Prepared for the U. S. Department of Energy
Assistant Secretary for Resource Applications
Grand Junction Office, Colorado

DPST-79-146-19

# GRAND CANYON 1° x 2° NTMS AREA ARIZONA

# DATA REPORT

## NATIONAL URANIUM RESOURCE EVALUATION PROGRAM

## HYDROGEOCHEMICAL AND STREAM SEDIMENT RECONNAISSANCE

G. R. KOLLER



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PREPARED FOR THE U. S. DEPARTMENT OF ENERGY UNDER CONTRACT DE-AC09-76SR00001

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## ABSTRACT

This data report presents results of ground water and stream/surface sediment reconnaissance in the National Topographic Map Series (NTMS) Grand Canyon 1° x 2° quadrangle. Surface samples (sediment) were collected from 1013 sites. The target sampling density was one site per 16 square kilometers (six square miles). Ground water samples were collected at 84 sites. Neutron activation analysis (NAA) results are given for uranium and 16 other elements in sediments, and for uranium and 9 other elements in ground water. Mass spectrometry results are given for helium in ground water. Field measurements and observations are reported for each site. Analytical data and field measurements are presented in tables and maps. Statistical summaries of data and a brief description of results are given. A generalized geologic map and a summary of the geology of the area are included.

Data from ground water sites (on microfiche in pocket) include (1) water chemistry measurements (pH, conductivity, and alkalinity), (2) physical measurements where applicable (water temperature, well description, and scintillometer reading), and (3) elemental analyses (U, Al, Br, Cl, Dy, F, He, Mg, Mn, Na, and V).

Data from sediment sites (also on microfiche in pocket) include (1) stream water chemistry measurements (pH, conductivity, and alkalinity), and (2) elemental analyses for sediment samples (U, Th, Hf, Al, Ce, Dy, Eu, Fe, La, Lu, Mn, Sc, Sm, Na, Ti, V, and Yb). Sample site descriptors (stream characteristics, vegetation, etc.) are also tabulated. Areal distribution maps, histograms, and cumulative frequency plots for most elements, U/Th, U/Hf, and Th/La ratios, and scintillometer readings for sediment samples are included on the microfiche.

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**USER'S GUIDE**

## DATA REPORT: GRAND CANYON 1° x 2° NTMS QUADRANGLE: ARIZONA

### INTRODUCTION

The National Uranium Resource Evaluation (NURE) program was established to evaluate domestic uranium resources in the continental United States and to identify areas favorable for uranium exploration. The Grand Junction Office (GJO) of the Department of Energy (DOE) is responsible for administering and coordinating NURE program efforts. The Savannah River Laboratory (SRL) has responsibility for hydrogeochemical and stream/surface sediment reconnaissance (HSSR) of 3.9 million square kilometers (1,500,000 square miles) in 37 eastern and western states. Other DOE laboratories are responsible for similar reconnaissance in the rest of the continental United States, including Alaska. The significance of the distribution of uranium in natural waters and sediments will be assessed as an indicator of areas favorable for the location of uranium deposits.

The principal objectives of the NURE program are:

- Increase geologic knowledge of U.S. uranium resources in regions where uranium ore bodies are known to exist and are candidate supplies under present and near-term market conditions.

- Complete assessment of lower cost potential uranium resources in the conterminous U.S. and Alaska.

- Improve reliability and validate resource estimates and increase confidence levels.

- Expand scope of uranium assessment to include higher cost and relatively unknown domestic resources that may be feasible uranium supply alternatives.

- Apply advanced technologies for detection and assessment of uranium resources.

DOE-GJO is responsible for administering and coordinating efforts to meet these objectives, including distribution of reports. Inputs to the NURE program come from DOE prime contractors, DOE-sponsored research and development, the uranium industry, U.S. Geologic Survey, U.S. Bureau of Mines, other federal and state government agencies, and independent sources.

The NURE program consists of six parts:

1. Hydrogeochemical and Stream Sediment Reconnaissance Survey

2. Aerial Radiometric Survey

3. Intermediate Grade Resource Studies

4. World Class Geologic Studies

5. Subsurface Geologic Investigation

6. Technology Application

The data presented here are reconnaissance data intended for use in identifying broad areas for further study. While care has been taken to provide reliable sampling and analyses, verification of individual analyses is beyond the scope of this report. The data should be viewed statistically because "one-point anomalies" may be misleading. Regional trends, however, should be reliable. With careful consideration of regional geology, these data should provide reliable guides to areas warranting further study.

This report is one of a series presenting basic data obtained by SRL reconnaissance. In the interest of disseminating available data as soon as possible, only neutron activation analyses are reported here. Supplementary reports will be issued later. All data will be available on magnetic tape from:

GJOIS Project
UCC-ND Computer Applications Department
4500 North Building
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, Tenn. 37830

A brief description of sampling and analytical procedures and a detailed description of the maps, tables, and figures contained in this report are presented in the SRL document **USER'S GUIDE** included on microfiche. A summary of the SRL development program in support of the reconnaissance is available in SRL-NURE progress reports (SRL-138). SRL data reports (SRL-146) have been open-filed for other western quadrangles (Figure 1).

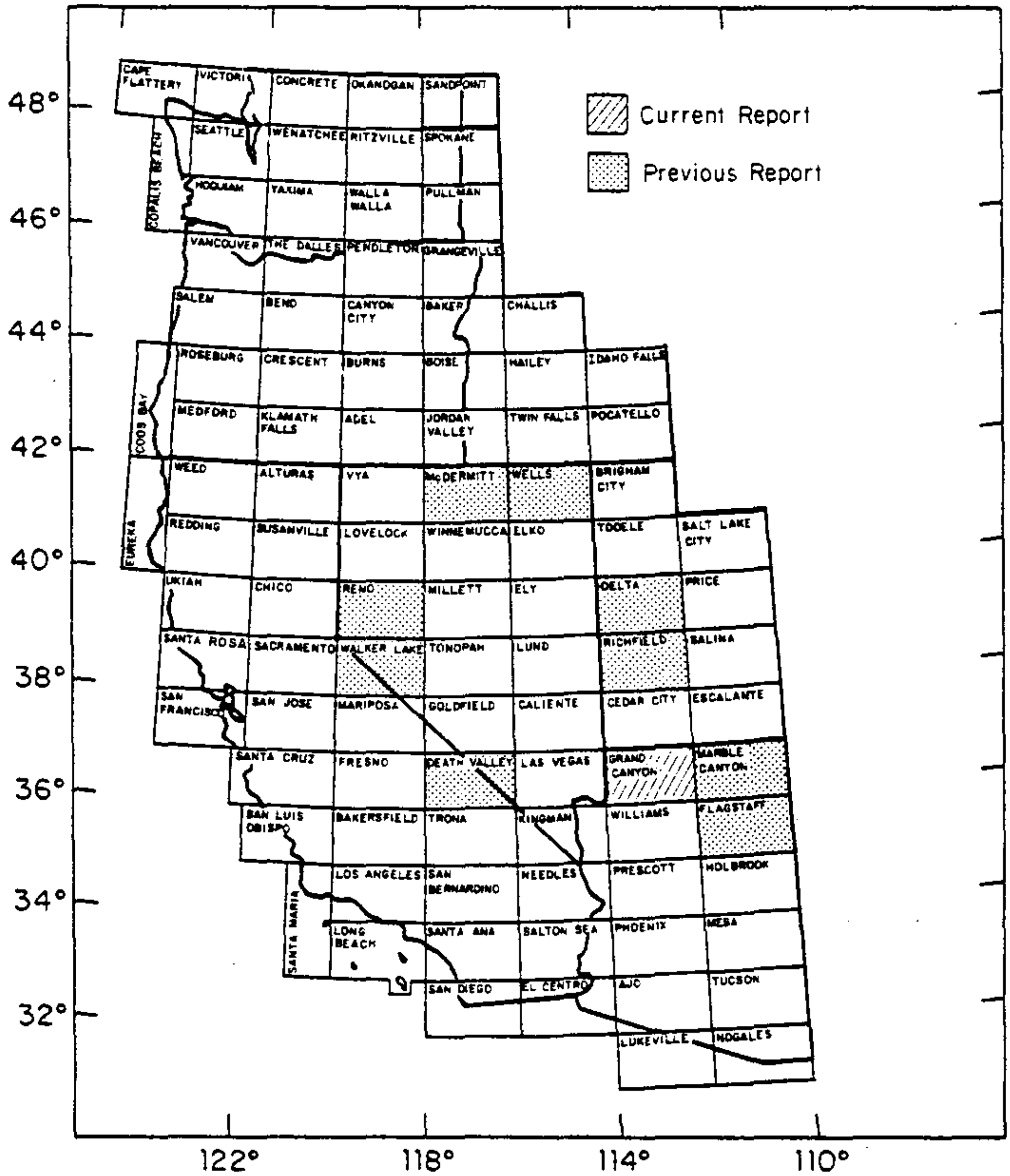



FIGURE 1. Location Map for the Grand Canyon 1° x 2° NTMS Quadrangle

## GEOLOGIC SUMMARY AND MINERAL OCCURRENCES

### Location and Geography

The Grand Canyon 1° x 2° NTMS quadrangle area is in northwestern Arizona and covers approximately 20,000 sq km (7725 sq mi) in northern Coconino and Mohave Counties. Most of the area is within the Grand Canyon Section of the Colorado Plateau Province, excepting a narrow wedge 0 to 29 km (0 to 18 mi) wide at the western edge, which is in the Basin and Range Province. The entire area is drained by the Colorado River. Elevations range from 2846 m (9333 ft) on the Kaibab Plateau north of eastern Grand Canyon to about 402 m (1220 ft) on the surface of Lake Mead in the southwestern corner of the quadrangle. Extreme variations in rainfall and temperature produce corresponding variations in vegetation from Sub-Alpine Conifer Forest on the Kaibab Plateau to Mohave Desert Scrub along the western edge of the quadrangle and in the bottom of the Grand Canyon. Topographic relief limits access to parts of the area, but rock exposures are excellent over most of the quadrangle. The canyon walls of east Grand Canyon afford magnificent outcrops of the Precambrian and Paleozoic rocks that underlie most of the quadrangle.

