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MASTER

National Uranium Resource Evaluation

A GEOLOGIC REPORT ON THE SAND WASH DRILLING PROJECT, MOFFAT AND ROUTT COUNTIES, COLORADO

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

This report is a result of work performed by Bendix Field Engineering Corporation, Operating Contractor for the U.S. Department of Energy, as part of the National Uranium Resource Evaluation. NURE is a program of the U.S. Department of Energy's Grand Junction, Colorado, Office to acquire and compile geologic and other information with which to assess the magnitude and distribution of uranium resources and to determine areas favorable for the occurrence of uranium in the United States.

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A Geologic Report on the Sand Wash Drilling Project, Moffat and Routt Counties, Colorado

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ABSTRACT

The Sand Wash Basin Drilling Project comprises twenty-seven (27) drill holes located in Moffat and Routt Counties, northwest Colorado, having an aggregate depth of 26,107.5 feet (7,957.6 m). The holes penetrate the Browns Park Formation of Miocene age, which is a tuffaceous continental sandstone deposited in fluvial, eolian, and lacustrine environments. Partly based on project drilling results, uranium potential resource estimates for this formation in the \$50/lb U_3O_8 forward-cost category have been increased by 34,476 tons U_3O_8 (35,036 metric tons).

Three areas between Maybell and Craig, Colorado, considered favorable for uranium occurrences were verified as favorable by project drilling, and a fourth favorable area northwest of Maybell has been expanded. In addition, project drilling results indicate two new favorable areas, one north and northwest and one south of Steamboat Springs, Colorado.

Anomalous radioactivity was detected in drill holes in all six study areas of the project. The most important factor in concentrating significant amounts of uranium in the target formation appears to be the availability of gaseous or liquid hydrocarbons and/or hydrogen sulfide gas as reductants. Where subjacent formations supply these reductants to the Browns Park Formation, project drilling encountered 0.05 percent to 0.01 percent uranium concentrations. Potential, though unproven, sources of these reductants are believed to underlie parts of all six project study areas.

INTRODUCTION

General Information

The Sand Wash Basin Drilling Project consists of 27 rotary drill holes located in Moffat and Routt Counties, Colorado (Figure 1). The combined total depth of drill holes is 26,107.5 feet (7,957.6 m).

The Sand Wash Basin Drilling Project was recommended in a U.S. Department of Energy (DOE) memorandum of October 11, 1977, signed by Richard A. Crawley of the Potential Resources Branch of the Grand Junction Office (GJO) of DOE. The memorandum states that the objective of this project is to test the "possible potential uranium resources" of the Browns Park Formation in the Sand Wash Basin in order to improve the reliability of potential uranium resource estimates assigned to it.

The purpose of this report is to summarize the information obtained by the project, to make geologic interpretations of the information, and to transmit the information and interpretations to the U.S. Department of Energy and the Geology Division of Bendix Field Engineering Corporation (BFEC), Grand Junction, Colorado. The report is also intended to provide reconnaissance geologic information to the mineral industry concerning the project area.

The target formation for this project is the Browns Park Formation, a continental sandstone of Miocene age. The Browns Park Formation is the host rock for economic concentrations of uranium minerals near Maybell, Colorado, and Baggs, Wyoming. In addition, many uranium prospects and claims are located on outcrops of this formation.

The project area, illustrated by Plate I, is restricted to the areas of Browns Park outcrop in northwest Colorado that are included on the Craig (Colorado) and Vernal (Utah) NTMS 1° x 2° quadrangle maps. The "excluded area" shown on Plate I is an area of industry activity (including the Maybell mining district) which was excluded from project drilling.

Elevations in the project area range from approximately 6,000 feet (1,800 m) in Moffat County to slightly over 10,000 feet (3,000 m) in Routt County. Climate in the lower areas is semi-arid; in the higher areas it is cooler and more humid. The steppe vegetation of the lower elevations grades into conifer forests and subalpine and alpine meadows at the higher elevations. The Green River is the master stream in this area, but little of the project area drains directly into it. Most of the project area lies in the drainages of the Little Snake and Yampa Rivers, tributaries of the Green River.

Craig and Steamboat Springs are the principal communities in the project area. U.S. Highway 40 traverses the area east to west. Project drill sites are reached by a network of state, county, and U.S. Forest Service roads.

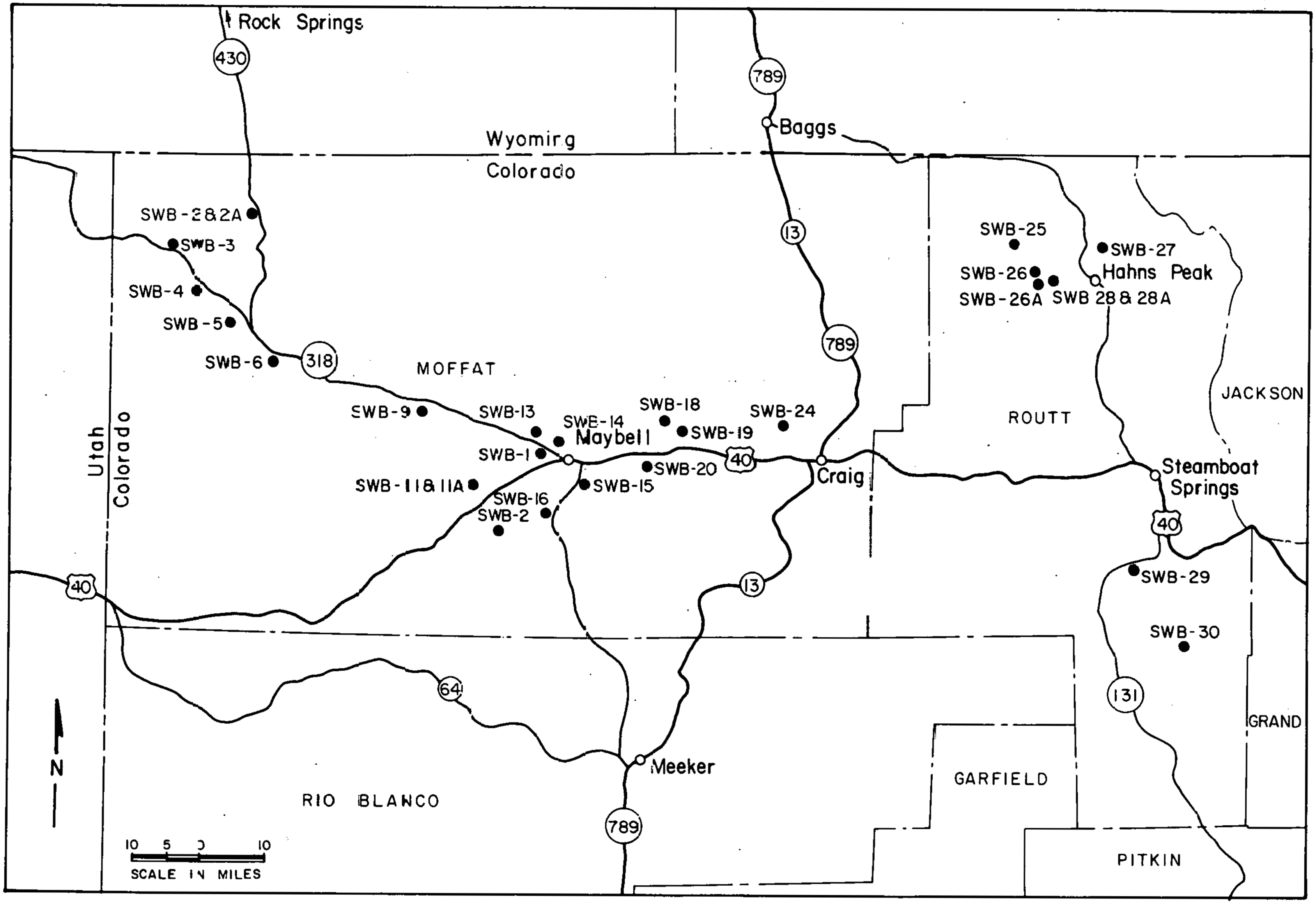


Figure 1. Location of Project Area

Industry Activity

The uranium deposits near Maybell were discovered in 1953 and were mined by open-pit methods. Trace Elements Corporation (TEC), the original operator in the district, also produced uranium from deposits in the Browns Park Formation in the Poison Basin area, near Baggs, Wyoming. The TEC operations at Maybell were acquired by Union Carbide Corporation in 1957. Union Carbide operated a uranium processing plant in the Maybell district from 1957 until 1964. Uranium ore production from the Maybell deposits, as of January 1, 1977, has been 1,609,200 tons of ore averaging 0.13 percent U_3O_8 (Chenoweth, 1978).

Currently (1981) Union Carbide is operating an open-pit mine and a heap leaching plant in the Maybell district.

Exploration for uranium in the project area has continued intermittently from the 1950s to the present. Scores of individuals and mineral companies have been involved in exploration, claim staking, and property transactions. Much of the activity in the project area has been concentrated near the Union Carbide Corporation's properties.

The Sand Wash Basin project area also contains productive petroleum reservoirs and coal seams. Coal and petroleum production in Moffat County predates uranium production in the area, and exploration and development of hydrocarbon fuels continues. The Big Gulch field near Lay, Colorado, produces minor amounts of hydrocarbons from formations underlying the Browns Park Formations.

Prior to project drilling, estimates of potential uranium resources assigned to the Browns Park Formation in the Sand Wash Basin were listed in the NURE Interim Report of June 1979 as:

Tons U_3O_8
(Metric Tons U_3O_8)

Probable	Possible	Speculative
15,000 (15,300)	10,500 (10,700)	--

These resource estimates are based on a forward cost of $50 per pound of U_3O_8 ($110 per kilogram).

The NURE program includes aerial geophysical surveys, geochemical studies, and geologic assessments of the Craig and Vernal Quadrangles. These NURE reports are now available:

"NURE Aerial Gamma-Ray and Magnetic Reconnaissance Survey, Colorado-Arizona area, Craig NK-13-10 Quadrangle," LKB Resources, Inc., U.S. Department of Energy Open-File Report GJBX-153(79), September 1979.

"Aerial Radiometric and Magnetic Survey, Vernal National Topographic Map, Colorado and Utah," Geo-Life, Inc., U.S. Department of Energy Open-File Report GJBX-167(79), November 1979.

"Uranium Hydrogeochemical and Stream Sediment Reconnaissance of the Craig NTMS Quadrangle, Colorado, Including Concentrations of Forty-Three Additional Elements," S. L. Bolivar and D. E. Hill, Los Alamos Scientific Laboratory, U.S. Department of Energy Open-File Report GJBX-76(79), May 1979.

"Uranium Hydrogeochemical and Stream Sediment Reconnaissance of the Vernal NTMS Quadrangle, Utah and Colorado, Including Concentrations of Forty-Two Additional Elements," J. D. Purson, Los Alamos Scientific Laboratory, U.S. Department of Energy Open-File Report GJBX-232(80), August 1980.

"Multivariate Statistical Analysis of Stream Sediments for Mineral Resources from the Craig NTMS Quadrangle, Colorado," M. Byeth and others, Los Alamos Scientific Laboratory, U.S. Department of Energy Open-File Report GJBX-145(80), June 1980.

"Uranium Hydrogeochemical and Stream Sediment Reconnaissance Data Release for Red Creek Quartzite Special Study Area, Vernal NTMS Quadrangle, Utah and Colorado, Including Concentrations of Forty-Six Additional Elements," Sue Goff and others, Los Alamos Scientific Laboratory, U.S. Department of Energy Open-File Report GJBX-173(81), April 1981.

"Detailed Uranium Geochemical Stream Sediment Survey Data Release for Selected Portions of the Craig NTMS Quadrangle, Colorado, and the Rawlins NTMS Quadrangle, Wyoming, Including Concentrations of Forty-Five Additional Elements," S. S. Shannon, Jr., and others, Los Alamos Scientific Laboratory, U.S. Department of Energy Open-File Report GJBX-216(81), April 1981.

"Uranium Resource Evaluation of the Craig NTMS 1° x 2° Quadrangle, Colorado," L. C. Craig and others, U.S. Department of Energy Preliminary Report PGJ-017, 1980.

"Uranium Resource Evaluation of the Vernal 1° x 2° Quadrangle, Colorado-Utah," L. C. Craig and others, U.S. Department of Energy Preliminary Report PGJ-026, 1980.

Regional Geologic Setting

The Browns Park Formation crops out at the margins of four physiographic provinces. Its northern outcrop areas lie in the Sand Wash Basin of the Wyoming Basins Province. To the west, it mantles the flanks of the Uinta Mountains of the Middle Rocky Mountain Province. Outliers to the southwest are within the Uinta Basin section of the Colorado Plateau Province and its central and southeastern outcrop areas lie in the Southern Rocky Mountains Province. For the most part, Browns Park Formation outcrops are preserved in structural or paleotopographic depressions. Regional structural units are illustrated by Figure 2.

In general, the Browns Park Formation is similar to the uranium-bearing Wyoming Basins Province formations: It is predominantly a continental fluvial sandstone with some eolian and lacustrine deposits and is rich in rhyolitic air-fall tuffs and tuffaceous material. The depressions it fills were prepared during and immediately after the Laramide orogeny (late Cretaceous - late Eocene).

Thorough discussion of the region's geologic history may be found in Sears (1924), Bradley (1936), Hansen (1965, 1969), Hansen and others (1960), Tweto (1975), Izett (1975), and Larson et al (1975). A brief account of events pertaining to potential uranium occurrences as taken from these papers follows.

As the Uinta Arch and Park-Sierra Madre Range were uplifted during the Laramide orogeny, sediments derived from them were deposited in the Sand Wash Basin as the Ft. Union, Wasatch, Green River, and Bridger Formations. These formations (except the Bridger) contain coal and other hydrocarbons and are potential sources of reductants.

After the conclusion of the Laramide orogeny, epeirogenic uplift and renewed erosion commenced in the region. The ancestral Green River carved a major paleovalley along the eastern portion of the crest of the Uinta Arch and probably flowed east then northeast into Wyoming around the north end of the Sierra Madre Range. Coincident with this, the eastern end of the Uinta Arch slowly began to collapse.

As the Uinta Arch began its collapse, the Browns Park Formation started to accumulate about 25 million years b.p. in the paleovalley of the ancestral Green River, on the flanks of the Uinta Mountains, the White River Uplift, and the Park-Sierra Madre Range, and across the relatively level surface of the Sand Wash Basin. Some tectonism occurred during deposition of the Browns Park Formation, resulting in intraformational unconformities which may affect the flow of uraniferous, oxidizing or reducing fluids within the formation.

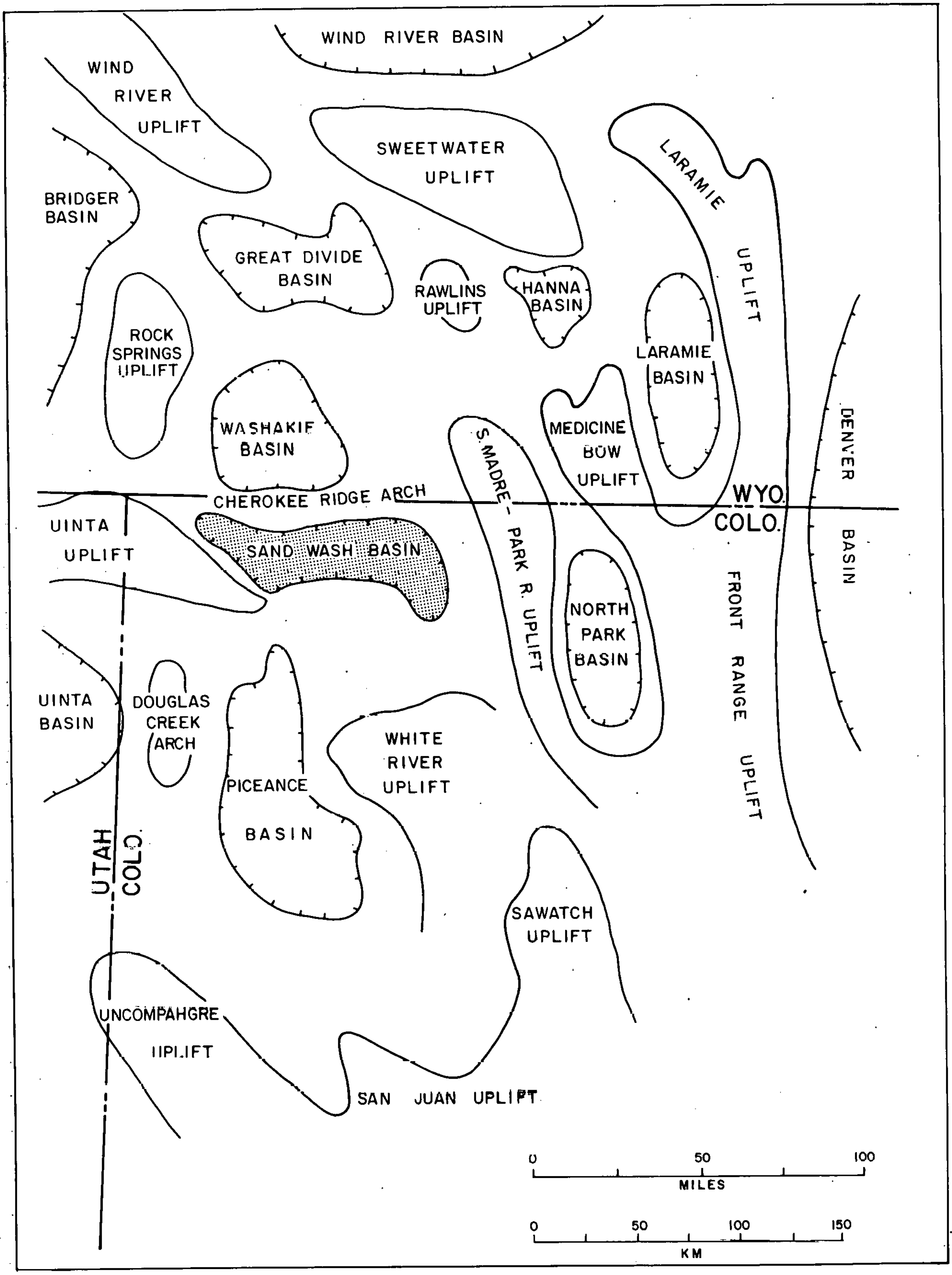


Figure 2. Regional Structural Units

Near the close of the Miocene, deposition of the Browns Park Formation ceased, probably due to piracy of the ancestral Green River from the North Platte River drainage to the present Colorado River Basin. Depth of oxidation of the Browns Park Formation appears, in places, to be related to present or former ground-water tables, which, in turn, appear to have fluctuated because of the piracy of the ancestral Green and subsequent development of the Little Snake and Yampa River drainages. Also, uranium may have been mobilized during the weathering and erosion of the Browns Park Formation, which was formerly of greater extent than at present.

Major tectonism in the area was renewed beginning about 10 million years b.p. Some Laramide structural features were reactivated, though generally the sense of movement along them was opposite to that of the Laramide movement. In the Elkhead Mountains, the Browns Park Formation was intruded by intermediate to basic igneous rocks and, in places, was capped by lava flows of these same rocks. Basalts and basaltic andesites of Miocene age also intertongue with and cap portions of the Browns Park Formation along the northern flank of the White River Uplift. These igneous rocks and recent structural features have preserved portions of the Browns Park Formation from erosion, often in topographically high positions. These topographically high remnants have been subject to oxidation and possibly leaching of uranium and may have been a source of uranium for mineralization of other areas.

Project Area Geology

The Browns Park Formation of Miocene age is the target formation for this project. For the purposes of the project, the project area has been divided into six study areas in which the target formation crops out and in which the geologic settings are different. The six study areas are the North Browns Park, Browns Park, West Yampa, East Yampa, North Routt, and South Routt areas (Plate I). Geologic information specific to each area is presented in the sections of this report dealing with drilling results in the areas. General geology of the project area is illustrated by Plate II.

The target formation is in unconformable contact with rocks ranging in age from Precambrian to Eocene, and, in places, is intertongued with and overlain or intruded by igneous rocks of Miocene or younger age (Buffler, 1967, Larsen et al, 1975). Except for these igneous rocks and Quaternary surficial deposits, the Browns Park Formation is the youngest formation in the area. It was formerly a blanket-like deposit covering the Sand Wash Basin and surrounding areas.

Weathering and erosion have removed the target formation except where it occupies depressions (as in much of the western part of the project area) or where it is protected by caprock (as in parts of the North and South Routt study areas). Where caprock protects the Browns Park Formation and it occupies a topographically high position, much of it has been subject to oxidation by weathering. Therefore, any uranium minerals that were contained in the eroded or weathered portions of the target formation may have been mobilized and transported to suitable sites for mineralization.

Some of the formations underlying the Browns Park Formation - in particular the late Cretaceous and early Tertiary formations - contain coal and other hydrocarbons and are potential sources of reductants. Reductants in these formations may serve to precipitate uranium minerals within the formations or may migrate upward into the Browns Park Formation to precipitate uranium there.

In general, the bulk of the Browns Park Formation is a poorly consolidated, fine- to medium-grained, moderately sorted lithic wacke. The sand grains are commonly subrounded or subangular and there is an abundance of tuffaceous material filling void spaces and occurring as thin tuff beds. However, there is quite a wide variance from this norm. The Browns Park Formation displays a discontinuous basal conglomerate or conglomeratic sandstone which reaches a maximum thickness of approximately 300 feet (Buffler, 1967). Project drilling also penetrated limestones, slightly welded volcanics, and arkosic wackes. Sorting ranges from well sorted to poorly sorted; rounding ranges from well rounded to angular; and consolidation ranges from well cemented to unconsolidated. There is enough tuffaceous material and feldspar in the formation to provide a source of uranium for mineralization, but it is possible that additional uranium was introduced to the Browns Park Formation by the Miocene and later igneous activity.

The environments of deposition of the Browns Park Formation differ somewhat between western and eastern parts of the project area. In the West and East Yampa, Browns Park, and North Browns Park study areas, fluvial deposition dominated. Periodic ponding of the ancestral Green River resulted in some lacustrine sedimentation (Hansen, 1965); there is also evidence of eolian transportation and deposition, particularly in the upper Browns Park Formation. In the North and South Routt study areas, eolian deposition dominated and fluvial sedimentation was subordinate (Hansen, 1965; Buffler, 1967). In all study areas, the basal conglomerate was probably deposited as alluvial fans or pediment gravels. Project drilling showed that it is discontinuous and the clasts in the conglomerate are derived from rocks exposed in adjacent highland areas. The fluvial and eolian sedimentation would tend to create permeable pathways for movement of fluids, whether uraniferous, oxidizing, or reducing. However, in these depositional environments, there is a great deal of lateral variation of the sediments, so these pathways are not traceable between drill holes. Also because the target formation is generally clay-rich, overall permeability is probably less than might otherwise be expected.

As noted above, drainage in the project area during deposition of the Browns Park Formation was probably from west to east along the ancestral Green River's paleovalley then north or northeast around the north end of the Sierra Madre Range. The ancestral Yampa River probably drained northward parallel to the Park Range.

Buffler (1967) performed detailed heavy mineral analyses of samples collected from the Browns Park sands in the North Routt area and the surrounding region and found that the provenance of these sands was probably far to the south rather than directly from the Park Range. He also postulated that much of the sand had been transported and deposited by wind. Heavy mineral analysis of project samples provides less definite evidence for provenance of the sediments. Sediments sampled in the North Routt area probably were not principally derived from the neighboring Park Range, but their source is otherwise indefinite. The heavy mineral assemblage in the North Routt area is closely similar to that from the basal Browns Park Formation in the West Yampa area. Heavy mineral assemblages in shallower sediments in the West Yampa area differed from those and may have been derived from metamorphic rocks exposed in the Uinta Mountains, from terrain farther upstream along the ancestral Green River, or from other terrain to the south or east. The provenance of the tuffaceous material in the Browns Park Formation is not known.

Most Browns Park sediments display evidence of post-depositional alteration. The most common types of alteration are calcification, silicification, oxidation of ferromagnesian minerals, sericitization and argillization of feldspars, development of authigenic chlorite and pyrite, and alteration of tuffaceous material to montmorillonite. In one drill hole, SWB-27, which is adjacent to the Hahn's Peak intrusion, hydrothermal alteration produced sericitization and argillization of feldspars with replacement by calcite and crytocrystalline quartz, vermiculization of biotite, and alteration of volcanic rock fragments and glass to clay. A few fractures in these rocks were also injected by a black, glassy-looking carbonaceous material.

Oxidized Browns Park Formation sediments that were encountered by project drilling contain abundant limonite and hematite and variable amounts of montmorillonite and are colored light tan to reddish brown. The reduced portions of the target formation are colored greenish gray to white and usually contain pyrite, montmorillonite, and some fresh volcanic glass shards. The green color is mainly due to authigenic chlorite in the matrix and coating sand grains. Interstitial clay generally constitutes between 10 and 40 percent of the target formation in both oxidized and reduced zones; it is mainly montmorillonite from argillization of tuffaceous material. In places, kaolinite (from argillization of feldspars) is the dominant clay mineral.

Because fresh volcanic glass shards appear in the reduced portions of the target formation but not in the oxidized portions, it is likely that most of the formation was either deposited under predominantly reducing conditions (such as the fluvial and lacustrine sediments in the western areas) or was protected from oxidation. The eolian sandstones of the eastern areas, for example, may not have been strongly oxidized because of the lack of groundwater in the eolian environment for oxidizing reactions. Present-day reduction/oxidation boundaries are probably fairly good predictors of which portions of the Browns Park Formation have been oxidized, thereby mobilizing any uranium present. They may also indicate where reductants are or have been available to precipitate uranium minerals.

