. Maximum thickness observed

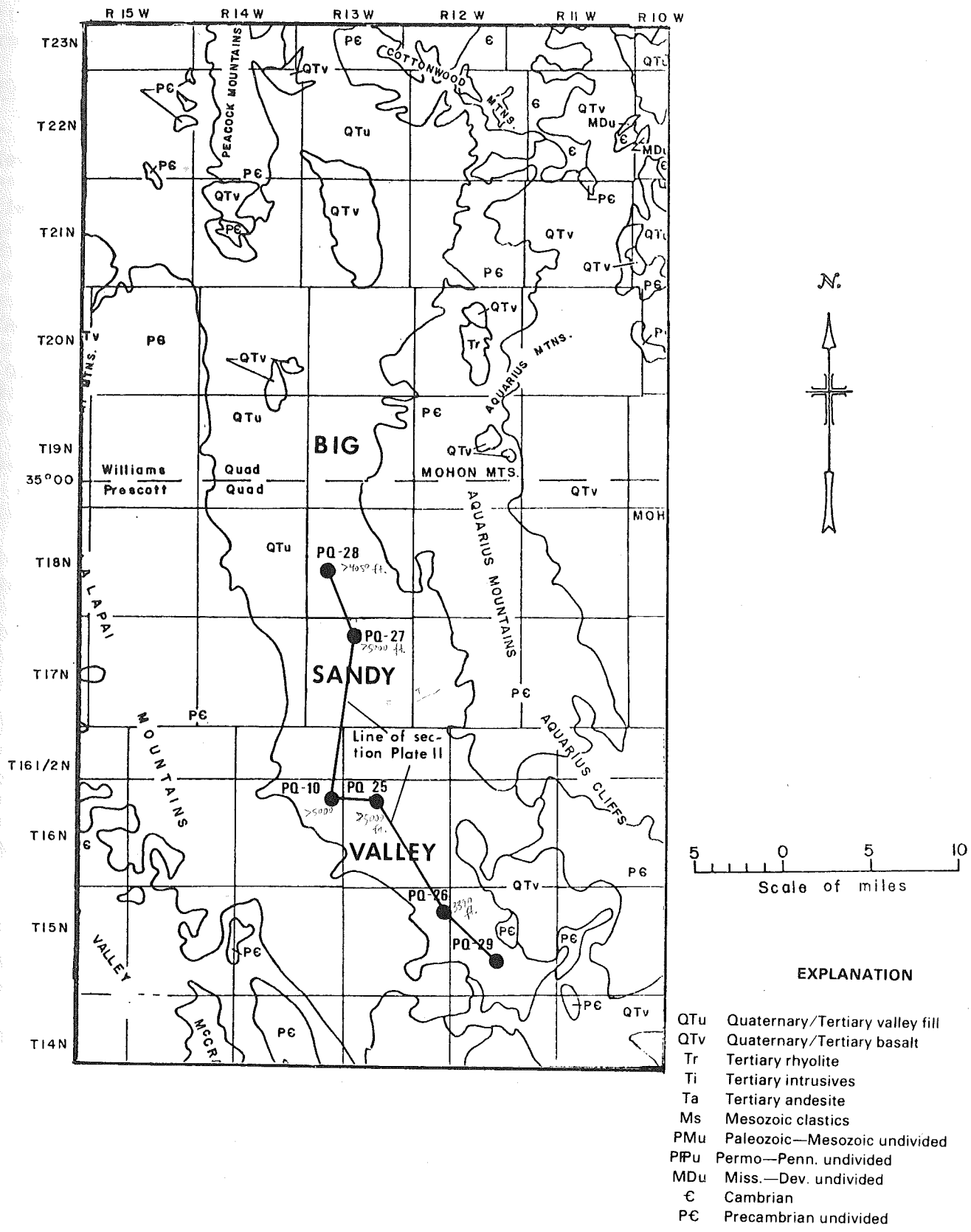



FIGURE 5. Big Sandy Valley—location of drill sites

was 245 feet (75 meters) (Sheppard and Gude, 1972). The lower basin fill is Miocene and Pliocene in age (Sheppard and Gude, 1972; Davidson, 1973; and Scarborough and Wilt, 1979).

Drill sites PQ-25, PQ-26, PQ-27, PQ-28, and PQ-29 were located to test different parts of Big Sandy Valley for the existence of rocks favorable for the formation of uranium deposits. Lacustrine facies had been identified in exposures of the "lower basin fill" in the southern part of the Big Sandy area (Davidson, 1973) as well as in the tilted and faulted sequence (Tule Wash section and others nearby) described by Scarborough and Wilt (1979). Several of these exposed lacustrine units are anomalously radioactive and are associated with volcanic ash beds that may have been the source of the radioactive minerals.

Drill holes PQ-27 and PQ-28 are located in the central part of the valley, on the east and north margins of a fairly large gravity low (West and Sumner, 1973). The gravity low suggests thick basin-fill deposits. Drill hole PQ-10 is located to confirm the presence of the lacustrine section and the mineralized intervals in PQ-25, as well as to be a part of a proposed east-west stratigraphic fence section across the valley. Only one gamma-ray anomaly was recorded in the Big Sandy Valley during the ARMS survey of the Prescott quad. The anomaly is centered in the southwest quarter of Township 17 north, Range 12 west, on the east flank of the valley, and covers a small area of approximately 1 square mile (2.6 square kilometers). The anomaly appears as a uranium anomaly of three or four times background at the same location on two flight lines. The rocks in the area of the anomaly consist of Quaternary "upper basin fill" and Tertiary "lower basin fill" between two NW-SE trending faults, just south of the Tule Wash section described by Scarborough and Wilt (1979).

The ARMS profiles across the Hualapai Mountains show an area of possible uranium concentration which suggests a possible source area of uraniferous solutions during periods of sediment accumulation in Big Sandy Valley. Some of this uranium could have been precipitated wherever favorable host rocks existed and the chemical environment was favorable.

The HSSR report GJBX-122(79) listed at least 14 water samples from springs and wells in the Big Sandy River drainage that contained more than 20 parts per billion (ppb) uranium. Uranium in these samples ranged from 21 ppb to 498 ppb, averaging 112 ppb. These high uranium values in the ground water in the valley and surrounding mountains demonstrate that a good source of leachable uranium is available in the area for the formation of uranium deposits.

Hole PQ-29, positioned in the extreme southern part of Big Sandy Valley, was projected to penetrate basement at a depth of 1,000 feet (305 meters). Actual depth to basement was 3,350 feet (1,021 meters). The upper 170 feet (52 meters) of this hole consisted of cobbly overburden. Below this section a variety of volcanic rocks were penetrated to a depth of 1,990 feet (607 meters) including andesite, tuff, and perlite. This section correlates with the "volcanic rocks of Sycamore Canyon" (Davidson, 1973) that crop out 1 mile (1.6 kilometer) northeast and 3/4 mile (0.40 kilometer) west of the drill site. Underlying this volcanic section are 50 feet (15 meters) of reddish-buff, calcareous mudstone and 1,310 feet (399 meters) of reddish-brown granite wash. This granite wash section probably correlates with the arkosic conglomerate (Davidson, 1973) exposed approximately 3 miles (4.8 kilometers)

northwest of PQ-29. The bottom 178 feet (54 meters) of this hole penetrated light to dark gray granite gneiss, partially stained with limonite. Neither radioactive zones nor favorable host rocks were penetrated in this hole.

PQ-26

This hole was drilled 4 miles (6.4 kilometers) northwest of PQ-29 in Big Sandy Valley. It was collared in "lower basin fill". Lower-basin fill was penetrated down to a depth of 1,040 feet (317 meters). The upper 600 feet (183 meters) consist of siltstone, white to medium gray, soft to hard, partially calcareous, and sandstone, white to medium gray, very fine to fine-grained, friable to well cemented with calcite. The lower 440 feet (134 meters) of the lower basin fill is medium- to coarse-grained, poorly sorted, angular to subrounded, unconsolidated sandstone with abundant granitic clasts. This portion of the interval fits Davidson's description of the "sandy gravel" portion of his lower basin fill section (Davidson, 1973, p. 22).

Below the lower basin fill, 2,450 feet (747 meters) of granite wash was drilled. This section contained several 30-to-80 foot (9 to 24 meter) intervals of basalt and amphibolite, and one 100-foot (30 meter) thick sandstone unit. The hole bottomed in quartz diorite which was encountered at a depth of 3,390 feet (1,033 meters) and was penetrated to a depth of 3,428 feet (1,045 meters).

Three low grade gamma-ray anomalies were recorded on the geophysical logs of this hole, scattered over an 800 foot (244 meter) interval in the lower massive granite wash section. These zones are listed in Table 1 of this report. Perhaps these anomalies are derived from granite boulders that contain a radioactive vein mineral. No cores were cut in these mineralized zones.

The section of lower basin fill penetrated in the upper 600 feet (183 meters) of this hole is the only sequence of sediments that contains units that may have been deposited in a Tertiary lacustrine environment. However, claystone is rare in the section, and limestone, tuff, fossil vegetal carbon, and gamma-ray anomalies are absent. The sandstone below the lacustrine section is unfavorable for the existence of uranium deposits because it lacks shale or claystone interbeds, fossil vegetal carbon, and gamma-ray anomalies.

PQ-10

This hole was drilled to confirm the mineralized intervals found in PQ-25, 2 miles (3.2 kilometers) to the east, as well as to be one of a line of three east-west holes from which to construct a stratigraphic fence across Big Sandy Valley (the third hole was cancelled for budgetary reasons). The rocks penetrated in PQ-10 consist of coarse-grained, oxidized sediments from top to bottom. From surface to 990 feet (301 meters) the section is pebble and cobble conglomerate with a fine- to coarse-grained sand matrix. Cobbles and pebbles are largely granitic or volcanic lithic clasts. Locally the conglomerate contains calcareous material or clay.

From 990 feet (301 meters) to the total depth of 5,000 feet (1,524 meters) the rocks penetrated are granite wash, containing coarse granitic clasts with a silt to sand matrix, which is locally well indurated.

No gamma-ray anomalies were recorded on the logs of this hole and no lacustrine sediments were encountered. The rocks penetrated are unfavorable for the occurrence of uranium deposits.

PQ-25

This hole was drilled 2 miles (3.2 kilometers) east of PQ-10, in the south-central part of Big Sandy Valley. The purpose of the hole was to determine if host rocks for uranium deposits exist in this part of the valley and to determine the nature of the geochemical environment in these rocks.

The upper 680 feet (207 meters) of section penetrated in this hole consists of very fine to coarse, poorly sorted, unconsolidated, feldspathic to arkosic sandstone, partially cemented with calcite. This section is correlated with the conglomerate in the upper part of PQ-10, as the medial portion of an alluvial fan originating in the Hualapai Mountains. It also may correlate eastward and southward with the lower basin fill, interfacing with the lacustrine sediments of this sequence.

From the depth of 680 to 4,100 feet (207 to 1,245 meters) the section consists of light gray to buff and tan calcareous, partially pyritic siltstone, mudstone, claystone, and gray limestone. This thick section (3,420 feet; 1,042 meters) of fine sediments is largely lacustrine in origin and is equivalent to the "lower basin fill" section described by Davidson (1973).

Twenty-three low grade (0.010 to 0.019 percent) $eU_3O_8$ uranium occurrences ranging from 0.5 to 11 feet (0.15 to 3.4 meters) thick were recorded in this interval between the depths of 1,794 and 2,292 feet (547 and 699 meters).

From the depth of 4,100 feet (1,250 meters) to the total depth of 5,000 feet (1,515 meters) the section consists of granite wash interbedded with mudstone, biotitic gray siltstone, shale, and sandstone (partially arkosic). This 900 foot (274 meters) section of interbedded lacustrine and coarse alluvial fan deposits indicates that as the lacustrine deposits were accumulating in the valley, the mountains were being elevated and coarse rock fragments and mud accumulated as thick deposits along the lake margins from time to time. During this period only very coarse rock fragments were accumulating in the vicinity of PQ-10, 2 miles (3.2 kilometers) west of PQ-25, and closer to the Hualapai Mountains.

PQ-27

Hole number PQ-27 was drilled 8.5 miles (13.6 kilometers) north of PQ-25, also in the central part of Big Sandy Valley. The upper 1,310 feet (399 meters) of section penetrated is a conglomerate consisting predominantly of quartz but locally arkosic and also containing granitic and volcanic clasts. Quartz grains are commonly stained yellow and feldspars are partially altered.

Below this upper conglomerate is a 220-foot (67 meter) interval of tan, soft, micaceous, sandy siltstone followed by a 320-foot (97 meter) interval of medium to coarse grained, white to yellow stained, feldspathic sandstone. Below the sandstone is a 460-foot (140 meter) section consisting of conglomerate containing abundant granitic clasts and locally volcanic clasts, red tuff, and mudstones.

Tan to red calcareous siltstone and shale were penetrated from 2,320 to 2,440 feet (707 to 744 meters). From the bottom of this unit to the total depth of 5,000 feet (1,524 meters) the section consists of brown boulder conglomerate in a matrix of reddish calcareous sandstone, siltstone, and claystone.

Although some parts of the sediments penetrated in this hole probably accumulated in a lacustrine environment, they appear to be oxidized. No gamma-ray anomalies were logged in this hole.

PQ-28

This hole is located on the northern margin of a prominent gravity low in the central part of Big Sandy Valley.