### General Geology

#### Introduction

A physiographic map showing the location of the Grand Canyon 1° x 2° NTMS quadrangle is shown in Figure 2. Over most of its length, the Grand Canyon is rimmed with Permian limestones of the Kaibab Formation that crop out over more than half the quadrangle. Older Paleozoic and Precambrian strata crop out in narrow bands within the canyons. Older Precambrian basement rocks occur in the inner gorge of Grand Canyon and along the Virgin Mountains at the western edge of the quadrangle. Mesozoic strata occur mainly along the northern edge of the quadrangle. Cenozoic volcanics occupy sizeable areas in the western half of the quadrangle on the Uinkaret and Shivwits plateaus, and east and south of the Virgin and Beaver Dam Mountains. Late Tertiary and Quaternary playa and basin fill deposits are extensive in the western part of the area.

#### Precambrian Basement Rocks

Precambrian crystalline rock outcrops are limited to the inner gorge of the Grand Canyon and the Virgin Mountains. Among the oldest of these rocks is the Zoroaster Plutonic complex consisting of granite plutons, gneissic bodies, and pegmatite dikes

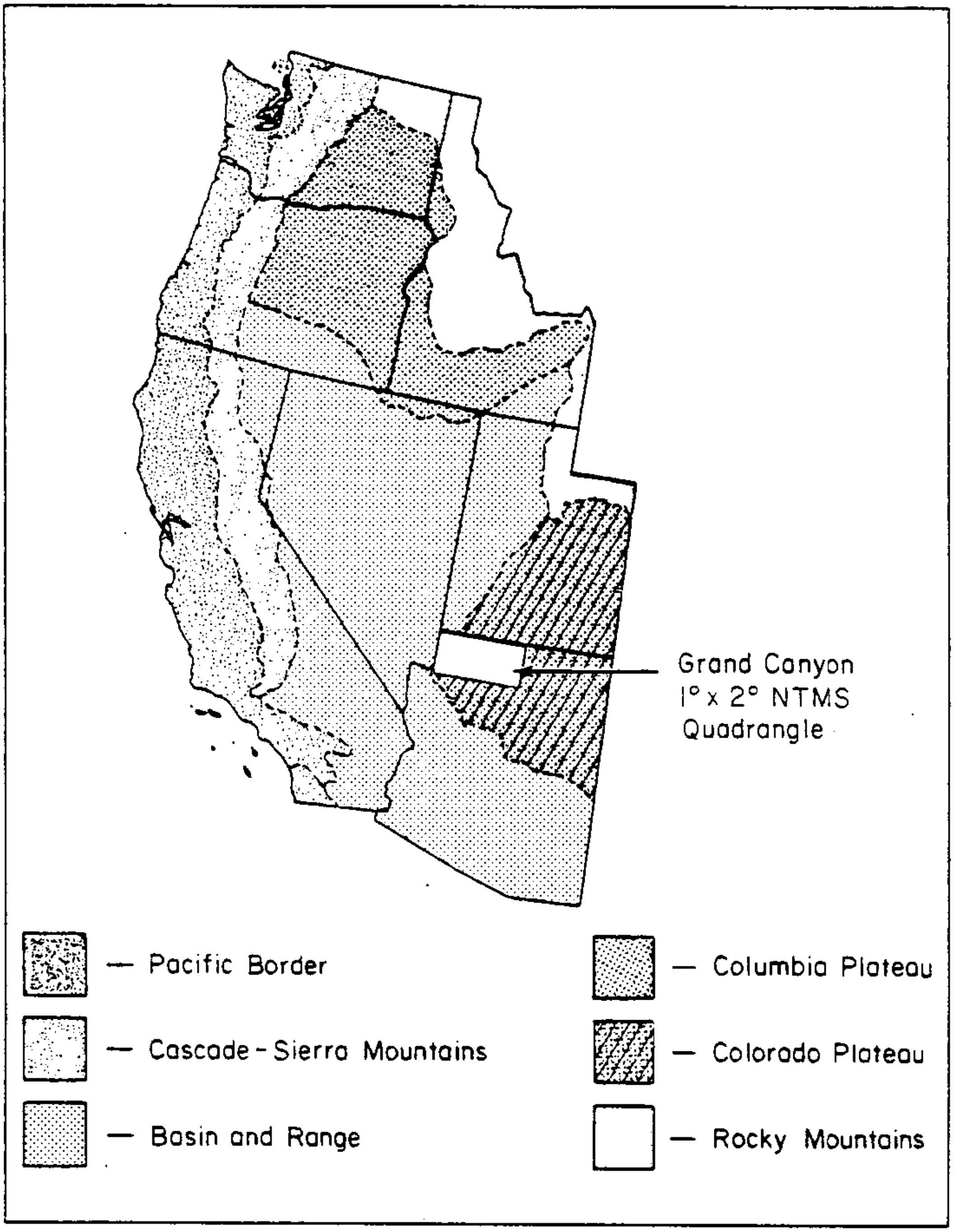



FIGURE 2. Location Map of the Grand Canyon Quadrangle on a Physiographic Province Map

about 1.7 billion years old (Babcock, et al., 1974; Brown, et al., 1979a,b) in eastern Grand Canyon. These rocks are, in part, intrusive into the Vishnu complex of mica schists and amphibolites.

Precambrian crystalline rocks in the Virgin Mountains are a similar complex of high-grade metamorphic rocks intruded by igneous rocks including pegmatite dikes. These are exposed mainly on the crest and western flank of the Virgin Mountains. They have yielded radiometric dates of about 1650 million years before the present (Myr BP) and are similar in age and composition to the Vishnu and Zoraster complexes in Grand Canyon (Wasserburg and Lanphere, 1965).

### Younger Precambrian Rocks

The Grand Canyon Supergroup, exposed mostly in eastern Grand Canyon, includes more than 3965 m (13,000 ft) of sedimentary rocks and volcanics (Table 1). The lower Unkar Group rests unconformably on the Vishnu and Zoroaster complexes and is exposed for a distance of 20 km (12 mi) upriver from Hance Rapids in the lower canyon walls. Sedimentary units of the Unkar Group originated mainly in shallow marine or intertidal and possibly some fluvial environments. The Unkar Group is 4595 m (5320 ft) thick. At the top of the group is a 300 m (1000 ft) unit of basaltic lava flows and associated dikes and sills, called the Cardenas Lavas. K-Ar and Rb-Sr dates from the Cardenas Lavas indicate an age of approximately 1100 My BP (McKee and Noble, 1976).

Unconformably over the Unkar Group is the Nankoweap Formation consisting of 100 m (330 ft) of red-brown sandstone and siltstone. The Nankoweap Formation is unconformably overlain by the Chuar Group, which includes some 2010 m (6600 ft) of strata. The Chuar Group has three formations, all of which are considered to be shallow marine or marginal marine to fluvial deposits (Ford and Breed, 1974).

### Paleozoic Rocks

Paleozoic sedimentary rock units outcrop over more than two-thirds of the quadrangle and are the host rocks for most of its mineral production thus far obtained. Strata of 13 formations totaling about 1220 m (4000 ft) of thickness are exposed in the walls of the Grand Canyon (Table 2). Similar units and some additional ones are exposed in the Virgin Mountains and Beaver Dam Mountains in the northwest part of the quadrangle. In general, the strata thicken from east to west across the area. Facies changes, especially in the upper Paleozoic rocks, represent a transition from nonmarine or marginal marine to shallow marine environments of deposition.

TABLE 1

**Rock Units of the Grand Canyon Supergroup (Precambrian) in the Grand Canyon Area**

| Group | Formation | Lithology | Thickness Meters | Thickness Feet |
|---|---|---|---|---|
| CHUAR | Sixty-Mile Formation | Breccia and pebbly sandstone | 36 | 120 |
| 2013 m (6610 ft) | Kwagunt Formation | Sandstone, shale, mudstone, and conglomerate | 675 | 2218 |
| | Galeros Formation | Dolomite, argillite, limestone, and shale | 980 | 4272 |
| | Nankoweap Formation | Red-brown siltstone and sandstone | 100 | 330 |
| UNKAR | Cardenas Lavas | Basaltic lava flows, dikes, and sills | 297 | 980 |
| 1596 m (5321 ft) | Dox Sandstone | Red-to-brown siltstone and sandstone | 937 | 3122 |
| | Shinumo Quartzite | White, red, or purple sandstone | 360 | 1200 |
| | Hakatai Shale | Red mudstone, argillite, and sandstone | 240 | 800 |
| | Bass Limestone | Red-brown dolomite, argillite, chert, and conglomerate | 100 | 327 |

TABLE 2

**Paleozoic Strata in Northwestern Arizona**

| Period | Virgin Mountains | Grand Canyon | Lithology | Thickness Meters | Feet |
|---|---|---|---|---|---|
| | Kaibab Limestone and Toroweap Formation (marine) | | Limestone and gypsum | 230 | 750 |
| PERMIAN | | Coconino Sandstone (eolian) | Sandstone | 15 to 90 | 50 to 300 |
| | Hermit Shale (fluvial) | Hermit Shale (fluvial) | Red sandstone and siltstone | 105 to 150 | 350 to 500 |
| | Supai Group (upper part) | Supai Group (upper part; marine and fluvial) | Sandstone and siltstone | 350 | 1000 |
| PENNSYLVANIAN | Callville Limestone (marine) | Supai Group (marine; lower part) | Sandstone, siltstone, and limestone | | |
| MISSISSIPPIAN | Redwall Limestone (marine) | Redwall Limestone (marine) | Limestone and dolomite | 120 to 145 | 500 to 800 |
| DEVONIAN | Undifferentiated dolomites (marine) | Temple Butte Limestone (marine) | Dolomite and minor sandstone | 0 to 670 | 0 to 2200 |
| SILURIAN-ORDOVICIAN | Undifferentiated dolomites (marine) | | | | |
| | Undiffferentiated dolomites (marine) | Muav Limestone (marine) | Limestone and dolomite | 120 to 300 | 400 to 1000 |
| CAMBRIAN | Bright Angel Shale (marine) | Bright Angel Shale (marginal marine) | Shale and dolomite | 120 to 185 | 400 to 600 |
| | Tapeats Sandstone (marginal marine) | Tapeats Sandstone (marginal marine) | Sandstone and conglomerate | 0 to 100 | 0 to 320 |

Porous and permeable sandstones in the Supai Group and Coconino Sandstone are the principal host rocks for the accumulation of uranium in the Orphan Mine (Table 3, Locality 24) in eastern Grand Canyon. The upper Paleozoic limestones and sandstones are also host rocks for minor sulfide ore bodies throughout the quadrangle.