Because overall permeability of the Browns Park Formation is reduced by its high clay content, folds, faults and intraformational unconformities will be significant factors in the movement of fluids involved in mineralization. In several areas, the target formation is preserved on the downthrown blocks of post-Laramide faults; these faults are potential conduits for reductants from underlying formations. Many small faults were observed during the project throughout the project area. In the Maybell-Lay area, such small faults are numerous and often contain uranium minerals and extensive iron oxide stains.

The principal folds in the project area are the Lay syncline and the Maybell monocline. The Lay syncline is a large asymmetric fold due primarily to differential compaction of Browns Park sediments, but the north limb has been steepened by later faulting (Hansen, 1965, Izett, 1975). The Maybell monocline, a smaller feature, parallels the Lay syncline and traverses the Maybell mining district. Further information concerning the area's structural geology may be found in Buffler (1976) and Izett (1975).

Known Uranium Occurrences

No visible uranium minerals were observed during project drilling, so characteristics of uranium occurrences in the Browns Park Formation are described from mines and prospects in the Maybell district of Colorado and the Poison Basin district of Wyoming as reported by Ormond (1957) and Lewis (1977).

In both areas, uranium minerals occur in faulted Browns Park Formation sediments overlying older folded formations which contain petroleum reservoirs near the uranium occurrences. The deposits are concordant with bedding in places.

The rocks containing the uranium minerals are usually fine- to medium-grained sandstones with varying amounts of interstitial clay, sandy clays and clay beds. Most of the clay is montmorillonite and is probably argillized tuffaceous material. The deposits occur in both oxidized and reduced rocks. Figures 3, 4, and 5 illustrate some uranium deposits at the Trace Elements Corporation (presently Union Carbide Corporation) properties.

The uranium minerals occur as impregnations in sandy beds, coatings on fracture surfaces, and disseminated specks in clayey beds. They are often distributed in rings concentric with heavily limonite-stained rings or in bands in cross-bedded sandstones (Ormond, 1957).

The principal ore minerals in these deposits are coffinite and uraninite in the reduced rocks and meta-autunite with subsidiary uranophane in the oxidized zone. Tyuyamunite, meta-tyuyamunite, becquerelite-schoepite, phosphuranylite and liebigite have also been identified in these deposits (Ormond, 1957).

The most common gangue minerals reported are quartz, calcite, gypsum, jarosite, and montmorillonite; pyrite occurs in reduced rocks and limonite in oxidized rocks. In some deposits, selenium and molybdenum have been reported as associated trace elements. No uranium minerals were identified in samples from Sand Wash Basin Project drill holes.

Uranium in the Maybell district is often out of equilibrium with uranium decay products. Radon gas may readily migrate or uranium may be dissolved and transported away from its less soluble (and more radioactive) decay products. As a result, high radioactivity may not correlate with high uranium concentrations and concentrations of uranium may not display high radioactivity. For some uranium ore samples from the Maybell area, Ormond (1957) reports that radiometric assay results average from 57 percent to 86 percent of the chemical assays.

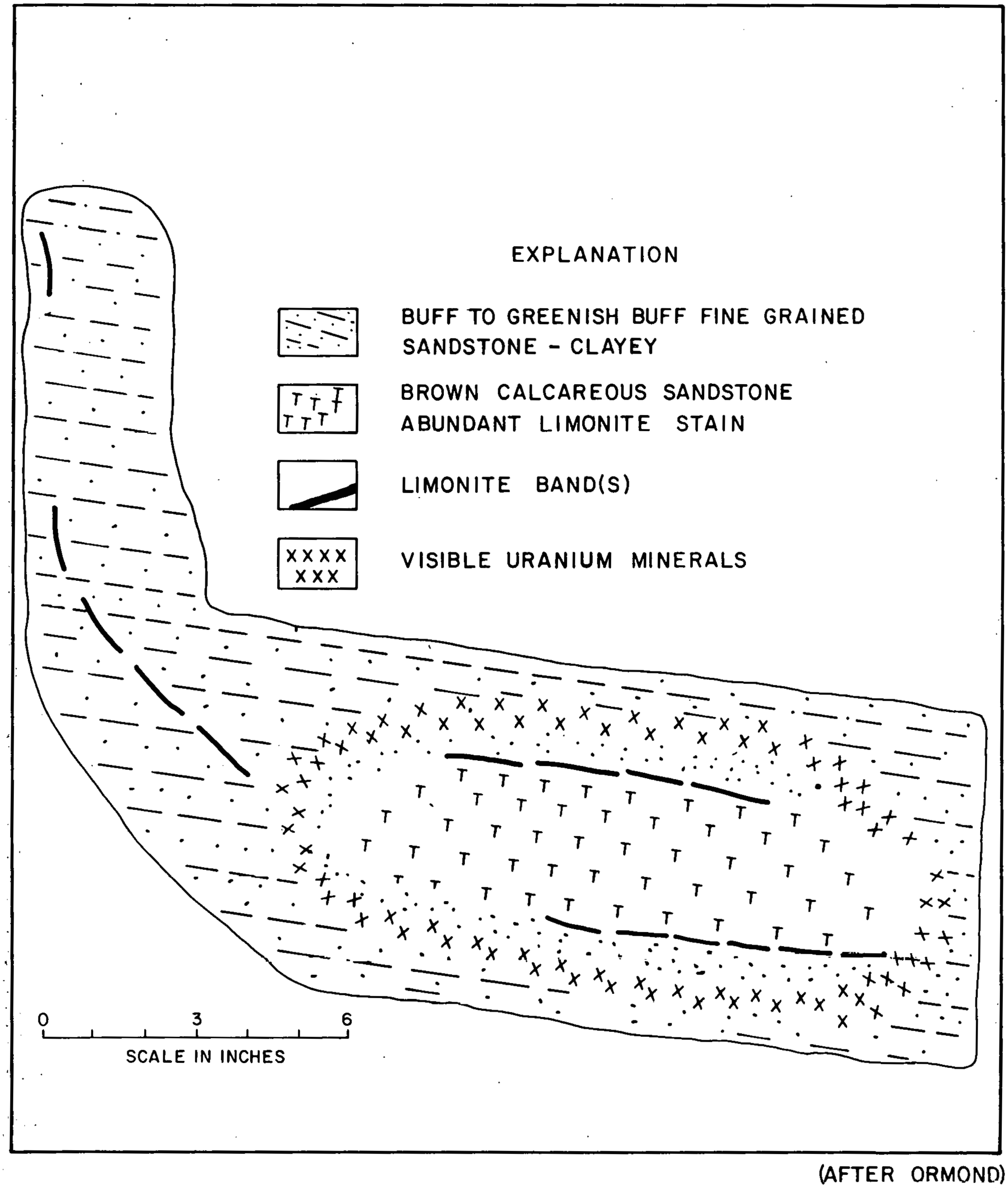


Figure 3. Association of Uranium, Limonite, and Calcium Carbonate in a Cross Section of Browns Park Sandstone in the Marge Mine

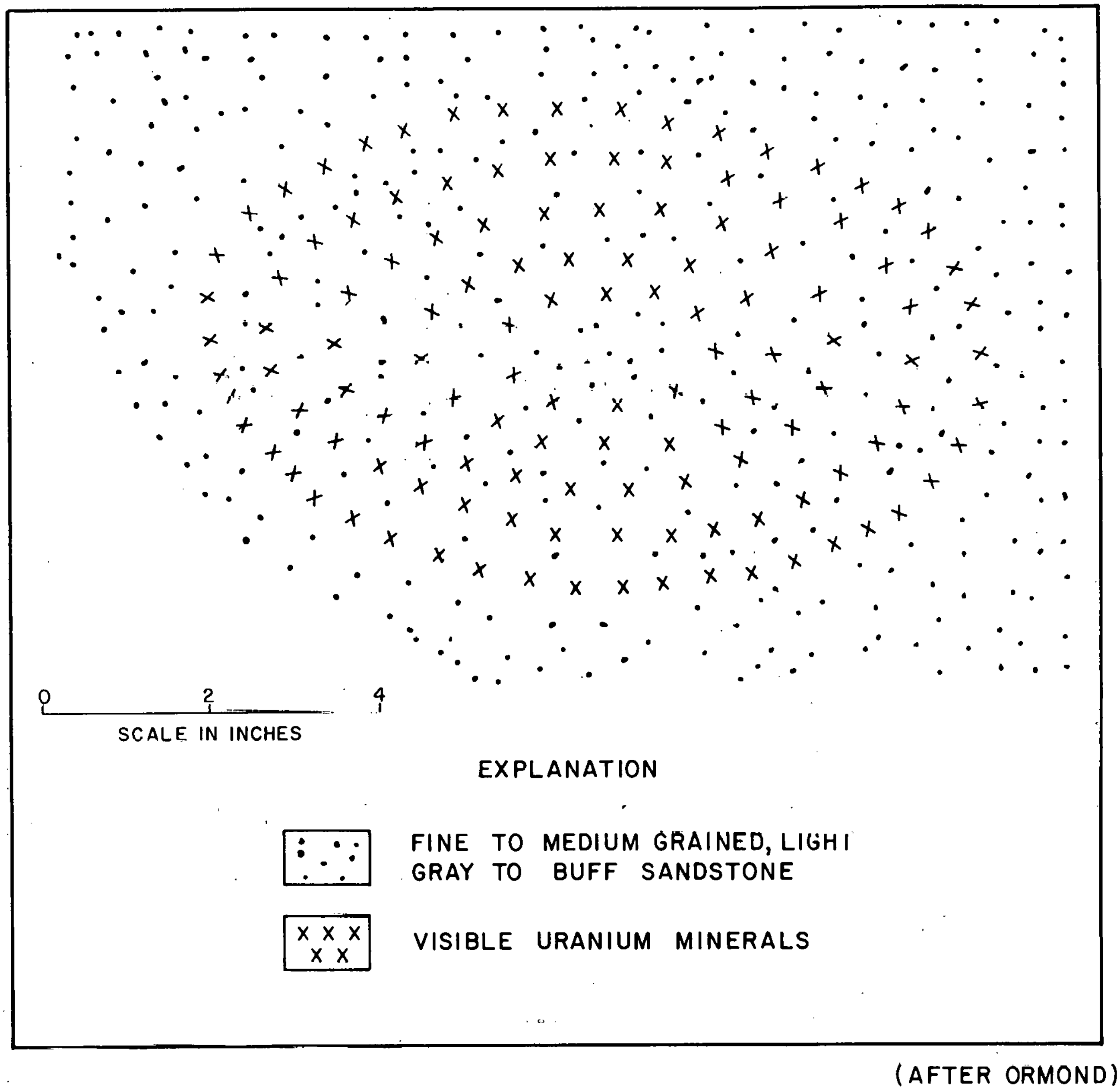
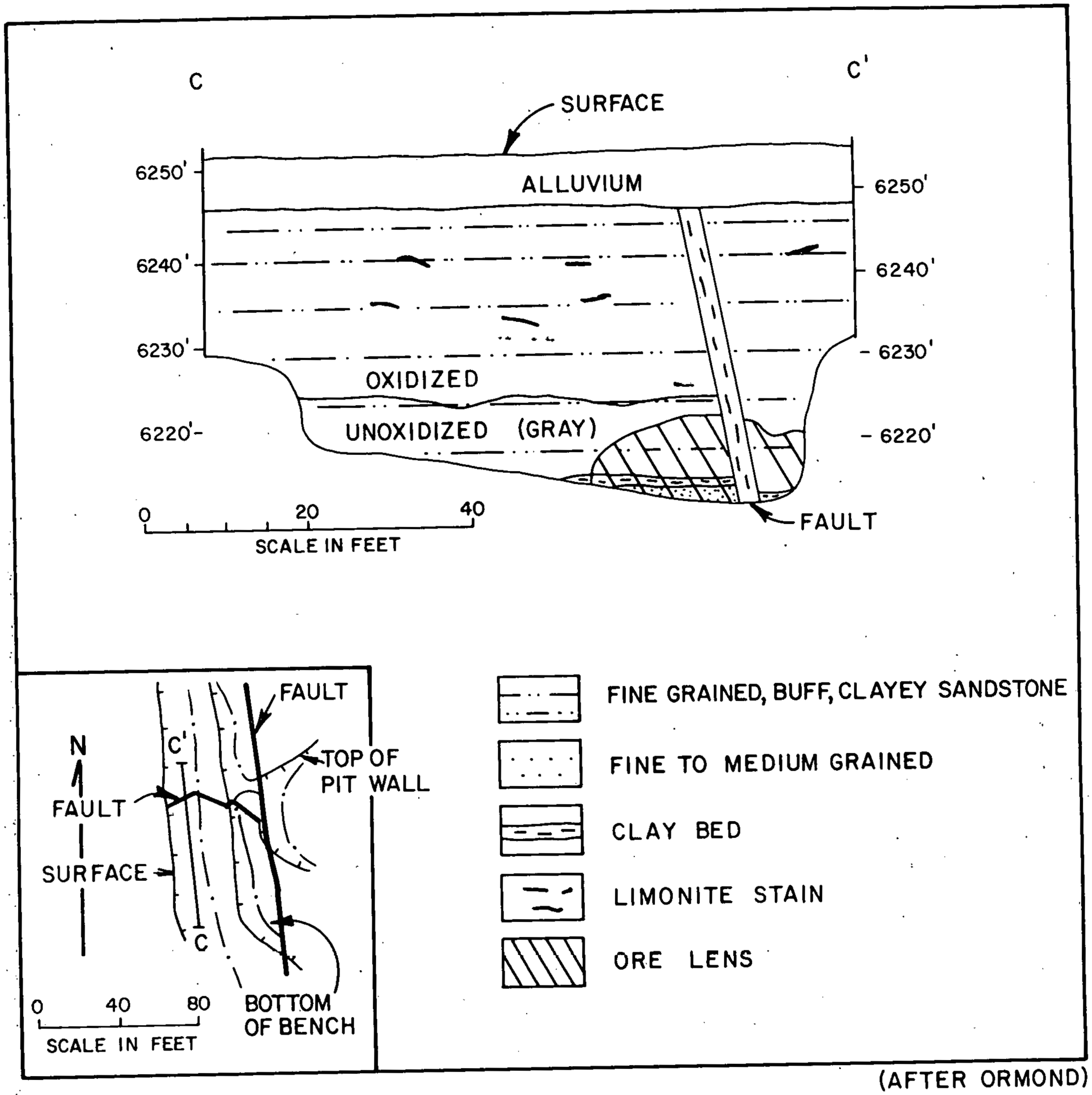


Figure 4. Concentric Rings of Visible Uranium Mineral in a Cross Section of Browns Park Sandstone in the Gertrude Mine



(AFTER ORMOND)

Figure 5. Geologic Cross Section C-C', Marge Open Pit Mine

DRILLING ACTIVITIES AND RESULTS

Project Schedule and Program

Review of the geologic literature concerning the project area commenced in November, 1977. In January, 1978, land status, environmental, and geological information gathering started and continued through mid-1979. Thirteen drill sites are on land administered by the Bureau of Land Management, four are on U.S. Forest Service land, five are on Colorado State-owned land, and two are on privately held land.

The criteria considered during selection of project drill-hole locations were: anomalously high radioactivity and/or visible uranium mineralization at the surface, favorable geological setting, even spacing of sites to provide a representative sampling of the target formation, availability of drilling and access permits, and ease of access. Drill-hole locations and related data are summarized in Table 1.

Drilling and logging was initially planned for FY 1978, but was delayed by program changes and adverse weather. Drilling and logging of the 27 project holes commenced May 18, 1979, and continued through November 4, 1979. The combined footage drilled and cored in all project holes is 26,107.5 feet (7,957.6 m); of this, 24,514.0 feet (7,471.9 m) were rotary drilled and 1,593.5 feet (485.7 m) were cored. Most of the drill sites were restored shortly after they were abandoned, but adverse weather delayed restoration of several sites at higher elevations until the summer of 1980. Detailed technical information about project drilling is presented by Callihan (1980).

Three types of samples were collected during project drilling: drill cuttings samples, core samples, and sidewall samples. Drill cuttings samples were collected at five-foot intervals by means of a mechanical sampling device (the Sample Master). This device continuously washes and sieves the cuttings as the drill operates, providing a sample of the sand-size cuttings. The limitation of this sampler is that it washes away both clay and coarser cuttings (which includes clay aggregates). The target formation is unconsolidated and contains abundant clay, so the samples collected by this device are biased toward the sand fraction. Any uranium minerals present as part of the matrix or as grain coatings may have been washed away as well. One hole (SWB-1) was completely cored except for the top 20 feet (6 m) to provide lithologic and stratigraphic base data for geophysical logging and cuttings logging. Core samples were collected from other holes at intervals selected to provide samples of representative lithologies or to confirm that the formation underlying the target formation had been penetrated and to identify the underlying formation. Sidewall samples were collected in some holes from intervals displaying anomalous radioactivity. They were intended to provide a relatively undiluted sample of possibly mineralized sediments.

Core and cuttings samples were described, packaged, and labeled in the field during drilling operations. Lithologies were described using a binocular microscope and/or hand lens and were recorded on standard BFEC logging forms. Microfiche copies of the lithology logs are in Appendix E of this report. A generalized stratigraphic columnar section of each hole is also presented in Appendix A.

Table 1. Drill-Hole Summary
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Hole Number	Rotary Feet	Rotary Meters	Core Feet	Core Meters	Total Feet	Total Meters	Elevation Feet	Elevation Meters	Qtr.	Location Sec.	T(N)	R(W)	USGS Topographic Map
SWB-1	20	6.1	1,1155.0	352.00	1,175.0	358.1	6,041	1,841.3	CW1/2	31	7	102	Maybell
SWB-2	510	155.5	10.0	3.05	520.0	158.5	6,945	2,116.8	SWNW	27	11	101	Sugar Loaf Butte
SWB-2A	881	268.5	0	0	881.0	268.5	6,942	2,115.9	SWNW	27	11	101	Sugar Loaf Butte
SWB-3	1,020	310.9	0	0	1,020.0	310.9	5,730	1,746.5	SESE	12	10	103	Lodore School
SWB-4	637	194.2	10.0	3.05	647.0	197.2	5,787	1,763.9	S1/2SE	4	9	102	Big Joe Basin
SWB-5	1,160	353.6	10.0	3.05	1,170.0	356.6	5,705	1,738.9	W1/2	30	9	101	Jack Springs
SWB-6	1,192	363.3	17.0	5.20	1,209.0	369.5	6,374	1,942.8	SW	12	8	101	Vermillion Mesa
SWB-9	1,230	374.9	10.0	3.05	1,240.0	378.0	5,907	1,800.5	NENE	35	8	98	Lone Moutain
SWB-11	500	152.4	0	0	500.0	152.4	6,043	1,841.9	S1/2SW	11	6	97	Elk Springs
SWB-11A	1,243	378.9	0	0	1,243.0	387.9	6,044	1,842.2	S1/2SW	11	6	97	Elk Springs
SWB-12	1,200	365.8	20.0	6.10	1,220.0	371.9	6,390	1,947.7	SE	6	5	96	Citadel Plateau
SWB-13	1,820	554.7	0	0	1,820.0	554.7	5,985	1,824.2	NWSW	13	7	96	Maybell
SWB-14	1,499	456.9	10.0	3.05	1,509.0	459.9	6,068	1,849.5	SWNE	20	7	95	Maybell
SWB-15	162	49.4	9.0	2.70	171.0	52.1	6,267	1,910.2	NESE	10	6	95	Citadel Plateau
SWB-16	1,140	347.5	70.0	21.30	1,210.0	368.8	6,129	1,868.0	NWSW	31	6	95	Citadel Plateau
SWB-18	1,000	304.5	50.0	15.20	1,050.0	320.0	6,345	1,934.0	SE	16	7	93	Lay SE
SWB-19	460	140.2	30.0	9.10	490.0	149.4	6,299	1,919.9	CNW	22	7	93	Lay SE

Table 1. Drill-Hole Summary
Page 2 of 2

Hole Number	Rotary Feet	Rotary Meters	Core Feet	Core Meters	Total Feet	Total Meters	Elevation Feet	Elevation Meters	Qtr.	Location Sec.	Location T(N)	Location R(W)	USGS Topographic Map
SWB-20	495	150.9	8.0	2.40	503.0	153.3	6,209	1,892.5	NWSE	36	7	94	Lay
SWB-24	952	290.2	30.0	9.10	982.0	299.3	6,898	2,102.5	SESE	8	7	91	Craig
SWB-25	264	80.5	26.0	7.90	290.0	88.4	8,202	2,500.0	SENW	10	10	87	Bears Ears Peak
SWB-26	100	30.5	10.0	3.05	110.0	33.4	8,820	2,688.3	SW	25	10	87	Meaden Peak
SWB-26A	1,624	495.0	24.0	7.30	1,648.0	502.3	9,000	2,743.2	NWNE	36	10	87	Meaden Peak
SWB-27	231	70.4	19.0	5.80	250.0	76.2	9,260	2,822.5	N1/2	8	10	85	Hahns Peak
SWB-28	1,660	506.0	0	0	1,660.0	506.0	9,370	2,856.0	NE	32	10	86	Meaden Peak
SWB-28A	1,937	590.4	58.0	17.70	1,995.0	608.1	9,370	2,856.0	NE	32	10	86	Meaden Peak
SWB-29	1,317	401.4	10.0	3.05	1,327.0	404.5	7,038	2,145.2	NENE	12	4	85	Blacktail Mountain
SWB-30	260	79.3	7.5	2.30	267.5	81.5	9,415	2,869.7	N1/2	6	2	84	Green Ridge

Portions of the cuttings and sidewall samples were submitted to the BFEC Mineralogy-Petrology Laboratory to be assayed for U_3O_8 content and/or for emission spectrometry analysis for various elements. Core samples from selected intervals in four drill holes were also submitted for detailed petrological and petrographic analysis. These samples were selected from anomalously radioactive intervals or from representative lithologies encountered by project drilling. Analytical results are presented in Appendix B of this report.

After completion of drilling, down-hole geophysical logs were obtained from each hole. The suite of logs obtained from each hole includes natural gamma, spontaneous potential, resistivity, neutron, temperature, and vertical deviation. In some holes, caliper logs were also obtained. Intervals displaying a significant thickness of anomalously high radioactivity (as determined by the BFEC geologist in the field) were relogged using a KUT tool. This tool measures total natural gamma radiation as well as natural gamma radiation in three separate spectral bands which correlate with the radiation spectra for decay of potassium (K) and daughter products of uranium (U) and thorium (T). The KUT tool does not measure gamma radiation directly from the decay of uranium and thorium; it measures gamma radiation from the decay of daughter products in the decay series of uranium and thorium. Where radioactivity was sufficiently intense, equivalent-uranium grades were calculated on the basis of gross gamma logs. Microfiche copies of all pertinent geophysical logs and the results of equivalent-uranium grade calculations are presented in Appendices C, D, and E of this report.

North Browns Park Study Area

This study area comprises approximately 25 square miles (65 km^2) in extreme northwestern Colorado and is overlain by an erosional remnant of the target formation (Plate I, Figure 6). The area can be reached from Maybell, Colorado, via Colorado State Highway 310.

The Browns Park Formation remnant is preserved on the downthrown block of a normal fault which is parallel to the older Uinta thrust fault. Along this fault, the remnant is bounded by the Wasatch and Green River Formations of Eocene age. To the west and southwest, the remnant is bounded by the Uinta Quartzite of Precambrian age cropping out on Cold Spring Mountain, which lies along the crest of the Uinta Arch. A sequence of Paleozoic and Mesozoic sedimentary rocks, which are upturned against the Uinta Quartzite, form the remnant's boundary on the south (Plate II and cross-section A-A', Plate IV).

Project drill holes in the area are SWB-2, which was abandoned due to difficult drilling conditions, and SWB-2A, an adjacent offset hole. The drill site was selected on the basis of outcrop geology and ease of access. Drilling results are summarized in Table 2.