The sediments penetrated in this hole consist almost entirely of coarse unconsolidated clastics. The top 100 feet (30 meters) consist of cobbly overburden. Below this is 1,650 feet (503 meters) of conglomeratic sandstone that is generally feldspathic, and contains minor percentages of other rock minerals. Below this thick sandstone sequence are 2,300 feet (701 meters) of alternating layers of conglomerate composed largely of granitic rocks and coarse feldspathic sandstone. Traces of clay and calcareous cement are included locally in the sandstone.

The sandstones exhibit a few of the favorable characteristics of fluvial sandstone hosts but are lacking in interbedded shale or clay, fossil vegetal carbon, and radioactive anomalies. Two weak radioactive anomalies were recorded in this hole (see Table 1), each over an interval of only 1 foot (0.3 meter) and intensity range of 0.009 to 0.011 percent $eU_3O_8$. One anomaly is in the lower granite wash section and one in basement granite.

## SUMMARY - BIG SANDY VALLEY

Big Sandy Valley contains as many as 5,000 feet (1,524 meters) of Tertiary sedimentary rocks, locally interstratified with volcanics (Plate 2). In some parts of the valley the sediments include thick sequences of paludal/lacustrine deposits lithologically similar to the uranium bearing rocks of the Date Creek basin. The six holes drilled here as part of this project have shown that the favorable sediments are thick but not widespread in this portion of the valley. The area between holes PQ-26 and PQ-27 appears to be most favorable. The uranium industry has drilled fairly extensively in this valley.

The Tertiary sedimentary sequence in this basin was found to be much thicker than anticipated, and possible paludal/lacustrine sediments occupy a large part of this sequence, locally. The existence of these "Anderson Mine" type sediments, and the existence of anomalous radioactivity in these sediments make the Big Sandy Valley appear favorable for the occurrence of uranium deposits.

Centennial Valley

Centennial Valley is in the southwestern part of the project area, north and west of the Buckskin and Rawhide Mountains, south of the Castaneda Hills, and southeast of the Bill Williams Mountains (Figures 3 and 6). Precambrian crystalline rocks are exposed in each of these mountain ranges. Tertiary or

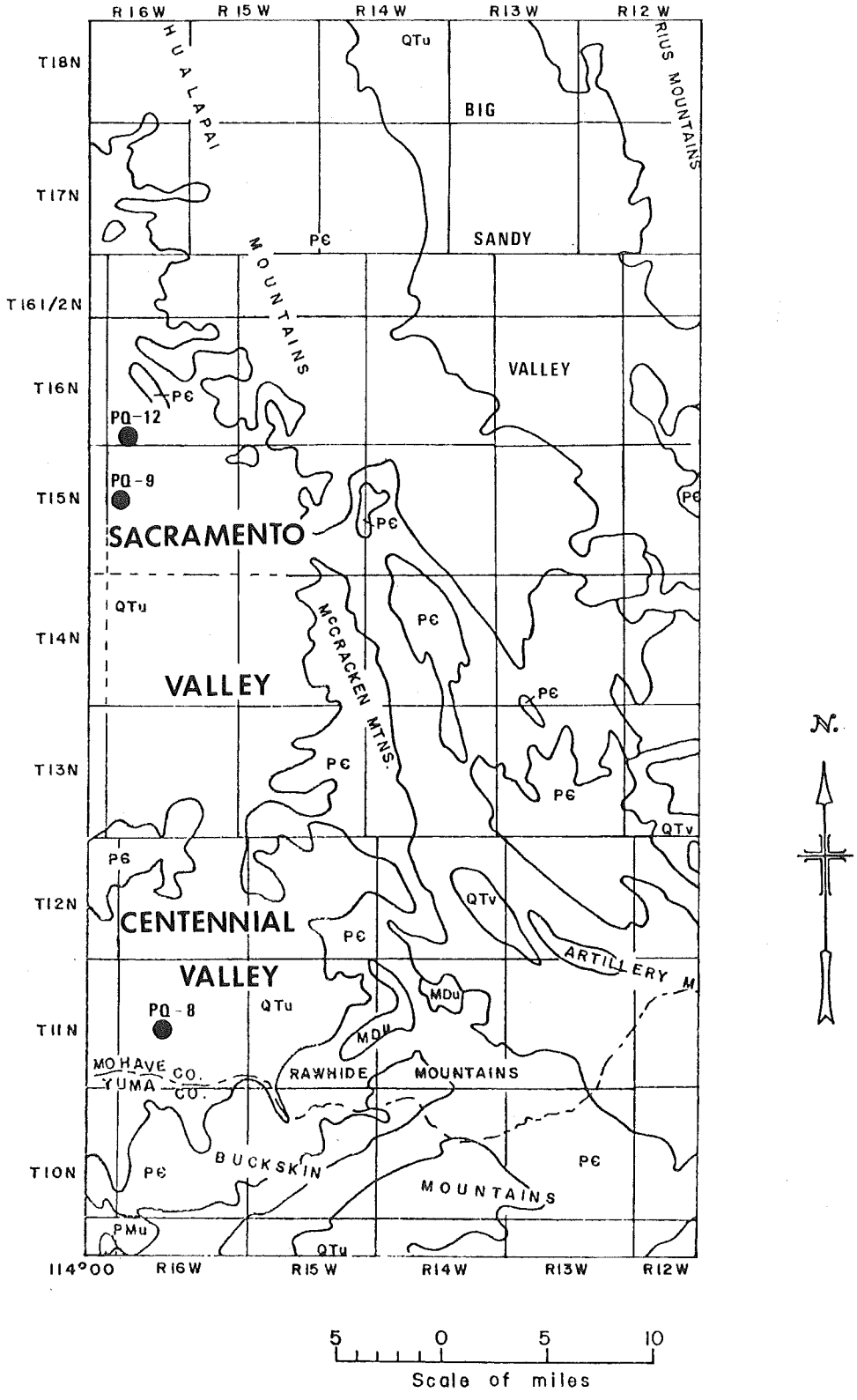



FIGURE 6. Sacramento and Centennial Valleys—location of drill sites

younger volcanic rocks are exposed on east, north, and west margins of the valley. The valley contains several thousand feet of Tertiary (?) and Quaternary sedimentary and volcanic rocks.

The ARMS report for the Prescott NTMS quadrangle did not show any anomalies in the vicinity of Centennial Valley, nor did the HSSR survey show any anomalous uranium content in the ground water. The single drill hole in Centennial Valley (PQ-8) was drilled here to test the basin for the existence of Artillery and/or Chapin Wash formations, both of which contain favorable lacustrine sediments and uranium occurrences to the east; the Artillery Formation in the Artillery Mountains and the Chapin Wash Formation in Date Creek basin.

PQ-8 cut predominantly coarse clastics. Except for an interval of 310 feet (94 meters) of volcanic rocks from 940 to 2,250 feet (287 to 381 meters) in depth the section penetrated was interlayered conglomerate, conglomeratic sandstone, and sandstone. The conglomerate portions contained abundant granitic clasts as well as volcanic clasts locally. The clastics are generally red to brown and hematite is common as matrix in some intervals. Calcareous cement is also common.

The hole penetrated 100 feet (30 meters) of rock interpreted as metasediments between the depths of 1,910 and 2,010 feet (582 and 613 meters). Chlorite schist was encountered below the metasediments and the hole bottomed in schist at a depth of 2,451 feet (747 meters).

No fossil vegetal material was found in the sediments penetrated and they appear to be oxidized throughout the section. No sediments of paludal/ lacustrine origin were found in this hole and no gamma-ray anomalies were logged.

Sacramento Valley

Sacramento Valley is in the extreme west-central part of the project area, bounded on the east by the Hualapai Mountains, on the south by the McCracken Mountains, and on the west by the Mohave Mountains (Figures 3 and 6). The mountain ranges consist predominantly of Precambrian crystalline rocks, with a few local areas of Tertiary volcanics.

The valley is filled with several thousand feet of alluvial deposits of Tertiary and Quaternary age. In some areas volcanic rocks are interbedded with the alluvial deposits. Both older and younger alluvial deposits are fanglomerates that formed along the mountain flanks and spread throughout the basin, generally becoming finer basinward and locally interbedded with clay and silt (Gillespie and Bentley, 1971).

Anomalous uranium concentrations have been found in the igneous rocks of the Hualapai Mountains, eight water samples from the Hualapai Mountains, and sites along the eastern and southern margins of the valley contain greater than 20 ppb uranium [HSSR basic data report GJBX-122(79)]. Also, the ARMS report GJBX-59(79) shows elongate vein-like areas of anomalous thorium concentrations in the Hualapai Mountains.

The HSSR and ARMS surveys had not been completed when drilling was first proposed for Sacramento Valley. However, the anomalous radioactivity in the

granitic rocks and the mapped gravity low in the valley (West and Sumner, 1973) influenced the selection of a drill site here. PQ-9 drill site is positioned on a gravity low, similar to those in Big Sandy Valley, Congress and Date Creek basins, which were thought to enhance the potential for encountering lacustrine sediments.

PQ-9

The upper 1,290 feet (393 meters) of this hole penetrate fine to very coarse grained, feldspathic to arkosic sandstone that is slightly calcareous and locally contains a trace of clay. Below this is a 760-foot (231 meter) interval of very fine to medium-grained feldspathic sandstone. Below this is 70 feet (21 meters) of conglomerate containing quartzite and schist clasts.

From the depth of 2,120 feet (646 meters) to the top of the basement granite at 5,192 feet (1,582 meters) the section consists of thin to thick, dark gray to red volcanic flows and tuffs alternating with thick layers of conglomerate and coarse arkosic sandstone. The hole bottomed in granite at a depth of 5,204 feet (1,586 meters).

None of the arkosic sandstones penetrated are favorable for the occurrence of uranium deposits, inasmuch as they contain no interbedded clay or shale, or fossil vegetal material. Four low-grade radioactive anomalies were recorded below the depth of 5,030 feet (1,533 meters), in intervals of 0.5 to 4 feet (0.15 to 1.2 meters). All anomalies are in rocks described as "granite wash" or conglomerate.

PQ-12

Because a radioactive anomaly was thought to have been found in the basement rocks of PQ-9, it was decided to locate 1 of the 10 optional holes to test Tertiary and Precambrian rocks at a more shallow depth in the vicinity of PQ-9. The rocks penetrated were very similar to those encountered in PQ-9. The upper 980 feet (299 meters) of rocks penetrated consist of conglomerate and coarse, conglomeratic, and arkosic sandstone. Some clay partings and tuff were found between the depths of 940 and 980 feet (286 and 299 meters). From 980 feet (299 meters) to the top of the basement at 1,750 feet (533 meters) the section consists of gray to red volcanics interlayered with conglomerate in layers 20 feet (6 meters) to more than 400 feet (122 meters) thick. Basement granite gneiss was penetrated from 1,750 feet (533 meters), to total depth at 1,819 feet (554 meters).

The only section penetrated that could be considered to be lacustrine in origin is the interval from 940 to 950 feet (286 to 289 meters), which included clay partings in a fine- to very coarse-grained, conglomeratic sandstone. No fossil vegetal carbon was recognized in this or any other part of the section, and no radioactive anomalies were recorded on the gamma-ray log.

The two holes, PQ-12 and PQ-9, drilled in Sacramento Valley again demonstrate the complex stratigraphy of the Tertiary sediments and volcanic rocks of these basins. No rocks of the type found at the Anderson Mine were encountered in either of these holes. Some industry drilling has been carried out in this basin, but locations, depths, and results are not available.

## Butler Valley

Butler Valley is in the southwestern part of the project area, southwest of Date Creek basin (Figure 4). The valley is bounded on the north by the Buckskin Mountains and on the south by the Harcuvar Mountains. These mountain ranges consist of Precambrian crystalline rocks, predominantly granite-gneiss. Towards the southwest, Mesozoic and Tertiary intrusives are exposed in the Harcuvar Mountains, Granite Wash Mountains, and Bouse Hills.

The Quaternary and late Tertiary fanglomerates that fill the basin obscure older sedimentary rocks that are presumed to have been deposited here. The fairly widespread occurrences of rocks similar to the Chapin Wash Formation in this part of Arizona suggest that these rocks may be preserved in Butler Valley, as well as other similar Tertiary basins. For this reason hole number PQ-7 was drilled in Butler Valley.

No anomalous radioactivity was detected in the valley during the ARMS survey, nor were the waters and stream sediments found to contain anomalous concentrations of uranium in the HSSR survey.

Hole number PQ-7 was drilled near the center of Butler Valley to a total depth of 1,241 feet (409 meters). The top 550 feet (168 meters) of this hole is granitic conglomerate. From 550 to 1,336 feet (168 to 407 meters) the section penetrated is very fine- to medium-grained sandstone, partly conglomeratic, and unconsolidated. The hole bottomed in biotite schist. None of the sedimentary rocks penetrated in this hole are favorable for the occurrence of uranium deposits because there are no interbeds of shale or clay in the thick sand intervals, no fossil vegetal carbon or other reductant was present, and no radioactive anomalies were recorded. The entire sedimentary sequence penetrated appears to have been oxidized. Two other drill holes in the same general area of the basin encountered similar rocks. One hole was drilled by the U.S. Bureau of Reclamation in the SE 1/4 SE 1/4 SW 1/4 of Section 29, T8N, R24W, for water, and went to a total depth of 1,484 feet (452 meters), bottoming in gray-green and red cemented breccia. The other hole was drilled by El Paso Natural Gas Company in the SW 1/4 SW 1/4 of Section 20, T8N, R13W, to a total depth of 1,360 feet (414 meters). This hole bottomed in granite gneiss and schist. Lithologic descriptions obtained from American Stratigraphic Co. and the Bureau of Reclamation and geophysical logs of these holes indicate that no favorable host rocks nor gamma-ray anomalies were found in either hole.