### Mesozoic Strata

Mesozoic clastic sedimentary units, mainly nonmarine, are exposed extensively in the northern half of the quadrangle; particularly in the lowland area north of the Kaibab and Kanab Plateaus, on the Paria Plateau, and along the downthrown block of the Hurricane fault. The Mesozoic strata total more than 1525 m (5000 ft) in thickness (Table 4) and represent mainly fluvial, eolian, or marine shoreline deposits. Cretaceous rocks outcrop only in the Virgin Mountains.

Uranium mineralization is common in carbonized wood of the Triassic Chinle Formation in the quadrangle. Much of the uranium mined from the Cameron, Arizona, area, just east of the quadrangle, is associated with petrified logs or wood trash in the Shinarump Conglomerate and Petrified Forest members of the Chinle. Uranium also occurs at localities within the sandstones of the Moenkopi Formation (Table 3, Localities 21 and 22).

### Cenozoic Rocks

The oldest known Cenozoic rock unit is the Muddy Creek Formation which is considered Miocene? to Pliocene? in age. It outcrops extensively in the Grand Wash trough and the Virgin River Valley at the western edge of the quadrangle. This formation is composed of nonmarine clastics and some evaporites (Moore, 1972).

Numerous basalt flows and associated dikes and cinder cones occur on the high plateaus north of western Grand Canyon. Aggregate thickness of flows is about 60 to 90 m (200 to 300 ft). Locally, where the flows cascaded into the Grand Canyon at Toroweap Valley, they are at least 425 m (1400 ft) thick (Hamblin and Best, 1970). Radiometric dates indicate an age of between 2 and 6 My BP for the lava flows.

Unconsolidated basin fill and alluvial fan deposits of Pliocene?, Pleistocene, and Recent age occur in the Grand Wash Trough and Virgin River Valley at the western edge of the quadrangle.

TABLE 3

**Mineral Localities in the Grand Canyon 1° x 2° NTMS Quadrangle, Arizona**

| Locality | Name | Location | Rock Unit | Comments | Significant Elements | Reference |
|---|---|---|---|---|---|---|
| 1 | Unnamed Claim | Boundary sec 12, T38N-R16W, and sec 7, T38N-R15W | Precambrian igneous | Beryllium in pegmatite | Be | Olson and Hinrichs, 1960 |
| 2 | Unnamed Claim | NC sec 10, T38N-R15W | Shinarump Conglomerate | Carnotite | U, V | Pierce, et al., 1970, p. 233 |
| 3 | Big Bend Claim | 36-49 N lat, 115-52 W long | Precambrian metamorphics | Scheelite | W | USGS Min Res Data Bank |
| 4 | Hidden Canyon Claim | SE¼ sec 17, T36N-R13W | Upper Supai | Breccia Pipe | U, Cu | George Billingsley, oral comm., 1979 |
| 5 | Grand Gulch Mine | Se¼SE¼ sec 21, T34N-R14W | Supai and Callville | Old copper mine | Cu, Pb, Zn, V | Galbraith, 1941, p. 65 |
| 6 | Savannic Mine | NE¼SW¼ sec 9, T33N-R14W | Supai | Old copper mine; breccia pipe | U, Cu | George Billingsley, oral comm., 1979 |
| 7 | Cunningham Mine | C sec 16, T33N-R14W | Supai | Old copper mine; breccia pipe | U, Cu | USGS Min Res Data Bank; George Billingsley, oral comm., 1979 |
| 8 | School Section Claim | Sec 16, T33N-R11W | Kaibab | Fracture and basalt dike | U, Fe | AEC 1970b, p. 61 |
| 9 | Copper House Coalition 1, 2 Claims | Sec 1, 2, T32N-R11W | Hermit and Supai | Breccia Pipe | U, Cu, Fe | AEC, 1970b, p. 101, 102 |
| 10 | Copper Mountain Mine | SW¼ sec 14, T32N-R10W | Supai | Breccia Pipe | U, Cu Pb, Zn | Pierce, et al., 1970, p. 262 |
| 11 | Chapel Claim | NE¼ sec 25, T33N-R10W | Hermit | Vein or breccia pipe; possibly few tons uranium ore shipped | U, Cu | Pierce, et al., 1970, p. 278 |
| 12 | Windy Jim Claims | Sec 6, T4N-R9W | Kaibab and Moenkopi | Shinarump float blocks are radio-active | U, Cu | AEC, 1970b, p. 59 |

TABLE 3 (Continued)

| Locality | Name | Location | Rock Unit | Comments | Significant Elements | Reference |
|---|---|---|---|---|---|---|
| 13 | Ridenour Mine | NE¼ sec 6, T31N-R8W | Supai | Breccia Pipe Old copper mine, some uranium shipped | U, V, Cu | Pierce, et al., 1970, p. 262 |
| 14 | "Supai Claim" | 36-15-40 N lat 112-42-30 W long beside Mooney Falls | Redwall, Mooney Falls Member | Vein and solution cavity fillings | V, Cu, Pb, Zn | George Billingsley, oral comm., 1979 |
| 15 | Radon Claims | SE¼ sec 23, T40N-R6W | Shinarump and Petrified Forest Members, Chinle | Lew loads shipped | U, Cu | Pierce, et al., 1970, p. 233 |
| 16 | Rainbow Claim (Last Chance) | NW¼ sec 25, T40N-R6W | Petrified Forest Member, Chinle | Probably continuation of Radon Claims (15) | U, Cu | Pierce, et al., 1970, p. 233 |
| 17 | Iris Claim | NC sec 4, T38N-R6W | Shinarump Conglomerate | Carbonaceous trash | U, Pb | Pierce, et al., 1970, p. 234 |
| 18 | Unnamed Claim | 36-33-45 N lat 112-42-46 W long | Supai | | U | USGS Min Res Data Bank |
| 19 | Hack's Mine Hack Canyon | NE¼ sec 26, T31N-R5W | Hermit | Breccia Pipe, Minor uranium production | U, Cu | Pierce, et al., 1970, p. 262 |
| 20 | Unnamed Claim | Sec 20, T37N-R4W | Supai | | U | USGS Min Res Data Bank |
| 21 | Katy J Claims | SW¼ sec 14, R39N-R4W | Moenkopi | Tobernite, in carbonaceous trash | U, Cu | AEC, 1970b, p. 147 |
| 22 | Little Three #1 | Sec 6, T39N, R3W | Moenkopi | Carbonaceous trash | U, Cu | AEC, 1970b, p. 149 |
| 23 | Kaibab Indian Reservation Lease | SE¼ sec 6, R41N-R3W | Petrified Forest Member, Chinle | | U | Pierce, et al., 1970, p. 233 |
| 24 | Orphan Mine | SW¼ sec 14, T31N-R2E | Coconino and Hermit | Breccia Pipe; 500,000 tons Uranium ore shipped--major producer in Arizona | U, Cu, Pb, Zn, Mo | Pierce, et al., 1970, p. 262 |

TABLE 4

Mesozoic and Cenozoic Rocks of the Grand Canyon 1° x 2° NTMS Quardangle, Arizona

| Age | Rock Unit | Lithology | Thickness Meters | Thickness Feet |
|---|---|---|---|---|
| Pliocene-Recent | Unnamed basin fill deposits and alluvium | Silt, sand, and gravel | 0 to 300 | 0 to 1000 |
| Pliocene-Pleistocene | Lava flows, cinder cones, and dikes | Basalt, cinder, and ash | 0 to 60+ | 0 to 200+ |
| Miocene | Muddy Creek Formation | Sand, silt, limestone, and local evaporites | 0 to 150 | 0 to 500 |
| Cretaceous-? Eocene | Cottonwood Wash and Jacobs Ranch formations (Virgin and Beaver Dam Mountains only) | Limestone, siltstone, sandstone, tuff, and conglomerate | 410+ | 1700+ |
| Jurassic | Navajo Sandstone | Cross-bedded sandstone | 150 to 610 | 500 to 2000 |
| | Kayenta Formation | Reddish siltstone and sandstone | 100 | 350 |
| | Moenave Formation | Reddish siltstone and sandstone | 100 | 350 |
| Triassic | Chinle Formation<br>Owl Rock Member, Petrified Forest Member, and Shinarump Conglomerate | Sandstone, siltstone, shale, abundant petrified wood, and carbonaceous trash | 90 to 120 | 300 to 400 |
| | Moenkopi Formation | Reddish sandstone and siltstone; limestone members in west | 150 to 610 | 500 to 2000 |

### Structure

Major structures in the quadrangle are north or north-northeast to north-northwest trending high-angle normal faults and monoclines of great extent. Some, such as the Grand Wash, Hurricane, and Toroweap faults, extend as much as 240 km (150 mi). Gentle anticlines and synclines occur in the Grand Canyon section, and a prominent anticline marks the major structure of the Virgin Mountains in the western extremity of the area. A zone of high-angle reverse-faulting extends along the eastern flank of the Virgin Mountains. Low-angle thrust-faulting is conspicuous along the west flank of the Beaver Dam Mountains in the northwest corner of the area (Moore, 1972, p. 25).

## Geologic History

### Precambrian Events

The Mazatzal Revolution (Wilson, 1939) in central Arizona involved major folding, foliation and faulting, and culminated in intrusion of large granitic plutons. This Precambrian orogeny affected the basement rocks now exposed in the Inner Gorge of the Grand Canyon and the Virgin Mountains. Radiometric U-Pb dates from zircons and monazites of the Grand Canyon basement rocks indicate granite intrusions about 1725 Myr BP, and dynamic metamorphism of both the Vishnu and Zoroaster complexes at about 1695 Myr BP (Pasteels and Silver, 1965).

Following deposition of the Grand Canyon Supergroup strata, a second Precambrian orogeny (the Grand Canyon Disturbance) produced northeast-trending folds and faults and northwest-trending fault-block mountains similar to those of the modern Basin and Range. This orogeny occurred sometime after the Cardenas Lavas and associated dikes and sills were formed (1100 Myr BP).

### Paleozoic History

During the Paleozoic Era, the Grand Canyon region occupied the position of a stable continental shelf east of the Cordilleran geosyncline and experienced only minor tectonic disturbance. Episodes of shallow marine deposition separated by long periods of gentle uplift and erosion or nondeposition occurred during early Paleozoic time. During the late Paleozoic, alternating marine and nonmarine eolian or fluvial sediments were deposited. The increase of clastics in the Supai during the Late Pennsylvanian and Early Permian may reflect the influences of distant orogenic activity far to the northeast in Colorado and Utah.