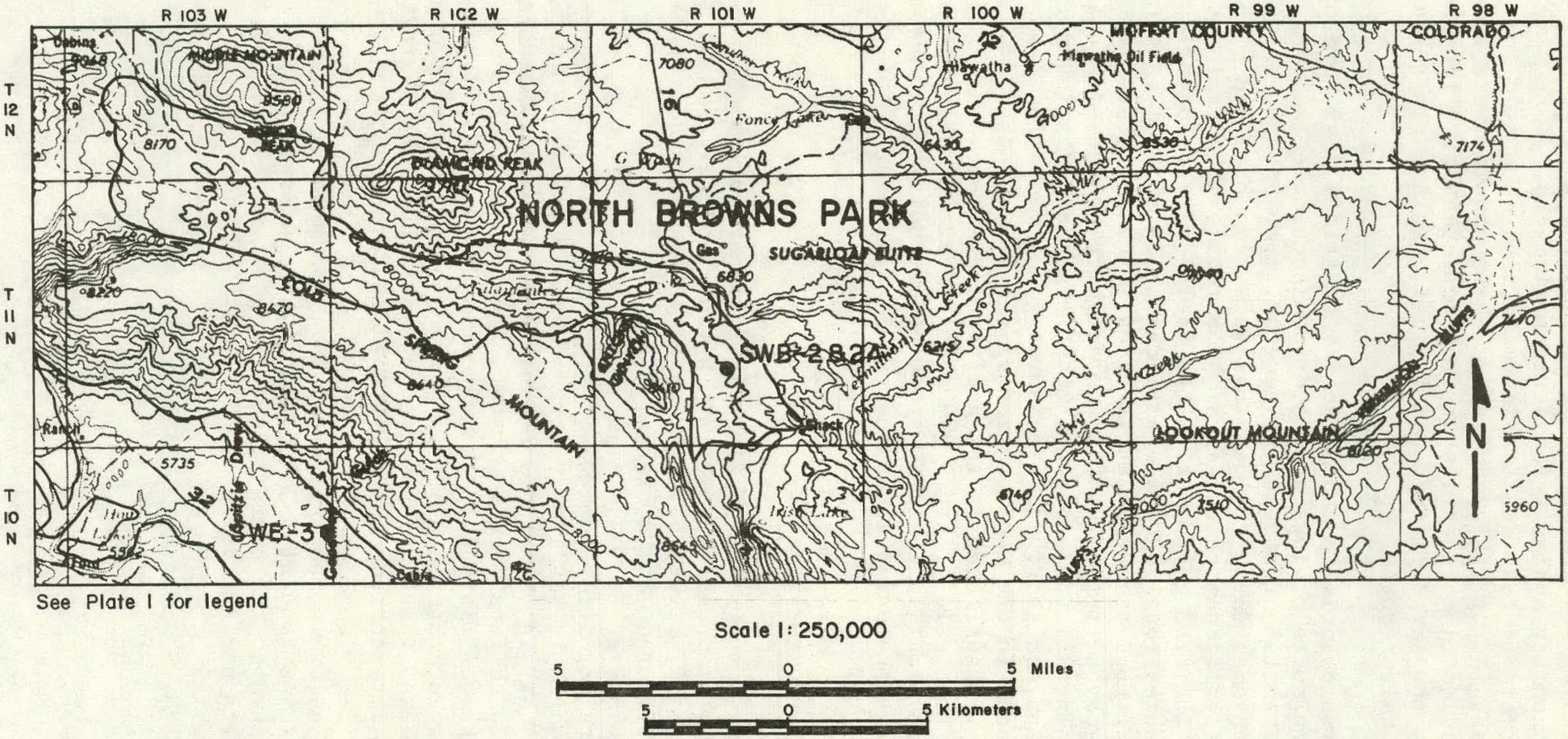


Figure 6. North Browns Park Area

Drill Hole SWB-2

In hole SWB-2, the upper 290 feet (88 m) was a clayey sandstone, feldspathic and tuffaceous, poorly sorted, fine- to medium-grained, and oxidized. Below 290 feet (88 m), the sandstone was pyritic, conglomeratic, and cemented by calcite in places. A core sample was collected from 380 to 390 feet (115 to 119 m); 3.7 feet (1.1 m) of pebbles, cobbles, and boulders derived from the Uinta quartzite were recovered. The hole was abandoned at 520 feet (158 m) due to difficult drilling conditions. Radioactivity 2-1/2 times background (200 CPS) was measured from 79 to 83 feet (24 to 25 m) which KUT logging showed to be principally from uranium and potassium decay.

Drill Hole SWB-2A

Hole SWB-2A was drilled adjacent to SWB-2, reached the Mancos Shale at 820 feet (250 m) and was bottomed at 881 feet (269 m). The upper 230 feet (70 m) of this hole was oxidized and was a clayey sandstone closely similar to the upper part of hole SWB-2. Below 230 feet (70 m), the formation was a reduced conglomeratic, calcareous sandstone closely similar to the lower part of hole SWB-2. Radioactivity approximately 2 times background (150 CPS) was measured at 77 feet (23 m) and from 721 to 734 feet (220 to 224 m). KUT logging did not measure the upper zone and showed the lower zone to be primarily the result of uranium and potassium radioactive decay.

If the sediments encountered in these two drill holes are representative of all the sediments in this study area, the Browns Park Formation here consists of a thick basal conglomerate largely derived from the rocks exposed on Cold Spring Mountain overlain by a thinner clayey sandstone. Much of the clay in the sediments appears to be argillized tuffaceous material.

Browns Park Study Area

The Browns Park study area occupies approximately 300 square miles northwest of the Little Snake River (Plate I, Figure 7). The area can be reached from Maybell, Colorado, via Colorado State Highway 318. Most project drill-hole sites lie near gravel or dirt roads maintained by Moffat County or the Bureau of Land Management.

In this area, the Browns Park Formation lies in the paleovalley of the ancestral Green River. This paleovalley is cut obliquely across the crestline of the Uinta Arch, which gently plunges to the southeast (Plate II). Outcrops of the Uinta quartzite form the southwestern boundary and part of the northeastern border of the area; elsewhere the bounding rocks are the Uinta quartzite, Paleozoic and Mesozoic sedimentary rocks, the Wasatch Formation, the Green River Formation, and the Bridger Formation.

Along the northeastern border, the paleovalley has been deepened by post-Laramide normal faulting. Much of the contact between the Browns Park Formation and older rocks is defined by normal faults. This faulting has slightly steepened the northeastern limb of the Lay syncline (also called the

Table 2. Drill-Hole Summary--North Browns Park Area

Hole No.	Location	Collar Elevation in Feet (m)	Driller's TD in Feet (m)	Geophysically Logged Depth in Feet (m)	Depth of Oxidation in Feet (m)	Depth to Basement in Feet (m)	Basement Formation
SWB-2	Section 28, T11N, R101W	6942 (2116)	520 (158)	355 (108)	290 (88)	Not reached	Not reached
SWB-2A	Section 28, T11N, R101W	6942 (2116)	881 (269)	881 (269)	230 (70)	820 (250)	Mancos Shale

Browns Park syncline), which is a broad syncline due principally to differential compaction of the Browns Park sediments (Hansen, 1965; Izett, 1975). Deformation of the Browns Park Formation and unconformities within the formation are reported in this area and are ascribed to late Cenozoic movement along normal faults in the area (Hansen, 1965, Izett, 1975).

The paleovalley containing the Browns Park sediments is rather steep-sided and appears to be deepest just northeast of the valley axis (Plate III). It is likely that the basement topography has been modified by fault movement such as that described above. Along the axis of the paleovalley, two basins can be discerned, separated by a basement high (Plate III and cross sections A-A' and B-B', Plate IV). A basement high separates this study area from the next area to the south, the West Yampa study area.

The depth of oxidation of the target formation in this area appears to be related to the elevation of the basement highs. In hole SWB-4, the basement was encountered at an elevation of 5,215 feet (1,590 m) and in hole SWB-6, at 5,179 feet (1,579 m). In both these holes, the entire target formation is oxidized. Southeast of SWB-4, the boundary between oxidized and reduced rocks was found to lie at elevations of 5,230 feet (1,594 m) and 5,137 feet (1,630 m). Thus the hypothetical surface of the redox boundary in this area slopes gently from northwest to southeast in this area at elevations near those of the basement highs encountered in SWB-4 and SWB-6 and from 110 to 200 feet (34 to 61 m) below the basement high separating this study area from the West Yampa area. The elevation of the redox boundary in this area does not appear related to likely groundwater table elevations associated with the Little Snake or Yampa Rivers. These two rivers cross the Browns Park Formation at approximately 5,600 feet (1,707 m) elevation, some 400 feet higher than the average redox boundary elevation. However, the Green River at the entrance to the Canyon of Lodore, in Browns Park, lies at approximately 5,300 feet (1,165 m) elevation, slightly higher than the elevation of the redox boundary in hole SWB-5. The depth of oxidation in this area was probably controlled by a ground-water table associated with the Green River before the courses of the Little Snake and Yampa Rivers were established. Interestingly, no reduced sediments were encountered in hole SWB-3, the hole closest to the present-day course of the Green River. However, the intensity of oxidation in this hole appears to be less below 5,125 feet (1,562 m) elevation, close to the elevation of the Green River.

In general, the Browns Park Formation in this area displays fairly thick, clean sands separated by thinner silty and clayey sands in its upper portion. Its lower portion is generally composed of thinly interbedded sand, mud, and clay. The lower portion reflects rapid deposition in a lacustrine/fluvial environment, and the upper portion represents fluvial/eolian deposition with development of channels and/or sand dunes with overbank deposits and air-fall tuffs. Only one project drill hole (SWB-5) encountered conglomeratic sediments near the base of the Browns Park Formation.

Project drill holes in the Browns Park study area are SWB-3, SWB-4, SWB-5, SWB-6, and SWB-9. Hole SWB-3 is located near a surface radiometric anomaly detected in the 1950's by an A.E.C. aerial survey. The other drill sites were selected to provide a representative sample of lateral variations in the formation and on the basis of accessibility. Project drilling results for these holes are summarized in Table 3.

Table 3. Drill-Hole Summary--Browns Park Area

Hole No.	Location	Collar Elevation in Feet (m)	Driller's TD in Feet (m)	Geophysically Logged Depth in Feet (m)	Depth of Oxidation in Feet (m)	Depth to Basement in Feet (m)	Basement Formation
SWB-3	Section 12, T10N, R103W	5730 (1747)	1020 (311)	872 (266)	1020 (311)	870 (265)	Uinta Quartzite
SWB-4	Section 4, T9N, R102W	5787 (1764)	647 (197)	647 (197)	647 (197)	572 (174)	Uinta Quartzite
SWB-5	Section 30, T9N, R101W	5705 (1739)	1170 (357)	1151 (351)	475 (145)	954 (291)	Uinta Quartzite
SWB-6	Section 12, T8N, R101W	6374 (1943)	1209 (369)	1210 (369)	1209 (369)	1195 (364)	Uinta Quartzite
SWB-9	Section 35, T8N, R98W	5907 (1800)	1204 (378)	1232 (376)	770 (235)	1020 (311)	Bridger Formation

Drill Hole SWB-3

In hole SWB-3, the upper 130 feet (40 m) consists of thick [10 to 20 feet (3 to 6 m)], clean sands with thinner interbedded muds or clayey sands. From 130 feet (40 m) to 600 feet (183 m), the bedding becomes thinner (mostly less than 3 feet or 1 m), and there is more clay and silt in the sediments. Below 600 feet (183 m), the Browns Park Formation is highly tuffaceous, poorly sorted and quite homogeneous, with only sparse thin beds of sand or clay within the mudstone. The formation is calcareous throughout. The hole penetrated the Uinta quartzite at 870 feet (265 m), and reached TD at 1,020 feet (311 m). Radioactivity 2 to 3 times background (200 to 300 CPS) was measured in the sandstone beds from 35 feet (11 m) to 128 feet (39 m), from 230 feet (70 m) to 245 feet (75 m), at 259 feet (79 m), and at 328 feet (100 m). Radioactivity associated with clay beds was measured to be 3-1/2 times background (350 CPS) from 162 feet (49 m) to 165 feet (50 m), 2 times background (210 CPS) at 510 feet (155 m), and 3 times background (320 CPS) at 573 feet (175 m). KUT logging indicates that uranium and potassium decay contribute most of the radioactivity in these zones.

Drill Hole SWB-4

In hole SWB-4, the upper 270 feet (82 m) consists of thick, clean, fine- to medium-grained sands [from 15 to 40 feet (5 to 12 m) thick] which are calcareous in places and often are fining-upward sequences of sediment. There are thin clayey or muddy beds between the sands and some tuffaceous material. From 270 to 400 feet (82 to 122 m), the target formation is a thinly bedded, calcareous, clayey sandstone, with common thin white tuff beds. The Uinta quartzite was penetrated at 570 feet (174 m), and the hole was completed at 647 feet (197 m). Radioactive anomalies in the 200 to 400 CPS range (2 to 4 times background) were common above 400 feet (122 m) in the clean sands and are illustrated in Figure 12. KUT logging indicates that radioactivity from thorium decay products is generally subordinate to that from uranium and potassium decay in these zones.

Drill Hole SWB-5

In hole SWB-5, the entire section is relatively thin-bedded and homogeneous, except for development of some clean sands in the upper 190 feet (58 m) and some coarse sand and possible conglomeratic sediment in the lowest 50 feet (15 m). The bulk of the Browns Park Formation here consists of medium- to fine-grained, moderately well sorted, tuffaceous, and calcareous sandstone with varying amounts of interstitial clay and some thin ash beds. It is oxidized to 475 feet (145 m) and reduced from there to its contact with the Uinta quartzite at 954 feet (291 m). Total depth of the hole is 1,170 feet (357 m). There are several zones of anomalous radioactivity (180 to 290 CPS or 2 to 3 times background) in the upper 240 feet (73 m) and thin ash or clay beds at 533 feet (163 m) and 600 feet (182 m) which display 3 times background radioactivity (300 CPS). KUT logging indicates that in these zones, most of the radioactivity derives from uranium and potassium decay.

See Plate I for legend

Scale 1:250,000

5 0 5 Miles

5 0 5 Kilometers

Figure 7. Browns Park Area

Drill Hole SWB-6

In hole SWB-6, the entire section is oxidized and consists of thinly interbedded, well sorted sandstone, poorly sorted clayey sandstone, and altered ash-fall tuffs. The section is feldspathic and irregularly calcite-cemented. From 770 to 780 feet (235 to 238 m), there is an altered sandy ash-fall tuff. The geophysical logs of SWB-6 show that there is a gradual increase in sediment size and development of some 2- to 3-foot (1 m)-thick sands in the bottom 80 feet of the hole. This may indicate development of a basal conglomerate or at least a coarse basal sandstone, but this was not observed in the drill cuttings. No zones of anomalous radioactivity were discovered.

Drill Hole SWB-9

In hole SWB-9, the upper 770 feet (235 m) consists of thick (greater than 10 feet or 3 m) sands that are medium- to fine-grained, moderately well sorted and slightly tuffaceous interbedded with thin (less than 3 feet or 1 m) sandy clays which are probably altered ash-fall tuffs. Below 770 feet (235 m), the formation is slightly pyritic and calcareous and the individual beds become progressively thinner with depth until at 900 feet (274 m) the target formation becomes a relatively homogeneous, moderately to poorly sorted tuffaceous sand. The formation is oxidized to a depth of 770 feet (235 m) and is reduced below to its contact with the Bridger Formation at 1,020 feet (311 m). The hole's total depth is 1,240 feet. No anomalously high radioactivity was measured.

West Yampa Study Area

This study area covers approximately 300 square miles (777 km^2) overlain by the Browns Park Formation west of the Maybell mining district (Plate I and Figure 8). The boundary between the Browns Park and West Yampa study areas is approximately defined by the watershed divide between the Little Snake and Yampa Rivers. The eastern boundary of this study area is the "excluded area" shown on Plate I.

Paved highways traversing the West Yampa study area are U. S. Highway 40 and Colorado State Highways 318 (north of Maybell) and 57 (south of Maybell).

The Browns Park Formation here lies in a relatively wide, steep-sided basin thought to be part of the paleovalley of the ancestral Green River (Plate III and cross sections B-B' and C-C', Plate IV). The Lay syncline traverses the northern half of the area from west to east, and the Axial Basin anticline (a southern extension of the Uinta Arch) traverses the southern half of the area from northwest to southeast. The Maybell monocline crosses the area parallel to and just south of the Lay syncline. Juniper Mountain, a dome on the Axial Basin anticline, rises above Browns Park sediments on the southeast margin of the study area. Cross Mountain, a faulted anticline along the Uinta Arch/Axial Basin anticline trend, forms the western margin of the study area.

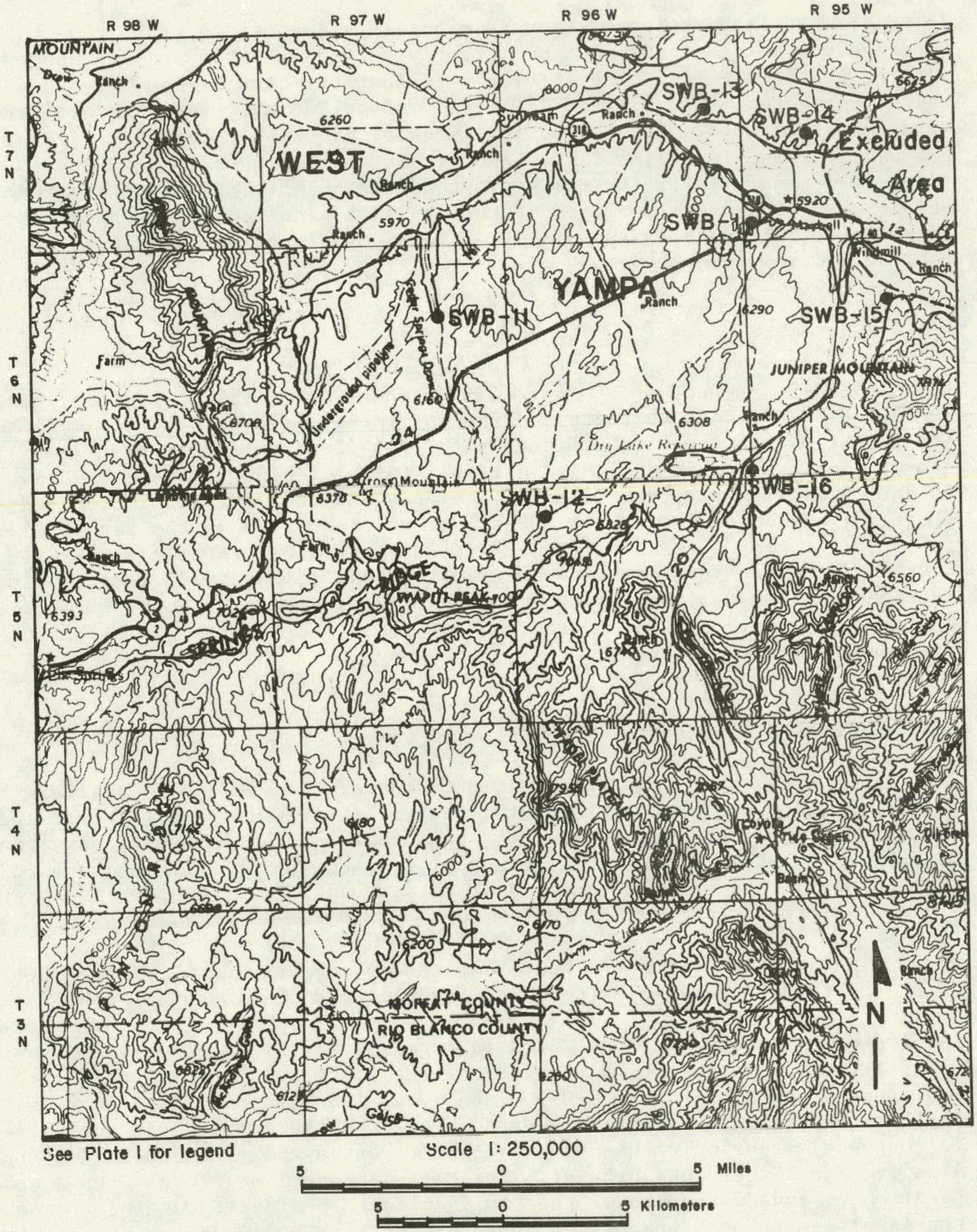


Figure 8. West Yampa Area

To the north, the Wasatch and Green River Formations of Eocene age form most of the study area boundary, along with a small area in which late Cretaceous rocks of the Williams Fork, Lewis, and Lance Formations crop out with the Fort Union Formation of Paleocene age. To the south, the study area is bounded by rocks of the Mancos, Williams Fork, and Iles Formations of late Cretaceous age, the Fort Union Formation of Paleocene age, and the Wasatch and Green River Formations of Eocene age. These rocks are exposed in a series of broad folds, the axes of which trend northwest to southeast.

Precambrian rocks of the Uinta quartzite and Paleozoic rocks of the Lodore, Morgan, and Madison Formations crop out in Cross Mountain and Juniper Mountain (Plate II). It appears that the depth of oxidation in most of this area is controlled by a ground-water table related to the Yampa River. In two holes close to the Yampa River (SWB-1 and SWB-13), the depth of oxidation corresponds closely with the elevation of the river. In three other holes farther away from the river (SWB-11A, SWB-12, and SWB-16), the elevation of the redox boundary lies from 300 to 430 feet (91 to 131 m) below the Yampa River, its depth being greater with increasing distance from the river. These observations correspond with what might be expected of a ground-water table fed by an influent river. However, in SWB-14, which is close to the Yampa River, the elevation of the redox boundary as determined by logging drill cuttings is approximately 200 feet (61 m) above the river. The depth of oxidation in this hole cannot be related to a ground-water table using available information; however, SWB-14 is close to the Maybell mining district and lies directly over the axis of the Maybell monocline. Thus it is possible that reductants ascending through the Browns Park Formation in this location have prevented the sediments in this hole from being oxidized to as great a depth as might otherwise be expected.

In general, the sediments encountered by project drilling in this area are medium- to fine-grained feldspathic quartzose sandstones with 5 to 40 percent interstitial clay, irregularly cemented by calcite and containing ash-fall tuffs. In the oxidized zone of each hole, the tuffs have been altered to montmorillonite and pyrite, and ferromagnesian minerals have been partly or completely oxidized. In the reduced zone of each hole, the tuffs are fresh or partly argillized and fresh pyrite is present in varying amounts.

The sandstones commonly display fining-upward bedding. In places, thin limestones were observed. The characteristics of these sediments indicate that the depositional environment in this area was mixed fluvial and lacustrine; probably an aggrading river valley with intermittent ponding. Drilling results are summarized in Table 4.

Drill Hole SWB-1

Hole SWB-1 was cored from 20 feet (6 m) to its TD at 1,175 feet (358 m) to provide a data base for interpretation of electric logs and drill cuttings to be collected from other project drill holes. Plate V is a detailed columnar section of this hole. In general, the target formation in this hole consists of thin- to medium-bedded (1 to 5 feet or 0.3 to 1.5 m thick) tuffaceous sandstone with varying amounts of interstitial clay derived from argillization of the tuffaceous material. It is oxidized to approximately 240 feet (73 m)

Table 4. Drill-Hole Summary--West Yampa Area

Hole No.	Location	Collar Elevation in Feet (m)	Driller's TD in Feet (m)	Geophysically Logged Depth in Feet (m)	Depth of Oxidation in Feet (m)	Depth to Basement in Feet (m)	Basement Formation
SWB-1	Section 31, T7N, R95W	6041 (1841)	1175 (358)	1170 (357)	240 (73)	1150 (351)	Mancos Shale
SWB-11	Section 11, T6N, R97W	6043 (1842)	500 (152)	Not logged	500 (152)	Not reached	Not reached
SWB-11A	Section 11, T6N, R97W	6044 (1842)	1243 (379)	1240 (378)	540 (165)	1085 (331)	Upper Paleozoic Limestone
SWB-12	Section 6, T5N, R96W	6390 (1948)	1220 (372)	1066 (325)	1020 (311)	Not reached	Not reached
SWB-13	Section 13, T7N, R96W	5985 (1824)	1820 (555)	1807 (551)	190 (58)	1084 (330)	Iles Formation
SWB-14	Section 20, T7N, R95W	6068 (1850)	1509 (460)	1501 (458)	65 (20)	1454 (443)	Mancos Shale
SWB-15	Section 10, T6N, R95W	6267 (1910)	171 (52)	165 (50)	171 (52)	156 (48)	Morgan Formation
SWB-16	Section 31, T6N, R95W	6129 (1868)	1210 (369)	1210 (369)	720 (219)	1163 (354)	Morrison Formation

with a gradational redox boundary. Below this boundary, much of the tuffaceous material is fresh, and calcite cement is common. The bedding in many places fines upward and where the sediment is finer, the clay content usually is greater. Three radioactive anomalies 2 times background (200 CPS) were detected in the target formation: at 468 feet (143 m), from 626 to 629 feet (191 to 192 m), and at 774 feet (236 m). In the Mancos Shale (the underlying formation in this hole), radioactivity 2 times background (200 CPS) was measured from 1,154 to 1,160 feet (352 to 354 m) and at 1,167 feet (356 m). KUT logging indicates that radioactive decay of uranium contributes a significant portion of the total gamma radiation in each of these zones.

Drill Holes SWB-11 and SWB-11A

Holes SWB-11 and SWB-11A are located in the western portion of the study area to provide representative sampling of lateral variations within the Browns Park Formation. SWB-11 was drilled using an air foam type drilling fluid and was abandoned when the hole collapsed. SWB-11A is an adjacent offset drill hole. The section here is similar to the section encountered in hole SWB-1: medium- to thinly-interbedded, moderately well to poorly sorted, medium- to fine-grained, tuffaceous, feldspathic quartzose sandstones; sandy ash-fall tuffs, partly or completely argillized; and sparse, thin, sandy limestones (logged as calcite-cemented sandstones). The target formation is oxidized from the surface to 540 feet (154 m) depth and reduced below this depth to its contact with an Upper Paleozoic limestone at 1,085 feet (331 m). Above 800 feet (244 m), background radioactivity in SWB-11A is lower than in most other project drill holes; it is approximately 60 to 70 CPS. In the top 20 feet (6 m) of SWB-11A, gamma radioactivity is about 2 times background (120 CPS), and from 450 to 464 feet (137 to 141 m), it is approximately 2.5 to 3 times background (150 to 200 CPS). This hole was not logged with the KUT probe.

Drill Hole SWB-12

Hole SWB-12, near the southern margin of the study area, is located near surface uranium prospects in the target formation. It was drilled to 1,220 feet (372 m) and abandoned before reaching the base of the Browns Park Formation. Because part of the hole collapsed, only 1,066 feet (325 m) were geophysically logged. The section here is similar to that encountered in holes SWB-1, SWB-11, and SWB-11A, except that it contains far less calcite. The target formation is oxidized from the surface to 1,020 feet (311 m) and reduced below. No anomalous radioactivity was detected.

Drill Hole SWB-13

Drill hole SWB-13 is near surface uranium prospects along the northern margin of the study area. The section displays variable sorting and is medium- to fine-grained, tuffaceous, feldspathic quartzose sandstone with sparse calcite-cemented "ribs" (possibly sandy limestones) and with interbedded sandy or silty clay beds which are usually partly or completely argillized air-fall tuffs. From the surface to approximately 460 feet, the sand and clay beds are nearly equal in proportion and are from 2 to 10 feet (1 to 3 m) thick. The target formation is oxidized to a depth of 190 feet (58 m) and reduced from there to its contact with the Iles Formation at 1,084 feet (330 m). At 900 feet, a radioactive anomaly 2 times background (200 CPS) was detected. The KUT probe was not used in this hole.