The area in which the three holes discussed above were drilled in Butler Valley does not appear to be favorable for the occurrence of uranium deposits of the Anderson Mine type. The sediments are coarse, unconsolidated, lack clay or shale interbeds and fossil vegetal material, and gamma-ray anomalies. However, if basin and range type faults exist near the basin margins, local lakes could have formed at some period in the Tertiary, favorable for the accumulation of paludal/lacustrine sediments of the Anderson Mine type.

## Aguila Valley

Aguila Valley is in the extreme southern part of the project area (Figure 4). It is separated from Date Creek basin by the Harcuvar Mountains, which form the northern boundary of the valley. The valley is bounded on the east by the Vulture Mountains and on the south by the Harquahala Mountains. The valley

merges on the west with McMullen Valley. The mountain ranges are composed principally of Precambrian granite or granite-gneiss, although large portions of the Harquahala and Vulture Mountains are Tertiary granite or other intrusives and Cretaceous andesite, and contain lesser areas of Tertiary or Quaternary basalt.

Along the southern margin of the Harcuvars a steeply south dipping 8,500-foot (2,591 meter) sequence of lower Miocene volcanic flows, pyroclastics, unstratified coarse conglomerates, flow breccias, lahar deposits, and fine-grained redbeds have been described by Scarborough and Wilt (1979). They suggest that the base of this sequence (Bullard Peak section) is in probable low angle "dislocation surface" contact with the plutonic rocks of the southern Harcouvar Mountains, and that this is a dislocation or detachment surface of an event that post dates both the lower Miocene Artillery Formation and the Anderson Mine uranium host rocks. Further, they suggest that the rocks of the Bullard Peak section did not accumulate in their present site, but were transported along the dislocation surface from their original accumulation site. What effect these events might have had on possible uranium host rocks in Aguila Valley is unknown. Uranium was discovered in the Aguila area at least as early as 1925 (Hewitt, 1925). Carnotite was found on the west end of the Vulture Mountains about 9 miles (14 kilometers) southeast of Aguila, and in an area 5 miles (8 kilometers) northeast of Aguila. The carnotite was in altered tuffs that were deposited in local fresh water lakes. The carnotite occurs as patches on poorly defined fractures cutting across the bedding planes. Hewitt thought the mineral was a recent deposit by circulating ground waters. The tuffs are older than mid-Tertiary tilting and brecciation of associated volcanic flows (Hewitt, 1925).

No anomalous radioactivity was detected in the Aguila Valley area in the recent ARMS survey, and no anomalous concentrations of uranium were found in the waters and stream sediments collected in the HSSR survey.

PQ-3 was drilled in the north-central part of the valley. It was projected to bottom in basement at 3,100 feet (945 meters) but drilling continued to 4,333 feet (1,320 meters) where the hole was terminated in altered volcanic rocks.

The upper 3,650 feet (1,112 meters) of the section consists predominantly of fine- to very coarse-grained sandstone, unconsolidated, feldspathic to arkosic, and locally iron stained and calcareous. Below 2,500 feet (762 meters) the section contains several intervals of gray-green tuff, partly altered to clay. The tuffs range from 20 to 90 feet (6 to 27 meters) thick. None of the sands drilled in this hole contain interbedded clay or shale, or fossil vegetal carbon. Several weak (1 - 4X background) radioactive anomalies were logged between the depths of 2,011 and 3,590 feet (613 and 1,094 meters). They appear to be associated with calcareous sandstones or where the sandstone contains a trace of clay.

Below 3,650 feet (1,112 meters) the section consists of dark reddish-gray brecciated, altered basalt and gray fine-grained sandstone containing lithic clasts of basalt. The hole bottomed in basalt. A thin section of a portion of core of fine grained dark volcanic rock from the depth of 3,935 feet (1,296 meters) is described as strongly altered basalt breccia.

No sediments similar to the Anderson Mine rocks were encountered in this hole, and the fluvial sandstones drilled lack several of the generally accepted

criteria of host rocks for uranium deposits. They lack clay or shale interbeds, fossil vegetal carbon, and radioactive anomalies.

## Walnut Grove Valley

Walnut Grove Valley is in the extreme southeastern part of the project area. It is bounded on the east and north by the Bradshaw Mountains, on the west by the Weaver Mountains, and on the south by a series of peaks of Precambrian rocks between the Bradshaw and Weaver Mountains. The valley is divided into eastern and western basins by Black Mountain, a northwestward projection of granite from the Bradshaw Mountains on the east. The surrounding mountains are composed of Precambrian schists and granites. Locally Tertiary dacite porphyry intrudes the Precambrian basement and a flow caps Black Mountain. The basins are filled with Tertiary to Quaternary fluvial and lacustrine sediments.

The Walnut Grove basin is not a structural feature like several other of the basins drilled in this project. The basin is thought to have been formed by erosion resulting from regional uplift and tilting of basement rocks. The basin fill sediments were deposited on the eroded Precambrian surface. Post depositional upwarping on the south has tilted the Tertiary sediments towards the northeast at angles of from 10 to 25 degrees. The younger lower Pliocene sediments are tilted less than the older Tertiary sediments, indicating several phases of upwarp, and the Pleistocene sediments that overlie the Lower Pliocene uncomformably, are essentially flat lying (Hook, 1956).

The Tertiary strata in the eastern basin are cut by two northwest trending normal faults, downthrown on the west. Vertical displacements on these faults range from 500 to 700 feet (152 to 213 meters). A northeastward trending normal fault, downthrown on the west, cuts across the northern part of the eastern basin from Black Mountain. Vertical displacement on this fault is 300 feet (91 meters). These faults and associated lesser faults are considered to have occurred in the Pleistocene (Hook, 1956).

Tertiary lacustrine and fluviatile sediments and interbedded basalt crop out in the eastern basin of Walnut Grove Valley whereas in the western basin the sedimentary section is composed almost entirely of lacustrine deposits (Plafker, 1956). The name, Milk Creek Formation, was proposed for these beds by Hook (1956). The formation has been assigned a lower Pliocene age (Hook, 1956, p. 16) on the basis of vertebrate fossils from the upper member. Hook (1956, p. 16) states that only the upper 300 to 400 feet (91 to 122 meters) of the section are of known Lower Pliocene age, but although there is no recognizable break in sedimentation in the underlying nearly 2,000 feet (610 meters) of sediments, the lower part of this section might be Miocene in age.

The Milk Creek Formation consists predominantly of siltstones with interbedded sandstones, conglomerates, mudstone, and tuff. In the eastern basin, the lower 150 feet (46 meters) of the section consists of sandy, silty, and conglomerate. Overlying this is 350 feet (107 meters) of generally massive silty sandstone with local interbeds of conglomerate and tuff. A 342-foot (104 meter) basalt flow overlies this sedimentary section.

Above the basalt is a 1,062-foot (324 meter) thick sequence of argillaceous sandstone interbedded with cross-bedded sandstones and tuffs. The tuffs generally occur as lenticular deposits of limited lateral extent. These tuff

lenses are generally white, 3 to 10 feet (1 to 3 meters) thick, and wedge out abruptly at their margins. The middle portion of the Milk Creek Formation consists of mudstones interbedded with calcareous sandstones and local ash-fall tuffs. This in turn grades upward into a 747-foot (228 meter) section of medium- to coarse-grained, cross-bedded sandstone, interlayered with argillaceous to sandy siltstone. Some of the sandstone layers are cemented with calcite. This section also contains some conglomeratic channel deposits.

Siltstones dominate the Milk Creek Formation in the western basin, but they contain some interbedded sandstones and tuffs (Plafker, 1956). Plafker estimated a thickness of more than 3,000 feet (914 meters) of sedimentary rocks in the western basin.

The lacustrine strata of the Mill Creek Formation grade laterally east and north into Pliocene conglomerates. These coarse sediments, derived from local highlands, were deposited around the margins of the basin, whereas the finer sediments were carried further into the basin where they were deposited as stream channel sands, overbank and floodplain muds and silts, and as muds in shallow, intermittent lakes and ponds. No lacustrine limestones or marls have been found in the formation, suggesting that lakes were shallow and short lived.

No anomalous radioactivity was detected in the ARMS survey of the Walnut Grove Valley or the immediate surrounding areas. One water sample from a well 2 miles (3.2 kilometers) east of Wilhoit at the north end of the valley was the only sample in the vicinity that contained more than 20 ppb uranium. Most water samples collected in the area in the HSSR survey contained less than 5 ppb uranium.

PQ-24 was drilled near the north end of Walnut Grove Valley, where it merges with Skull Valley to the north. The purpose of the hole was to test the uranium potential of the lacustrine sediments of the Milk Creek Formation. The hole penetrated 1,550 feet (472 meters) of very fine to very coarse-grained conglomeratic sandstone and conglomerate with sandy matrix, and locally some very hematitic clay cement. The hole bottomed in basement granite at 1,563 feet (476 meters). This hole obviously was located in an area where only conglomeratic material had accumulated, between the highland source of the sediments and the deeper parts of the basin. The sandstones in this hole are highly oxidized, do not contain interbeds of clay or shale, or vegetal organic carbon. No gamma-ray anomalies were recorded on the geophysical logs of the hole.

Truxton Valley

Truxton Valley is a broad, roughly circular basin in the northwestern part of the project area. The valley is southeast of the Music Mountains and north of the Cottonwood Mountains. Peach Springs Canyon extends northeastward towards the Colorado River from the northern part of the valley. Truxton Valley, like the Walnut Grove Valley, has been formed by erosion rather than by faulting that created typical basins of the Basin and Range Province.

It is a 15-mile (24 kilometer) wide valley eroded in the Paleozoic rocks on the edge of the Hualapai Plateau. Present drainage of Truxton Valley is by means of Truxton Wash which drains to the southwest through the Grand Wash

Cliffs into Hualapai Valley on the west. Young and Brennan (1974) contend that erosion of Truxton Valley was begun by drainage along the Hurricane fault zone to the northeast, through Peach Springs Canyon, as a result of pre-middle Miocene movement along the fault. The Hurricane fault is a major north-south structural feature in southwestern Utah and northwestern Arizona. It extends 170 miles (272 kilometers) northward from the Colorado River in Arizona, and from the same point southward through Peach Springs Canyon and Truxton Valley to the Cottonwood Cliffs southeast of the town of Valentine, Arizona (Young and Brennan, 1974).

The stream that eroded Truxton Valley, as well as those that eroded Milkweed, Hindu, and Peach Springs Canyons are considered by Young and Brennan (1974) and Young and McKee (1978) to have flowed northeastward across the Hualapai Plateau from a pre-Basin and Range upland on the southwest, in pre-middle Miocene time. Following erosion of these valleys structural movements in the area resulted in deposition of fanglomerates and blockage of the valleys. Local lakes formed in some of these valleys and deposits of lacustrine limestones interbedded with siltstone and claystone were formed. These deposits later were covered with gravels, volcanics and volcaniclastics, and the valleys then filled with Peach Springs Tuff in middle Miocene time.

The tuff in Truxton Valley is covered by at least 230 feet (70 meters) of post volcanic gravel, and is displaced vertically across the valley between 100 and 200 feet (30 and 60 meters) by the Hurricane fault (Young and Brennan, 1974). An early (?) Tertiary fluvial arkosic sandstone and conglomerate (Music Mountain Conglomerate) on the Hualapai Plateau, northwest of Truxton Valley, is estimated to contain from 0.06 to 0.09 percent uranium over an area of 0.1 square mile (0.25 square kilometer). This deposit contains Precambrian crystalline rock clasts that are thought to have been derived from the pre-Basin and Range upland to the southwest (Young and Brennan, 1974).

If the present mountains to the south and southwest of Hualapai Plateau are the eroded or down-dropped remnants of the pre-Basin and Range uplands hypothesized by Young and others, and inasmuch as those mountains presently contain anomalous concentrations of uranium (Clark, 1979), it is possible that uranium in solution was available in the stream waters that deposited the pre-middle Miocene fluvial and lacustrine sediments on the Hualapai Plateau. If any of these sediments were favorable as host rocks, uranium deposits may have been formed at that time. Major Basin and Range movements after deposition of the Peach Spring Tuff altered the drainage and disruption of the stream flow may have allowed preservation of any such deposits.

Hole number WQ-32 was drilled in Truxton Valley to test for the existence and uranium potential of pre-Peach Springs Tuff Tertiary fluviolacustrine deposits. The upper 240 feet (73 meters) of section drilled in this hole consists of 130 feet (40 meters) of a variety of pebbles in a clay and silt matrix followed by 110 feet (34 meters) of conglomerate. The Peach Springs Tuff was penetrated between the depths of 240 and 270 feet (73 and 82 meters). Below this is a 70 foot (21 meter) section of conglomerate consisting largely of volcanic clasts. Very fine to coarse-grained sandstone occupies the next 310 feet (94 meters) to a depth of 650 feet (198 meters). The sandstone is unconsolidated, slightly feldspathic, and partially iron stained. The section from 650 to 950 feet (198 to 290 meters) consists of oxidized, sandy conglomerate of granitic clasts with a thin quartzitic sandstone near the middle of the section. The red, gray, and white siltstone interval between the

depths of 950 and 1,020 feet (290 and 311 meters) is the only section of possible lacustrine sediments encountered. It also lacks fossil vegetal carbon and gamma-ray anomalies.