### Mesozoic-Cenozoic History

Following a Permian-Triassic episode of gentle erosion, nonmarine and occasionally shallow marine clastic sediments accumulated in the quadrangle through much of Triassic, Jurassic, and probably Cretaceous time. The "Laramide Revolution" from Late Cretaceous to Early Tertiary time involved intense deformation in the Cordilleran and Rocky Mountain regions, but had only a moderate effect on the Colorado Plateau. Thrust-faulting and related folding occurred in the Beaver Dam Mountains early in this orogenic period (Moore, 1972, p. 59). Subsequently, compressional stresses applied to the southwestern Colorado Plateau resulted in formation of the Virgin anticline, Kaibab Upwarp, and numerous north-trending monoclines. High-angle reverse movement, in part associated with monoclinal folding, occurred along many faults of the older Precambrian network. Beginning in Miocene time, movement along north-trending high-angle normal faults occurred during and following volcanic episodes in the western part of the quadrangle. Evidence from the Hurricane fault indicates intermittent movement occurred from Miocene through Recent time. This movement involved at least 1830 m (6000 ft) of displacement (Hamblin and Best, 1970, p. 12).

The late Tertiary Muddy Creek Formation and unnamed basin fill deposits accumulated in basins and troughs produced in part by the faulting.

## Mineral Occurrences

### Uranium

Uranium-bearing minerals occur in most (20) of the mineral localities shown on Plate 2. They are of two major types:

1) **Peneconcordant deposits in sandstones or mudstones of fluvial or nearshore marine deposits (Triassic Moenkopi or Chinle Formations).** The uranium occupies pore space in the sandstones or has replaced sand grains or carbonized plant fossils. The uranium deposits are thought to originate through transport by ground water from volcanic glass or granitic terranes and precipitation in the presence of carbonaceous matter (Finch, et al., 1973).

2) **Breccia pipe or vein deposits in collapsed breccia pipes within Late Palezoic, mainly clastic, rocks.** The uranium in these deposits is thought to be derived from hydrothermal solutions coming from a magma, and then moving through the porosity afforded by the brecciation in the pipes (Finch, et al., 1973).

Most recorded uranium production has been from the breccia pipe localities. The now closed Orphan Mine (Location 24 of Table 3) in eastern Grand Canyon has shipped 500,000 tons. The Hack Canyon Mine (Location 19 in Table 3) is currently producing when the road permits transport. Numerous other breccia pipe (Localities 6, 9, 10, 11, 13 in Table 3) occur in Paleozoic strata. These and perhaps others yet to be examined hold the greatest promise for further uranium production.

Prospects for further uranium production from peneconcordant deposits in Triassic sandstones (Moenkopi and Chinle Formations) appear only moderately favorable in the quadrangle (Green and Piersen, 1978, p. 30). Production from peneconcordant deposits in the Shinarump conglomerate in the Lee's Ferry and Cameron areas (east of the Grand Canyon quadrangle) are recorded, but most such localities known in the quadrangle are not sufficiently large or concentrated to warrant mining.

The time and exact nature of the concentration of uranium in these localities is still unresolved. Radiometric dates are not always reliable and commonly show discordance of dates between different sets of isotopes (Miller and Kulp, 1963). In most cases, the dates available indicate mineral concentration much later than the age of the host rocks. For example, the Orphan Mine deposit occurs in Permian age rocks, but has yielded a Late Cretaceous Pb-U radiometric date of 87 My BP (Kerr, 1958, p. 1081). Kofford (1969) considers the actual uranium concentration of the Orphan Mine to have been in the Quaternary and aided by bacterial processes.

Walker (1975) has suggested that ore-grade concentrations of uranium in sedimentary rocks may result from diagenetic alterations of first-cycle, nonmarine, red beds with the uranium coming from detrital silicate minerals.

**Vanadium**

Vanadate deposits associated with copper, lead, and zinc occur at Localities 5 and 14 (Table 3), but no vanadium production is reported in the literature. Vanadium-uranium deposits of carnotite occur at Locality 2 and at the Ridenour Mine (Locality 13), but no vanadium production and only a small quantity of uranium production at Ridenour is reported (Pierce, et al., 1970, p. 262). Minor vanadate deposits are associated with the Carbonate breccia pipe in Havasu Canyon, near Locality 14. Possibly other breccia pipes in this region may yield more significant amounts of vanadium.

### Tungsten

Scheelite occurs in quartz veins and as irregular replacement bodies in Precambrian metamorphic rocks (Locality 3 on Table 3), but no production is reported.

### Beryllium

Beryllium occurs in the form of beryl and chrysoberyl in pegmatite dikes cutting a Precambrian schist-gneiss complex in the Virgin Mountains just west of the quadrangle boundary. A similar though less well-defined occurrence (Locality 1 of Table 3) is shown by Olson and Hinrichs (1960) just inside the quadrangle boundary. Only traces of beryllium are found at these localities, and they appear too small to be economically significant.

### Molybdenum

Molybdenum is reported only at the Orphan Mine, where it occurs as molybdenite and wulfenite associated with uranium in a breccia pipe deposit. The molybdenum content of the deposit is minor and of little economic significance (Granger and Raup, 1962, p. 11).

### Rare-Earth Minerals

A rare occurrence of monazite and xenotime is reported in a granite augen gneiss at the western boundary of the quadrangle (near Locality 1 on Table 3) by Young and Sims (1961, p. 274). Further exploration in the Precambrian outcrops in the Virgin Mountains might yield additional sources of these minerals.

## Geologic Literature

### Previous Studies

The early studies of the Grand Canyon region by Dutton (1882), Walcott (1894, 1895), and Noble (1914) provided preliminary maps and set the stage for ongoing geologic studies. Geologic maps of the Grand Canyon region by Maxson (1961, 1967, 1969) and Huntoon, et al. (1976) provide details of the southeastern and central parts. Peter W. Huntoon and George H. Billingsley recently completed forty-one 7-1/2-minute quadrangle and two 15-minute quadrangle geologic maps of the central and western Grand Canyon region. These maps are open-filed at the Grand Canyon Natural History Society, Grand Canyon National Park. The geology of the northwest corner of the Grand Canyon quadrangle is covered by Moore (1972). A number of 7-1/2-minute United States Geologic Survey (USGS) photogeologic map sheets are available (Marshall, 1956a-h, 1957; McQueen, 1957; Minard, 1956, 1957; Morris, 1956, 1957; Pillmore, 1956; and Pomeroy, 1957, 1959) for the northern edge of the area. The state geologic map (Wilson and Moore, 1969) also provides reasonably accurate data on the Grand Canyon quadrangle.

The mineral localities shown on Plate 2 are mainly from the Arizona Bureau of Mines report of Pierce, et al. (1970) and AEC (1970a,b) reports.

### Current Research

A geologic map of the Grand Canyon 1° x 2° NTMS quadrangle at 1:250,000 was begun by J. H. Maxson and continued by his USGS colleagues after his death, but is still not completed. Presently (1979) no one at the USGS is working on the map owing to recent changes in personnel. A summary study of the Precambrian Unkar Group in eastern Grand Canyon is currently under way by faculty and students at Northern Arizona University, Flagstaff, Arizona. This study should be ready for publication in 1980 and will provide local geologic map details. Sporadic uranium mineral exploration is being done in the northern part of the quadrangle.

## HYDROLOGY

### Climate

The Grand Canyon 1° x 2° NTMS quadrangle area is relatively dry both summer and winter. The average July temperature is about 27°C, and the average January temperature is 5°C. The higher areas stay below 0°C during winter months. The small amount of rainfall is fairly evenly distributed over the area, ranging from about 180 mm to 300 mm (NOAA, 1977). The heavier rainfalls occur between July and September. Precipitation data for the months in which field sampling took place are presented in Table 5.

TABLE 5

**Precipitation Totals for 1978 at Selected Weather Stations in the Grand Canyon 1° x 2° NTMS Quadrangle**

| Weather Station | Precipitation at Selected Weather Stations (in millimeters) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
| Mount Trumbull (1710 m) | 21.1 | 20.1 | 26.9 | 18.3 | 16.3 | 10.4 | 12.7 | 52.3 | 15.7 | 20.3 | 20.1 | 24.9 |
| Tuweep (1460 m) | 27.9 | 22.9 | 31.8 | 18.5 | 10.2 | 10.2 | 32.5 | 50.0 | 20.1 | 20.3 | 19.6 | 33.3 |
| Saint George* (2760 m) | 22.4 | 21.1 | 22.9 | 13.2 | 9.65 | 4.83 | 15.5 | 16.3 | 12.2 | 14.7 | 17.5 | 22.1 |

* Cedar City 1° x 2° NTMS quadrangle.

**Geography**

Most of the study area belongs in the Grand Canyon section of the Colorado Plateau, but the Basin and Range Province occupies the western edge (Figure 2). The Grand Canyon section is the southwestern part of the Colorado Plateau in which uplift was so great and denudation so deep as to expose Carboniferous rocks, the oldest rocks of the province, at altitudes of 2200 m to 2700 m (Fenneman, 1931, p. 278).

The northern half of the study area is characterized by four plateaus separated by north-trending faults and west-facing escarpments. The Kaibab Plateau on the east is the highest and most spectacular plateau, reaching altitudes of 2700 m. The Kaibab Plateau is capped by the Permian Kaibab Limestone, which shows some evidence of karstification in higher, flatter regions where "parks" and broad solution-valleys occur (Strahler, 1944). The nearly flat-lying rocks of the province have extensive outcrops that change abruptly at the fault scarps; such a fault scarp is Hurricane Cliffs, which separates the Uinkaret Plateau in the northcentral part of the study area from the Shivwits Plateau farther west. Both the Uinkaret and Shivwits Plateaus contain many volcanic cones with seemingly fresh lava flows. Mount Trumbull, rising nearly 600 m above the plateau, consists of several lava masses.

Bordering the Shivwitz Plateau on the west is the Grand Wash Fault and the Wash Cliffs that represent the escarpment facing westward on the lower valley of the Great Basin.

The great topographic relief of the study area is in the southern part, where the Colorado River is deeply entrenched in canyon walls. The canyons radiate outward in tributaries as deep reentrants in the plateau surface.

Agricultural activities are limited because of the dry weather and rugged terrains. Irrigation is practiced in a few areas to raise grain and forage crops in support of the cattle and sheep farming. A portion of the area will support year-round grazing without irrigation.

The area is sparsely populated with only a few thousand people (U.S. Bur. Census, 1970). Tourists increase the population during the summer months. Fredonia, Arizona, is the largest town in the quadrangle.