Drill Hole SWB-14

SWB-14 also lies near uranium prospects along the northern margin of the study area. The sediments encountered in this hole are remarkably homogeneous: Thin- to medium-interbedded, moderately well sorted sandstone, sandy clay, and mixtures of sand, clay, and silt. The section is tuffaceous throughout and pyritiferous and calcareous in the reduced zone, which is from 65 feet (20 m) to the contact between the target formation and the Mancos Shale at 2,454 feet (443 m). Below 975 feet (297 m), fresh pumice fragments were observed in the drill cuttings. A zone of 2 to 2.5 times background (200 to 250 CPS) was measured from the surface to 60 feet. Two other radioactive anomalies were detected in SWB-14, both approximately 2 times background; one was at 864 feet (263 m), the other at 932 feet (284 m). KUT logging indicates that uranium decay products contribute more radioactivity in these zones than do thorium decay products.

Drill Hole SWB-15

SWB-15 is located on the northwest flank of Juniper Mountain at the site of a radioactive anomaly detected by airborne radiometrics. From the surface to 108 feet (33 m), the target formation is a tuffaceous, poorly sorted sandstone composed of quartz and calcite grains in a clay matrix. Below 108 feet (33 m), it is a conglomerate containing quartzite and limestone clasts in a clayey matrix. The section is oxidized from the surface to the hole's bottom at 171 feet (52 m); the Morgan Formation, encountered at 156 feet (48 m), is so weathered that its contact with the target formation is gradational, passing from the Morgan Formation upward through a regolith into the Browns Park Formation. Traces of limonite, hematite, and tarnished pyrite were observed in cuttings from the upper 15 feet (5 m) and lower 50 feet (15 m) of the target formation, which suggests that sediments in this hole have been less intensely oxidized than sediments in the oxidized zones of other project drill holes. Radioactivity 2 to 4.5 times background (200 to 440 CPS) was measured at the top of the conglomerate from 108 to 122 feet (33 to 37 m). KUT logging indicates that thorium decay products contribute a negligible proportion of the radioactivity. This radioactive zone was analyzed for equivalent U_3O_8 ore grade and was calculated to contain 6.0 feet (1.8 m) of 0.004 percent equivalent U_3O_8 from 108.0 to 114.5 feet (32.9 to 34.9 m).

Drill Hole SWB-16

SWB-16 is near some uranium prospects along the southern margin of the study area, just west of Juniper Mountain. The target formation is oxidized from the surface to 720 feet (219 m) and reduced from there to its contact with the Morrison Formation at 1,163 feet (334 m). Sediments in the oxidized zone consist of fine- to medium-grained, tuffaceous, calcareous, feldspathic sandstone with varying amounts of interstitial clay and sparse, thin, argillized, ash-fall tuffs. In the reduced zone, sediments are similar to those in the oxidized zone, except that they contain as much as 2 percent pyrite. At 815 feet (248 m), a one-foot-thick zone of radioactivity 2 times background (200 CPS) was measured but was not investigated using the KUT probe.

East Yampa Study Area

This study area covers approximately 100 square miles (260 km^2) of Browns Park Formation outcrop between the "excluded area" to the west and Craig, Colorado, to the east (Plate 1, Figure 9). Most of the area is traversed by U. S. Highway 40. An erosional remnant of the Browns Park Formation lying northwest of Craig can be reached via Moffat County Road 7.

The erosional remnant northwest of Craig is preserved on the downdropped blocks of two parallel normal faults. Cedar Mountain, capped by a basalt flow remnant, rises above the rest of this Browns Park Formation remnant. The Fort Union Formation of Paleocene age crops out along the southwest boundary of the remnant and the Wasatch Formation of Eocene age forms the northeast boundary.

The Browns Park Formation lies in the easternmost part of the ancestral Green River's paleovalley in most of the East Yampa study area. The paleovalley is rather steep-sided here, and some parts of it seem to have been deepened somewhat by fault movements. Even so, it is not as deep here as it is to the west (Plate III).

Along the northern border of this study area, the Lance Formation of late Cretaceous age and the Fort Union and Wasatch Formations of early Tertiary age crop out. The southern border of the study area is defined by outcrops of the Lance, Williams Fort, Iles, and Mancos Formations, all of late Cretaceous age (Plate II and cross section C-C', Plate IV). The axis of the Lay syncline (or Browns Park syncline) trends east-west across the study area. The Maybell monocline, parallel to and just south of the Lay syncline, dies out in the "excluded area".

Four project drill holes are located in the East Yampa area: SWB-18, SWB-19, SWB-20, and SWB-24. The sites of SWB-18, SWB-19, and SWB-20 were selected to test for easterly and southerly extensions of known mineralization in the "excluded area". The site of SWB-24 was selected to sample the Browns Park Formation in an unexplored erosional remnant. Drilling results are summarized in Table 5.

Figure 9. East Yampa Area

Table 5. Drill-Hole Summary--East Yampa Area

Hole No.	Location	Collar Elevation in Feet (m)	Driller's TD in Feet (m)	Geophysically Logged Depth in Feet (m)	Depth of Oxidation in Feet (m)	Depth to Basement in Feet (m)	Basement Formation
SWB-18	Section 16, T7N, T93W	6345 (1934)	1050 (320)	1043 (318)	85 (26)	456 (139)	Fort Union Formation
SWB-19	Section 22, T7N, R93W	6299 (1920)	490 (149)	471 (144)	80 (24)	452 (138)	Lewis Shale
SWB-20	Section 36, T7N, R94W	6209 (1893)	503 (153)	501 (153)	50 (15)	30 (9)	Iles Formation
SWB-24	Section 8, T7N, R91W	6898 (2103)	982 (299)	982 (299)	540 (165)	902 (275)	Fort Union Formation

Drill Hole SWB-18

In drill hole SWB-18, the Browns Park Formation consists of poorly sorted, fine- to medium-grained, tuffaceous, calcareous sandstone with varying amounts of clay and silt matrix. The proportion of silt and clay increases with depth. There are a few poorly developed, better sorted sands in the upper 150 feet (46 m) of the hole and some thin ash-fall tuffs scattered through the section. The upper 85 feet (26 m) of the target formation is oxidized; it is reduced from there to its contact with the Fort Union Formation at 456 feet (139 m). Gaseous hydrocarbons were detected in the drill cuttings during drilling. Anomalous radioactivity was measured in the target formation below 290 feet (88 m). KUT logging indicates that most of the radioactivity is in the uranium and potassium spectral bands. The radiometric data were used to calculate equivalent uranium ore grade percentages, and the results are presented in Appendix D. Samples from several radioactive horizons were submitted for uranium assay, and uranium oxide concentrations were found to be slightly lower than expected on the basis of equivalent-uranium grade calculations (see Appendix C); it is not known whether this is due to the sampling procedure (see Part IV, sec. 1) or a disequilibrium situation (see Part III, sec. 3).

Drill Hole SWB-19

In drill hole SWB-19, the Browns Park Formation consists mainly of fine-grained or fine- to medium-grained, poorly sorted, calcareous, tuffaceous sandstone with abundant thin ash-fall tuffs partly or completely altered to clay. The target formation is oxidized to a depth of 80 feet (24 m) and reduced from there to its contact with the Lewis Shale at 452 feet (138 m). Gaseous hydrocarbons were detected in the drill cuttings during drilling. Anomalous radioactivity was measured in the target formation from approximately 130 feet (40 m) to its base. Anomalous radioactivity was also detected in the underlying Lewis Shale. Most of the radioactivity measured was in the uranium and potassium spectral bands of the KUT probe. The radiometric data were used to calculate equivalent uranium ore grade percentages, and samples were submitted for uranium assay; the analytical results are presented in Appendices C and D. Again, uranium oxide concentrations were somewhat lower than expected on the basis of equivalent-uranium grade calculations, perhaps for the same reasons as mentioned above.

Drill Hole SWB-20

SWB-20 encountered a 30-foot(9-m)-thick layer of the Browns Park Formation overlying the Iles Formation of Cretaceous age. The target formation here consists of a fine- to medium-grained, poorly sorted, calcareous, tuffaceous sandstone. Oxidation extends 20 feet (6 m) into the Iles Formation. No anomalous radioactivity was measured in the Browns Park Formation. In the Iles Formation, however, zones of radioactivity 2 to 3 times background (200 to 300 CPS) were detected from 45 to 50 feet (14 to 15 m) and at 66 feet (20 m), 88 feet (27 m), 196 feet (60 m), and 243 feet (74 m). The two uppermost zones may be associated with the oxidation/reduction boundary, and the lower three zones are associated with clay or shale beds. These zones were not investigated with the KUT tool.

Drill Hole SWB-24

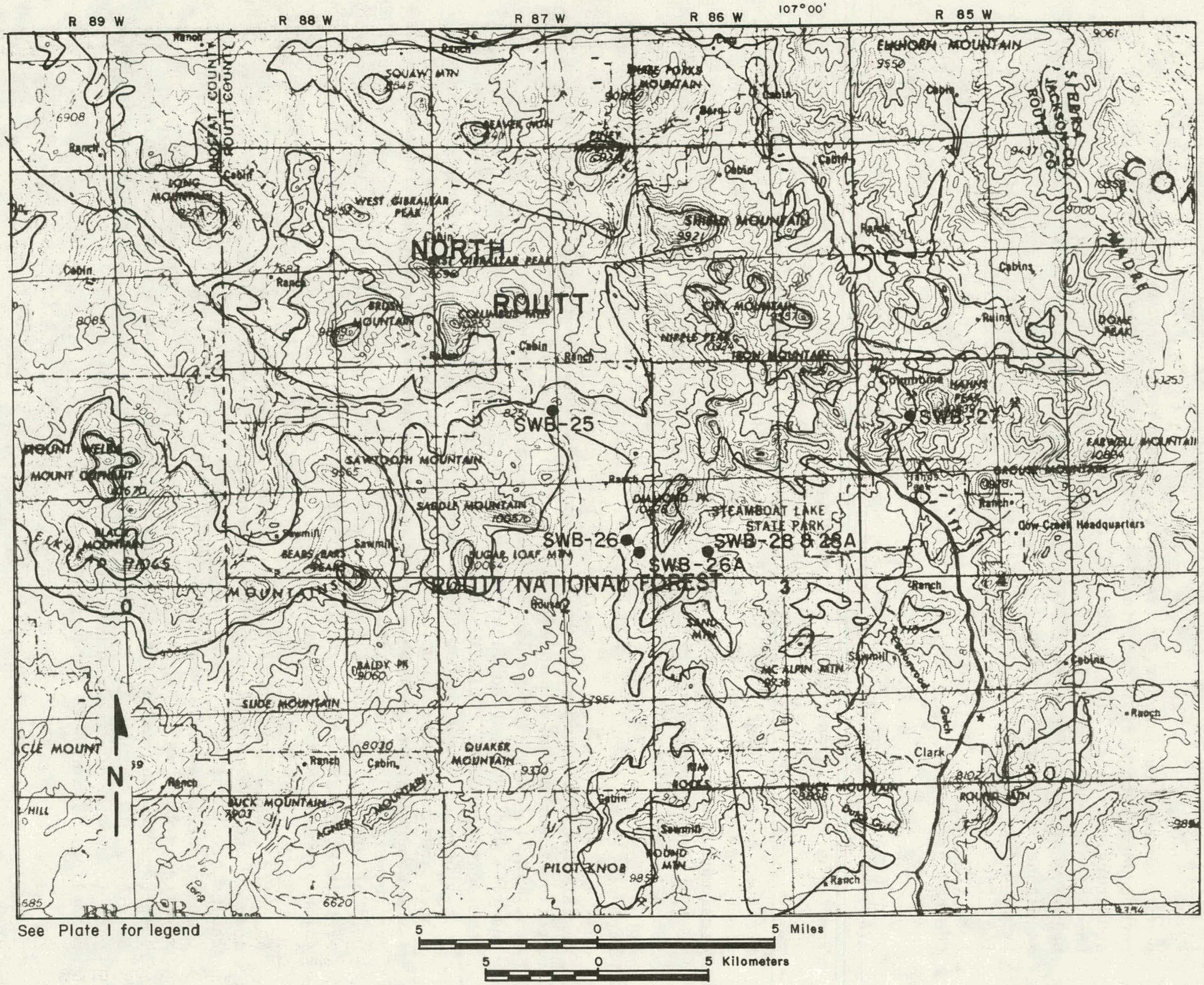
In drill hole SWB-24, the upper 540 feet (165 m) of the Browns Park Formation is oxidized and consists of medium to thick (3 to 18 feet or 1 to 5 m) beds of poorly sorted, tuffaceous, feldspathic, locally calcareous sandstone interbedded with medium to thin (less than 3 feet or 1 m) beds of clayey sandstone and sandy clay. From 540 feet (165 m) to the top of the Fort Union Formation at 902 feet (275 m), the target formation is reduced and is a thinly bedded medium- to fine-grained, tuffaceous, feldspathic, locally calcareous sandstone with varying amounts of clay matrix. Radioactivity approximately twice background (200 CPS) was detected in the Browns Park Formation at 597 feet (182 m), from 700 to 706 feet (213 to 215 m), at 760 feet (232 m), 805 feet (245 m), and 844 feet (257 m). These zones were not investigated with the KUT probe.

North Routt Study Area

The North Routt area comprises approximately 300 square miles (777 km^2) north and northwest of Steamboat Springs, Colorado. The Browns Park Formation crops out discontinously in the area as erosional remnants preserved in grabens, on the downthrown side of faults, under caps of volcanic rocks, and where igneous dikes and sills retard erosion of the intruded sediments. These erosional remnants range in size from less than one square mile (2-1/2 km^2) to approximately 150 square miles (389 km^2). The principal roads traversing the area are maintained by Routt County or the U.S. Forest Service; also, an unnumbered paved road connects Hahns Peak Village, Colorado, with Steamboat Springs (Figure 10).

In this area, the Browns Park Formation rests on a structurally deformed erosional surface which once sloped westward from the crest of the Park Range. From east to west, rocks ranging from Precambrian to early Tertiary in age underlie and crop out adjacent to the Browns Park Formation (Plate II). Intermediate to basic dikes, sills, stocks, and diatremes (such as the Hahns Peak stock and the dikes at Pilot Knob) inject the Browns Park sediments in places and intermediate-composition volcanic rocks cap parts of the formation, as at Sand Mountain and Meaden Peak (Buffler, 1967) (Plates I and III). The general structural relationships in this area are illustrated by cross section D-D', Plate IV. Buffler (1967) presents a cross section of the western part of this study area and a contour map drawn on the base of the Browns Park Formation in the North Routt area.

As noted above, the Browns Park Formation is preserved in parts of the study area on the downthrown blocks of various post-Laramide faults. Most of these faults are parallel to Laramide-age faults but moved in the sense opposite to that of the Laramide movement (Buffler, 1967; Izett, 1975). Buffler (1967) reports as much as 2,000 feet (600 m) of displacement on one of the post-Laramide faults in the study area and lesser, though considerable, displacements on others. He also states that some of the post-Laramide faults vary in amount of displacement along their lengths, and may even fade into monoclinal flexures as throw decreases.



See Plate I for legend

Figure 10. North Routt Area

In general, the Browns Park Formation in this area is poorly consolidated, poorly to moderately well sorted, tuffaceous, feldspathic, quartzose sandstone with varying amounts of clay matrix and calcite cement. A basal conglomerate was encountered in some project drill holes in this study area; it contains pebbles and cobbles of plutonic and metamorphic rocks most likely derived from the nearby Park Range.

In this area, the Browns Park Formation appears to consist of fluvial and eolian sediments eroded from the Park Range and deposited in the adjacent basin to the west; a depositional environment similar to the intermontane basins of the Wyoming Basin physiographic province. However, Buffler (1967) performed a detailed heavy mineral analysis of samples from the Browns Park and other formations in the North Routt area as well as stream sediment samples from the Park, Gore, Sawatch, and Elk Mountains and found that the Park Range could not have provided the heavy mineral assemblage present in this part of the Browns Park Formation. He postulates a source area for the Browns Park sandstones far to the south, possibly in the southern Gore Range, the Elk Mountains near Aspen, Colorado, or the Sawatch Range and San Juan Mountains of southern Colorado. Furthermore, on the basis of detailed sedimentologic work and field mapping, Buffler (1967) indicates that most of the primary sedimentary structures and sedimentology of the Browns Park Formation in this area indicate considerable eolian transport and deposition in an eolian environment.

There are six project drill holes in the North Routt area, one of which is an offset drill hole adjacent to a hole abandoned due to difficult drilling and another of which is a hole offset approximately 1/2 mile (1 km) from a hole which may not have encountered the target formation. Drill-hole locations were selected to sample relatively unexplored portions of the target formation and on the basis of ease of access. Drilling results are summarized in Table 6.

Drill Hole SWB-25

SWB-25 is adjacent to a fault that bounds a portion of the Browns Park Formation. From the surface to 100 feet (30 m), the target formation is a fine- to medium-grained, poorly sorted, feldspathic sandstone, tuffaceous in part, and it is oxidized. Below 100 feet (30 m) lies the basal conglomerate, which is partly oxidized and contains traces of pyrite. The underlying formation is the Lewis Shale, which was penetrated at 130 feet (40 m). No anomalous radioactivity was detected.

Drill Hole SWB-26

SWB-26 is located adjacent to the mapped contact between the Browns Park Formation and the Lewis Shale. The Lewis Shale was penetrated at 55 feet (17 m). The sediments above that are oxidized and consist of pebbles, cobbles, and boulders of intermediate composition, volcanic rocks with a sandy matrix composing approximately 15 to 20 percent of the sediment. The volcanic clasts are angular to subrounded. It is uncertain whether these sediments are part of the Browns Park or are a younger surficial deposit. No anomalous radioactivity was detected.

Table 6. Drill-Hole Summary--North Routt Area

Hole No.	Location	Collar Elevation in Feet (m)	Driller's TD in Feet (m)	Geophysically Logged Depth in Feet (m)	Depth of Oxidation in Feet (m)	Depth to Basement in Feet (m)	Basement Formation
SWB-25	Section 10, T10N, R87W	8202 (2500)	290 (88)	291 (89)	100 (30)	130 (40)	Lewis Shale
SWB-26	Section 25, T10N, R87W	8820 (2688)	110 (34)	110 (34)	55 (17)	55 (17)	Lewis Shale
SWB-26A	Section 36, T10N, R87W	9000 (2743)	1648 (502)	1648 (502)	80 (24)	1496 (456)	Lewis Shale
SWB-27	Section 8, T10N, R85W	9260 (2822)	250 (76)	250 (76)	250 (76)	180 (55)	Mancos Shale
SWB-28	Section 32, T10N, R86W	9370	1660	1662	520	Not reached	Not reached
SWB-28A	Section 32, T10N, R86W	9370 (2856)	1995 (608)	1995 (608)	420 (128)	1864 (568)	Iles Formation

Drill Hole SWB-26A

Because of the uncertainty concerning the sediments in SWB-26, an offset hole, SWB-26A, was drilled approximately 1/2 mile (1 km) to the east-southeast. In this hole, 1,496 feet (456 m) of Browns Park Formation sediments were penetrated; the Lewis Shale underlies the target formation here. The upper 80 feet (24 m) is oxidized, the remainder of the section appears to be partly oxidized; it displays wide variation in alteration of tuffs and feldspars and contains both pyrite and limonite. Otherwise, the target formation in this hole is remarkably homogeneous. It is a fine-grained, moderately well sorted, tuffaceous, feldspathic sandstone. The clay matrix varies from 10 to 35 percent of the rock, and there are scattered calcite-cemented "ribs". A core sample representing the interval from 507.0 to 507.4 feet (154.5 to 154.7 m) was submitted for petrographic analysis; the results are presented in Appendix B. No anomalous radioactivity was detected.

Drill Hole SWB-27

SWB-27 is adjacent to the igneous intrusion at Hahns Peak. The section in this hole is fairly complex, but in general, it grades from a tuffaceous sandstone at the surface to a pebble-cobble conglomerate at 180 feet (55 m) where the Browns Park Formation contacts the Mancos Shale. The formation displays varying degrees of post-depositional alteration apparently related to the Hahns Peak intrusion. A core sample representing a portion of the basal conglomerate between 145 and 150 feet (44 to 46 m) was submitted for petrographic analysis and the results are presented in Appendix B. From 40 to 42 feet (12 to 13 m), radioactivity 3 times background (300 CPS) was measured but was not investigated using the KUT tool.

Drill Holes SWB-28 and SWB-28A

SWB-28 and SWB-28A are located on the east side of Sand Mountain and were intended to penetrate the entire Browns Park Formation where it is thought to reach its greatest thickness. When hole SWB-28 was abandoned short of the base of the Browns Park Formation, an offset hole, SWB-28A, was drilled adjacent to it and reached the underlying Iles Formation at 1,864 feet (568 m). In both holes, the target formation is composed of fine- to medium-grained, poorly to moderately well sorted, tuffaceous, feldspathic sandstone with variable amounts of clay matrix, occasional thin clay beds, and scattered traces of calcite. There were some significant differences between the holes, however. In hole SWB-28, the oxidized zone penetrated 100 feet (30 m) deeper than in hole SWB-28A. Also, below 500 feet (152 m) in both holes, numerous zones of anomalous radioactivity (from 2 to 40 times background) were detected, but by comparing the geophysical logs of the two holes, it was found that the zones are associated with different beds and lie at different depths in the two holes. Equipment difficulties prevented KUT logging of hole SWB-28, but in hole SWB-28A, KUT logging shows that thorium decay products do not contribute a significant proportion of the total gamma radioactivity. Using the gamma logs, equivalent-uranium grade uranium oxide concentrations were calculated, and cuttings samples from some of the radioactive intervals were assayed for uranium content. The results are presented in Appendices C and D. The surprisingly low concentrations may be the result of sampling procedures (see Part IV, sec. 1) or a disequilibrium situation (see Part III, sec. 3). A core sample representing the interval from 922.0 to 922.4 feet (281.0 to 281.1 m) in hole SWB-28A was submitted for petrographic analysis, and the results are presented in Appendix B.

South Routt Study Area

This area consists of Browns Park Formation erosional remnants cropping out in a 150-square-mile (46 km^2) area south of Steamboat Springs, Colorado (Plate I; Figure 11). Colorado State Highway 131 traverses the area.

The geological setting of this study area is almost identical to that of the North Routt study area. The Browns Park Formation is preserved on the downthrown blocks of post-Laramide faults. These faults are parallel to Laramide faults with movement in the opposite sense to the Laramide movements. The principal difference in the geologic setting between the two areas is that the igneous rocks intruding and capping the Browns Park Formation are of basic composition in this area in contrast to the mixture of intermediate- and basic-composition igneous rocks in the North Routt area. The general structural and stratigraphic relationships are illustrated by Plate II and cross section E-E', Plate IV.

There are two project drill holes in this area: SWB-29 and SWB-30. Hole SWB-29 was intended to sample the target formation in a low-lying area; hole SWB-30 was to sample the target formation in a topographically high area and is located near a site of anomalously high thorium radioactivity detected by a BFEC in-house radiometric survey. Drilling results are summarized in Table 7.

Drill Hole SWB-29

In hole SWB-29, the target formation is oxidized from the surface to its contact with the Mancos shale at 1,210 feet (402 m). The Browns Park Formation in this hole is a thinly bedded, fine-grained, calcareous, tuffaceous, feldspathic sandstone with thin interbeds of clay and calcite-cemented sandstone. There is generally an abundant clay matrix (15 to 40 percent), possibly argillized tuffaceous material. Below 1,030 feet (314 m), it is locally conglomeratic, containing pebbles of metamorphic and/or plutonic rocks. Limonite is common throughout. Radioactivity ranging from 2 to 4-1/2 times background (200 to 450 CPS) was measured at 15 feet (5 m), 201 feet (61 m), from 414 to 420 feet (126 to 128 m), from 724 to 728 feet (221 to 222 m), at 771 feet (235 m), 940 feet (287 m), 991 feet (302 m), 1,001 feet (305 m), 1,096 feet (334 m), 1,010 feet (336 m), and 1,172 feet (357 m). Only 1,189 feet (362 m) of SWB-29 was geophysically logged because the hole collapsed below that point. The uranium oxide grade equivalent to the measured gamma radiation was calculated to be three feet (1 m) of 0.003 percent U_3O_8 from 725 to 728 feet (221 to 222 m). KUT logging shows that this radioactivity is primarily the result of uranium decay products.