Two low gamma-ray anomalies were recorded on the gross-gamma logs from this hole. One anomaly is in a 300 foot (91 meter) oxidized conglomeratic sandstone interval at a depth of 763 feet (232 meters). The other anomaly is in Precambrian granite. The sediments penetrated in this hole generally were very coarse grained and oxidized. No interbeds of clay or shale, fossil vegetal carbon, or other reductant were found in the sediments.

### General Conclusions from Drilling Activity

This drilling project has shown that although Tertiary lacustrine sediments are widespread in some of the basins in the subsurface and in surface exposures, they probably are only locally developed within the basins.

The published gravity maps of the area have not proven to be useful for predicting the existence of thick sequences of lacustrine rocks in the subsurface, nor for predicting depth to basement in the basins.

The fluvial sediments encountered in the project are not favorable for the formation of uranium deposits because they lack interbeds of shale or clay and fossil vegetal carbon or other reductant. The present chemical environment in most of these rocks seems to be one of oxidation.

The stratigraphy of Tertiary sediments and volcanics in the subsurface is complex and correlation of sedimentary units between widely spaced holes is uncertain.

## CONCLUSIONS ON URANIUM FAVORABILITY AND RESOURCES

### Assessment Criteria

The favorability of each basin was assessed by comparing available data with the criteria. These criteria are based on the geological setting of the uranium occurrence at the Anderson Mine and on the generally accepted characteristics of uranium mineralization in fluvial sandstone-shale sequences. To be considered favorable for uranium deposition:

1. Paludal/lacustrine sediments, similar to those of the Anderson Mine and vicinity, are present:
   a) These consist of tuffaceous mudstone and siltstone, carbonaceous micritic fresh-water limestones, marlstones, and carbonaceous clays.
   b) These sediments are in reduced chemical state. If they are gray or green, they are considered to be reduced. Fossil vegetal carbon and pyrite may also be present.

2. Fluvial sandstones with these characteristics are present:
   a) They are medium to coarse grained, poorly sorted, gray, green, or tan and contain intervals of gray or green mudstone.
   b) The thickness of the sandstones is greater than 25 feet (7.6 meters).

c) They occur in sequences that have sand/shale ratios ranging from 1/1 to 4/1.
d) They dip at angles of less than 5°.
e) They contain vegetal carbonaceous matter.

3. Strata containing radioactive anomalies greater than 5X background are present as a possible guide to deposits in the same general area.

4. Zones of pervasive post-depositional alteration are present.

Uranium Favorability

Lacustrine sediments were found in at least 7 of the 18 holes drilled in this project. Of these, three are in Date Creek basin and four in Big Sandy Valley. One other hole, PQ-32, in Truxton Valley, contained possible lacustrine sediments.

This drilling project has shown that the Tertiary lacustrine sediments are widespread but probably locally developed. In each section of lacustrine sediments penetrated, fossil vegetal carbon was generally lacking, and all uranium mineralized zones were low grade (0.010 to 0.02 percent) and thin, ranging from 0.5 feet to 11 feet (0.15 to 3.3 meters), with the bulk of the anomalies in the 0.5 to 3 foot (0.15 to 0.9 meters) thickness range.

On the basis of the results of drilling and interpretations expressed in the foregoing paragraph, the uranium potential of some of the Tertiary basins should be modified (Figure 7); whereas the potential of others should remain unchanged. One barren drill hole, in a basin containing many cubic miles of sediments, may not condemn the basin, but one drill hole that penetrates favorable host rocks or contains anomalous radioactivity may greatly improve the potential of a basin. Several holes in the project were of this latter type.

The one hole (PQ-1) drilled in Congress basin showed the basin to be much more shallow, at that point, than was anticipated. Inasmuch as no lacustrine sediments were encountered, this hole did not improve the uranium potential of the basin. The one hole (PQ-3), drilled in Aguila Valley, adequately tested the northern part of that valley for postulated basin-wide lacustrine sediments, but found none. On the basis of the one hole (PQ-7) drilled in Butler Valley, an exploratory oil well drilled by El Paso Natural Gas Corporation in the same general area, and a deep water well drilled by the United States Bureau of Reclamation (U.S.B.R.), this valley rates a low uranium potential. All three holes penetrated only coarse clastic sediments.

Plafker (1956) reported the existence of thick sequences of lacustrine rocks in outcrops in Walnut Grove Valley. Hole number PQ-24 penetrated only conglomeratic sandstone and sandy conglomerate in the northern part of this valley. The uranium potential of Walnut Grove Valley has not been changed by this hole inasmuch as the part of the basin in which lacustrine sediments have been described was not drilled. Centennial Valley was tested with one hole, PQ-8. Only coarse clastics were encountered in this hole. The results of this test diminished the potential of this basin, although local areas of lacustrine sediments may exist in the subsurface. Although some industry drilling has been carried out in this basin, locations, depths, and results are not available.

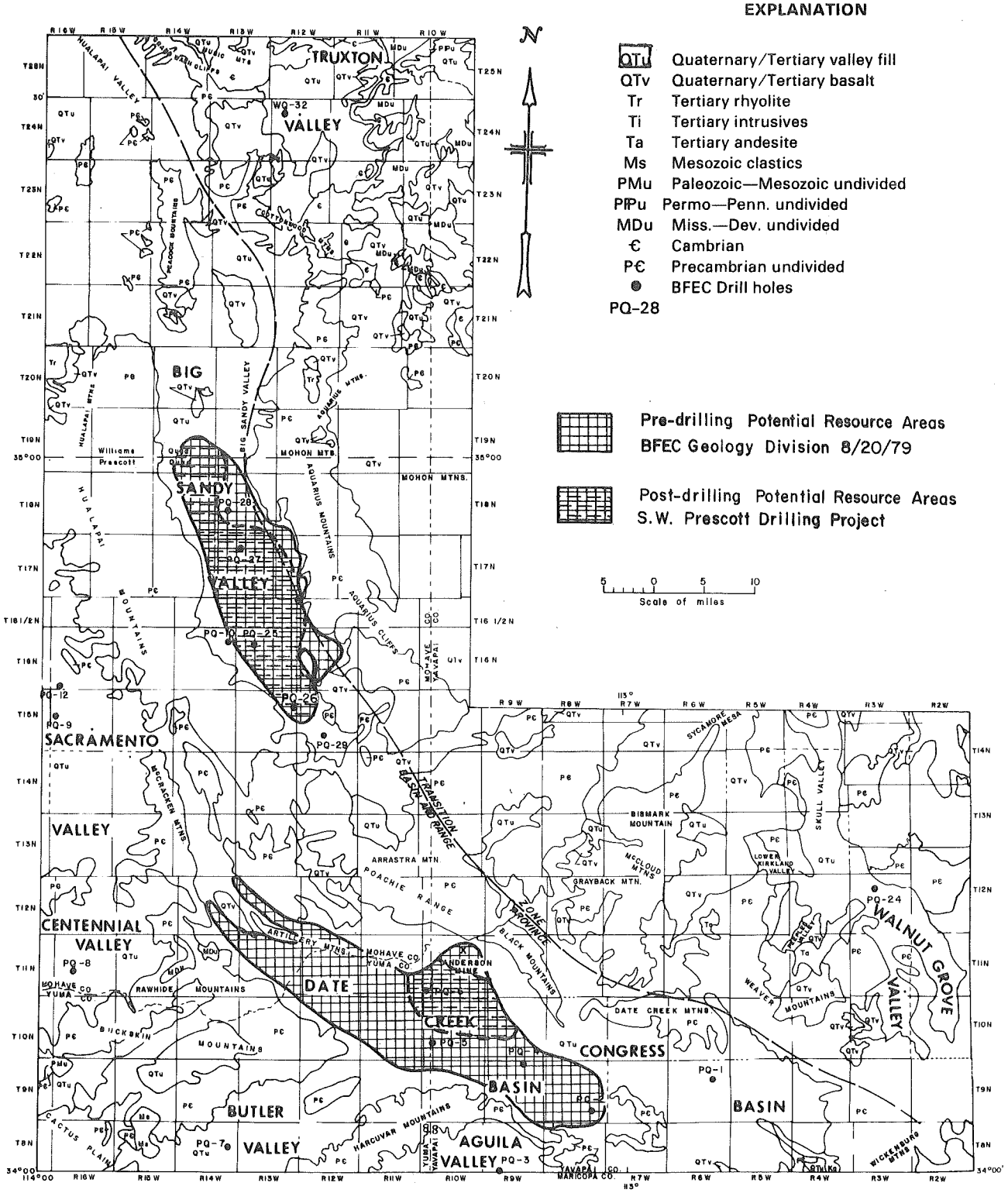



FIGURE 7. Potential Resource Areas

The two holes, PQ-9 and PQ-12, drilled in Sacramento Valley penetrated only coarse clastic sediments above basement. Some industry drilling has also been carried out in this basin but locations, depths, and results are not available. Vast areas in the basin probably have not been tested. The uranium potential of this basin remains basically unchanged by the drilling in this project. The radioactive anomalies logged in PQ-9 were thin, low grade, and below 5,000 feet (1,524 meters) in depth.

Figure 7 shows the resource areas A, B, D, F, and I as outlined on the Areas Favorable for Uranium Deposits map included as Plate 1 of DOE open-file folio PGJ-006, Uranium Evaluation of the Prescott Quadrangle, Arizona. Figure 7 also shows the redefinition of Area B (Date Creek basin) based on the Southwest Prescott project. The drill holes PQ-2, PQ-4, and PQ-5 show that the "Anderson Mine Formation" does not extend as far south as PQ-4 or PQ-5. Only low-grade uranium occurrences exist in sediments of this type in a number of industry holes drilled between PQ-5 and PQ-6, and the NE 1/4 of T10N, R11W. Industry has done extensive drilling in T10N, Ranges 9, 10, and 11W, but only a very small percentage of this information has been made available to BFEC for this project. Big Sandy basin was designated as area F on Plate 1 of the DOE folio mentioned above. The resource area outline includes all of Big Sandy basin as far north as T19N, R14W. Six holes were drilled in this basin in this project. Holes numbered PQ-25, PQ-26, PQ-27, PQ-28, and PQ-29 are located along the geographical axis of the basin. PQ-25 and PQ-26 are within the known distribution area of the Big Sandy Formation (Pliocene) (Sheppard and Gude, 1972), and penetrated siltstone intervals 4,320 and 520 feet (1,317 and 159 meters) thick, respectively.

In PQ-27, a similar siltstone appears to interfinger with coarse clastics through a vertical interval of 540 feet (164.6 meters). This may be a northern extension of the Big Sandy Formation in the subsurface, or a separate lacustrine environment of the same age.

PQ-25 was the only drill hole in this basin in which any significant uranium anomalies were recorded, all 25 of which were in the thick fine grained sedimentary units. Although the ore grade of these mineralized zones was low, they were equal to the ore grade recorded in PQ-6 in Date Creek basin. Industry has drilled extensively in this basin. On the basis of the Prescott project drilling, the resource area for Tertiary lacustrine host rocks is restricted, as shown in Figure 7, because of the absence of lacustrine sediments in the sections drilled in holes numbered PQ-10 and PQ-28.

The Tertiary sedimentary sequence in this basin was found to be much thicker and more extensive than anticipated and therefore the possibilities of finding local basins of paludal/lacustrine sediments appear more favorable.

The fact that a thick interval of Tertiary lacustrine sediments was penetrated in holes drilled in Big Sandy basin, and anomalous radioactivity was recorded scattered over a 498-foot (152 meter) interval in these sediments appears to be adequate justification for changing the uranium potential of this basin from "speculative" to "possible". This has been done in the DOE Assessment Report on Uranium in the United States of America, GJO-111(80).

## Resource Estimate

The distribution of potential uranium resources in Southwest Prescott project area is shown on Figure 7. The basins outlined conform to the resource areas A, B, D, F, and I on Plate 1 of the DOE open-file folio PGJ-006, Uranium Evaluation of the Prescott Quadrangle, Arizona. In the DOE Assessment Report on Uranium in the United States of America, GJO-111(80), these areas were partially combined for reporting potential resources of the Chapin Wash and equivalent sediments, the sediments that were the objectives of this drilling project.

Uranium industry drilling has provided most of the data for the potential resource estimate in Date Creek basin, and probably to a lesser extent for the other basins. The 18 holes drilled in the Southwest Prescott project have provided useful information for the potential resource estimates, partially corroborating industry drilling and partially by providing information from greater depths than normally drilled by industry. The project also provided information on areas that had received limited attention from industry or areas for which industry logs were not available for the potential resource estimate calculations.

The potential resources estimate for the Chapin Wash lacustrine and equivalent lacustrine sediments in the Prescott quadrangle are listed below. These estimates are presented in DOE Assessment Report on Uranium in the United States of America, GJO-111(80).

| | Mean Tons $U_3O_8$ @ $100/lb* | |
|---|---|---|
| Chapin Wash Formation | Probable | Possible |
| Lacustrine sediments | | |
| Date Creek basin | 91,075 | |
| Big Sandy basin (Wickieup) | | 65,965 |
| Equivalent lacustrine sediments | | |
| Walnut Grove Valley | | 5,288 |

*All figures are in tons of $100/lb $U_3O_8$.