**Drainage and Hydrology**

Most of the drainage of the study area is to the Colorado River, chiefly in elongated canyon-wall tributaries. The longest tributary is Kanab Creek, which flows southward to reach the Colorado River after draining adjacent slopes of the Kaibab and Kanab Plateaus. Almost all of the local drainage is in dry washes or intermittent streams.

Surface water supplies on the plateau areas are small and not reliable in time of drought (McGuinness, 1963, p. 145). The Colorado River near Grand Canyon has had an average annual discharge over 13 years of 360.2 $m^3$/sec (12,720 $ft^3$/sec). There are many diversions above this point for industrial, municipal, and irrigation uses. The largest tributary in the area, Kanab Creek, originates in Utah and joins the Colorado River at Kanab Point. The annual discharge for Kanab Creek at Fredonia over 14 years has averaged 0.145 $m^3$/sec (5.12 $ft^3$/sec).

Ground-water supplies are sparse. Pumping lifts are as much as 300 m on the plateaus, and supplies for domestic and stock use are at a premium. Many of the sedimentary rocks have low permeability, and to the extent to which infiltration may occur, much of the water is discharged as small springs in upland coves. Spring discharge from the Kaibab Limestone into tributary canyons of the Colorado River is greater than from other formations. Most springs in the study area lead down valleys to dry washes or intermittent streams. The alluvium in the broad basin west of Wash Cliffs contains ground water in storage. Saturated alluvium in the plateau area and along the Colorado River is sparse.

Most of the ground water contains less than 1000 mg/L of total dissolved solids, although locally the water is more mineralized.

The quality of the Colorado River is affected by upstream municipal, industrial, and irrigation uses. During lower flows, the dissolved solids often goes above 1000 mg/L. Because of the large volume of flow in the Colorado River, inflow from tributaries has little effect on quality.

## FACTORS AFFECTING THE DATA

Sediment and ground-water samples were collected during the spring and winter of 1979. The Grand Canyon National Park and the Grand Canyon National Monument areas were not sampled. The lack of surface-water samples is due to the arid nature of most of the quadrangle. The scarcity of ground-water sites is due primarily to the low population of the area. Windblown contamination likely is a factor affecting the analyses of sediment samples. It is the opinion of the author that a tactical error was made in not collecting and analyzing both a fine and coarse sediment fraction from each site as was done for subsequent quadrangles.

## QUALITY ASSURANCE

### Sample Collection

Sampling teams marked each sampling site on an SRL-approved map and completed a Field Data Form (Figure 3) for every sample. 108 sediment and 12 ground-water sampling sites were field-checked by an SRL subcontractor during February and March 1980. No evidence has been discovered of deliberate malfeasance by the sampling teams. Ninety-seven percent of the sites checked were found to be located within 800 m (0.5 mi) of the locations plotted on sample maps. Thus, the goals of a regionnal reconnaissance have not been compromised by map errors. Details of the quality assurance program are given elsewhere (SRL-138).

### Analytical Standards

Sediment Standards SRL 2.2, 3.1, and 4.1 were analyzed along with NURE sediment samples. Analyses of the standards indicate the level of precision and provide routine checks of the analytical equipment and software. Tables 6a, 6b, and 6c contain the results from the standards run during the same time period as the Grand Canyon sediment samples. These results give a good estimate of the precision of the data and can be used in estimating bias between this and other SRL reports.

Periodically, DOE intersite comparison standards are analyzed. An independent quality assurance program based on these standards is conducted for DOE by Ames (Iowa) Laboratory (D'Silva, et al.).

## DESCRIPTION OF DATA TABLES

This section of the report summarizes the types of data tabulated on microfiche. Detailed descriptions of the tables and definitions of abbreviations can be found on the microfiche labeled **USER'S GUIDE**. Ground-water analyses and site descriptions are tabulated in Tables A-1 and A-2, both of which can be found on the microfiche titled **GRAND CANYON TABLES**. Sediment analyses and site descriptions are tabulated in Tables B-1, B-2, and B-3, which are also on the microfiche titled **GRAND CANYON TABLES**.

Table A-1 begins with the sample's SRL identification number, which is composed of four letters and a three-digit number. The first two letters identify the quadrangle. GC is the two-letter designator for the Grand Canyon 1° x 2° NTMS quadrangle. The

DSR-24-A-202

# SRL FIELD DATA FORM

| SITE CODE | | | | | | | | DATE | | | | | | | | TEAM NO. | | | SURFACE SITE DATA | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sheet | | Map Code | | Site Number | | | | Mo. | | Day | | Yr. | | Hr. | | | | | Sample Type | Rock Type | Sed Size | Width | Depth | Flow | Level | Veg Type | Veg Density | Relief | No. of Sample Composites | | Activities Contaminants (List up to four) | | | | Formation | | | | Odor |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | (20) | (21) | (22) | (23) | (24) | (25) | (26) | (27) | (28) | (29) | 30 | 31 | (32) | (33) | (34) | (35) | 36 | 37 | 38 | 39 | (40) |

HAVE A GOOD DAY

| pH | | | SPECIFIC CONDUCTANCE µmhos/cm | | | | | WATER TEMP. °C | | ALKALINITY: Drops $H_2SO_4$ | | ml Water | | ml OF WATER ION-EXCHANGED | | | WELL DATA: WELL DEPTH | | | | Condepth | Well Class. | Where Sample Taken | STATE | | SCINTILLOMETER READING | | | | | | | | | | Inform. Request | DO NOT USE | | CARD CODE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | (62) | (63) | (64) | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | (77) | 78 | 79 | (80) |

| Sheet | | Map Code | | Site Number | | | | ADDRESS (use / to separate lines) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 3 |
| 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |

IN THE CASE OF EACH CIRCLED ENTRY SPACE, ENTER MOST APPROPRIATE DESIGNATORS LISTED BELOW

**(20)**
A Other sediment (8)
B Other resin (9)
C Well water (9)
D Spring water (9)
E Stream sediment + water (8)
F Stream sediment only (8)
G Soil (8)
H Talus (8)

**(21)**
1 Other (explain)
2 Volcanic - Felsic
3 Volcanic - Mafic
4 Plutonic - Felsic
5 Metamorphic
6 Clastics - coarse
7 Sandstone
8 Shale
9 Carbonate

**(22)**
1 Other (explain)
2 Pebbles & coarser
3 Sand
4 Silt & clay
5 Organic muck

**(23) and (24)**
1 Dry
2 < ½'
3 ½ - 1'
4 1 - 2'
5 2 - 4'
6 4 - 8'
7 8 - 16'

**(25)**
1 Dry
2 Slow
3 Moderate
4 Fast
5 Torrent

**(26)**
1 Dry
2 Low
3 Normal
4 High

**(27)**
1 Other
2 Forest
3 Desert scrub
4 Grassland
5 Saltbush
6 Marsh

**(28)**
1 Sparse
2 Moderate
3 Dense

**(29)**
1 0 - 10'
2 10 - 50'
3 50 - 200'
4 >200'

**(32) thru (35)**
1 Other
2 None
3 Chemical
4 Smelting
5 Mining
6 Garbage
7 Farming
8 Grazing
9 Oil Field

**(40)**
1 Other
2 None
3 $H_2S$
4 Oil

**(62)**
1 Certain
2 Probable
3 Possible
4 Educated guess
5 Unknown

**(63)**
1 Other
2 Domestic
3 Municipal
4 Livestock
5 Irrigation
6 Industrial - commercial

**(64)**
1 Others
2 Immediately after storage tank
3 Before storage tank
4 Direct from pump
5 Direct from well or spring
6 From municipal system

**(77)**
Enter "X" when analysis information is requested

**(80)**
Enter number in parentheses ( ) for column 20 options

*Sampler(s) Signature(s)*

*Field Supervisor (initials)*

Standard Letters and Numbers A B C D E F G H I J K L M N Ø P Q R S T U V W X Y Z 0 1 2 3 4 5 6 7 8 9

FIGURE 3. SRL Field Data Form for Western Quadrangles

TABLE 6

Accuracy and Precision of Analyses of SRL Standards

a. Sediment Standard SRL 2.2

| Element | Number | Mean, ppm | Coefficient of Variation, % | Accepted Value, ppm |
|---|---|---|---|---|
| U | 30 | 19.6 | 16.2 | 22.2 |
| Th | 30 | 108 | 17.7 | 125 |
| Hf | 26 | 109 | 23.9 | 173 |
| Al | 30 | 6350 | 20.1 | 6500 |
| Ce | 24 | 531 | 21.5 | 614 |
| Fe | 29 | 7750 | 34.6 | 6700 |
| Mn | 26 | 314 | 85.6 | 300 |
| Sc | 30 | 2.58 | 37.4 | 3.9 |
| Na | 26 | 127 | 24.6 | 145 |
| Ti | 29 | 10,600 | 23.8 | 13,200 |
| V | 30 | 31.5 | 19.9 | 34.7 |
| Dy | 29 | 17 | 38.4 | <22 |
| Eu | 24 | 2.9 | 109 | 2.5 |
| La | 30 | 325 | 25.3 | 301 |
| Lu | 25 | 2.4 | 22.0 | 2.9 |
| Sm | 27 | 47.1 | 37.8 | 51.3 |
| Yb | 24 | 15.9 | 22.3 | 18.2 |

TABLE 6 (Continued)

b. Sediment Standard SRL 3.1

| Element | Number | Mean, ppm | Coefficient of Variation, % | Accepted Value, ppm |
|---|---|---|---|---|
| U | 28 | 39.3 | 22.3 | 41.3 |
| Th | 28 | 145 | 22.4 | 162 |
| Hf | 16 | 4.8 | 57.4 | 7.4 |
| Al | 27 | 35,200 | 22.9 | 30,600 |
| Ce | 23 | 791 | 24.5 | 903 |
| Fe | 28 | 15,600 | 28.3 | 15,200 |
| Mn | 27 | 399 | 115 | 289 |
| Sc | 28 | 4.0 | 30.8 | 4.19 |
| Na | 25 | 1450 | 184 | 901 |
| Ti | 17 | 4820 | 18.9 | 6100 |
| V | 27 | 46.7 | 24.8 | 54.4 |
| Dy | 24 | 42.3 | 50.8 | 50* |
| Eu | 27 | 3.5 | 41.2 | 3.86 |
| La | 28 | 406 | 23.7 | 443 |
| Lu | 23 | 4.1 | 25.4 | 4.4 |
| Sm | 23 | 71.7 | 73.0 | 69.2 |
| Yb | 25 | 28.7 | 26.0 | 29.9 |

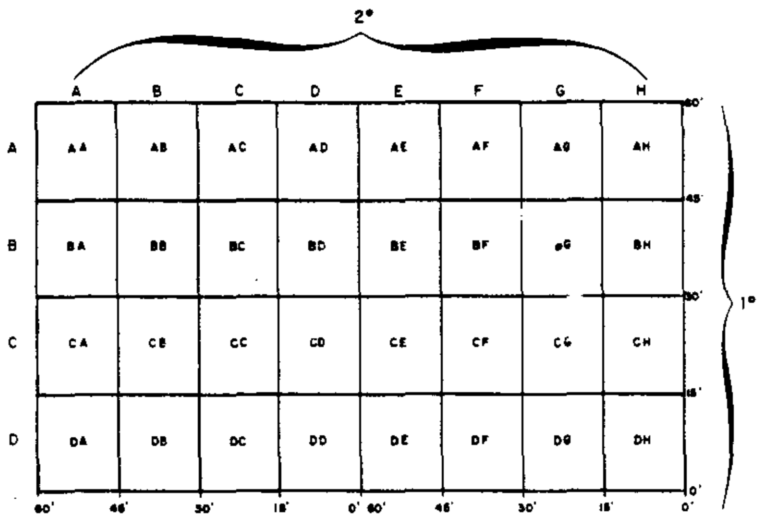
* Only one laboratory reported values for dysprosium.