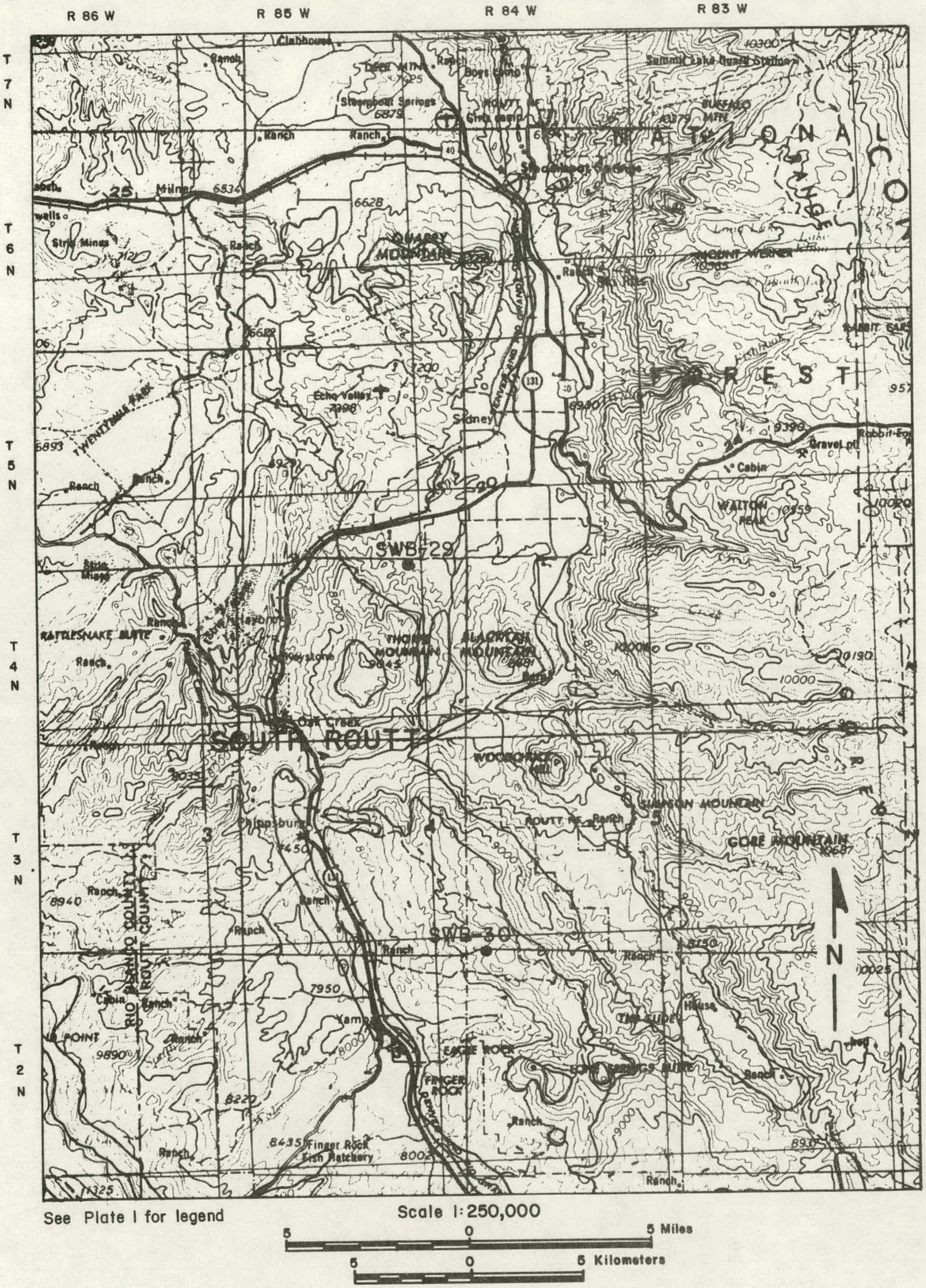


Figure 11. South Routt Area

Table 7. Drill-Hole Summary--South Routt Area

Hole No.	Location	Collar Elevation in Feet (m)	Driller's TD in Feet (m)	Geophysically Logged Depth in Feet (m)	Depth of Oxidation in Feet (m)	Depth to Basement in Feet (m)	Basement Formation
SWB-29	Section 12, T4N, R83W	7038 (2145)	1327 (404)	1189 (362)	1327 (404)	1320 (402)	Mancos Shale
SWB-30	Section 6, T2N, R84W	9415 (2870)	268 (82)	270 (82)	268 (82)	180 (55)	Mancos Shale

Drill Hole SWB-30

In hole SWB-30, the Browns Park Formation is oxidized from the surface to its contact with the Mancos Shale at 180 feet. The upper 20 feet (6 m) of the target formation is a moderately poorly sorted, fine- to very fine-grained, calcareous sandstone with as much as 30 percent clay matrix. From there to the base of the formation, it is a conglomerate containing pebbles and cobbles of plutonic and/or metamorphic rocks. The conglomerate is tan to gray, has a matrix of fine-grained sand, silt and clay, is calcareous and can probably be classified as an arkose. The bottom 20 feet (6 m) of the conglomerate is yellow-brown in color and contains angular siltstone and claystone fragments. Background radioactivity in this hole is higher than in other project drill holes (150 to 180 CPS in contrast to the usual 80 to 120 CPS). No radioactive anomalies were detected in hole SWB-30.

CONCLUSIONS ON URANIUM FAVORABILITY AND RESOURCES

Assessment Criteria

Known economic uranium deposits in the Browns Park Formation are largely classified as nonchannel-controlled peneconcordant sandstone-type deposits as defined by Austin and D'Andrea (1978) (Craig et al, 1980a, 1980b). There are minor economic uranium deposits in the Browns Park Formation which are classified as vein deposits in sandstone as defined by Mathews (1978) (Craig et al, 1980a, 1980b). The criteria for favorability of an area for uranium mineralization ("favorability criteria") used in this report are based on the criteria established for these types of deposits by Austin and D'Andrea in Mickle and Mathews (1978) and by Mathews, Jones, Pilcher, and D'Andrea (1978).

The favorability criteria for the Browns Park Formation as used in this report are:

1. Presence of uranium minerals and/or anomalously high radioactivity.
2. Presence of quartzose continental sediments that are feldspathic and/or tuffaceous as a source of uranium.
3. Presence of moderately poorly sorted medium- to coarse-grained sands alternating with siltstones or mudstones.
4. Presence of unconformities within or underlying the target formation.
5. Presence of organic carbonaceous material.
6. Presence of reductants. In the project area, these may be pyrite, hydrocarbons or hydrogen sulfide gas within the target formation or a source of hydrocarbons and/or hydrogen sulfide gas underlying the target formation.
7. Presence of pervasive, post-depositional alteration such as bleaching, oxidation of ferromagnesian minerals, and argillization of feldspars or tuffaceous material.

Another important favorability criterion for uranium mineralization is the presence of fractures, faults, and folds in the target formation. These structural features can provide conduits to pass gaseous or liquid reductants through the host rocks and provide sites for the accumulation of reductants and uranium minerals. This criterion is not used in this report because structural features cannot be detected in drill cuttings samples. However, uranium mineralization concentrated along fractures and faults is reported from the Maybell and Poison Basin mining districts (Ormond, 1957, Lewis, 1977).

The two most important favorability criteria for uranium mineralization in the Sand Wash Basin are the presence of uranium minerals and/or anomalously high radioactivity and the presence of reductants, particularly hydrocarbons or hydrogen sulfide gas. Potential, though unproven, sources of hydrocarbons and/or hydrogen sulfide gas underlie the target formation in parts of all six study areas, and project drilling detected anomalously high radioactivity in all six areas.

Favorability Assessments

A number of areas favorable for uranium mineralization within the Browns Park Formation have been identified by previous investigators. Project drilling verified the favorability of portions of the Browns Park, West Yampa, and East Yampa study areas. These areas were designated as favorable for uranium mineralization in the target formation by Craig et al (1980a, 1980b) and Bennett (1980). Project drilling results also show that parts of the North Routt and South Routt study areas are favorable for uranium mineralization. Neither tract was regarded as favorable for uranium mineralization by Craig et al (1980a), though Bennett (1980) designated the South Routt study area as favorable, and Bolivar and Hill (1979) found anomalous concentrations of uranium in surface water and stream sediment samples from portions of the South Routt region.

The East Yampa and West Yampa study areas are the most favorable for uranium mineralization in the Browns Park Formation. The other regions, in descending order of favorability are: the South Routt area, the Browns Park area, the North Routt area, and the North Browns Park area. This hierarchy of favorability is based on project drilling results, the Craig and Vernal NTMS quadrangle evaluations (Craig et al, 1980a and 1980b), interpretation of aerial radiometric data from the Craig and Vernal quadrangles (Bennett, 1980), and hydrogeochemical and stream sediment sampling of the Craig and Vernal quadrangles (Bolivar and Hill, 1979).

Target formation sediments in the East Yampa and West Yampa tracts meet all seven favorability criteria used in this report; the thickest and most radioactive zones measured during project drilling are in holes SWB-18 and SWB-19 in the East Yampa area. The two regions are separated by the Maybell mining district, near which conditions for uranium mineralization are most favorable. Favorability decreases with distance from the Maybell district, as reflected by radioactivity measured in project drill holes. These two tracts encompass three favorable areas outlined by Craig et al (1980a, 1980b) and are part of a favorable area designated by Bennett (1980).

Low-lying portions of the Browns Park Formation in the South Routt region are favorable for uranium mineralization; uranium may be supplied to these sediments by uraniferous surface waters and stream sediments from the nearby Park and Gore Ranges (as reported by Bolivar and Hill, 1979) or by leaching of the higher portions of the target formation. Sediments penetrated by project drilling in this location meet five of the favorability criteria used in this report. This is a new favorable area, recognized as such by Bennett (1980) but not by Craig et al (1980a).

Browns Park Formation sediments encountered by project drilling in the Browns Park study area meet six of the seven favorability criteria. All of this region is designated as favorable by Bennett (1980), and Craig et al (1980b) expanded a designated favorable area to include the part of this region from hole SWB-5 to the Utah-Colorado border. Project drilling detected anomalous radioactivity in the target formation, but it is too weak to indicate equivalent-uranium grades exceeding 0.001 percent U_3O_8.

The North Routt region is a new favorable area, not recognized as such by previous workers. Project drilling encountered significant anomalous radioactivity in holes SWB-27, SWB-28, and SWB-28A; this is the first reported evidence of uranium occurrences in this area. Target formation sediments penetrated by project drilling in this tract meet six of the seven favorability criteria.

The North Browns Park study area is the least favorable of the six tracts for uranium mineralization, although sediments penetrated by project drilling in this locale meet five of the favorability criteria. Only minor anomalous radioactivity was detected by project drilling here, the volume of Browns Park Formation sediments is small, and the region is not recognized as favorable by other workers.

Resource Estimate

Potential uranium resource estimates assigned to the Browns Park Formation in the Sand Wash Basin have been revised upward as of October, 1980, by the Resource Division of the Department of Energy's Grand Junction Office. The new estimates are based in part on the results of this project:

Potential Uranium Resources
Browns Park Formation
Tons U_3O_8
(Metric Tons U_3O_8)
at a Forward Cost of $50/lb U_3O_8
($110 per Kilogram)

	Probable	Possible	Speculative
June 1979	15,100 (15,300)	10,500 (10,700)	Not assigned
October 1980	17,486 (27,766)	42,590 (43,270)	Not assigned

For future exploration in the Sand Wash Basin, the Browns Park Formation may be regarded as a suitable host for uranium mineralization, or, as suggested by Bennett (1980), as a source of uranium for underlying formations suitable as host rocks for uranium mineralization. In the North Routt and South Routt tracts, large volumes of Browns Park Formation sediments occupy topographically high positions and are subject to leaching of uranium. Most of the target formation is oxidized, and perhaps leached of most of its uranium, in the Browns Park region. In and near the North Browns Park study area, an unknown volume of the target formation has been weathered and removed by erosion. In each of these areas, uranium contained in the Browns Park Formation has been mobilized, and therefore it is possible that the uranium has been concentrated in suitable host formations presently or formerly underlying the Browns Park Formation.

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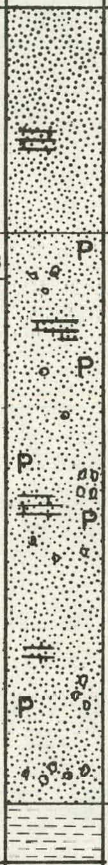
APPENDIX A

GENERALIZED STRATIGRAPHIC

COLUMNAR SECTIONS

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB-2A



Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	DESCRIPTION & REMARKS
		Ox	(Surface Soil)
	150		Sandstone, tan, clayey, fine- to medium-grained with sparse coarse grains, subrounded to subangular, feldspathic, minor calcareous interbeds
200			
		Trans	Sandstone, conglomeratic, gray to grayish-green, calcareous, clayey, clasts up to boulder size, pyritic, feldspathic
		Red	
400			
600			
	150		
800			
			Mancos Shale - 820 feet
			TD - 881 feet
1000			

LEGEND

Vertical Scale

0 100 200 ft

Conglomerate (ic)

Sandstone

Clay (shale)

Limestone (calcareous)

Tuff

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB-3

Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	Graphic	DESCRIPTION & REMARKS
		Ox		(Surface Soil)
	~250			Sandstone, tan to brown, fine-grained, calcareous, feldspathic, moderately well sorted with interbedded white to brownish-gray clay
	360			
200				Sandstone, tan to gray, fine- to medium-grained, calcareous, tuffaceous, feldspathic, clayey and silty, with interbedded sandy clays
	240			
	200			Tuffaceous clean sandstone, 230 to 246 feet
400				
	200			
	320			
600				
				Highly tuffaceous, clayey sandstone, tan to reddish-brown or gray, calcareous, fine- to medium-grained, with interbedded fresh and altered tuff (as ash)
800				
				Uinta Quartzite - 870 feet
1000				
				TD - 1,020 feet
1200				

LEGEND

Vertical Scale

0 100 200 ft

- Conglomerate (ic)
- Sandstone
- Clay (shale)
- Limestone (calcareous)
- Tuff

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB-4

Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	Graphic	DESCRIPTION & REMARKS
	300	Ox		(Surface Soil)
	400			Sandstone, tan to buff, fine to medium grained, moderately well-sorted, subrounded, partly calcareous, with interbedded sandy clay
	240			
	200			
	230			
200				Ash bed
	300			
	300			
	200			
400				
				Sandstone, light brown to buff, clayey, moderately sorted, highly calcareous, with some thin, buff to white ash beds
600				Uinta Quartzite - 572 feet T D - 647 feet
800				

LEGEND

Vertical Scale: 0 100 200 ft

- Conglomerate (ic)
- Sandstone
- Clay (shale)
- Limestone (calcareous)
- Tuff

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB-5

Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	Graphic	DESCRIPTION & REMARKS
200 400	150 290 200 190 200	Ox		(Surface Soil) Interbedded sandstone, tan to brown, medium- to fine-grained, moderately well sorted, subrounded, calcareous, tuffaceous; and clay, white to buff, sandy, probably altered tuff
600 800	300 300	Red		As above, except greenish-gray color, interbeds are thinner, sandstone is clayey, less well sorted Sands becoming coarser-grained near the base of the Browns Park Formation
1000		Ox		Uinta Quartzite - 954 feet TD - 1,170 feet
1200				

LEGEND

Vertical Scale

0 100 200 ft

Conglomerate (ic)

Sandstone

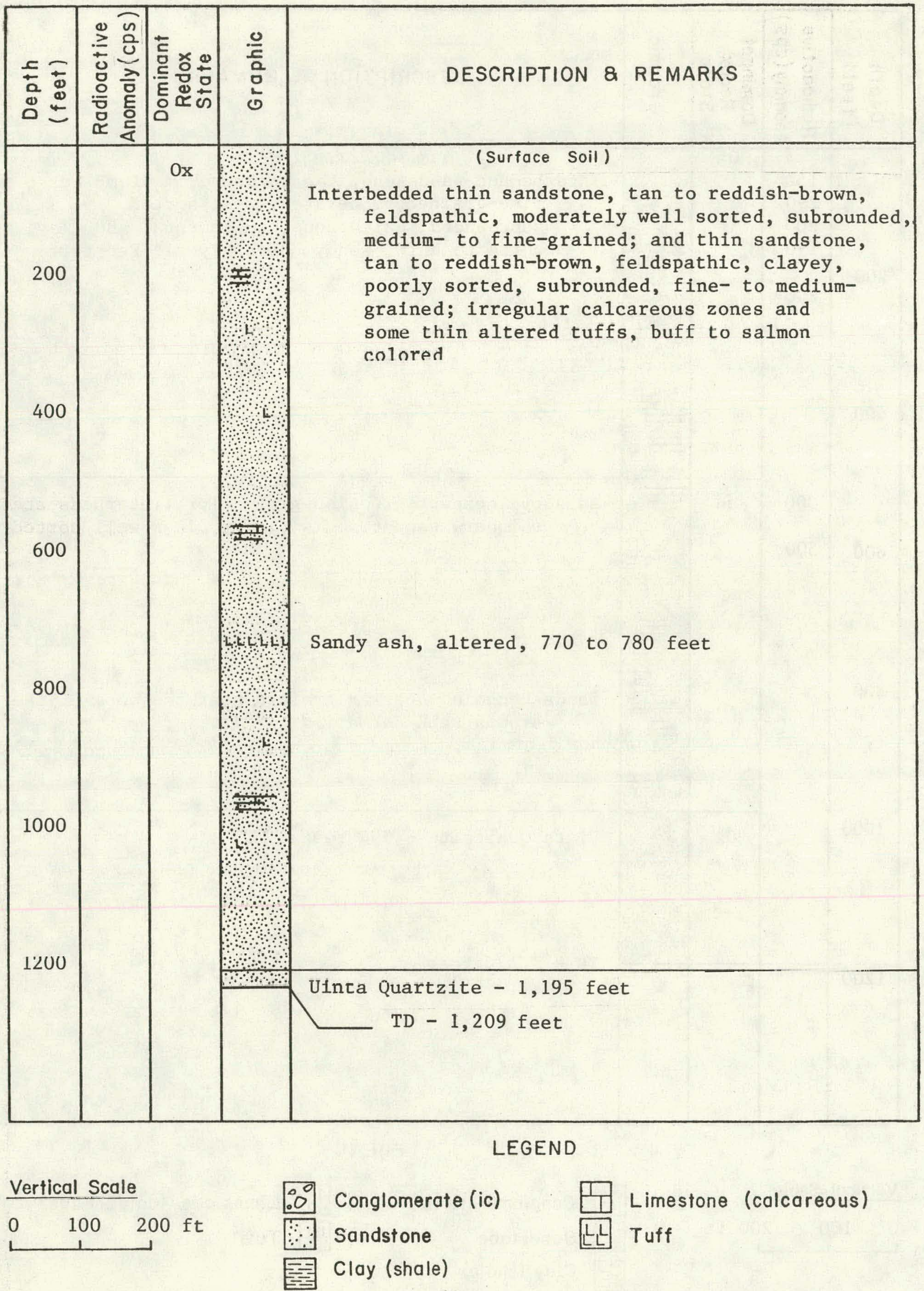
Clay (shale)

Limestone (calcareous)

Tuff

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB-6



STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB-9

Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	Graphic	DESCRIPTION & REMARKS
200 400 600		Ox		(Surface Soil) Interbedded thick sandstone, buff to tan, medium- to fine-grained, moderately well sorted, subangular, tuffaceous; and thin clay, sandy, buff to white, probably altered tuffaceous material
800 1000		Red		Same as above, except color is gray, traces of pyrite and calcite, interbeds of sand and clay become thinner with depth
1200		Ox		Bridger Formation - 1,020 feet TD - 1,240 feet
1400				

LEGEND

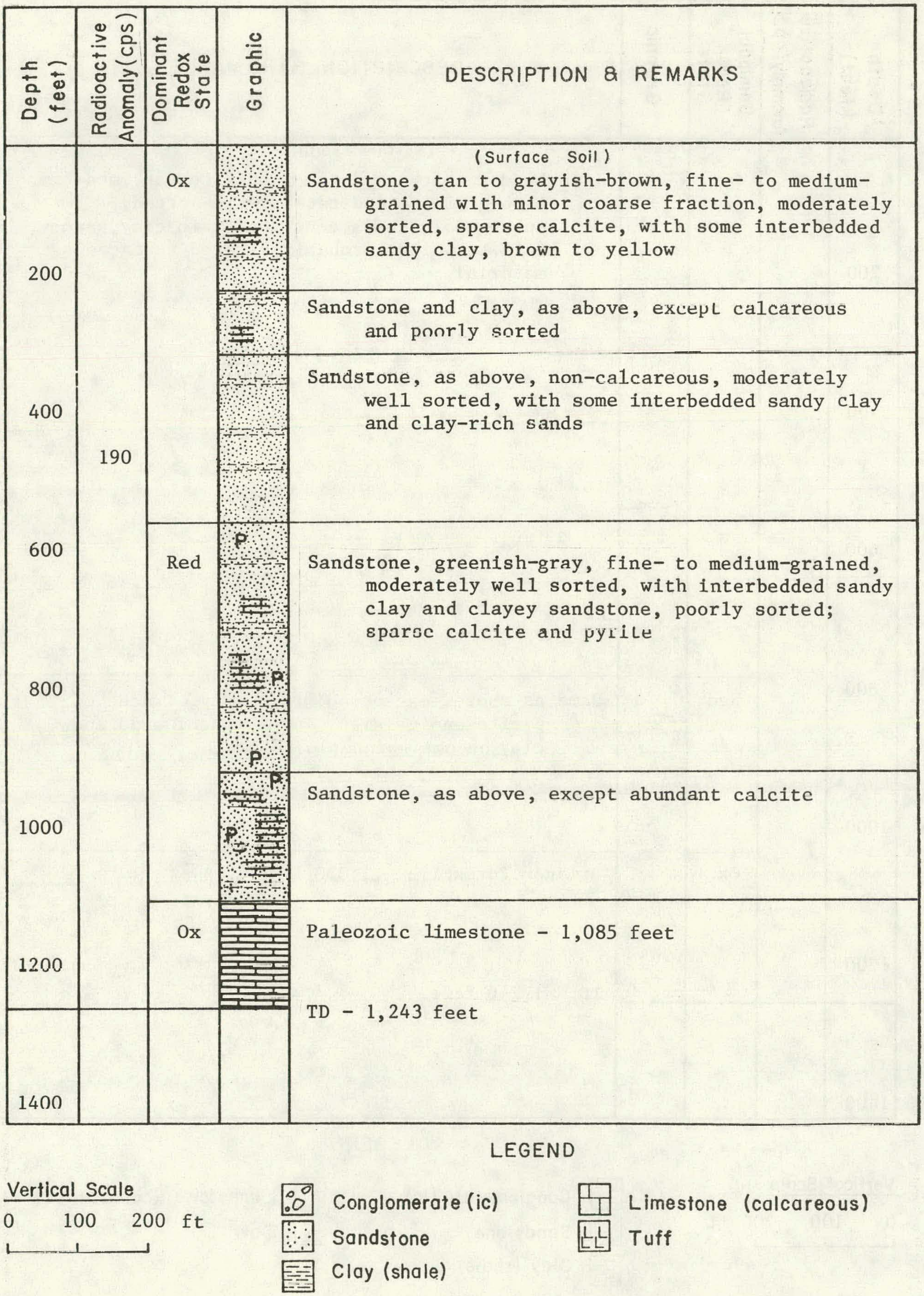
Vertical Scale

0 100 200 ft

- Conglomerate (ic)
- Sandstone
- Clay (shale)
- Limestone (calcareous)
- Tuff

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB-11A



STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB-12

Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	Graphic	DESCRIPTION & REMARKS
		Ox		(Surface Soil)
200				Sandstone, tan to brown, fine- to medium-grained, moderately well sorted, subangular to subrounded, with minor interbedded sandy clay, white, probably derived from tuffaceous material
400				Sandstone, tan to brown, tuffaceous, fine- to medium-grained, poorly sorted, most of tuffaceous material is altered to clay, traces of feldspar and calcite
600				
800				
1000				
1200		Red		Sandstone, greenish gray, fine- to medium-grained poorly to moderately sorted, tuffaceous, sparse volcanic ash beds, traces of pyrite
				TD - 1,220 feet, still in the Browns Park Formation
1400				

LEGEND

Vertical Scale

0 100 200 ft

- Conglomerate (ic)
- Sandstone
- Clay (shale)
- Limestone (calcareous)
- Tuff

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB-13

Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	Graphic	DESCRIPTION & REMARKS
		Ox		(Surface Soil) Sandstone, tan to brown, medium- to fine-grained, moderately well to well sorted, slightly feldspathic; with minor interbedded clay, sandy, white to tan, probably altered volcanic ash
200		Red		Sandstone, as above, except greenish-gray, sparse calcite and pyrite; with some interbedded clay, white to pale green, probably volcanic ash
400				
600				
				Sandstone, as above, except tuffaceous; with some interbedded clay, as above; and thin calcite-cemented sandstone lenses
800				
	220			
1000				
		Trns. (?)		Possible Iles Formation - 1,084 feet
1200				
1400				
1600				
	220			
1800				TD - 1,820 feet
2000				