Inasmuch as no favorable fluvial host rocks were encountered in this project, the resource estimate for Chapin Wash fluvial and equivalent fluvial sediments have not been included in this report.

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APPENDIX A

## LITHOLOGIC DESCRIPTIONS

### HOLE NO. PQ-1

| | |
|---|---|
| 0' - 100' (0-30 m) | No samples. |
| 100' - 150' (30-46 m) | Quaternary alluvium (Qal). |
| 150' - 730' (46-223 m) | Sandstone, arkosic, light pink, fine to coarse grained, locally silty matrix, poorly sorted, angular, slightly calcareous, trace magnetite-biotite-clay (400'-600', 122-183 m). |
| 730' - 960' (223-293 m) | Volcanics, light gray, fine crystalline, with abundant feldspar, red phenocrysts (darker, with less feldspar near base). |
| 960' - 1380' (293-421 m) | Sandstone, light pink (gray), medium to very coarse grained (20% volcanic and metamorphic lithic clasts), poorly sorted, subrounded to subangular, feldspathic, trace magnetite and biotite. |
| 1380' - 1500' (421-457 m) | Volcanics, similar to above. |
| 1500' - 1580' (457-482 m) | Claystone, white, very soft, biotitic, slightly calcareous, ~10% sand near base, (possible altered tuff). |
| 1580' - 2190' (482-668 m) | Volcanics, dark gray, otherwise similar to above, porphyritic/with gray-green mineral, partly heavy limonite stain. |
| 2190' - 2850' (668-869 m) | Conglomerate or "wash", pink, abundant iron stain, quartz diorite-metamorphic-and volcanic pebbles and cobbles, subrounded, silty matrix, abundant biotite, trace magnetite-red clay-silica cement, slightly calcareous.<br><br>Core 2337' - 2347' (712-715 m) recovered 10' (3 m), cobbles and boulders of plutonic rock cemented in matrix of pink to red granite fragments, cemented with silica and some calcite. |

| | |
|---|---|
| 2850' - 2880' (869-878 m) | Volcanics, green - in shades of light and dark green, aphanitic, vitreous, moderately calcareous, trace pyrite. (Possibly detrital or welded tuff). |
| 2880' - 2900' (878-884 m) | Conglomerate similar to above. |
| 2900' - 2947.5' (884-898 m) | Quartz diorite. |
| | Core 2945' - 2947.5' (897.6-898 m) recovered 2-1/2' (0.8 m). Quartz diorite, 60% plagioclase, 30% quartz, 5-10% biotite, very coarse crystalline. Finer crystalline rock of 40-50% quartz, 15% white feldspar and very abundant biotite. |

## LITHOLOGIC DESCRIPTIONS

### HOLE NO. PQ-2

| | |
|---|---|
| 0 - 200' (0-61 m) | No samples. |
| 200' - 1640' (61-500 m) | Sandstone, white, fine to coarse grained, poorly sorted, angular to subangular, locally silty, feldspathic unconsolidated, trace of magnetite, locally stained yellow. |
| 1640' - 1730' (500-528 m) | Siltstone, tan, unconsolidated, partly sandy and partly with clay matrix, micaceous. |
| 1730' - 2190' (528-668 m) | "Granite wash" (pegmatite material?), coarse angular fragments of feldspar, trace of quartz, abundant muscovite and biotite, silty matrix.<br><br>Core 2133' - 2137' (650-651 m). Cobble and boulder size weathered granitic clasts in loose matrix of white to pink granitic material (2-10 min) with slight amount of clay matrix. |
| 2190' - 2230' (668-680 m) | Igneous rock, gray to green, very fine crystalline with greenish yellow and orange phenocrysts. |
| 2230' - 2260' (680-689 m) | "Granite wash". Coarse conglomerate of igneous and metamorphic rock clasts in a silt-sand matrix. |
| 2260' - 2290' (689-698 m) | Igneous rock, very fine crystalline, similar to above. |
| 2290' - 2550' (698-777 m) | "Granite wash", conglomerate of igneous and volcanic lithic clasts in a matrix of sand, silt, and locally some red clay, feldspars partially altered to highly altered. |
| 2550' - 2621' (777-799 m) | Biotite gneiss, pink to black, porphyritic (large crystals of K-feldspar and biotite, 40-50% orthoclase, 30-40% quartz, 10% biotite, muscovite. Trace of serpentine, some fracture fillings of calcite. Heavy limonite stain.<br><br>Core 2616' - 2621' (797-799 m), recovered 4.25' (1.3 m). Biotite gneiss, variable texture and composition. As above. |

LITHOLOGIC DESCRIPTIONS

HOLE NO. PQ-3

| | |
|---|---|
| 0' - 120' (0-37 m) | No samples. |
| 120' - 700' (37-213 m) | Valley fill, alluvium brownish red, coarse sand to 10-15 mm pebbles, subangular, quartz, feldspar, volcanic and metamorphic lithic clasts, partially calcareous. |
| 700' - 1060' (213-323 m) | Sandstone, pinkish gray, unconsolidated, feldspathic medium to very coarse grained, subangular to subrounded grains, 20% volcanic and metamorphic clasts locally, 20% feldspar, traces of muscovite, biotite, hornblende, slightly calcareous, iron stained. |
| 1060' - 1480' (323-451 m) | Sandstone, pinkish gray, unconsolidated arkosic, medium to very coarse grained, poorly sorted, subrounded to rounded, 40-50% feldspar, ~5% liths, trace biotite, muscovite, magnetite. Conglomeratic 1400-1420' (427-433 m). |
| 1480' - 1560' (451-475 m) | Sandstone, light brown, unconsolidated, very fine to very coarse grained, poorly sorted, subangular to subrounded, feldspathic, slightly calcareous, trace of muscovite-magnetite-biotite. |
| 1560' - 1650' (475-503 m) | Sandstone, light brown, unconsolidated, very fine to fine grained, moderately well sorted, subrounded, ~5% feldspar, 2-3% magnetite-hornblende and accessories, slightly calcareous. |
| 1650' - 2040' (503-622 m) | Sandstone, light brown, unconsolidated, feldspathic, fine to coarse grained, poorly sorted, subangular, 5% accessories, slightly calcareous, trace of clay. |
| 2040' - 2400' (622-732 m) | Sandstone, light tan to pink, friable, feldspathic, fine to coarse grained (predom. fine), poorly sorted, subrounded, slightly calcareous, traces biotite-hornblende-magnetite. |
| 2400' - 2420' (732-738 m) | Sandstone, light gray, friable, feldspathic, calcareous, fine to very coarse grained, poorly sorted, subrounded, silty, trace muscovite. |

| | |
|---|---|
| 2420' - 2570' (738-783 m) | Sandstone, light brown, friable, feldspathic calcareous, very fine to coarse grained, poorly sorted, subangular to subrounded, trace biotite-muscovite. |
| 2570' - 2640' (783-805 m) | Tuff, gray green, 50%+ gray clay from alteration of tuff, 50% fragments of very fine grained quartz and volcanic glass (welded tuff), very calcareous. |
| 2640' - 2960' (805-902 m) | Sandstone, light brown, friable, slightly feldspathic, fine to very coarse grained, poorly sorted, 10% lithic clasts (metamorphic and volcanic) trace magnetite. |
| 2960' - 3200' (902-975 m) | Sandstone, light brownish gray, friable, feldspathic, silt to medium grained, moderately sorted, subangular, 2% accessory minerals. |
| 3200' - 3220' (975-981 m) | Tuff, light gray, very fine volcanic glass shards; some sandstone, tuffaceous, calcareous. |
| 3220' - 3480' (981-1061 m) | Sandstone, light tannish-gray, friable feldspathic very fine to coarse grained (predom. fine grained), trace of accessories. |
| 3480' - 3530' (1061-1076 m) | Tuff, light gray green, welded-aphanitic, partially altered to clay (10%). |
| 3530' - 3650' (1076-1113 m) | Sandstone, calcareous, as above. |
| 3650' - 3740' (1113-1140 m) | Volcanics, reddish gray, trace of glass and clay, slightly calcareous. Trace of fine grained sandstone. |
| 3740' - 3910' (1140-1192 m) | Sandstone, light gray/reddish cost, fine grained, moderately well sorted, angular to subangular, trace of feldspar and magnetite, ~20% fine volcanic clasts. |
| 3910' - 3960' (1192-1207 m) | Basalt, dark red-gray, very fine crystalline, hard, many hairline fractures filled with calcite, partings with smooth polished surfaces (slickensides?). |
| | Core, 3929' - 3942' (1198-1202 m), recovered 13'(0.4 m). This section of core described as highly altered basalt breccia, hematitic, and limonitic. |

| | |
|---|---|
| 3960' - 3970' (1207 - 1210 m) | Altered tuff, gray to white, abundant chlorite, calcareous. |
| 3970' - 4333' (1210 - 1321 m) | Basalt breccia as above (possible serpentine fracture fillings). |
| | Core 4326' - 4333' (1319-1321 m) recovered 7' (2 m). Basalt breccia, highly altered, as above. |

## LITHOLOGIC DESCRIPTIONS

(Depths adjusted to geophysical logs)

HOLE NO. PQ-4

| | |
|---|---|
| 0' - 100' (0-31 m) | No samples. |
| 100' - 290' (31-88 m) | Conglomerate, pink-gray-tan-brown, subangular to subrounded pebbles, unconsolidated, traces of sand and siltstone, calcareous. |
| 290' - 790' (88-228 m) | Sandstone, yellow, fine to very coarse grained (predom. coarse to very coarse), poorly to moderately well sorted, unconsolidated, feldspathic. Bottom 20' (6 m) subangular to round pebbles. |
| 790' - 1050' (228 -320 m) | Volcanic/volcaniclastics, red-orange-brown-gray, aphanitic, partly well cemented, calcareous, groundmass of fine to medium crystalline clasts. |
| 1050' - 1300' (320-396 m) | Sandstone, light brown to red, feldspathic, fine to medium grained, subangular to subrounded quartz and feldspar, moderately sorted, unconsolidated, slightly calcareous, trace muscovite and biotite. |
| 1300' - 1720' (396-524 m) | Volcanic/volcaniclastics, gray-white-pink, aphanitic, slightly calcareous, groundmass of hornblende, quartz, hematite, coarse to very coarse grained, poorly sorted, angular to subangular grains. Some sandstone lenses. |
| 1720' - 1960' (524-597 m) | Sandstone, gray with pink cast, medium to coarse grained, poorly to moderately sorted, subround to rounded grains, unconsolidated, quartz-trace feldspar- biotite-hornblende, 20-50% volcanic clasts. Interbedded claystone or altered volcanics. |
| 1960' - 3654' (597-1114 m) | Volcanics/volcaniclastics, light brown to gray and red, very coarse grained, angular, light to dark gray sucrosic, very fine grained groundmass with hematite, biotite and quartz phenocrysts, 10-20% pink claystone, slightly calcareous, 10-30% coarse angular quartz sand in top portion. Thin section of cuttings 3250' - 3280' (991-1000 m) - altered basalt. |

| | |
|---|---|
| 3654' - 3766' (1114-1148 m) | Volcaniclastics, light gray, 30-40% quartz sand, coarse grained, poorly sorted, angular, calcareous; 10% red clay. |
| 3766' - 3870' (1148-1180 m) | Volcanics, red gray, some vesicular fragments, fine white phenocrysts in red groundmass, 10-20% coarse, angular quartz sand, trace of clay. |
| 3870' - 3930' (1180-1198 m) | Volcaniclastics, red, very coarse pebble size angular clasts, red groundmass with quartz and dark crystals, slightly calcareous. |
| 3930' - 4230' (1198-1289 m) | Volcanics, red and gray, slightly calcareous, locally 5-10% tan clay. |
| 4230' - 4280' (1289-1305 m) | Altered volcanics, white-green-gray, calcareous, trace clear quartz, marble, limestone, abundant chlorite (?), possible epidote, trace pyrite. |
| 4280' - 4674' (1305-1425 m) | Volcanics, red-gray as above, trace pyrite, much green alteration mineral. Abundant orange mudstone. |
| 4674' - 4840' (1425-1475 m) | Granite wash (conglomerate), white-pink-gray, 60-70% quartz, 30% feldspar, 5-10% volcanics, white clay, altered volcanics, chlorite. |
| 4840' - 4930' (1475-1503 m) | Conglomerate, white-pink-brown, 60% quartz fragments, 10-20% volcanics, 20% epidote and calcite fragments, trace brown and white clay. |
| 4930' - 5035' (1503-1535 m) | Altered volcanics, red, green porphyritic-plagioclase, magnetite and unknown red phenocrysts, chlorite(?), epidote(?), very calcareous. |
| 5035' - 5050' (1535-1539 m) | Siltstone, brownish gray, calcareous, much clay and very fine to medium grained quartz sand, abundant magnetite, trace of hematite. |
| 5050' - 5084' (1539-1550 m) | Conglomerate, white-brown-green, calcareous, quartz sand and brown clay matrix, abundant alteration minerals [chlorite, calcite, epidote (?)]. |

| | |
|---|---|
| 5084' - 5155' (1550-1571 m) | Sandstone, white to gray, calcareous, 60% medium to coarse-grained angular quartz sand plus quartzite clasts and 30-40% gray and reddish-brown volcanic clasts. Trace of chlorite, biotite, and muscovite. |
| 5155' - 5214' (1571-1589 m) | Volcaniclastics, reddish gray, calcareous, (10-20% quartz sand), red groundmass with white phenocrysts, trace chlorite-epidote-feldspar. |
| 5214' - 5270' (1589-1606 m) | Marble, white crystalline (cored 5242' - 5262' (1598-1604 m), recovered 20' (6 m). |
| 5270' - 5302' (1606-1616 m) | Conglomerate, white to gray, calcareous, ~60% red and gray volcanic sand and pebbles, 30% calcite, 10% sand, quartz, medium to very coarse grained, subrounded to rounded. |
| 5302' - 5450' (1616-1661 m) | Altered volcanics, green, glassy, aphanitic generally with occasional magnetite phenocrysts, calcareous, trace pyrite. |
| 5450' - 5583' (1661-1692 m) | Volcanics, reddish gray, porphyritic with fine feldspar, phenocrysts, glassy, calcareous. |