TABLE 6 (Continued)

c. Sediment Standard SRL 4.1

| Element | Number | Mean, ppm | Coefficient of Variation, % | Accepted Value, ppm |
|---|---|---|---|---|
| U | 28 | 0.5 | 14.7 | 0.58 |
| Th | 13 | 2.9 | 31.0 | 2.1 |
| Hf | 25 | 2.9 | 31.1 | 4.4 |
| Al | 28 | 59,700 | 25.9 | 66,700 |
| Ce | 15 | 51.1 | 27.1 | 44 |
| Fe | 28 | 77,200 | 13.6 | 87,300 |
| Mn | 24 | 1,520 | 21.9 | 1970 |
| Sc | 28 | 13.2 | 36.1 | 21 |
| Na | 27 | 15,500 | 21.6 | 16,100 |
| Ti | 23 | 19,700 | 24.1 | 25,200 |
| V | 27 | 217 | 20.6 | 273 |
| Dy | 3 | 4.4 | 97.4 | <22 |
| Eu | 20 | 1.2 | 49.6 | 1.16 |
| La | 23 | 15.2 | 22.2 | 18.6 |
| Lu | 16 | 0.2 | 36.6 | 0.28 |
| Sm | 22 | 2.9 | 30.6 | 4.2 |
| Yb | 7 | 1.6 | 24.3 | 1.6 |

third and fourth letters define which 15-minute quadrangle contains the sampling site (see chart below).




Numbers from 001 to 499 designate surface sites. Numbers from 501 to 999 designate ground-water sites. The first sediment sample, therefore, taken from the extreme northeastern portion of the Grand Canyon 1° x 2° NTMS quadrangle would be GCAH001.

Other entries on Table A-1 include a DOE identification number; pH, conductivity, alkalinity, and scintillometer readings; analyses for U, Br, Cl, F, He, Mn, Na, and V; and the ratio of uranium-to-conductivity (multiplied by 1000 for convenience; U x 1000/cond.). All entries are self-explanatory except those noted below.

DOE ID is a 28-digit number that includes the following parts:

| Digit Number | |
|---|---|
| 1-2 | State (See Table 1 in the **USER'S GUIDE**) |
| 4-10 | Latitude of site |
| 12-19 | Longitude of site |
| 21 | Laboratory code (4 = SRL) |
| 23-24 | Sample type (See Table 2 in the **USER'S GUIDE**) |
| 26-28 | Replication code. Generally only original samples (-000) are reported in the Data Reports. |

Table A-2 shows SRL identification number; concentrations of Al, Dy, and Mg; sampling date; sample collection team number; and the following characteristics of the well or spring that was sampled:

| | |
|---|---|
| WATRTEMP | Water Temperature, in °C. |
| WELDEPTH | Depth of well in feet. |
| DPTHCONF | Confidence in depth measurement (see p. 14 in **USER'S GUIDE**). |
| WELCLASS | Classification of well use (see p. 15 in **USER'S GUIDE**). |
| SMPPOINT | Point in plumbing system where water was taken (see p. 14 in **USER'S GUIDE**). |
| WELLODOR | Presence or strength of hydrogen sulfide or other odor. |

Sediment analyses and site descriptions are tabulated in Tables B-1, B-2, and B-3, which are on the microfiche labeled **GRAND CANYON TABLES**.

Table B-1 includes SRL and DOE identification numbers similar to those described above for ground-water sites. Table B-1 also includes scintillometer readings, pH, conductivity, and alkalinity of stream water, plus elemental concentrations of U, Th, Hf, Ce, Fe, Mn, Na, Sc, Ti, and V.

Table B-2 (Supplementary Data - Sediments) includes the SRL identification number and concentrations of Al, Dy, Eu, La, Sm, Yb, and Lu.

Table B-3 (Supplementary Data - Sediments) includes the SRL identification number and the following entries:

| | |
|---|---|
| SAMPTYPE | Type of soil, sediment, etc., sampled (see Table 2 in the **USER'S GUIDE**). |
| ROCKTYPE | Type of rock underlying sampling site (see p. 16 in the **USER'S GUIDE**). |
| SEDSIZE | Dominant size of particles in sediment at site (see p. 17 in **USER'S GUIDE**). |

| | |
|---|---|
| STRWIDTH<br>STRDEPTH<br>STRFLOW<br>STRLEVEL | Size and flow rate of stream at sampling site (see p. 17 in **USER'S GUIDE**). |
| VEGTYPE | Dominant type of vegetation at site (see p. 17 in **USER'S GUIDE**). |
| VEGDENS | Vegetation density at site (see p. 17 in **USER'S GUIDE**). |
| RELIEF | Local relief at site (see p. 18 in **USER'S GUIDE**). |
| COMPOSIT | Number of subsamples blended into sample. |
| CONTAMN1<br>CONTAMN2<br>CONTAMN3<br>CONTAMN4 | Activities or contaminants that may affect the material sampled (see p. 18 in the **USER'S GUIDE**). |
| FRMATION | The rock formation that underlies the site (see **FORM** on p. 13 of the **USER'S GUIDE**). |
| ODOR | Odors detected in sampled material (see p. 15 in the **USER'S GUIDE**). |
| WATERTEMP | Water temperature in °C. |
| SAMPDATE | Date sample was collected. |
| TEAM | Numerical designator of sample collection team. |

Site descriptions and field measurements are recorded on the SRL Field Data Form (Figure 3). Data are recorded in the spaces numbered 1 through 80. The spaces have self-explanatory labels. Spaces whose numbers are circled are filled with one of the choices listed beneath the appropriate number on the Field Data Form. Some data are listed differently on the Field Data Form and in the data tables on microfiche. For example, well water samples are coded as Sample Type "C" on the Field Data Form and are reported as Sample Type "52" in Table A-1. Details of how the Field Data Form is used can be found in the **USER'S GUIDE** and in SRL's **Training Manual for Water and Sediment Geochemical Reconnaissance** (Price and Jones, 1979, Du Pont SRL Internal Doc. DPST-79-219).

## Elemental Analyses

The elements after uranium are generally listed alphabetically. Concentrations of each element are reported in parts per million (ppm) by weight. Values have been rounded to appropriate significant figures. Note that elemental (not oxide) concentrations are quoted in this table. Values below detection limits are indicated by a minus (-). For example, -3 means that the sample contains less than 3 ppm of that element. If background is high and a lower limit is not available, a period (.) is used to indicate not only that the element was not detected, but that the detection limit is unusually high in that sample. Missing data are indicated by "M". All analytical results are missing when there was insufficient sample for analysis.

# RESULTS AND DISCUSSION OF THE DATA

## Surface Sediment Samples

Sediment samples were collected from 1013 surface sites in the Grand Canyon 1° x 2° NTMS quadrangle. Basic statistical data for uranium and 16 other elements in these sediments are given in Table 7. Log histograms, cumulative frequency plots, and areal distribution maps for these 17 elements as well as elemental ratios (log U/Th, log U/Hf, and log Th/La) are shown on the microfiche sediment plots.

SRL experience suggests that most uranium in surface sediment samples is present in resistate minerals. Interpretation of the areal distribution of uranium (Plate 5) is best done by studying the areal distributions of the ratio of uranium to geochemically associated elements such as Th, Hf(Zr), Ce, etc. Elemental associations suggested here should be considered speculative pending detailed mineralogical investigations.

An areal distribution map of uranium concentrations in a given stream sediment sample may be more dependent on stream gradient or sampling conditions than on any proximity to a commercial uranium deposit. For example, if uranium were uniformly present in the mineral zircon at a concentration of 5000 ppm, then a uranium distribution map for stream sediment samples comprised of particles of less than 149 micrometers would have highs and lows which were functions of many factors. These include: (1) the areal distribution of zircon, (2) the areal distribution of zircon grain size, (3) the effectiveness of sampled streams in sorting and concentrating zircon relative to diluent minerals such as quartz or micas, and (4) the effectiveness of the sampling method in obtaining "representative" samples.

TABLE 7

Statistical Summary of Elemental Analyses - Sediment; Grand Canyon

| Element | n* | Measured Values: Maximum** | Measured Values: Minimum† | Log Mean†† $\left[\frac{(\Sigma \text{Log}_{10} x)}{n}\right]$ | Log Std.¶ Deviation |
|---|---|---|---|---|---|
| U | 1001 | 10.8 | 0.4 | 0.37 | 0.13 |
| Th | 992 | 98.0 | 1.0 | 0.86 | 0.20 |
| Hf | 970 | 54.0 | 1.0 | 0.94 | 0.23 |
| Al | 985 | 112,000 | 8290 | 4.65 | 0.14 |
| Ce | 942 | 408 | 7.0 | 1.64 | 0.20 |
| Fe | 987 | 73,100 | 1700 | 4.25 | 0.20 |
| Mn | 943 | 2630 | 50.0 | 2.66 | 0.29 |
| Na | 919 | 111,000 | 100 | 3.60 | 0.29 |
| Sc | 996 | 21.8 | 0.6 | 0.64 | 0.22 |
| Ti | 688 | 12,700 | 200 | 3.43 | 0.19 |
| V | 975 | 300 | 10.0 | 1.60 | 0.21 |
| Dy | 416 | 19.3 | 0.2 | 0.46 | 0.28 |
| Eu | 459 | 4.3 | 0.2 | 0.03 | 0.24 |
| La | 946 | 574 | 3.0 | 1.35 | 0.20 |
| Lu | 907 | 1.5 | 0.1 | -0.50 | 0.17 |
| Sm | 950 | 46.0 | 1.0 | 0.50 | 0.25 |
| Yb | 696 | 9.5 | 0.4 | 0.35 | 0.19 |

* Number of observations
** Elemental concentrations in ppm.
† Minimum or detection limit.
†† Mean of values above detection limit.
¶ Log units.