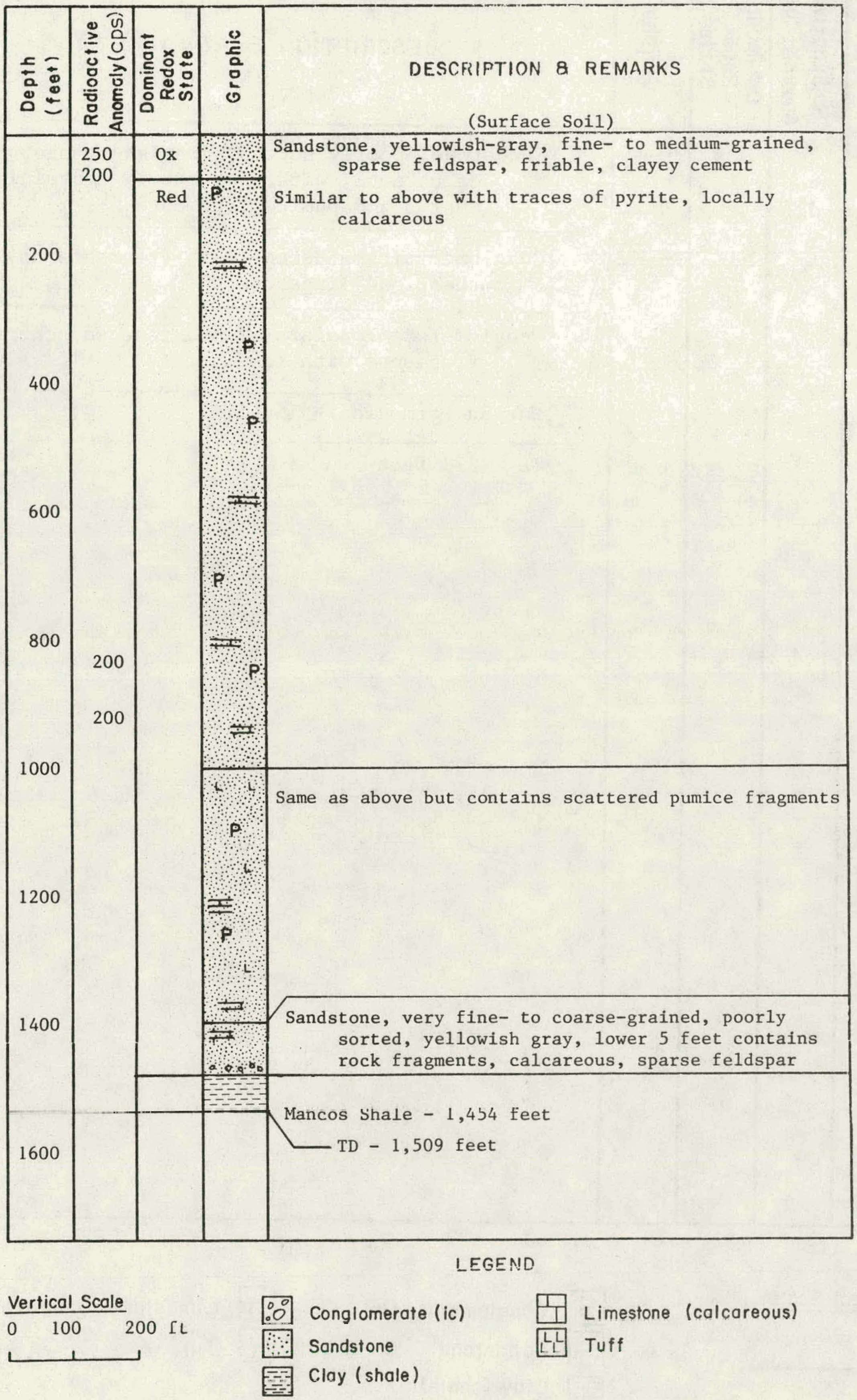
LEGEND

Vertical Scale: 0 100 200 ft

- Conglomerate (ic)
- Sandstone
- Clay (shale)
- Limestone (calcareous)
- Tuff

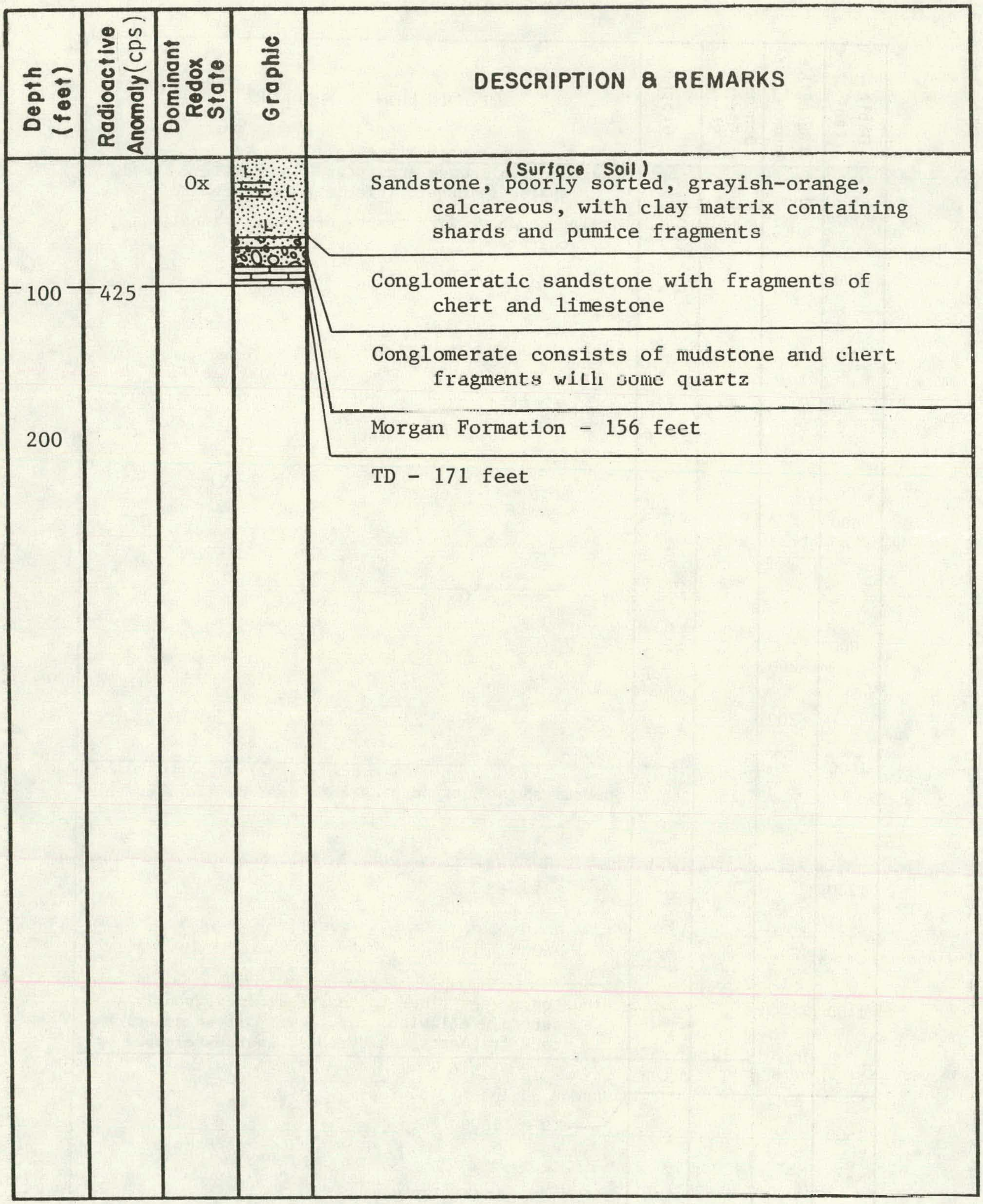
STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB- 14



STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB- 15



LEGEND

Vertical Scale

0 100 200 ft

- Conglomerate (ic)
- Sandstone
- Clay (shale)
- Limestone (calcareous)
- Tuff

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB- 16

Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	Graphic	DESCRIPTION & REMARKS
200 400 600		Ox		(Surface Soil) Sandstone, yellowish-gray, fine- to medium-grained, tuffaceous, calcareous, sparse feldspar, clayey
800	200	Red		Sandstone, greenish-gray, fine-grained, highly tuffaceous, pyritic
				Sandstone, green and tan, medium- to coarse-grained, tuffaceous, pyritic, calcareous
1000				Sandstone, light greenish-gray, fine- to medium-grained, tuffaceous, pyritic
1200				Morrison Formation - 1,163 feet TD - 1,210 feet
1400				

LEGEND

Vertical Scale

0 100 200 ft

- Conglomerate (ic)
- Sandstone
- Clay (shale)
- Limestone (calcareous)
- Tuff

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB- 18

Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	Graphic	DESCRIPTION & REMARKS
				(Surface Soil)
		Ox		Sandstone, brown-yellow, medium-grained, poorly sorted, tuffaceous calcareous, clayey
200		Red		Sandstone, dark greenish-gray, medium-grained, poorly sorted, tuffaceous, increasing clay content with depth, calcareous, traces of pyrite and organic carbonaceous material
400	4500 3200 4000 1300			Mudstone, dark greenish-gray, tuffaceous calcareous, traces of sedimentary rock fragments, pyrite and organic carbonaceous material
600 800 1000				Fort Union Formation - 456 feet
				TD - 1,050 feet

LEGEND

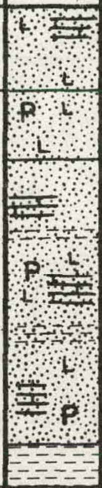
Vertical Scale

0 100 200 ft

- Conglomerate (ic)
- Sandstone
- Clay (shale)
- Limestone (calcareous)
- Tuff

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB- 19



Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	DESCRIPTION & REMARKS
		Ox	(Surface Soil) Sandstone, yellow-brown, tuffaceous, medium-grained, poorly sorted, calcareous
			Sandstone, green-gray, fine-grained, abundant tuff and clay, traces of pyrite; with green clay partings
200	2000 1700 1900	Red	
400			Thinly interbedded tuffaceous, medium- to fine-grained, moderately well sorted, calcareous sandstone and sandy, silty, calcareous clay and clay partings, colors as above; traces of pyrite
			Clay content decreases with depth
			Lewis Shale - 452 feet
600			TD - 490 feet

LEGEND

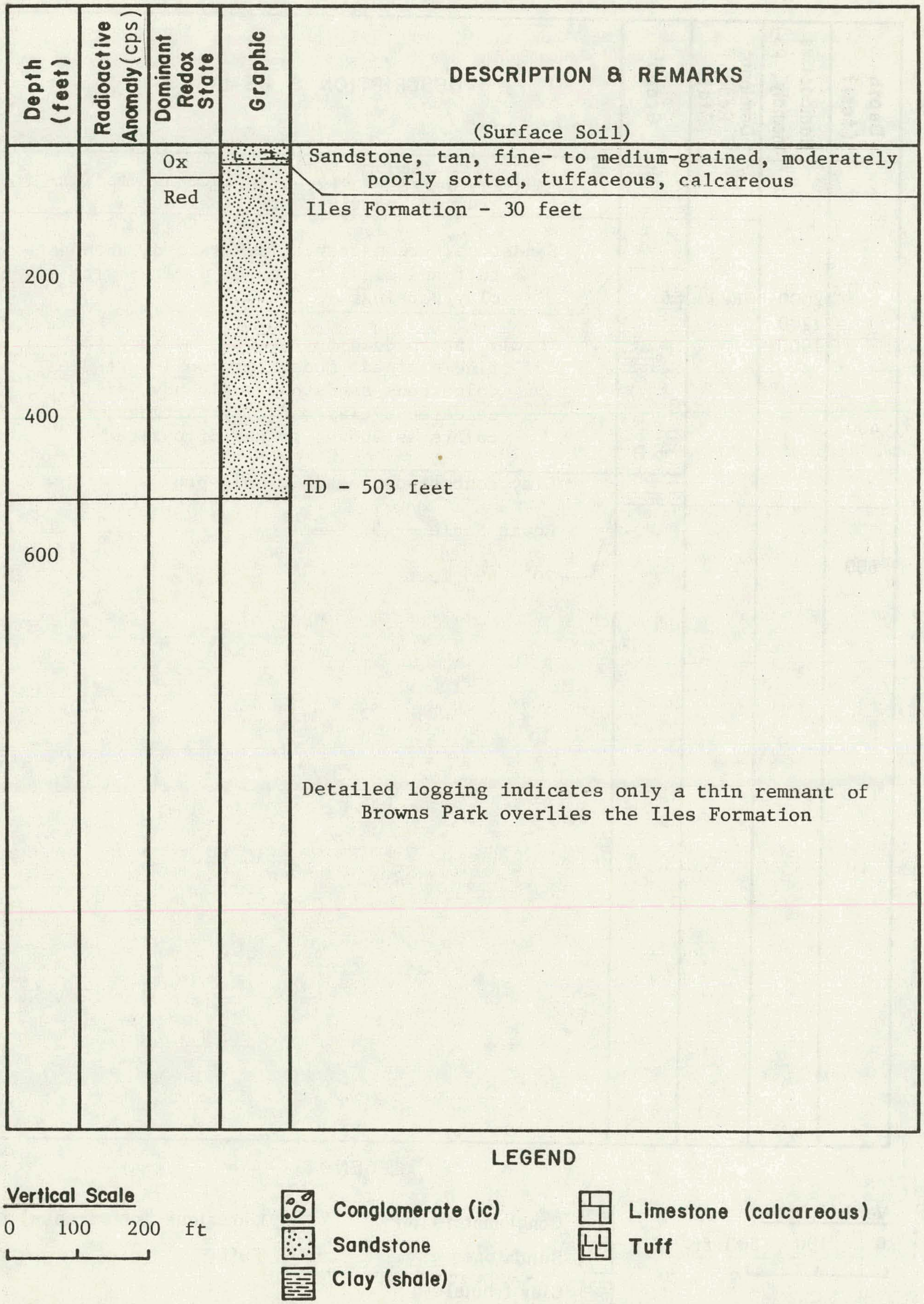
Vertical Scale

0 100 200 ft

- Conglomerate (ic)
- Sandstone
- Clay (shale)
- Limestone (calcareous)
- Tuff

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB- 20



STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB-24

Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	Graphic	DESCRIPTION & REMARKS
				(Surface Soil)
200 400		Ox		Sandstone, yellowish-brown, fine- to coarse-grained, poorly sorted, tuffaceous, locally calcareous, feldspathic, with interbedded clayey sandstone and sandy clays; most clay is argillized tuff, feldspars partly argillized
600 800	200 200 200 200 200	Red		Sandstone, gray-green, medium- to fine-grained abundant clay matrix, locally calcareous, feldspathic, with sparse ash-fall tuff beds; clays are probably partly argillized tuffs Traces of pyrite below 870 feet
				Fort Union Formation - 902 feet TD - 982 feet
1000				

LEGEND

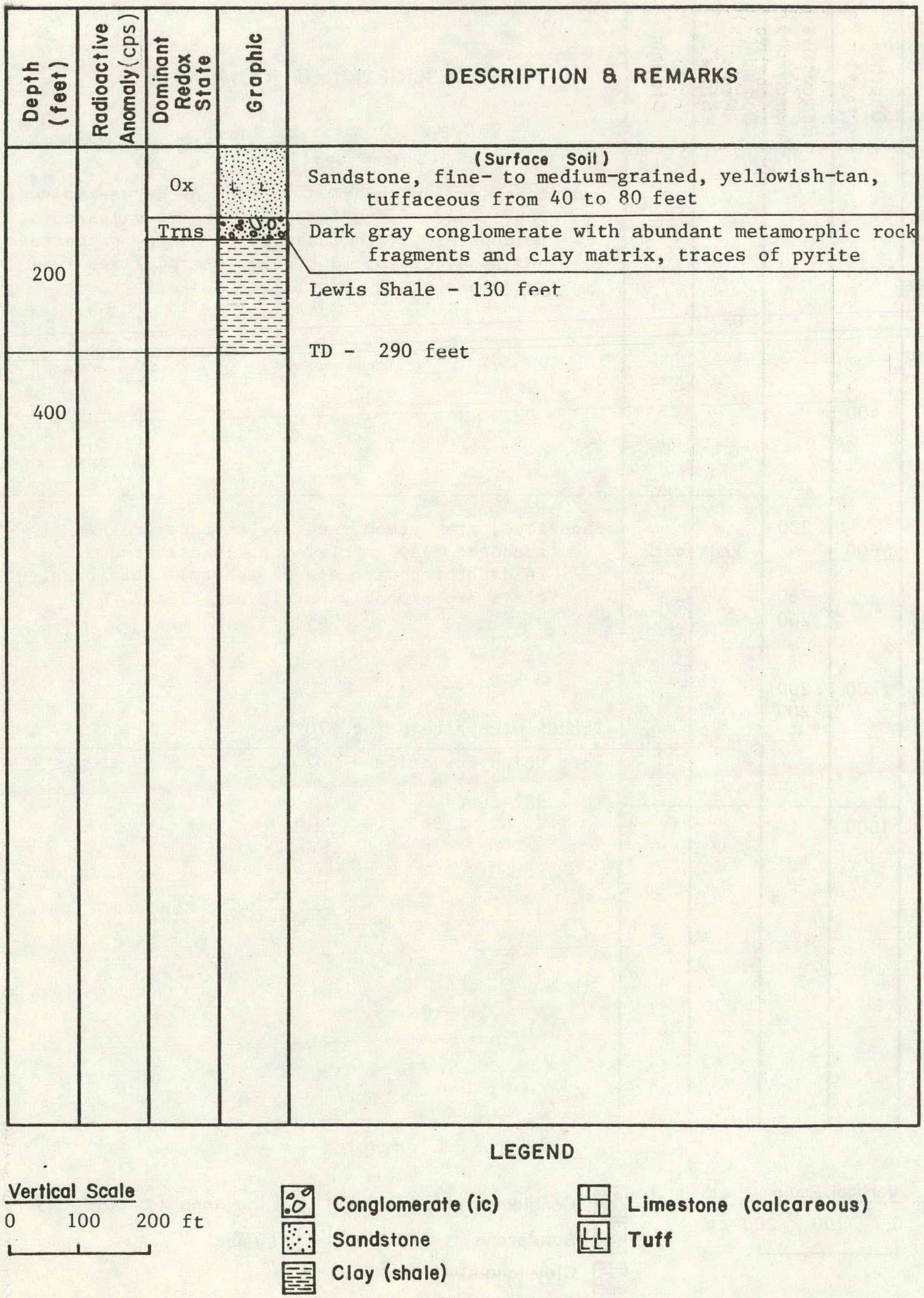
Vertical Scale

0 100 200 ft

- Conglomerate (ic)
- Sandstone
- Clay (shale)
- Limestone (calcareous)
- Tuff

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB- 25



STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB-26

Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	Graphic	DESCRIPTION & REMARKS
		Ox		(Surface Soil) Conglomerate - angular to subrounded volcanic rock fragments in sandy matrix with sparse clay
200				Lewis Shale - 55 feet
				TD - 110 feet
				This hole collared near mapped contact of the Browns Park Formation and Tertiary igneous rocks. Material overlying the Lewis Shale may be either basal Browns Park or simply a residuum from the Tertiary igneous rocks

LEGEND

Vertical Scale

0 100 200 ft

- Conglomerate (ic)
- Sandstone
- Clay (shale)
- Limestone (calcareous)
- Tuff

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB- 26A

Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	Graphic	DESCRIPTION & REMARKS
		Ox		Sandstone, tan, (Surface Soil) fine-grained, weakly calcareous, generally homogenous
200 400 600 800 1000 1200 1400		Trns		Sandstone, mottled greenish-gray, and tan, fine-grained, moderately well sorted, tuffaceous, feldspathic, weakly calcareous with sparse calcite-cemented ribs, clay matrix from 10 % to 35% of rock, scattered traces of pyrite, scattered limonite stain
1600		Ox		Lewis Shale - 1,496 feet TD - 1,648 feet
1800				

LEGEND

Vertical Scale

0 100 200 ft

- Conglomerate (ic)
- Sandstone
- Clay (shale)
- Limestone (calcareous)
- Tuff

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB- 27

Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	Graphic	DESCRIPTION & REMARKS
	300	Ox		(Surface Soil)
				Sandstone, iron-stained, conglomeratic, tuffaceous, very poorly sorted, angular to subangular clasts, calcite increases with depth
200				Pale grayish orange, with minor amounts of silt, calcite content increases with depth
				Clay, pink, approximately 10% sand
400				Sandstone, variegated iron-stained grays, conglomeratic, tuffaceous, clayey, partly altered
				Conglomerate, variegated iron stained whites and grays, calcareous, injected by carbonaceous material, partly altered
				Mancos Shale - 180 feet
				TD - 250 feet

LEGEND

Vertical Scale

0 100 200 ft

- Conglomerate (ic)
- Sandstone
- Clay (shale)
- Limestone (calcareous)
- Tuff

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB-28

Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	DESCRIPTION & REMARKS
200 400		Ox	(Surface Soil) Sandstone, light tan, medium-grained, tuffaceous, feldspathic with clay matrix and interbeds of clay
600 800	250 950 600 4000 1300	Red	Same as above except sands are finer grained, light greenish-gray, scattered traces of pyrite
1000 1200 1400	450		Sandstone, fine-grained, with more clay as matrix, more homogenous, scattered traces of pyrite and limonite, tuffaceous, feldspathic
1600			Similar to above with interbeds of clay and sandstone, sparse pebbles
			Hole bottomed short of Browns Park Formation Base TD - 1,660 feet

LEGEND

Vertical Scale: 0 — 100 — 200 ft

Conglomerate (ic)	Limestone (calcareous)
Sandstone	Tuff
Clay (shale)	

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB-28A

Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	Graphic	DESCRIPTION & REMARKS
200 400		Ox		(Surface Soil) Interbedded sands and clays, yellowish gray to tan, fine- to medium-grained, moderately poorly sorted, clayey, tuffaceous
600 800 1000	400 550 575 375	Red		Sandstone, fine- to medium-grained, tuffaceous, feldspathic, light green and interbedded clays, traces of pyrite
1200 1400	475			Sandstone, light green, as above except more clay and much more homogenous than above; scattered traces of pyrite and limonite
1600 1800				Slightly conglomeratic sandstone, light green, with variable amounts of clay matrix, locally calcareous, scattered traces of pyrite and limonite, tuffaceous, feldspathic
				Iles Formation - 1,864 feet
2000				TD - 1,995 feet

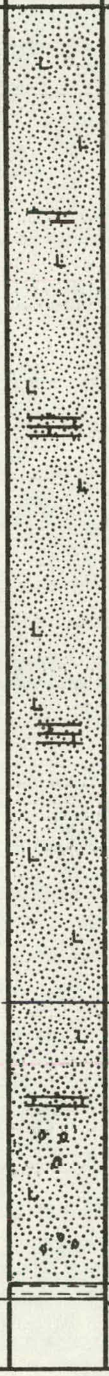
LEGEND

Vertical Scale: 0 — 100 — 200 ft

- Conglomerate (lc)
- Sandstone
- Clay (shale)
- Limestone (calcareous)
- Tuff

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB-29



Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	DESCRIPTION & REMARKS
			(Surface Soil)
	250		Sandstone, tan, fine-grained, moderately well sorted, with clayey matrix, calcareous, tuffaceous, feldspathic, common limonite, thinly bedded; and thin beds of sandy clay, tan, white and pink, tuffaceous; also sparse calcite-cemented "ribs"
200	200		
400			
600			
	450		
	350		
800			
	375		
1000	250		
	275		Sandstone, very fine-grained, moderately well sorted, locally conglomeratic, calcareous, feldspathic, clayey, tuffaceous, limonitic
1200			
			Mancos Shale - 1,320 feet
1400			TD - 1,327 feet

LEGEND

Vertical Scale

0 100 200 ft

- Conglomerate (ic)
- Sandstone
- Clay (shale)
- Limestone (calcareous)
- Tuff

STRATIGRAPHIC COLUMNAR SECTION

HOLE SWB- 30

Depth (feet)	Radioactive Anomaly (cps)	Dominant Redox State	Graphic	DESCRIPTION & REMARKS
		Ox		(Surface Soil) Conglomeratic sandstone, tan and gray, granitic and metamorphic cobbles and pebbles in fine-grained sand, silt and clay matrix, calcareous
200				Mancos Shale - 180 feet TD - 267.5 feet
400				

LEGEND

Vertical Scale

0 100 200 ft

Conglomerate (ic)

Sandstone

Clay (shale)

Limestone (calcareous)

Tuff

APPENDIX B

RESULTS OF PETROGRAPHIC AND PETROLOGICAL ANALYSES

INDEX TO

COLOR MICROFICHE OF PETROGRAPHIC PHOTOMICROGRAPHS

(fiche in back pocket)

Field Number	Fiche Frame Number	Description
MIP-647	1	General texture of the lithic wacke; 40x, crossed polarizers.
MIP-648	2	General texture of the sandy limestone; much of the opaque-appearing phase is fresh glass shards; 40x, crossed polarizers.
MIP-650	3	Clast-rich layers interbedded with ash layers in the ash; 40x, plane polarized light.
MIP-650	4	Same as Frame 3; crossed polarizers.
MIP-702	5	General texture of the arkosic wacke; 40x, crossed polarizers.
MIP-703	6	Grain mount section of the heavy mineral fraction; heavies are mostly carbonate with limonite inclusions; 40x, crossed polarizers.
MIP-704	7	Plutonic and metamorphic rock fragments in the lithic arenite (conglomerate) with carbonate cementation; 16x, crossed polarizers.

PETROGRAPHIC DESCRIPTION

PROJECT: Sand Wash Basin

HOLE NO: 28A
922.0-922.4 ft
(281.0-281.1 m)

SAMPLE NO: MIP-647

ROCK NAME: Lithic Wacke

PETROLOGIST: LMF

MINERAL/COMPONENT	%	COMMENTS
Quartz	38	
Clay Matrix	26	Thin coatings on clasts and void-filling; may be in part jarosite.
Volcanic Rock Fragments	18	Tuffaceous and aphanitic.
Plagioclase	7	Variable sericitic alteration.
K-feldspar	4	Microcline > sanidine.
Chert	2	May be in part silicified volcanic rock fragments.
Plutonic Rock Fragments	2	Quartz and microcline.
Secondary Quartz Cement	2	
Sedimentary Rock Fragments	tr	Carbonate.
Iron Oxides	tr	Limonite.
Zircon	tr	
Muscovite	tr	
Biotite	tr	Vermiculized.
Metamorphic Rock Fragments	tr	Biotite schist.

Texture: Poorly sorted, subangular to subrounded clasts.

No evidence observed of hydrothermal activity.

Clays: Kaolinite >> Montmorillonite.