Drillers total depth 5491' (1674 m)
Geophysical log total depth 5583' (1692 m)

LITHOLOGIC DESCRIPTIONS

HOLE NO. PQ-5

| | |
|---|---|
| 0 - 100' (1-31 m) | No samples. |
| 100' - 300' (31-91 m) | Conglomerate, light brown to yellow, fine sand to 10 mm pebbles, poorly sorted, subround to rounded, feldspathic, trace of biotite, lithic clasts, limonite stain, slightly calcareous. |
| 300' - 780' (91-238 m) | Sandstone, light brown to yellow, very fine to coarse grained, poorly sorted, subrounded to rounded, poorly consolidated, partially conglomeratic, traces feldspar-magnetite, hornblende-biotite, 2-3% calcite. |
| 780' - 970' (232-296 m) | Sandstone, brown calcareous, in clay matrix, very fine grained, moderately sorted, subangular to subrounded, traces magnetite-altered biotite-feldspar. |
| 970' - 1100' (296-335 m) | Sandstone, brown, calcareous, fine to very coarse grained, poorly sorted, feldspathic, angular to subrounded, partially conglomeratic, traces magnetite-hornblende, poorly consolidated. |
| 1100' - 1200' (335-366 m) | No samples - insufficient cuttings. |
| 1200' - 1300' (366-396 m) | Conglomerate, light brown, coarse sand to 10 mm pebbles, volcanic and metamorphic clasts, moderately calcareous. |
| 1300' - 1790' (396-546 m) | Breccia, brown to white, grain sizes coarse, metamorphic lithic clasts, 3-5% chlorite, biotite, slightly calcareous. |
| 1790' - 1870' (546-570 m) | Sandstone, light brown to white, fine to very coarse grained, poorly sorted, angular, 70-80% white quartz fragments, 20% metamorphic clasts. Trace chlorite-biotite, slightly calcareous. |
| 1870' - 2100' (570-640 m) | Sandstone, light tan, very fine grained, moderately well sorted, subrounded calcareous, abundant muscovite, trace biotite-magnetite. |

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| 2100' - 2450' (640-747 m) | Conglomerate pink-white-gray, coarse sand to 10 mm pebbles, poorly sorted, subangular to rounded, gneiss and quartzite clasts, interbedded red siltstone, calcareous. |
| 2450' - 4500' (747-1372 m) | Siltstone, light red, calcareous, abundant red clay. |
| | Core 2510' - 2522' (765-769 m), recovered 12' (3.6 m) siltstone, dull red, firm to hard, dense, slightly calcareous. |
| dip? | Core 4040' - 4041' (1231.4-1231.6 m) recovered 1' (0.3 m) siltstone, dull red, slightly sandy, calcareous, and halite 3"-4" (7.5-10 cm). |
| | Core 4480' - 4490' (1366-1369 m) recovered 10' (3 m) siltstone, dull red, slightly sandy, calcareous. Halite-dark brown, crystalline, hard. |
| 4500' - 4660' (1372-1420 m) | Siltstone, dark red, calcareous, salty (halite), 10% medium grained, subrounded quartz sand, trace carbonaceous material. |
| 4660' - 4790' (1420-1460 m) | Siltstone, light red, calcareous, as above but no carbonaceous material. |
| 4790' - 4930' (1460-1503 m) | Siltstone, similar to 4500' - 4660' (1371-1420 m), ~20% red quartz sand. |
| 4930' - 5044' (1503-1537 m) | Volcanics, light green, dark gray, red, hard, fine crystalline, porphyritic. (Poor samples - lithology uncertain.) |

LITHOLOGIC DESCRIPTIONS

HOLE NO. PQ-6

| | |
|---|---|
| 0 - 100' (0-30 m) | No samples. |
| 100' - 280' (30-85 m) | Quartz pebble conglomerate, white-pink-gray, (coarse sand to 5 mm pebbles), angular to subrounded, unconsolidated, feldspathic, trace of volcanic and chlorite schist clasts, trace of green clay, trace of biotite-magnetite, calcareous. Grades to fresh granite wash with ~ 20% feldspar at base. |
| 280' - 980' (85-299 m) | Sandstone, light tan to pink, fine to very coarse grained, poorly sorted, angular to subrounded. Partly conglomeratic, trace of biotite-magnetite-muscovite, slightly calcareous [strongly calcareous 530' - 660' (162-201 m)]. Trace of volcanics from 700' to 980' (213-299 m), reddish-gray groundmass with white and dark phenocrysts. |
| 980' - 1140' (299-347 m) | Volcanic flow, basic to intermediate composition-possibly basalt. Very fine crystalline, dark gray, dark red to black obsidian inclusions (very fine), hard.<br><br>Core 986' - 994' (301-303 m), recovered 8' (2.4 m), basic to intermediate volcanic rock, dark gray, very fine crystalline, partially vesicular with some calcite fill, grades to reddish brown, and abundant vesicular pore space. |
| 1140' - 1160' (347-354 m) | Clay, red, highly calcareous. |
| 1160' - 1190' (354-363 m) | Siltstone and claystone, reddish brown, 10% fine grained quartz, feldspar and biotite, calcareous. |
| 1190' - 1320' (363-402 m) | Sandstone, light brown to pink, fine to coarse grained, argillaceous, poorly sorted, subangular to subrounded, partially conglomeratic, abundant volcanic clasts (white groundmass with dark phenocrysts), moderately to highly calcareous, 5% gypsum locally. |

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| 1320' - 1350' (402-411 m) | Limestone, grayish white, micrite, trace of siltstone inclusions. |
| 1350' - 1550' (411-472 m) | Basic to intermediate volcanic flow as above, dark gray, very fine crystalline groundmass with white phenocrysts. Trace chlorite-obsidian-orange calcareous claystone (fracture filling?). |
| 1550' - 1640' (472-500 m) | Sandstone, white, medium to coarse grained, calcareous, poorly sorted, subangular to subrounded. Trace of feldspar siltstone, magnetite and volcanic clasts. |
| 1640' - 1671 (500-509 m) | Depth correction +30' (9 m). |
| 1671' - 1692' (509-516 m) | Sandstone, tan, fine to medium grained, argillaceous, calcareous, poorly sorted, subangular. Trace of muscovite, magnetite, hematite. Claystone stringers throughout. |

Core 1671' - 1692' (509-516 m) recovered 21' (6.4 m).

1671-1672.5' (509-509.7 m): Sandstone, tan, poorly consolidated, fine to medium grained, 2% feldspar, calcareous, some volcanic clasts.

1672.5'-1673' (509.7 - 509.9 m): Mudstone, brown, medium firm, calcareous, some very fine grained sand and biotite intermixed.

1673'-1681' (509.9 - 512.3 m): Sandstone, tan, red brown, fine to medium grained, silty, meidum consolidated, angular to subrounded, moderately sorted.

1681'-1681.5' (512.3-512.5 m): Mudstone, brown and reddish-brown, very soft, tuffaceous, some black, hard volcanic clasts (0.1-5 mm), very fine crystalline.

1681.5'-1688' (512.5 - 514.5 m): Sandstone, light tan, brown, moderately consolidated, angular to subangular, poor to moderate sorting, fine to medium grained, feldspathic, tuffaceous, trace mica and magnetite.

1688'-1688.8' (514.5-514.7 m): Sandy tuff, light tan to tan, medium firm, very fine to medium grained, 5-10% feldspar, some mica, calcareous.

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| | 1688.8-1689' (514.7-514.8 m): Claystone, brown, firm, 10% mica, calcareous. |
| | 1689'-1693' (514.8-515.7 m): Tuff, green and tan, medium soft very fine grained, trace of feldspar-mica-sand, calcareous trace volcanic clasts, some thin bedded mudstone (end of core). |
| 1692' - 1700' (516-518 m) | Tuff, mottled white and light tan, much volcanic glass and glass altered to clay. Trace of feldspar-biotite-volcanic clasts-quartz sand, calcareous. Stringer of thin bedded brown claystone. |
| 1700' - 1740' (518-530 m) | Sandstone, white-gray-pink, fine to very coarse grained, poorly sorted, subangular to subrounded, trace of quartz fragments-volcanic clasts-biotite-magnetite-feldspar-hornblende. |
| 1740' - 1760' (530-536 m) | Limestone, gray to white, micrite, firm, marly. |
| 1760' - 1800' (536-549 m) | Sandstone, white-gray-tan, fine to coarse grained, poorly sorted, subangular to subrounded, trace of green limestone-white limestone - calcite-feldspar-magnetite and volcanic clasts. |
| 1800' - 1840' (549-560 m) | Limestone, gray to white, micrite, much clay - possible tuff association. |
| 1840' - 2040' (560-622 m) | Sandstone, white-gray-tan, fine to coarse grained, poorly sorted, subangular to subrounded, partly silty and tuffaceous. |
| 2040' - 2120' (622-646 m) | Sandstone, reddish brown, fine to coarse grained, subangular to subrounded, 20% red clay, trace volcanic clasts, feldspar, and biotite [2-6 mm quartzite pebbles in top 20 feet (6 m)]. |
| 2120' - 2140' (646-652 m) | Claystone, red, tuffaceous, highly calcareous. |
| 2140' - 2160' (652-658 m) | Sandstone, light brown to red, medium to very coarse grained, subround to rounded, calcareous; trace siltstone-volcanic clasts hornblende. |
| 2160' - 2180' (658-664 m) | Conglomerate, light gray, brown, 3-5 mm subround and rounded quartz and volcanic pebbles, calcareous; 30% white altered tuff, 20% gray and red clay. |

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| 2180' - 2250' (664-686 m) | Siltstone, red, calcareous, 10-15% fine quartz sand, abundant mica, trace white altered tuff. |
| 2250' - 2270' (686-692 m) | Sandstone, red, brown, gray, very coarse grained, subround to rounded, ~10% red siltstone and clay. |
| 2270' - 2280' (692-695 m) | Claystone and siltstone, brownish red and gray, tuffaceous. |
| 2280' - 2440' (695-744 m) | Sandstone, conglomeratic, brown-gray-pink, coarse sandstone to pebble size grains (abundant 2-5 mm quartz and quartzite rounded pebbles) calcareous, poorly sorted, subangular to rounded, 2-3% biotite (in schist (?) clasts) trace of clay and tuff. [No returns 2360' - 2420' (719-738 m) lost circulation.] Trace of dark volcanic rock from 2420 to 2440' (738-744 m). |
| 2440' - 2470' (744-753 m) | Claystone, red, calcareous, trace quartz sand (sample predominately Portland cement from cementing in lost circulation zone). |
| 2470' - 2990' (753-1216 m) | Sandstone, red, fine to very coarse grained, subangular to subrounded, partly conglomeratic, calcareous cement, 3-5% feldspar.<br><br>Core 2508' - 2528' (764-771 m) recovered 20' (6 m).<br><br>2508'-2518.5' (764-767.5 m): Sandstone, coarse to very coarse, quartzose, 90% red stained, angular to subrounded, friable, 3-5% silty matrix, calcareous, some pebbles and cobble lithic clasts-mixed source.<br><br>2518.5' - 2521' (767.5 -768.4 m): Sandstone, red stained as above, medium to coarse grained with 10% rounded pebbles, predominantly quartz with 3-5% feldspar.<br><br>2521' - 2524.5' (768.4 - 769.5 m): Sandstone, coarse to very coarse grained, red stained, silty matrix. |
| 2524.5' - 2526' (769.5 - 770 m) | Conglomeratic sandstone, fine to medium grained sand matrix of red stained quartz, feldspathic, angular to subrounded, firm to hard, variety of igneous lithic clast pebbles. |

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| 2526' - 2528' (770-770.5 m) | Similar to above, sand is medium to very coarse grained. |
| 2998' (914 m) | Driller's total depth. No geophysical logs below 2269' (691.6 m) due to lost circulation problems and tight hole. |
| | Many samples between 2480' and 2998' (756-914 m) of poor quality because of hole problems. |

LITHOLOGIC DESCRIPTIONS

HOLE NO. PQ-7

| | |
|---|---|
| 0 - 100' (0-30 m) | No samples. |
| 100' - 550' (30-168 m) | Rock fragments and coarse sand. |
| 550' - 1294' (168-394 m) | Sandstone, conglomeratic, unconsolidated, locally slightly calcareous. |
| 1294' - 1302' (394-397 m) | Granite wash (cobbles to very fine sand). |
| 1302' - 1336' (397-407 m) | Sandstone, tan, fine grained, unconsolidated, micaceous. |
| 1336' - 1341' (407-409 m) | Biotite schist. |
| | Core 1336' -1341' (407-409 m) recovered 5 feet (1.5 m). Biotite schist, well developed schistosity, biotite, feldspar, chlorite, quartz, hornblende. |