On the other hand, comparison of a map showing the distribution of uranium with a map showing the distribution of the U/Hf (or U/Zr) ratio should show where zircon is an important contributor to the amount of uranium. The areal distribution of this ratio is presented on microfiche. The ratio of U/Hf should be low where zircon is the primary mineral host of uranium in sediment samples. High values of the ratio indicate areas where uranium is present in minerals other than zircon or where zircon is particularly enriched in uranium.

Using the same logic, areas where values of the U/Th ratio (on microfiche) are high show either that uranium is present in minerals other than resistates (such as monazite) or that these resistates are particularly enriched in uranium. Anomalous areas which persist on several ratio figures may be areas where uranium is present in some mineral other than common resistate minerals. If these anomalous areas are supported by other considerations (such as radioactivity highs, geologic conditions, or high values of dissolved uranium in natural waters), then they may warrant a detailed field examination or detailed geochemical sampling.

Uranium concentrations in sediment samples from the Grand Canyon 1° x 2° NTMS quadrangle are comparatively low, with a maximum uranium content of 10.8 ppm. Most uranium anomalies (3 to 6 ppm) are associated with Permian and Triassic rocks (Pkt and ℞mt, respectively). Jurassic rocks (Jn) typically are low in uranium. Values for log U/Th and log U/Hf are predominantly negative, likely indicating little free uranium.

Due to equipment malfunction, manganese analyses for the 15-minute quadrangles BF, BH, and CA and for scintillometer readings in the 15-minute quadrangles BF, BG, and BH should be considered suspect.

Most of the uranium-producing localities (Table 3) do not correspond to areas of anomalous uranium concentrations (see uranium areal distribution map on microfiche labeled **GRAND CANYON PLOTS PG 1**). Mineral localities 1 to 5 (Table 3), however, do correspond to areas from which samples were taken that had relatively high uranium contents. Regional trends defined by relatively high uranium concentrations in sediments are mimicked by trends defined by the elements Th, Hf, Ce, La, Sc, V, Na, Al, and Fe.

**Stream and Ground Water Samples**

Water samples were collected from 84 ground water sites in the Grand Canyon quadrangle. A statistical summary of key field measurements and elemental analyses for ground water sites is

TABLE 8

Statistical Summary of Ground-Water Analyses; Grand Canyon

| Variable | n* | Measured Values: Maximum** | Measured Values: Minimum† | Mean†† | Log Mean¶ $\left[\frac{(\Sigma \text{Log}_{10} x)}{n}\right]$ | Log Std.¶ Deviation | Standard Deviation ±1 σ |
|---|---|---|---|---|---|---|---|
| pH | 84 | 9.6 | 1.8 | 7.5 | | | 1.1 |
| Conductivity | 84 | 12,000 | 45.0 | | 3.0 | 0.5 | |
| Alkalinity | 81 | 9.5 | 0.4 | | 0.5 | 0.3 | |
| U | 82 | 250 | 0.03 | | 0.4 | 0.8 | |
| Al | 76 | 8760 | 86.0 | | 2.7 | 0.5 | |
| Br | 59 | 5010 | 16.1 | | 2.4 | 0.5 | |
| Cl | 80 | 986,000 | 9100 | | 4.8 | 0.5 | |
| Dy | 6 | 1.3 | 0.06 | | -0.3 | 0.4 | |
| F | 45 | 18,400 | 18.0 | | 2.3 | 0.5 | |
| He¶¶ | 81 | 200 | 4.1 | | 0.9 | 0.3 | |
| Mg | 73 | 960,000 | 910.00 | | 4.6 | 0.6 | |
| Mn | 15 | 2230 | 55.3 | | 2.6 | 0.6 | |
| Na | 81 | 728,000 | 4250 | | 4.60 | 0.6 | |
| V | 45 | 154 | 1.0 | | 0.6 | 0.5 | |

* Number of observations. Some values are missing for reasons other than being below detection limit.

** Elemental concentrations in ppb; conductivity in umhos/cm; alkalinity in meq/L.

† Minimum or detection limit.

†† Mean of values above detection limit.

¶ Log units.

¶¶ Helium in ppm by volume in 2 mL air gap over 300 mL of water.

given in Table 8. Log histograms, cumulative frequency plots, and areal distribution plots for uranium and ten other elements (Al, Br, Cl, Dy, F, He, Mg, Mn , Na, and V) in ground waters are shown on microfiche. Helium concentrations were determined by mass spectrographic analyses.

Uranium concentrations in stream and ground water samples are dependent on several factors: (1) the concentration of uranium in the rocks and soils through which the ground water passes, (2) the rate at which uranium-bearing minerals in the rocks (soils) release uranium, (3) the hydrologic character of the rocks (soils), and (4) the chemistry of the water (especially Eh, pH, and alkalinity).

The interpretation of uranium analyses in natural waters is not straightforward. In active roll-front deposits, solubility of uranium may be low. Concentrations of uranium in natural waters may be very low near areas of active uranium deposition or very high in oxidizing zones near dissolving ore bodies.

Uranium concentrations in water can be expected to vary with total dissolved solids in the water. Because conductivity of water increases with increasing total dissolved solids, the ratio of uranium concentration to conductivity gives an approximation of the proportion of uranium in natural waters. The areal distribution of uranium concentration/conductivity ratios for ground water and stream water are shown on the ground-water and stream-water plots on microfiche.

Interpretation of the ground-water analyses is tenuous due to the scarcity and spacing of the 84 samples collected. It should be noted, however, that ground-water samples having relatively high uranium contents cluster in the 15-minute quadrangles AD, AE, BD, and BE; whereas uranium contents in sediment samples in these four quadrangles are relatively low.

## ACKNOWLEDGMENTS

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| No. | Period | SRL Doc. No. | DOE-GJO Doc. No.* |
|---|---|---|---|
| 1 | January-March 1975 | DPST-75-138-1 | GJBX-5(76) |
| 2 | April-June 1975 | DPST-75-138-2 | GJBX-6(76) |
| 3 | July-September 1975 | DPST-75-138-3 | GJBX-7(76) |
| 4 | October-December 1975 | DPST-75-138-4 | GJBX-8(76) |
| 5 | January-March 1976 | DPST-76-138-1 | GJBX-17(76) |
| 6 | April-June 1976 | DPST-76-138-2 | GJBX-27(76) |
| 7 | July-September 1976 | DPST-76-138-3 | GJBX-63(76) |
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| 11 | July-September 1977 | DPST-77-138-3 | GJBX-90(77) |
| 12 | October-December 1977 | DPST-77-138-4 | GJBX-37(78) |
| 13 | January-March 1978 | DPST-78-138-1 | GJBX-66(78) |
| 14 | April-September 1978 | DPST-78-138-2 | GJBX-13(79) |
| 15 | October 1978-March 1979 | DPST-79-138-1 | GJBX-86(79) |
| 16 | April-September 1979 | DPST-79-138-2 | GJBX-160(79) |
| 17 | October 1979-March 1980 | DPST-80-138-1 | (in process) |

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| No. | NTMS 1° x 2° Quadrangle | SRL Doc. No. | DOE-GJO Doc. No.* |
|---|---|---|---|
| 1 | Winston-Salem† | DPST-77-146-1 | GJBX-66(77) |
| 2 | Spartanburg | DPST-77-146-2 | GJBX-09(78) |
| 3 | Charlotte | DPST-78-146-1 | GJBX-40(78) |
| 4 | Greenville | DPST-78-146-2 | GJBX-47(78) |
| 5 | Winston-Salem†† | DPST-78-146-3 | GJBX-58(78) |
| 6 | Greensboro | DPST-78-146-4 | GJBX-74(78) |
| 7 | Knoxville | DPST-78-146-5 | GJBX-75(79) |
| 8 | Scranton | DPST-78-146-6 | GJBX-02(79) |
| 9 | Athens | DPST-78-146-7 | GJBX-20(79) |
| 10 | Harrisburg | DPST-79-146-1 | GJBX-31(79) |
| 11 | Portland | DPST-79-146-2 | GJBX-28(79) |
| 12 | Glens Falls | DPST-79-146-3 | GJBX-44(79) |
| 13 | Augusta | DPST-79-146-4 | GJBX-45(79) |
| 14 | Dyersburg | DPST-79-146-5 | GJBX-58(79) |
| 15 | Poplar Bluff | DPST-79-146-6 | GJBX-63(79) |
| 16 | Hartford | DPST-79-146-7 | GJBX-94(79) |
| 17 | Williamsport | DPST-79-146-8 | GJBX-152(79) |
| 18 | Newark | DPST-79-146-9 | (in process) |

| | | | |
|---|---|---|---|
| 19 | Albany | DPST-79-146-10 | GJBX-140(79) |
| 20 | Atlanta | DPST-79-146-11 | GJBX-129(79) |
| 21 | Delta, Richfield††† | DPST-79-146-12 | GJBX-161(79) |
| 22 | Walker Lake | DPST-79-146-13 | (in process) |
| 23 | McDermitt, Wells††† | DPST-79-146-14 | (in process) |
| 24 | Reno | DPST-79-146-15 | (in process) |
| 25 | Death Valley | DPST-79-146-16 | (in process) |
| 26 | Flagstaff | DPST-79-146-17 | (in process) |
| 27 | Marble Canyon | DPST-79-146-18 | (in process) |
| 28 | Grand Canyon | DPST-79-146-19 | (this report) |

† Sediment only.
†† Ground water only.
††† SRL analyses of samples collected by Lawrence Livermore Laboratory.