PETROGRAPHIC DESCRIPTION

PROJECT: Sand Wash Basin
HOLE NO: 28A
933.8-934.2 ft
(284.6-284.7 m)
SAMPLE NO: MIP-648
ROCK NAME: Sandy Limestone
PETROLOGIST: LMF

MINERAL/COMPONENT	%	COMMENTS
Carbonate	58	Micrite and sparite.
Quartz	17	
Fresh Glass	8	Shards.
Volcanic Rock Fragments	4	Mostly aphanitic.
Iron Oxides	3	Limonite.
Plagioclase	2	Fresh.
K-feldspar	2	Microcline and sanidine.
Chert	2	
Clay (SRF's ?)	1	
Secondary Quartz	1	Cement (?).
Amphibole	1	Hornblende.
Epidote	1	
Biotite	tr	
Zircon	tr	
Authigenic Chlorite	tr	Coatings on clasts: origin of green coloration (?).

Texture: Poorly sorted, angular to subrounded clasts. Fresh glass shards are evidence of tuffaceous material.

Clay: Montmorillonite.

PETROGRAPHIC DESCRIPTION

PROJECT: Sand Wash Basin

ROCK NAME: Ash

HOLE NO: 1
885.0-885.3 ft
(269.7-269.8 m)

SAMPLE NO: MIP-650

PETROLOGIST: LMF

MINERAL/COMPONENT	%	COMMENTS
Glass	74	Mostly fresh; somewhat welded; minor axiolitic devitrification interbedded with sand in ash cement matrix.
Quartz	15	Clastic.
Volcanic Rock Fragments	6	Mostly aphanitic.
Plagioclase	3	Variable sericitic alteration. Zoned volcanic types observed.
K-feldspar	tr	Microcline > sanidine.
Biotite	tr	
Garnet	tr	
Metamorphic Rock Fragments	tr	Phyllites.
Carbonate Cement	tr	Patchy.
Tourmaline	tr	
Amphibole	tr	Hornblende.
Iron Oxides	tr	Limonite and hematite.
Rutile	tr	
Epidote	tr	

Texture: Poorly sorted, subrounded to subangular clasts in ash cement; matrix interbedded with ash.

Clay: Montmorillonite.

PETROGRAPHIC DESCRIPTION

PROJECT: Sand Wash Basin

HOLE NO: 1
423.0-424.0 ft
(128.9-129.2 m)

SAMPLE NO: MIP-701

ROCK NAME: (Unconsolidated) Lithic Arenite

PETROLOGIST: LMF

MINERAL/COMPONENT	%	COMMENTS
Zircon	tr	
Celadonite	tr	
Quartz	36	
Volcanic Rock Fragments	25	Predominantly aphanitic; few pumice fragments.
Plagioclase	15	Variable argillic and sericitic alteration: slight to strong. Zones volcanic-types common.
K-feldspar	13	Microcline > sanidine. Variable fresh to strong argillic alteration.
Sedimentary Rock Fragments	7	Consolidated by clay.
Chert	2	May be in part silicified volcanic rock fragments.
Iron Oxides	tr	Limonite and hematite.
Biotite	tr	
Muscovite	tr	
Amphibole	tr	Hornblende.
Epidote	tr	
Sphene	tr	

Texture: Moderately well sorted, subrounded clasts.

Clay: Montmorillonite.

PETROGRAPHIC DESCRIPTION

PROJECT: Sand Wash Basin **HOLE NO:** 1 1117.0-1117.4 ft (340.5-340.6 m) **SAMPLE NO:** MIP-702

ROCK NAME: Arkosic Wacke **PETROLOGIST:** LMF

MINERAL/COMPONENT	%	COMMENTS
Matrix	28	Thin coating of authigenic chlorite on clasts; not sufficient quantity to be manifested in clay analysis. Voids filled by montmorillonite.
Quartz	26	
Plagioclase	12	Variable sericitic and argillic alteration; fresh to strong. Zones volcanic-types common.
Secondary Quartz Cement	10	
K-feldspar	7	Microcline and sanidine.
Volcanic Rock Fragments	7	Aphanitic types, few pumice fragments.
Carbonate	6	Dolomite (?). Rhombs in matrix.
Iron Oxides	1	Limonite and hematite.
Chert	1	May be in part silicified volcanic rock fragments.
Biotite	1	
Epidote	tr	

Texture: Poorly sorted, subangular to subrounded clasts.

Clay: Montmorillonite.

Green coloration of rock probably due to thin coatings of authigenic chlorite on clasts.

PETROGRAPHIC DESCRIPTION

PROJECT: Sand Wash Basin

ROCK NAME: Lithic Wacke

HOLE NO: 26A
507.0-507.4 ft
(154.5-154.7 m)

SAMPLE NO: MIP-703

PETROLOGIST: LMF

MINERAL/COMPONENT	%	COMMENTS
Matrix	33	Thin coating of authigenic chlorite on clasts; not sufficient quantity to be manifested in clay analysis. Voids filled by montmorillonite.
Quartz	27	
Volcanic Rock Fragments	14	Altered tuffs > microaphanitic types.
K-Feldspar	6	Microcline and sanidine.
Carbonate Cement	6	Limonite-stained.
Chert	5	May be in part silicified volcanic rock fragments.
Plagioclase	3	Variable sericitic and argillic alteration: minor to strong.
Secondary Quartz Cement	2	
Biotite	1	
Plutonic Rock Fragments	1	Quartz and feldspars.
Metamorphic Rock Fragments	tr	Phyllite.

Texture: Moderately sorted, angular to subangular clasts.

Clay: Montmorillonite.

Green coloration of rock probably due to thin coating of authigenic chlorite on clasts.

PETROGRAPHIC DESCRIPTION

PROJECT: Sand Wash Basin

HOLE NO: 27
144.0-144.5 ft
(43.9- 44.0 m)

SAMPLE NO: MIP-704

ROCK NAME: Lithic Arenite (conglomerate)

PETROLOGIST: LMF

MINERAL/COMPONENT	%	COMMENTS
Carbonate Cement	min	Fine-grained sparite.
Plutonic Rock Fragments	mod	Allotriomorphic granular granite and altered diorite and aplitic quartz monzonite.
Metamorphic Rock Fragments	mod	Quartzite, quartz monzonite gneiss, and phyllite.
Chert	tr	
Silicified Rock Fragments	tr	
Volcanic Rock Fragments	tr	Altered vitric tuff.
Quartz	min	
Plagioclase	tr	
K-feldspar	tr	Microcline microperthite.
Epidote	tr	
Opaque Inclusions in Cement	tr	Carbonaceous material: the black glassy "injected" phase.

Texture: Very poorly sorted, subangular to rounded clasts.

Alteration: Plutonic rock fragments (all), plagioclase has strong argillic and sericitic alteration with replacement by calcite and cryptocrystalline quartz; K-feldspar is fresh except for minor to moderate argillic alteration of exsolved albite; biotite is totally vermiculized; volcanic rock fragments; glass is totally altered to clay.

APPENDIX C

ANALYTICAL RESULTS

Definitions of Statistical Parameters of Grain Size*

ϕ = phi units; a standard grain size classification based on the Wentworth grade scale. Integers represent the class limits in the phi scale so it is possible to use conventional statistical operations on sedimentological data. The transformation equation is $\phi = -\log_2$ (grain size in mm).

Wentworth Grades	ϕ	Wentworth Grades	ϕ
32 mm	-5	1/4 mm	+2
16 mm	-4	1/8 mm	+3
8 mm	-3	1/16 mm	+4
4 mm	-2	1/32 mm	+5
2 mm	-1	1/64 mm	+6
1 mm	0	etc.	etc.
1/2 mm	+1		

M_z = graphic mean; formula used → $M_z = \frac{\phi 16 + \phi 50 + \phi 84}{3}$

answer given in standard phi (ϕ) classification

O_I = inclusive graphic standard deviation; formula used→

$$O_I = \frac{\phi 84 - \phi 16}{4} + \frac{\phi 95 - \phi 5}{6.6}$$

O_I under		
	0.35ϕ	very well sorted
	0.35ϕ-0.50ϕ	well sorted
	0.50ϕ-0.71ϕ	moderately well sorted
	0.71ϕ-1.00ϕ	moderately sorted
	1.00ϕ-2.00ϕ	poorly sorted
	2.00ϕ-4.00ϕ	very poorly sorted
	over 4.00ϕ	extremely poorly sorted

Sk_I = inclusive graphic skewness; formula used→

$$Sk_I = \frac{\phi 16 + \phi 84 - 2\phi 50}{2(\phi 84 - \phi 16)} + \frac{\phi 5 + \phi 95 - 2\phi 50}{2(\phi 95 - \phi 50)}$$

Sk_I from		
	+1.00- +0.30	strongly fine-skewed
	+0.30- +0.10	fine-skewed
	+0.10- -0.10	near-symmetrical
	-0.10- -0.30	coarse-skewed
	-0.30- -1.00	strongly coarse-skewed

K_G = graphic kurtosis; formula used→ $K_G = \frac{\phi 95 - \phi 5}{2.44 (\phi 75 - \phi 25)}$

K_G		
	under 0.67	very platykurtic
	0.67 - 0.90	platykurtic
	0.90 - 1.11	mesokurtic
	1.11 - 1.50	leptokurtic
	1.50 - 3.00	very leptokurtic
	over 3.00	extremely leptokurtic

*Taken from Folk, R. L., 1968, Petrology of Sedimentary Rocks: Hemphills, Austin, Texas, 170 pp.

Sieve Analysis and Heavy
Mineral Analysis of Sample from SWB-26A

	Sample MIP-703 507.0-507.4 ft (154.5-154.7 m)
Mean Size	2.27
Standard Deviation (Sorting)	0.93
Skewness	0.12
Kurtosis	1.32
% Separated by bromoform (Sp. Gr. 2.85)	4.9
Mineral/Component	**Volume Percent in Sample**
Amphibole	-
Epidote	-
Garnet	-
Biotite	3
Muscovite	tr
Chlorite	-
Tourmaline	tr
Magnetite	-
Magnetite/Ilmenite[1]	-
Hematite	-
Geothite	tr
Zircon	-
Rutile	-
Monazite (?)	-
Sphene	-
Sillimanite[2]	-
Carbonate/Limonite[3]	83
Pyrite-Cemented SRF's	11
Pyrite	2
Marcasite-Cemented SRF's	-
Marcasite	-

[1]Exsolved ilmenite in magnetite.

[2]Sillimanite inclusions in quartz.

[3]Limonite inclusions in carbonate.

U_3O_8 Chemical Assay Results

(* Indicates sidewall sample; the rest are cuttings samples)

HOLE NO.	SAMPLE NO.	DEPTH FEET	DEPTH METERS	ppm U_3O_8
2A	MIP-714	75-85	23-26	1
2A	MIP-715	725-735	221-224	6
3	MIP-716	35-45	11-14	13
3	MIP-717	60-70	18-21	8
3	MIP-718	90-100	27-30	7
3	MIP-719	235-245	72-75	4
4	MIP-720	55-65	17-20	5
4	MIP-721	140-150	43-46	5
4	MIP-722	250-265	76-81	2
4	MIP-723	370-390	113-119	2
5	MIP-724	110-125	34-38	6
5	MIP-725	200-220	61-67	2
5	MIP-626	600-610	183-186	10
6	MDG-627	500-520	152-158	1
9	MDG-628	800-820	244-250	8
11A	MDG-629	450-470	137-143	2
12	MDG-630	500-520	152-158	1
13	MDG-631	890-910	271-277	5
14	MDG-632	0-30	0-9	4
15	MDG-633	100-120	30-37	7
16	MDG-634	420-440	128-134	<1
18	MIP-626	350-355	107-108	12
18	MIP-627	355-360	108-110	23
18	MIP-628	400-405	122-123	40

U_3O_8 Chemical Assay Results (continued)

HOLE NO.	SAMPLE NO.	DEPTH FEET	DEPTH METERS	ppm U_3O_8
18	MIP-629	410-415	125-126	60
18	MDG-635*	410-420	125-128	109
18	MIP-630	415-420	126-128	69
18	MDG-636*	420-430	128-131	73
18	MIP-631*	425-430	130-131	49
18	MIP-632*	430-435	131-133	58
18	MIP-633*	440-445	134-136	97
19	MIP-705	130-135	40-41	64
19	MDG-637*	130-135	40-41	54
19	MIP-706	160-165	49-50	7
19	MIP-707	235-240	72-73	51
19	MIP-708	265-270	81-82	85
19	MIP-709	275-280	84-85	97
19	MIP-710	295-300	90-91	88
19	MIP-711	310-315	94-96	97
19	MIP-634	335-340	102-104	37
19	MIP-635	380-385	116-117	41
19	MIP-636	395-400	120-122	38
19	MDG-638	405-410	123-125	20
19	MIP-637	410-415	125-126	33
19	MIP-638	415-420	126-128	51
19	MIP-639	420-425	128-130	49
19	MIP-640	435-440	133-134	16
19	MIP-641	440-445	134-136	31
19	MIP-642	445-450	136-137	55

U_3O_8 Chemical Assay Results (continued)

HOLE NO.	SAMPLE NO.	DEPTH FEET	DEPTH METERS	ppm U_3O_8
24	MDG-639	590-610	180-186	2
24	MDG-640	700-720	213-219	1
24	MDG-641	840-860	256-262	1
26A	MDG-642	510-530	155-162	1
27	MDG-643	40-50	12-15	2
27	MDG-644	100-110	30-34	1
28	MDG-645*	650-655	198-200	1
28	MIP-645	660-665	201-203	<1
28	MDG-646*	695-705	212-215	4
28	MDG-647*	700-720	213-219	2
28	MIP-644	715-720	218-219	3
28	MIP-643	785-790	239-241	3
28	MDG-648*	1040-1060	317-323	8
28A	MIP-646	780-785	238-239	1
28A	MIP-712	950-955	290-291	9
29	MDG-649	410-430	125-131	4
29	MDG-650	725-740	221-226	3

Sieve Analyses and Heavy
Mineral Analyses of Samples from SWB-1

	Sample MIP-649 669.5-670.0 ft (204.0-204.4 m)	Sample MIP-701 423.0-424.0 ft (128.9-129.1 m)	Sample MIP-702 1117.0-1117.4 ft (340.5-340.6 m)
Mean Size	2.50	2.41	3.01
Standard Deviation (Sorting)	0.61	0.71	1.07
Skewness	0.08	0.15	-0.07
Kurtosis	1.51	1.33	1.17
% Separated by bromoform (sp. Gr. 2.85)	1.7	2.8	5.6
Mineral/Component	Volume Percent in Sample		
Amphibole	19	25	-
Epidote	17	6	tr
Garnet	15	13	tr
Biotite	11	10	1
Muscovite	-	tr	tr
Chlorite	-	-	tr
Tourmaline	11	3	1
Magnetite	5	7	tr
Magnetite/Ilmenite[1]	-	10	-
Hematite	8	6	3
Goethite	2	6	tr
Zircon	6	3	2
Rutile	2	tr	tr
Monazite (?)	2	tr	-
Sphene	1	3	tr
Sillimanite[2]	-	tr	-
Carbonate/Limonite[3]	tr	-	67
Pyrite-Cemented SRF's	-	5	9
Marcasite-Cemented SRF's	-	-	1
Marcasite	-	-	1

[1]Exsolved ilmenite in magnetite.

[2]Sillimanite inclusions in quartz.

[3]Limonite inclusions in carbonate.

Emission Spectroscopic Semiquantitative Analytical Results - Page 1 of 4
(Concentrations in ppm)

Element	Hole 2A 75-85 ft (23-26 m)	Hole 2A 725-735 ft (221-224 m)	Hole 3 35-45 ft (11-14 m)	Hole 3 60-70 ft (18-21 m)	Hole 3 90-100 ft (27-30 m)	Hole 3 235-245 ft (72-75 m)	Hole 4 55-65 ft (17-20 m)	Hole 4 140-150 ft (43-46 m)	Hole 4 250-265 ft (76-81 m)
	MIP-714	MIP-715	MIP-716	MIP-717	MIP-718	MIP-719	MIP-720	MIP-721	MIP-722
AG	<10	<10	<10	<10	<10	<10	<10	<10	<10
AL	8820	13400	20200	37300	48900	28300	26100	23000	25400
AS	<200	<200	<200	<200	<200	<200	<200	<200	<200
B	<10	<10	<10	<10	<10	<10	<10	<10	<10
BA	154	212	176	317	263	245	269	208	166
BE	<10	<10	<10	<10	<10	<10	<10	<10	<10
BI	<50	<50	<50	<50	<50	<50	<50	<50	<50
CA	10100	7600	71600	40700	13500	64100	28400	49900	76100
CD	<10	<10	<10	<10	<10	<10	<10	<10	<10
CO	<10	<10	<10	<10	<10	<10	<10	<10	<10
CR	<10	<10	<10	<10	<10	<10	<10	<10	<10
CU	<10	<10	<10	<10	<10	<10	<10	<10	<10
FE	4300	4660	10500	15100	14400	11700	7280	12100	10900
K	<5000	<5000	7180	27700	39300	16300	12100	9980	9020
LA	<10	<10	<10	<10	<10	<10	<10	<10	<10
LI	<20	<20	<20	<20	<20	<20	<20	<20	<20
MG	<100	349	7930	4620	2890	4060	2930	6190	2900
MN	275	255	443	515	350	292	294	366	367
MO	<10	<10	<10	<10	<10	<10	<10	<10	<10
NA	<100	<100	1380	8470	12600	3760	7670	3210	5190
NB	<100	<100	<100	<100	<100	<100	<100	<100	<100
NI	<40	<40	<40	<40	<40	<40	<40	<40	<40
P	<100	<100	<100	<100	<100	<100	<100	<100	<100
PB	<40	796	1080	810	<40	727	<40	<40	<40
SB	<100	<100	<100	<100	<100	<100	<100	<100	<100
SC	<3	<3	<3	<3	<3	<3	<3	<3	<3
SI	289000	355000	140000	254000	262000	182000	253000	202000	201000
SN	<10	<10	<10	<10	<10	<10	<10	<10	<10
SR	58	62	176	<100	51	96	136	171	135
TI	<300	442	572	1150	975	996	712	1180	705
W	<100	<100	<100	<100	<100	<100	<100	173	<100
Y	<10	<10	<10	<10	<10	<10	<10	<10	<10
ZN	<100	<100	<100	<100	<100	<100	<100	189	121
ZR	<40	<40	<40	77	<40	<40	<40	<40	<40

< Indicates current limits of analysis.

Emission Spectroscopic Semiquantitative Analytical Results - Page 2 of 4
(Concentrations in ppm)

Element	Hole 4 370-390 ft (113-119 m)	Hole 5 110-125 ft (34-38 m)	Hole 5 200-220 ft (61-67 m)	Hole 5 600-610 ft (183-186 m)	Hole 6 500-520 ft (152-158 m)	Hole 9 800-820 ft (244-250 m)	Hole 11A 450-470 ft (137-143 m)	Hole 12 500-520 ft (152-158 m)	Hole 13 890-910 ft (271-277 m)
	MIP-723	MIP-724	MIP-725	MDG-626	MDG-627	MDG-628	MDG-629	MDG-630	MDG-631
AG	<10	<10	<10	<10	<10	<10	<10	<10	<10
AL	35600	35000	35000	29000	19900	31000	37800	24200	23600
AS	<200	<200	<200	<200	<200	<200	<200	<200	<200
B	<10	<10	<10	<10	<10	<10	<10	<10	<10
BA	269	899	243	204	257	232	367	300	306
BE	<10	<10	<10	<10	<10	<10	<10	<10	<10
BI	<50	<50	<50	<50	<50	<50	<50	<50	<50
CA	53000	71000	>100000	42000	38900	97300	11000	5870	7460
CO	<10	<10	<10	<10	<10	<10	<10	<10	<10
CD	<10	<10	<10	<10	<10	<10	<10	<10	<10
CR	<10	<10	<10	<10	<10	<10	<10	<10	<10
CU	<10	<10	<10	<10	<10	<10	<10	<10	<10
FE	11300	12300	15400	9870	7690	11800	9640	3350	3880
K	16300	15800	20900	8460	9560	12300	18000	<5000	6440
LA	<10	<10	<10	<10	<10	<10	<10	<10	<10
LI	<20	<20	<20	<20	<20	<20	<20	<20	<10
MG	2520	4510	9410	24700	2270	1060	1790	<100	<100
MN	336	309	380	305	263	356	260	224	206
MO	<10	<10	<10	<10	<10	<10	<10	<10	<10
NA	10700	7260	8260	6930	1870	6930	9910	3010	4820
NB	<100	<100	<100	<100	<100	<100	<100	<100	<100
NI	<40	<40	<40	<40	<40	<40	<40	<40	<40
P	<100	<100	<100	<100	<100	<100	<100	<100	<100
PB	<40	800	50	1000	<40	<40	<40	<40	<40
SB	<100	<100	<100	<100	<100	<100	<100	<100	<100
SC	<3	<3	<3	<3	<3	<3	<3	<3	<3
SI	284000	275000	224000	235000	257000	223000	329000	317000	311000
SN	<10	<10	<10	<10	<10	<10	<10	<10	<10
SR	180	151	166	170	83	153	197	115	132
TI	858	999	1180	645	712	877	1020	515	512
W	<100	114	468	<100	<100	226	<100	<100	<100
Y	<10	<10	<10	<10	<10	<10	<10	<10	<10
ZN	<100	<100	<100	<100	<100	<100	<100	<100	<100
ZR	<40	42	<40	<40	<40	<40	<40	<40	<40

> < Indicates current limits of analysis.

Emission Spectroscopic Semiquantitative Analytical Results - Page 3 of 4
(Concentrations in ppm)

Element	Hole 14 0-39 ft (0-9 m)	Hole 15 100-120 ft (30-37 m)	Hole 16 420-440 ft (128-134 m)	Hole 18 410-420 ft (125-128 m)	Hole 18 420-430 ft (128-131 m)	Hole 19 130-135 ft (40-41 m)	Hole 19 405-410 ft (123-125 m)	Hole 24 590-610 ft (180-186 m)	Hole 24 700-720 ft (213-219 m)
	MDG-632	MDG-633	MDG-634	MDG-635	MDG-636	MDG-637	MDG-638	MDG-639	MDG-640
AG	<10	<10	<10	<10	<10	<10	<10	<10	<10
AL	20800	25100	23200	54200	37900	44100	33600	49100	29300
AS	<200	<200	<200	<200	<200	<200	<200	<200	<200
B	<10	<10	<10	<10	<10	<10	<10	<10	<10
BA	257	178	271	275	257	323	235	319	220
BE	<10	<10	<10	<10	<10	<10	<10	<10	<10
BI	<50	<50	<50	<50	<50	<50	<50	<50	<50
CA	3710	>100000	7170	47100	30700	15000	50000	25700	9980
CD	<10	<10	<10	<10	<10	<10	<10	<10	<10
CO	<10	<10	<10	<10	<10	<10	<10	<10	<10
CR	<10	<10	<10	<10	<10	<10	<10	<10	<10
CU	<10	<10	<10	<10	<10	<10	<10	<10	<10
FE	2400	14800	3690	20800	17800	15900	6160	16400	5010
K	<5000	9480	5210	31600	13600	15100	12200	28700	14300
LA	<10	<10	<10	<10	<10	<10	<10	<10	<10
LI	<20	<20	<20	<20	<20	<20	<20	<20	<20
MG	<100	6800	<100	3240	2260	3910	<100	3030	<100
MN	194	387	224	472	553	270	334	379	265
MO	<10	<10	<10	53	20	<10	<10	<10	<10
NA	3020	825	3170	18700	9050	10700	8640	18200	8550
NB	<100	<100	<100	<100	<100	<100	<100	<100	<100
NI	<40	<40	<40	<40	<40	<40	<40	<40	<40
P	<100	<100	<100	393	<100	177	<100	195	<100
PB	<40	<40	<40	<40	<40	<40	<40	<40	<40
SB	<100	<100	<100	<100	<100	<100	<100	<100	<100
SC	<3	<3	<3	<3	<3	<3	<3	<3	<3
SI	289000	178000	294000	250000	212000	227000	233000	285000	259000
SN	<10	<10	<10	<10	<10	<10	<10	<10	<10
SR	108	103	103	202	189	227	165	210	108
TI	429	854	<300	1310	1130	1030	520	1160	403
W	<100	265	<100	<100	<100	<100	<100	<100	<100
Y	<10	<10	<10	<10	<10	<10	<10	<10	<10
ZN	<100	<100	<100	<100	<100	<100	<100	<100	<100
ZR	<40	<40	<40	<40	<40	<40	<40	<40	<40

< Indicates current limits of analysis.

Emission Spectroscopic Semiquantitative Analytical Results - Page 4 of 4
(Concentrations in ppm)

Element	Hole 24 840-860 ft (256-262 m)	Hole 26A 510-530 ft (155-162 m)	Hole 27 40-50 ft (12-15 m)	Hole 27 100-110 ft (20-34 m)	Hole 28 650-655 ft (198-200 m)	Hole 28 695-705 ft (212-215 m)	Hole 28 700-720 ft (213-219 m)	Hole 28 1040-1060 ft (317-323 m)	Hole 29 410-430 ft (125-131 m)	Hole 29 725-740 ft (221-226 m)
	MDG-641	MDG-642	MDG-643	MDG-644	MDG-645	MDG-646	MDG-647	MDG-648	MDG-649	MDG-650
AG	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
AL	34500	24200	52000	63200	42700	31600	39500	46900	37000	37700
AS	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200
B	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
BA	270	254	676	342	357	248	307	334	242	453
BE	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
BI	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
CA	13500	6280	26700	48100	5720	3970	5060	10400	63000	29800
CD	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
CO	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
CR	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
CU	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
FE	9090	12000	17700	33000	6750	2880	6140	22200	15100	14200
K	11900	8420	50200	35700	22100	22600	23100	22000	20200	17300
LA	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
LI	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
MG	<100	<100	12600	7450	108	<100	<100	442	4140	3100
MN	286	246	1010	735	290	186	209	327	527	426
MO	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
NA	9730	2590	2060	18000	9370	11900	12000	16000	5880	5950
NB	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
NI	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40
P	<100	<100	429	228	<100	<100	<100	105	<100	<100
PB	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40
SB	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
SC	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
SI	273000	281000	250000	258000	306000	249000	322000	303000	217000	236000
SN	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
SR	137	61	108	114	148	105	132	228	139	118
TI	668	488	1520	1590	1030	538	1040	1370	1340	1040
V	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
W	<100	<100	110	<100	<100	<100	<100	<100	<100	<100
Y	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
ZN	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
ZR	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40

< indicates current limits of analysis.