## LITHOLOGIC DESCRIPTIONS

### HOLE NO. PQ-8

| | |
|---|---|
| 0' - 500' (0-152 m) | Conglomerate, pink, white, gray, coarse sand to 10 mm angular to subrounded pebbles, unconsolidated, abundant quartzite and granitic clasts, trace of volcanic lithic clasts, partially highly calcareous, partially yellow to red stained. |
| 500' - 600' (152-183 m) | Sandstone, light tan, medium grained, moderately to well sorted, subround to rounded grains, trace of lithic clasts magnetite and biotite, very slightly calcareous, limonite stain common. |
| 600' - 790' (183-241 m) | Sandstone, conglomeratic, light brown, fine sand to 5 mm pebbles, poorly sorted, unconsolidated, subround to well rounded sand grains, angular pebbles. Trace of lithic clasts, feldspar, and hornblende. Calcareous cement 730' - 790' (223-241 m). |
| 790' - 940' (241-287 m) | Conglomerate, light brown to gray, 30-40% silica cemented sandstone clasts, medium grained to 4 mm angular quartz fragments. |
| 940' - 1140' (287-348 m) | Volcanic tuff (or flow), gray, red-gray groundmass with quartz, olivine, hematite phenocrysts, abundant hard, red clay fragments - slightly vesicular - possibly altered volcanics. |
| 1140' -1200' (348-366 m) | Tuff, red, white phenocrysts in red groundmass, trace of clear, calcareous quartz sand. |
| 1200' - 1250' (366-381 m) | Volcanic flow or tuff (?), gray and red, 40% red vesicular fragments, 60% gray volcanic rock with sucrose texture, hematite specks and phenocrysts in gray volcanic rock. |
| 1250' - 1890' (381-576 m) | Conglomerate, pink, gray, fine grained sand to 3 mm pebbles, angular to subrounded feldspathic, 10% clasts of red volcanic rock, biotite-magnetite common, abundant gneiss and volcanic clasts 1550'-1630' (472-497 m). Hematite matrix 1630'-1890' (497-576 m). Increased red clay in bottom 80' (24 m). |

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| 1890' - 2010' (576-582 m) | Sandstone, red, fine to medium grained, calcareous, angular to subrounded, 20% red and gray volcanics with hematite matrix. |
| 1910' - 2010' (582-613 m) | Metasediments, red fragments of quartzite, metamorphics with hematite matrix, several fragments exhibit micaceous habit, 10% feldspar, increasing green schist fragments with depth. |
| 2010' - 2451' (613-747 m) | Chlorite schist, green to white, vitreous, micaceous, chlorite, quartz, feldspar, distinct lineations, calcareous. |
| | Core 2433' - 2439' (742-743 m), recovered 3-1/2' (1 m). Green schist, strong cleavage planes, 60% dip, some feldspar visible (partially altered to kaolin). Muscovite, chlorite, serpentine and various mafics, crystalline quartz stringers. |
| | Core 2441' - 2451' (743-747 m), recovered 3 feet (0.9 m). Similar to above. |
| 2451' (747 m) | Logger's total depth. |
| 2456' (748 m) | Driller's total depth. |

## LITHOLOGIC DESCRIPTIONS

### HOLE NO. PQ-9

(Depths adjusted to geophysical logs)

| | |
|---|---|
| 0 - 200' (0-61 m) | No samples. |
| 200' - 900' (61-274 m) | Sandstone, quartzose, pale yellow to tan, fine to coarse grained, moderately to well sorted, subangular to subrounded, friable, feldspathic, trace biotite, magnetite, partially iron stained, slightly calcareous, trace limonite stain. |
| 1290' 1800' (393-549 m) | Sandstone light tan to yellow, very fine to medium grained (locally coarse grained), subrounded, poorly to moderately well sorted, feldspathic, trace biotite and magnetite, slightly calcareous. [Arkosic lenses 1480' -1540' (451-469 m) 1780' - 1800' (543-549 m)]. |
| 1800' - 2120' (549-646 m) | "Granite wash", poorly sorted, predominantly angular, white to pink feldspar crystals, biotite, quartz, and schist lithic clasts, medium grained to small pebble size, partially silty, unconsolidated.<br><br>Core 1984' - 1997' (605-609 m), recovered 13-1/2' (4 m), granite wash, pebble to cobble size rounded granite clasts in a moderately consolidated quartz rich, fine to coarse grained, subangular, poorly stained with limonite and hematite. Also some clasts of metamorphic and volcanic rocks. |
| 2120' - 2370' (646-722 m) | Volcanic flow, reddish brown, very fine crystalline, white phenocrysts, trace of epidote, calcareous. Oxidized red to 2180' (664 m), dark gray basaltic (?) below. |
| 2370' - 2980' (722-908 m) | Conglomerate, white to pink, medium grained sand to pebble size metasediment clasts, abundant iron stain on quartz sand grains (partially, 10-20% feldspar), trace of kaolin. |
| 2980' - 3150' (908-960 m) | Rhyolite flow, dark gray to white groundmass with hematite phenocrysts, sucrose texture, abundant obsidian, trace of feldspar laths in groundmass, some kaolinization. |

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| 3150' - 3170' (962-966 m) | Conglomerate, white to pink and gray, medium grained sand to pebble size grains, rounded to well rounded, ~ 40% feldspar, trace of altered biotite and schist. |
| 3170' - 3460' (966-1055 m) | Rhyolite flow, dark gray to white groundmass with hematite phenocrysts, sucrose texture, abundant obsidian, trace of feldspar laths in groundmass, some kaolinization. |
| 3460' - 3510' (1055-1070 m) | Altered volcanics - possibly tuff, partially or wholly altered to brown clay, trace of feldspar-obsidian-glass and hematite (?). |
| 3510' - 3600' (1070-1097 m) | Rhyolite flow, dark gray to white groundmass with hematite phenocrysts, sucrose texture, abundant obsidian, trace of feldspar laths in groundmass, some kaolinization. |
| 3600' - 3620' (1097-1103 m) | As above, oxidized red-possibly pyroclastics (?). |
| 3620' - 4650' (1103-1417 m) | Volcanics, alternating flows (gray) and pyroclastics (red), rhyolite as above, slightly calcareous. |
| 4650' - 4780' (1417-1457 m) | Sandstone, pink with black specks, arkosic, very coarse grained, poorly sorted, angular, 5-10% biotite and magnetite. |
| 4780' - 5192' (1457-1582 m) | "Granite wash", pink to gray, (high percentage feldspar content conglomerate, close to granite source). |
| 5192' - 5204' (1582-1586 m) | Granite (basement). |
| | Core 5200' - 5204' (1585-1586 m), recovered 3.5' (1 m) granite. |
| 5138.5' (1566 m) | Sample driller's depths (T.D.) |
| 5204' (1586 m) | Strapped drill pipe T.D. |
| 5191' (1582 m) | Log T.D. |

## LITHOLOGIC DESCRIPTIONS

### HOLE NO. PQ-10

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|---|---|
| 0 - 50' (0-15 m) | Coarse Quaternary alluvium. |
| 50' - 990' (15-302 m) | Conglomerate, coarse sandstone to pebble size clasts (igneous and volcanic) iron stained, abundant feldspar, angular to subrounded, trace magnetite, unconsolidated. |
| 990' - 4000' (302-1219 m) | "Granite wash", conglomerate, coarse, unconsolidated, angular to subangular clasts, quartz, feldspar (partially altered to kaolin), muscovite, chlorite, magnetite, some iron stain.<br><br>Core 3193' - 3203' (973-976 m), recovered 2.5 feet (0.76 m).<br><br>Core 3212' - 3224' (979-983 m), recovered 6.5 feet (2 m), cobble size clasts of coarse crystalline granite wash. Granite wash as above, granitic and mafic clasts. |
| 4000' - 5000' (1219 - 1524 m) | Granite wash as above, partially silt and sand matrix. |
| 5000' (1524 m) | Driller's T.D. |
| 4990' (1520 m) | Logger's T.D. |

## LITHOLOGIC DESCRIPTIONS

### HOLE NO. PQ-12

| | |
|---|---|
| 0 - 30' (0-9 m) | Alluvium. |
| 30' - 280' (9-85 m) | Conglomerate, gray to brown and pink, coarse sand to 10 mm, pebbles, quartz, feldspar and lithic clasts, subangular to subrounded, slightly calcareous, trace of biotite. |
| 280' - 980' (85-299 m) | Sandstone, light tan to pink, fine to very coarse grained, arkosic, partially conglomeratic, angular, trace biotite-magnetite-hornblende, slightly calcareous, grain size decreases with depth and sand becomes cleaner (less fine material such as silt and clay). Clay parting 940'-950' (287-290 m), trace of tuff 960'-980' (293-299 m), light pink groundmass with biotite and quartz phenocrysts. |
| 980' - 1020' (299-311 m) | Altered volcanics, red, altered to clay containing 10% epidote crystals. |
| 1020' - 1440' (311-439 m) | Volcanics, gray, possible flow (basalt?) vesicular with calcite fill, traces hematite and epidote in gray groundmass. |
| 1440' - 1500' (439-457 m) | Conglomerate, yellow-pink-gray, fine grained sand to 5 mm angular metasediment and volcanic clasts, much limonite stain, trace clay - 10-20% brown clay, 1460'-1500' (445-457 m) trace epidote. |
| 1500' - 1530' (457-466 m) | Volcanics (basalt?), gray, as above. |
| 1530' - 1750' (466-533 m) | Conglomerate as above. |
| 1750' - 1819' (533-554 m) | Granite gneiss, white-pink-gray, medium to finely crystalline. |
| | Core 1758-1764' (536-538 m), recovered 6' (1.8 m) granite gneiss. |

## LITHOLOGIC DESCRIPTIONS

### HOLE NO. PQ-24

| | |
|---|---|
| 0 - 50' (0-15 m) | No samples (Quaternary alluvium). |
| 50' -100' (15-31 m) | Conglomerate, gray-yellow-brown, sand size grains and up to 15 mm diameter pebbles of quartzite and gneiss, slightly calcareous. |
| 100' - 300' (31-91 m) | Sandstone, light brown and pink or gray, medium to very coarse grained, angular to subrounded, poorly sorted, feldspathic, trace of biotite and magnetite, slightly calcareous. Granules of dark gray-green fine grained metasediments - gneiss or schist from 200' to 300' (61-91 m) depth. |
| 300' - 520' (91-158 m) | Sandstone, conglomeratic, arkosic, light tannish gray, fine grained sand to small pebbles of quartzite and other crystalline metamorphics. Trace biotite, 50% metamorphic clasts 490' to 520' (149-158 m). |
| 520' - 680' (158-207 m) | Sandstone, light tannish pink, fine to very coarse grained, arkosic, slightly calcareous, trace of biotite-chlorite-magnetite-lithic clasts. |
| 680' - 730' (207-223 m) | "Granite wash", pink-brown-gray, fine grained sand to granule size angular fragments, abundant metamorphic crystalline rock fragments, abundant magnetite, slightly calcareous. |
| 730' - 880' (223-268 m) | Sandstone, light tan to pink, medium to very coarse grained, predominantly medium grained, poorly sorted, feldspathic, biotite, chlorite, quartzite and crystalline metamorphic rock clasts common. |
| 880' - 910' (268-277 m) | Volcanics, red, hematite and quartz phenocrysts in red groundmass, calcareous, (tuff?). |
| 910' - 990' (277-302 m) | Sandstone, red, very fine to coarse grained, poorly sorted, feldspathic to arkosic, 10% gray volcanic clasts with heavy hematite stain, trace of red clay, slightly calcareous, much alteration of feldspar - much oxidation of minerals. |

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| 990' - 1550' (302-472 m) | Granite wash, tan-pink-gray, 40% feldspars, 5% biotite, trace of clay locally, slightly to highly calcareous, tuffaceous 1410' - 1420' (430-433 m). |
| 1550' - 1563' (472-476 m) | Granite, pink to gray, feldspars largely altered to kaolin, abundant hematite in matrix. |
| 1563' (476 m) | Driller's and logger's T.D. |

## LITHOLOGIC DESCRIPTIONS

### HOLE NO. PQ-25

| | |
|---|---|
| 0 - 200' (0-61 m) | No samples. |
| 200' - 660' (61-201 m) | Sandstone, tan, very fine to coarse grained, arkosic, partially cemented with calcite but generally unconsolidated, trace of magnetite. |
| 660' - 2050' (201-625 m) | Siltstone, tan, calcareous, locally abundant tan mudstone, partially sandy, trace of free pyrite, locally limonite stained. |
| 2050' - 2100' (625-640 m) | Mudstone, light gray, calcareous, pyritic. |
| 2100' - 2250' (640-686 m) | Limestone, light gray, micritic, hard, scattered clusters of pyrite crystals. |
| 2250' - 2300' (686-701 m) | Siltstone, light gray, micaceous, much limestone as above. |
| 2300' - 2320' (701-707 m) | Limestone, variegated gray to brown, dense, micritic. |
| 2320' - 2370' (707-722 m) | Limestone, dirty gray, and siltstone, medium gray, calcareous. |
| 2370' - 2410' (722-735 m) | Siltstone and mudstone, medium gray, calcareous. |
| 2410' - 2530' (735-771 m) | Limestone, light gray to tan, micritic, dense. |
| 2530' - 2680' (771-817 m) | Mudstone and claystone, medium gray, siltstone, gray, trace sandstone, very fine grained. |
| 2680' - 2790' (817-850 m) | Limestone, dark gray and tan, dense, micritic, abundant pyrite. |
| 2790' - 2810' (850-857 m) | Siltstone, medium gray, biotitic, pyritic, partially finely banded, calcareous. |
| | Core 2798' - 2808' (852-856 m) recovered 10' (3 m). Shale, grayish white, hard, fissile, interbedded clay and limestone, slightly micaceous and pyritic. |