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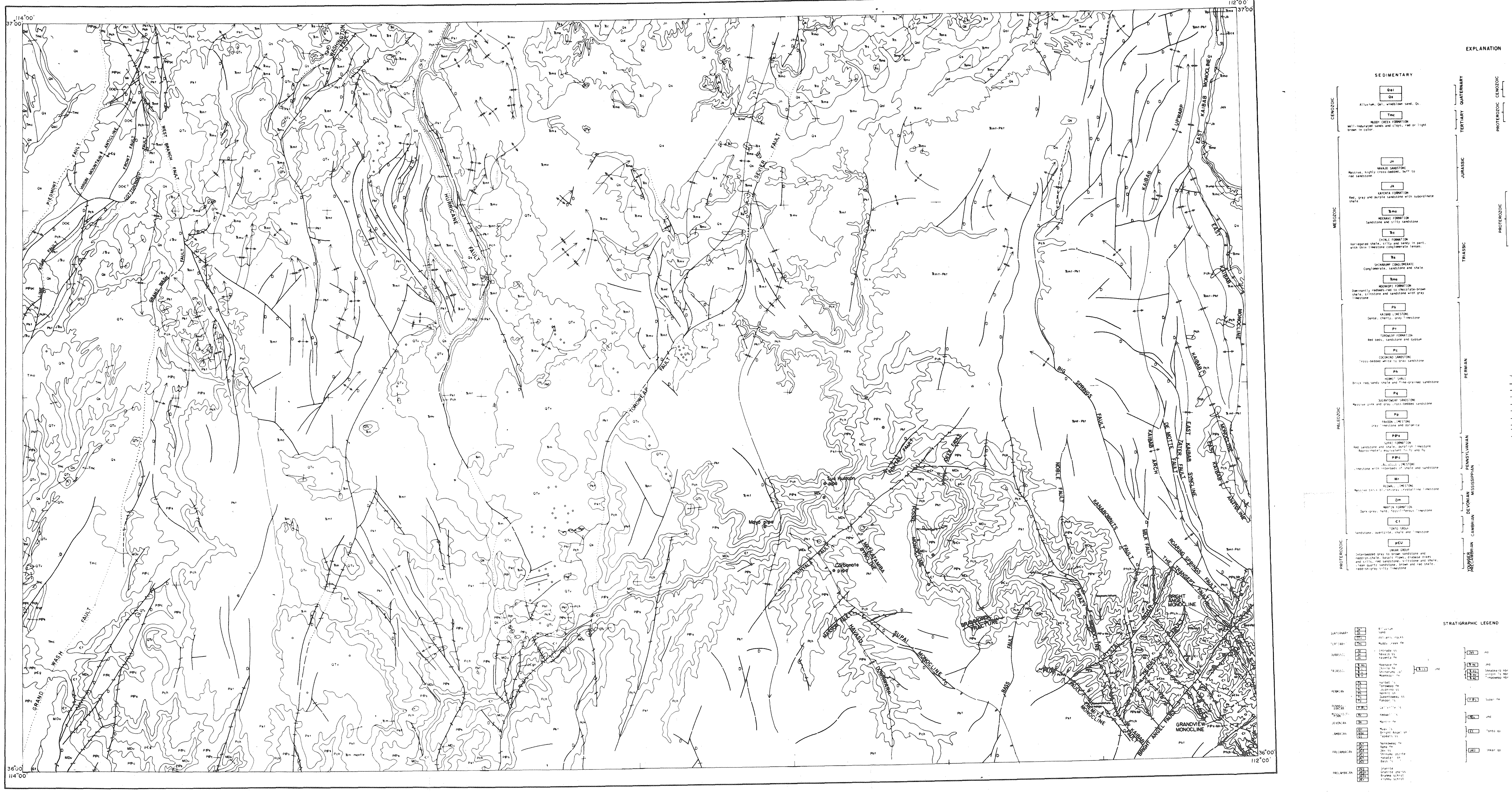
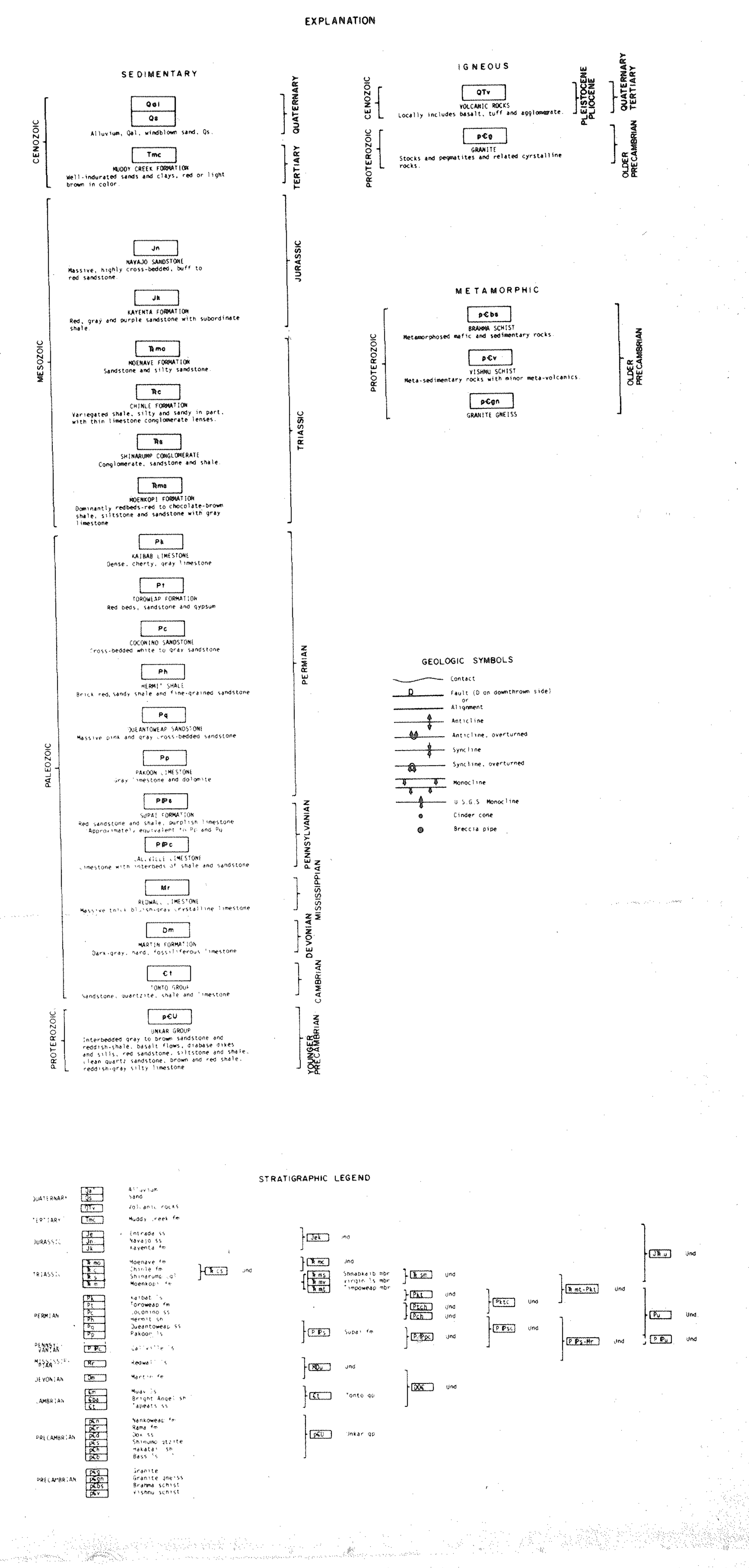
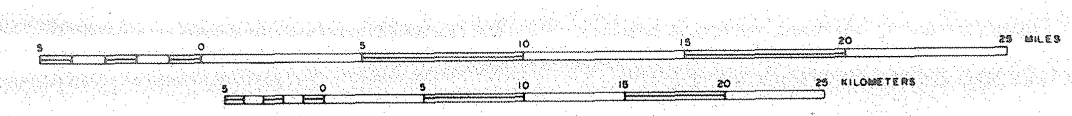
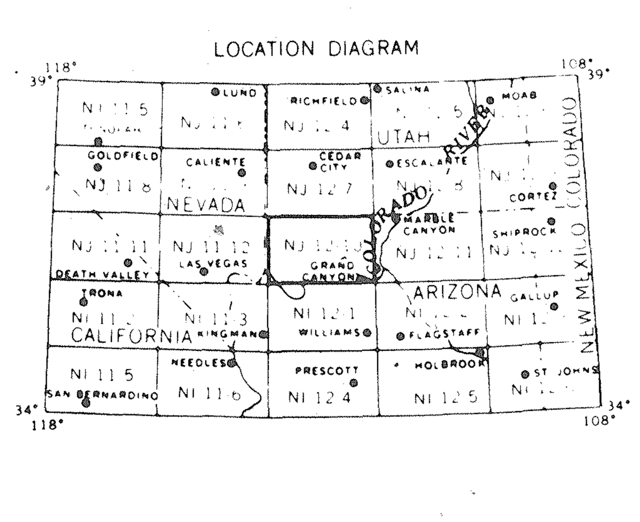
GRAND CANYON, ARIZONA

# GRAND CANYON GEOLOGY



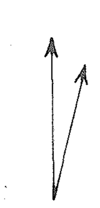

## GEOLOGY OF THE GRAND CANYON QUADRANGLE

Prepared by
IntraSearch
Denver, Colorado

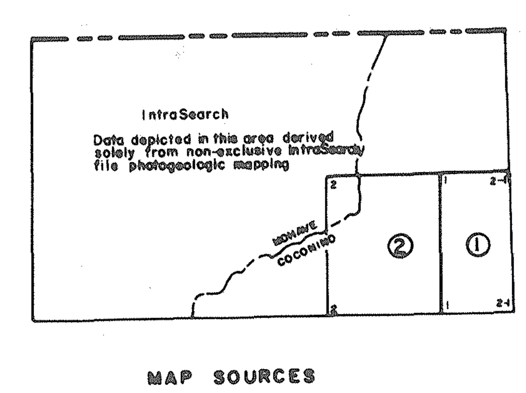
In Accordance With BFEC Specification #1125

For

UNITED STATES DEPARTMENT OF ENERGY



1970 MAGNETIC DECLINATION FROM TRUE NORTH VARIES FROM 15° (270 MILS) EASTERLY FOR THE CENTER OF THE WEST EDGE TO 14°30' (260 MILS) EASTERLY FOR THE CENTER OF THE EAST EDGE




### MAP SOURCES

1. Maxon, J.H. 1961, 1966, Preliminary Geologic Map of the Grand Canyon and vicinity, Grand Canyon Natural History Association.
2. Breed, W.J. et al 1976, Geologic Map of the Grand Canyon National Park, Arizona, Grand Canyon Natural History Association.

PLATE 1

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