APPENDIX D

EQUIVALENT-URANIUM GRADE CALCULATIONS

Equivalent-Uranium Grade Calculations
SWB-18

≥ 0.001 % eU_3O_8			≥ 0.005% eU_3O_8			≥ 0.01% eU_3O_8		
Depth in Feet (Meters)	Thickness in Feet (Meters)	Average Grade (% eU_3O_8)	Depth in Feet (Meters)	Thickness in Feet (Meters)	Average Grade (% eU_3O_8)	Depth in Feet (Meters)	Thickness in Feet (Meters)	Average Grade (% eU_3O_8)
86.5- 90.5 (26.4- 27.6)	4.0 (1.2)	0.003	88.0- 89.0 (26.8- 27.1)	1.0 (0.3)	0.005			
287.0-299.5 (87.5- 91.3)	12.5 (3.8)	0.004	288.5-289.5 (87.9- 88.2)	1.0 (0.3)	0.008			
			291.5-293.0 (88.8- 89.3)	1.5 (0.5)	0.007			
			297.5-298.0 (90.6- 90.8)	0.5 (0.2)	0.006			
			309.0-447.0 (94.2-136.2)	138.0 (42.0)	0.007			
						351.5-353.0 (107.1-107.6)	1.5 (0.5)	0.012
						356.0-357.0 (108.5-108.8)	1.0 (0.3)	0.011
						393.0-445.0 (119.8-135.6)	52.0 (15.8)	0.011

Equivalent-Uranium Grade Calculations
SWB-19

≥ 0.001 % eU_3O_8			≥ 0.005% eU_3O_8			≥ 0.01% eU_3O_8		
Depth in Feet (Meters)	Thickness in Feet (Meters)	Average Grade (% eU_3O_8)	Depth in Feet (Meters)	Thickness in Feet (Meters)	Average Grade (% eU_3O_8)	Depth in Feet (Meters)	Thickness in Feet (Meters)	Average Grade (% eU_3O_8)
3.0- 34.0 (0.9- 10.4)	31.0 (9.4)	0.001						
41.0- 44.0 (12.5- 13.4)	3.0 (0.9)	0.001						
53.0-101.5 (16.2- 30.9)	48.5 (14.8)	0.001						
102.5-142.0 (31.2- 43.3)	39.5 (12.0)	0.002	127.5-128.0 (38.9- 39.0)	0.5 (0.2)	0.005			
			130.0-132.0 (39.6- 40.2)	2.0 (0.6)	0.010	130.5-131.5 (39.8- 40.1)	1.0 (0.3)	0.015
143.0-145.0 (43.6- 44.2)	2.0 (0.6)	0.001						
146.0-146.5 (44.5- 44.7)	0.5 (0.2)	0.002						
			147.0-452.5 (44.8-137.9)	305.5 (93.1)	0.008	162.5-163.0 (49.5- 49.7)	0.5 (0.2)	0.010
						191.5-192.0 (58.4- 58.5)	0.5 (0.2)	0.011
						192.5-195.0 (58.7- 59.4)	2.5 (0.8)	0.013
						198.5-204.0 (60.5- 62.2)	5.5 (1.7)	0.010
						223.5-224.0 (68.1- 68.3)	0.5 (0.2)	0.010

Equivalent-Uranium Grade Calculations
SWB-19 (Page 2 of 2)

≥ 0.001 % eU_3O_8			≥ 0.005% eU_3O_8			≥ 0.01% eU_3O_8		
Depth in Feet (Meters)	Thickness in Feet (Meters)	Average Grade (% eU_3O_8)	Depth in Feet (Meters)	Thickness in Feet (Meters)	Average Grade (% eU_3O_8)	Depth in Feet (Meters)	Thickness in Feet (Meters)	Average Grade (% eU_3O_8)
						225.5-226.0 (68.7- 68.9)	0.5 (0.2)	0.010
						234.0-243.5 (71.3- 74.2)	9.5 (2.9)	0.012
						246.0-327.0 (75.0- 99.7)	81.0 (24.7)	0.012
						336.0-337.5 (102.4-102.9)	1.5 (0.5)	0.013
						346.0-346.5 (105.5-105.6)	0.5 (0.2)	0.010
						381.0-382.0 (116.1-116.4)	1.0 (0.3)	0.011
						396.5-398.5 (120.9-121.5)	2.0 (0.6)	0.010
						413.0-425.0 (125.9-129.5)	12.0 (3.7)	0.010
						437.5-450.5 (133.4-137.3)	13.0 (4.0)	0.010

Equivalent-Uranium Grade Calculations
SWB-28

≥ 0.001 % eU_3O_8			≥ 0.005% eU_3O_8			≥ 0.01% eU_3O_8		
Depth in Feet (Meters)	Thickness in Feet (Meters)	Average Grade (% eU_3O_8)	Depth in Feet (Meters)	Thickness in Feet (Meters)	Average Grade (% eU_3O_8)	Depth in Feet (Meters)	Thickness in Feet (Meters)	Average Grade (% eU_3O_8)
			660.0-664.5 (201.2-202.5)	4.5 (1.4)	0.005	662.0-663.0 (201.8-202.1)	1.0 (0.3)	0.014
698.0-702.0 (212.8-214.0)	4.0 (1.2)	0.004	699.5-700.5 (213.2-213.5)	1.0 (0.3)	0.007			
			701.5-702.0 (213.8-214.0)	0.5 (0.2)	0.006			
714.5-720.0 (217.8-219.5)	5.5 (1.7)	0.013	716.0-718.5 (218.2-219.0)	2.5 (0.8)	0.026	716.5-718.0 (218.4-218.8)	1.5 (0.5)	0.039
			785.5-791.5 (239.4-241.2)	6.0 (1.8)	0.007	787.0-789.5 (239.9-240.6)	2.5 (0.8)	0.012
1056.0-1060.0 (321.9-323.1)	4.0 (1.2)	0.004	1057.5-1058.5 (322.3-322.6)	1.0 (0.3)	0.005			

Equivalent-Uranium Grade Calculations
SWB-28A

≥ 0.001 % eU_3O_8			≥ 0.005% eU_3O_8			≥ 0.01% eU_3O_8		
Depth in Feet (Meters)	Thickness in Feet (Meters)	Average Grade (% eU_3O_8)	Depth in Feet (Meters)	Thickness in Feet (Meters)	Average Grade (% eU_3O_8)	Depth in Feet (Meters)	Thickness in Feet (Meters)	Average Grade (% eU_3O_8)
780.5- 784.0 (237.9- 239.0)	3.5 (1.1)	0.003				782.0-782.5 (238.4-238.5)	0.5 (0.2)	0.01
951.5- 955.5 (290.0- 291.2)	4.0 (1.2)	0.003	953.0- 954.0 (290.5- 290.8)	1.0 (0.3)	0.007			
1235.5-1239.0 (376.6- 377.7)	3.5 (1.1)	0.003	1237.0-1237.5 (377.0- 377.2)	0.5 (0.2)	0.006			

APPENDIX E

LITHOLOGIC LOGS

(Microfiche Located in Pocket)

GEOPHYSICAL LOGS

Refer to: Engineering report on drilling in the Sand Wash Basin, Colorado: U.S. Department of Energy Open-File Report GJBX-125(80), Grand Junction, Colorado, 85 p.

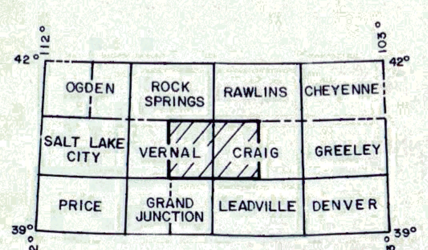
VERNAL CRAIG

WESTERN UNITED STATES 1:250,000

Outline of Outcropping Areas of Browns Park Formation

SWB-3 Project Drill Hole Locations

WEST YAMPA Study Areas



Scale 1:250,000

0 5 10 15 20 Miles

0 5 10 15 20 25 30 Kilometers

CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS
TRANSVERSE MERCATOR PROJECTION

PLATE I
SAND WASH BASIN PROJECT AREA

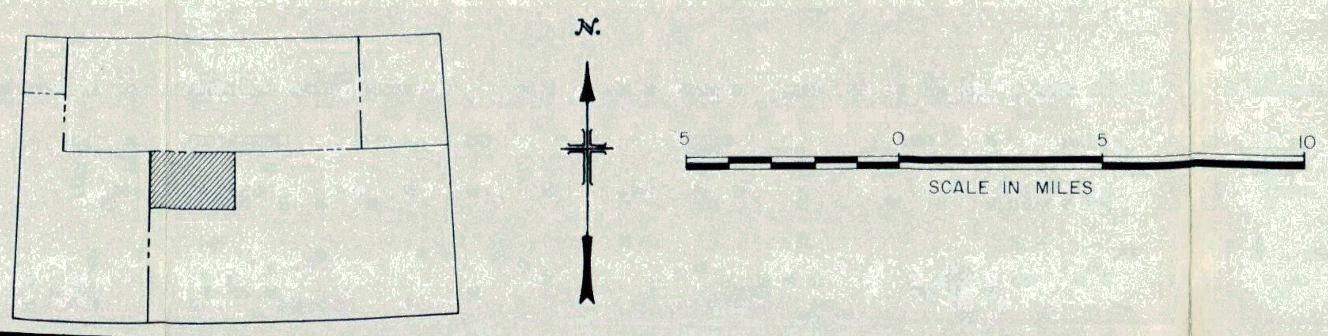
VERNAL-CRAIG

UNITED STATES 1:250,000

From DOE Composite Geologic Map (Multiple Sources)

Qal	Quaternary alluvium
	Tertiary intrusive and volcanic rocks
Tbp	Browns Park Formation
Tb	Bridger Formation
Tw	Wasatch Formation
Tgr, Tgt	Green River Formation, Tgt-Tipton Tongue
Tf	Fort Union Formation
	Post-Morrison Mesozoic sediments
Jm	Jurassic Morrison sediments
J₹g	Jurassic-Triassic
₹	Triassic Chinle sediments
	Paleozoic sediments
P₽	Permian-Pennsylvanian
P₽wm	Weber Sandstone and Maroon Formation
Mr	Mississippian
Єr	Cambrian
Yu	Precambrain
	Fault-dashed where inferred, barbell on downthrown side, teeth on upper plate
	Anticline
	Syncline
	Monocline
⚒	Prospect
AA	Airborne Anomaly
A—A'	Cross section location

PLATE II
GEOLOGY OF SAND WASH BASIN PROJECT AREA



SCALE IN MILES

VERNAL CRAIG

WESTERN UNITED STATES 1:250,000

Generalized Outline of Browns Park Formation Outcrop

SWB-9 Project Drill Holes

IH-7 Industry Drill Holes, Proprietary Information Used in Contouring

Basement Contour of Browns Park Formation

OGDEN	ROCK SPRINGS	RAWLINS	CHEYENNE
SALT LAKE CITY	VERNAL	CRAIG	GREELEY
PRICE	GRAND JUNCTION	LEADVILLE	DENVER

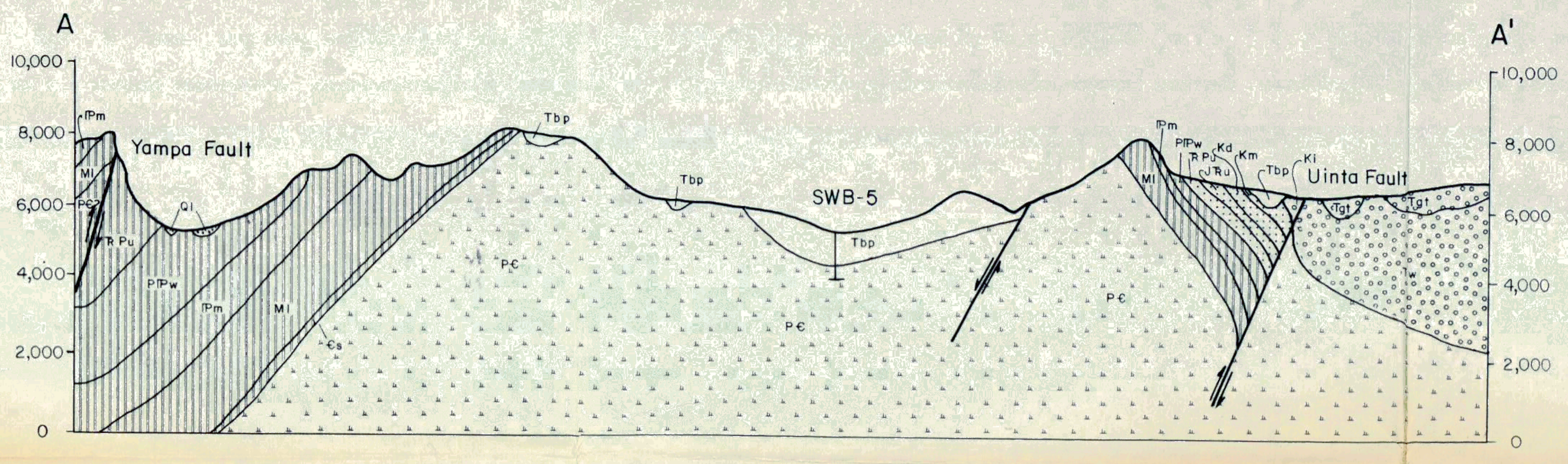
Scale 1:250,000

5 0 5 10 15 20 Miles

5 0 5 10 15 20 25 30 Kilometers

CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS
TRANSVERSE MERCATOR PROJECTION

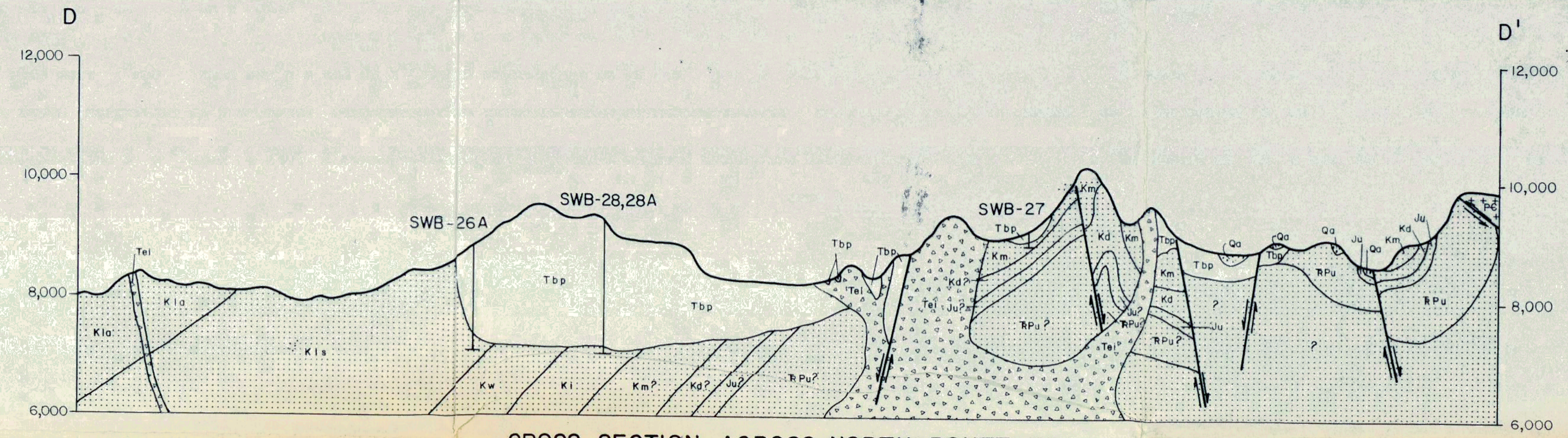
PLATE III
BASEMENT CONTOURS OF PART OF THE
SAND WASH BASIN PROJECT AREA
CONTOUR INTERVAL - 500 FT



CROSS SECTION OF THE NORTH BROWNS PARK AND BROWNS PARK AREAS

(A-A')

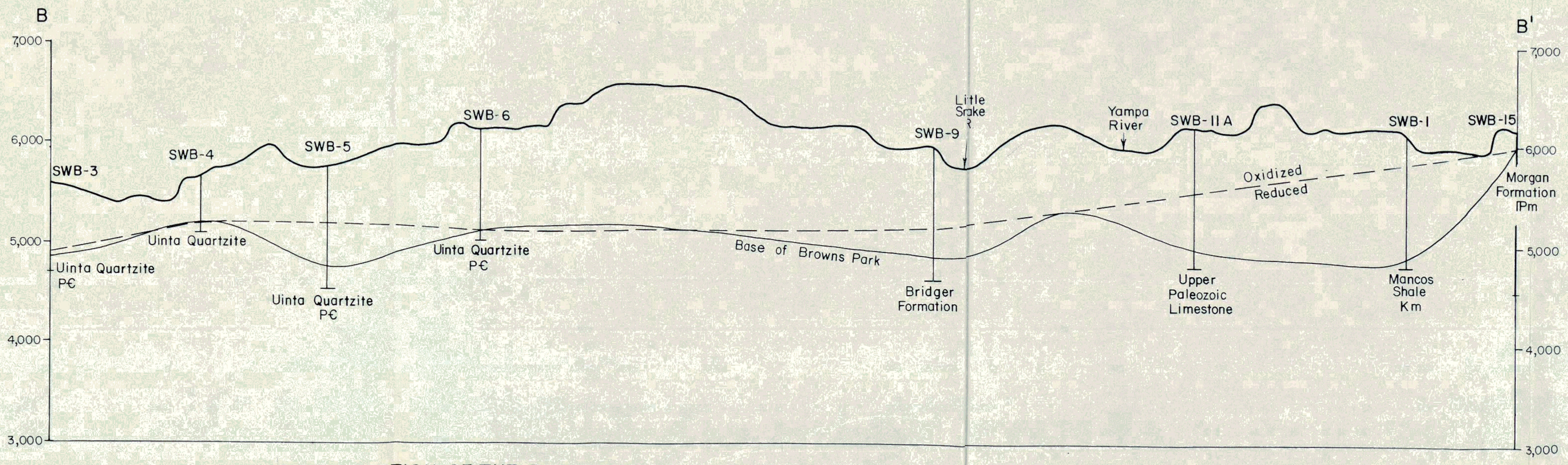
Horizontal Scale 1:250,000
Vertical Scale 1:48,000
Vertical Exaggeration 5.2:1



CROSS SECTION ACROSS NORTH ROUTT AREA

(D-D')

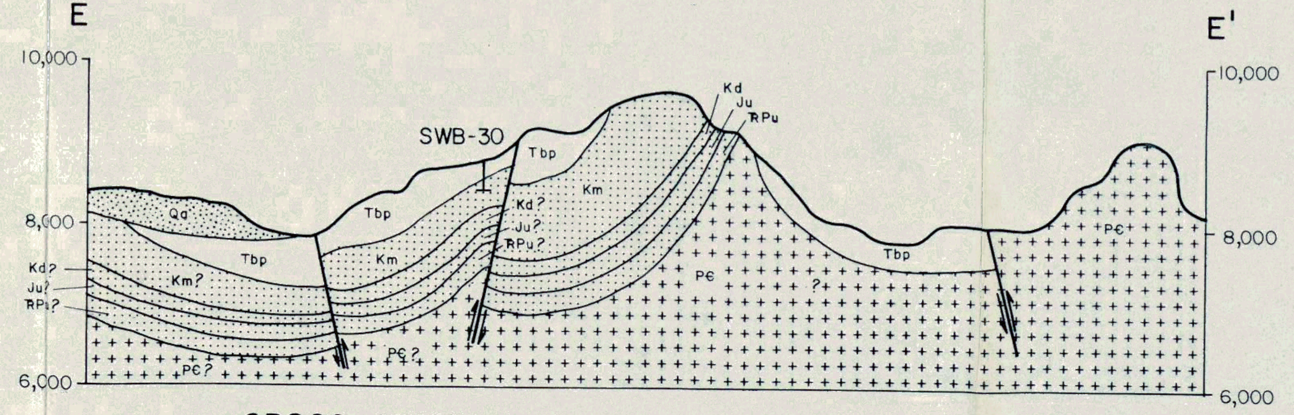
Horizontal Scale 1:126,720
Vertical Scale 1:24,000
Vertical Exaggeration 5.3:1



CROSS SECTION OF THE BROWNS PARK AND WEST YAMPA AREAS, HOLE SWB-3 TO HOLE SWB-15

(B-B')

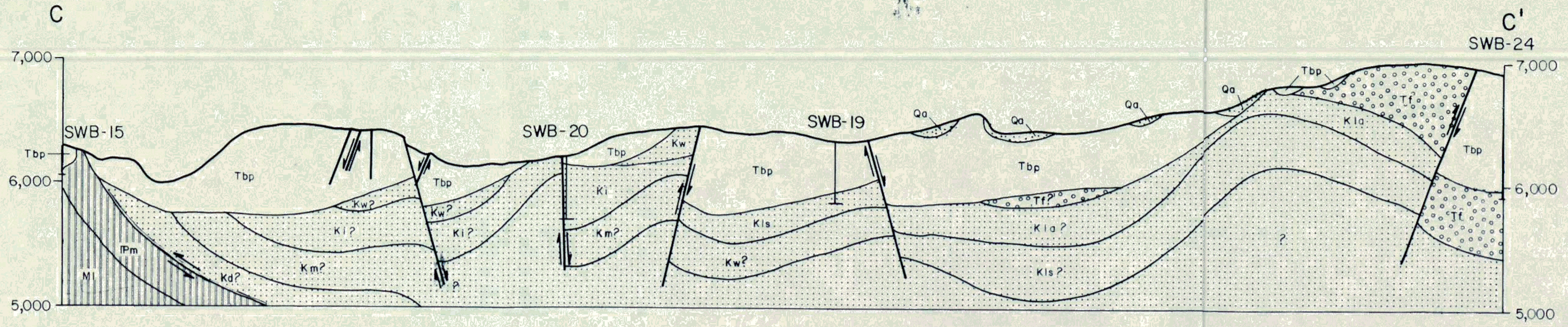
Horizontal Scale 1:250,000
Vertical Scale 1:12,000
Vertical Exaggeration 20.8:1



CROSS SECTION OF SOUTH ROUTT AREA

(E-E')

Horizontal Scale 1:126,720
Vertical Scale 1:24,000
Vertical Exaggeration 5.3:1



CROSS SECTION OF THE WEST YAMPA AND EAST YAMPA AREAS, HOLE SWB-15 TO HOLE SWB-24

(C-C')

Horizontal Scale 1:126,720
Vertical Scale 1:12,000
Vertical Exaggeration 10.6:1

SOURCES OF INFORMATION

1) Miller, Allan E., 1977, Geology of Moffat County, Colorado: Department of Natural Resources, Colorado Geological Survey.

2) Miller, Allan E., Geology of Routt County, Colorado: Department of Natural Resources, Colorado Geological Survey.

3) Izett, Glen A., 1975, Late Cenozoic sedimentation and deformation in northern Colorado and adjoining areas: Geological Society of America Memoir 144, p 179-192.

LEGEND

Cenozoic Erathem

- Ql (Quaternary) - Landslide Deposits
- Qa (Quaternary) - Stream Valley Sediments

Unconformity

- Tei (Pliocene, Miocene, Oligocene) - Igneous Rock
- Tbp (Miocene) - Browns Park Formation

Unconformity

- Tb (Eocene) - Bridger Formation
- Tgt (Eocene) - Tipton Tongue of Green River Formation
- Tw (Eocene) - Wasatch Formation

Unconformity

- Tf (Paleocene) - Fort Union Formation

Unconformity

Mesozoic Erathem

- Kla (Upper Cretaceous) - Lance Formation
- Kls (Upper Cretaceous) - Lewis Shale
- Kw (Upper Cretaceous) - Williams Fork Formation
- Ki (Upper Cretaceous) - Iles Formation
- Km (Upper and Lower Cretaceous) - Mancos Formation
- Kd (Lower Cretaceous) - Dakota Sandstone

Unconformity

- J₸u, Ju (Jurassic and/or Triassic Rocks)
- ₸Pu (Triassic and Permian Rocks)

Unconformity

Paleozoic Erathem

- PIPw (Permian and Pennsylvanian) - Weber Sandstone
- IPm (Pennsylvanian) - Morgan Formation

Unconformity

- Ml (Mississipian) - Leadville Limestone

Unconformity

- Єs (Cambrian) - Sawatch Quartzite

Unconformity

Precambrain Erathem

- PЄ (Precambrian) - Basement Complex

CROSS-SECTION LOCATIONS ON PLATE II

PLATE IV

CROSS SECTIONS OF THE SAND WASH BASIN PROJECT AREA

PLATE V
COLUMNAR SECTION OF HOLE SWB-1
C W½ sec. 31, T7N R95W
Moffat County, Colorado

EXPLANATION

- Sandstone
- Conglomerate, conglomeratic
- Pebbles
- Shale (clay, claystone)
- Calcite cement (calcareous)
- Tuffaceous material or ash, fresh or altered
- Organic carbonaceous material
- P — Pyrite
- Fining-upward sequence of beds
- F — Feldspathic

Vertical scale: 1 inch = 30 feet