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| 2810' - 2840' (857-866 m) | Claystone, medium gray, calcareous, abundant gray limestone and tan siltstone. |
| 2840' - 2850' (866-869 m) | Limestone, as above, and tan, siltstone, calcareous. |
| 2850' - 3050' (869-930 m) | Siltstone, tan as above, and shale, gray. |
| 3050' - 3100' (930-945 m) | Siltstone, buff, calcareous, sandstone, tan, very fine grained, micaceous, friable. |
| 3100' - 3220' (945-982 m) | Siltstone or mudstone, tan, hard (poor samples). |
| 3220' - 3300' (982-1006 m) | Siltstone and limestone as above. |
| 3300' - 3390' (1006-1033 m) | Quartzite, 20% very fine to coarse quartz grains, light gray, limestone 40%, tan-gray, some shale and mudstone, gray, partially micaceous (poor samples). |
| 3390' - 3490' (1033-1064 m) | Shale and limestone as above. |
| 3490' - 3600' (1064-1097 m) | Limestone, gray, finely crystalline (some granitic material in sample). |
| 3600' - 4100' (1097-1250 m) | Siltstone and shale, gray, calcareous; some limestone as above. |
| 4100' - 4190' (1250-1277 m) | Granite wash. |
| 4190' - 4220' (1277-1286 m) | Granite wash and brown mudstone. |
| 4220' - 4300' (1286-1311 m) | Granite wash, unconsolidated coarse sandstone and granitic liths and minerals. |
| 4300' - 4360' (1311-1329 m) | Interbedded biotitic siltstone and shale as above, and granite wash. |
| 4360' - 4620' (1329-1404 m) | Shale and siltstone as above, biotite. |
| 4620' - 4700' (1408-1433 m) | Sandstone, tan, medium to coarse grained, arkosic, unconsolidated. |
| 4700' - 4890' (1433-1491 m) | Granite wash and siltstone, medium gray, biotitic, calcareous. |
| 4890' - 5008' (1491-1526 m) | Claystone, gray, calcareous and granite wash with coarse sandstone, arkosic, angular to subangular, unconsolidated. |
| 5000' (1524 m) | Logger's T.D. |
| 5008' (1526 m) | Driller's T.D. |

## LITHOLOGIC DESCRIPTIONS

HOLE NO. PQ-26

(Depths corrected to geophysical logs)

| | |
|---|---|
| 0' - 215' (0-66 m) | No samples. |
| 215' - 340' (66-104 m) | Siltstone and sandstone, very fine to fine grained, white to medium gray, friable to well cemented with calcite, micaceous. |
| 340' - 405' (104-123 m) | Sandstone as above. |
| 405' - 520' (123-159 m) | Siltstone and sandstone as above. |
| 520' - 600' (159-183 m) | Sandstone as above, partially feldspathic. |
| 600' - 1040' (183-317 m) | Sandstone, gray, medium to coarse grained, poorly sorted, angular to subrounded, some biotite, abundant granite fragments, 5-10% magnetite, unconsolidated. (Verging on granite wash.) |
| 1040' - 1400' (317-427 m) | Granite wash, highly oxidized. |
| 1400' - 1500' (427-457 m) | Sandstone, fine to very coarse grained, arkosic, angular, unconsolidated. |
| 1500' - 1630' (457-497 m) | Granite wash. |
| 1630' - 1640' (497-500 m) | Sandstone, dark reddish brown, very fine grained, calcareous, tight, biotitic, arkosic. |
| 1640' - 1700' (500-518 m) | Volcanic rock same color as above. |
| 1700' - 1900' (518-579 m) | Granite wash. |
| 1900' - 1980' (579-604 m) | Volcanic rock, dark brown (basalt?), iron rich, partially altered. |
| 1980' - 2130' (604-649 m) | Granite wash. |
| 2130' - 2200' (649-671 m) | Amphibolite, (conglomerate or breccia?). |
| 2200' - 3390' (671-1033 m) | Granite wash. |
| 3390' - 3434' (1033-1047 m) | Quartz diorite, coarsely crystalline quartz, feldspar, biotite, abundant green clay-like mineral with pyrite - sometimes associated with biotite, mostly along fractures (hydrothermal alteration?). |

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| | Core 3426-3434' (1044-1047 m) recovered 8 feet (2.4 m), quartz diorite described above. |
| 3428' (1045 m) | Logger's T.D. |
| 3434' (1047 m) | Driller's T.D. |

LITHOLOGIC DESCRIPTIONS

HOLE NO. PQ-27

| | |
|---|---|
| 0 - 100' (0-30 m) | No samples. |
| 100' - 1320' (30-402 m) | Conglomerate, coarse sand to pebble size particles, angular to subrounded, pink, yellow, colorless grains, quartzose, feldspathic, trace magnetite-biotite-chlorite. Slightly calcareous, unconsolidated. Yellow and orange stained grains common. |
| 1320' - 1540' (402-469 m) | Siltstone, tan to light brown, abundant mica, soft to firm, calcareous. Trace to abundant very fine quartz grains. |
| 1540' -1860' (469-567 m) | Sandstone, colorless to yellow, medium to coarse grained, angular to rounded, moderately sorted, feldspathic to arkosic, trace volcanic clasts, trace biotite, calcareous. |
| 1860' - 2320' (567-707 m) | Conglomerate, colorless to yellow pebbles, quartzose, angular to rounded, feldspathic, trace biotite and volcanic fragments, calcareous. |
| 2320' - 2430' (707-741 m) | Siltstone, red to brown, soft, calcareous. |
| 2430' - 2440' (741-744 m) | Interbedded siltstone and shale, tan, buff, reddish, micaceous, calcareous, and sandstone, fine to coarse grained, locally well rounded grains, quartz, feldspar, and some rock clasts. |
| 2440' - 5000' (744-1524 m) | Granite wash, conglomerate, brown, quartz diorite pebbles, cobbles and boulders in clay and siltstone matrix.<br><br>Core 3439' - 3454' (1048-1053 m) recovered 15' (4.6 m) very coarse sand to pebble size clasts in finer groundmass (medium to coarse sand, subangular to rounded), and clay and silt, red or brown, local red or yellow stain.<br><br>Core 4836' - 4846' (1474-1477 m) recovered 6' (1.8 m).<br><br>Boulder conglomerate with cobbles of quartz diorite in clay and siltstone matrix (granite wash?), hard. |
| 5000' (1524 m) | Drillers and loggers T.D. |

LITHOLOGIC DESCRIPTIONS

HOLE NO. PQ-28

| | |
|---|---|
| 0 - 65' (0-20 m) | No samples. |
| 65' - 100' (20-31 m) | Conglomerate, light brown to gray, angular to subangular, unconsolidated, poorly sorted, arkosic, 10% lithic clasts, 10% biotite and hornblende, calcareous. |
| 100' - 280' (31-85 m) | Sandstone, partially conglomeratic, feldspathic, light brown to gray, unconsolidated, poorly sorted, medium to coarse grained, angular to subrounded, quartzose, 5% lithic fragments, 5% hornblende and biotite, slightly calcareous. |
| 280' - 340' (85-104 m) | Conglomerate, light tan to pink, fine sand to pebble size particles. Trace clay-biotite and other accessory minerals. |
| 340' - 960' (104-293 m) | Sandstone, partially conglomeratic, feldspathic, light brown-gray to orange and yellow, fine to very coarse grained, poorly sorted, subangular to subrounded, unconsolidated, 10-15% biotite-hornblende, slightly calcareous. |
| 960' - 1750' (293-533 m) | Sandstone, conglomeratic, light brown, gray orange to yellow, fine to coarse grained, poorly consolidated, angular to subrounded, quartzose, feldspathic, trace biotite-hornblende, 5% lithic clasts. |
| 1570' - 1800' (533-549 m) | Granite wash, light tan to gray, 2-6 mm angular fragments, slightly calcareous. |
| 1800' - 2640' (549-805 m) | Sandstone, feldspathic, light brown to yellow, fine to coarse grained, angular to subangular, quartzose, 10% biotite-muscovite-chlorite-magnetite-hornblende. |
| 2640' - 2710' (805-826 m) | Granite wash as above. |
| 2710' - 2810' (826-857 m) | Feldspathic sandstone as above. |
| 2810' - 4050' (857-1234 m) | Granite wash as above, interbedded with arkosic sandstone, abundant limonite and hematite stain, locally some siltstone and mudstone matrix. |

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| | Core 2850' - 2858' (869-871 m) recovered 2 feet (0.6 m) |
| | Core 2880' - 2885' (877-879 m) recovered 1.5 feet (0.45 m). |
| | All granite wash, 10-30 mm pebbles in a finer groundmass of quartz and feldspar sand. Pebbles are medium to dark gray quartz diorite with equigranular texture. |
| 4050' - 4122' (1234-1256 m) | Granite, pink to dark gray, large unaltered biotite books. |
| 4122' (1256 m) | Driller's T.D. |
| 4089' (1246 m) | Logger's T.D. |

LITHOLOGIC DESCRIPTIONS

HOLE NO. PQ-29

(Depths adjusted to geophysical logs)

| | |
|---|---|
| 0 - 160' (0-49 m) | No samples. |
| 160' - 170' (49-52 m) | Conglomerate, unconsolidated, sand to pebble size volcanic and metamorphic lithic clasts, quartz and feldspar. |
| 170' - 400' (52-122 m) | Volcanics (andesite?), bright red to light gray, firm to hard, partially slightly vesicular with calcite fill. |
| 400' - 600' (122-183 m) | Crystal tuff (albite) and biotite crystals in white tuff matrix. |
| 600' - 1855' (183-565 m) | Volcanics (andesite?), light brown, aphanitic to porphyritic, locally slightly vesicular. |
| 1855' - 1935' (565-590 m) | Perlite, medium gray, vitreous. |
| 1935' - 1990' (590-607 m) | Tuff, off-white. |
| 1990' -2040' (607-622 m) | Mudstone, reddish-buff, partially silty, calcareous. |
| 2040' - 3414' (622-1041 m) | Granite wash, locally fine to coarse sandstone, feldspathic and reddish brown, silty mudstone, scattered fragments of chert, chalcedony and quartzite. Dark red to black very finely crystalline, hard igneous rock clasts scattered through interval 2300' - 2420' (701-741 m). |
| 3414' - 3528' (1041-1075 m) | Granite gneiss, light to dark gray, hard, limonite stained (15%). |
| | Core 3464' - 3474' (1056-1059 m), recovered 10 feet (3 m) of granite gneiss as above, highly fractured, limonite stained. |

## LITHOLOGIC DESCRIPTIONS

### HOLE NO. WQ-32

| | |
|---|---|
| 0' - 30' (0-9 m) | No samples. |
| 30' - 130' (9-40 m) | A variety of pebbles of different rocks in a matrix of clay and silt (40%-60%) qal. |
| 130' - 240' (40-73 m) | Conglomerate, reddish brown, tan, gray, fine to coarse sand, and pebble of volcanic rock in a matrix of clay with silty stringers. |
| 240' - 270' (73-82 m) | Tuff, pink, gray, reddish brown, soft to medium hard, very fine texture with phenocrysts of various minerals (sanidine, olivine(?), biotite, etc.). |
| 270' - 340' (82-104 m) | Conglomerate, white, cream, fine to coarse groundmass of angular sand with tuffaceous cobble size fragments, generally iron stained. |
| 340' - 650' (104-198 m) | Sandstone, white, tan, reddish brown, very fine to coarse grained, slightly feldspathic, oxidized, unconsolidated, locally conglomeratic. |
| 650' - 950' (198-290 m) | Sandstone, conglomeratic, white-tan-yellow, fine to coarse grained, unconsolidated, partially iron stained. |
| 950' -1020' (290-311 m) | Siltstone, white, gray, red, soft, abundant mica. |
| 1020' - 1220' (311-372 m) | Granite wash, red, tan subangular rock fragments and silicate rock minerals. |
| 1220' - 1255' (372-383 m) | Sandstone, variegated colors, medium grained, subangular, feldspathic. |
| 1255' - 1560' (383-476 m) | Granite wash, mostly iron stained, generally sandy to silty. |
| 1560' - 1624' (476-495 m) | Granite and schist, pink, reddish brown, medium to coarse crystalline, generally iron stained. |
| | Core 1618' -1624' (493-495 m), recovered 6 feet (1.8 m), granite, pink to gray, medium to coarse crystalline, in contact with underlying amphibolite (?) schist, gray-green, micaceous - very finely crystalline texture. |

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| 1624' (495 m) | Driller's T.D. |
| 1615' (492 m) | Logger's T'D. |